FINAL REPORT (DRAFT), 19 MARCH 2007: "CLASSIFICATION, ECOLOGICAL CHARACTERIZATION, AND PRESENCE OF LISTED PLANT TAXA OF VERNAL POOL ASSOCIATIONS IN CALIFORNIA"

UNITED STATES FISH AND WILDLIFE SERVICE AGREEMENT/STUDY NO. 814205G238 and UNIVERSITY OF CALIFORNIA, DAVIS ACCOUNT NO. 3-APSF026 and SUBACCOUNT NO. FMGB2

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Chapter 1: Introduction

A group of approximately 100 plant taxa more commonly occur in vernal pools than any other habitat. Most are native, amphibious annuals capable of slow underwater growth in winter followed by rapid development and reproduction in spring after the ponded water is gone. More than half are endemic to California, while others extend north to Oregon, Washington, and Idaho, east to Nevada, and south to Baja California. Some 15 taxa are federally listed (10 endangered and 5 threatened; all but two of the 15 are also state listed) and 37 others are either state-listed or considered to be “species of concern” by the California Native Plant Society (USFWS 2004; Lazar 2005). In this report, we investigated a subset of 18 taxa that had a distribution matching the geographic limits of our study.

Although vernal pools are most abundant in the Central Valley, they occur in >30 California counties in such diverse regions as the Modoc Plateau, the Mendocino coast, the Central coast, and southwestern basins. As mapped by Keeler-Wolf et al. (1998) and USFWS (2004), vernal pools are known to occur in 17 regions that differ in climate, topography, and rare plants. At the time of Euro-american contact, there may have been about 1.6 million hectares of vernal pool landscape throughout California (Holland 1968, Barbour et al. 2003, Barbour and Witham 2004). The proximity of vernal pools to areas of expanding agriculture and homes, and the relatively low cost of vernal pool land, have lead to rapid decline in vernal pool acreage, estimated to be a loss of 60-95%, depending on the region.

Chapter 2: Classification.

Our classification is based on pool and vegetation data collected from 2177 plots (each 10 square meters in area), placed in 700 pools, at 68 locations. A “location” is a single-owner parcel of land, usually several hundred hectares in area and incorporating a network or complex of many vernal pools. The intensity of sampling correlated with the density of vernal pool locations and pools, thus 79% of all plots, pools, and locations were from the Central Valley.

Data were collected from all six Central Valley vernal pool regions, as defined by Keeler-Wolf et al. (1998), and from all but two (Carrizo and Sierra Velley) of the vernal pool regions outside the Central Valley. We also obtained data from southern Oregon and northwestern Nevada, locations outside of California's 17 vernal pool regions.

We subdivided the landscape of a location into polygons of unique landform, geology, and topographic position, using air photos, topographic maps, and soil/geology maps, and then we sampled as many pools in each polygon type as possible in 1-2 days. The vegetation of each selected pool was visually divided into 2-4 subtypes (some pools were homogeneous and were not subdivided). These subtypes typically had narrow boundaries and appeared different because of the color of stems, leaves, or flowers, the height of the vegetation, or dominant growth forms.

Every species in a plot was recorded, together with its estimated percent cover. Habitat data (relative depth in the pool where the plot was located, pool position of the plot (on a scale of 1-5, 5 being the bottom of the pool, and 1 being the top edge of the pool), geologic substrate, elevation, geographic location, landform, geomorphic surface, soil series, etc.) were also recorded. Classification of community types was accomplished by placing floristic data from all sample plots into a single table, each column being a separate plot and each row being a separate species. A series of iterative re-arrangements of the table, placed together more tightly species with similar distributions and plots with similar floristic composition.

We concluded that Californian vernal pool vegetation belongs to a single class, Downingia-Lasthenia, named after two dominant vernal pool genera, *Downingia* and *Lasthenia* (gold fields). This class comprises plant communities of hardpan, claypan and volcanic rock vernal pools, including those on fresh or alkaline soils and those located in deep centers or shallow edges of pools. Diagnostic species of the class, which occur throughout all of these habitats, include: *Lasthenia fremontii, Navarretia leucocephala, Downingia bicornuta, Plagiobothrys stipitatus, Psilocarphus brevissimus, Deschampsia danthonioides, Pilularia americana, Elatine californica, Veronica peregrina* ssp. *xalapensis, Alopecurus saccatus, Eryngium vaseyi, Isoetes orcuttii, Pogogyne* *ziziphoroides, Juncus bufonius, Eleocharis acicularis, Callitriche marginata, Crassula aquatica.* The geographic range of the class extends from southeastern Washington, throughout Oregon and California in North America, and in Chile and Argentina in South America.

Vernal pool communities in the state (and in the Central Valley) fall into three major groups called orders. (1) Communities in long-inundated pools (some fresh-water and some alkaline) are placed in the order Lasthenia glabberima, named after rayless goldfields, which is abundant in the wetter, deeper centers of vernal pools). (2) Communities in short-inundated pools or at shallow edges of deeper fresh-water pools are in the order Downingia-Lasthenia, the type order of the class. (3) Communities in saline/alkaline pools or large playas are in the order Myosurus-Lasthenia, named after the genus of mousetail annuals and such shallow-pool goldfields as L. fremontii, vernal pool goldfields). Communities of long-inundated pools are unique in high constancy and abundance of the extremely flood-tolerant taxa *Lasthenia glaberrima* and *Eleocharis macrostachya*. Communities of short-inundated pools or pool edges are unique in the presence of less-tolerant species such as *Cicendia quadrangularis, Blennosperma nanum, Trifolium depauparatum, Triphysaria eriantha, Lasthenia californica, Trifolium variegatum, Layia fremontii, Lepidium nitidum*, and *Microceris acuminata*, as well as upland species such as the exotics *Hypochaeris glabra, Erodium botrys, Vulpia bromoides, Bromus hordeacious, Aira caryophyllea*, and *Briza minor*, and the natives *Plagiobotrys greenei* and *Achyrachaena mollis*. Communities in saline/alkaline pools are different in the higher presence of such halophytes as *Distichlis spicata, Plagiobothrys leptocladis, Frankenia salina, Cressa truxillensis, Eryngium aristulatum, Pleuropogon californicus*, and *Crypsis schoenoides*.

Chapter 3: Persistence

To test the robustness of the classification with respect to variation of rainfall from year to year, we analyzed a set of 80 vernal pools, the vegetation data of which had been collected along a 300-km-long section of a PGT/PGE gas pipeline corridor through the Northwestern Sacramento Valley vernal pool region. Each pool was visited twice each year (early spring and late spring) over a 5-year-period and the percent cover for every plant species encountered was recorded.

Precipitation varied over the 5 yr from 420 mm to 1050 mm and average pool speices richness rose and fell with rainfall. The magnitude of change in abundance or presence/absence of individual species was highly variable. Diagnostic specie (species that must be present in order to classify the unit) at the class level had higher persistence than those at the order level, and the order higher than those at the association level (averages of 73%, 63%, and 51%, respectively). We agreed in principle that any single diagnostic species could not be expected, for any vegetation type in general, to have 100% persistence. We then agreed that a lower persistence limit that would be practical, realistic, and still useful would be 70%; that is, we should choose diagnostic species that have >70% persistence.

If species with persistence <70% were eliminated from the list of diagnostic species, that still left 10 taxa at the class level that could be retained, and as many as seven in two of the orders, but only one for the order of alkaline/saline pools (however, that one species, *Downingia insignis*, had 100% persistence). Diagnostic species for classification levels below the order generally were more sensitive to annual fluctuations, but at least one diagnostic species with >70% persistence existed for most associations. Our results indicate that a floristically-based statewide classification of vernal pool community types can be sufficiently robust to show that the same communities are present in the same pools, regardless of the current year's weather pattern.

Chapter 4: Correlations between rare taxa and vernal pool associations

The 18 rare taxa whose distributions were examined in this study had variably strong relationships with particular vernal pool associations. Only five were exclusively found in single associations, whereas 10 were less restricted to two associations, and three were spread among three or more associations. Furthermore, their constancy was low, rarely >10%, meaning that a search for new populations, focused by attention to particular associations, is unlikely to provide much efficiency and new information.

Some rare taxa were capable of existing in pool vegetation that had >30% cover by introduced taxa, meaning that not all rare taxa should be regarded as poor competitors. Rare taxa associated with the lowest cover of exotics were *Tuctoria greenei* and *Orcuttia pilosa*, suggesting that these taxa might be the least competitive among the 18 rare taxa. Rare taxa completely avoided associations in the alkaline/saline pool order, and only a few tolerated volcanic rock pools.

Chapter 5: Implications for conservation, recovery, and management

One implication from the work reported here is that conservation and restoration activities should be focused on sub-pool community types. To identify such types, one must sample each biologically uniform and repeatable sub-pool unit separately, neither combining plots from diverse sub-pool units nor locating plots so that they cross from one homogeneous unit to another.

Another significant finding is that most community types are limited in their distribution to a single vernal pool region. Of the 29 associations and communities we defined as occurring within the Central Valley, only two were found in more than half of the six Central Valley vernal pool regions and 21 were limited to a single vernal pool region withing the Central Valley. Associations of long-inundated pools tended to be more widespread than short-inundated fresh-water associations and than alkaline/saline associations

The implications of the paragraphs above for conservation is that it will be better to select many small reserves than one or even a few large reserves. Given the high turnover of community types from region to region, only a small percentage of community diversity can be captured in any one preserve, no matter how many hectares it might contain. Local reserves need to be large enough to include pools that contain different mixtures of the same community types as well as enough pools to contain uncommon as well as common community types and rare taxa.

Chapter 6: Restoration targets should include natural, regional community types

The classification work reported here has shown that a subset of approximately two dozen vernal pool plant taxa are widely distributed throughout California and they constitute the species that characterize the single vegetation class that includes all the vernal pools in California. At the same time, however, there are as many or more *additional* taxa that are diagnostic for the 29 different communities/associations within that class in the Central Valley. If our intent, in conservation and restoration, is to maintain community type diversity, then targets for restoration should not be widespread class species but instead more locally restricted species that are diagnostic for local communities.

As a case study in how this might be done, the vegetation of 13 created and 13 natural pools, all within Wurlitzer Ranch near Chico, was studied. This site was selected because, in our opinion, the degree of care and planning taken with pool construction and subsequent monitoring was exceptional. During 1994-1996, 60 pools were constructed that imitated the size, shape, and range of depths of 40 adjacent natural pools. In 2003, 13 created pools and 13 natural pools were selected and sampled by 84 within-pool plots, using the same protocols as described for the Central Valley study.

No significant difference was found between natural and constructed pools in species richness, native species richness, total species richness, species diversity index, nor in absolute or relative vip-vpa species richness. Of the 101 species encountered in the study, only seven had a significant ($p < 0.05$) indicator value for constructed pools: *Allium aplectens Downingia ornatissima, Epilobium pygmaeum, Eremocarpus setigerus, Lythrum hysspofifolium, Mimulus latidens*, and *Veronica peregrina.* The pattern of these seven taxa. however, was not enough to separate vegetation when analyses were based on all 101 species. Apparently, over the course of 7-8 years (and perhaps sooner), the plants colonizing created pools had organized themselves into communities with some differences to natural pools, but none large enough to be significant.

Using a simple formula, one can quantitatively express the degree of similarity or difference between any two plots or community types. When applieid to the Wurlitzer data, the percent similarity between the floras of created vs natural pools was 67%, which is far higher than the usual standard of 50% that vegetation scientists use to judge whether two samples belong to the same association.

Current restoration standards, generated by the Army Corps of Engineers and the US Fish and Wildlife Service, appropriately address hydrology and flora as the most important targets. However, in our opinion, some of the details in those standards are difficult to quantify because of the formulas used. We suggest seven specific criteria, or amendments to existing criteria used to judge the success of vernal pool restorations. (1) Depth and/or duration of ponded water in created pools should not differ statistically ($p = 0.05$) from those in nearby natural pools. (2) Absolute and relative cover by vernal pool endemics in constructed pools should not be statistically different ($p = 0.05$) from the average values in reference pools. (3) The number of vernal pool endemics in constructed pools should not be statistically lower ($p = 0.05$) than the average number of those taxa among reference pools. (4) The number and cover of exotic species in any constructed pool should not be significantly higher than the average among reference pools. (5) The identify of community types in created pools and the mixture in which they occur should match that of reference pools (using a Sorensen Similarity Index formula where "matching" means an SSI >50%. In other words, constructed pools collectively should contain deep, shallow, and edge community types if reference pools have those community types, meaning that the depth, side slope, shape, and area of created pools should be as diverse as that of reference pools. (6) Reference pools should be chosen subjectively so that collectively they represent the diversity of species and communities that exist in the pools to be taken. (7) We recommend the deletion of the present criterion, "…any vernal pool endemic that is dominant (>20% relative cover) in at least 30% of the reference pools shall be present as a dominant species in all of the constructed pools." This emphasis on common, widespread dominant species could result in the homogenization of constructed pools.

Finally, we propose that a training course be developed, with the collaboration of USFWS, the California Department of Fish and Game, and the California Native Plant Society; that it be offered on an annual basis; and that tudents be trained in the field on plant identification, sampling protocol for documenting plant community types, the use of an annotated key to determine vernal pool community types, and major ecosystem differences between vernal pools on floodplains, terraces, hardpans, claypans, and in saline/alkaline situations. Prototypes for such a course already exist as certification courses to train biologists to survey marbled murelets and northern spotted owls, in certifying specialists in wetland deliniation, and in training biologists in the flora of vernal pools (the latter is being offered for the first time this April by CNPS). If USFWS staff are interested in the development of such a course and certification program, we will be pleased to work with them and to have in place a first offering by April of 2008.

CHAPTER 1: INTRODUCTION

Vernal pools are seasonal ephemeral wetlands that fill and dry each year. They are shallow depressions underlain with a layer impermeable to water. In California, they become wetted in November with the onset of winter rains. Water collects in the depressions and stands for varying lengths of time (typically10-65 days at maximum depth <50 cm; Solomeshch et al. 2007) during winter and spring, then recedes as temperature rise and precipitation diminishes. The soil remains moist through April and May, then desiccates and stays dry until the following winter rains. The impermeable layer can be a claypan, cemented hardpan, or rock (Nikiforoff 1941, Weltkamp et al. 1996, Hobson and Dahlgren 1998). The inundation regime is too short and unpredictable to support aquatic species but long enough to eliminate upland species, and the ponded water is relatively oligotrophic; these are the major attributes that differentiate vernal pools from salt pans, alkali meadows, and fresh-water marshes.

Recent hydrological studies show that vernal pools do not simply fill from direct precipitation nor do they empty only by evapo-transpiration. Instead, lateral subsurface flow imparts a high degree of connectivity among pools. Once the soils have become saturated, water can move laterally above the impervious horizon, moving from hillocks into pools and vice-versa, ultimately draining downslope within a single watershed as late-season riverine flow (Hanes et al. 1990, Hanes and Stromberg 1998, Rains et al. 2005). This linkage buffers pool volume and chemistry, much like the effect that riparian vegetation has on adjacent waterways.

A specific group of approximately 100 plant taxa more commonly occur in vernal pools than any other habitat. Most are native, amphibious annuals capable of slow underwater growth in winter followed by rapid development and reproduction in spring after the ponded water is gone. More than half are endemic to California, while others extend north to Oregon, Washington, and Idaho, east to Nevada, and south to Baja California. Some 15 taxa are federally listed (10 endangered and 5 threatened; all but two of the 15 are also state listed) and 37 others are either state-listed or considered to be "species of concern" by the California Native Plant Society (USFWS 2004; Lazar 2005). In this report, we investigated only a subset of 18 taxa that had a distribution matching the Great Valley region that was the geographic target for this report (Table 1-1).

Table 1-1. Listed taxa included in this report. Vernal Pool Regions (Keeler-Wolf et al. 1998): 1-Modoc Plateau, 2-Sierra Valley, 3-NW Sacramento Valley, 4-NE Sacramento Valley, 5-SE Sacramento Valley, 6-Mendocino, 7-Lake-Napa, 8-Santa Rosa, 9-Solano-Colusa, 10-Livermore, 11-Central Coast, 12-Carrizo, 13-San Joaquin, 14-Southern Sierra Foothills, 15-Santa Barbara, 16-Western Riverside County, 17- San Diego.

Species Name	**Status**	**VP Region**	**% Extant Occurrences Sampled by UCD Team**
Tuctoria mucronata	FE	9	100%
Orcuttia viscida	FE	5	30%
Lasthenia conjugens	FE	6, 7, 8, 9, 10, 11	14%
Orcuttia pilosa	FE	4, 9, 14	11%
Chamaesyce hooveri	FT	4, 9, 13, 14	8%
Orcuttia tenuis	FT	1, 3, 4, 5, 7	7%
Neostapfia colusana	FT	9, 13, 14	5%
Tuctoria greenei	FE	1, 4, 14	5%
Castilleja campestris ssp. *succulenta*	FT	6, 14	4%
Gratiola heterosepala	CA-E	1, 4, 5, 7, 9, 14	7%
Navarretia prostrata	CNPS 1B	11, 12, 13, 16, 17	27%
Astragalus tener var. *tener*	CNPS 1B	7, 9, 10, 11, 13	15%
Navarretia myersii ssp. *myersii*	CNPS 1B	5, 14	15%
Navarretia leucocephala ssp. *bakeri*	CNPS 1B	3, 4, 6, 7, 8, 9	12%
Legenere limosa	CNPS 1B	3, 4, 5, 7, 8, 9,	7%
Downingia pusilla	CNPS 2	3, 5, 7, 8, 9, 14	4%
Lasthenia ferrisiae	CNPS 4	9	--
Navarretia heterandra	CNPS 4	4, 5	--

Vernal pools also provide habitat for such rare and endangered animals as the longhorn fairy shrimp, conservancy fairy shrimp, delta green ground beetle, western spadefoot toad, and Pacific tiger salamander, and for a large number of migratory birds (Alexander 1976, Silveira 1998, Helm 1998, USFWS 2004).

Although vernal pools are most abundant in the Central Valley, they occur in >30 California counties in such diverse regions as the Modoc Plateau, the Mendocino coast, the Central coast, and southwestern basins. They are only excluded from deserts (pre-cipitation too low), elevation >1000 m (frost too frequent, precipitation too high), steep slopes, deep soils, and northwestern parts of the state (>800 cm of annual precipitation and thus beyond the definition of Mediterranean-type climate (Aschmann 1973 and 1985, Barbour and Minnich 2000). As mapped by Keeler-Wolf et al. (1998) and USFWS (2004), vernal pools are known to occur in 17 regions that differ in climate, topography, and rare plants (Fig. 1). At the time of Euro-american contact, there may have been about 1.6 million hectares of vernal pool landscape throughout California (Holland 1968, Barbour et al. 2003, Barbour and Witham 2004). Unfortunately, the proximity of vernal pools to areas of expanding agriculture and homes, and the relatively low cost of vernal pool land, have lead to a rapid decline in vernal pool acreage, estimated to be a loss of 60-95%, depending on the region. It is this rapid decline in habitat and vegetation, taking with it rare taxa, that induced the USFWS to fund the research described in our February 2005 proposal and summarized in this report.

STRUCTURE OF THE REPORT

The objectives of the research described in the February 2005 proposal were: (1) to complete a classification of vernal pool plant community types that occur naturally in the Central Valley; (2) to distinguish Central Valley plant communities from those found elsewhere in California; (3) to name, floristically define, and environmentally character-ize Central Valley vernal pool communities; and (4) to describe the geographic range, degree of commonness, and presence of state or federally listed plant taxa for each Central Valley community.

The rationale for the proposed research was that such information would provide a more realistic basis for knowing where to locate preserves for maximum capture of plant community and species diversity, how best to measure the degree of vegetation restoration success, and how to increase the probability of predicting the location of as-yet-undocumented populations of rare plant taxa.

The products promised in the proposal were: (1) the preparation of a major paper, ultimately to be published an appropriate international journal, provisionally titled “A floristically based classification of California vernal pool communities;” (2) the preparation of a more focused paper, ultimately to be published in a regional journal, provisionally titled “The distribution of listed plant taxa among Californian vernal pool communities;” (3) the assessment of persistence among diagnostic species through time, testing the hypothesis that vernal pool communities do remain perennially identifiable despite the progression of seasons and fluctuations in annual precipitation; (4) testing the hypothesis that a practical and ecologically meaningful way to quantify the degree of success for vernal pool mitigation is to calculate the percent similarity of a mitigated community with natural community types known to occur in the region; and (5) a key to vernal pool plant communities in the Central Valley, written primarily for agency scientists, non-profit conservation staff, and private consultants.

The key would permit an individual, with a minimum of specialized training, to stand in the midst of vernal pool vegetation and identify/name the community type(s) present. Each type would be attributed in terms of diagnostic species, distributional range, habitat (pool depth, geologic substrate, type of impervious layer, degree of salinity), degree of commonness or rarity, and the likely presence of listed taxa. The attributed key would be compiled and distributed after significant consultation with USFWS and CDFG staff.

Consultation with those agencies will also be sought for the creation of a training course in the identification of vernal pool species, the method of visually dividing a vernal pool into more than one distinctive community type, and in using the vernal pool key. At this point in time we are beginning to design a 5-day course that would be offered either through University of California Extension or under the aegis of a non-profit consulting company. The content of such a training course would have to be approved by those agencies most likely to send employees to it and the course would be open to agency visitation for the purposes of maintaining an agreed-upon level of rigor and content, documented by the awarding of a certificate of completion to each person who satisfactorily completes the course.

CHAPTER 2: CLASSIFICATION OF VERNAL POOL PLANT COMMUNITIES

PREVIOUS APPROACHES TO CLASSIFICATION

A classification of vernal pool types that will capture their most important biological and ecological attributes is a critical step in the development of vernal pool conservation, regulation, and management strategies (Leidy and White 1998). Existing vernal pool classifications can be divided into two groups based on whether they use only habitat characteristics or both biological and environmental information.

A landform-based classification (Jones and Stokes 1990; Smith and Verrill 1998) distinguished four pool types according to geomorphic settings: volcanic mud/lava flow, high terrace, low terrace, and drainageway. The advantage of habitat-based classifications is that they do not require botanical knowledge and an ability to recognize hundreds of troublesome tiny little plants. In many cases, habitat-based units can provide all necessary information because vernal pool biota are linked to such habitat characteristics as edaphic settings, pool age, size, depth, and hydrology, which collectively define habitat conditions suitable for plants and animals. However, habitat-based classifications are too coarse to address all the biotic diversity among vernal pools. They are also insufficient to provide information about species abundance, which habitat characteristics are most important for each species, and where to draw biologically sound boundaries between classification units. For successful management and conservation we need a classification that is based on vegetation characteristics linked with abiotic habitat traits.

The first ecologic-floristic classification of vernal pool vegetation was developed by Holstein (1984) and later refined by Holland (1986). Both recognized seven vernal pool types based on geographic regions, type of aquatard and/or underlying geology, and indicator species: Northern Hardpan, Northern Claypan, Nothern Basalt Flow, Northern

Sandstone, Southern Interior Basalt Flow, San Diego Mesa Hardpan, and San Diego Mesa Claypan Pools. This classification was revised by Sawyer and Keeler-Wolf (1995), who identified eight vernal pool types, but still using Holland's criteria. Although they retained most of Holstein-Holland types unchanged, they added additional species to refine and expand the classification. Keeler-Wolf et al. (1998) later subdivided California into 17 vernal pool regions (Fig. 2.1). Each region was characterized by a

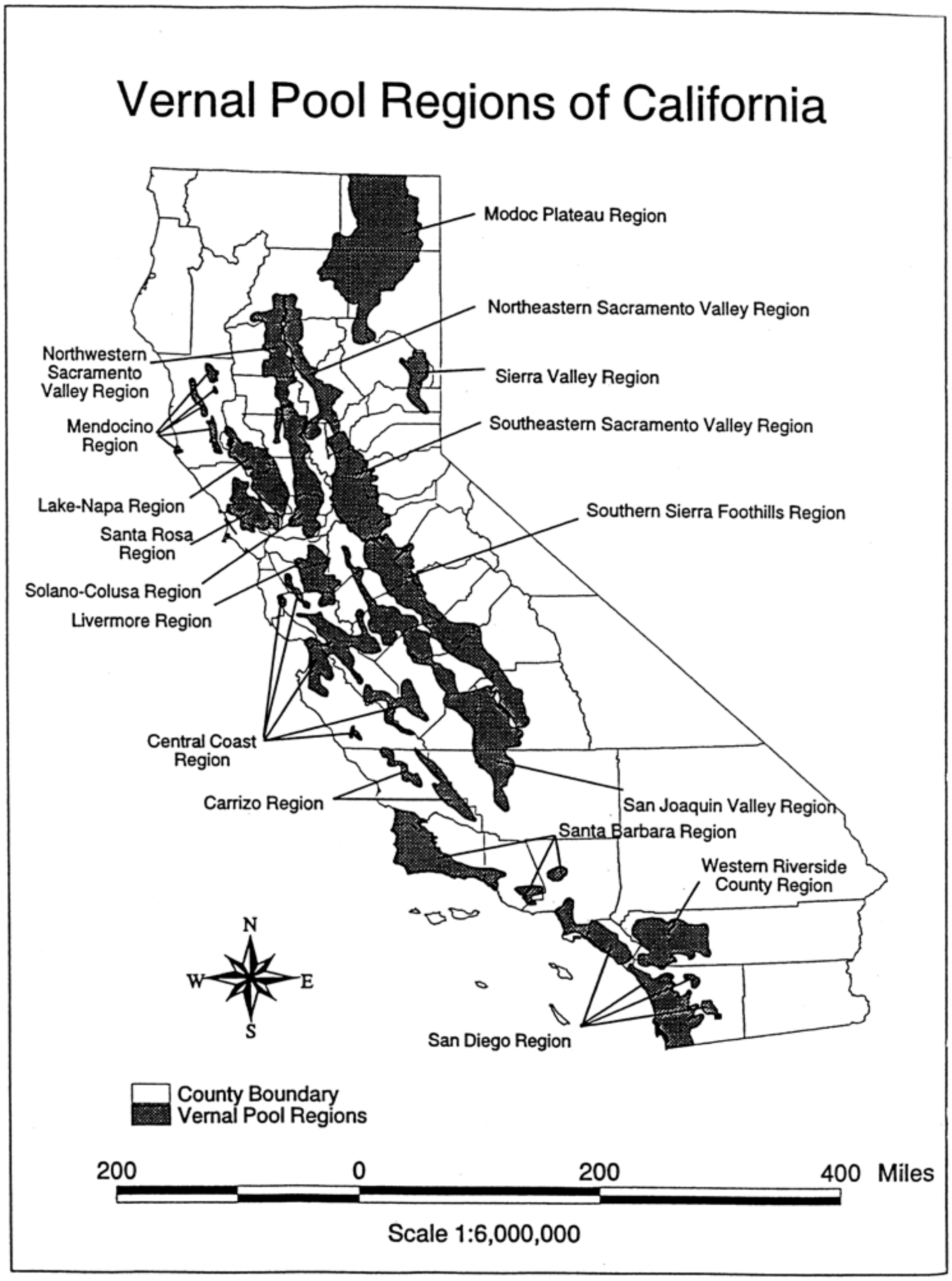


Fig. 2.1. Vernal pool regions recognized by Keeler-Wolf et al. (1998).

unique set of geologic, edaphic, and hydrologic conditions, as well as the presence of rare and endemic plants and animals. Their choice of geographic criteria successfully grouped pools with similar human impacts and into somewhat homogeneous floristic units. For example, among the 17 regions are Modoc Plateau and San Diego, which differ in climate, geology, flora, human impacts, degree of endangerment, and management options. However, these geographical regions do not define homogeneous vegetation types. Rather, each consists of a variety of vernal pool types. The classification of vernal pool regions was an important step toward developing vernal pool management areas, regions affected by the same threats and for which the same management tools could be applied.

An attempt to create a statewide fine-scale classification of vernal pools was made by Ferren et al. (1994, 1996), who listed hundreds of vernal pool types based on both abiotic and biotic traits. They built a hierarchical classification system of vernal pools, subdividing them from top down according to water regime / water chemistry / hydrogeomorphology / substrate / species dominance. They recognized more then 50 hydrogeomorphic units, such as Interior-Valley Vernal Swales, Interior-Valley Vernal Plains, Interior-Valley Vernal Pools, Coastal Dune Ponds, Montane Vernal Meadows, and Vernal Marshes, and below that level, several hundred more local types according to dominant plant or animal taxa. Because several dominants can be present, their system recognized mixed types such as "Nonpersistent Emergent Types (Dicots, Monocots, and Non-Flowering Vascular)". Classifications based on dominant species are typically applied to vegetation dominated by a small number of perennial species that maintain their dominance over a period of years. In many vernal pools, however, four or five annual dominant species coexist or replace each other during the spring months and also from year to year. As we will show later in this chapter, most pools consist of several equally represented growth forms and taxonomic groups, the abundance of each changing within and between years. Under Ferren's system, such pools would be placed in a single mixed type, which is not helpful for recognizing vernal pool diversity. Because of the broad overlapping of units based on single dominant species, and the enormous number of local types, this system has never been widely used.

To avoid inconsistency of classification units due to seasonal or annual replacement of dominant species, and to address the high floristic diversity within vernal pool vegetation, other researchers have applied a floristically based approach. Macdonald (1976) was the first to classify vernal pool vegetation types based on complete species lists. He studied vernal pool vegetation at Phoenix Park in Sacramento County by placing 10 m^2 plots within homogenous vegetation patches and listing all species that occurred in the plots along with their percent cover. He analyzed species assemblages from 41 plots using a numerical algorithm developed by Ceska and Roemer (1971), and identified 6 community types. All types were related to a microtopographic position along a gradient from blue oak woodland on hillock tops to *Eleocharis macrostachya* on deep vernal pool bottoms. Two similar studies were conducted by Jokerst (1990) and Holland and Dains (1990), but they were not taken to the classification level.

OUR METHODS

Our classification is based on pool and vegetation data collected from 2177 plots (each 10 square meters in area), placed in 700 pools, in 68 locations. A “location” is a single-owner parcel of land, usually several hundred hectares in area and incorporating many vernal pools. An attempt was made to stratify locations by vernal pool region, landform, geologic substrate, soil traits, and topographic location. Superimposed on this template was the requirement that the owner(s) would grant permission to trespass and gather data, and that access to their properties by road were possible. Those locations that combined several habitat categories were preferred over those that were more homogeneous, because heterogeneous properties would maximize the efficiency of data collection from diverse environmental settings. Locations were also constrained by the team’s available field time and the budget. The intensity of sampling correlated with the density of vernal pool locations and pools; thus approximately 79% of all plots, pools, and locations were from the Central Valley.

Data were collected from all six Central Valley vernal pool regions, as defined by

Keeler-Wolf et al. (1998), and from all but two (Carrizo and Sierra Velley) of the vernal pool regions outside the Central Valley. We also obtained data from southern Oregon and northwestern Nevada, locations outside of California's 17 vernal pool regions.

Within a given heterogeneous location, we subdivided the landscape into polygons of unique landform, geology, and topographic position, using air photos, topographic maps, and soil/geology maps, and sampled as many pools as possible in 1-2 days. If the location was homogeneous, then the team more or less sampled the first 6-10 pools encountered. The team consisted of a minimum of four individuals, and they usually broke into two pairs, so that two pools at a time could be sampled. At small locations, all pools could be sampled; at large locations only 10% of the pools could be sampled.

The vegetation of each selected pool was visually divided into 2-4 subtypes (some pools were homogeneous and could not be subdivided). These subtypes typically had narrow boundaries and appeared different because of the color of stems, leaves, or flowers, the height of the vegetation, or the dominant growth forms. For example, Fig. 2.2 is a sketch of an actual vernal pool in Jepson Prairie, Solano County. The pool had two different subtypes of vegetation, A and B. Subtype A recurred in two patches, both of which corresponded with the deeper parts of the basin (-15 cm below the fill line), whereas subtype B was a relatively shallower matrix of continuous vegetation (-10 cm below the fill line). Each subtype was sampled once with a 10 square meter plot subjectively placed in what seemed to be a representative location. Subtype A was visually distinct as bright green because of high abundance of *Lasthenia glaberrima*; subtype B was visually distinct because of the tall grass *Lolium multiflorum*, white-flowered *Limnanthes douglasii* ssp. *rosea*, yellow-flowered *Lasthenia fremontii*, and a greater species richness. We chose a plot area of 10 square meters because observations showed us that smaller plots failed to capture as many species and larger plots were too big to fit within a single subtype. The basic unit that was sampled, therefore, was not the entire vernal pool but rather the smaller homogeneous units within it.

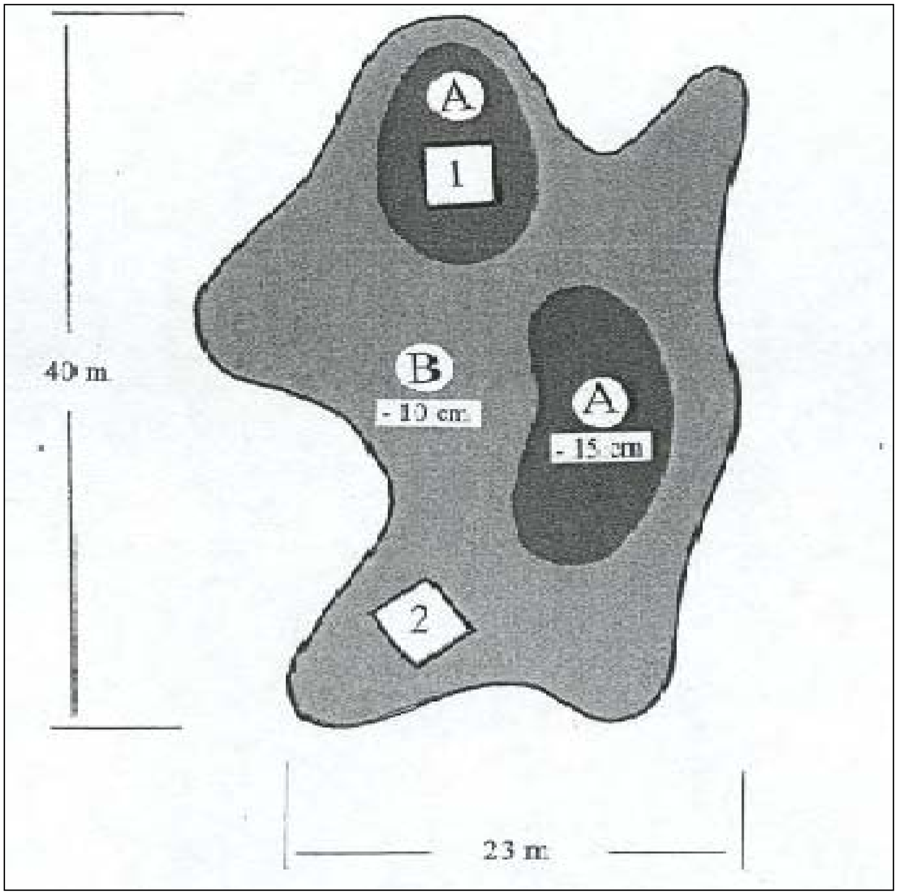


Fig. 2.2. Vegetation zonation within one Jepson Prairie pool. The location of visually different subtypes and of the 10 square meter plots are shown to scale. Subtype A occurred in the deepest parts of the pool (-15 cm) and subtype B occupied the shallowest parts (-10 cm). From Barbour et al. (2003).

Every species in a plot was recorded, together with its estimated percent cover. Habitat data (relative depth, pool shape, geologic substrate, elevation, geographic location, etc.) were also recorded. Classification of community types was accomplished by placing floristic data from all sample plots into a single table, each row being a separate plot and the data in each cell being the percent cover of each species noted. A series of iterative re-arrangments of the table, each time placing together more tightly species with similar distributions and plots with similar floristic composition. The iteration was performed with the new and widely used database Turboeg, developed for vegetation classification by Hennekens and Schaminee (2001). Then, the numerical classification algorithm Twinspan was applied to produce a first-approximation of putative community types (Hill 1979), subsequently refined and made more distinctive by using the visual editor Megatab Hennekens and Schaminee (2001). In order to condense large tables, each column is telescoped to represent all the plots belonging to the same community type, and the data in each cell are percent constancy of the species (for example, if species x occurred in 9 out of 10 of the plots now represented by a single row of data, species x would have 90% constancy). Condensed tables are called synoptic tables.

CENTRAL VALLEY COMMUNITIES IN A CALIFORNIA-WIDE CONTEXT: THE CLASS DOWNINGIA-LASTHENIA

All Californian vernal pool vegetation belongs to the class *Downingio-Lasthenietea*. This class comprises plant communities of hardpan, claypan and volcanic vernal pools, including those on fresh or alkaline soils and those in deep or shallow pools. Diagnostic species of the class, which occur throughout all of these habitats, include *Lasthenia fremontii, Navarretia leucocephala, Downingia bicornuta, Plagiobothrys stipitatus, Psilocarphus brevissimus, Deschampsia danthonioides, Pilularia americana, Elatine californica, Veronica peregrina* ssp. *xalapensis*, *Alopecurus saccatus, Eryngium vaseyi*, *Isoetes orcuttii*, *Pogogyne ziziphoroides*, *Juncus bufonius*, *Eleocharis acicularis, Callitriche marginata, Crassula aquatica* (Table 2.1; attached at end of report). Among them are both California endemics and species with circumboreal distribution.

Californian vernal pools are similar to European ephemeral wetlands of the class Isoeto-Nanojuncetea Br.-Bl. et Tx. ex Westhoff, Dijk et Passchier 1946 in the joint presence of *Centunculus minimus*, *Crassula aquatica*, *Eleocharis acicularis, Juncus bufonius, J. capitatus, Lythrum hyssopifolia, Mentha pulegium, Montia fontana*, and *Myosurus minimus*. They also share vicariant species of *Callitriche, Elatine, Eleocharis, Isoetes, Marsilea,* and *Pilularia*. Nevertheless, Californian vernal pools are uniquely characterized by the high number of genera endemic to California or the west coast of North and South America, such as *Downingia, Lasthenia, Navarretia, Plagiobothrys,* *Pogogyne,* and *Psilocarphus*. These endemic taxa also typically contribute high cover. From data about the distribution of these species we can assume that the geographic range of the class extends from southeastern Washington, throughout Oregon and California in North America, and in Chile and Argentina in South America.

This report focuses on the Central Valley, where the highest density and variety of pools occur. It includes six of the vernal pool regions recognized by Keeler-Wolf et al. (1998), as columns 1-13: Northwestern Sacramento Valley, Northeastern Sacramento Valley, Southeastern Sacramento Valley, Southern Sierra Foothills, Solano-Colusa, and San Joaquin Valley. Table 2.1 highlights how vegetation from those six regions are related to other regions: Central Coast (column 14), Livermore (15), Mendocino (16 and 17), Santa Rosa (18), Santa Barbara (21), Western Riverside (22), San Diego (23), Modoc (24 and 25). Three Keeler-Wolf regions are not shown: Lake-Napa, Carrizo, and Sierra Valley because we have too few samples to make a robust comparison. Two regions outside Keeler-Wolf's regions are, however, included: Southern Oregon (19 and 20) and Western Nevada (26-29).

The diversity of vernal pool communities from the Central Valley falls into three major groups. Communities of long-inundated pools (columns 1-3) are placed in the order Lasthenia glabberima; shallower pools (columns 4-7) are in the order Downingia-Lasthenia; saline/alkaline pools (columns 8-13) are in the order Myosurus-Lasthenia. Communities of long-inundated pools are unique in high constancy and abundance of the extremely flood-tolerant taxa *Lasthenia glaberrima* and *Eleocharis macrostachya*. Commuinities of short-inundated pools (such as upland edges or uniformly shallow and "flashy" pools) are unique in the presence of less-tolerant species such as *Cicendia quadrangularis, Blennosperma nanum, Trifolium depauparatum, Triphysaria eriantha, Lasthenia californica, Trifolium variegatum, Layia fremontii, Lepidium nitidum,* and *Microceris acuminata*, as well as upland species such as *Hypochaeris glabra, Erodium botrys, Vulpia bromoides, Bromus hordeacious, Aira caryophyllea*, and *Briza minor*, and the natives *Plagiobotrys greenei* and *Achyrachaena mollis*. Saline/alkaline pools are different in the higher presence of such halophytes as *Distichlis spicata, Plagiobotrys leptocladis, Frankenia salina, Myosurus minimus, Cressa truxillensis, Eryngium aristulatum, Pleuropogon californicus*, and *Crypsis schoenoedes*.

Table 2.1 is an overview of diversity among all Californian vernal pool regions, allowing a visual comparison between the Central Valley pools and those regions outside the valley. Central Coast and Livermore pools fall into the order of Central Valley alkaline pools. Mendocino and Santa Rosa pools are unique in their presence *of Mentha pulegium, Plagiobotrys bracteatus, Pleuropogon californicus* var. *davyi, Juncus xiphioides*, and *Geranium dissectum*. As can be seen from columns 16-18, they have fewer class species but they still fall within the long-inundated and short-inundated Central Valley pool orders. Oregon pools (19 and 20) stand out in the presence of *Downingia yina* and *Eryngium petiolatum* and the higher constancy of *Triteleia hyacinthina, Isoetes nuttallii*, and *Trichostema lanceolatum*. They are similar enough to Central Valley pools to fall within the long-inundated and short-inundated pool orders. Santa Barbara communities have higher constancy of *Plagiobotrys unbulatus*, but otherwisethey are undistinguishable from Central Valley pools. Southern California pools (columns 22 and 23) differ in the presence of such endemic taxa as *Eryngium aristulatum* var. *parishii, Navarretia prostrata, Orcuttia californica*, *Hemizonia fasciculata*, *Pogogyne abramsii*, and *Brodiaea orcuttii*. They also contain most species of the class, so they fall within the long-inundated and short-inundated pool orders. There are no halophytes in these pools. Pools from the Modoc region (columns 24 and 25) are different in the presence of *Epilobium cilulatum, E. brachycarpum, E. pallidum, Eryngium alismifolium, E. mathiasae, Polygonum polygaloides* ssp. *conferti*, *Brodiaea coronaria* ssp. *coronaria*, and ssp. *minima*. At the same time they have many class species, so they will form some subunit (level not yet determined, possibly as high as an order) within the class. Finally, pools from Nevada (columns 26-29) are floristically distinctive: they do not contain diagnostic species of the class and they have instead species not found in Californian pools, such as *Muhlenbergia richardsonis, Phlox gracilis, Camissonia thanacethifolia, Potentilla newberrryi, Artemisia tridentata, Gayophytum diffusum, Polyctenium williamsiae, Agoseris heterophylla, Collinsia sparsiflora, Polygonum douglasii, Bromus tectorum, B. salicifolium* var. *lacustris, Erodium cicutarium, Descurania sophia*. With additional work, this vegetation will no doubt be described as another class.

In sum, Central Valley vernal pool vegetation, at the level of orders, is diverse enough to capture the vegetation of other regions in Table 2.1, except for Modoc and Nevada. Listed taxa and species of concern are boldfaced in the table as a group. Some have diagnostic value (eg, *Lasthenia conjugens*, *Eryngium aristulatum* var. *parishii*) but others are too rare. Many vernal species (natives and exotics) that are common also occur in other habitats, so they are not of diagnostic value; but they still are part of the vernal pool flora and they are listed near the end of Table 2.1.

KEY TO CENTRAL VALLEY COMMUNITIES

Key to Groups

1. Halophytes (*Distichlis spicata, Frankenia salina, Cressa truxellensis, Myosurus minimus, Crypsis schoenoides*) present as a group or, if fewer then with >5% cover; habitat is saline or alkaline and a salt crust or salty soil taste is present; order Frankenia-Lastenia fremontii (saline/alkaline pools)……………………………………GROUP A

1. Halophytes absent, reduced in number, and only occasional; nonsaline habitat…...2

2. Species tolerant to long inundation (*Lasthenia glaberrima, Eleocharis macrostachya*) present with high cover; in optimal conditions, cover by these species >10% (to 80%); in lower parts of pools; saline or fresh water; order Lasthenia glaberrima….GROUP B

2. Long-inundation species *Lasthenia glaberrima* and *Eleocharis macrstachya* absent or present with low cover; located in shallower parts of pools; fresh-water pools; *Lasthenia fremontii, Psilocarphus brevisimus, Navarretia leucocephala, Alopecurus saccatus, Deschampsia danthonioides, Eryngium vaseyi, E. castrense,* and *Pogogyne ziziphoroides* abundant in part or collectively; order Downingia-Lasthenia fremontii…… GROUP C

GROUP A: saline pools, order Frankenia-Lasthenia fremontii

0. Sacramento Valley communities……………………………………………….....1

0’. San Joaquin Valley communities……………………………………………………8

1. *Lasthenia ferrissiae, L. conjugens, Arthrocnemum subterminale, Spergularia platensis*, and *Lepidium dictyotum* var. *acutidens* present as a group; the southern part of the Solano-Colusa vernal pool region ……**association Lasthenia ferrissia/conjugens**

1'. Taxa above not present as a group……………………………………………….2

2. *Downingia insignis, Epilobium densiflorum, E.pygmaeum* present, Northern part of Solano-Colusa vernal pool region .... **association Downingia insignis-Psilocarphus brevissimus** …..3

2'. Species present not as above, southern part of Solano-Colusa vernal pool region .4

3. *Navarretia leucocephala, Grindelia camporum*, and *Polypogon monspeliensis* present and often abundant. Sacramento Wildlife Refuge .... **Downingia insignis-Psilocarphus brevissimus, subass. Grindelia camporum**

3'. *Eliocharis acicularis, Scirpus maritimus*, and *Xanthium strumarium* present. Sacramento Wildlife Refuge ....…... ...... **Downingia insignis-Psilocarphus brevissimus, subass. Eleocharis acicularis**

3''. Species of diagnostic of subassociations Grindelia camporum and Eleocharis acicularis are not present. *Lagophylla species, Hemizonia fitchii, Malvella leprosa* ocasionally present. Dolan Ranch .... **Downingia insignis-Psilocarphus brevissimus, subass. Lagophylla sp.**

4. *Lasthenia platycarpha, L. dictyotum, Lepidium latipes* v. *latipes, L. oxycarpum, Crassula connata, Brodiaea coronaria, Plantago coronopus*, and *Poa secunda* present. Jepson Prairie, Gridley Ranch .... **association Lasthenia platycarpha-Lepidium dictyotum**

4. Not as above……………………………………………………………………….5

5. *Crypsis schoenoides* and *Cressa truxillensis* abundant, *Atriplex persistens, Croton setigerus, Juncus balticus, Lasthenia glaberrima, Polygonum arenastrum, Gnaphalium palustre* present. Communities occur on edges of playas. Willcox Ranch ....**association Atriplex persistens-Lasthenia glaberrima**

5. *Pleuropogon californicus, Lasthenia fremontii, Crassula aquatica, Callitriche marginata* present. Many locations in the southern part of Solano-Colusa vernal pool region ....………… 6

6. Indicator species of long innundation *Lasthenia glaberrima* and *Eleocharis macrostachya* abundant, *Pilularia americana, Lillaea scilloides* present. In deepest parts of pool bottoms .... **association Pleuropogon californicus-Lasthenia glaberrima**[2]

6'. Not as above………………………………………………………………….... 7

7. Indicators of short period of innundation *Limnanthes douglasii* ssp. *rosea, Blennospermum nanum v. nanum, Triphysaria eriantha* s. *eriatha, Trifolium depauperatum.* v. *depauperatum, Cicendia quadrangularis, Phalaris lemmonii, Psilocarphus tenellus* var. *glabiferous, Achaerachena mollis, Hemizonia congesta s. luzulifolia, Holocarpha virgata, Plagiobothrys greenei, Vulpia bromoides,* and *Hypochoeris glabra* present. Vernal pool edges, sometimes only 1-2 meters wide ....**association Pleuropogon californicum-Limnanthus douglasii**

7'. *Lasthenia fremontii* abundant, *Crassula aquatica, Pogogyne ziziphoroides, Myosurus minimus* s. *minimus* more common than in two defined above associations. Nither indicators of long innundation (*Lasthenia glaberrima* and *Eleocharis macrostachya*), nor short innundation (*Limnanthes douglasii* ssp. *rosea, Blennospermum nanum* v. *nanum, Triphysaria eriantha* s. *eriatha, Cicendia quadrangularis, Achaerachena mollis, Plagiobothrys greenei*, *Vulpia bromoides*, *Hypochoeris glabra* etc.) are abundant .... association **Pleuropogon californicum-Lasthenia fremontii**

8. *Plagiobothrys stipitatus* v. *micranthus, Pilularia americana, Callitriche marginata* present. Southern Sierra Foothills vernal pool region 9

8'. Not as above or these species are rare and not present as a group. San Joaquin Valley vernal pool region 11

9. *Hemizonia pungens, Deshampsia danthonioides, Trifolium variegatum, Trifolium depauperatum* var. *amplectens, Phalaris lemmonii, Medicago polymorpha*, and *Downingia bella* present. Edges of deep pools or bottoms of shallow pools. Southern Sierra Foothills vernal pool region… **association Downingia bella-Hemizonia pungens**

9'. Not as above. *Lilaea scilloides, Pilularia americana, Callitriche marginata* are typically present indicating nonger period of innundation ....…................... 10

10. *Downingia bella* abundant, *Epilobium brachycarpum,* and *Marsilia vestita* present. Often occurs within the same pools with association Downingia bella-Hemizonia

pungens but at deeper locations. Southern Sierra Foothills vernal pool region…..
....**association Downingia bella-Lillaea scilloides**
10’. *Downingia cuspudata, Myosurus minimus* s. *minimus* present. Southern Sierra Foothills vernal pool region… **association Downingia cuspidata-Myosurus minimus**
11. *Hordeum depressum* present, *Hordeum murinum s. leporinum, Spergullaria rubra, Lepidium nitidum* present ...**Hordeum depressum/murinum s. leporinum community**
11’. *Distichlis spicata* or *Cressa truxillensis* is usually abundant, *Hordeum marinum s. gussonianum, Downingia pulchella, Navarretia prostrata, Plagiobothrys undulatus, Plagiobothrys humistratus, Myosurus minimus* s. *apus* present............……………12
12. *Distichlis spicata* dominant, *Myosurus minimus* s. *minimus, Lasthenia chrysantha, Lasthenia glabrata* s. *glabra, Lasthenia glabrata* s. *coulteri, Navarretia prostrata,* and *Atriplex persistens* occasionaly present…….**ass. Downingia pulchella-Distichlis spicata**
12’. *Cressa truxillensis* and *Frankenia salina* dominant, *Myosurus sessilis,* and *Cuscuta howelliana* occasionally present ...**association Downingia pulchella-Cressa truxillensis**

GROUP B: long-inundated pools, order Lasthenia glaberrima

1. *Downingia bicornuta, Ranunculus bonariensis* var. *trisepalus, Gratiola ebracteata,* and *Plagiobothrys undulatus* present and abundant in part or collectively; hardpan and volcanic rock pools…………………………………………………………………...2
1’. Those species absent as a group, or some present but with low cover; claypan and volcanic rock pools…………………………………………………………………...4
2. *Trifolium variegatum, T. depauperatum var. depauperatum, Juncus capitatus* present, with such upland native species as *Holocarpha virgata, Tritiliaea hyacinthine* and exotics *Erodium botrys, Vulpia bromoides, Briza minor, Trifolium dubium, Geranium dissectum*
……………………………**association Trifolium variegatum-Lasthenia glaberrima**
2’. Not as above…………………………………………………………………………3
3. *Downingia cuspidata, Isoetes nuttallii, Castilleja campestris* ssp. *succulenta, Gratiola heterosepala* present; *Gratiola ebracteata* and *Plagiobothrys undulatus* and *Ranunculus*

bonariensis var. *trisepalus* absent or present at very low cover; in volcanic rock pools on table mountains………………**association Pogogyne douglasii-Lasthenia glaberrima**[2]

3'. *Gratiola ebracteata*, *Plagiobothrys undulatus*, and *Ranunculus bonariensis* var. *trisepalus* present ……..….**association Downingia bicornuta-Lasthenia glaberrima**

4. *Downingia insignis, Grindelia camporum, Epilobium densiflorum, Cressa truxillensis, Cotula coronopifolia,* and *Crepsis schoenoides* present; Solano-Colusa and Northern SacramentoValley vernal pool regions; claypan pools…………………………………. ………………………. **association Downingia insignis-Lasthenietum glaberrimae**

4'. Not as above……………………………………………………………………5

5. *Hemizonia fitchii*, *Lupinus bicolor*, *Pogogyne douglasii*, *Epilobium cleystogamium, Eryngium aristulatum, Myosurus minimus, Medicago polymorphia* present; on Vertisols in Solano-Colusa vernal pool region……………………………………………………. …………………………………. **association Lupinus bicolor-Lasthenia glaberrima**

5'. Not as above……………………………………..……………………………..6

6. *Distichlis spicata, Pleuropogon californicus,* and *Downingia concolor* present; latter species has lower constancy but when present it is a good indicator of this community type; in the southern part of the Solano-Colusa vernal pool region……………………. ……………………….. **association Pleuropogon californicus-Lastheia glaberrima**[2]

6'. *Downingia cuspidata, Isoetes nuttallii, Castilleja campestris* ssp. *succulenta, Gratiola heterosepala* present; *Gratiola ebracteata* and *Plagiobothrys undulatus* and *Ranunculus bonariensis* var. *trisepalus* absent or present at very low cover; volcanic rock pools on table mountains……………………………………………………………. ………………………………. **association Pogogyne douglasii-Lasthenia glaberrima**[2]

DESCRIPTIONS OF COMMUNITY TYPES

Communities in long-inundated habitats (*Lasthenia glaberrima* order)

The diagnostic species are: *Lasthenia glaberrima* and *Eleocharis macrostachya*. Communities of this order develop in the deepest parts of vernal pools and indicate habitats with the longest period of inundation. They are characterized by the high relative cover, as well as high constancy, of *Lasthenia glaberrima* and *Eleocharis macrostachya*. Because deep pool bottoms keep moisture for longer period, they also have high constancy and abundance of such perennial species as *Eryngium vaseyi* and *Isoetes howellii*. These communities differ from those of the other order of fresh-water communities (*Downingia-Lasthenia* order) in their absence or much lower constancy of *Blennosperma nanum* var. *nanum, Cicendia quadrangularis, Downingia cuspidata, Hemizonia fitchii, Lepidium nitidum, Limnanthes douglasii* ssp. *rosea, Plagiobothrys greenei*, and *Trifolium depauperatum*, which can not survive such long periods of inundation. Lengthy inundation also leads to a lower degree of invasion by exotic species.

Communities of the *Lasthenia glaberrima* order occur throughout the Great Valley, Sierra Nevada foothills, and table mountains on a variety of geomorphic surfaces, landforms (Basin, Low and High Terraces, and Basalt and mud flows), and soil series (Capay, Colusa, Corning, Hideaway, Pescadero, Redding, Riz, and San Joaquin,) and they may be underlayed by either a claypan, hardpan, or volcanic rock. They are restricted to fresh water pools. Within the order are 6 associations: three are characteristic of hardpan pools and three of claypan pools.

<u>Ass. Downingia bicornuta-Lasthenia glaberrima</u>. Diagnostic species: *Downingia bicornuta, Ranunculus bonariensis* var. *trisepalus, Gratiola ebracteata, Plagiobothrys undulata*. This association comprises plant communities of hardpan vernal pools on high terrace or low terrace landforms. Fits within the “Nothern Hardpan” category of Sawyer and Keeler-Wolf (1995). It is the most widespread association of all orders, occurring on Riverbank, Laguna, Tuscan, Turlock Lake, and Modesto geomorphic surfaces, and on Alamo, Fiddymint, San Joaquin, Clear Lake, Redding, Toomes, Corning, Anita, Tuscan, and Cometa soil series. It is present in five Central Valley vernal pool regions: Northeastern Sacramento Valley, Northwestern Sacramento Valley, Southeastern Sacramento Valley, Solano-Colusa, and San Joaquin Valley. Nearly 140 samples were taken of this association, and it is summarized in columns 1-7 of Table 2.2. Pools average 5000 square meters. The association is dominated by *Lasthenia glaberrima* and

Eleocharis macrostachya, and present in high constancy are *Downingia bicornuta, Ranunculus bonariensis* var. *trisepalus, Gratiola ebracteata*, and *Plagiobothrys undulatus*, which differentiate them from communities of other associations. Rare taxa encountered include *Legenere limosa*, *Gratiola heterosepala*, *Navarretia leucocephala* ssp. *bakeri, N. myersii* ssp. *myersii, N. prostrata, Orcuttia viscida*, *O. pilosa*, and *Orcuttia tenuis*. The number of species per plot averages 16. Average depth below pool edge is 17 cm (range = 2-48 cm), and topographic position averages 4.2 (on a scale of 1-5, 5 being pool bottom and 1 being upland edge). Herb cover averages 80% (range = 50-95%) and herb height averages 13 cm (range = 4-45 cm).

Because floristic variation within this association is not obviously linked with environmental variation, we described communities within it as variants: *Typica* (Table 2.2, column 1), *Eleocharis macrostachya* (Table 2.2 column 2), *Castilleja campestris* (Table 2.2 column 3), *Isoetes howellii* (Table 2.2 column 4), *Lilaea scilloides* (Table 2.2 column 5), *Glyceria occidentalis* (Table 2.2 column 6), *Lythrum portula* (Table 2.2 column 7), and *Convolvulus arvensis* (Table 2.2 column 8).

<u>Ass. Trifolio variegati-Lasthenietum glaberrimae</u> (Table 2.2 column 9). Diagnostic species: *Trifolium veriegatum*, *T. depeuperatum*, and *Holocarpha virgata* plus the invasive species *Hordeum marinum* ssp. *gussonianum, Erodium botrys, Vulpia bromoides*, *Briza minor*, and *Trifolium dubium*. The association is dominated by *Lasthenia glaberrima* and *Eleocharis macrostachya* and it differs from other associations in the high constancy of the native species *T. variegatum, T. depauperatum*, and *H. virgata* and a consistent presence of the invasive species *H. marinum* ssp. *gussonianum, E. botrys, V. bromoides, B. minor*, and *T. dubium*, all facultative wetland plants much more common in the grassland. No rare species were encountered. This association comprises communities of hardpan pool edges and bottoms on low terrace and high terrace landforms, Riverbank, Red Bluff, Laguna, and Modesto geomorphic surfaces, and the soil series San Joaquin, Alamo, Fiddyment, Redding, Anita, Hideaway, and Crevis Creek. This type fits within the “Northern Hardpan” category of Sawyer and Keeler-Wolf (1995). Pool size averaged 1600 square meters. This description is based on 18 samples, most located in the Southeastern Sacramento Valley region, but once on

Kennedy Table in the Southern Sierra Foothills region and once in the Northeastern Sacramento Valley region. The average depth of below pool edge is 7 cm (range = 1-24 cm) and pool position is 3.3. Herb cover averaged 80% (range = 65-92) and herb height averaged 15 cm (range = 7-25 cm).

Ass. Pogogyne douglasii-Lasthenia glaberrima (Table 2.2 column 10). Diagnostic species of the association: *Pogogyne douglasii*, *Downingia cuspidata*. Dominants include *Lasthenia glaberrima*, *L. fremontii*, *Eryngium castrense/vaseyi*, *Plagiobothrys stipitatus* var. *micranthus*. Two common vernal pool species, *Callitriche marginata* and *Psilocarphus brevissimus* var. *brevissimus*, have high constancy but low cover. Floristically, this association is unique in the presence of *P. douglasii* and *D. cuspidata*, and in the absence of diagnostic species of other associations. Species richness per plot is low (average = 11). Communities of this association occur in volcanic rock pools on volcanic landform with Lovejoy geomorphic surface and on Hideaway soil series, and they are characteristic of table mountains. This type fits withing the “Northern Basalt Flow” category of Sawyer and Keeler-Wolf (1995). The association is based on 20 samples in the Southern Sierra Foothills region. Pool depth for this association averaged 16 cm (range = 14-18 cm) and pool position averaged 3.6. Herb cover averaged 57% (range = 25-85) and herb height averaged 16 cm (range = 5-50 cm).

Ass. *Lupinus bicolor-Lashtenia glaberrima* (Table 2.2 column 11). Diagnostic species of the association: *Lasthenia glaberrima, Lupinus bicolor, Hemizonia fitchii, Pogogyne douglasii, Medicago polymorpha, Myosorus minimus*. The only rare taxon encountered was *Hesperevax caulescens* (5% constancy). The association is based on 22 samples, all on clay pans of basin and basin rim landforms with Holocene geomorphic surface and the vertisol soil series Capay and Clear Lake. This type fits within the “Northern Claypan” category of Sawyer and Keeler-Wolf (1995). Pool areas are large, averaging 49,000 square meters. The association was limited to the Solano-Colusa region. Average depth for the association is 16 cm (range = 5-20) and pool position averaged 3.8. Plant cover averaged 64% (range = 45-85%) and plant height averaged 7 cm (range = 2-12 cm).

Ass. Pleuropogon californica-Lasthenia glaberrima (Table 2.2 column 12). Diagnostic species of the association: *Distichlis spicata*, *Pleuropogon californica*, *Myosurus minumus*. This association comprises plant communities of deep bottoms of slightly saline/alkaline claypan vernal pools. They are dominated by *Lasthenia glaberrima* and *Eleocharis macrostachya*, but they are unique in the presence of salt-tolerant species. The widespread vernal pool species *Eryngium castrense/vaseyi*, *Lasthenia fremontii*, *Psilocarphus brevissimus* var. *brevissimus*, among others, are typically present. Species richness per plot averaged 14. The invasive species *Lolium multiflorum*, *Lythrum hyssopifolia*, and *Erodium botrys* are common, and *L. multiflorum* is sometimes abundant. Rare taxa encountered are *Legernere limosa* (17% constancy), *Downingia pusilla* (13%), *Gratiola heterosepala* (2%), and *Lastheneia conjugens* (2%). The association is based on 53 samples in the Solano-Colusa region, in claypan pools on alluvial fan, basin rim, and low terrace landforms with Modesto geomorphic surface and on soil series Pescadero, San Ysidro, Antioch, and Solano (Sycamore once only). This type fits within the "Northern Claypan" category of Sawyer and Keeler-Wolf (1995). Pool area was intermediate, 5500 square meters. Pool depth for this association averaged 15 cm (range = 4-45 cm) and pool position was extreme, averaging 4.6. Plant cover averaged 75% (range = 55-95%) and plant height averaged 10 cm (range = 4-25 cm)

Ass. *Downingia insignis-Lasthenia glaberrima* (Table 2.2 column 13). Diagnostic species of the association: *Lasthenia glaberrimua*, *Downingia insignis*, *Grindelia camporum*, *Cotula coronopifolia*, *Epilobium densiflorum*, *Cressa truxellensis*, *Crypsis schoenoides*. No rare taxa were encountered. The association is based on 15 samples, all in somewhat saline/alkaline claypan pools on basin and basin rim landforms with Holocene and Modesto geomorphic surfaces and on the soil series Colusa, Riz, and Willows (once only). This type fits within the "Northern Claypan" category of Sawyer and Keeler-Wolf (1995). Pools are large, averaging 11,500 square meters. The association is limited to the Solano-Colusa region.

Communities of fresh-water, short-inundated pools: order Downingia bicornuta- Lasthenia fremontii

The diagnostic species of the order are: *Blennosperma nanum, Downingia cuspidata, Hemizonia fitchii, Trifolium depauperatum, Limnanthes douglasii* ssp. *rosea, Cicendia quadrangularis, Lepidium nitidum, Plagiobothrys greenei.*

This order represents a broad variety of vernal pool communities of relatively shallow pool bottoms and pool edges. They occur on various landforms ranging from low and high terraces to volcanic basalt and lava flows. Geologic formations range from Modesto, Riverbank, Turlock Lake, Red Bluff, and Laguna formations on terraces to Mehrten, Valley Spring and Lovejoy formations on volcanic mud flows and basalts. Soil varies from Palexeralfs and Durixeralfs on terraces to Haploxeralfs and Xerorthents on basalt and mud flows. Communities of this order are found in both hardpan and claypan pools, but always in fresh-water systems. Despite tremendous variety of edaphic and physiographical conditions, these pools share a group of common taxa. This order has the richest flora of all three orders, in part because taxa from ecotones with uplands are included (especially the exotics *Hypochaeris glabra, Bromus hordeaceus, Erodium botrys, Vulpia bromoides, Aira caryophyllea,* and *Briza minor,* and the natives *Hemizonia fitchii, Trifolium depauperatum,* and *Lepidium nitidum).*

<u>Ass. Lupinus bicolor-Eryngium aristulatum</u> (Table 2.3, column s 1 and 2). Diagnostic species: *Hemizonia congesta ssp. lusulifolia, Lupinus bicolor, Eryngium aristulatum, Trifolium wormskioldii, Medicago polymorpha*. No rare taxa were encountered. The association was defined on the basis of 18 samples, all in claypan pools of basin and basin rim landforms with Holocene geomorphic surface and on the vertisol soil series Capay and Clear Lake. This type is included in the “Northern Claypan” category of Sawyer and Keeler-Wolf (1995). This association was restricted to the Solano-Colusa region. Pools are large, averaging 50,000 square meters. Average depth below fill line for this association is 4 cm (range = 3-8 cm) and average pool position is 2.7. Plant cover averages 73% (range = 60-92%) and plant height averages 9 cm (range = 3-18 cm).

Two subassociations are distinguished: Lasthenia glabrata ssp. glabrata and Lepidium latipes.

Basal/typal community Eryngium vasei/astrense (Table 2.3, column 3). Diagnostic species: no unique diagnostic species, but various taxa that define the class are missing from each of the 86 samples. Rare taxa present are *Castilleja campestris* ssp. *succulenta* (5% constancy) and *Downingia pusilla* (3% constancy). This community is found in hardpan pools on alluvial fan, low terrace, and high terrace landforms with Riverbank, Laguna, China Hat, Modesto, and Red Bluff geomorphic surfaces, and on Corning, Redding, San Joaquin, Greenfield, Tuscan, and Berrendos soils. This type fits within the "Northern Hardpan" category of Sawyer and Keeler-Wolf (1995). Pools are small, averaging 1000 square meters. Limited to Southern Sierra Foothills and Northeastern Sacramento Valley vernal pool regions. Depth averages 11 cm (range = 0-36 cm) and pool position averages 4.1 Vegetation cover averages 68% (range = 35-99%) and height averages 10 cm (range = 5-15 cm).

Ass. Downingia ornatissima-Lasthenia fremontii (Table 2.3, column 4). Diagnostic species: *Downingia ornatissima*. Rare taxa that can be present (but seldom in this case) are *Downingia pusilla, Orcuttia tenuis,* and *Limnanthes floccose* ssp. *californica*. The association description is based on 100 samples. It is common in hardpan pools on high terrace and low terrace landforms with Red Bluff and Riverbank geomorphic surfaces, and on Redding, Corning, Arbuckle, and Tuscan soil series. Pools are small, averaging 1000 square meters. This type is included in the "Northern Hardpan" category of Sawyer and Keeler-Wolf (1995). Pool depth where the communities exist averages 9 cm (range = 0-26) and pool position averages 3.6. Plant cover is 79% (range = 40-99%) and height is 10 cm (range = 5-15 cm).

Ass. Downingia cuspidata/bicornuta (Table 2.3, columns 5 and 6). Diagnostic species: *Downingia cuspidata, D. bicornuta, Marselia vestita*. The rare species *Legenere limosa* could be present. This association is also unique in the absense *of Ranunculus bonariensis var. trisepalus, Castilleja campestris ssp. campestris*, and

Gratiola ebracteata, common elements in other associations. This is a relative common association in volcanic pools on volcanic, high terrace, or mud flow landforms, with Red Bluff, Tuscan, or Holocene geomorphic surfaces, and on Toomes, Tuscan, or Anita soil series. It is only found in the Northeastern Sacramento Valley region, and it fits within the "Northern Mudflow" category of Sawyer and Keeler-Wolf (1995). Pools are large, 25,000 square meters in area. The association is defined from 131 plots. Pool depth is 17 cm (range = 5-54 cm) and pool position is 3.3. Plant cover is 63% (range = 20-99%) and height is 21 cm (range = 3-50 cm).

Two variants are distinguished: Orcuttia tenuis and O. pilosa.

Ass. Downingia bicornuta-Lasthenia fremontii (Table 2.3, columns 7-10). Diagnostic species: *Downingia bicornuta, Ranunculus bonariensis* var *trisepalus, Gratiola ebracteata, Castilleja campestris* ssp. *campestris*. Species richness per plot is relatively high, averaging 20 species. The rare taxa *Downingia pusilla, Gratiola ebracteata, Navarretia myersii, Legenere limosa,* and *Orcuttia viscida* were sometimes present. This association is described on the basis of 178 plots. It is a common association in hardpan pools on Low terrace, high terrace, and (occasionally) on volcanic landforms, with Riverbank, Modesto, Turlock, Laguna, Valley Springs, Mehrten, and China Hat geomorphic surfaces, and on a wide variety of soils series (Pentz, Redding, Bear Creek, Rocklin, Cometa, San Joaquin, Amador, Gillender, Crevis Creek, Hicksville, Clear Lake, Fiddyment, Kaseberg, and Alamo). Pools are small, 700 square meters in area. This common association fits within the "Northern Hardpan" category of Sawyer and Keeler-Wolf (1995), and it occurs in the Southeastern Sacramento Valley and Southern Sierra Foothills vernal pool regions. Pool depth is 9 cm (range = 0-19) and pool position is 4.1. Plant cover is 75% (range = 52-98%) and height is 11 cm (range = 3-30 cm).

Four variants are recognized: Typica, Orcuttia viscida, Navarretia myersii, and Merced.

Ass. Ranunculus bonariensis-Holocarpha virgata (Table 2.3, columns 11-14. Diagnostic species*:* *Ranunculus bonariensis, Juncus capitatus, Holocarpha virgata*. No rare taxa were encountered. The association is based on 85 plots. This is a common association in hardpan pools on a wide variety of landforms (sedimentary, alluvial fan, low terrace, high terrace, and volcanic), geomorphic surfaces (Modesto, Turlock, Riverbank, Laguna, Valley Springs, Mehrten, Ione), and soil series (Redding, Bear Creek, Pentz, Keyes, Corning, Hornitos, Amador, Gillender, San Joaquin, Clear Lake, Fiddyment, Kaseberg, Alamo, Cometa). It is limited to Sotheastern Sacramento Valley and Southern Sierra Foothill vernal pool regions. Pools are very small, averaging 450 square meters. This association fits within the "Northern Hardpan" category of Sawyer and Keeler-Wolf (1995). Pool depth is 5 cm (range = 2-35 cm) and pool position is 3.6. Plant cover is 70% (range = 35-99%) and height is 36 cm (15-70 cm).

Four variants are apparent, but their analyses have not been completed.

Ass. Layia fremontii-Achyrachaena mollis (Table 2.3, columns 15 and 16). Diagnostic species: L. fremontii, Achyrachaena mollis, Triphysaria eriantha ssp. eriantha, Taeniatherum caput-medusae, Clarkia purpurea. No rare taxa were encountered. The association was defined from 56 plots, all in hardpan pools on high terrace and low terrace landforms with Red Bluff and Riverbank geomorphic surfaces, and on Corning, Redding, Arbuckle, Toomes, and Anita soil series. The association is limited to Northeastern Sacramento Valley and Northwestern Sacramento Valley vernal pool regions. It fis within the "Northern Hardan" category of Sawyer and Keeler-Wolf (1995). Pools are among the smallest of any association, 100 square meters in area. Pool depth is 5 cm (range = 0-16 cm) and pool position is 3.5. Plant cover is 70% (range = 15-85%) and height is 14 cm (range = 5-20 cm).

Two variants are distinguished, one in the Northwestern Sacramento Valley region and the other in the Northeastern Sacramento Valley region.

<u>Ass. Plagiobothrys austinae-Achyrachaena mollis</u> (Table 2.3, columns 17 and 18). Diagnostic species: *Plagiobothrys austiniae, Chlorogalum angustifolium, Dodecathion clevelandii* ssp. *patulum, Lasthenia californica, Microseris acuminata, Navarretia tagetina, Plantago erecta, Vulpia microstachys*. No rare taxa were encountered. The association was defined on the basis of 40 plots. This association has a limited

distribution, in volcanic rock vernal pools on volcanic landform with Red Bluff or Holocene geomorphic surfaces, and on Tuscan or Inskip soil series. Pools are intermediate, 2400 square meters in area. This association fits within the “Northern Baslat Flow” category of Sawyer and Keeler-Wolf. Pool depth is 7 cm (range = 0-21 cm) and pool position is 4.1. Plant cover is 49% (range = 23-75%) and height is 12 cm (range = 6-20 cm).

Two subassociations are recognized: Brodiaea minor and Linanthus parviflorus.

Ass. Hesperevax caulescens-Trifolium gracilentum (Table 2.3, column 19). Diagnostic species: the natives *Hesperevax caulescens* and *Trifolium gracilentum* plus the exotics *Hedypmois cretica, Erodium cicutarium, Microseris elegans, Soliva sessilis, Sonchus oleraceous*. No rare taxa were encountered. This is an uncommon association, which is defined on the basis of only 5 plots, all in hardpan pools on alluvial fan landform (once on high terrace) with Modesto geomorphic surface (once on Red Bluff), and on Bear Creek soil (once on Tuscan). The association is limited to the Southern Sierra Foothills region. Pools are small, 400 square meters. This association fits within the “Northern Hardpan” category of Sawyer and Keeler-Wolf (1995). Pool depth is 7 cm (range = 1-10 cm) and pool position is extreme bottom (5.0). Plant cover is 57% (range = 30-75%) and height is 7 cm (range = 4-12 cm).

Ass. Montia Fontana-Sidalcea calycosa (Table 2.3, columns 20-22). Diagnostic species: *Montia Fontana, Sidalcea calycosa*. No rare taxa were encountered. This is an association specific to table mountains; that is, in volcanic rock pools on volcanic landform with Lovejoy geomorphic surface, atop island-like mesas 500 m in elevation, on Hideaway or Kramn Beatsonhollow soil series. Pools are small, 2000 square meters. The association is restricted the Northeastern Sacramento Valley and Southern Sierra Foothill vernal pool regions. Pool depth is 9 cm (range = 1-35 cm) and position is 3.9. Plant cover is 72% (range = 25-100%) and height is 17 cm (range = 4-30 cm).

Two variants are recognized: Castilleja campestris ssp. succulenta and Mimulus guttatus.

Community Tuctoria greenei-Chamaesyce hooveri (Table 2.3, column 23). Diagnostic species: *Tuctoria greenei*, *Chamaesyce hooveri* (both rare taxa). At this time, the community seems held together only in the presence of the rare plant *Tuctoria greenei*; only 11 plots are in the database. The community occurs in large playa-type pools 37,500 square meters in area on high terrace landform with a Red Bluff geomorphic surface and on the Anita soil series. The community is restricted to the Northeastern Sacramento Valley region. Pool depth is 28 cm (range = 16-33 cm) and position is extreme bottom (5.0). Vegetation cover is low, only 38% (range = 4-60%) and height is short (9 cm, range = 3-30 cm).

Communities of saline pools: Myosurus-Lasthenia fremontii

The diagnostic species of the order are: *Myosurus minimus, Plantago elongata, Downingia insignis, Cressa truxillensis, Distichlis spicata, Frankenia salina, Crypsis schoenoides, Cotula coronopifolia*.

The communities in this order occur in saline or alkaline claypan pools on the Central Valley floor at the elevations typically < 30 m above sea level. They are on Basin and Basin Rim landforms and on Holocene-age alluvial deposits < 20,000 years old. Soils are alkaline (pH >9) and in the Natrixeralfs Great Group. Subsoil layers accumulate sodium-rich clay and have a xeric moisture regime. Low permeability of water and flat topography make pools almost disconnected hydrologically, and they loose water mostly through evaporation.

Pools and especially playas are large and might be flooded for periods of time (until late May and June), much longer than other pool types. Consequently, plants in these pools develop later. Floristically, communities of this order differ from other vernal pool communities in the presence of halophytes. Many of these species are perennials *(Cressa truxillensis, Distichlis spicata, Frankenia salina, Eleocharis macrostachya, Eryngium vaseyi)*, which probably indicate a longer period of inundation, a shorter dry phase, and a shallower ground water table. Although environmental stress usually depresses invisibility, these pools are often heavily invaded by salt-tolerant exotic species such as *Crypsis schoenoides, Polypogon monspeliensis*, and *Cotula coronopifolia*.

Communities of this order are home for many rare species such as *Atriplex depressa, Chamaesyce hooveri, Neostapfia colusana, Orcuttia pilosa, O. viscida,* and *Tuctoria mucronata*, which are endemic to saline pools.

Twelve associations or communities (Table 2.4, columns 7-21) belong to this order. The units in columns 1-6 contain perennial halophytes--in common with the order of saline pools--but they lack most of the species of the class. For this reason, we have not placed them in this order, but consider them to represent vegetation outside the vernal pool habitat, transitional between vernal pools and sinks (playas).

Playas and alkali sinks (Crypsis schoenoides-Cressa truxillensis)

Communities of this group develop in saline/alkaline habitats. They consist of halophytic species such as *Cressa truxillensis* and *Crypsis schoenoides* . In comparison with vernal pool comunities, they lack most or all species diagnostic for the vernal pool class Downingia-Lasthenia (such as *Lasthenia fremontii, Crassula aquatica, Plagiobothrys stipitatus* etc.). We sampled these communities either because some rare species that traditionally are affiliated with vernal pool vegetation occur in of them, or because the answer to the question wether or not they can be called as vernal pools, was not clear in the field.

<u>Community with Neostapfia colusana-Malvella leprosa</u> (Table 2.4, column 1) Diagnostic species: *Neostapfia colusana, Malvella leprosa, Phyla nodiflora.* This community has a very limited distribution: only in Olcott Lake in Jepson Prairie, in the southern part of the Solano-Colusa region, on Modesto geomorphic surface, Basin Rim landform, and Pascaredo soil series. All plots are from Olcott Lake. Cover varied from 15 to 70% and height of herbs from 3 to 20 cm. Plots were sampled in August.

<u>Community with Neostapfia colusana-Polypogon maritimus</u> (Table 2.4, column 2). Diagnostic species: *Neostapfia colusana, Polypogon maritimus.* This community has a very limited distribution, in the southern part of the Solano-Colusa region, about 12 km southeast of Davis, on Holocene geomorphic surface, alluvial fan landform, and the

Marine soil series. All plots are from a single pool 90 m long x 20 m wide. Cover varied from 35 to 75% and height varied from 3 to 8 cm. Plots were sampled in August 2005.

Community with Tuctoria mucronata (Table 2.4, column 3) . Diagnostic species: *Tuctoria mucronata.* This community has a very limited distribution, in the southern part of the Solano-Colusa region 12 km southeast of Davis and one plot in the Hamilton area on Modesto geomorphic surface, basin rim landform, and the Pascaredo soil series. Pools were approximately 70 m long x 15 m wide. Cover varied from 25 to 60% and height ovaried from 3 to 15 cm.

Community Chamaesyce hooveri-Orcuttia pilosa (Table 2.4, column 4). Diagnostic species: *Chamaesyce hooveri, Orcuttia pilosa.* This community has a very limited distribution, in the Sacramento Wildlife Refuge, within the Solano-Colusa region on Modesto geomorphic surface, basin and basin rim landforms, and Willows and Riz soil series. Cover varied from 15 to 50% and height varied from 3 to 15 cm.

Communities with Lepidium dictyotum (Table 2.4, columns 5 and 6). Diagnostic species: *Lepidium dictyotum v. dictyotum, Hemizonia fitchii , Lasthenia chrysantha, Atriplex* spp., *Spergularia macrotheca, Suaeda moquinii, Puccinellia simplex.* These communities were sampled because their relationship to vernal pool vegetation was not clear in the field. After classification of the entire dataset, it is clear that they do not belong to vernal pool vegetation because they lack most vernal pool species. For this reason, they have little relevance to this report and they are not discribed.

Vernal pool associations and communities from saline/alkaline pools

Ass. Lasthenia ferrissia/conjugens. (Table 2.4, columns 7 and 8). Diagnostic species include *Lasthenia ferrissiae, L. conjugens* (a rare taxon) *Arthrocnemum subterminale, Spergularia platensis,* and *Lepidium dictyotum* var. *acutidens*. No rare taxa were encountered. Species richness per plot ranges from 15 to 28. This is an uncommon association in claypan pools on basin rim landform with Modesto geomorphic surface, and on the Solano soil series. Pools are large (22,500 square meters). As true for all associations and communities that follow, they fit within the "Northern Claypan" category of Sawyer and Keeler-Wolf (1995). It is restricted to the Solan-Colusa region. The association's definition is based on 22 plots. Pool depth is 36 cm (range = 4-67 cm) and pool position is 3.1. Plant cover is 47% (range = 15-90%) and height is 8 cm (2-12 cm).

Ass. Downingia insignis-Psilocarphus brevissimus (Table 2.4, columns 9-11). Diagnostic species: *Lasthenia insignis, Grindelia camporum, Navarretia leucocephala, Polygonum monspeliensis*, and *Epilobium densiflorum*. The rare taxon *Orcuttia pilosa* can be present (6% constancy). This is the most common, widely distributed association on alkaline claypans in the Sacramento Valley. It occurs on basin and basin rim landforms with Modesto or Holocene geomorphic surfaces, and on Riz or Willows soil series within the Solano-Colusa vernal pool region. Species richness is moderate, 10-20 per plot. Pool depth is 12 cm (range = 1-25 cm) and position is 4.0. Plant cover is 65% (range = 15-90%) and height is 12 cm (range = 1-60 cm).

Three subassociations are recognized: Eleocharis acicularis, Grindelia camporum, and Lagophylla spp.

Ass. Atriplex persistens-Lasthenia glaberrima (Table 2.4, column 12). Diagnostic species: *Atriplex persistens, Lasthenia glaberrima, Navarretia leucocephala* ssp. *bakeri, Croton setigerus, Juncus balticus, Polygonum renastrum, Gnaphalium palustre*. No rare taxa were encountered. A relatively uncommon association in claypan pools on low terrace landform, with Modesto geomorphic surface. Association description is based on 22 plots. Pools are large (45,000 square meters). Restricted to the Solano-Colusa region. Pool position is 3.5, plant cover is 55% (range = 45-75%), and plant height is very short (4 cm, range = 3-6 cm).

Ass. Pleuropogon californicus-Lasthenia fremontii (Table 2.4, column 13). Diagnostic species: *Pleuropogon californicus, Navarretia leucocephala* ssp. *bakeri,* *Lasthenia fremontii* (the latter is dominant). More rare taxa were encountered in this association than any other: *Astragalus tener* var. *tener, Downingia pusilla, Legenere limosa*, and *Gratiola heterosepala* (none with >5% constancy). A common association (44 plots) in the Solano-Colusa region, in claypan pools on alluvial fan, basin rim, and low terrace landforms on Modesto or Holocene geomorphic surfaces, and on Antioch, Pescadero, Solano, Capay, and Colusa soil series. Pool depth is 17 cm (range = 0-46 cm) and pool position is 4.3. Plant cover is 65% (range = 15-90%) and height is 7 cm (range = 2-20 cm).

<u>Ass. Pleuropogon californicus-Limnanthes douglasii ssp. rosea</u> (Table 2.4, column 14). Diagnostic species: *Pleuropogon californicus, Navarretia leucocephala* ssp. *bakeri, Cicendia quadrangularis, Limnanthes douglasii* ssp. *rosea, Psilocarphus oregonus, Achyrachaena mollis, Psilocarphus tenellus* var. *globiferus, Hemizonia congesta* ssp. *luzulifolia, Phalaris lemmonii*. The rare taxa *Astragalus tener* var. *tener* (5% constancy) and *Downingia pusilla* (12% constancy) could be present. In claypan pools on alluvial fan, basin rim, or low terrace landforms, with Modesto geomorphic surface, and on Solano, Antioch, Pescadero, and San Ysidro soil series. Relatively common (65 plots). Pool area is moderate, 2100 square meters. Pool depth is 9 cm (range = 0-19 cm) and pool position is 4.4. Plant cover is low (60%, range 45-80%) and height is 9 cm (range = 3-20 cm).

<u>Ass. Lasthenia platycarpha-Lepidium latipes var. latipes</u> (Table 2.4, column 15). Diagnostic species: *Lasthenia platycarpha, Lepidium dictyotum, L. latipes* var. *latipes, L. oxycarpum, Crassula connata, Brodiaea coronaria, Plantago coronopus, Poa secunda, Cynodon dactylon*. The rare taxon *Astragalus tener* var. *tener* could be present. Association description based on 16 plots. In large claypan pools (17,000 square meters) on basin rim landform with Modesto geomorphic surface, on the Solano soil series. Restricted to the Solano-Colusa vernal pool region. Pool depth is 19 cm (range = 2-45 cm) and pool position is 3.3. Plant cover is low (59%, range = 15-90%) and so is plant height (6 cm, range = 2-8 cm).

Ass. Downingia bella-Hemizonia pungens (Table 2.4, column 16). Diagnostic species: *Downingia bella, Hemizonia pungens, Trifolium variegatum, T. depauperatum* var. *amplectens,* and the exotics *Medicago polymorpha, Lactuca serriola, Senecio vulgaris.* No rare taxa were encountered. A relatively uncommon association (13 plots) in claypan pools of low terrace landform, with Riverbank geomorphic surface, and on Exteter, Quonal, and Lewis soil series. Pools are very small (200 square meters), and all are within the Southern Sierra Foothills region. Pool depth is shallow (5 cm, range = 1-11 cm) and pool position is 3.1. Plant cover is 83% (range = 15-99%) and height is 26 cm (range = 7-40 cm).

Ass. Downingia bella-Lilaea scilloides (Table 2.4, column 17). Diagnostic species: *Downingia bella, Lilaea scilloides, Marsilea vestita, Epilobium brachycarpon*. No rare taxa were encountered. Similar distribution to the association above: claypan pools on low terrace landform, with Riverbank geomorphic surface and on Exeter, Quonal, and Lewis soils. Pools very small (200 square meters). Description based on 13 plots, all within the Southern Sierra Foothills region. Pool depth is 8 cm (range = 3-11 cm) and pool position is 4.0. Plant cover is 70% (range = 55-95%) and height is 20 cm (range = 10-35 cm).

Ass. Downingia cuspidata-Myosurus minimus ssp. minimus (Table 2.4, column 18). Diagnostic species: *Downingia cuspidata, Myosurus minimus* ssp. *minimus, Lilaea scilloides*. No rare taxa were encountered. Similar distribution to two associations above: in claypan pools on low terrace landform, with Riverback geomorphic surface and on Qunal and Lewis soil series. Pools very small (250 square meters), and all within the Southern Sierra Foothills region. Association description based on 13 plots. Pool depth is shallow (6 cm, range = 3-10 cm) and pool position is 3.7. Plant cover is low (54%, range = 15-80%) and height is short (6 cm, range = 1-12 cm).

Community Hordeum depressum/leporinum (Table 2.4, column 19). Diagnostic species: *Hordeum depressum, H. murinum* ssp. *leporinum*. No rare taxa were encountered. Characteristic of the drier parts of the San Joaquin Valley, in claypan pools on low terrace landform with Riverbank geomorphic surface, and on the Crosscreek soil series. Limited to the San Joaquin Valley vernal pool region. Pools very small (100 square meters in area). Community description is based on 15 plots. Pool depth is 8 cm (range = 0-16 cm) and pool position is 4.1. Plant cover is 70% (range = 10-99%) and height is 11 cm (range = 1-25 cm).

<u>Ass. Downingia pulchella-Distichlis spicata</u> (Table 2.4, column 20). Diagnostic species: *Downingia pulchella, Distichlis spicata, Atriplex persistens, Lasthenia glabrata* ssp. *glabra, L. glabrata* ssp. *coulteri, Myosurus minimus* ssp. *minimus, M. minimus* ssp. *apus, Navarretia prostrata*. No rare taxa were encountered. A relatively common association (49 plots) in claypan pools on dunefield or basin landforms, with Modesto geomorphic surface (Holocene rarely), and on Hillmar, Edminster, or Kesterson soil series. Moderate-small pools (1000 square meters in area), all in the San Joaquin Valley region. Pool depth is 8 cm (range = 0-19 cm) and pool position is 3.5. Plant cover is 70% (range = 3-97%) and height is 14 cm (range = 3-30 cm).

<u>Ass. Downingia pulchella-Cressa truxillensis</u> (Table 2.4, column 21). Diagnostic species: *Downingia pulchella, Cressa truxillensis, Frankenia salina, Myosurus minimus* ssp. *apus, Navarretia prostrata*. The rare taxon *Astragalus tener* var. *tener* could be present (but only at 5% constancy). A relatively common association (based on 43 plots) in claypan pools on basin and basin rim landforms, with Modesto or Holocene geomorphic surface, and on Edminster or Kesternson soil series. Moderate size pools (3300 square meters in area), all in the San Joaquin Valley vernal pool region. Pool depth is 10 cm (range = 1-21 cm) and pool position is 3.7. Plant cover is very low (50%, range = 1-96%), and plant height is low (6 cm, range = 1-25 cm).

DISCUSSION

Altogether, 29 entities at the level of community or association were named and defined (Table 2.5). Seven subassociations and 18 variants were also defined, but at this stage of classification it is premature to examine those in any detail. The order of long-inundated pools had the fewest named entities, which makes ecological sense in that the longer the inundation, the fewest the number of species present. Thus, long-inundated sites have few species and this limits the number of possible combinations of

Table 2.5. Summary of associations: Number of plots and vernal pool regions in which the association occurs; the nature of the impervious layer; the depth in the pool and the topographic position (1-5, 1 shallow edge and 5 pool bottom) at which the association is found; average pool area in square meters, and the number of rare taxa encountered in plots of that association.

Association name	Plots/Regions	Substrate	Depth/Position	Size	Rare spp
Long-inundated					
Downingia bicornuta-Lasthenia glaberrima	139/6	hardpan	17/4.2	5,000	7
Trifolium variegatum-Lasthenia glaberrima	18/3	hardpan	7/3.3	1,600	
Pogogyne douglasii-Lasthenia glaberrima	20/1	volcanic rock	16/3.6	4,000	
Lupinus bicolor-Lasthenia glaberrima	22/1	claypan	16/3.8	49,000	
Pleuropogon californica-Lasthenia glaberrima	53/1	claypan	15/4.6	5,500	4
Downingia insignis-Lasthenia glaberrima	15/1	claypan	15/5.0	11,500	
Short-inundated					
Lupinus bicolor-Eryngium aristulatum	18/1	vertisol claypan	4/2.7	49,500	
Community Eryngium vaseyi/castrense	86/2	hardpan	11/4.1	1,000	2
Downingia ornatissima-Lasthenia fremontii	100/2	hardpan	9/3.6	1,000	3

Downingia cuspidata/ bicornuta	131/1	volcanic rock	17/3.3	25,000	1
Downingia bicornuta-Lasthenia fremontii	178/2	hardpan	9/4.1	700	2
Ranunculus bonariensis-Holocarpha virgata	85/2	hardpan	5/3.6	450	
Layia fremontii-Achyrachaena mollis	56/2	hardpan	5/3.5	100	
Plagiobothrys austinae-Achyrachaena mollis	40/1	volcanic rock	7/4.1	2,400	
Community Hesperevax caulescens-Trifolium gracilentum	5/1	hardpan	7/5.0	400	
Montia contana-Sidalcea calycosa	78/2	volcanic rock	9/3.9	2,100	
Community Tuctoria greenei	11/1	claypan	28/5.0	37,500	2
Alkaline/Saline					
Lasthenia ferrisia-Lashtenia conjugens	22/1	claypan	36/3.1	22,500	
Downingia insignis-Psilocarphus brevissimus	112/1	claypan	12/4.0	17,500	1
Atriplex persistens-Lasthenia glaberrima	19/1	claypan	17/3.5	45,000	
Pleuropogon californicus-Lasthenia fremontii	44/1	claypan	17/4.3	9,500	4
Pleuropogon californicus-Limnanthes douglasii	65/1	claypan	9/4.4	2,100	
Lasthenia platycarpha-Lepidium latipes var. latipes	16/1	claypan	19/3.3	16,900	1

Downingia bella-Hemizonia pungens	13/1	claypan	5/3.1	200	
Downingia bella-Lilaea scilloides	13/1	claypan	8/4.0	200	
Downingia cuspidata-Myosurus minimus ssp. minimus	13/1	claypan	6/3.7	300	
Community Hordeum depressum ssp. leporinum	15/1	claypan	8/4.1	100	
Downingia pulchella-Distichlis spicata	49/1	claypan	8/3.5	1,100	
Downingiia pulchella-Cressa truxillensis	43/1	claypan	10/3.7	3,200	1

taxa. We should expect few community types, and we should expect that those types have broader distributions than communities in other orders. Indeed, the association Downingia bicornuta-Lasthenia glaberrima was found in six of the Central Valley's vernal pool regions. It occurred on low terrace and high terrace landforms, on five geomorphic surfaces (Riverbank, Laguna, Tuscan, Turlock Lake, and Modesto), and on 10 soil series (Alamo, Fiddyment, San Joaquin, Clear Lake, Redding, Toomes, Corning, Anita, Tuscan, and Cometa). This, in contrast to the usual distribution of other types that occurred in only one or two regions and were much more restricted in geomorphic surface or soil series. Fewer rare taxa were present in this order, as expected because fewer taxa of all kinds—rare or common—should be tolerant of long periods of inundation. Although one other association from long-inundated sites—Trifolium variegatum-Lasthenia glaberrima—occurred in three regions, the remaining four associations were limited to single regions. Apparently, not all associations in this order had equally broad tolerances of different microenvironments.

A nearly equal number of communities/associations were in the order of alkaline pools and fresh-water, short-inundated pools. We could interpret this pattern as meaning that an equal number of species assemblages can be tolerant of dry soil, and “dry” can be at the edge of fresh-water pools, the bottom of shallow fresh-water pools, or in saline/alkaline pools that may be moist, but are physiologically dry.

The commonness, or rarity of the 27 named entities were obviously not equal, as seen from the first column of data in Table 2.5, where the number of plots and number of regions in which each type occurred is summarized. A few types, found in two regions and in 100 or so plots, can easily be identified as the most common: Downingia bicornuta-Lasthenia glaberrima, community Eryngium vaseyi-castrense, Downingia ornatissima-Lasthenia fremontii, Downingia bicornuta-Lasthenia fremontii, Ranunculus bonariensis-Holocarpha virgata, and Montia Fontana-Sidalcea calycosa. The majority of all types, and none of the associations/communities in alkaline/saline pools, however, fit these criteria.

The rarest—with fewer than 20 plots and present in only one region—were Downingia sinsignis-Lasthenia glaberrima (long-inundaded order); Lupinus bicolor-Eryngium aristulatum, community Hesperevax caulescens-Trifolium gracilentum, and community Tuctoria greenei (short-inundated, fresh-water order); and Atriplex persistens-Lasthenia glaberrima, Lasthenia platycarpha-Lepidium latipes var. latipes, Downingia bella-Hemizonia pungens, Downingia bella-Lilaea scilloides, Downingia cuspidate-Myosurus minimus ssp. minimus, and community Hordeum depressum ssp. leporinum (alkaline/saline order). The rest were somewhere between. We have not settled yet on a quantitative method for expressing degree of rarity for vernal pool associations, but developing such a method would be invaluable for rating the impact of any one “take.” This is work for the next phase.

Pool size did not correlate with the orders. For example, we might have expected the alkaline/saline claypan pools to be largest. Indeed, some were among the largest (45,000 square meters), but some were the smallest of all (100-300 square meters). A similar range of sizes is apparent for short-inundated fresh-water pools and long-inundated pool orders.

Another attribute that did not correlate as expected, was the depth in the pool at which a type occurred, and the topographic position of that location (third column in Table 2.5). One might expect that the deeper the location, the larger the position number should be. In a few cases those two factors did correlate: Downingia insignis-Lasthenia glaberrima occurred at a relatively deep 15 cm and its position was consistently pool bottom (5.0); and Lupinus bicolor-Eryngium aristulatum occurred at a relatively shallow 4 cm and its position was very high in the pool, 2.7. But many others seemed to be poorly correlated if at all. Perhaps these attributes are not very useful in describing the habitat of a typical vernal pool association.

The pattern of association distributions among vernal pool regions was not equal (Table 2.6). This is not unexpected, because substrates are highly correlated with vernal pool regions. The Solano-Colusa and San Joaquin Vallery regions, for example, are characterized by claypans, whereas the Northeastern Sacramento Valley and Southern Sierra Foothills regions are characterized by hardpans or volcanic rocks. Beyond this, The Solano-Colusa region is rich, with 10 associations (mostly claypan types), whereas the Northwestern Sacramento Valley, with only two, is very depauparate. These patterns may mererly be artifacts of sampling design or they may express some unique environmental differences among the regions. An alaysis of this pattern is work for the next phase of research.

Table 2.6. Distribution patterns of 29 defined associations and communities. Some associations are located in more than one region, so the numbers do not add to 29.

	Number of associations per substrate		
Vernal pool region	Claypan	Hardpan	Volcanic
Northwestern Sacramento Valley		2	
Northeastern Sacramento Valley	1	5	3
Southeastern Sacramento Valley		4	
Southern Sierra Foothills	3	5	2
Solano-Colusa	10	1	
San Joaquin Valley	3		

CHAPTER 3: PERSISTENCE OF DIAGNOSTIC SPECIES AND COMMUNITY TYPES

For half a dozen years, we have been creating a classification of vernal pool associations, alliances, and orders that are defined and named after one or more diagnostic species. If the diagnostic species are not resistant to stresses, such as annual fluctuations in precipitation, then their abundance and even presence/absence will vary every year, and so will the community type(s) that they represent. A useful classification system should be robust. To test the robustness, we analyzed a set of vernal pools, the vegetation data of which had been collected over a five year period of time.

METHODS

All field data were provided by Carol Witham. She located 10 vernal pool complexes along a 300-km-long section of a PGT/PGE gas pipeline corridor that largely ran through the Sacramento Valley, from Fall River Mills in Shasta County to Jepson Prairie in Solano County. A total of 156 vernal pools were permanently located within those complexes, 80 of these pools were consistently visited twice each year (early spring and late spring) over a 5-year-period of 1994-1998. This subset of pools included seven vernal pool complexes, from Red Bluff in Tehama County to Wilson Creek in Glenn County (Table 3.1).

During each visit, the absolute percent cover for every species in each pool was recorded. The pool area sampled was defined as the area within the boundary of the high water mark, which is defined as the zone where the vegetation composition shifts in dominance from wetland to upland plant species. In general, the width of this boundary zone is <1 m. Daily precipitation for each complex was obtained from data available at the University of California’s Integrated Pest Management Program website (Statewide IPM Program 2004). Precipitation totals were partitioned into seasonal components

Table 3.1. Location and elevation of the seven vernal pool complexes, the number of pools within each that had been sampled twice a year for 5 years, and average species richness per pool over the entire period of observation. Sites are arranged from north to south.

Site name	County	Elevation (m)	No. pools	Richness
Red Bluff	Tehama	88	8	37
Coyote Creek	Tehama	82	1	45
Truckee Creek	Tehama	95	12	38
Thomes Creek	Tehama	99	18	40
Corning	Tehama	106	24	38
Hall-Stony Creek	Tehama	103	15	31
Wilson Creek	Glenn	77	2	34

(eg, Sep-Nov, Dec-Feb, Mar-May).

Statistical analyses were performed at the whole-pool scale and at the vernal pool complex scale. All 80 pools fell within a single vernal pool region, the Northwestern Sacramento Valley of Keeler-Wolf et al. (1998). The complete data set included 800 samples and 187 plant taxa. We used repeated measures analysis of variance, which takes into account covariation within repeatedly sampled pools (Sokal and Rohlf 1995), and linear regression to examine the relationship between precipitation and species richness.

Resistance for any given species was quantified as temporal persistence (P), calculated as:

$$P = \frac{100 \left(\sum a/b \right)}{n},$$

where a = the number of occurrences of a species in one pool over time, b = the number of sample periods for that pool, and n = the number of pools in which a particular taxon was present at least once during the 5 years of observation. Persistence is expressed as a percentage. It represents the average probability of finding a species in a pool in consecutive surveys over time.

A Mantel test was used to detect relationships between distances with 1000 runs of randomized data, for a Monte Carlo test of significance (McCune and Grace 2002). Tests were run comparing the similarities of species composition among pools to eight variables: distance apart along the pipeline, habitat, year, season, annual precipitation, and the three seasonal components of annual precipitation. Data were analyzed with the software package PC-ORD for Windows, Version 4.27 (McCune and Mefford 1999).

RESULTS AND DISCUSSION

Precipitation varied over the 5 years from an average low in 1993-4 of 420 mm to an average high in 1997-8 of 1050 mm (Fig. 3.1). Mean pool species richness rose and fell with rainfall, from a low of 33 species in 1993-4 to 41 in 1997-8 (Fig. 3. 2). The

Fig. 3. 1. Average precipitation (mm) across ten vernal pool sites for 5 yr. Total rainfall is partitioned into three seasonal components. From the bottom of each bar to the top they are: Sep-Nov, Dec-Feb, and Mar-May. From Buck (2004).

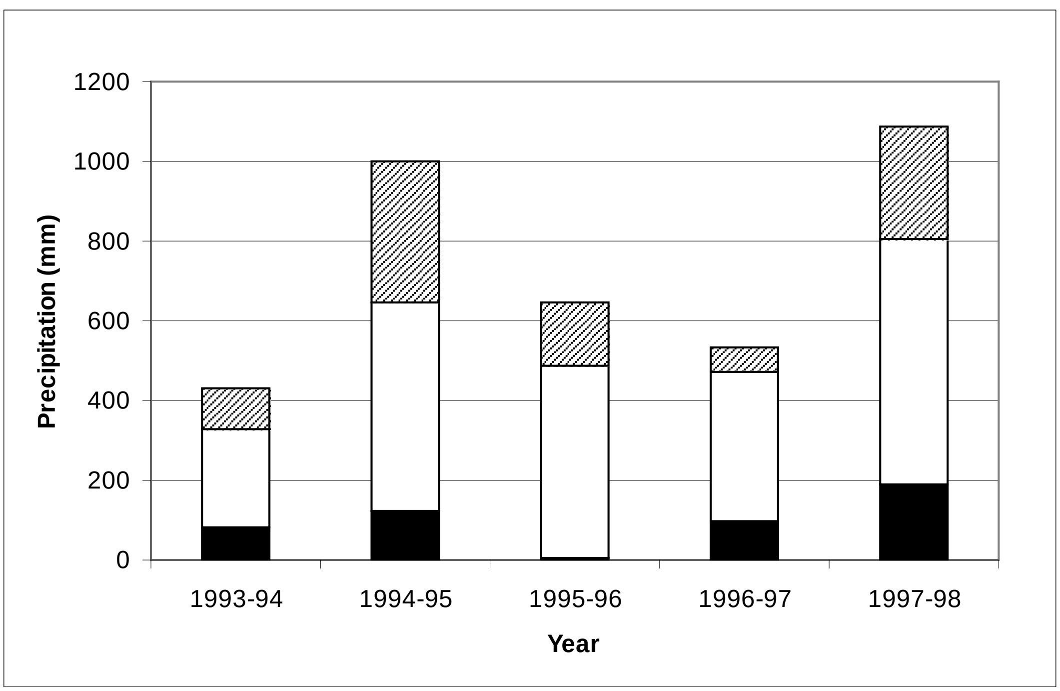
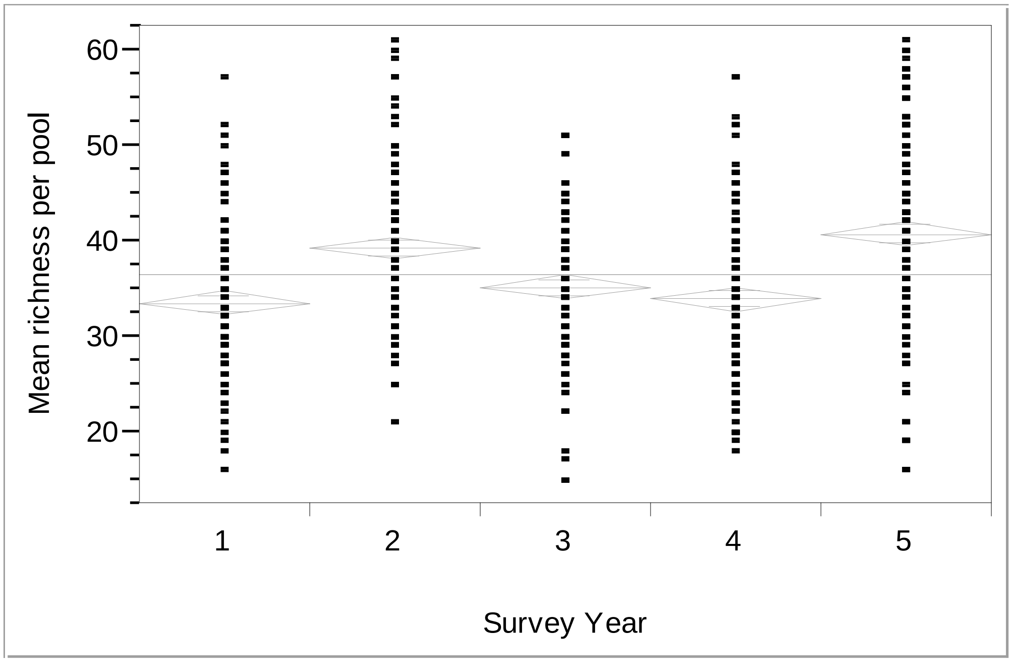


Fig. 3. 2. Mean species richness per pool over 5 yr for 80 pools. Diamonds above the grand mean line are significantly different from those below the line. From Buck (2004).



correlation between annual rainfall and richness was significantly positive at $p < 0.0001$. Partitioning of annual precipitation into seasonal components showed that winter and spring (but not fall) seasons were significantly correlated with richness ($p < 0.0001$).

The magnitude of change in abundance or presence/absence of individual species was highly variable. Diagnostic species at the class level in general had higher persistence than those at the order level, and those at the association level were the lowest (73%, 63%, and 51%, respectively; Table 3.2). Each classification level had a range of persistence values for the several species that had been preliminarily chosen by Barbour et al. (2003, 2005) as diagnostic elements. For example, at the class level, six of 15 diagnostic taxa had persistence values > 90%, and only five had values < 70%. If the number of diagnostic taxa were selectively reduced to those with relatively high persistence, as many as 10 could be retained that had persistence > 70%. Similarly, the diagnostic taxa for two out of the three orders could be selectively reduced in number to include two to seven each that had persistence values > 70%. Only Order 3, the order for saline vernal pools within the Central Valley, had just one diagnostic species with > 70%

persistence (but in this case, that single diagnostic species-- Downingia insignis--had 100% persistence.

Table 3.2. Temporal persistence (P, in percent) for diagnostic species of the class Downingio bicornutae-Lasthenietea fremontii, three orders within it, and 11 associations within those orders. The classification levels and their diagnostic species were defined by Barbour et al. (2003, 2005).

Species name	Classification Level	P
Eryngium vaseyi	Class	99
Lasthenia fremontii	Class	95
Deschampsia danthonioides	Class	94
Pogogyne zizyphoroides	Class	92
Navarretia leucocephala ssp. leucocephala	Class	91
Psilocarphus brevissimus var. brevissimus	Class	90
Juncus bufonius var. occidentals	Class	79
Crassula aquatica	Class	76
Plagiobothrys stipitatus var. micranthus	Class	75
Alopecurus saccatus	Class	70
Veronica peregrina ssp. xalapensis	Class	54
Callitriche marginata	Class	50
Isoetes orcuttii	Class	45
Pilularia americana	Class	42
Eleocharis acicularis var. acicularis	Class	41
Eleocharis macrostachya	Order 1	77
Lasthenia glaberrima	Order 1	60
Trifolium depauperatum	Order 2	86
Erodium botrys	Order 2	85
Hypochaeris glabra	Order 2	81
Limnanthes douglasii ssp. rosea	Order 2	76
Plagiobothrys greenei	Order 2	74
Hemizonia fitchii	Order 2	73
Blennosperma nanum var. nanum	Order 2	71
Lepidium nitidum var. nitidum	Order 2	65
Bromus hordeaceus	Order 2	63
Cicendia quadrangularis	Order 2	60
Vulpia bromoides	Order 2	51
Downingia insignis	Order 3	100
Cressa truxillensis	Order 3	58
Plantago elongata	Order 3	49
Cotula coronopifolia	Order 3	48
Myosurus minimus	Order 3	32

Crypsis schoenoides	Order 3	15
Pleuropogon californicus	Ass 2,8	78
Isoetes howelli	Ass 4	31
Castilleja campestris	Ass 6	69
Mimulus tricolor	Ass 9	73
Hesperevax caulescens	Ass 9	53
Psilocarphus oregonus	Ass 9,10	51
Holocarpha virgata ssp. virgata	Ass 9	44
Trifolium gracilentum var. gracilentum	Ass 9	43
Cerastium glomeratum	Ass 9	39
Trifolium variegatum	Ass 9.13,14	29
Medicago polymorpha	Ass 9	25
Achyrachaena mollis	Ass 10,11,12	76
Triphysaria eriantha ssp. eriantha	Ass 10,11,12	74
Layia fremontii	Ass 10,11,12	72
Phalaris lemmonii	Ass 10	70
Microseris acuminata	Ass 10,11,12	61
Psilocarphus tenellus var. globiferus	Ass 10	46
Taeniatherum caput-medusae	Ass 10,11,12	46
Lasthenia californica	Ass 10,11,12	41
Lupinus bicolor	Ass 11	43
Trifolium willdenovii	Ass 11	38
Navarretia tagetina	Ass 12	68
Chlorogalum angustifolium	Ass 12	64
Plantago erecta	Ass 12	59
Plagiobothrys austinae	Ass 12	43
Vulpia microstachys	Ass 12	40
Navarretia pubescens	Ass 12	20
Montia fontana	Ass 13,14	36
Mimulus guttatus	Ass 14	33
Frankenia salina	Ass 16	75

Diagnostic species of classification levels below the order generally were more sensitive to annual fluctuations: 11 species had persistence >60%, 3 species between 50% and 60%, and 16 species between 20% and 50%. Thus, community types 2, 6, 8, 9, 10, 11, 12, and 16 would have been likely to be identifiable most years. Persistence of diagnostic species for communities 4, 13, and 14, however, was <50%, meaning that those species were absent at most visits, making these communities less recognizable.

Eleven listed rare taxa had the lowest persistence of all, with a 40% probability (on average) of detecting a listed species in a pool in consecutive surveys over time (Table 3.3). However, none of these species was assigned diagnostic value for

Table 3.3. Listed vernal pool taxa recognized by the California Native Plant Society (2001) that were detected among the 80 vernal pools over the 5 yr period of time. Persistence (P) is expressed as a percent.

Species	Status	P
Juncus leiospermus var. leiospermus	1B	63
Downingia pusilla	2	61
Psilocarphus brevissimus var. multiflorus	4	61
Hesperevax caulescens	4	53
Navarretia cotulifolia	4	43
Pogogyne floribunda	1B	43
Navarretia leucocephala ssp. bakeri	1B	37
Legenere limosa	1B	29
Paronychia ahartii	1B	25
Navarretia heterandera	4	14
Astragalus tener var. tener	IB	14

classification units at any level. Examples of extremely low persistence include: *Astragalus tener* var. *tener*, which occurred only once (and then at < 1% cover) in five years of observations; *Juncus leiospermus* var. *leiospermus* was found in one pool for the first two years, then was not detected again; *Legenere limosa* blinked in and out of four pools; and *Navarretia cotulifolia*, *Paronychia ahartii*, and *Pogogyne floribunda* each occurred only three times. These results emphasize the importance of repeated surveys conducted over different years in order to detect certain rare taxa. In addition, some species presence was tied tightly to season, for example, *Navarretia heterandra* was usually found in late season surveys. This reinforces the importance of conducting rare plant surveys that are timed appropriately with the life cycle of the given species.

The degree of correlation between species composition in a given pool and abiotic factors was statistically significant for some factors (habitat type defined by Holland (1986) and geographic distance), but in most cases the Mantel statistic (r) was low, meaning that dissimilarity over time was only weakly related to measured factors (year and season; Table 3.4). Surprisingly, annual precipitation was not significantly related to changes in whole pool species composition. Geographic distance had more to do with floristic differences than did climate: the species composition of pools far apart are much more different, at any one time or over time, than the species composition of nearby pools or of releves within pools. This result implies that a floristically-based statewide classification may very well be robust in describing differences in vegetation across a geographic range.

Table 3.4. Mantel statistic (r) and significance of correlations between species composition within plots and abiotic variables. Asterisk = not statistically significant at p = 0.01.

Variable	r	p-value
Habitat (landform)	0.518	0.001
Location along pipeline	0.409	0.001
Year	0.113	0.001
Season (early vs late)	0.025	0.001
Annual precipitation	0.014	0.075*
Fall precipitation	-0.027	0.050*
Winter precipitation	0.108	0.001
Spring precipitation	0.121	0.001

In sum, vernal pool vegetation *does* exhibit resistance to annual variations in climate stress, and the degree of resistance increases with the scale of the classification level examined. Many diagnostic species for classes and orders show high persistence, such that the probability of finding them in the same pool, year after year, exceeds 0.7 (where 1.0 is the highest possible probability, meaning that the species is always present). Among 11 associations, however, a minority had more than one diagnostic species with persistence probability > 0.7. This potential problem can be rectified in two ways. First of all, the classification of vernal pool plant communities is still preliminary. As the classification becomes more complete, the identification of diagnostic species will change, and the new ones selected may have higher persistence. Secondly, for those associations whose diagnostic taxa remain unchanged, data about persistence from this study, and others, will permit us to select a subset of diagnostic taxa that have the highest persistence, relegating others to a less critical status in terms of identifying associations.

CHAPTER 4: PRESENCE OF LISTED PLANTS IN CENTRAL VALLEY COMMUNITIES

While vernal pool ecosystems are rare in and of themselves, some vernal pool taxa are even further restricted. In order to determine why some species are rare, one must first understand the habitat and ecology of the species. This information is not available for the majority of vernal pool species, even those that are considered common. The goals of this chapter are: (1) to characterize the habitat requirements of 18 listed vernal pool plant species; (2) to identify the community types that most commonly co-occur with rare taxa; and (3) to summarize what is known about the environmental variables that influence the distribution of rare vernal pool plants.

METHODS

We collected data on vernal pools throughout California for field seasons between 2001 and 2006, and rare taxa were encountered in many of the plots. A rarity dataset for vernal pool plants exists, based on information from CNPS listings, California State listings, and Federal listings. This dataset contains information on 39 plant species, but only a subset of them were selected for this project. We omitted species that are not vernal pool endemics, that have an extremely small number of populations, or that were located outside of Central Valley vernal pool, leaving a total of 18 rare vernal pool plant species summarized here.

In order to identify clusters of vernal pool species the co-existed with listed species, the multivariate program SYN-TAX (sub-routine HIERCLUS) was used to create a dendrogram (Podani 1994). For this analysis, all rare species with < 3 occurrences and all other species that had <10 occurrences in the database were excluded from the analysis. In this program, an average linkage procedure was used with a 1-V coefficient, where $V= (ad-bc)/\sqrt{[(a+b)(a+c)(b+d)(c+d)]}$ and where a, b, c, and d are cells in a 2x2 contingency table (Pielou 1977).

To identify which environmental variables contribute the most to predicting rare species distribution, analyses were performed using CANOCO (ter Braak 2002). In order to use the most consistent data, plots taken outside of California, that were not 10 m^2 in area, and lacking information on depth of the pool, depth of the plot, or GPS coordinates were removed from the analysis.

A Canonical Correspondence Analysis (CCA) was performed on the dataset. A primary matrix of the sample units and species was set up, as well as two other matrices with the environmental variables and the co-variables. The environmental variables used in this analysis included cover of natives and non-natives, soil, litter, algae, open water, bare rock, drop (i.e. animal dropping), and punch (i.e. indentations made from animal hooves); total vegetation cover; the area of the pool, its maximum depth, and the depth at which releves were taken (expressed as a negative number). The co-variables used in this analysis include coordinates and phenology. Co-variables were included in an effort to remove the effect that location and time of sampling might have on the results.

RESULTS AND DISCUSSION

Overview

By summarizing the numerous measurements and observations taken for each rare species, we were able to link certain habitat preferences with each taxon (Table 4.1). For example, some species were most often encountered in deep pools (>40 cm): *Lasthenia ferrisiae*, *Neostapfia colusana*, *Orcuttia viscida*, *O. tenuis*, and *Gratiola heterosepala*; and others in shallow pools (<20 cm): *Navarretia heterandra* and *Castilleja campestris* ssp. *succulenta*. Rare taxa that occurred in the largest pools (> 50,000 m^2 in area) include *Lasthenia ferrisiae*, *Gratiola heterosepala*, *Orcuttia pilosa*, *O. tenuis*, and *Tuctoria greenei*; those that occurred in the smallest pools (< 5,000 m^2) were *Navarretia myersii* ssp. *myersii* and *Tuctoria mucronata*. Many of the rare grass species tend to occupy very

Table 4.1. Habitat characterization of listed rare vernal pool plant species. Data are summarized from the UC Davis vernal pool team database from field work conducted between 2001 and 2005. Unkn indicates that data was not taken. "Site" is synonymous with "location" as used in other parts of this report.

Species Name	**Listing**	**Sites**	**Pools**	**Releves**	**Avg. Releve Herb Cover (%)**	**Avg. Pool Max Depth (cm)**	**Avg. Releve Depth (cm)**	**Avg. Pool Area (m2)**	**% Non-native**	**Richness**
Astragalus tener var. *tener*	CNPS 1B	6	10	11	70	27	14	32,500	20	20
Castilleja campestris ssp. *succulenta*	Federal-Threatened	4	15	35	59	19	9	5,500	18	15
Chamaesyce hooveri	Federal-Threatened	2	6	12	29	21	20	37,400	23	5
Downingia pusilla	CNPS 2	2	4	4	66	20	12	10,200	20	22
Gratiola heterosepala	CA-Endangered	6	9	23	57	41	24	69,500	14	14
Lasthenia conjugens	Federal-Endangered	3	11	42	75	23	17	14,200	26	15
Lasthenia ferrisiae	CNPS 4	2	2	14	64	68	31	66,800	31	17
Legenere limosa	CNPS 1B	4	9	24	73	23	14	27,600	19	17
Navarretia heterandra	CNPS 4	4	5	9	64	12	+3	9,400	25	23
Navarretia leucocephala ssp. *bakeri*	CNPS 1B	4	10	21	64	23	19	29,000	26	24
Navarretia myersii ssp. *myersii*	CNPS 1B	2	24	51	64	20	15	1,540	22	23
Navarretia prostrata	CNPS 1B	5	11	49	74	22	11	19,000	24	16
Neostapfia colusana	Federal-Threatened	2	2	20	50	41	Unkn	25,400	23	6
Orcuttia pilosa	Federal-Endangered	3	7	28	45	26	19	57,200	11	11
Orcuttia tenuis	Federal-Threatened	5	6	41	68	42	31	184,100	20	12
Orcuttia viscida	Federal-Endangered	3	6	17	64	45	42	18,800	16	12
Tuctoria greenei	Federal-Endangered	1	1	8	30	33	30	160,200	10	5
Tuctoria mucronata	Federal-Endangered	2	2	11	37	Unkn	Unkn	3,300	17	5

open vernal pools. Pools containing *Neostapfia colusana*, *Orcuttia pilosa*, *Tuctoria greenei*, and *T. mucronata* had a low average herbaceous cover (< 50%), indicating that densely vegetated pools may be an environment in which these grasses cannot survive.

Although it is commonly written that vernal pool plants are poor competitors with exotic species, three of the listed species in our study occurred in pools with ≥30% cover from non-native plants: *Lasthenia ferrisiae*, which grew in the deepest pools of all the rare species (68 cm); *Navarretia fossalis*, found in fairly shallow pools of 18 cm; and *Pogogyne nudiuscula*, in shallow pools of 15 cm depth. The pools with the lowest percent cover of non-natives contained *Tuctoria greenei* and *Orcuttia pilosa*, with maximum depths averaging in the middle range of 26-30 cm.

There were apparent relationships with the type of impervious soil horizon and/or the alkalinity/salinity of the soil. No rare taxa were present in associations of the alkaline/saline order. Most rare taxa also avoided volcanic rock pools, but *Castilleja campestris* ssp. *succulenta* was positively associated with that habitat, and it was tolerated (but not preferred) by *Gratiola heterosepala* and *Orcuttia viscida*.

The pattern of rare species distribution with associations was variable. Very few rare taxa occurred with only one association: *Navarretia prostrata* and *N. heterandra* were exclusively found in Downingia bicornuta-Lashtenia glaberrima, *Lasthenia conjugens* was exclusively found in Pleuropogon californica-Lasthenia glaberrima (but rarely), and *Chamaecyse hooveri* was exclusively found with community Tuctoria greenei-Chamaecyse hooveri (and vice-versa). *Gratiola heterosepala*, in contrast, was linked with no less than six different associations, *Castilleja campsestris* ssp. *succulenta* was linked with three associations, and *Orcuttia tenuis* was also linked with three associations. The remaining ten rare taxa were linked with two associations each.
In sum, the hope for predicting new populations of rare taxa, by searching for particular associations, is still promising, but clearly limited. Only a minority of the rare taxa were strongly linked with a single association, and furthermore had a high enough constancy, to make such a community-based search likely to bear results. Seldom did a rare taxon have >10% constancy in any given association.

Species summaries

The next section of the chapter reviews each of the 18 species separately, in alphabetical order, with a combination of prose and tabular material.

***Astragalus tener* v. *tener* (alkali milk-vetch)**

<u>Status</u>: CNPS List 1B.

<u>Description and Range:</u>

Astragalus tener v. *tener* is an annual member of the family Fabaceae. It flowers from March through June and can occur at elevations of 1 to 60 m (CNPS 2001), in playas and in grasslands as well as in alkali vernal pools (CNPS 2001). *A. tener* v. *tener* is known from 5 vernal pool regions with the majority of extant occurrences in the Solano-Colusa Vernal Pool Region (69%) followed by the San Joaquin Valley Vernal Pool Region (23%).

The database contains information on *A. tener* v. *tener* from two of the five vernal pool regions (Solano-Colusa and San Joaquin Valley). Data were collected from five sites in the Solano-Colusa Vernal Pool Region and one site in the San Joaquin Valley Vernal Pool Region. A total of 10 pools and 11 releves were collected from the six sites (Table 4.2). Sites containing *A. tener* v. *tener* occurred on both Modesto and Holocene geomorphic surfaces and three landforms including: alluvial fans, low terrace, and basin rim. This species was found on quite a few different soil series; Antioch, Solano, Solano-Pescadero, Capay clay, Edminster-Kesterson, and Sycamore.

<u>Associations:</u>

Lupinus bicolor-Eryngium aristulatum; occasionally.

<u>Habitat and Ecology of Sites:</u>

Maximum depth of all pools at each site was averaged as well as the depth across releves at each site. Across all sites, the average maximum depth of the pools was 27 cm with the shallowest pool 6 cm and the deepest pool 72 cm deep. On average, releves were taken at a depth of 14 cm with the shallowest at 5 cm and the deepest releve at 33 cm. Average pool area across sites was 32,500 m2 with a maximum pool area of 155,200 m2 and a minimum pool area of 750 m2. The average total herb cover across sites was 70%

with a maximum herb cover of 91% and a minimum herb cover of 15%. Average cover of litter was <5% across sites and the average cover of algae was 5% across sites. The average species richness across sites was high at 20 species. There were a total of 86 species that co-occured with *A. tener* v. *tener*, 26% that are not native to California.

Table 4.2. *Astragalus. tener* v. *tener* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	**County**	**Historical Occurrences**	**Extant Occurrences**	**Sites**	**% Occurrences Sampled**	**Pools**	**Releves**
Central Coast	Alameda	6	1				
	Monterey	1	0				
	San Benito	1	0				
	Santa Clara	4	0				
Livermore	Alameda	4	1				
	Contra Costa	2	0				
San Joaquin Valley	Merced	9	9	1	11%	2	2
	San Joaquin	1	0				
	Stanislaus	1	0				
Solano-Colusa	Solano	24	19	4	21%	7	7
	Yolo	11	8	1	13%	1	2
Santa Rosa	Napa	2	1				
	Sonoma	1	0				
TOTALS		**67**	**39**	**6**	**15%**	**10**	**11**

***Castilleja campestris s. succulenta* (succulent owl's-clover)**

Status: Federally threatened, CA endangered, CNPS List 1B.

Description and Range:

Castilleja campestris s. *succulenta* is an annual hemiparasitic member of the Scrophulariaceae family. It flowers in April and May and can occur in vernal pools at elevations of 50 to 750 m (CNPS 2001). *C. campestris* s. *succulenta* is known from 2 vernal pool regions and has all but one of its 91 occurrences in the Southern Sierra Foothills Vernal Pool Region (CNDDB 2006). The other occurrence is in the SE Sacramento Valley Vernal Pool Region (CNDDB 2006).

The UCD database contains information on *C. campestris* s. *succulenta* from 4 sites in the Southern Sierra Foothills Vernal Pool Region. A total of 15 pools and 35 releves were collected in these 4 sites (Table 4.3). Sites containing *C. campestris* s. *succulenta* occurred on three geomorphic surfaces; Redding, Keyes, and Lovejoy and on both high terrace and volcanic landforms. This species was surveyed on three soils series; Chinahat, Riverbank, and Hideaway.

Associations:

Pogogyne douglasii-Lasthenia glaberrima; common

Montia fontana-Sidalcea calycosa; occasional.

Downingia bicornutae-Lasthenia fremontii; occasional.

Habitat and Ecology of Sites:

Maximum depth of all pools at each site was averaged as well as the depth across releves at each site. Across all sites, the average maximum pool depth was 19 cm with the shallowest pool being 8 cm and the deepest pool 42 cm deep. Those releves that contained *C. campestris* s. *succulenta* had an average depth of 9 cm with a range of 2 cm to 20 cm. The average pool area of the 15 pools sampled was 3,900 m^2, with the smallest pool $200m^2$ and the largest pool 24,500 m^2.

Average total herb cover in *C. campestris* s. *succulenta* releves across the 4 sites was 59% with a range of 20% to 97%. Average cover of bare rock was also fairly high with at 18% with a low of 0% and a high of 55%. Average open water cover was 9% and average algal cover was 7%; however, the majority of the releves had no cover of open water and algae with only a few releves having a very high cover. Species richness across sites averaged 15 per releve. There were a total of 67 plant species co-occuring with *C. campestris* s. *succulenta,* 18% of which were non-native species.

Table 4.3. *Castilleja campestris* s. *succulenta* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	**County**	**Historical Occurrences**	**Extant Occurrences**	**Sites**	**% Occurrences Samples**	**Pools**	**Releves**
SE Sacramento Valley	San Joaquin	1	1				
Southern Sierra Foothills	Fresno	11	10	1	10%	7	21
	Madera	9	9	1	11%	3	3
	Merced	65	65	2	3%	5	11
	Stanislaus	5	5				
TOTALS		**92**	**91**	**4**	**4%**	**15**	**35**

***Chamaesyce hooveri* (Hoover's spurge)**

Status: Federally Threatened and CNPS List 1B.

Description and Range:

Chamaesyce hooveri is a prostrate annual member of the Euphorbiaceae family. It can flower from July through August and occurs in vernal pools at elevations of 25 to 250 meters (CNPS 2001). *C. hooveri* is believed to have a significant seed bank and pollination is thought to be by a variety insects (Stone et al. 1988 as cited in USFWS 2004). The prostrate growth form of this species is believed to contribute to a resistance to light and moderate grazing (Stone et al. 1987), however, there are several locations where heavy grazing has been shown to negatively affect the *C. hooveri* population (Stone et al. 1987). *C. hooveri* is known from 4 vernal pool regions with the majority of extant occurrences in the NE Sacramento Valley Vernal Pool Region (58%) followed by the Southern Sierra Foothills Vernal Pool Region (27%).

Our database has information on *C. hooveri* from two of the four vernal pool regions (NE Sacramento Valley and Solano-Colusa). Data were collected from two sites with a total of 6 pools and 12 releves sampled (Table 4.4). *C. hooveri* occurred on both Modesto and Red Bluff geomorphic surfaces and three landforms including Basin, Basin Rim, and High Terrace. This species was also found of three different soil series; Willows, Riz and Anita.

Associations:

Tuctoria greenei-Chamaesyce hooveri; common.

Habitat and Ecology of Sites:

Maximum depth of all pools at each site was averaged as well as the depth of all releves at each site. Across all sites, the average maximum pool depth was 21 cm with the shallowest pool sampled 8 cm and the deepest pool sampled 33 cm. Those releves that contained *C. hooveri* had an average depth of 20 cm with a range of 8 cm to 33 cm. The average pool area in the two sites sampled was 37,400 m^2, with the smallest pool 940 m^2 and 160,200 m^2. Average herb cover in releves with *C. hooveri* across both sites was 29% (maximum of 45% in one releve, minimum of 4% in another releve). Average litter cover and bare rock cover were both less than 1%. Species richness was low at 5 per releve across all sites. There were a total of 13 plant species co-occuring with *C. hooveri*, three of which were non-native.

Table 4.4. *Chamaesyce hooveri* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	**County**	**Historical Occurrences**	**Extant Occurrences**	**Sites**	**%Occurrences Sampled**	**Pools**	**Releves**
NE Sacramento Valley	Butte	4	3				
	Tehama	14	12	1	8%	1	4
Southern Sierra Foothills	Tulare	6	5				
	Stanislaus	2	2				
Solano-Colusa	Glenn	3	3	1	30%	5	8
San Joaquin Valley	Merced	1	1				
TOTALS		**30**	**26**	**2**	**8%**	**6**	**12**

***Downingia pusilla* (dwarf downingia)**

Status: CNPS List 2.

Description and Range:

Downingia pusilla is an annual member of the Campanulaceae. It flowers from March to May and is present in vernal pools at elevations of 1 to 445 m. This species is known to occur in six vernal pool regions with most extant occurrences evenly distributed among them (CNPS 2001).

The UCD database has information on *D. pusilla* from four sites, one in the Solano-Colusa Vernal Pool Region, two from the Southern Sierra Foothills Vernal Pool Region and one from the NW Sacramento Valley. A total of 16 pools and 23 releves were sampled at these four sites (Table 4.5). *Downingia pusilla* occurred on five different geomorphic surfaces; China Hat, Ione, Laguna, Modesto, and Red Bluff with four separate landforms including alluvial fan, basin rim, high terrace, and sediments. The soils were quite variable and included San Ysidro, Antioch, Pescadero, Corning-Redding, Redding, Corning, and Hornitos.

Associations:

Pleuropogon californicus-Lasthenia glaberrima; occasionally.
Downingia bicornuta-Lasthenia fremontii; rarely.
Downingia ornatissima-Lasthenia fremontii; rarely.

Habitat and Ecology of Sites:

Maximum depth of all pools at each site was averaged as well as the depth across releves at each site. Across sites, the average maximum pool depth is 20 cm with the shallowest pool sampled 6 cm deep at its maximum and the deepest pool sampled 39 cm deep at its maximum. Average depth of the releves was 12 cm with a minimum of 2 cm and a maximum of 25 cm. Across all sites, the average pool area was 10,200 m^2 with the smallest pool sampled 220 m2 and the largest pool sampled 56,500 m^2. Average herb cover across sites is about 66% with a range of 33% to 95%. Average cover of litter and open water were both minimal with average values of < 5% across sites. Average algal cover was 7% across sites and average cover of bare rock was 5% across sites. The 23 releves sampled had an average richness across sites of 22 species per releve. A total of 88 species were found to co-occur with *D. pusilla*, of which 20% were not native to California.

Table 4.5. *Downingia pusilla* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	**County**	**Historical Occurrences**	**Extant Occurrences**	**Sites**	**% Occurrences Sampled**	**Pools**	**Releves**
Lake-Napa	Napa	8	7				
	Solano	1	1				
NW Sacramento Valley	Tehama	12	12	1	8%	2	2
Santa Rosa	Sonoma	15	12				
Solano-Colusa	Solano	22	22	1	5%	10	17
SE Sacramento Valley	Placer	17	15				
	Sacramento	8	7				
	San Joaquin	1	1				
	Yuba	2	2				
Southern Sierra Foothills	Fresno	1	1				
	Merced	10	10	2	20%	4	4
	Stanislaus	17	17				
TOTALS		**114**	**107**	**4**	**4%**	**16**	**23**

***Gratiola heterosepala* (Boggs Lake Hedge-Hyssop)**

Status: State Endangered and CNPS List 1B.

Description and Range:

Gratiola heterosepala is an annual member of the Scrophulariaceae, it flowers from April to August and can occur in vernal pools at elevations of 10 to 2,375 m in elevation (CNPS 2001). The species has seeds that germinate and grow under water; however, it lacks the distinctly different aquatic juvenile foliage present in many other vernal pool species such as *Orcuttia* (Dittes and Guardino Consulting 2003). *G. heterosepala* is self-compatible (Kaye et al. 1990 as cited in USFWS 2004) and is believed to have a significant seed bank evidenced by greatly fluctuating populations (Corbin et al. 1994 as cited in USFWS 2004). This species is known from six vernal pool regions with the primary area of concentration in the Modoc Plateau Vernal Pool Region (45%) followed by the NE Sacramento Valley Vernal Pool Region (20%) (CNDDB 2006).

Our database has information on *G. heterosepala* from five of the six vernal pool regions it is known from. There are no samples from the Modoc Plateau Vernal Pool Region. A total of 9 pools and 23 releves were collected in these six sites (Table 4.6). Sites containing *G. heterosepala* occurred on a high number of geomorphic surfaces including Lovejoy, Modesto, Red Bluff, and Laguna. It was surveyed on many landforms including volcanic, basin rim, and high terrace and on at least six soil series.

Associations:

Pogogyne douglasii-Lasthenia glaberrima; commonly.
Downingia bicornuta-Lasthenia fremontii; occasionally.
Downingia bicornuta-Lasthenia glaberrima; rarely.
Pleuropogon californicus-Lasthenia glaberrima; rarely.
Montia fontana-Sidalcea calycosa; rarely.
Downingia cuspidata-Lasthenia fremontii; rarely.

Habitat and Ecology of Sites:

Maximum depth of all pools at each site was averaged as well as the depth of all releves at each site. Across all sites, the average maximum pool depth was 41 cm for the 4 sites in which this measurement was taken. Releves that contained *Gratiola heterosepala* had an average depth of 24 cm with a range of 5 cm to 70 cm. The average pool area across sites was about 69,500 m2 with the smallest pool sampled 3,000 m2 and the largest pool sampled 283,000 m2. Average herb cover in releves with *G. heterosepala* across sites was 57% with a high of 85% and a low of 5%. Average litter cover was < 1%; however there was a significant amount of bare rock cover, algal cover, and open water cover with average cover values of 20%, 6%, 15%, respectively. Species richness in the releves sampled averaged 14 species in each releve containing *G. heterosepala* across sites. There was a total of 58 plant species found to co-occur with G. heterosepala, 14% of which were not native to California.

Table 4.6. *Gratiola heterosepala* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	**County**	**Historical Occurrences**	**Extant Occurrences**	**Sites**	**% Occurrences Sampled**	**Pools**	**Releves**
Lake-Napa	Lake	3	3				
Modoc Plateau	Lassen	2	2				
	Modoc	19	19				
	Shasta	14	14				
	Lake	3	3	1	30%	1	1
NE Sacramento Valley	Tehama	17	17	2	12%	2	4
Solano-Colusa	Solano	6	6	1	17%	1	2
SE Sacramento Valley	Placer	3	3				
	Sacramento	11	9	1	11%	2	2
	San Joaquin	4	4				
Southern Sierra Foothills	Fresno	4	4	1	25%	3	14
	Madera	2	2				
	Merced	1	1				
TOTALS		**87**	**85**	**6**	**7%**	**9**	**23**

***Lasthenia conjugens* "Contra Costa goldfields"**

Status: Federally Endangered, CNPS List 1B.

Description and Range:

L. conjugens is an annual member of the Asteraceae. It flowers from March through June and can occur in vernal pools at elevations of 0-470 m (CNPS 2001) and is known from six vernal pool regions with the majority of extant occurrences in the Solano-Colusa Vernal Pool Region (43%) followed by the Central Coast Vernal Pool Region (24%) (CNDDB 2006).

Our database has information on *L. conjugens* from two sites in the Solano-Colusa Vernal Pool Region and one site in the Central Coast Vernal Pool Region. A total of 42 releves from 11 pools were sampled in these three sites (Table 4.7). Sites containing *L. conjugens* were all found on the Modesto geomorphic surface with either a low terrace or basin rim landform. It was found on three soil series including Solano, Sycamore, and Pescadero.

Associations:

Pleuropogon californicus-Lasthenia glaberrima; rarely.

Habitat and Ecology of Sites:

The maximum pool depth averaged 23 cm across sites, with the shallowest pool sampled being 5 cm deep and the deepest pool being 72 cm deep. Those releves that contained *L. conjugens* had an average depth of 17 cm, with a range of 5 cm above the pool's edge to 62 cm below the pool's edge. The average pool area across sites was 14,200 m^2, with a low of 100 m^2 and a high of 70,700 m^2. Total herbaceous cover in *L. conjugens* releves averaged 75% across the 3 sites, with a range of 40% to 95% herb cover. Average cover of litter and algae were both minimal (< 5%) at all sites. Species richness across all sites averaged 15 per releve. There were a total of 88 plant species found to co-occur with *L. conjugens*, including 23 that were not native to California.

Table 4.7. *Lasthenia conjugens* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	County	Historical Occurrences	Extant Occurrences	Sites	% Occurrences Sampled	Pools	Releves
Central Coast	Monterey	2	2				
	Alameda	4	3	1	30%	8	20
	Santa Clara	1	0				
Lake-Napa	Napa	2	1				
Livermore	Contra Costa	5	2				
Mendocino	Mendocino	1	1				
Santa Barbara	Santa Barbara	1	0				
Santa Rosa	Marin	1	1				
	Napa	2	1				
	Sonoma	1	1				
Solano-Colusa	Solano	12	9	2	22%	3	22
TOTALS		**32**	**21**	**3**	**14%**	**11**	**42**

Lasthenia ferrisiae **"Ferris's goldfields"**

Status: CNPS List 4.

Description and Range:

L. ferrisiae is an annual in the Asteraceae. It flowers from February through May and can be present in alkali and clay vernal pools at elevations of 20-700 m (CNPS 2001). There are no listed occurrences of *L. ferrisiae* in the CNDDB (CNDDB 2006).

The UCD database contains information on *L. ferrisiae* from two sites in the Solano-Colusa Vernal Pool Region. A total of 2 pools and 13 releves were sampled from these two sites (Table 4.8). This species occurred on a Modesto geomorphic surface underlain by basin rim and low terrace landform, and is associated with Solano and Sycamore soils.

Habitat and Ecology of Sites:

The two pools sampled had maximum depths of 72 cm and 64 cm. Average depth of the releves across sites was 31 cm, with a maximum of 62 cm and a minimum of 4 cm. The two pools sampled had areas of 62,800 m^2 and 70,700 m^2. Releves had 64% herb cover on average, with a range of 40% to 90%. Average cover of litter was < 1% across sites. Species richness in the releves averaged 17 with a total of 54 plant species found to co-occur with *L. ferrisiae* including 17 species that are not native to CalifornTable 3.8. *Lasthenia ferrisiae* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Table 4.8. *Lasthenia ferrisiae* occurrence and distribution.

Vernal Pool Region	County	Historical Occurrences	Extant Occurrences	Sites	% Occurrences Sampled	Pools	Releves
Solano-Colusa	Solano	--	--	2	--	2	14

***Legenere limosa* "legenere"**

Status: CNPS List 1B.

Description and Range:

L. limosa is an annual member of the Campanulaceae. It blooms from April through June and can occur in vernal pools at elevations of 1-880 m (CNPS 2001). *L. limosa* is one of the most variable vernal pool annual plants as it has been observed to disappear for several decades before once again reappearing (Holland 1984 as cited in USFWS 2004) suggesting that it has a long-lived seed bank. *L. limosa* occurs in eight vernal pool regions with the majority of extant occurrences in the SE Sacramento Valley Vernal Pool Region (52%) followed by the Solano-Colusa Vernal Pool Region (20%) (CNDDB 2006).

The UCD database has information on *L. limosa* from three of the vernal pool regions it is known from (SE Sacramento Valley, Solano-Colusa, and NE Sacramento Valley). A total of 9 pools with 24 releves were sampled in these four sites (Table 4.9). This species is quite variable, occurring on four geomorphic surfaces: Riverbank, Modesto, Turlock Lake, and Redbluff. It was also found on three landforms including Low and High Terrace and Basin Rim underlain by five soil series.

Associations:

Pleuropogon californicus-Lasthenia glaberrima; occasionally.

Downingia bicornuta-Lasthenia glaberrima; occasionally.

Downingia bicornuta-Lasthenia fremontii; rarely.

Downingia cuspidata-Lasthenia fremontii; rarely.

Habitat and Ecology of Sites:

Average maximum depth for pools containing *L. limosa* was 23 cm, with the shallowest pool being only 4 cm and the deepest pool 38 cm. Those releves that contained *L. limosa* had an average depth of 14 cm, with a range of 5 cm to 91 cm. The average pool area across sites was 27,600 m^2, with a low of 220 m^2 and a high of 141,400 m^2. The average pool size tended to be smaller in the SE Sacramento Valley Vernal Pool Region and was the largest in the NE Sacramento Valley Vernal Pool Region. Average total herb cover in *L. limosa* releves across sites was 73%, with a range of 60% to 95%. Average litter cover, bare rock cover, and open water cover were all < 5%. Overall, algal cover averaged 9% across sites. Releves containing *L. limosa* had an average species richness of 17 species in each releve sampled across sites. There were a total of 74 plant species found to co-occur with *L. limosa*, including 14 that were non-native.

Table 3-9. *Legenere limosa* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	County	Historical Occurrences	Extant Occurrences	Sites	% Occurrences Sampled	Pools	Releves
Central Coast	San Mateo	1	1				
Lake-Napa	Lake	3	2				
	Napa	1	1				
Solano-Colusa	Solano	13	11	1	9%	3	10
SE Sacramento Valley	Sacramento	23	22	1	5%	2	3
Other	Placer	3	2				
	Sonoma	2	1				
	Stanislaus	1	0				
	San Joaquin	3	2	1	50%	3	5
	Shasta	3	3				
	Tehama	5	5	1	20%	1	6
	Alameda	1	1				
	Santa Clara	1	1				
	Yuba	3	3				
TOTALS		**63**	**55**	**4**	**7%**	**9**	**24**

***Navarretia heterandra* "Tehama navarretia"**

Status: CNPS List 4, Oregon – Endangered.

Description and Range:

N. heterandra is an annual herb from the Polemoniaceae that flowers from April through June (CNPS 2001). This species can occur in vernal pools at elevations of 30-945 m (CNPS 2001). The CNDDB does not track occurrence information for *N. heterandra* (CNDDB 2006).

Our database contains information on *N. heterandra* from four sites in two vernal pool regions. Data were collected from three sites in the NE Sacramento Valley Vernal Pool Region and one site from the SE Sacramento Valley Vernal Pool Region. A total of 5 pools and 9 releves were sampled from the 4 sites (Table 4.10). Sites containing *N. heterandra* occurred on three geomorphic surfaces including Holocene, Red Bluff and Riverbank under three landforms; Low and High Terraces and Volcanic and three soil series.

Associations:

Layia fremontii-Achyrachaena mollis; occasionally.

Habitat and Ecology of Sites:

Across all sites, the average maximum depth of the pools was 12 cm, with the shallowest pool 7 cm deep and the deepest pool 18 cm deep. On average, releves were taken at an elevation of 3 cm above the pool's edge, with a range of 11 cm above the pool's edge to 2 cm below the pool's edge. Average pool area across sites was 9,400 m^2, with the smallest pool sampled 1,600 m^2 and the largest pool 21,400 m^2. Average herb cover across sites was 64%, with a range of 50% to 75%. Average cover of litter and bare rock both averaged < 5% across sites. Species richness across sites averaged 23 species. There were a total of 80 species found to co-occur with *N. heterandra*, 20 of these were non-native.

Table 3-10. *Navarretia heterandra* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	County	Historical Occurrences	Extant Occurrences	Sites	% Occurrences Sampled	Pools	Releves
SE Sacramento Valley	Placer	--	--	1	--	1	1
NE Sacramento Valley	Tehama	--	--	3	--	4	8
TOTALS				**4**		**5**	**9**

Navarretia leucocephala ssp. **b*akeri* "Baker's navarretia"**

Status: CNPS List 1B.

Description and Range:

N. leucocephala ssp. *bakeri* is an annual from the Polemoniaceae. It flowers from May through July and can occur in vernal pools at elevations of 15-1740 m (CNPS 2001). *N. leucocephala* ssp. *bakeri* can be distinguished from its sister taxa by having a head that is cymosely branched within and a calyx that is not villous (Day 1995). In addition, the corolla tube is inclusive, equal to or greater than the calyx and the stems are erect with 10-60 flowered inflorescences (Day 1993a). *N. leucocephala* ssp. *bakeri* occurs in six vernal pool regions, with the majority of extant occurrences in the Santa Rosa Vernal Pool Region (42%) followed by the Solano-Colusa Vernal Pool Region (21%) (CNDDB 2006).

Our database has information on *Navarretia leucocephala* ssp. *bakeri* from four sites in the Solano-Colusa Vernal Pool Region. A total of 10 pools and 21 releves were collected from the 4 sites (Table 4.11). Sites containing *Navarretia leucocephala* ssp. *bakeri* occurred on a Modesto geomorphic surface under a Basin Rim landform and both Solano and Pescadero soil series.

Associations:

Downingia bicornuta-Lasthenia glaberrima; rarely.
Pleuropogon californicus-Lasthenia glaberrima; rarely.

Habitat and Ecology of Sites:

Maximum depth and releve depth of the pools was available for 3 of the 4 sites sampled. Maximum depth averaged 23 cm, with the shallowest pool 10 cm deep and the deepest pool 46 cm deep. Depth at which the releves were taken averaged 19 cm, with the shallowest releve at 0 cm and the deepest releve 45 cm. Pool area was taken in all 10 pools, with an average area of 29,000 m^2. The smallest pool sampled was 600 m^2 and the largest pool sampled was 141,400 m^2. Releves containing *N. leucocephala* ssp. *bakeri* averaged 64% total herb cover across sites, with the lowest herb cover at 15% and a maximum herb cover of 80%. Releves containing *N. leucocephala* ssp. *bakeri* also had about 5% algal cover; while average cover of litter and bare rock were both < 1% across sites. Species richness averaged 24 species per releve across sites (Table 16-4b). A total of 99 plant species were found to co-occur with *N. leucocephala* ssp. *bakeri*, with 26 of those species (26%) non-native.

Table 3-11. *Navarretia leucocephala* ssp. *bakeri* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	County	Historical Occurrences	Extant Occurrences	Sites	% Occurrences Sampled	Pools	Releves
Lake-Napa	Lake	3	3				
	Napa	2	1				
Mendocino	Mendocino	5	5				
Santa Rosa	Marin	1	1				
	Sonoma	17	13				
NE Sacramento Valley	Sutter	1	1				
NW Sacramento Valley	Glenn	1	1				
	Tehama	1	1				
Solano-Colusa	Colusa	1	1				
	Solano	7	5	4	80%	10	21
	Yolo	1	1				
TOTALS	**11**	**40**	**33**	**4**	**12%**	**10**	**21**

Navarretia myersii **ssp.** ***myersii*****, "pincushion navarretia"**

Status: CNPS List 1B.

Description and Range:

Navarretia myersii ssp. *myersii* is an annual herb in the Polemoniaceae that flowers in May (CNPS 2001). This species can occur at elevations of 20-330 m (CNPS 2001). *Navarretia myersii* ssp. *myersii* can be distinguished from its closest *Navarretia* counterparts by its unbranched head and villous calyx tube (Day 1995). In addition, its corolla is 12-21 mm long and white (Day 1995). *N. myersii* ssp. *myersii* is known from two vernal pool regions (SE Sacramento Valley Vernal Pool Region and Southern Sierra Foothills Vernal Pool Region), with the majority of extant occurrences in the SE Sacramento Valley Vernal Pool Region (69%) (CNDDB 2006).

Our database contains information on *N. myersii* ssp. *myersii* from the SE Sacramento Valley Vernal Pool Region. Data were collected from a total of two sites, 24 pools, and 51 releves (Table 4.12). This species was found on both Laguna and Valley Spring geomorphic surfaces with Sediment and High Terrace landforms, with 3 different soil series.

Associations:

Downingia bicornuta-Lasthenia fremontii; commonly.
Downingia bicornuta-Lasthenia glaberrima; occasionally.

Habitat and Ecology of Sites:

Across all sites, the average maximum pool depth was 20 cm, with a range of 9 cm to 44 cm. Those releves that contained *N. myersii* ssp. *myersii* had an average depth of 15 cm, with the shallowest releve taken at 0 cm and the deepest releve at 36 cm. The average pool area across sites was 1,540 m^2, with the smallest pool sampled 380 m^2 and the largest pool 4,000 m^2. Average total herb cover across sites was 64%, with a range of 35% to 85% herb cover. Average covers of algae, litter, open water, and bare rock were all < 5% across sites. Species richness in releves containing *N. myersii* ssp. *myersii* averaged 23/releve. A total of 90 species were found to co-occur with *N. myersii* ssp. *myersii*, with 20 of those species non-native.

Table 3-12. *Navarretia myersii* ssp. *myersii* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	County	Historical Occurrences	Extant Occurrences	Sites	% Occurrences Sampled	Pools	Releves
SE Sacramento Valley	Amador	2	2				
	Calaveras	1	1				
	Placer	1	1				
	Sacramento	5	5	2	40%	24	51
Southern Sierra Foothills	Merced	4	4				
TOTALS		**13**	**13**	**2**	**15%**	**24**	**51**

***Navarretia prostrata* "prostrate navarretia"**

Status: CNPS List 1B.

Description and Range:

N. prostrata is an annual herb from the Polemoniaceae and flowers from April through July (CNPS 2001). This species can occur in vernal pools at elevations of 15-700 m (CNPS 2001). *N. prostrata* can be distinguished from its closest sister taxa by having a head that is not branched within and corollas that are 6-9 mm long (Day 1995). *N. prostrata* can be distinguished from *N. fossalis* by having a longer corolla and shorter calyx (Moran 1977). While *N. prostrata* and *N. fossalis* both occur together on the Santa Rosa Plateau, there are numerous differences between the two species that are maintained in nature (Day 1993b as cited in Day 1995). *N. prostrata* is known from five vernal pool regions, with the majority of occurrences in the San Diego Vernal Pool Region (32%) followed by the Central Coast Vernal Pool Region (27%) (CNDDB 2006).

Our database has information on *N. prostrata* from six sites, four of which are in the San Joaquin Valley Vernal Pool Region, one in the Central Coast Vernal Pool Region, and one in the Western Riverside County Vernal Pool Region. In these six sites, data were collected from 11 pools and 49 releves (Table 4.13). This species was found on two geomorphic surfaces, Holocene and Modesto, on three landforms Basin, Basin Rim, and Dunes, and on three soil series.

Associations:

Downingia bicornuta-Lasthenia glaberrima; rarely.

Habitat and Ecology of Sites:

The maximum depth for all pools averaged 22 cm, with the deepest pool sampled 47 cm and the shallowest 12 cm. The average depth at which the releves containing *N. prostrata* were taken was 11 cm, with the deepest releve 47 cm below the pool's edge and the shallowest releve 6 cm above the pool's edge. Average pool area across sites was

19,000 m^2, with the largest pool 48,700 m^2 and the smallest pool 360 m^2. Average herb cover across sites was 74%, with a maximum herb cover of 100% and a minimum herb cover of 25%. Average algal, litter, and bare rock covers were all < 5% across sites. Species richness across sites averaged 15 per releve. A total of 102 species were found to co-occur with *N. prostrata*, including 24 that were non-native.

Table 3-13. *Navarretia prostrata* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	County	Historical Occurrences	Extant Occurrences	Sites	% Occurrences Sampled	Pools	Releves
Carrizo	San Luis Obispo	3	3				
Central Coast	Alameda	2	2	1	50%	1	1
	Monterey	5	4				
San Diego	Los Angeles	6	0				
	Orange	3	3				
	San Diego	4	4				
San Joaquin Valley	Merced	4	4	4	100%	7	29
Western Riverside County	Riverside	2	2	1	50%	3	19
Other	San Bernardino	2	0				
TOTALS		**31**	**22**	**6**	**27%**	**11**	**49**

***Neostapfia colusana* "Colusa grass"**

Status: Federally Threatened, CA Endangered, and CNPS List 1B.

Description and Range:

N. colusana is an annual member of the Poaceae. *N. colusana* flowers from May to August and can occur in vernal pools at elevations of 5-200 m (CNPS 2001). *N. colusana* is the least specialized of all the members of the Orcuttieae tribe to the aquatic environment (Keeley 1998). *N. colusana* is known from three vernal pool regions, with the majority of occurrences in the Southern Sierra Foothills Vernal Pool Region (82%) followed by the San Joaquin Valley Vernal Pool Region (10%) (CNDDB 2006).

The UCD database has information on *N. colusana* from the Solano-Colusa Vernal Pool Region. Data were collected from two sites for a total of 2 pools and 20 releves (Table 4.14). Sites included Modesto and Holocene geomorphic surfaces with Basin Rim and Alluvial Fan landforms underlain by two soil series, Pescadero and Marvin.

Habitat and Ecology of Sites:

The only data collected on depth was a single maximum depth measurement which was 41 cm. However, the area of two of the three pools was taken, with areas of 5,700 m^2 and 45,200 m^2. Average herb cover was 50% in releves with *N. colusana*, with a minimum of 13% and a maximum herb cover of 75%. Both litter cover and algal cover were less than 5% for releves containing *N. colusana*. Average species richness in the releves is low (about 6 species per releve), which is consistent with the observation in The Draft Recovery Plan for Vernal Pool Ecosystems (USFWS 2004) stating that *N. colusana* tends to grow in single species stands. There was a total of 30 species found to co-occur with *N. colusana*, including 7 that were non-native.

Table 4.14. *Neostapfia colusana* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	County	Historical Occurrences	Extant Occurrences	Sites	% Occurrences Sampled	Pools	Releves
San Joaquin Valley	Merced	6	1				
Solano-Colusa	Colusa	1	0				
	Yolo	2	2	1	50%	1	12
	Solano	2	2	1	50%	1	8
Southern Sierra Foothills	Merced	26	22				
	Stanislaus	23	15				
TOTALS		**60**	**42**	**2**	**5%**	**2**	**20**

***Orcuttia pilosa* "hairy Orcutt grass"**

<u>Status</u>: Federally Endangered, CA Endangered, and CNPS List 1B.

<u>Description and Range:</u>

O. pilosa is an annual member of the Poaceae. It blooms May through September (relatively late compared to most vernal pool taxa) and can occur in vernal pools at elevations of 55-200 m (CNPS 2001). *O. pilosa* is morphologically distinguished from other *Orcuttia* species by its equal lemma teeth and upright culms that branch from the lower nodes (Reeder 1982). *O. pilosa* is known from three vernal pool regions, with the majority of extant occurrences in the Southern Sierra Foothills Vernal Pool Region (41%), followed by the NE Sacramento Valley Vernal Pool Region (37%), and the Solano-Colusa Vernal Pool Region (22%) (CNDDB 2006). One of the occurrences in the Southern Sierra Vernal Pool Region is an introduction into an artificial vernal pool (CNDDB 2006).

Our database has information on *O. pilosa* from two of the three vernal pool regions (NE Sacramento Valley and Solano-Colusa). Data were collected from two sites in the NE Sacramento Vernal Pool Region and one in the Solano-Colusa Vernal Pool Region. A total of seven pools and 28 releves were collected in these three sites (Table 4.15). Sites landforms; Basin Rim, Basin and High Terrace. Soil series included Anita, Riz and Willows.

<u>Associations:</u>

Downingia cuspidata-Lasthenia fremontii; commonly.
Downingia bicornuta-Lasthenia glaberrima; rarely.

<u>Habitat and Ecology of Sites:</u>

Across all sites, the average maximum pool depth was 26 cm, with the shallowest pool being 18 cm deep and the deepest pool 40 cm deep. Those releves that contained *O. pilosa* had an average depth of 19 cm, with a range of 9-28 cm. The average pool area across sites was about 57,200 m^2, with a low of 2,800 m^2 and a high of 42,000 m^2.

Average total herb cover in *O. pilosa* releves across the 3 sites was 45%. Average litter cover and average bare rock cover were both minimal (< 5%) at all sites. Species richness across sites averaged 11 per releve. There was a total of 56 plant species found to be co-occur with *O. pilosa*, including 6 (11%) that were non-native.

Table 4.15. *Orcuttia pilosa* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team. * one occurrences was introduced into an artificial vernal pool.

Vernal Pool Region	County	Historical Occurrences	Extant Occurrences	Sites	% Occurrences Sampled	Pools	Releves
NE Sacramento Valley	Butte	1	1				
	Tehama	10	9	2	22%	4	20
Solano-Colusa	Glenn	6	6	1	17%	3	8
Southern Sierra Foothills	Madera	12*	9*				
	Merced	2	0				
	Stanislaus	8	2				
TOTALS		**39**	**27**	**3**	**11%**	**7**	**28**

***Orcuttia tenuis* "slender Orcutt grass"**

Status: Federally Threatened, CA Endangered, and CNPS List 1B.

Description and Range:

O. tenuis is an annual member of the Poaceae. It flowers from May through October (relatively late for vernal pool taxa) and can occur in vernal pools at elevations of 35-1,760 m (CNPS 2001). *O. tenuis* can be distinguished from other members of the *Orcuttia* genus by its equal lemma teeth and upright culms that branch from the upper nodes (Reeder 1982). Of all the *Orcuttia* species, *O. tenuis* has been observed to occur in the highest density stands (Stone et al. 1987, Griggs & Jain 1983). This high density may give *O. tenuis* a distinct advantage under grazing pressure, advantages such as resistance to trampling invasion by exotics species post-grazing (Stone et al. 1987). In addition, *O. tenuis* seeds are thought to need fungi in order for germination to be activated (Griggs 1981). *O. tenuis* is known from 5 vernal pool regions, with the majority of extant occurrences in the NE Sacramento Valley Vernal Pool Region (43%) and the Modoc Plateau Vernal Pool Region (38%) (CNDDB 2006). Three of the occurrences in the NE Sacramento Valley Vernal Pool Region are introductions into artificial vernal pools (CNDDB 2006).

Our database has information on *O. tenuis* from two of the five vernal pool regions (NE Sacramento Valley and Lake-Napa). A total of 6 pools and 41 releves were collected in these 5 sites (Table 4.16). Pools with *O. tenuis* occurred on Red Bluff geomorphic surface with either a High Terrace or Mudflow landform including three soil series; Anita, Tuscan and Toomes.

Associations:

Downingia cuspidata-Lasthenia fremontii; commonly.
Downingia ornatissima-Lasthenia fremontii; occasionally.
Layia fremontii-Achyrachaena mollis; rarely.
Downingia bicornuta-Lasthenia glaberrima; rarely.

Habitat and Ecology of Sites:

Measurements on depth were available for all sites except Boggs Lake. The maximum depths averaged 42 cm, with a minimum of 20 cm and a maximum of 65 cm. Those releves that contained *O. tenuis* had an average depth of 31 cm, with a range of 5-62 cm. The average pool area across sites was 184,100 m^2, with the smallest pool 37,200 m^2 and the largest pool 371,500 m^2. Average total herb cover in *O. tenuis* releves across the 5 sites was 68%, with a range of 25% to 95%. Percent covers of litter, bare rock, and open water were all minimal with an average of < 5%. Algal cover averaged 12%, but varied widely from 0% in the majority of releves to 100%. Species richness was averaged at 12 per releve. Of the 70 species found to co-occur with *O. tenuis* in the releves sampled, 14 were not native to California.

Table 4.16. *Orcuttia tenuis* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team. * three occurrences were introduced into artificial vernal pools.

Vernal Pool Region	**County**	**Historical Occurrences**	**Extant Occurrences**	**Sites**	**% Occurrences Sampled**	**Pools**	**Releves**
Lake-Napa	Lake	2	2	1	50%	1	6
Modoc Plateau	Lassen	5	5				
	Modoc	4	4				
	Plumas	4	4				
	Shasta	13	12				
	Siskiyou	2	2				
NE Sacramento Valley	Butte	2	2				
	Tehama	30*	29*	4	14%	5	35
NW Sacramento Valley	Shasta	9	9				
SE Sacramento Valley	Sacramento	3	3				
TOTALS		**74**	**72**	**5**	**7%**	**6**	**41**

Orcuttia viscida **"Sacramento Orcutt grass"**

Status: Federally Endangered, CA Endangered, and CNPS List 1B.

Description and Range:

O. viscida is an annual member of the Poaceae. It flowers from April to July and occurs in vernal pools at elevations of 30-100 m (CNPS 2001). *O. viscida* can be distinguished from other *Orcuttia* species by its unequal lemma teeth that are 6-7 mm long and which terminate in awns at least 1 mm long (Reeder 1982). *O. viscida* appears to have a larger population when precipitation levels reach a certain threshold amount or greater (Holland 1987). *O. viscida* is the rarest of the *Orcuttia* species (Stone et al. 1987) as it only occurs in the SE Sacramento Valley Vernal Pool Region and is endemic to Sacramento County.

The UCD database has information on *O. viscida* from three vernal pool sites all within the SE Sacramento Valley Vernal Pool Region. In these three sites, a total of 6 pools and 17 releves were sampled (Table 4.17). *O. viscida* can be found on a High Terrace landform and a Laguna geomorphic surface underlain by either Redding or Corning soils.

Associations:

Downingia bicornuta-Lasthenia fremontii; commonly.

Downingia bicornuta-Lasthenia glaberrima; occasionally.

Habitat and Ecology of Sites:

Measurements on depth were available for all sites except Rancho Seco. The 5 pools in which depth data was taken had an average depth of 45 cm, with the shallowest pool 23 cm and the deepest pool 70 cm. Releves were taken at an average depth of 42 cm in the 15 releves in which depth was recorded. This depth of the releves ranged from 18 cm to 70 cm. The average pool area for all 6 pools was 18,800 m^2, with the smallest pool 2,900 m^2 and the largest pool 42,400 m^2. Average total herb cover in *O. viscida* releves across the 3 sites was 64%, with a range of 5% to 90%. Average covers of litter, bare rock, and algae were all < 5%. Species richness across sites averaged 12 per releve. There were a total of 43 species found to co-occur with *O. viscida*, including 7 that were non-native.

Table 4.17. *Orcuttia viscida* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team. * one occurrences was introduced into an artificial vernal pool.

Vernal Pool Region	**County**	**Historical Occurrences**	**Extant Occurrences**	**Sites**	**% Occurrences Sampled**	**Pools**	**Releves**
SE Sacramento Valley	Sacramento	10*	9*	3	30%	6	17

***Tuctoria greenei* "Greene's tuctoria"**

Status: Federally Endangered, CA – Rare, and CNPS List 1B.

Description and Range:

T. greenei is an annual member of the Poaceae. It flowers May through September (relatively late for vernal pool taxa) and can occur in vernal pools at elevations of 30-1,070 m (CNPS 2001). *T. greenei* can be distinguished from other members of the genus by its terminal inflorescence, which is exerted from the upper leaves at maturity (Reeder 1982). The inflorescence is born on culms 30 cm or less long thereby distinguishing it from Mexican Tuctoria, *Tuctoria fragillis* (Reeder 1982). *T. greenei* is thought to be one of the most susceptible of the Orcuttieae Tribe to grazing due to its preference for the margin zone in vernal pools (Stone et al. 1987). *T. greenei* is known from three vernal pool regions with the majority of extant occurrences in the NE Sacramento Valley Vernal Pool Region (64%), followed by the Southern Sierra Foothills Vernal Pool Region (32%), with only one extant occurrence in the Modoc Plateau Vernal Pool Region (CNDDB 2006).

Our database has information on *T. greenei* from one site located in the NE Sacramento Valley Vernal Pool Region. Data were collected from one pool with 8 releves (Table 4.18). This pool has a Red Bluff geomorphic surface, Laguna landform, and Anita soil series.

Associations:

Tuctoria greenei-Chamaesyce hooveri; commonly.

Habitat and Ecology of Site:

The pool sampled had a maximum depth of 33 cm. The 8 releves were taken in an average depth of 30 cm, with a range of 21 cm to 33 cm. The pool was fairly large with an area of 160,200 m^2. Average total herb cover in the releves containing *T. greenei* was 30%, with a minimum of 4% and a maximum of 50%. Litter cover in these releves averaged 1%; however, bare rock cover had a higher average of about 6%. This 6% average was due mostly to one releve that had a 40% bare rock cover, whereas the other 7 releves had either 0% or 1% cover of bare rock. Species richness averaged 5 per releve with a total of 10 species co-occuring with *T. greenei*, only one out of these ten was non-native.

Table 4.18. *Tuctoria greenei* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	**County**	**Historical Occurrences**	**Extant Occurrences**	**Sites**	**% Occurrences Sampled**	**Pools**	**Releves**
NE Sacramento Valley	Tehama	13	10	1	10%	1	8
	Butte	4	4				
Southern Sierra Foothills	Fresno	3	0				
	Madera	1	0				
	Merced	11	7				
	San Joaquin	2	0				
	Stanislaus	5	0				
	Tulare	1	0				
Modoc Plateau	Shasta	1	1				
TOTALS		**41**	**22**	**1**	**5%**	**1**	**8**

***Tuctoria mucronata* "Solano grass"**

Status: Federally Endangered, CA Endangered, and CNPS List 1B.

Description and Range:

T. mucronata is an annual member of the Poaceae that flowers April through August and can occur in vernal pools at elevations of 5-10 m (CNPS 2001). *T. mucronata* can be distinguished from other members of the genus by having a terminal inflorescence that is partially included in the upper leaves at maturity (Reeder 1982). This inflorescence is born on culms 30 cm or less long (Reeder 1982). While many species in the Orcuttieae Tribe seem to do best in wet years, Holland (1987) showed that *T. mucronata* had smaller populations in years that were really wet, as well as in years that were really dry. *T. mucronata* is only known from the Solano-Colusa Vernal Pool Region, with only 2 of the 3 known sites remaining extant (CNDDB 2006)

Our database has information on *T. mucronata* from both extant sites. The Hamilton site had one pool and one releve (< 10 individuals) while the DOD site had more individuals of *T. mucronata* and therefore more releves taken. A total of two pools and 11 releves were sampled across the 2 sites (Table 4.19). Each site had a different geomorphic surface, Holocene and Modesto, one located on an Alluvial Fan landform with the other a Basin Rim landform. The two soil series were Marvin and Pescadero.

Habitat and Ecology of Sites:

Data on depth of the pools and releves was not recorded at either site. However, pool area was recorded for one of the sites, with a pool area of 3,300 m^2. Average herb cover across releves was about 37%, with a range of 25% to 65%. The cover of litter was < 1%. There were a total of 12 species that co-occur with *T. mucronata*, including 2 that were non-native.

Table 4.19. *Tuctoria mucronata* occurrence and distribution. Occurrence data comes from a 2006 search of the CNDDB Rarefind 3 database. Sites, pools and releves indicate data collected by the UC Davis team.

Vernal Pool Region	**County**	**Historical Occurrences**	**Extant Occurrences**	**Sites**	**% Occurrences Sampled**	**Pools**	**Releves**
Solano-Colusa	Solano	2	1	1	100%	1	1
	Yolo	1	1	1	100%	1	10
TOTALS		**3**	**2**	**2**	**100%**	**2**	**11**

CLUSTER ANALYSIS AND CORRELATIONS WITH ENVIRONMENTAL VARIABLES

A cluster analysis produced a dendrogram with several large clusters of rare species, as well as a number of rare species that are more isolated. All clusters are summarized in Table 4.20.

Table 4.20 A summary of important clusters of rare species and commonly co-occurring species. Species in bold are listed by Federal, State or CNPS.

Cluster	Species
1	**Astragalus tener v tener**
	Navarretia leucocephala s. bakeri
2	**Hesperevax caulescens**
	Plagiobothrys stipitatus v. stipitatus
	Mimulus tricolor
3	**Microseris douglasii s. platycarpha**
	Avena barbata
	Filago gallica
4	**Navarretia heterandra**
	Castilleja attenuata

Cluster	Species
5	**Lasthenia conjugens**
	Lasthenia ferrisiae
	Salicornia subterminalis
	Lepidium dictyotum v. acutidens
	Parapholis incurva
	Spergularia platensis
	Cotula coronopifolia
	Salicornia virginica
	Lasthenia glabrata s. coulteri
	Myosurus minimus s minimus
6	**Atriplex persistens**
	Orcuttia pilosa
	Convolvulus arvensis
	Eryngium vaseyi
	Epilobium pallidum
	Epilobium cleistogamum
	Amsinckia species
	Chamaesyce hooveri

	Tuctoria greenei **Orcuttia tenuis** Damasonium californicus Elatine rubella Marsilea vestita
7	**Castilleja campestris s succulenta** Downingia bicornuta v. picta **Gratiola heterosepala**
8	**Downingia pusilla** Epilobium species **Legenere limosa** Eleocharis macrostachya **Lasthenia glaberrima**
9	**Navarretia myersii s. myersii** Castilleja campestris s campestris Elatine brachysperma Lilaea scilloides
10	**Orcuttia viscida** Polypogon maritimus Glyceria declinata Callitriche heterophylla

One cluster (6) contains three rare *Lasthenia* species; *Lasthenia conjugens* and *Lasthenia ferrisiae* co-occur with *Salicornia subterminalis, Lepidium dictyotum* var. *acutidens, Parapholis incurva*, and *Spergularia platensis. Lasthenia glabrata* ssp. *coulteri* clusters in this group as well and co-occurred closely with *Myosurus minimus* ssp. *minimus*. Another large cluster (7), groups species that occur in alkaline habitats (similar to that found in pools of the Sacramento National Wildlife Refuge).

An initial CCA analysis performed on the dataset showed that nearly all of the environmental variables had a significant effect on the distribution of species. The only environmental variables that did not have an effect were cover of natives, cover of cattle droppings, and cover of litter, all of which had p-values >0.05. Subsequent analyses showed rare species are more likely to occur in large, deep pools with lots of bare ground.

Analyses were also performed with non-native species richness overlaid on the environmental CCA vectors. These illustrated that non-native species were more abundant in shallower plots and in areas with higher vegetation cover. This is the exact opposite of the pattern for rare species, which were less abundant in shallower plots and with greater total vegetation cover. Analyses focusing on native species and total species richness were overlain on an ordination diagram. This result gives evidence that the increase in species as you move toward the edge of a vernal pool is not due to non-native species; instead higher species richness at the edge of a pool is due to an increase in native species richness.

CCA analyses revealed that cover of non-native species was the environmental variable that most heavily influenced the distribution of rare species. This provides additional evidence that numbers of rare species are negatively correlated with numbers of non-native species. This negative correlation is likely due to the strong effect of certain non-native species. In order to determine which non-native species were having the strongest effect on structuring vernal pool communities, 20 of the non-native species with the highest total cover values were used as environmental variables. This analysis indicated that *Medicago polymorpha*, *Vulpia bromoides*, and *Cotula coronopifolia* had the most significant influence on the vernal pool community. While these species seem to be important in structuring vernal pool communities, they do not appear to have a direct negative effect on rare species.

CONCLUSIONS

The data and analyses presented in this chapter summarize the habitat and co-occurring species of 18 listed taxa. Through these summaries the habitat requirements of rare species can be analyzed and applied to many different situations. One possibility is the selection of the best areas for reintroductions of listed taxa. This information may also be used to guide management practices in order to create a favorable environment for a particular rare species. For example, members of the Orcuttieae tribe tend to occupy open, large, and deep pools, a finding that correlates with Crampton's 1959 observation that members of this tribe grow only in large pools with scattered barren areas. In a proposed reintroduction of species in this tribe, it would be important to take into account the size and depth of the pool, as well as the amount of vegetation cover in the pool.

To complement the habitat summaries, a cluster dendrogram was analyzed to catalogue which rare species tend to group together and which common species tend to co-occur with rare taxa. This detailed species co-occurrence data should be taken into consideration when conducting field studies and identifying potential restoration sites, as co-occurring species may indicate suitable habitat for targeted rare species.

An in-depth analysis of environmental variables illustrates that rare vernal pool species prefer large, deep pools with low vegetation cover. Many ecosystems are conserved on the basis of which rare species occur in them. This philosophy may not be well-suited to vernal pool habitats. Pools that contain rare species are not a good representation of all of the pools of California as pools containing rare species are often among the most species-poor pools. This means that, in restricting conservation efforts to vernal pools containing rare species, one is most likely not conserving a high richness of native plant species. Concentrating conservation efforts only on pools with rare species will mean that there will be a significant loss in biodiversity.

Rare species tend to be absent when there is an abundance of non-native species. Some of the non-native species that appear to have the greatest negative influence on vernal pool community structure were *Medicago polymorpha*, *Vulpia bromoides*, and *Cotula coronopifolia*. However, this does not necessarily mean that non-native species are detrimental to the survival of rare species. It may mean that non-natives are better able to colonize places which do not support rare species. In general, the results presented here are consistent with other recent studies that found very limited *direct* effects of non-native plant species on rare native plant species (Farnsworth 2004). The effects that non-native species have on vernal pools and rare species in particular, needs further study.

CHAPTER 5: IMPLICATIONS OF THE FINDINGS FOR CONSERVATION, RECOVERY, AND MANAGEMENT

POOLS CONTAIN MORE THAN ONE COMMUNITY TYPE

One significant finding of the research reported here is that vernal pools are not single integrated units, but rather complexes of two or more community types (some uniformly shallow pools can contain only a single community type). Each community type is geographically autonomous, meaning that it can be spatially associated in the same pool, with a number of other community types. Although some combinations of community types are more common than others, the fact remains that pools are usually composed of two or more independent communities and the vegetation of vernal pools can be most accurately and defensibly classified by sampling homogeneous sub-pool units, rather than entire pools as a unit.

The implication for conservation and restoration is that the units to be conserved and targets for restoration are sub-pool community types. To identify community types within a pool, one must sample each biologically uniform and repeatable sub-pool unit separately, neither combining plots from diverse sub-pool units nor locating plots so that they cross from one homogeneous unit to another.

MOST COMMUNITY TYPES ARE NOT WIDESPREAD

Another significant finding is that most community types are limited in their distribution to a single vernal pool region. Of the 29 associations and communities we defined as occurring within the Central Valley, only two were found in more than half of the six Central Valley vernal pool regions and 21 were limited to a single vernal pool region withing the Central Valley. Associations of long-inundated pools tended to be more widespread than short-inundated fresh-water associations and than alkaline/saline associations in large part because deep pools harbor fewer species and thus the choice for diagnostic species that distinguish local associations is more limited.

The implication for conservation is that it will be better to select many small reserves than one or even a few large reserves. Given the high turnover of community types from region to region, only a small percentage of community diversity can be captured in any one preserve, no matter how many hectares it might contain. At best, each vernal pool region deserves its own reserve. These local reserves need to be large enough to include pools that contain different mixtures of the same community types as well as enough pools to contain uncommon as well as common community types and enough pools to contain rare or listed taxa.

Based on our data, the density of pools within a given location ranges from 4 to 10 per hectare and the basins of these pools (the wettable area) collectively account for only 1-3% of the land area. The terrace landform with hardpan contains the highest density of pools, in part because the pools are small, ranging from only 100 to 5000 square meters and averaging 1600 square meters (Table 2.5; Holland, personal communication; and Solomesch et al. 2007). If the conservation objective is to protect a half-dozen replicates of a half-dozen community types and all combinations of types, then the area protected should total at least:

Pools required = (6 replicates) x (6 x 5 combinations of associations, maximum) = 180;
Minimum area required if we assume 10 pools/ha = 18 ha;
Maximum area required if we assume 4 pools/ha = 45 ha.

CHAPTER 6: RESTORATION TARGETS SHOULD INCLUDE NATURAL, REGIONAL COMMUNITY TYPES

As summarized by De Weese (1998), vernal pool restoration by "creation" has been a common mitigation technique for the past two decades. De Weese evaluated the degree of mitigation success of more than 1500 constructed pools in the Sacramento Valley between 1988 and 1994. She found that the percentage of pools meeting all compliance criteria varied with the year of creation, from 25 to 100%, overall averaging 62%. The usual reasons for failing to attain vegetation standards were construction on inappropriately steep slopes and on soils without natural horizons that restrict drainage, failure to apply sufficient inoculant to the pools, failure to construct pools where natural pools did not already exist, and lack of continuous weed control.

Solomeshch et al. (2007), Ferren and Gevirtz (1990), Leidy and White (1998) criticized current compliance criteria on several grounds: the length of monitoring time has not been standardized and it is usually too brief (3-5 years at most), agreement as to which attributes should be measured has not been reached, and some criteria are not ecologically meaningful. It is the latter attribute that we addressed in our work for USFWS.

At present, success criteria include the cover, number, vigor, and identity of vernal pool endemics present. Our classification work has shown that a subset of approximately a dozen vernal pool plant taxa are widely distributed throughout California and they constitute the species that characterize the single vegetation class that includes all the kinds of vernal pools in California. At the same time, however, there are as many or more additional taxa that are diagnostic for the community types within that class. Both groups of species can be called "endemic" to vernal pools, but their distributions are enormously different. If our intent, in conservation and restoration, is to maintain community type diversity, then targets for restoration should not be widespread class species but instead more locally restricted species that are diagnostic for local communities.

As a case study in how this might be done, the vegetation of 13 created and 13 natural pools, all within Wurlitzer Ranch near Chico, was studied. This site was selected because, in our opinion, the degree of care and planning taken with pool construction and subsequent monitoring was exceptional. The design was created and the results quantified by vernal pool experts and independent consults Rod Macdonald and Steve Talley, followed by UC Davis MS candidate Sandi Starr (2004).

Wurlitzer Ranch is a 24-ha preserve 10 km north of Chico in the Sacramento Valley that was established as a mitigation site in 1992. It originally supported 40 natural pools on a terrace of Red Bluff and Modesto-Riverbank formations with 0-2% slopes. During 1994-1996, 60 pools were constructed that imitated the size, shape, and range of depths of adjacent natural pools. They were inoculated with material from either on-site pools or from pools "taken" at the Doe Mill Preserve a few kilometers south of the Wurlitzer Preserve. In spring of 2002, half of the site and pools was burned to control the abundance of medusa head grass. Grazing by domesticated livestock has been absent since 1992.

In the spring of 2003, 26 pools were jointly selected for study by Macdonald, Talley, and Starr. Some 84 within-pool plots, each 10 square meters in area, representing visually homogeneous community types, were sampled, using the same protocols that our state-wide survey employed (Barbour et al. 2003). Data were entered in Turboveg format and exported to Excel (Microsoft 1985-2001) for formatting. PC Ord 4 (McCune and Mefford 1999) and Excel were used for non-metric multidimensional scaling ordination, cluster analysis, linear regression, and indicator species analysis. In addition to single-species and community-type analyses, we examined patterns of species richness, native species richness, non-native species richness, percent of native species, and the number of vernal pool indicator (vpi) and vernal pool associates (vpa) present.

No significant difference was found between natural and constructed pools in species richness, native species richness, total species richness, species diversity index, nor in absolute or relative vip-vpa species richness. Of the 101 species encountered in the study, only seven had a significant ($p < 0.05$) indicator value for constructed pools: *Allium aplectens Downingia ornatissima, Epilobium pygmaeum, Eremocarpus setigerus, Lythrum hysspofifolium, Mimulus latidens,* and *Veronica peregrina.* The pattern of these seven taxa. however, was not enough to separate vegetation when analyses were based on all 101 species.

However, comparison of the *floristic compostion* of plots did show differences between created and natural pools. The first three divisions of an agglomerative hierarchical cluster analysis of the 84 plots (Fig. 5.1), at 0-55% information levels, did separate unequal ratios of constructed-to-natural pools. Although in this particular case we did not aggregate the plots into a discrete number of named and defined community types, experience with vernal pool complexes elsewhere indicate that we should expect half a dozen community types in such a small area with two treatments—a number generated by the second level of branching. A chi-square analysis of the ratios created by the first two levels of branching failed to show that they were statistically different at $p = 0.05$ (Table 5.1), meaning that the horizontal lines in the dendrogram (formed by the second branching) were not different enough to represent discrete plant communities. An NMS ordination figure, based on differences in the floristic composition among plots, revealed little separation of plots in created pools (Fig. 5.2, triangles in left portion of ordination space) from those in natural pools (circles in right portion), and instead a great deal of overlap among plots from created and natural pools. The absence of tight clusters of plots, with clear separations between them, is evidence that there was only one variable community type.

In sum, statistically there was no significant difference between the plant communities in constructed pools and natural pools. Apparently, over the course of 7-8 (and perhaps sooner), the plants colonizing created pools had organized themselves into communities with some differences, but none large enough to be significant at p = 0.05 level. In this particular case, the restoration success for constructed pools rated highly when the measures for success were based on the presence of individual species from a generic, state-wide list of vernal pool taxa, *and also* when the measures for success were based on the presence of natural communities of such species.

A test of community similarity need not require the complex ordination and clustering figures used for this example. Rather, a Sorenesen similarity index could be calculated, where

$$\text{SSI}(\%) = \frac{(2) \times (\text{number of taxa in common, any two samples})}{(\text{number of taxa in one sample + number in other})} \times (100) .$$

The possible range of Sorensen similarity index (SSI) values extends from 0 (no species in common) to 100 (all species in common). A general rule of thumb, among experienced phytosociologists, is that any two plot samples or summaries belong to the same community type when SSI >50% (Mueller-Dombois and Ellenberg 1974). In the Wurlitzer case, we would create a list of all species encountered in all plots from created pools, a list of all species encountered in all plots from natural pools, and a list of all species in common. Using the actual plot data, the formula is:

$$\text{SSI} = \frac{(2) \times (53)}{(82 + 77)} \times (100) = 67\% ,$$

which is > 50%, indicating that the two groups of plots represent the same single community type. Such a high value can be taken as evidence that the vegetation in restored pools is the same as in natural pools.

In summary, our suggestion is that restoration targets become natural pool community types in the region. This vegetation standard is not proposed because it is a higher, more difficult and onerous standard to achieve than those currently in place. It is proposed because it is more ecological and more meaningful it is based on the diversity

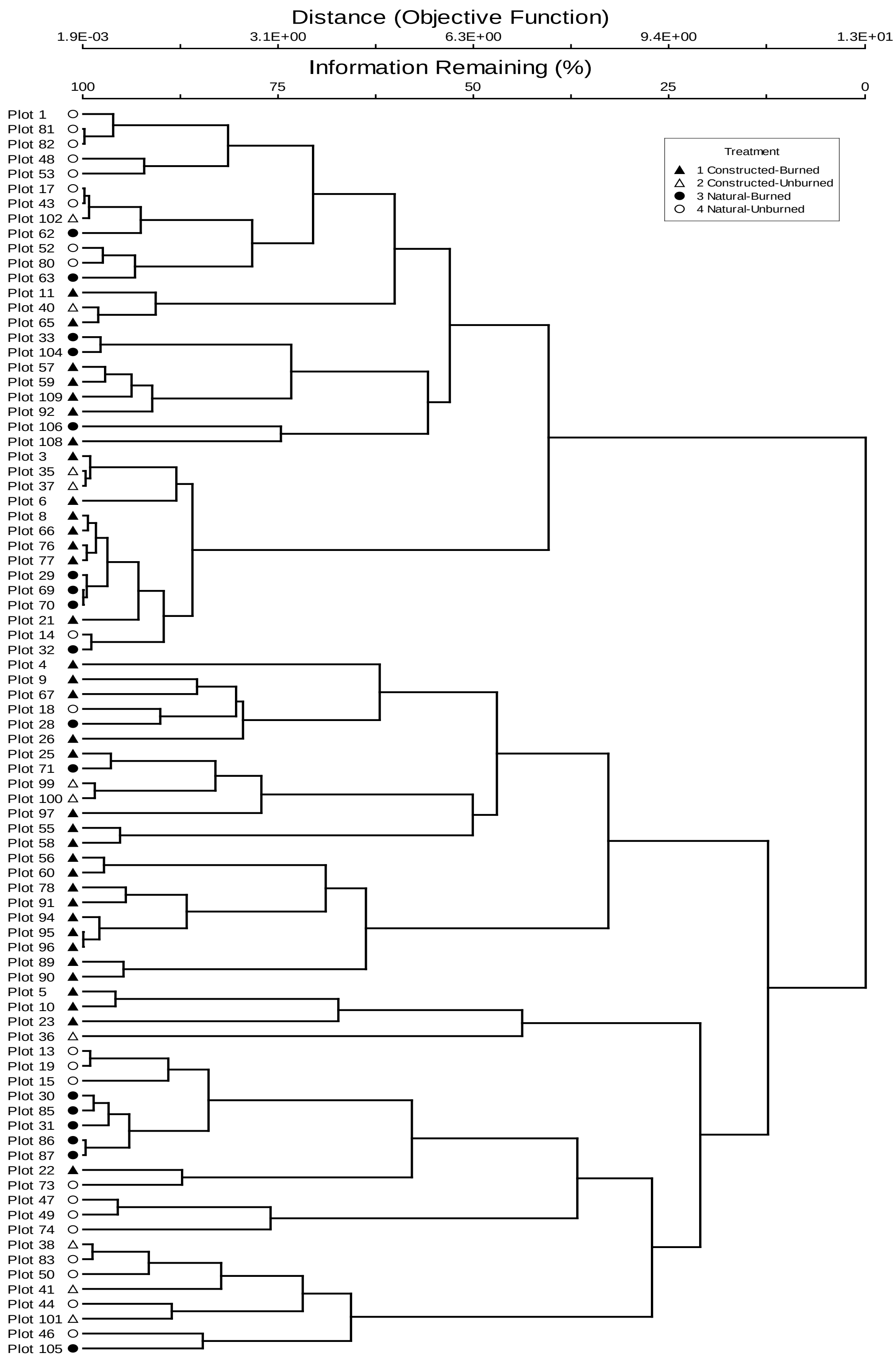


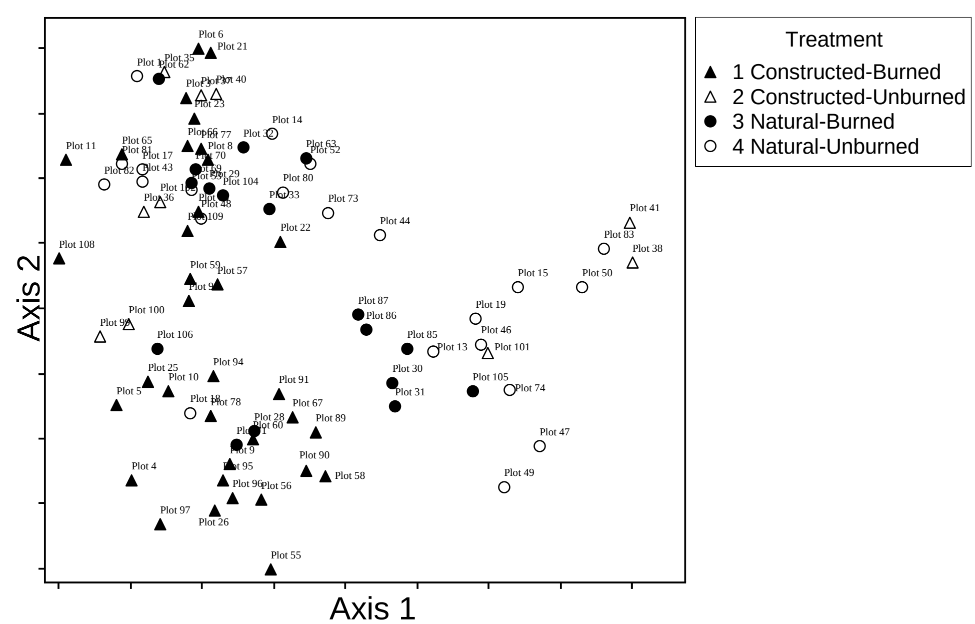
Fig. 5.1 Dendrogram for all 101 species of the within-pool data set, created by agglomerative hierarchical cluster analysis using Sorensen distance measures. Triangles are plots from constructed pools; circles are from natural pools. From Starr (2004).

TABLE 5.1. Chi-square test of the ratio of treatments observed vs the ratio expected (assuming no treatment effect) for the first two levels of branching in the dendrogram shown in Fig. 5.1

Treatment	Expected	Group 1 Observed	Group 2 Observed
1 Constructed-Burned	0.422	0.378	0.477
2 Constructed-Unburned	0.108	0.108	0.136
3 Natural-Burned	0.205	0.243	0.136
4 Natural-Unburned	0.265	0.270	0.250

Group 1 Chi	Group 2 Chi
0.999663 **NS**	0.998013 **NS**

Fig. 5.2. Ordination of plots from four treatments. Triangles are plots from constructed pools, circles are plots from natural pools. From Starr (2004).



of community types in the area, not on the presence of widely distributed species that do not characterize different communities.

RESTORATION CRITERIA IN GENERAL NEED REVISION

Current restoration standards appropriately address hydrology and flora as the most important targets. However, in our opinion, some of the details in those standards are difficult to quantify because of the formulas used. We suggest the following changes:

(1) The current criterion specifies that created pools should not hold water longer and/or deeper than 125% of the values in reference pools. In order to make this criterion more consistent and statistically defensible, it should be amended to state, "Depth and/or duration of ponded water in created pools should not differ statistically ($p = 0.05$) from those in nearby natural pools."

(2) The current criterion is that absolute and relative cover by vernal pool endemics in constructed pools should not be less than the minimum among reference pools. The minimum is not appropriate because that value will often be zero for any given species in at least one or some of the reference pools. Amend to read, "Absolute and relative cover by vernal pool endemics in constructed pools should not be statistically different ($p = 0.05$) from the average values in reference pools."

(3) The current criterion is that the number of vernal pool endemics in constructed pools should not be less than the lowest number of species among the reference pools. We suggest that the minimum should not be a measure for success because the floristically poorest reference pool may be an anomaly. Amend to read, "The number of vernal pool endemics in constructed pools should not be statistically lower ($p = 0.05$) than the average number of those taxa among reference pools."

(4) No change proposed to the current criterion, "The vigor (biomass accumulation) and reproductive activity (seed production) of vernal pool endemics in constructed pools should not be statistically lower ($p = 0.05$) than those of the same species in reference pools."

(5) Current criteria do not address exotic species, therefore, we propose a new criterion, “The number and cover of exotic species in any constructed pool should not be significantly higher than the average among reference pools.”

(6) Current criteria are species-oriented rather than community oriented, therefore we propose a new criterion, “The identify of community types in created pools and the mixture in which they occur should match that of reference pools (using a Sorensen Similarity Index formula where “matching” means an SSI >50%.” In other words, constructed pools collectively should contain deep, shallow, and edge community types if reference pools have those community types, meaning that the depth, side slope, shape, and area of created pools should be as diverse as that of reference pools.

(7) A follow-up new criterion, based on (6) above, is that “Reference pools should be chosen subjectively so that collectively they represent the diversity of species and communities that exist in the pools to be taken.” We add this criterion to avoid the random selection of inappropriate pools as reference targets, and to address the need to replicate community type diversity in addition to the presence of particular species.

(8) We recommend the deletion of the present criterion, “…any vernal pool endemic that is dominant (>20% relative cover) in at least 30% of the reference pools shall be present as a dominant species in all of the constructed pools.” Again, this emphasis on common, widespread dominant species could result in the homogenization of constructed pools. Furthermore, even natural pools fail to meet this criterion because of innate floristic differences.

TRAINING OPPORTUNITIES IN RECOGNIZING VERNAL POOL FLORA, VEGETATION SAMPLING, AND COMMUNITY KEYING NEED TO BE PROVIDED

In this report, we have provided names and attributes for an hierarchical series of plant community types, from local associations to more regional alliances, orders, and classes. The task yet to complete is demonstrating the degree of adequacy and usefulness of the classification. If the community types are too difficult to differentiate for the average field botanist, then the classification will not be used for long. If the classification is appropriate, it may still not be used unless it becomes institutionalized, meaning that its use is not only encouraged by agencies, but its use becomes routinely expected.

We propose to develop a training course, with the collaboration of USFWS, the California Department of Fish and Game, and the California Native Plant Society; that it be offered on an annual basis; and that students be trained in the field on plant identification, sampling protocol for documenting plant community types, the use of an annotated key to determine vernal pool community types, and major ecosystem differences between vernal pools on floodplains, terraces, hardpans, claypans, and in saline/alkaline situations. We propose that the class be five consecutive days in length, that its location vary from year to year, that it be staffed by a minimum of three vernal pool experts and three assistants, that enrollment be capped at 20, and that the class be open to agency staff, NGO staff, consultants, and academics. We expect that the cost per individual for such a class (including transportation, lunches, and field supplies) would be approximately $1200. A prototype of such a course is actually being planned for April 18-20 by Carol Witham of the California Native Plant Society; its focus is only on taxonomy, however, and no time will be devoted to determining plant communities.

Similar certification courses have been in existence for the past 15 years in the training of biologists for surveys of marbled murelets (jointly designed by CDFG, USFWS, USDA Forest Service, and California Department of Forestry and Fire Protection) and northern spotted owls (jointly designed by CDFG and USFWS); for training foresters in archaeology (CDFF); and in certifying specialists in wetland deliniation (Society of Wetland Science). The programs above are not mandated by regulatory/statutory legislation. Individuals are simply encouraged to enroll by informal policy expectations that those who hold certain positions will routinely take the course to become certified.

If USFWS staff are interested in the development of such a course and certification program, we will be pleased to work with them and to have in place a first offering during April of 2008.

Finally, we propose to continue working on providing an annotated key suitable for distribution (outside this report) to agency personnel and others who will require it. The key presented this draft is incomplete and its format can be improved and simplified if we subdivide the key into regions.

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