DEVELOPMENT OF THE SANTA ROSA VERNAL RESERVE SYSTEM.

II. INSTALLATION OF A LONG-TERM RESTORATION EXPERIMENT AND DESCRIPTION OF BASELINE VEGETATION

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Prepared for

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California Department of Fish and Game
P.O. Box 47 Yountville, CA 94599

and

Plant Conservation Program
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1416 Ninth Street
Sacramento, CA 95814

Funded by

U.S. Fish and Wildlife Service Section 6 Funds
Contract No. FG 8014 IF

April 2000

ABSTRACT

The first goal of the Santa Rosa Vernal Reserve System (SRVRS, Sonoma County, California) is to develop management prescriptions for improving the habitat quality of native plant populations, especially those of conservation interest (Pavlik, Smith and Miller 1998). This report describes the first installation of experiments for restoring vernal pools and swales on the Santa Rosa Plain, and includes the following components: 1) the use of mowing and phytomass removal as ecologically sound and practical manipulations for shifting plant cover from exotic to native (for dominant species) and from sparse to abundant (for rare species), 2) a description of the pre-treatment vegetation of uplands, pool margins and pool bottoms, and 3) consideration of the life history characteristics of rare animals associated with these habitats in order to minimize collateral impact of the management regime.

The first field experiment was installed during the spring and summer of 1999 to determine if seasonal mowing and phytomass removal can improve habitat quality for native plants in vernal pool and adjacent grassland habitats. Three SRVRS properties were chosen; Cramer (174 acres, relatively unaltered pool and swale system, mostly diverse native vegetation), FEMA (69 acres, hydrologically altered pools and swales, extensive weed cover), and Haroutunian (30 acres, unaltered swale system, mix of native and exotic cover). All are located on Wright clay-loam soils and have supported multiple *Limnanthes vinculans* (Sebastopol meadowfoam) subpopulations, a state and federally-listed endangered plant.

A total of 90 permanent plots were established, marked, sampled and treated. These were large (30 m X 5 m), included 2 habitats (coastal prairie uplands and vernal pool/swale margin), and consisted of control, mowed with phytomass removal, and mowed without phytomass removal (mulched) plots. We will be testing the hypothesis that the mowing with removal treatment reduces annual grass cover, thus improving habitat quality in the long-term for native plants, especially those of conservation interest.

The treatment could work by reducing soil nitrogen availability (a disadvantage for exotic annual grasses), improving soil surface microenvironment (e.g. light, temperature), and prolonging soil moisture for native species that are more nitrogen-use efficient. We have also collected baseline phytomass and soil samples in all 90 plots for later analysis.

Vegetation in the upland and pool margin habitats was characterized in all of the plots prior to treatment by recording species presence, cover and density (of rare taxa and a few weeds only) in more than 300 samples using a bipartite quadrat. Samples were added in pool bottom habitat to complete description of a topographic transect. The record provides a baseline description useful for comparing to other sites on the Santa Rosa Plain and for evaluating subsequent restoration projects.

We found that species richness was greatest in the margin habitat of vernal pools and swales, declining slightly towards the uplands and dramatically towards the pool bottoms. Pool bottoms had 40% fewer taxa than the other two habitats, but a higher proportion were native (54%) that contributed much more (84%) of the total plant cover. Pool bottoms also had the highest live plant cover and the least amount of thatch, but the lowest total cover (live + thatch) and the most bare ground. Total cover (live + thatch) usually exceeded 100% in the upland and margins because of layered canopy structure. Vertical structure of this vegetation could be described, therefore, as ranging from tall and non-native to short and native.

An analysis of importance values in different habitats revealed only one native plant with a high degree of dominance in the uplands; *Vulpia octoflora var. octoflora* consistently had the highest value because of high relative cover. The next four most dominant taxa in the uplands were all non-native, with *Lolium multiflorum* always having the second highest importance value. Importance values in the margin habitat showed a shift towards dominance by natives. This was especially true at the Cramer property, where all five most dominant taxa in the margins were native and headed by *Pleuropogon californicus*. Pools at Cramer are thus among the highest quality remaining on the Santa

Rosa Plain and justify the use of Cramer vegetation characteristics as standards for restoration. In contrast, only three of the top five dominants in pool margins at FEMA and Haroutunian were natives. These margins were of lower quality than those at Cramer due to dominance by *Lolium multiflorum*, *Convolvulus arvensis* and *Rumex crispus*. Consequently, these taxa become the highest priority targets for restoration activities because they usurp resources for native taxa restricted to margins (e.g. *Limnanthes vinculans*). In contrast to the uplands and margins, all of the most dominant taxa in the pool bottoms were native to California. The pool bottom habitat across this portion of the Santa Rosa Plain appears consistently dominated by the same native taxa and would not require or justify intensive restoration efforts at this time.

All of the vernal pool characteristic (VPC) taxa encountered at the three properties were found in the margin and pool bottom habitats. Dense swards of exotic annual grasses with similar phenology (e.g. *Lolium multiflorum, Bromus hordeaceus)* may limit the performance of VPC populations on the upland side of the margin. Consequently, efforts to restore VPC populations on the Santa Rosa Plain should concentrate on improving the quality of pool and swale margins, rather than pool bottoms. Reversing degradation of the margins (e.g. lowering cover by exotics, reducing their tall overstory layer, decreasing thatch) is most likely to benefit VPC and other native taxa.

Limnanthes vinculans was the most widely distributed and abundant VPC taxon on the three properties, both historically and in the spring of 1999. *Limnanthes vinculans* was present in 80% of our blocks at Cramer but 0% of our blocks at Haroutunian (despite its historical occurrence). Cramer also had highest subsample frequency among properties (indicating a less clumped distribution), and the highest frequency of occurrence in the top (upslope) quadrat (indicating greater intrusion into the margin-upland transition). Increasing any of these parameters (live cover, density, block/subsample/top quadrat frequency) would indicate a successful manipulation for restoring this rare plant.

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ACKNOWLEDGMENTS

The authors appreciate the contributions and expertise of Allan Buckmann (CDFG), Dr. Cynthia Gilbert (San Francisco State University), Betty Guggolz (California Native Plant Society, CNPS), Jack Guggolz (CNPS), Lisbeth Louderback (Mills College), Jennifer Randall (Mills College), Abigail Smith (Lawrence Livermore National Lab), and Carl Wilcox (CDFG). Ben Pavlik deserves recognition for many hours spent mowing in the hot Santa Rosa sun. Special thanks to Tyson Holmes (Stanford University) who was consulted on many statistical aspects of experimental design and sampling. He provided innovative and helpful ideas that greatly improved the quality of our work. Support, helpful suggestions, and careful review were provided by Diane Ikeda (CDFG) from beginning to end. A review by Gene Cooley (CDFG-Yountville) greatly improved this report.

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INTRODUCTION

The vernal swales and pools of the Santa Rosa Plain were once part of an interconnected network of creeks, floodplains, and wetlands that drained west-southwest towards the Laguna de Santa Rosa, a tributary to the Russian River. Over the last 140 years, the hydrologic network of the plain has been fragmented by roads and property lines, altered by drainage channels, levees and irrigation, and degraded by runoff from farms and dairies. The vernal pools of the Santa Rosa Plain also played an important role in delaying runoff to the Laguna de Santa Rosa (and the Russian River), thus providing natural filtration of runoff. Urban development and channelization of streams have reduced these benefits, thus exacerbating flooding and water quality problems. Cultivation brought orchards, vineyards and row crops, and introduced more than 100 species of competitive weeds to the remnants of wetland and upland communities. Such rapid and significant changes, described in greater detail by Patterson *et al.* (1994a) and CH2M Hill (1995), now determine the biological character of the Santa Rosa Plain, especially affecting the abundance and distribution of native species that occupy vernal pool and swale habitats.

During 1991-1995, the Santa Rosa Plain Task Force, (a coalition of federal, state and local agencies, and local community groups) developed recommendations for the preservation and management of vernal wetland resources on the Santa Rosa Plain. Implementation has been coordinated by California Department of Fish and Game (CDFG) and includes the U.S. Environmental Protection Agency (EPA), U.S. Fish and Wildlife Service (USFWS), and the U.S. Army Corp of Engineers (ACE) along with local partners such as the Sonoma County Agricultural Preservation and Open Space District (SCAPOSD), Sonoma County Water Agency (SCWA), citizen environmental groups (e.g. California Native Plant Society, CNPS) and landowners (e.g. Sonoma County Airport). The emphasis has been on the regulatory issues associated with development within vernal pool areas and minimizing impacts through land acquisition. Although acquisition began with the establishment of the Laguna de Santa Rosa Ecological Reserve on Todd Road in 1980, now more than 18 separate properties, ranging in size from 1 acre to 174 acres, have been placed under the regulatory auspices of the CDFG in cooperation with local agencies, such as SCAPOSD and SCWA. The presence of three plant taxa that are federally- and state-listed as endangered (*Blennosperma bakeri* Hieser (Sonoma sunshine), *Lasthenia burkei* (E. Greene) E. Greene (Burke's goldfields) and *Limnanthes vinculans* Ornd. (Sebastopol meadowfoam) has provided additional incentive for preserving vernal wetland habitat in this region. The collection of CDFG properties, extending from Windsor to Cotati, are now referred to as the Santa Rosa Vernal Reserve System (SRVRS) in an effort to integrate their long-term management (Pavlik et al. 1998). This will better ensure that our restoration research helps meet the land management, water quality and fire control objectives of local partners.

Current efforts to preserve the vernal wetlands of the Santa Rosa Plain must also take into account the effects of fragmentation, degradation, and invasion on biological diversity, even where habitat destruction has been stopped. For example, populations of *Limnanthes vinculans* and *Lasthenia burkei* have apparently declined by several orders of magnitude at the Todd Road Reserve (Figure 1, data from CDFG files, Pavlik et al. 1998) after removal of domestic livestock and no active vegetation management. *L. burkei* may be effectively extirpated from the site (B. Guggolz, pers. comm. 5/98). Invasive Mediterranean grasses and other weedy plants could be responsible (Patterson *et al.* 1994a), especially when they develop dense, competitive swards in the absence of grazing or periodic fire. Light- to moderate-levels of grazing and low-intensity burns are generally thought to favor the maintenance of high native species richness in grasslands around the globe (Meurk *et al.* 1989, Parker 1989, Rosentreter 1994, Schlising 1996, Fensham 1998, Muller *et al.* 1998, Davison and Kindscher 1999). Mowing has also been shown to favor native perennial grasses over exotic annuals in California (Danielsen 1996) and to increase species diversity in the chalk grasslands of France (Fensham 1998). Reducing excessive inputs of nutrients, especially nitrogen from crops and pastures, would also favor native perennial grasses over non-native annual grasses (Claassen and Marler 1998) and possibly shift the "competitive balance" back towards a higher diversity of less aggressive plant species (Wedin and Tilman 1996, Choi and Pavlovic 1998). There is, therefore, a clear need for site-specific management prescriptions that lessen the effects of fragmentation, disruption, degradation, and invasion, and thus conserve native plant species richness and ecosystem integrity within the SRVRS.

The first goal of the Santa Rosa Vernal Reserve System is to develop management prescriptions for improving the habitat quality of native plant populations, especially those of conservation interest. Such prescriptions require the preliminary use of scientific approaches and statistical analyses of outcomes. An experiment designed to uncover limitations on population growth by implementing practical manipulations of habitat quality can be a very effective tool for reintroducing a species or enhancing its abundance or distribution (Pavlik 1994, Sutter 1996, Guerrant and Pavlik 1998). Treatment variables (e.g. controlled fire, selective herbicides) are chosen according to the best available information for the taxa in question. Field observations, greenhouse studies, or inference from related ecosystems, provide testable hypotheses for the first round of trials. These initial choices may not be the most effective for restoring a population or community, but the experiments will provide new information for choosing other variables or treatments in subsequent rounds. Restoration is, therefore, an iterative process that benefits from "failure" as well as "success" (Pavlik 1996) and requires a long-term commitment to do the science required for developing management prescriptions.

During the first phase of this project (Pavlik et al. 1998) we met three major objectives. First, we integrated CDFG properties into a single, scientifically-based planning, management and public service system. Biological, logistical and security information was collated into a database, using CDFG file records, property acquisition documents, California Natural Diversity Database (CNDDB) records, and all available "gray literature", supplemented with field visits. We then suggested a system of short-term management regimes that would help organize and prioritize restoration activities. Each property was placed in one of four categories (experimental, ecosystem enhancement, intensive care or quiescent) to guide management decisions over the next 5 to 10 years. Finally, we designed an initial management experiment to provide practical prescriptions for maintaining plant species richness and ecosystem integrity with respect to vernal pools and swales.

The second phase of this project (described herein) installs the first management experiment to determine the effects of mowing and phytomass (mostly graminoid) removal. Mowing with phytomass removal (i.e. hay baling) is a practical, potentially profitable management tool that could improve native vegetation and water quality while reducing fire hazard in many wildland areas of the state. It was chosen as the first treatment to be tested because it is easiest to do logistically (compared to replicated, meso-scale controlled burns or grazing) and because others have reported benefits to native grasses and vernal pool plants (Danielsen 1996, Muller *et al.* 1998, Collins et al. 1998, J. Menke pers. comm. 9/98, M. Waaland pers. comm. 5/98) throughout the state. Anecdotal evidence suggests that local mowing on a regular basis (e.g. Sonoma County Airport) minimizes annual grass cover and favors populations of native plants, especially *Lasthenia burkei* (Pavlik et al. 1998).

This report describes the first installation of experiments for restoring vernal pools and swales on the Santa Rosa Plain, including the following major components: 1) the use of mowing and phytomass removal as ecologically sound and practical manipulations for shifting plant cover from exotic to native (for dominant species) and from sparse to abundant (for rare species), 2) a description of the pre-treatment vegetation of uplands, pool margins and pool bottoms, and 3) an initial set of property-specific prescriptions for intensive vegetation management that favors native plants over exotics. Appendices to this report give additional information on the flora of the permanent plots, field keys to difficult taxa, maps of the permanent plots and life history characteristics of rare animals associated with these habitats to minimize collateral impact of restoration activities.

METHODS AND MATERIALS

Installation of the Primary Restoration Experiment: Effects of Mowing and Phytomass Removal

Description of the Listed Plants of the SRVRS

A total of nine plant taxa of conservation concern are known from ephemeral wetlands of the Santa Rosa Plain (CH2MHill 1995). These include three state and federally-listed endangered species (*Blennosperma bakeri* - Sonoma sunshine, *Lasthenia burkei* - Burke's goldfields, and *Limnanthes vinculans* - Sebastopol meadowfoam), one state endangered and federally-proposed endangered subspecies (*Navarretia leucocephala* ssp. *plieantha* - many-flowered navarretia) and five uncommon and unlisted taxa (*Downingia pusilla* - dwarf downingia, *Navarretia leucocephala* ssp. *bakeri* - Baker's navarretia, *Perideridia gairdneri* ssp. *gairdneri* - Gairdner's yampah, *Pogogyne douglasii* var. *parviflora* - Douglas's pogogyne, and *Ranunculus lobbii* - Lobb's aquatic buttercup). Of these, all but two (Gairdner's yampah and Lobb's aquatic buttercup) could potentially benefit from restoration of pool and swale margin habitat (the yampah and buttercup utilize grassland and aquatic habitats, respectively). The main focus of these restoration efforts, however, will be the three listed plants, emphasizing the most abundant and evenly distributed; *Limnanthes vinculans* (see Appendix F).

Limnanthes vinculans Ornd.

Limnanthes vinculans (Sebastopol meadowfoam - Limnanthaceae) is endemic to vernal pools and their adjacent, moist grasslands in southern Sonoma and Napa counties. Most populations occur in the Laguna de Santa Rosa watershed below 300 m elevation (CH2MHill 1995). Of the 18 properties currently included in the SRVRS (Pavlik et al. 1998), *Limnanthes vinculans* occurred naturally on 13 (72%), with one recent apparent extirpation (Airport Wildflower Reserve) and one accidental introduction (Alton Lane). Estimates of population size on a single property range from 10^6+ (Cramer) to as low as 10^2 (Crinella, Gobbi). These estimates should be regarded, however, as mere guesses that disguise the difficulty and uncertainty associated with attempts to "rough count" a species that grows in dense, tangled and often extensive patches from a large, cryptic seedbank.

This fleshy annual, distinguished from the common *L. douglasii* by its small number of leaflets (3-5 vs. 5-13, see Ornduff in Hickman 1993), may not germinate in response to the first rains of the growing season (usually November). It is not easy to confirm seedlings until late winter (February-March), because of inundation and the lack of distinctive vegetative features when small. The erect, paddle-like leaves often protrude above the water surface along pool or swale margins, among the floating leaves of *Lasthenia glaberrima* and *Pleuropogon californicus*. Stem production and elongation occur rapidly in March and April, when the first floral buds appear. Peak flowering is usually in early May, with subsequent fruit formation and senescence dependent upon the rate of soil drying. It is still possible to identify dried plants with fruits in mid-June, but these quickly shatter and assimilate into the grassy thatch. As with all rare species, demographic studies are required to determine critical life history events and measure vital rates of emergence, survivorship and fecundity.

Blennosperma bakeri Heiser

Blennosperma bakeri (Baker's blennosperma - Asteraceae) is endemic to vernal pools and their adjacent, moist grasslands in Sonoma County. In the Laguna de Santa Rosa watershed, the few known populations are found in the central and southern portions of the plain (CH2MHill 1995). Of the 18 properties currently included in the SRVRS (Pavlik et al. 1998), *Blennosperma bakeri* occurred naturally on 7 (39%), with two recent apparent extirpations (Simi and San Miguel). Estimates of population size on a single property range from 10^5+ (Alton Lane, Haroutunian, Todd Road) to as low as 10^1 (SW Santa Rosa Bank). At some properties the populations of *B. bakeri* have been significantly supplemented by pool creation/mitigation/salvage projects (e.g. Alton Lane) while at others the populations have apparently declined for lack of management (e.g. Todd Road). These estimates and trends should be regarded, however, as mere guesses that disguise the difficulty and uncertainty associated with attempts to "rough count" a species that grows in dense, ephemeral patches from a cryptic seedbank.

This erect annual is distinguished from the common *B. nanum* var. *nanum* by its red stigma lobes (ray flowers only) and small number of leaf lobes (1-3 vs. 3-15, see Ornduff in Hickman 1993). Its leaves are alternate, not opposite like those of *Lasthenia glaberrima* which often shares the same habitat later in the season. Observations on its vegetative phenology are lacking, but it may be one of the early germinating pool margin plants of the Santa Rosa Plain because it is the earliest of the natives with respect to floral anthesis. Flowers can begin opening in late February, with peak flowering in March and early April. A small proportion of plants can continue to flower into May, but these are scattered and difficult to find. As with all rare species, demographic studies are required to determine critical life history events and measure vital rates of emergence, survivorship and fecundity.

Lasthenia burkei (E. Greene) E. Greene

Lasthenia burkei (Burke's goldfields - Asteraceae) is endemic to vernal pools and their adjacent, moist grasslands in southern Lake and Mendocino counties to northeastern Sonoma County. In the Laguna de Santa Rosa watershed, the majority of the populations are found in the northwestern and central portions of the plain north of Highway 12 (CH2MHill 1995). Of the 18 properties currently included in the SRVRS (Pavlik et al. 1998), *Lasthenia burkei* occurred naturally on 8 (44%), with one recent apparent extirpation (Simi). Estimates of population size on a single property range from 10^6+ (Airport) to as low as 10^1 (Cramer). At some properties the populations of *B. bakeri* have been significantly supplemented by pool creation/mitigation/salvage projects (e.g. Airport, Alton Lane) while at others the populations have apparently declined for lack of management (e.g. Todd Road). These estimates and trends should be regarded, however, as mere guesses that disguise the difficulty and uncertainty associated with attempts to "rough count" a species that grows in dense, ephemeral patches from a cryptic seedbank.

This small, stout annual is distinguished from the common *L. glaberrima* by its free phyllaries and pappus awn (phyllaries fused and pappus of scales only in the latter, see Ornduff in Hickman 1993). Observations on its vegetative phenology are lacking. Flowers can begin opening in late March, with peak flowering in April and early May. As with all rare species, demographic studies are required to determine critical life history events and measure vital rates of emergence, survivorship and fecundity.

Selection and Description of Experimental SRVRS Properties

Three SRVRS properties were chosen to represent a broad range of habitat qualities found on the Santa Rosa Plain; Cramer (174 acres, relatively unaltered pool and swale system, mostly diverse native vegetation), FEMA (69 acres, hydrologically altered pools and swales, extensive weed cover), and Haroutunian (30 acres, unaltered swale system, mix of native and weed cover). All are located on Wright clay-loam soils and have supported multiple *Limnanthes vinculans* (Sebastopol meadowfoam) subpopulations.

Cramer (174 acres)

This large, topographically-complex parcel is widely regarded as the most pristine and, therefore, the best reference site for restoration in the central Santa Rosa Plain (C. Wilcox, C. Patterson, pers. comm. 5/98). Numerous swales and shallow pools with *Limnanthes vinculans* are relatively unaltered and rather evenly distributed across the northern, eastern and southern portions, with extensive, interconnecting stands of *Pleuropogon*. Cover by native vernal pool and wetland species is moderate to high, but *Mentha pulegium* can be locally dominant and probably restricts the abundance of *Limnanthes vinculans* and *Lasthenia burkei*. Estimates of population sizes of *Limnanthes vinculans* range between 3,000 and 100,000 individuals (1988-1994), while those of *Lasthenia burkei* tend to vary between 100 and 1,000 individuals (1988-1993) (Patterson 1994a). The property apparently supports the largest single concentration of *Limnanthes vinculans* in the county (CH2M Hill 1995). Other rare species include *Navarrentia leucocephala* ssp. *bakeri*, *Ranunculus lobbii*, and California Tiger Salamander. Uplands that separate the pools have pockets of *Danthonia californica, Hordeum brachyantherum* and, to a lesser extent, *Nassella pulchra*. There is much cover by *Erodium botrys*, *Avena*, non-native *Hordeum* and *Lolium* (sometimes greater than 1 m tall), especially in the west-central portion of the property where dairy corrals may have held animals for long periods of time. The area to the north of the northern drainage canal was disked in the past, and consequently is weedier (*Convolvulus arvensis*) and flatter than the interior. A wetland delineation report (Patterson 1992b) provides detailed descriptions of soils, vegetation, and hydrology, including a map and inventory of all pools and swales, and a comprehensive flora.

The size and complexity of this parcel, combined with the presence of many subpopulations of *Limnanthes vinculans*, allow replicated experimentation with mowing, grazing and possibly fire. Plots could be large and include both upland and swale habitats in areas with relatively high native cover (e.g. the north and central interior) and areas with no native cover (west). The buildings on adjacent parcels (to the east and south) are a good distance away from many swales and could easily be protected from controlled burns. Access from the north and west is good, although the large stream channels could restrict mower movements. In the future it may be expedient to build at least one bridge across the northern canal to allow the mower easy access to more interior portions of the property.

FEMA (69 acres)

Located along the southeast quarter of the Santa Rosa Air Center (SRAC), the FEMA parcel is largely comprised of annual grassland with scattered valley oaks (78%) and semi-permanent marsh (12 %) (see "Map of Biological Resources...." in the FEMA file at Yountville Fish and Game) . The vernal swales and pools support a modest, occasionally large, population of *Limnanthes vinculans* (range of 1,000 to 10,000 individuals, 1990-1993, Patterson 1994a) in a well-developed matrix of *Pleuropogon, Eleocharis* and *Juncus.* Other rare species include *Pogogyne douglasii* ssp. *parviflora, Ranunculus lobbii,* and California Tiger Salamander. *Mentha pulegium* is abundant within the wetlands. The uplands are dominated by exotic annual grasses, with dense infestations of *Dipsacus fullonum* where disking was done for fire control. The southern boundary is shared with the Broadmoor North parcel (see below) and is transected by water flowing from northeast to southwest. A plant and wildlife list is available in the Final Environmental Assessment Report (1995). Patterson (1992a) provides detailed maps and discussion of the biological resources on the adjacent SRAC and Madera parcels.

Access to the center of the site is good because of a circular road that services a number of storage bunkers used by FEMA and the Sonoma County Sheriff's Department. The road allows mowers and fire control vehicles to be used with minimal damage to wetland soils and vegetation. Security is also better than on most other parcels, although there are several places along the southern and eastern borders where fence repairs need to be made. Overall, given the number of rare plants, the moderate population sizes, good access and security, and the general restoration potential, management experiments could readily be conducted on this parcel. Mowing, small scale controlled burns (depending on the contents of the bunkers), and selective herbicide application are recommended as variables to test here.

Haroutunian (30 acres)

This property is owned and administered by Sonoma County Agricultural Preservation and Open Space District. Although its northern third has been heavily impacted by horses (removed in 1997), the southern two-thirds supports remnant perennial grasslands (*Danthonia, Nassella, Hordeum brachyantherum* and native forbs) and excellent swales (with *Pleuropogon californicus, Blennosperma bakeri, Limnanthes vinculans*, and *Juncus occidentalis*). The swale system is extensive, relatively undisturbed and supports a very large population of *Blennosperma bakeri* (10^4 - 10^5 individuals). However, no *B. bakeri* individuals were observed during the 1998-1999 field season. Small colonies of *Limnanthes vinculans* are found near the southern boundary, with a total of 100 to 200 plants (1998-1999 observations). *Mentha pulegium* and *Rumex* spp. are common throughout. The uplands are largely annual grassland and an old prune orchard, but growth of the non-natives (e.g. *Erodium, Brassica*) is not overwhelming. A plant list is available (Jack and Betty Guggolz) based on surveys begun in 1994 (B. Guggolz, pers. comm. 4/98). Doug Eakins began a survey of the aquatic fauna in 1994 and produced a list (see CDFG files, Yountville).

The Haroutunian property has high restoration potential because of the relatively unaltered hydrology and presence, if not local dominance, of native plants. It may be desirable to manage the grasslands with fire on an experimental basis. There are no structures adjacent to the south end of the property and fire trucks could be brought in along the railroad tracks on the eastern edge of the parcel. Mowing and grazing treatments might also be appropriate, and the large *Blennosperma bakeri* population would even allow some replicated experiments. Coordination with the Sonoma County Agricultural Preservation and Open Space District would be essential for conducting any management action.

Design and Establishment of a Block Design

A power analysis was conducted for three properties having equal quantities of blocks (Holmes 1998, T. Holmes, pers. comm. 2 Feb 1999). In order to detect a treatment effect of 0.39 with at least 80% power (Type I error rate = 5%, the probability of missing a difference between treatments and controls when there was one, Type II error rate = 20%, the probability of falsely concluding there was a difference between treatments and controls when there was none), a minimum of four blocks would be needed per property. The treatment effect could be reduced to 0.33 with five blocks and to 0.26 with six. Given the anticipated effort needed to perform the mowing and raking, we decided to use five blocks per property (15 total). Consequently, our experiment on three properties using five blocks each will be able to detect a 33% difference between control and treatments with a Type I error rate of 5% and a Type II error rate of 20% (power = 80%).

An individual block was a single vernal pool or vernal swale locality, each encompassing a margin zone (the apparent edge of vernal pool or swale vegetation) and an upland zone (coastal prairie). Block locations were determined by assigning numbers to every pool or swale feature on a wetlands delineation map for each property with the following exclusion. Excluded were numbered pools/swales in areas that had less than 50% live cover during the last two years (1997 and 1998), such as corrals, holding paddocks, barn areas, pavement, and compacted road beds. Random numbers were then used to select a subset of numbered pools/swales for block locations.

The start location for establishing a block *in situ* was determined by another random number between one and four (inclusive) that corresponded to a quarter of a circle (for a pool) or a quarter of the total linear dimension (swale). This location was found during field work in mid-April 1999, but the actual marking stake was established by blindly tossing a survey arrow behind the back within the quarter. From the arrow a path perpendicular to the pool/swale margin was established (Figure 2). A 2 foot section of 2" white PVC pipe was driven into the wet (low) end of the path, at a point that centered the pool margin vegetation (at least 50% cover by wetland species, especially *Pleuropogon californicus*) within a 5 m width (presumably the perennial vegetation integrates variations in water level from year to year). This permanently marked point is hereafter referred to as the "initial boundary" of the block. Another PVC pipe was driven in at the 5 m (upslope) point, the origin of a meter tape that ran parallel to the margin for 90 meters, thus delineating the pool margin strip of the block. The upland portion was another 5 X 90m strip, marked with PVC, at least 5 m from the upper edge of the margin and usually (but not always) parallel to it. The upland strip could deviate from the 5 m spacing in order to avoid wet depressions and maintain its grassland character. Within each margin or upland strip, 0.5 m along all edges was designated as a buffer zone to be treated but not sampled for vegetation, phytomass or soil characteristics.

Mowing and Phytomass Removal

Each 5X90 m margin or upland strip was divided into three 5X30 m long plots that were randomly assigned one of three treatments; 1) an unmowed control (C), 2) mowed with clippings left as mulch (Mm), and 3) mowed and raked to remove the clippings from the plot (Mr). A Bauchtold 8 horsepower "Whipper" (Chicago, Illinois), with a 24" cut width and a 3" cut height was used to mow the entire 5 X 30m Mm and Mr plots on seven days between 25 June and 22 July 1999. The machine was self-powered, lightweight, and fit with large diameter, narrow tires that had no apparent effect on the soil surface (i.e. no compaction or erosive spinning). In general, a single passage of the mower was sufficient to cut down all plant cover, whether it be dense pockets of *Juncus*, thick swards of grass, or tall stems of *Dipsacus*. Missed or partially-cut spots were, however, mowed again to ensure consistency across all plots. The blade was disengaged manually so the mower could be run throughout control plots without cutting. An extra can of fuel was usually required to finish all plots on a single property and gloves and safety glasses were essential for protection of the operator. A factory-installed spark arrester apparently did a very good job (considering the amount of surrounding dry grass), but we also made sure the blade avoided hitting rocks and other hard objects.

Immediately after mowing, a light gauge leaf rake was used to remove cut phytomass from the Mr plots. The material was moved towards the downwind (usually north) edge of the plot, where it was lifted and dispersed across adjacent, untreated areas at least 1 m away. Gray, unrooted thatch from the previous year was also raked away, but only if it could be moved with little disturbance to the soil surface. Care was taken to ensure eveness of raking among and within blocks. Raking was by far the most time-consuming and arduous part of the treatment process. A total of 80 person-hours was required to mow and rake all 15 blocks on all properties.

Sampling Post-treatment Phytomass and Soil

Above ground phytomass samples were collected in each plot (C, Mr, Mm) during the fall of 1999 prior to the onset of major winter rains (October-November). The 1 m^2 PVC frames (0.5 x 2 m) were placed at two positions along the top edge (long) of each plot: 1 m downslope at the 8 m position, and 2 m downslope at the 23 m position. A total of 180 phytomass samples were thus collected: 2/plot X 3 plot/habitat X 2 habitats/block X 5 blocks/property X 3 properties. Canopy height was estimated in the two halves of each frame by randomly dropping a petri dish on a string and measuring the distance between the dish center and the firm soil surface.

Most of the phytomass was removed by clipping (usually 2-4 cm above the soil) and sorted into three categories; standing, thatch, and dicot. Phytomass rooted within the frame was considered standing if it was yellow (1998-1999 production) and attached to the roots. Any plant material that was unattached to the roots (it was often gray) was considered thatch. The majority of standing and thatch material was composed of grasses or graminoids (e.g. *Juncus*) so that all broadleaf forbs and windborne leaves (e.g. *Quercus*) constituted the dicot fraction. The phytomass fractions were put in separate, labeled paper bags taken back to the lab and dried to constant weight in a warm room at 40°C. Phytomass data will be presented in a subsequent report.

Soil samples were taken next to each frame at the time of phytomass sampling. They were taken as cylindrical cores (5 cm deep, 5 cm diameter) using a bulb planter driven into the soil surface. The two cores from each plot were combined into a single ziplock bag (n = 90 with pooled subsamples), labeled and sealed. They were taken back to the lab and refrigerated (4°C). Within a month the soil was air dried (5-7 days if wet, 2 days if drier) and 100-150 g frozen (-20°C) in a labeled ziplock bag. The remaining portions of the dried samples were then stored at room temperature in a dry, dark cupboard. Soil nutrient data will be presented in a subsequent report.

Baseline Characteristics of Pre-Treatment Vegetation

Vegetation Sampling

At each property, the pre-treatment vegetation in the marked plots was sampled in three habitat zones; the pool/swale bottom, the pool/swale margin, and the upland (the term "pool" will be used herein to refer to both pool and swale features). We defined the pool bottom as the deepest and flattest zone that retained standing water into the rainless, late spring season (May-June). It tended to be characterized by the presence of emergent or floating wetland macrophytes, such as *Eleocharis* spp. and *Ranunculus lobbii,* respectively. The pool margin was then the sloping edge zone, submerged during early to mid-spring (February to early April) but dry later on. The margin tended to be the primary habitat of the perennial grass *Pleuropogon californicus* and a mixture of wetland and upland taxa. The upland habitat was found on the undulating hillocks between pools and was never submerged in water. It supported coastal prairie or valley oak woodland, dominated by a grassy mixture of exotic annuals (e.g. *Lolium multiflorum* and *Bromus hordeaceus*) and natives (e.g. *Vulpia octoflora* and *Danthonia californica*).

We used a bipartite, PVC sampling frame consisting of two 0.5 m^2 quadrats (each 0.75 X 0.67 m) separated by 0.75 m (Figure 3). At one end of the frame an additional 1m section of PVC pipe acted as a spacer to determine distance from the upper edge of the plot. The frame could than be placed in a "high" or "low" topographic position relative to nearest pool bottom (see below), always excluding the buffer strips. This arrangement would maximize the amount of variation in the vegetation samples caused by topographic gradients (especially in the pool margin strip).

The positions of the frame along the upper, long (90 m) edge of the plots were determined using random numbers between 5 and 85 that corresponded to meter tape positions outside of a 5m buffer between treatments. If the number selected was even the sampling frame was placed in its high position. Likewise, if the number selected was odd, the sampling frame was placed in its low position. Care was taken to ensure that the placement of the frame on the ground was always perpendicular to the upper edge of the plot, that it never overlapped a previously sampled area (especially on curves or bends in the strip) and that it did not cause the plant cover to be compressed.

At each property, one block was sampled along its entire 90 m length. In this block a total of 27 frame positions (= 27 samples, = 54 subsamples) were used to characterize the vegetation of the pool margin habitat and another 27 samples were taken in the upland habitat. This would allow us to assess the amount of variation in the vegetation samples caused by spatial heterogeneity around the pools and thus to determine the minimum number of samples that would be necessary for characterizing post-treatment vegetation during spring 2000. In each of the other four blocks, a total of six frame positions (= 6 samples, = 12 subsamples) were taken between the first 5 and 30m from the initial boundary of the pool margin and upland plots. Therefore, at a single property there were 51 samples (102 subsamples) per pool margin and 51 (102 subsamples) per upland and for all three properties in both habitats there was a total of 306 samples (612 subsamples).

Using the bipartite frame, pool bottoms were sampled from the three largest of the five marked pools or swales at each property. We established a 30m transect which started at the initial boundary and ended near the deepest spot in the pool or swale. Six positions along the transect were selected using random numbers. If the position number was odd, the sampling frame was placed one side of the tape. If the position number was even, the sampling frame was placed on the other side of the tape. Therefore, at a single property there were 18 samples (36 subsamples) of pool bottom habitat and for all three properties there was a total of 54 samples (108 subsamples).

Absolute cover (%) of every species within each quadrat of the bipartite frame was estimated by projecting total live canopy area for all rooted plants onto the planar ground surface. We attempted to mentally cluster the canopy of the species, subtract gaps, and then apply a first approximation value (near 10, 25, 50, 75 or 100%). A second and final value was then assigned to give a better estimate (e.g. if > 25%, then 28%) and recorded. A clenched fist could also be used as a 2% estimate for this size frame, and be added up to give estimates between 2 and 20%. A 1% value was uniformly applied for the rarest, low-cover estimates. Cover by thatch and bare ground were included as "species" within the frames. Thatch was defined as dead plant material from the previous growing season that was no longer contributed to standing cover. We "calibrated" teams of people (2 per frame) during each sample day to maximize precision and found that after several warm-ups most cover estimates were within 5-10% of each other. Taxonomic checks were frequent, with a roving specialist who collected and compared voucher specimens during the sampling (see below).

Absolute density (# live plants/0.5 m^2 frame) was also estimated for the following coarse weeds and native or rare species; *Danthonia californica, Dipsacus fullonum, Downingia concolor*, *Limnanthes vinculans, Rumex* spp., and *Pogogyne douglasii* ssp. *parviflora*. Exceptionally high densities (e.g. *Limnanthes vinculans*) were estimated by counting individual plants in a 10% area of the quadrat and multiplying by the cover estimate for that species (e.g. 4.5 for 45% cover).

A master datasheet was developed prior to field work that grouped plant taxa and subsequent cover estimates by life form/restoration categories (Appendix A). The broadest categories were native vs. non-native (using Hickman 1993 for these designations), and nested within these were annual grass, perennial grass, monocots, dicots, rare dicots (native only), thatch, and bare ground categories. An additional category was kept for unknown taxa, especially those which were infrequent or with very low cover (e.g. <5%, usually <1%). This organization would facilitate transfer of the field data to an Access or Excel database for subsequent analysis and hypothesis testing (a prototype for the restoration experiment). Gopher disturbance (entrances to burrows, excavated soil mounds) and cattle impacts (when animals pushed through fences from adjacent properties) were also noted on the datasheets.

Field sampling occurred after the apparent peak of vegetative growth and during maximum floral display of most plant taxa. Pool margins and uplands were sampled on May 18, 19, 20, 21, 25, 27, 28, June 8 and 9, 1999. The soil surface in these habitats was dry and not "squishy" under the feet. Pool bottoms were sampled on June 23 after the last standing water had evaporated and the late season wetland taxa were fully developed. In general it took two independent teams working about 24 hours each per property to complete the vegetation sampling (setting up and taking down tapes, collecting data, checking plant identifications). Additional time was spent collecting voucher specimens, calibrating, checking datasheets and having lunch.

Calculations of mean absolute cover, mean relative cover (RC), relative frequency (RF) and importance value (IV = RC+RF) by species (thatch was also a "species") were made according to Mueller-Dombois and Ellenberg (1973). Importance index was calculated as the sum of IV's of species within a habitat (maximum value = 200%). It can express the relative degree to which a few species can dominate a habitat. Life form and native/non-native (non-native is synonomous with exotic) status were determined from Hickman (1993).

Plant Identification and Voucher Collection

The collection, identification, and compilation of voucher specimens, construction of field keys, and the creation of a local flora emphasized the 90 sampled plots of pool margin and upland habitats in the 15 total blocks from the three Santa Rosa Vernal Reserve System properties. Voucher specimens were also collected for the nine sampling transects in the pool bottom habitat of the three properties. Existing floras from Alton Lane mitigation site (Patterson, 1991-1993), Cramer (Patterson, 1991-1992), FEMA, and Haroutunian (Betty and Jack Guggolz pers. comm.) were also consulted.

Specimens were collected during or after vegetation sampling on 5/18, 5/21, 5/27, and 6/24, 1999. Collections consisted of full root to inflorescence when possible and were either immediately pressed in the field or carried in a cooler for preservation at a later date. All specimens were labeled with property name, block number, date, and either Latin binomial or temporary identification name. All collections were organized and kept separated by property. Species lists by property were generated and included: property name, date, the Latin binomial or identification name, the collection date, and an ascribed accession number. Once specimens were sorted by name and property, the lists were used to sort all specimens into "identified" and "unidentified" categories.

The Cramer property was designated as the type specimen site. All "identified" specimens were compared to Cramer specimens and entered into a master flora of species from these sampled plots (Appendix B). Specimens from Cramer were mounted as type specimens in protective, see-through jackets and will be used for plant identifications during field studies in subsequent years.

The "unidentified" specimens were sorted into two categories: "unknown" and "likely". The "unknown" category consisted of specimens that did not have enough material for positive identification and, therefore, would not be identified this year. Field names where given to these specimens and will require correction in subsequent years.

They were included as part of tallies of species richness (see below). The "likely" category consisted of specimens with enough useful material to permit eventual identification. Additional effort on "likely" specimens consisted of; 1) comparison to collections made for the local floras of Alton Lane, Cramer, FEMA, and Haroutunian, 2) keying in standard regional floras (e.g. Hickman 1993, Crampton 1974), 3) comparison to herbarium collections at UC (Jepson Herbarium), and/or 4) submission to a taxonomic specialist in a particular genus. During identification, critical characteristics used in constructing key couplets were noted from these sources previously mentioned. The couplets were used to create local field keys specific to the properties for use during future sampling (Appendix C).

Initial Intensive Care Prescriptions

An initial set of intensive care prescriptions was developed during field visits in 1999 and 2000 (see also Pavlik et al. 1998). These were based on observations of exotic taxa that appeared to be aggressively invading pool margin or adjacent grassland habitats. Some had small or moderate population sizes and vulnerable growth forms that would allow removal by hand (e.g. wild radish at Cramer). Others had large populations with difficult growth forms for hand removal (e.g. rosettes of teasel, rhizomes of pennyroyal) and would require careful application of appropriate herbicides. Estimates of field effort were expressed as number of person-days to accomplish an action at a given property. They were made as best-guesses in first-round implementation and will be revised with experience.

RESULTS

Installation of the Primary Restoration Experiment

Marked plots were easy to find and reconstruct on all field days. The row of four, white PVC pipes (two inch diameter) that identified the initial boundary could be seen from up to 20 m away in most cases, even when surrounded by tall grass. When tapes were to be laid out along the upslope (or outside) long edge, 1 m length segments of PVC (half inch) were inserted into the larger marker pipes so the tape could be laid out rapidly and held in place around bends. One person could reconstruct an entire 5m X 90m strip in approximately 5 minutes. The shapes, relative locations, and arrangements of all strips and plots are shown as maps in Appendix D).

Vegetation sampling was time consuming and often tedious. It was necessary to stop a couple of times during the day to re-calibrate cover estimates and check our consistent use of scientific and field names. Teams working within a strip frequently tallied absolute total cover (total live + thatch) for comparison. This was to maximize precision around an estimate that describes overall community structure (i.e. canopy density and ground cover). In general, we found agreement within 10%, but re-calibrated and corrected our estimates to ensure consistency.

The mowing treatment was relatively easy to perform, even when blocks were located far from road access. The "Whipper" was able to cut its own path through very dense grass and even small, woody debris in order to get to the blocks. This created a path that was subsequently easy to travel, minimized exposure to ticks, and limited impacts to the experimental plots. The mowing itself appeared uniform, leaving less than 8 cm of stubble where a 50+ cm tall canopy once stood. Raking was much more arduous and less even than the mowing. It was difficult not to scratch the soil surface when the previous year's thatch was readily moved. Other, more automated technologies for mowing and raking will need to be implemented in the future to ensure treatment eveness and practicality.

Baseline Characteristics of Pre-Treatment Vegetation

Analysis by Habitat (Properties Combined)

Total species richness (SR) was greatest in the pool margin plots (Table 1), as was native species richness (SR_n). Among the 15 pools sampled on the three properties, 44 species were encountered in this habitat, of which 19 (43%) were native to California. Pool bottoms had the lowest SR (28) but the highest proportion that was native (54%) . The uplands had an intermediate SR but the lowest absolute and relative number of natives. The composition of these species assemblages was rich in dicots and poor in perennial grasses, regardless of habitat (Table 2). Annual grasses were the next most common type in the uplands and pool bottoms while in the margins it was the non-grass monocots (especially *Juncus*). Dicots endemic to vernal pools were found in margins and bottoms. Of these, *Limnanthes vinculans* was found in both habitats while Pogogyne *douglasii* ssp. *parviflora* was largely confined to bottoms. *Downingia concolor* only appeared in margin samples. Thus, a trend towards higher native species richness (32 to 54% of the total SR) and a higher probability of dicot endemism was detected along upland to pool bottom transects.

Native absolute live cover followed a similar but even more pronounced trend, which doubled from 42% in the uplands to 84% in the pool bottoms (Table 1). Uplands had low live cover by all species (Table 3), the least amount of bare ground but the most amount of thatch (which surpassed the amount of live cover in this year). Pool bottoms supported the highest live cover (50% more than the uplands) and the most bare ground with the least amount of thatch. Pool margins were intermediate in all respects.

Dominance in the upland (i.e. species with the highest importance value (IV)) was by the native annual grass *Vulpia octoflora var. octoflora*, which also had the highest mean live absolute cover (Table 4). Dense swards of *Vulpia* were common beneath the taller canopy of the non-native annual grass *Lolium multiflorum,* the broad array of plant sizes indicating continuous germination during the growing season. Four out of the five most dominant taxa were non-native (of which three were annual grasses), and the sum of their absolute live cover and IV's both exceeded those of the native *Vulpia*. In contrast, the dominant species in the pool margin habitat was the native graminoid *Juncus phaeocephalus,* followed by the native grass *Pleuropogon californicus*. These perennial taxa were patchier in their distribution than the top two dominants of the uplands, as evidenced by their low frequencies despite having similar absolute cover. *Lolium multiflorum* was the only dominant non-native of the margins, its contributions somewhat reduced relative to the adjacent grassland. Finally, the pool bottom was dominated by the native graminoid *Eleocharis macrostachya*, followed by the late-flowering dicot *Eryngium aristulatum* . Thus, another trend towards dominant natives, mostly graminoids, was typically observed on the upland to pool bottom transect (Figure 4).

<u>Analysis by Property</u>

The highest total species richness (SR) occurred at the Cramer property with a total of 48 plant species from the five pools sampled (Table 5). Haroutunian had the next highest richness with a total of 44 species, and FEMA had 39 species. Cramer also had the highest proportion of native species relative to SR (19 = 39%), compared to Haroutunian (34%) and FEMA (36%). It was difficult to detect much of a richness or compositional trend between properties.

A total of three vernal pool characteristic (VPC) species appeared among the three properties during the 1998-1999 growing season, out of a total of six potential species historically inventoried (Table 6). *Blennosperma bakeri* (federally and state-listed endangered, CNPS 1B) has been recorded at Cramer and Haroutunian but was not found on these properties or in any of the sample plots this year (spring 1999). *Lasthenia burkei* (federally and state-listed endangered, CNPS 1B) is known only from Cramer but was not seen this year. *Limnanthes vinculans* (federally and state-listed endangered, CNPS 1B) occurs at all three sites, but has historically been most abundant at Cramer (CH2M Hill 1995, Pavlik et al. 1998). We found it associated with pool margins in four out of five Cramer blocks (2-5), although it was known from all five in the past. It was also found in a few samples of the pool bottom. At FEMA this *Limnanthes* was found in 3 blocks (2,4,5) and historically was known from one more (#1). This species was non found in the blocks at Haroutunian during 1998-1999, but historically (even in 1997-1998) it was recorded from two (blocks 4,5). *Pogogyne douglasii* ssp. *parviflora* was found this year only in one block (#4) at Cramer, but has been abundant in the past at FEMA. *Downingia concolor*, a common VPC plant, has been recorded at all properties in the past, but had only a minor presence in 1999. *Navarettia leucocephala* ssp. *plieantha* has never been recorded on the three properties and was not found in our blocks: it was included in Table 5 because of possible confusion with *N. l.* ssp. *bakeri*, which has been recorded from Cramer.

In terms of habitat distribution, *Limnanthes vinculans* occurred in margins and pool bottoms at Cramer (the later in early June), but only in margins at FEMA (Table 7). In previous years, this species occurred at Haroutunian primarily in margins. *Pogogyne douglasii* ssp. *parviflora* appeared to be very limited geographically and ecologically during 1999, as it was found only in the pool bottom samples of a single pool at Cramer. However, at this pool it was very abundant and contacted the sloping margin during the early summer. *Downingia concolor* was sparsely distributed between margins and pool bottoms at Haroutunian, but was restricted to the margin at FEMA. None of these taxa were ever recorded from plots in the upland habitat.

Patterns in total absolute cover were difficult to discern among properties (Table 8). Although the highest total cover was found at FEMA, the lowest was at Cramer, which also had the highest proportion of native cover. FEMA had the highest native absolute cover (52%) and Haroutunian the lowest (45%). Dense thatch was typical of all three properties in the upland and margin habitats. Small patches of bare ground were created where gophers, ground squirrels, and predators (coyote, fox) burrowed, especially at Cramer. Otherwise, no differences in bare ground distribution were detected among properties.

Dominance within habitats varied by property (Table 9). Pools bottoms at Cramer were dominated by native species (all five accounting for 70% of the total importance index), especially *Eleocharis macrostachya* and *Pleuropogon californicus* . In pool bottoms at FEMA and Haroutunian, non-native annual grasses (*Polypogon* spp. and *Lolium multiflorum*, respectively) were among the top four dominants, but *Eleocharis* spp., *Eryngium aristulatum* and *Pleuropogon californicus* were important native components. Moving upslope into the margins elevated dominance by *Pleuropogon californicus* and *Juncus phaeocephalus* and diminished the role of *Eleocharis macrostachya* at all three properties. Natives were still completely dominant at Cramer (54% of the total importance index), but FEMA and Haroutunian each had two non-natives among the top five. *Lolium multiflorum* was a margin dominant at both along with the forbs *Convolvulus arvensis* and *Rumex crispus.* Moving upslope into coastal prairie produced a similar dominance pattern at all three properties: the native annual grass *Vulpia octoflora* was the most dominant (but accounted for only about 23% of the total importance index), and the remaining top five were all non-natives. These non-natives were mostly annual grasses, especially *Lolium multiflorum* and *Bromus hordeaceus*, but could also be forbs (especially *Convolvulus arvensis*).

Among the three properties, Cramer had the highest absolute live cover contributed by vernal pool characteristic plants in pool bottom and margin habitats

(Table 10). Total VPC cover averaged 4% within the sampled blocks, contributed by *Limnanthes vinculans* and *Pogogyne douglasii* ssp. *parviflora* . The former species had an 80% frequency among blocks of the margin (20% for the latter in pool bottoms), an average frequency among subsamples of 44% (100% for *Pogogyne*), and a mean density of 7 plants/m^2 (190 plants/m^2 for *Pogogyne*). FEMA had lower VPC cover, most of which was *Limnanthes vinculans*. Densities in the margin were higher than at Cramer (46 plants/m^2) but the species was found in only 60% of the blocks and 15% of the subsamples. Haroutunian had the lowest VPC cover, all of which in 1999 was contributed by *Downingia concolor* .

Initial Intensive Care Prescriptions

An initial set of intensive care prescriptions was developed during field visits in 1999 and 2000 (Table 11). All recommendations deal with weeds, rather than directly with rare plant populations to avoid conflicts with the mowing experiment and to begin the long process of slowing invasion by these aggressive taxa. These could be implemented over a three year period (e.g. 2000-2003) using paid student assistants and local volunteers. Additional recommendations will be developed for intensive care of rare plant populations once the preliminary results of the mowing experiment are available and additional "tool development" studies have taken place. Weeds with relatively small or moderate population sizes and vulnerable growth forms could be removed by hand (e.g. wild radish at Cramer). Others with large populations and difficult growth forms for hand removal (e.g. rosettes of teasel, rhizomes of pennyroyal) will require careful application of appropriate herbicides. Rodeo (a glyphosate herbicide from Monsanto) is approved for aquatic systems, has no vertebrate toxicity, no activity in soil or water and cannot be taken up by roots, and is broken down by microorganisms. If applied at a time when the targets were suseptible and the non-targets were dormant (e.g. mid- to late summer), effect, safe and benign control could be acheived. This will require, however, a protocol that establishes best practices, treatment recording, and assement techniques.

DISCUSSION

Intensive sampling at three Santa Rosa Vernal Reserve System properties has provided the first quantitative description of vernal pool and upland vegetation of the Santa Rosa Plain. Although much has been written about the vernal pools of California (Ikeda and Schlising 1990, Keeler-Wolf et al. 1998, Witham et al. 1998), the emphasis has been on those of the Central Valley (e.g. Holland 1978, Holland and Jain 1988) and the coastal watersheds of the central and southern portions of the state (Zedler 1987, Ferren et al. 1996 a,b,c). Sawyer and Keeler-Wolf (1995) point to a lack of vegetation data on vernal pools in general, making comparison and classification of these ecosystems difficult. Therefore, our data on species richness, cover, contributions of native and non-native components, dominance, occurrence of vernal pool characteristic species, and architecture in three habitats cannot be readily interpreted from a statewide perspective. Nevertheless, the record we have thus obtained provides a baseline description useful for comparing to other sites on the Santa Rosa Plain and for evaluating subsequent restoration projects.

We found that in general, species richness was greatest in the margin habitat of vernal pools and swales, declining slightly towards the uplands and dramatically towards the pool bottoms (Table 1). This ecotonal feature of margins was also described by Kopecko and Lathrop (1975) for pools near Rancho Seco (Sacramento Valley). The margin was rich in dicots (Table 2), a few of which were vernal pool endemics but many were exotic with low or patchy cover (e.g. *Dipsacus fullonum, Convolvulus arvensis*). Santa Rosa pool bottoms had 40% fewer taxa than the other two habitats, a higher proportion were native (54%) and contributed much more (84%) of the total cover. Again, dicots were the most common category, but these tended to be natives that contributed high cover (e.g. *Eryngium aristulatum*). Bliss and Zedler (1998) suggested that inundation stress on seeds keeps unspecialized, upland competitors out of pools, including exotic grasses and forbs. Wetland specialists, such as *Eleocharis* and the vernal pool endemics, may actually require inundation and/or anaerobic conditions to germinate (Bliss 1998). The composition of Santa Rosa vernal pool vegetation is, therefore, determined by a steep gradient: from pool bottom conditions (e.g. hydric, low soil oxygen) that favor an ephemeral wetland of relatively few native taxa of high cover to upland conditions (dry, high soil oxygen) that favor a grassland of many species, 70% of which are exotic.

Pool bottoms not only had the most native cover, they also had the highest live plant cover and the least amount of thatch (Table 3), but the lowest total cover (live + thatch) and the most bare ground. There tended to be a single, dark green, relatively tall canopy layer of taxa with vertical photosynthetic shoots (e.g. *Eleocharis*) or rigid, vertical leaves (e.g. *Juncus*). This single, vertical canopy layer appeared to be regularly spaced, set against a uniform background of bare ground. Evidently the rapid decomposition of last year's thatch, combined with a lack of annual grasses, produced the bare ground. In contrast, the upland had the lowest live plant cover, the highest amount of thatch, and almost no bare ground. The canopy had multiple layers of vertical and horizontal leaves but was set against a patchy background of last year's straw-colored thatch. The thatch appeared to slow and/or inhibit spring germination of grassland taxa. For example, on 30 March 1999, thatch cover was greater than 90% at Cramer and 5 to 22 cm deep, the remnant of high grass productivity during the 1998-1999 El Nino pattern (precipitation 200% of average). Consequently, live cover in the upland had only 2 months to develop and was low at the peak of reproductive activity. Even though pool bottoms were sampled a month later, they were at the same phenological stage as the uplands when sampled and did not have significantly longer to develop cover because of persistent standing water. Nevertheless, variations in cover and species composition are to be expected seasonally and from year to year as patterns of temperature and precipitation vary (Shannon and Bliss 1998).

We do expect these variations to be more pronounced in the margin habitat, rather than the upland or pool bottoms. Margins would be most susceptible to annual fluctuations in rainfall and the rate of evaporation, and consequently, the level of standing water. These seasonal fluctuations are known to effect the composition of vernal pool communities (Holland and Jain 1988). Pool bottoms are nearly always inundated and uplands almost always free of standing water. This environmental variability will accentuate differences among properties as well. Properties with steep-sided pools and swales (e.g. Haroutunian) or with levied roads (e.g. FEMA) are going to be more variable in their ecosystem characteristics (e.g. degree of margin inundation, water persistence) and, therefore, in their species composition, vegetation structure and phenology.

Total cover (live + thatch) usually exceeded 100% in the upland and margins because of layered canopy structure. While no taxa encountered in our samples grew to a height exceeding 1.5 m, there were many, shorter taxa that created "understory" layers. The tallest "overstory" layer was occupied by erect annual grasses such as *Lolium multiflorum* and *Avena barbata*, and some weedy dicots such as *Dipsacus fullonum* and *Rumex crispus*. It tended to be dominated by non-natives, but was occasionally joined by *Danthonia and Nassella*. A lower, middle canopy layer included many native monocots, such as *Eleocharis macrostachya, Brodiaea coronaria, Juncus phaeocephalus, Juncus occidentalis*, *Vulpia octoflora* and *Pleuropogon californicus*. Also included in the middle canopy layer were late-germinating cohorts of annual grasses, or those that were simply shorter due to resource limitation. A third, distinctive canopy layer included diminutive, prostrate or decumbent taxa whose height tended to be less than 15 cm. Low canopy layer species included *Limnanthes vinculans, Downingia concolor, Eleocharis acicularus, Eremocarpus setigerus*, and *Navarretia intertexta. Convolvulus arvensis* was generally confined to this canopy layer but was sometimes found climbing into upper layers by clasping to taller plants with its tendrils. Also included in the lowest canopy layer were late-germinating cohorts of annual grasses, especially those of *Vulpia octoflora,* which could form dense swards only 10-12 cm tall. Vertical structure of this vegetation could be described, therefore, as ranging from tall and non-native to short and native.

An analysis of importance values in different habitats across all sites (Table 4) revealed only one native plant with a high degree of dominance in the uplands; *Vulpia octoflora* var. *octoflora* consistently had the highest value because of high relative cover (see also Table 9). This widespread taxon (formerly *Festuca octoflora*) is not particularly characteristic of north coastal prairie, although its close relatives (*F. californica, F. occidentalis, F. pacifica* (= *V. microstachys*)) are considered dominants in the *Festuca-Danthonia* type (Heady et al. 1988). It will be interesting to see if *V. octoflora* maintains dominance in untreated control plots from year to year, or only in years with particular environmental characteristics. The next four most dominant taxa were all non-native, with *Lolium multiflorum* always having the second highest importance value. It has been referred to as one of the "new natives" because of its widespread abundance in coastal prairie (Heady et al. 1988). *Convolvulus arvensis* and *Bromus hordeaceus* were always among the other non-natives. These particular and consistent patterns in upland dominants suggest a high level of homogeneity in the grassland vegetation of the Santa Rosa Plain. Comparison with grassland sites to the west (e.g. Sea Ranch) and east (e.g. central valley), however, suggest abrupt discontinuities in composition and structure (Heady et al. 1988).

Analyzing importance values in the margin habitat showed a shift towards dominance by natives. This was especially true at the Cramer property, where all five most dominant were native and headed by *Pleuropogon californicus*. This taxon was considered by Cronise (1868) to be the most characteristic species of wet meadows from Ukiah to Oakland at a time of minor human disturbance. Our data validate the assumption that pools at Cramer are among the highest quality remaining on the Santa Rosa Plain and justify the use of Cramer vegetation characteristics as standards for restoration activities. In contrast, only three of the top five dominants at FEMA and Haroutunian were natives. These margins were of lower quality than those at Cramer due to dominance by *Lolium multiflorum, Convolvulus arvensis* and *Rumex crispus* (Table 9). Consequently, these taxa become the highest priority targets for restoration activities because they usurp the greatest proportion of resources for native taxa that are restricted to this habitat (e.g. *Limnanthes vinculans*).

In contrast to the uplands and margins, all of the most dominant taxa in the pool bottoms were native to California (Table 4). Two species of *Eleocharis* were widespread and dominant, matched only by the late-developing dicot *Eryngium aristulatum*. The top five dominants accounted for a much higher proportion of the total live cover (64 vs. 46 % in the other habitats), reinforcing the well-known inverse relationship between dominance and diversity (e.g. Howe 1999). When properties were examined separately (Table 9), only *Polypogon maritimus* (at FEMA) and *Lolium multiflorum* (at Haroutunian) were the only exotic pool bottom plants with high importance values, superseding *Pleuropogon californicus.* Otherwise, the pool bottom habitat across this portion of the Santa Rosa Plain appears consistently dominated by the same native taxa and would not require or justify intensive restoration efforts at this time.

All of the vernal pool characteristic (VPC) taxa encountered at the three properties were found in the margin and pool bottom habitats. Dense swards of exotic annual grasses with similar phenology (e.g. *Lolium multiflorum, Bromus hordeaceus)* may limit the performance of VPC populations on the upland side of the margin.

Another possibility is that specific habitat requirements for germination, growth and reproduction of VPC taxa are not met outside of the margin and pool bottom zones. They may require a particular temperature, inundation, pH, salinity, or nutrient regime found only in ephemeral wetlands (Holland and Jain 1988, Stone 1990, Keelor-Wolf et al. 1998). Consequently, efforts to restore VPC populations on the Santa Rosa Plain should concentrate on improving the quality of pool and swale margins, rather than pool bottoms. This is because of the aforementioned high quality of pool bottom vegetation on these properties and the high degree of compositional and structural modification found in the margins. Reversing degradation of the margins (e.g. lowering the cover by *Lolium* and *Bromus,* eliminating the exotic overstory layer, reducing the persistence of thatch) is most likely to benefit VPC and other native taxa.

The three properties exhibited large differences in the quality of upland, margin and pool bottom habitats. Cramer was the largest (174 acres) and had the highest total and native species richness in our samples (Table 5) and the highest absolute and relative native cover (Tables 5 and 8). Haroutunian was the smallest property (30 acres) and had the lowest native species richness and cover. Haroutunian was most heavily dominated by the exotic grass *Lolium multiflorum* in all three habitats (Table 9). As predicted by island biogeography, the size of an isolated segment of land affects the extent and diversity of habitats available for exploitation. Therefore, larger "islands" are expected to have a greater number of species than smaller islands (Holland and Jain 1981). This trend was observed in remnants of California chaparral (Soule 1991), as well as in tropical rain forests (Benitez-Malvido 1998), and seasonal forests (Laurence et al. 1998). Fragmentation and disturbance blur these patterns by promoting extirpation, but it is clear that the smaller FEMA and Haroutunian properties are not proportionally less diverse. Perhaps more taxa will be lost from these smaller properties in the absence of restoration. We also did not sample the summer active flora in our plots, so that strict application of biogeographic principles is not possible.

Limnanthes vinculans was the most widely distributed and abundant VPC taxon on the three properties, both historically and in the spring of 1999 (Table 6). *Limnanthes vinculans* was present in 80% of our blocks at Cramer but 0% of our blocks at Haroutunian (despite its historical occurrence). Its cover was highest at Cramer (Table 10), but not density: FEMA had many small individuals that rapidly senesced in late spring. Cramer also had highest subsample frequency (indicating a less clumped distribution), and the highest frequency of occurrence in the top (upslope) quadrat (indicating greater intrusion into the margin-upland transition). Increasing any of these parameters (live cover, density, block/subsample/top quadrat frequency) would indicate a successful manipulation for restoring this rare plant.

SUMMARY AND MANAGEMENT RECOMMENDATIONS

1) The first field experiment was installed during the spring and summer of 1999 to determine if seasonal mowing and phytomass removal can improve habitat quality for native plants in vernal pool and adjacent grassland habitats. A total of 90 permanent plots were established, marked, sampled and treated on three SRVRS properties: Cramer (174 acres, relatively unaltered pool and swale system, mostly diverse native vegetation), FEMA (69 acres, hydrologically altered pools and swales, extensive weed cover), and Haroutunian (30 acres, unaltered swale system, mix of native and exotic cover). All are located on Wright clay-loam soils and have supported multiple *Limnanthes vinculans* (Sebastopol meadowfoam) subpopulations, a state and federally-listed endangered plant. These were large (30 m X 5 m), included 2 habitats (coastal prairie uplands and vernal pool/swale margin), and consisted of control, mowed with phytomass removal, and mowed without phytomass removal (mulched) plots. We

have also collected baseline phytomass (above ground) and soil samples in all 90 plots for later analysis.

We recommend that these permanent plots be maintained into the indefinite future to allow for analysis of vegetation characteristics through time. This will require thorough documentation of their placement and shape, maintenance of the pvc markers, coordination with agencies and individuals that use the properties, and a system for obtaining and storing plot-based information.

2) Vegetation was characterized in all of the plots prior to treatment by recording species presence, cover and density (of rare taxa and a few weeds only) in more than 300 samples using a bipartite quadrat. Samples were added in pool bottom habitat to complete the description. The record we have thus obtained provides a baseline description useful for comparing to other sites on the Santa Rosa Plain and for evaluating subsequent restoration projects.

Management agencies (CDFG, SCAPOSD, SCWA) should be aware that a standard, relatively expedient sampling protocol was developed and should recommend its use to individuals proposing to perform vegetation analysis on the Santa Rosa Plain. Such individuals could include college students, restoration consultants, and conservation groups (e.g. CNPS). The hope is to expand the existing vegetation database with studies whose basic methods and results would be comparable.

3) We found that in general, species richness was greatest in the margin habitat of vernal pools and swales, declining slightly towards the uplands and dramatically towards the pool bottoms. Pool bottoms had 40% fewer taxa than the other two habitats, but a higher proportion were native (54%) contributing 84% of the total cover. The composition of Santa Rosa vernal pool vegetation is, therefore, determined by a steep gradient: from pool bottom conditions (e.g. hydric, low soil oxygen) that favor an

ephemeral wetland of relatively few native taxa of high cover to upland conditions (dry, high soil oxygen) that favor a grassland of many species, 70% of which are exotic.

Maintenance of pool and swale hydrology appears to be essential for preserving habitat conditions for native wetland species. Ephemerally wet conditions produce a pool bottom habitat with the highest live plant cover and the least amount of thatch, but the lowest total cover (live + thatch) and the most bare ground. This habitat is essential for aquatic stages in the life histories of California Tiger Salamander, California Red-Legged Frog and California Linderiella Fairy Shrimp. Efforts must be made to minimize disturbance to pool and swale hydrology during all restoration activities (see Appendix E).

4) Total cover (live + thatch) usually exceeded 100% in the upland and margins because of layered canopy structure. Vertical structure of this vegetation could be described as ranging from tall and non-native to short and native.

Restoration activities can be evaluated with respect to this generalization: manipulations which minimize the development of the tall, exotic overstory would be regarded as successful.

5) An analysis of importance values in different habitats across all sites revealed only one native plant with a high degree of dominance in the uplands; *Vulpia octoflora var. octoflora* consistently had the highest value because of high relative cover. The next four most dominant taxa were all non-native, with *Lolium multiflorum* always having the second highest importance value. In the margin habitat we noted a shift towards dominance by natives. This was especially true at the Cramer property, where all five most dominant were native and headed by *Pleuropogon californicus.* In contrast, only three of the top five dominants at FEMA and Haroutunian were natives. In contrast to the uplands and margins, all of the most dominant taxa in the pool bottoms were native to California.

Our data validate the observation that pools at Cramer are among the highest quality remaining on the Santa Rosa Plain and justify the use of Cramer vegetation characteristics as standards for restoration activities. Pool margins at other sites were of lower quality than those at Cramer due to dominance by *Lolium multiflorum, Convolvulus arvensis* and *Rumex crispus.* Consequently, these taxa in the margin habitat become the highest priority targets for restoration activities because they usurp the greatest proportion of resources for ecologically-restricted native taxa (e.g. *Limnanthes vinculans*). The pool bottom habitat across this portion of the Santa Rosa Plain appears consistently dominated by the same native taxa and would not require or justify intensive restoration efforts at this time.

6) All of the vernal pool characteristic (VPC) taxa encountered at the three properties were found in the margin and pool bottom habitats. Dense swards of exotic annual grasses with similar phenology (e.g. *Lolium, multiflorum, Bromus hordeaceus)* may limit the performance of VPC populations on the upland side of the margin.

Efforts to restore VPC populations on the Santa Rosa Plain should concentrate on improving the quality of pool and swale margins, rather than pool bottoms. Reversing degradation of the margins (e.g. lowering the cover by *Lolium* and *Bromus,* eliminating the exotic overstory layer, reducing the persistence of thatch) is most likely to benefit VPC and other native taxa.

7) *Limnanthes vinculans* was the most widely distributed and abundant VPC taxon on the three properties, both historically and in the spring of 1999. *Limnanthes vinculans* was present in 80% of our blocks at Cramer but 0% of our blocks at Haroutunian (despite its historical occurrence). Cramer also had highest subsample frequency (indicating a less clumped distribution), and the highest frequency of occurrence in the top (upslope) quadrat (indicating greater intrusion into the margin-

upland transition). Increasing any of these parameters (live cover, density, block/subsample/top quadrat frequency) would indicate a successful manipulation for restoring habitat of this rare plant.

Subsequent analysis of the effects of mowing and phytomass removal on the margin habitat should employ these parameters to determine restoration success for *Limnanthes vinculans* .

8) As with all rare species, demographic studies are required to determine critical life history events and measure vital rates of emergence, survivorship and fecundity. Consequently, many important ecological attributes of *Blennosperma bakeri* , *Lasthenia burkei* , and *Limnanthes vinculans* remain unknown.

We recommend preliminary demographic studies be performed on each of the listed plants to better understand the relation of their population biology and restoration activities.

9) An initial set of intensive care prescriptions was developed that could be implemented over a three year period (e.g. 2000-2003) on the Cramer, FEMA and Haroutunian properties. Weeds with relatively small or moderate population sizes and vulnerable growth forms could be removed by hand. Others with large populations and difficult growth forms for hand removalwill require careful application of appropriate herbicides. If applied at a time when the targets were suseptible and the non-targets were dormant (e.g. mid- to late summer), effect, safe and benign control could be acheived. This will require, however, a protocol that establishes best practices, treatment recording, and assement techniques.

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Table 1. Total species (= taxon) richness, native species richness, % native species, and % native absolute (live) cover in three habitats (properties combined) of the SRVRS,1999. n = 15 blocks (upland and margins) or n = 9 blocks (pool bottom).

	total # taxa	# native taxa	% native taxa	% native cover
upland	41	13	31.7	42.4
margin	44	19	43.1	70.9
pool bottom	28	15	53.5	83.8

Table 2. Number of plant taxa by category in three habitats (properties combined) of the SRVRS, 1999.

	upland		margin		pool bottom	
category	**# of taxa**	**% of total**	**# of taxa**	**% of total**	**# of taxa**	**% of total**
annual grasses	9	22	7	16	6	21
perennial grasses	4	9	4	9	1	4
monocots (no grasses)	8	19	8	19	5	18
dicots (no VPC)	15	36	22	51	15	54
vernal pool characteristic (VPC)	0	0	2	4	2	7
unidentified taxa	5	12	2	4	0	0
total # of taxa	41		44		28	

Table 3. Mean values (%) of absolute total live cover, thatch cover, total cover (live + thatch) and bare ground in three habitats (properties combined) of the SRVRS, 1999. n = 15 blocks (upland and margin) or n = 9 blocks (pool bottom).

	total live cover	**thatch cover**	**total cover**	**bare ground**
upland	55.2	59.6	114.8	1.9
margin	68.7	39.7	108.4	4.9
pool bottom	85.1	13.3	98.4	17.5

Table 4. Mean values (%) of absolute cover (live only), relative cover (RC), relative frequency (RF), and importance value (IV) of the five most dominant plant taxa (ranked by IV) from three properties (combined) and three habitats of the SRVRS, 1999. N = 15 blocks (upland and margin) or n = 9 blocks (pool bottom). * = non-native taxon.

upland

taxa	live cover	RC	RF	IV
Vulpia octoflora var. octoflora	17.7	32	15	47
Lolium multiflorum *	11.1	20	15	35
Convovulus arvensis *	7.8	14	8	22
Bromus hordeaceus *	4.8	9	12	21
*Hordeum marinum gussoneanum**	1.4	3	6	9
	sum = 42.8			

margin

taxa	live cover	RC	RF	IV
Juncus phaeocephalus	14.7	21	8	29
Pleuropogon californicus	10.8	16	9	25
Lolium multiflorum *	8.4	12	8	20
Eleocharis macrostachya	6.3	9	9	18
Eleocharis acicularis	6.1	9	5	14
	sum = 46.3			

pool bottom

taxa	live cover	RC	RF	IV
Eleocharis macrostachya	20.5	24	13	37
Eryngium aristulatum	15.2	18	13	31
Eleocharis acicularis	13.6	16	10	26
Pleuropogon californicus	9.4	11	11	22
Juncus phaeocephalus	5.6	7	6	13
	sum = 64.3			

Table 5. Total species (= taxon) richness, native species richness, % native species, and mean % native cover for three properties (habitats combined) of the SRVRS,1999. N = 24 blocks

property	total # taxa	# native taxa	% native taxa	% native cover
Cramer	48	19	39	69
FEMA	39	14	36	67
Haroutunian	44	15	34	60

Table 6. ***Property-specific (bold) and block-specific (1-5)*** occurrences of endemic plants. Columns are for presence in spring 1999 or in the recent history *(hist) of the property.* ? = no historical record for that particular block. 1 = *Navarrettia leucocephala* var. *bakeri* is known from Cramer, but was not found in 1999. (FE, SE = federally or state-listed endangered). Rows in bold indicate occurrence for the property as a whole.

	Blennosperma bakeri (FE, SE)		*Lasthenia burkei* (FE, SE)		*Limnanthes vinculans* (FE, SE)		*Pogogyne douglasii parviflora*		*Navarrettia leucocephala plieantha*		*Downingia concolor*	
	1999	hist	1999	hist	1999	hist	1999	hist	1999	hist	1999	hist
Cramer	**no**	**no**	**no**	**yes**	**yes**	**yes**	**yes**	**yes**	**no**	**no**[1]	**no**	**yes**
1	no	no	no	no	no	yes	no	?	no	?	no	?
2	no	no	no	no	yes	yes	no	?	no	?	no	?
3	no	no	no	no	yes	yes	no	?	no	?	no	?
4	no	no	no	no	yes	yes	yes	yes	no	?	no	?
5	no	no	no	no	yes	yes	no	?	no	?	no	?
FEMA	**no**	**no**	**no**	**no**	**yes**	**yes**	**no**	**yes**	**no**	**no**	**yes**	**yes**
1	no	no	no	no	no	yes	no	no	no	no	yes	?
2	no	no	no	no	yes	yes	no	yes	no	no	yes	?
3	no	no	no	no	no	no	no	no	no	no	yes	?
4	no	no	no	no	yes	no	no	no	no	no	no	?
5	no	no	no	no	yes	yes	no	no	no	no	no	?
Haroutunian	**no**	**yes**	**no**	**no**	**no**	**yes**	**no**	**no**	**no**	**no**	**yes**	**yes**
1	no	no	no	no	no	no	no	no	no	no	no	?
2	no	yes	no	no	no	yes	no	no	no	no	no	?
3	no	yes	no	no	no	no	no	no	no	no	no	?
4	no	yes	no	no	no	yes	no	no	no	no	yes	?
5	no	yes	no	no	no	no	no	no	no	no	no	?

Table 7. Presence of vernal pool characteristic (VPC) plants in samples of each habitat a three properties of the SRVRS, 1999. * *Downingia concolor* had senecessed in the pool bottoms before sampling.

	Cramer	FEMA	Haroutunian
upland	no VPE's	no VPE's	no VPE's
margin	*Limnanthes vinculans*	*Limnanthes vinculans* *Downingia concolor*	*Downingia concolor*
pool bottom	*Limnanthes vinculans* *Pogogyne douglasii ssp. parviflora*	no VPE's	*Downingia concolor* *

Table 8. Mean values (%) of absolute total live cover, absolute native live cover, and relative native cover (% of total live) at three properties (habitats combined) of the SRVRS, 1999.

	total live cover	native live cover	relative native cover
Cramer	63.5	47.3	74.5
FEMA	76.2	52.2	68.5
Haroutunian	71.6	44.8	62.6

Table 9. The five most dominant plant taxa (ranked by mean importance value, IV) in each habitat at three properties of the SRVRS, 1999. n = 5 for upland and margin IV's, n = 3 for pool bottom IV's. * = non-native taxon.

	upland		**margin**		**pool bottom**	
	taxa	**IV**	**taxa**	**IV**	**taxa**	**IV**
Cramer	*Vulpia octoflora*	43	*Pleuropogon californicus*	31	*Eleocharis macrostachya*	48
	*Lolium multiflorum**	37	*Eleocharis macrostachya*	26	*Pleuropogon californicus*	30
	*Hordeum marinum goss.**	19	*Juncus phaeocephalus*	22	*Eryngium aristulatum*	21
	*Convovulus arvensis**	18	*Eleocharis acicularis*	17	*Eleocharis acicularis*	25
	*Bromus hordeaceus**	17	*Juncus occidentalis*	13	*Juncus phaeocephalis*	16
FEMA	*Vulpia octoflora*	49	*Juncus phaeocephalus*	48	*Eryngium aristulatum*	40
	*Lolium multiflorum**	33	*Pleuropogon californicus*	27	*Eleocharis acicularis*	32
	*Bromus hordeaceus**	20	*Lolium multiflorum**	25	*Eleocharis macrostachya*	31
	*Convovulus arvensis**	17	*Eleocharis macrostachya*	17	*Polypogon maritimus**	22
	*Dipsacus fullonum**	12	*Rumex crispus**	15	*Pleuropogon californicus*	20
Haroutunian	*Vulpia octoflora*	46	*Lolium multiflorum**	25	*Eleocharis macrostachya*	34
	*Lolium multiflorum**	34	*Convovulus arvensis**	19	*Eryngium aristulatum*	32
	*Convovulus arvensis**	30	*Pleuropogon californicus*	17	*Lolium multiflorum**	28
	*Bromus hordeaceus**	25	*Juncus phaeocephalus*	17	*Eleocharis acicularis*	25
	*Bromus diandrus**	12	*Eryngium aristulatum*	16	*Pleuropogon californicus*	22

Table 10. Mean absolute live cover (%), mean plant density , block frequency (% of blocks), mean sampling frequency (% of subsamples) and mean top quadrat frequency (% of top subsamples) for VPC species at three properties of the SRVRS, May and June 1999. Standard deviation in parentheses. * = margin, ** = pool bottom occurrence. NA = data not available.

	live cover (%)	density (#/m2)	block freq (%)	subsample freq (%)	top quad freq (%)
Cramer					
Limnanthes vinculans*	1.6	7.3 (5.9)	80	43.8 (16.0)	37.6 (12.5)
Pogogyne douglasii**	2.2	189.6 (88.8)	20	100	50
FEMA					
Limnanthes vinculans*	0.5	46.3 (52.8)	60	13.6 (15.3)	12.3 (17.3)
Downingia concolor*	0.1	9.0 (5.4)	20	14.8 (7.3)	33.3 (27.1)
Haroutunian					
Downingia concolor*	0.1	5.4 (6.0)	40	14.4 (6.1)	68.2 (31.8)

Table 11. Inital intensive care prescriptions for the Cramer, FEMA and Haroutunian properties of the SRVRS. Actions could be carried out with minimal interference to the restoration experiment within the next three years (e.g. 2000-2003). n = north, w = west, s = south

property	action	location	when	how	estimated effort
Cramer	pull wild radish and mustard	w & n fencelines	March	by hand	6 person-days
	pull orchard grass	n canal	April-Sept	by hand	4 person-days
	pull Echium	s of block 4	May	by hand	2 person-days
	kill pennyroyal	most pools/swales	late summer	herbicide	6 person-days
	kill bindweed	n third of property	July-Aug	herbicide	6 person-days
FEMA	pull wild radish and mustard	mostly w half	March	by hand	4 person-days
	pull orchard grass	throughout	April-Sept	by hand	4 person-days
	kill pennyroyal	most pools/swales	late summer	herbicide	4 person-days
	kill teasel	throughout	July-Sept	herbicide	6 person-days
	kill fennel	roadsides	July-Sept	herbicides	2 person-days
Haroutunian	pull wild radish and mustard	mostly n third	March	by hand	4 person-days
	pull orchard grass	mostly n third	April-Sept	by hand	2 person-days
	kill teasel	throughout	July-Sept	herbicide	4 person-days
	kill bindweed	n third of property	July-Aug	herbicide	6 person-days

wild radish = *Raphanus* , mustard = *Brassica* , orchard grass = *Dactylis glomerata*, Echium = *Echium plantagineum*, pennyroyal = *Mentha pulegium* , teasel = *Dipsacus fullonum*, fennel = *Foeniculum vulgare*, bindweed = *Convolvulus arvensis*

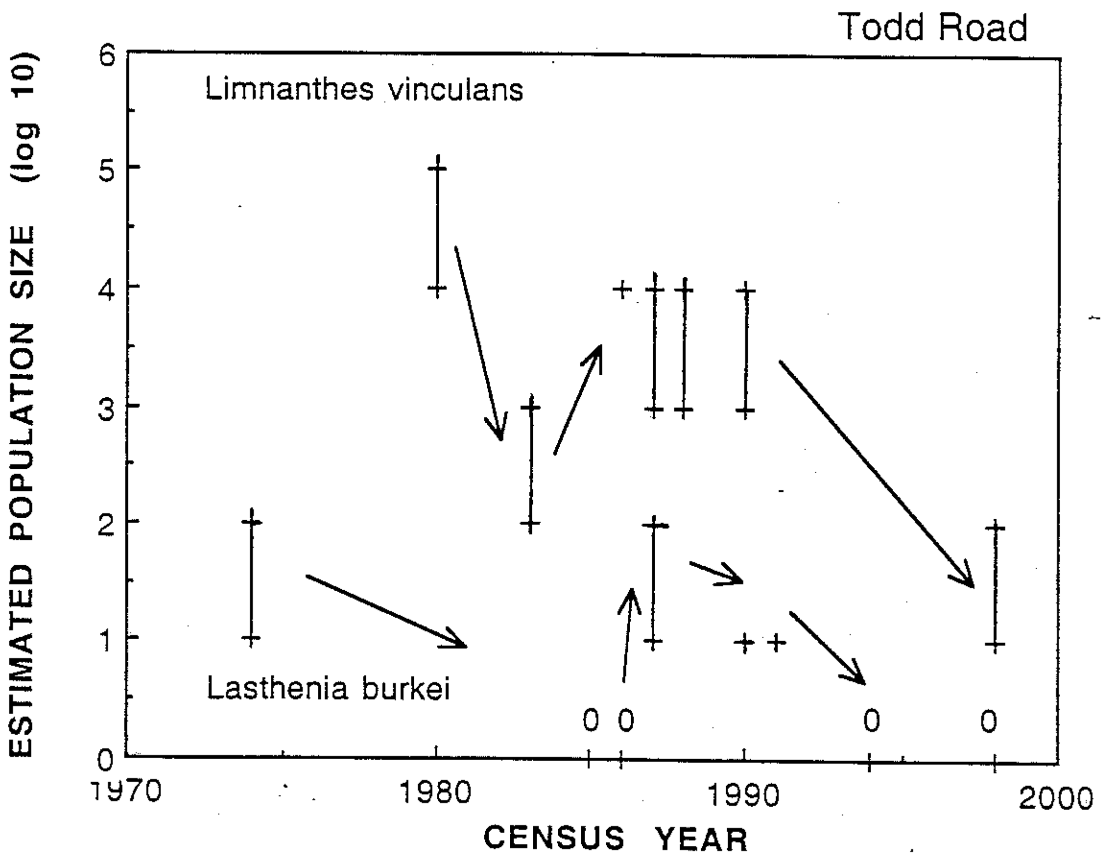


Figure 1. Trends in estimated population sizes of two endangered plants (Limnanthes vinculans and Lasthenia burkei) at the Todd Road Ecological Reserve. Bars indicate estimated ranges. Data sources cited in Pavlik et al. (1998).

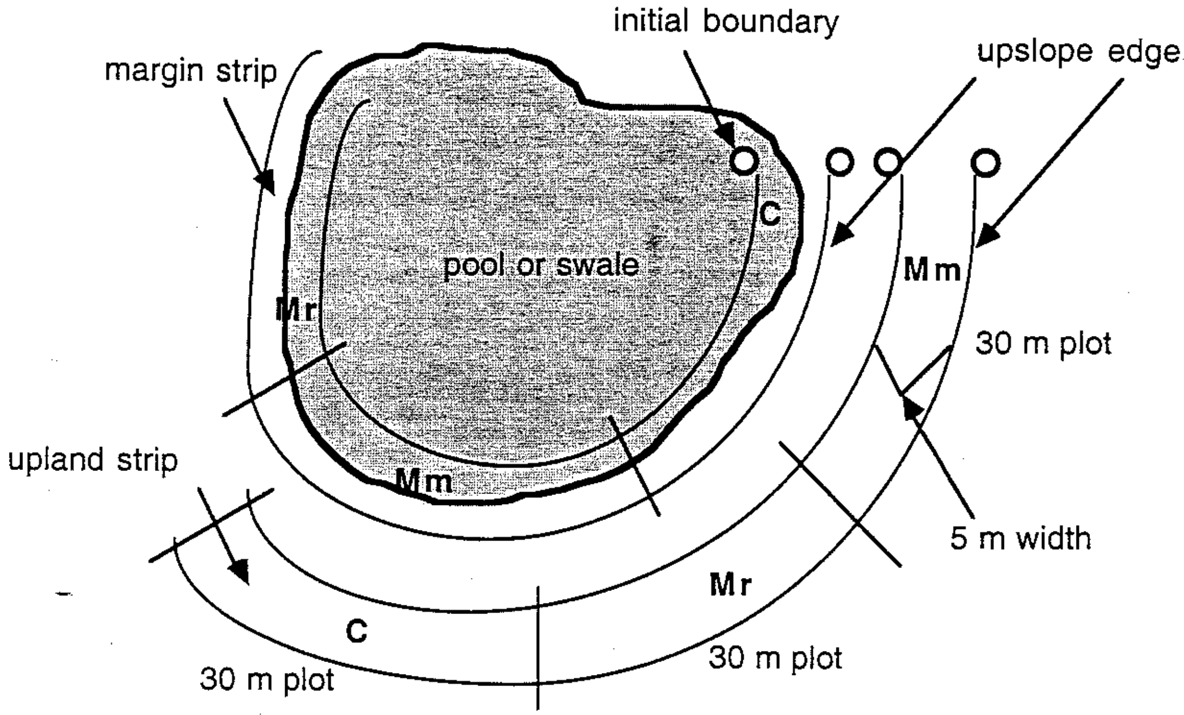


Figure 2. Block design for a vernal pool consisting of two habitat strips (pool margin and upland) each 90 m long. Position of the initial boundary was randomly assigned and each treatment (C= control, Mm= mowed and mulched, Mr=mowed and raked) was randomly assigned.

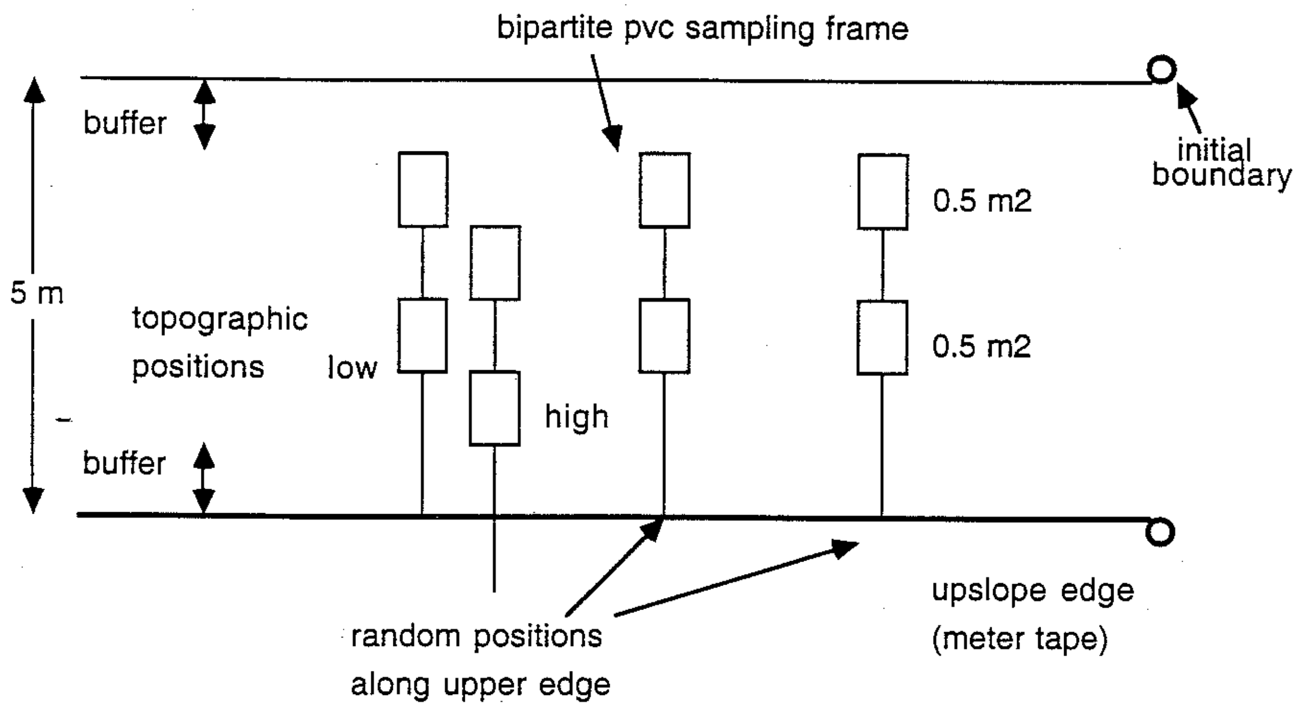
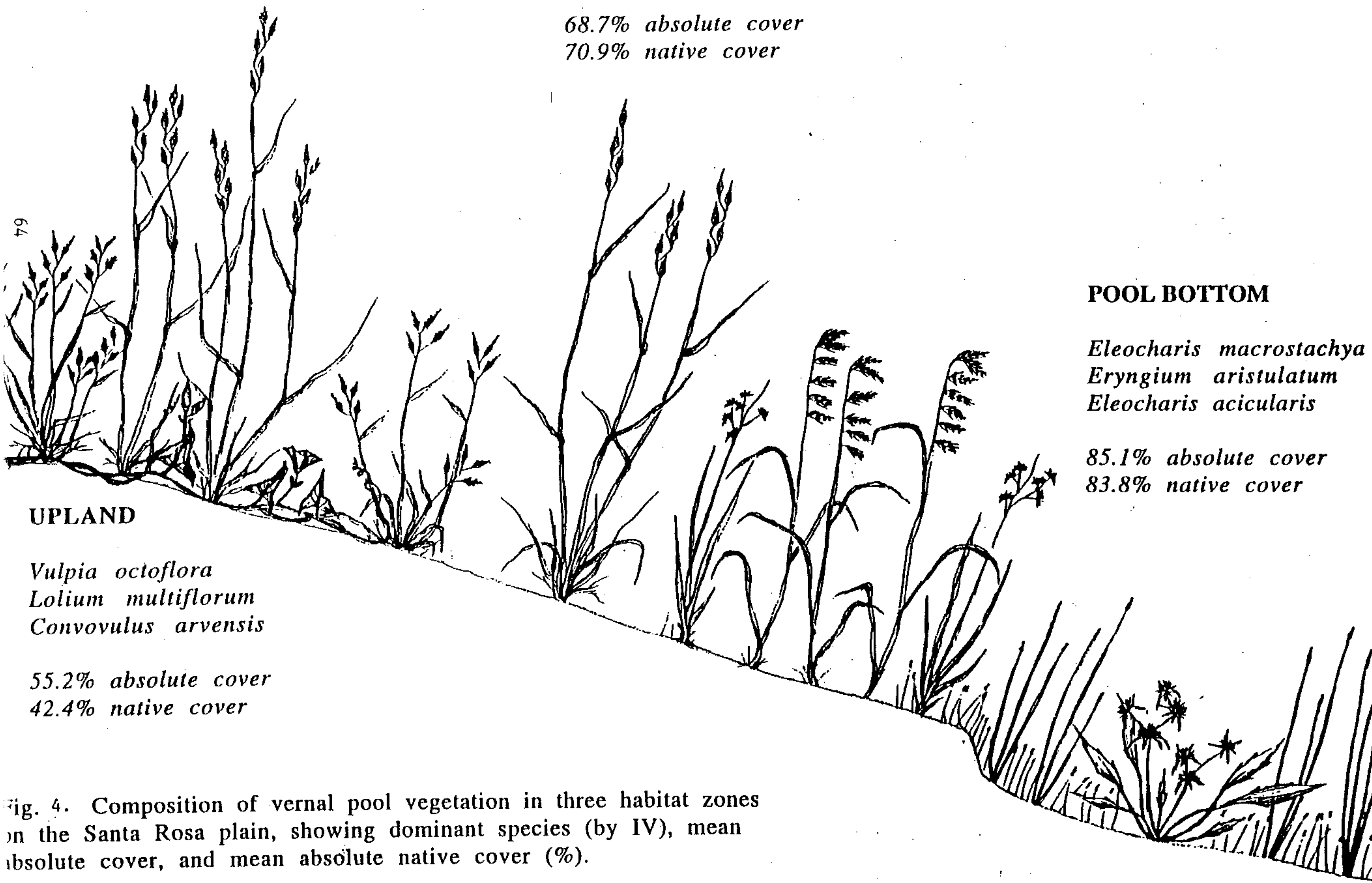


Figure 3. Use of a bipartite sampling frame within a 5 m wide strip plot. Frame consists of two 0.5 m2 subsamples spaced 0.75 m apart. Position along the upslope edge determined with random numbers and a meter tape. Topographic position (high or low relative to the pool bottom) also randomly assigned.



'ig. 4. Composition of vernal pool vegetation in three habitat zones ɔn the Santa Rosa plain, showing dominant species (by IV), mean ıbsolute cover, and mean absolute native cover (%).

APPENDIX A:

Master Datasheet for Vegetation Sampling

roperty C F H	Blk 1 2 3 4 5		Habitat U M Pb			Plot Co M Mr					Date
											Page
	pos	U/L	pos	U/L	pos	U/L	pos	U/L	pos	U/L	Samplers
Native	T	B	T	B	T	B	T	B	T	B	
nnual grass											
ulpia octoflora var. octoflora											
erennial grass											
romus carinatus											
anthonia californica											
ordeum brachyantherum											
leuropogon californicus											
lonocot graminoid											
leocharis acicularis											
leocharis macrostachya											
uncus phaeocephalis											
uncus occidentalis ssp tenuis											
Monocot forb											
Brodiaea coronaria											
Chlorogalum pomeridianum											
Dicots											
Eryngium aristulatum											
VPE Dicots											
Blennosperma bakeri											
Downingia concolor											
Limnanthes vinculans											
Pogogyne douglasii parviflora											
Non-Native											
Annual grass											
Avena barbata											
Bromus diandrus											
Bromus mollis											
Hordeum murnium ssp.gussoneaum											
Lagurus ovatus											
Lolium multiflorum											
Dicots											
Convolvulus arvenis											
Dipsacus fullonum											
Mentha pulegium											
Rumex crispus											
Bare Ground											
Thatch											
Density											
Blennosperma bakeri											
Downingia concolor											
Limnanthes vinculans											
Pogogyne douglasii parviflora											

APPENDIX B:

Master Flora of the Permanent Plots

Appendix B. Master list of plant taxa found in the 90 sampled plots in three habitats and properties of the SRVRS, 1999. Corrected names according to Hickman (1993). C = Cramer, F = FEMA, H = Haroutunian properties. Late bloom = June-July. * = no voucher specimen. # = genus uncertain.

field name	corrected name	native/non	property	late bloom
	Alisma sp. *	N. Am, Euarasia	C, F	F
white brodiaeae	*Allium sp.*		C,H	C
Lighthouse	*Anagalis arvensis*		C,F,H	
Herby composite	*Anthemis arvensis*	EUR	H	H*
Avena	*Avena barbata*	EUR	C,H	
	Briza minor	EUR	C,F,H	
Paddle lilly	*Brodiaea coronaria ssp. coronaria*	CA	C,F*,H	
	Bromus carinatus	CA	F	
	Bromus diandrus	EUR	C,F,H	
	Bromus hordeaceus	naturalized	C,F,H	
Sedge edge, Juncus thin	*Carex densa*	CA	F,H	
	Chlorogalum pomeridianum	CA	C,F	
	Cirsium sp.		F	
Convolvula	*Convolvulus arvensis*	EUR	C,F,H	C*,F*,H*
	Cryptantha sp.	depends on sp.		F
	Danthonia californica	EUR	C,F,H	
	Dipsacus fullonum	Eur	F	
Alternate grass	*Distichlis spicata*	CA	H	H*
	Downingia concolor	CA	F,H	F*
Fine monocot	*Eleocharis acicularis*	CA	C,F,H	C*,F*,H*
Eleocharis	*Eleocharis macrostachya*	CA	C,F,H	C*,F*
Silver fur	*Eremocarpus setigerus*	CA	C	C*
	Eryngium aristulatum	CA	C,F,H	C*,F*
	Eschscholzia californica	CA	C	
	Hordeum brachyantherum	CA	C,F,H	H*
Hordeum A,B,C,D	*Hordeum marinium ssp. gussoneanum*	EUR	C,F,H	H*

Spiral	*Juncus mexicanus*	CA	H	
Juncus head, J. thin	*Juncus occidentalis*	CA	C,H	H*
	Juncus patens	CA	C*	C
Juncus O, Juncus p	*Juncus phaeocephalus*	CA	C,F,H	
	Lasthenia glabberima	CA	C,F,H	
	Limnanthes vinculans	CA	C,F,H*	C*,F*
	Lolium multiflorum	EUR	C,F,H	C*,H*
	Mentha pulegium	EUR	C,F,H	C*,F*
	Navarretia intertexta	N.Am, S.Am		C
	Oenothera ovata	CA, OR	C	
Barn grass, long grass	*Phalaris sp. #*	EUR	C,H	
	Plagiobothrys sp.		C,H*	
Plantago	*Plantago lanceolata*	EUR	H	
	Pleuropogon californicus	CA	C,F,H	C*,F*,H*
Delicate	*Poa annua*	Eurasia	F,H	C
	Pogogyne douglasii ssp. parviflora	CA	C,F	C
rabbit's foot	*Polypogon maritimus*	EUR	H	C*,F*,H
	Polypogon monspeliensis	EUR		F*
ranunc (tiny petal)	*Ranunculus pusillus*	CA, e&s US	C	
ranunc	*Ranunculus muricatus*		H*	
Rumex AC	*Rumex acetosella*	EUR	C,H	
Rumex Y	*Rumex pulcher*	EUR	H	H*
Rumex	*Rumex crispus*	Eurasia	C,F,H	
	Sonchus asper	Eurasia	C,F,H	
trifolium	*Trifolium varigatum*		C	
trifolium X	*Trifolium sp.*		C	C, F*
	Triphysaria sp.	CA	H*	
Orthocarpus, yellow scroph(C)	*Triphysaria versicolor ssp. faucibarbata*	CA	C	
Vetch	*Vicia sativa*	EUR	F,H	
Feather grass, long/short	*Vulpia octoflora var. octoflora*	AM,EUR	C,F,H	
	Xanthium sp.	world wide		

Miscellaneous				
blue-green grass			F	
brassica			F	
dandilion			F	
dandilion B			F	H
dandy			H	
decumbant				F*
delight			C	
disk/disc	*Lasthenia glabberima* ?		C,F,H	F
Eliocharus grass			?	F
Euphorb				
Fabaceae				
Geranium			C,F,H	
hair grass	*Aira* ?		C	
Hordeum Z			H	
Juncus B	*bufonius* ?		C,H*	
Juncus D (stout)	may be *oxymeris*		C, H*	
juncus delicate	not enough specimen		F	
lolium fan- mutant			H	
Malva			C	C
mustard			H	F
opposite			F	
pinky	not enough specimen			
punctate			?	
purple haze			H*	
red stemmed seedling			C	
splinter grass			?	
sprout			H	
strap grass			C	
thistle A			H	
thistle B			H	
thistle C			H	
thistle D			H	

thistle pink			F	
thistle soft			F	
toad			C	
toothed/spiney aster			H	
unknown grass			F	
wild garlic			H	
yellow schroph	*Parentucellia*		H	

APPENDIX C:

Field Keys to Difficult Taxa

FIELD KEYS

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Vegetation of the Santa Rosa Vernal Reserve System

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Pavlik, Fine, Archibold and O'Hanley

for the

California Department of Fish and Game

~

~

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APIACEAE-Eryngium
JUNCACEAE-Juncus
POACEAE-Avena
POACEAE-Hordeum
POLYGONACEAE-Rumex
RANUNCULACEAE-Ranunculus
SCROPHULARIACEAE-Orthocarpoids

~

April 2000

FIELD KEYS

The following field keys were created to help identify the flora of the Santa Rosa Vernal Reserve System (SRVRS) at the Alton Lane, Cramer, FEMA, and Haroutunian properties. They include species found in the sample plots used to describe vernal pool and upland vegetation in this report (specimens collected on May 18, May 21, May 27, and June 24 1999) and species listed by other workers as occurring on these four properties (see Pavlik et al. 1998).

The keys were constructed for problematic taxa that are often confused in the field. Couplets were derived from keys in the Jepson Manual (Hickman 1993) or amended with consistent characteristics observed in the field or on UC and Jeps specimens.

List of Properties

(A) Alton Lane
(C) Cramer
(F) FEMA
(H) Haroutunian

Field Key for *Avena*
(*Poaceae*)

Known species	SRVRS Property
A. barbata	C,H,F
A. fatua	C,F

Avena

1. gen 2-fld spikelets on curved capillary pedicels, 2 slender hyaline bristles on lemma apex-gen 3-4 mm..*A. barbata*

1′. gen 3-fld spikelets on curved capillary pedicels, gen 0 hyaline bristles on lemma tip or 0-1mm ....*A. fatua*

Field Key for *Eryngium*
(*Apiaceae*)

Known species	SRVRS Property
E. aristulatum	A,C,F
E. armatum	H

Eryngium

1\. bracts and bractlets very rigid, margins gen entire, prominently thickened...*E. armatum*

1′. bracts and bractlets flexible, margins gen sharply toothed, not thickened...*E. aristulatum*

Field Key for *Hordeum*
(*Poaceae*)

Known species	SRVRS Property
H. brachyantherum	C,H
H. marinum ssp. gussoneaum (H. hystrix)	C,F
H. murinum ssp. leporinum (H. leporinum)	C

<u>Hordeum</u>

1. perennial...***H. brachyantherum***

1′. annual

2. lf sheath appendages well developed, 1-4mm, lateral florets excl awns 8-14mm, central floret << lateral florets.......
.....***H. murinum ssp. leporinum***

2′ lf sheath appendages < 2mm or 0, lateral florets excl awns <5mm, lemma of lateral spiklet with awn 3-8mm....
.............***H. marinum ssp. gussoneaum***

Field Key for *Juncus*
(*Juncaceae*)

Known species	SRVRS Property
J. bufonius	A,C,F,H
J. capitatus	A
J. mexicanus	A,C
J. occidentalis	None
J. oxymeris	C
J. patens	A,H
J. phaeocephalus var. paniculatus	A,F
J. tenuis	A,C
J. tenuis var. congestus	A,C,F

Juncus

1. annual, gen < 10cm
    2. flrs solitary at nodes, each fl subtended by bractlet, infl open panicle, slightly scorpiod head, stamen 6................................***J. bufonius***

    2′. flrs terminal, 1-6 in clusters subtended by bractlets, rarely branched, stamen 2-3...***J. capitatus***

1′. perennial, gen larger in all respects
    3. lower infl bract cylindric, resembling continuation of stem, infl appears lateral
        4. anther gen < filament, perianth 1.8-4.2mm. Large robust infl gen shiny and light mahogany, 6 stamen......***J. patens***

        4′ anther gen < filament, perianth 3.5-8+mm...........***J. mexicanus***

    3′ lower infl bract not resembling continuation of stem, infl appears terminal. Leaf blade cylindric or flat
        5. distal 1/2 of adaxial blade faces stem, bases overlap, crosswalls gen incomplete, blade flat

6. perianth gen < 4mm, delicate and many open branched, infl never drk brwn, heads few-fld and gen v-shape..*J. oxymeris*

6′ perianth gen > 4mm, dark brn tipped heads, rarely branched, if branched never more than 2-3 inch from involucre, heads mostly globose..... ....*J. phaeocephalus*

7. infl 5-10mm wide, 10+ few-fld clusters....... ....*J. phaeocephalus var. paniculatus*

7′ infl 10-15mm wide, 1-10 many-fld clusters.......... .....*J. phaeocephalus var.phaeocephalus*

5′ distil 1/2 of adaxial blade does not face stem, crosswalls 0, blade cylindrical

9. lvs gen < 1/2 st length, perianth gen > 4mm.... ....*J. occidentalis*

9′ lvs gen > 1/2 st length, perianth gen < 4mm..... ......*J. tenuis*

Field Key for *Orthocarpoid Figworts*
(*Schropulariaceae*)

Known species	SRVRS Property
C. attenuata (*O. attenuatus*)	A
C. campestris (*O. campestris*)	C
C. densiflora (*O. densiflorus*)	A,C
C. exerta (*O. purpurascens*)	A
T. pusilla (*O. pusillus*)	A
T. versicolor ssp. faucibarbata (*O. faucibarbata*)	C

(*Orthocarpoid Schrophulariaceae*)

1. lvs alternate, not all basal
    2. beak tip closed (opening down): stigma unexpanded (dot-like)..........
    ....*Orthocarpus*

    2′. beak tip open: stigma expanded (head-like or 2-lobed)
        3. anther sacs 2 per stamen, lower corolla lip lightly reduced......
        ....*Castilleja*

        3′. anther sacs 1 per stamen, lower corolla lip < 6mm or strongly pouched...*Triphysaria*

1′. lvs all basal (rarely cauline, opposite, or whorled) .... see Jepson flora

Castilleja

1. bracts green throughout..*C. campestrus*

1′. bracts tipped purplish, yellowish, or whitish
    2. Corolla beak hooked, densely shaggy hair, filaments puberulent........
    ....*C. exserta*

2′. corolla beak straight, puberulent, filaments glabrous

3 infl. 10-20mm wide, corolla linear, pouches ~2mm wide, stigma well included.. *C. attenuata*

3′. infl. 20-40mm wide, corolla wider distilly, pouches gen 3-5mm, stigma gen exerted.................................. ***C. densiflora***

Triphysaria

1. pl gen <<15cm, decumbent-branched from base, corolla 4-7mm, beak hooked, pouches ~1mm deep.. ***T. pusilla***

1′. pl gen >15cm ~ascending-branched, corolla 8-25mm and yellow only, beak not hooked, pouches gen 1.5-4mm deep....***T. versicolor ssp. faucibarbata***

Field Key for *Ranunculus*
(*Ranunculaceae*)

Known species	SRVRS Property
R. alsimaefolius	A
R. californicus	A,C,F,H
R. lobbii	A,C,F
R. muricatus	C,F,H
R. occidentalis var. occidentalis	F
R. pusillus	A,C,H

<u>*Ranunculus*</u>

1. aquatic, floating plnts..*R. lobbii*

1′. terrestrial plnts

2. basal lf entire or crenate-lobed << 1/2 way to midrib or blade base

3. petals 1-3, 1-3mm..*R. pusillus*

3′. petals 5-many, 3-15mm ....*R. alismaefolius*

2′. basal lvs gen lobed > 1/2 way to midrib or blade base, to dissected or compound

4. lf blade gen glabrous, petiole hairs < sparse to 0...*R. muricatus*

4′. lf blade gen soft, hairy to tomentose, petiole hairs gen > sparse

5. fr body sides papillate or spiny, puberulent or glabrous, basal lvs cordate to reniform................*R. muricatus*

5′. fr body sides smooth, not papillate, gen glabrous

6. petals gen 7-22mm, fr beak gen 0.5-1mm..... ....*R. californicus*

6′. petals gen 5-6mm, fr beak gen 1.5-2.5mm..... ....*R. occidentalis*

Field Key for *Rumex*
(*Polygonaceae*)

Known species	SRVRS property
R. acetosella	A,C,F,H
R. crispus	A,C,F,H
R. pulcher	C,H
R. salicifolius	F

Rumex

1. tubercles 0, stem gen < 4dm, plnts dioceous, rarely bisexual.......*R. acetosella*

1′. tubercles various, fl bisexual, stem gen > 7dm
  2. lvs cauline only, gen branched at most nodes................*R. salicifolious*

  2′. lvs basal and cauline, gen unbranched below infl
    3. margin of perianth lobe entire

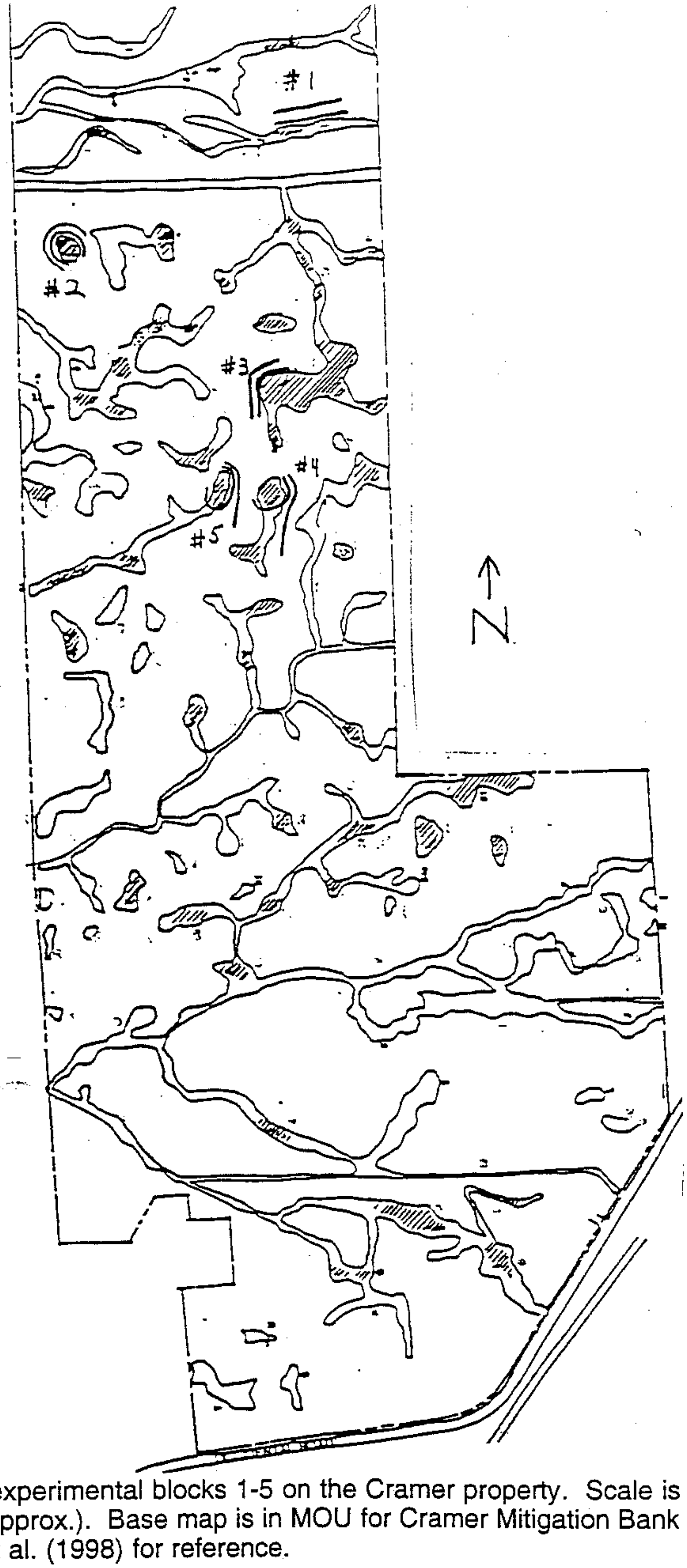
      4. inner perianth lobe 2-3mm, tubercle + 1/3 width of lobe, infl open and interrupted..............*R. conglomeratus*

      4′. inner perianth lobe 5-6mm, tubercle << 1/3 of lobe, infl dense and continuous..................................*R crispus*

    3′ margin of inner perianth lobe with 0.5-4mm teeth..*R. pulcher*

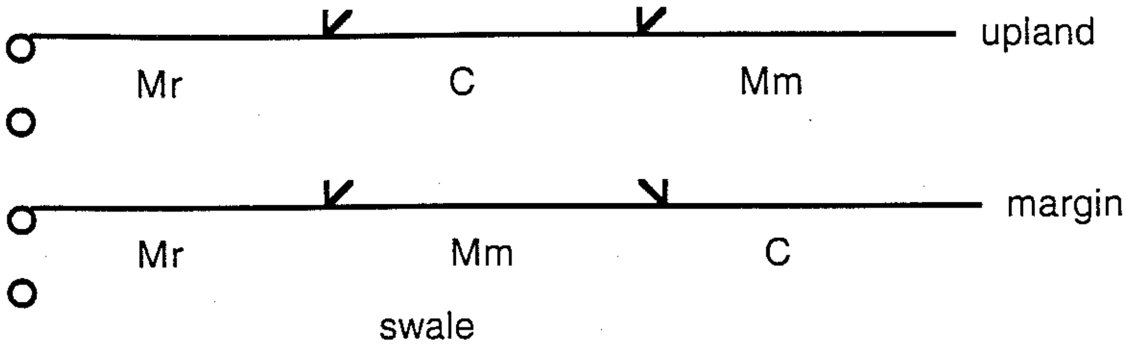
APPENDIX D:

Maps of the Permanent Plots

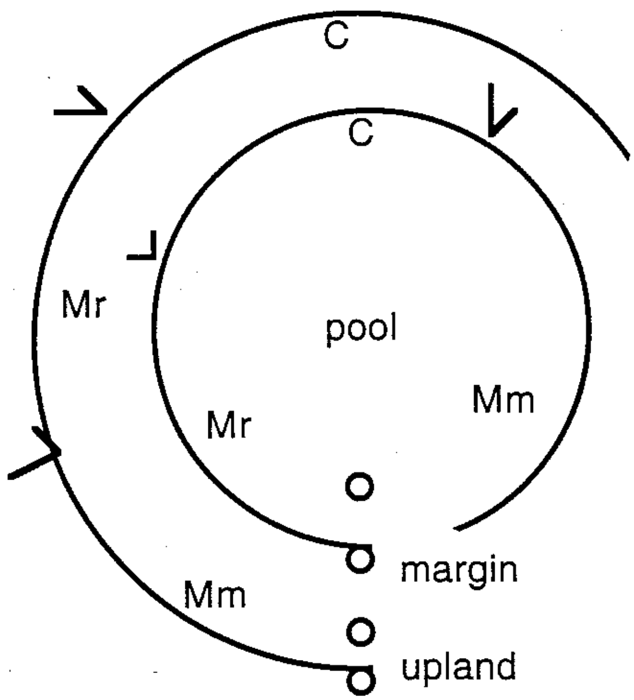


Location of experimental blocks 1-5 on the Cramer property. Scale is one inch = 600 feet (approx.). Base map is in MOU for Cramer Mitigation Bank (1996). see Pavlik et al. (1998) for reference.

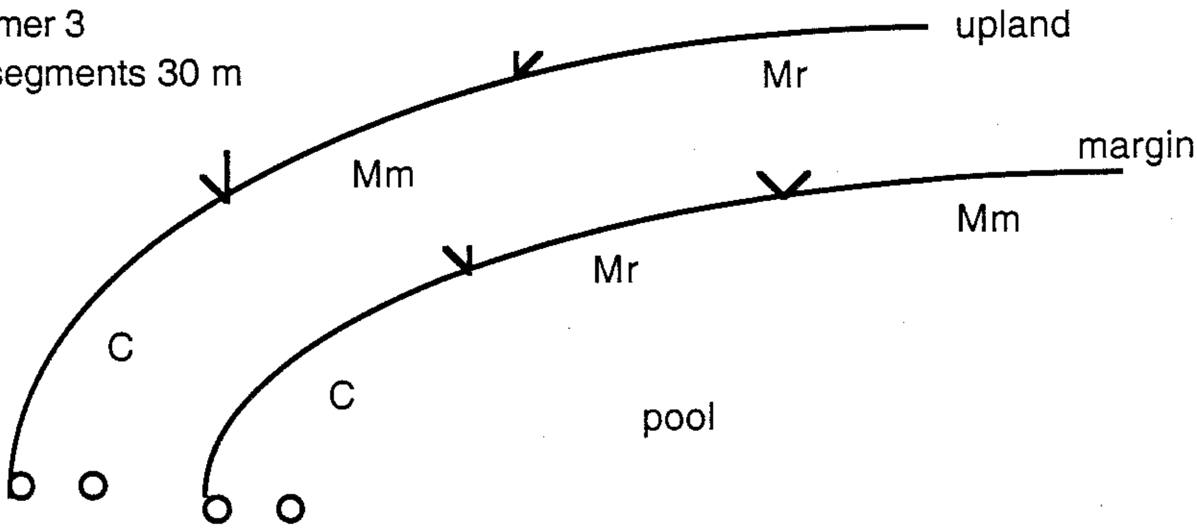
Cramer 1
all segments 30 m



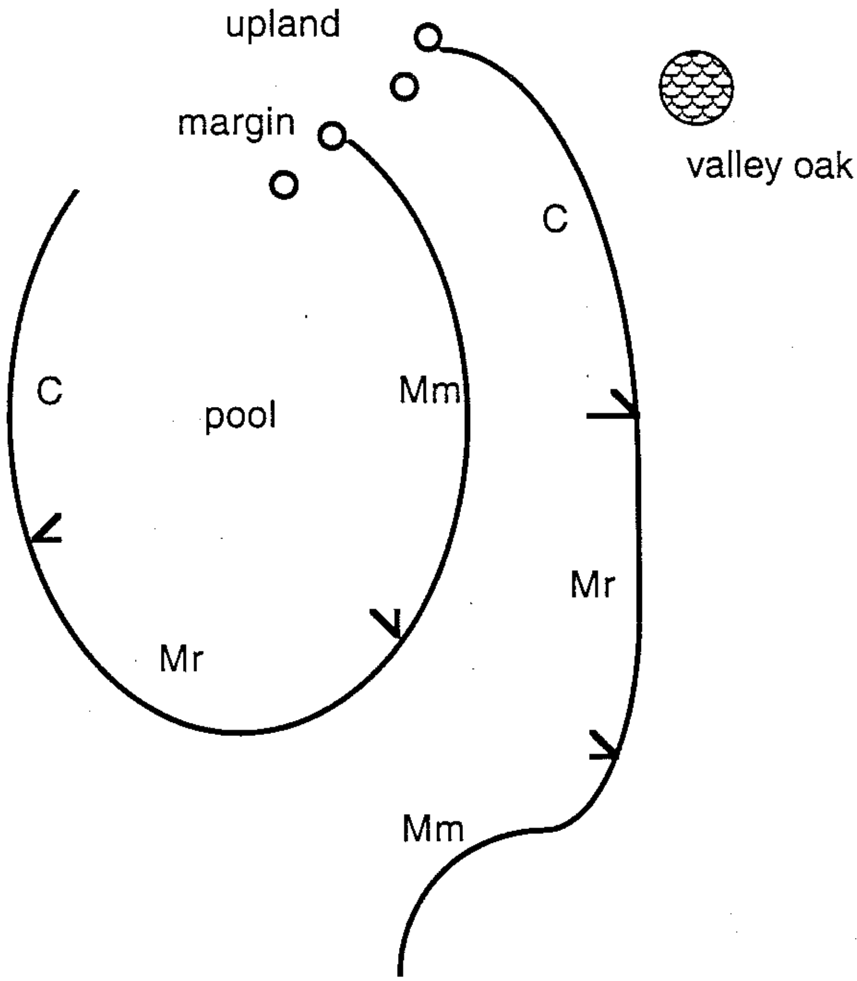
Cramer 2
all segments 30 m



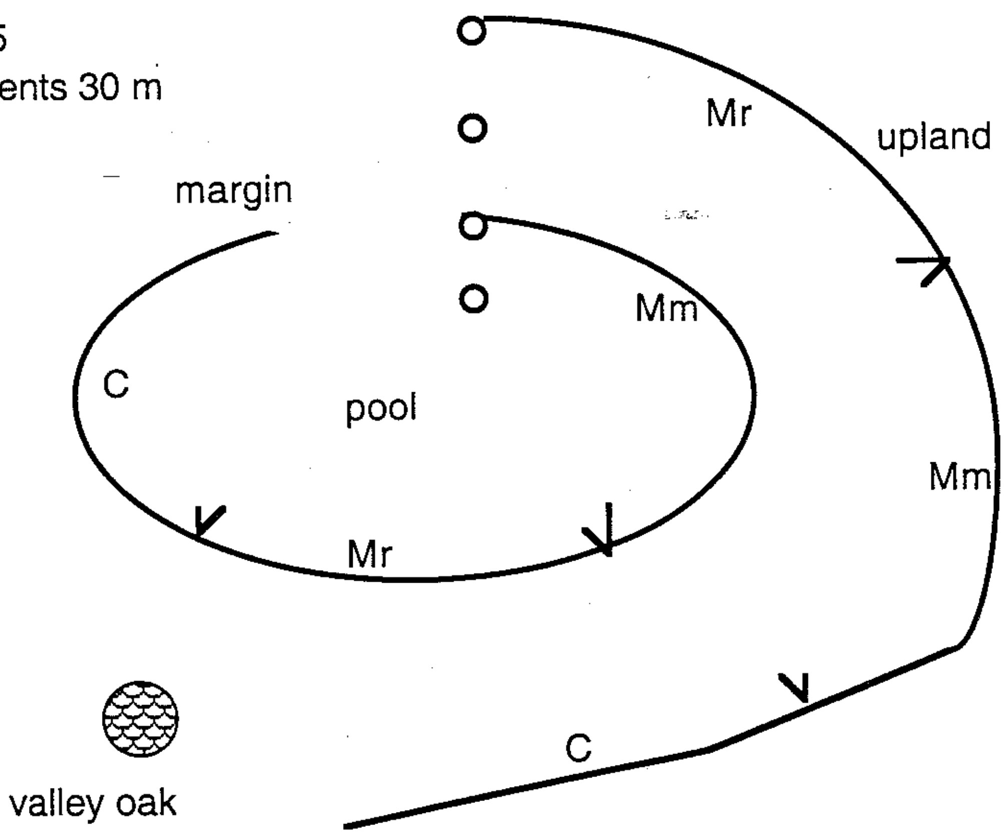
Cramer 3
all segments 30 m

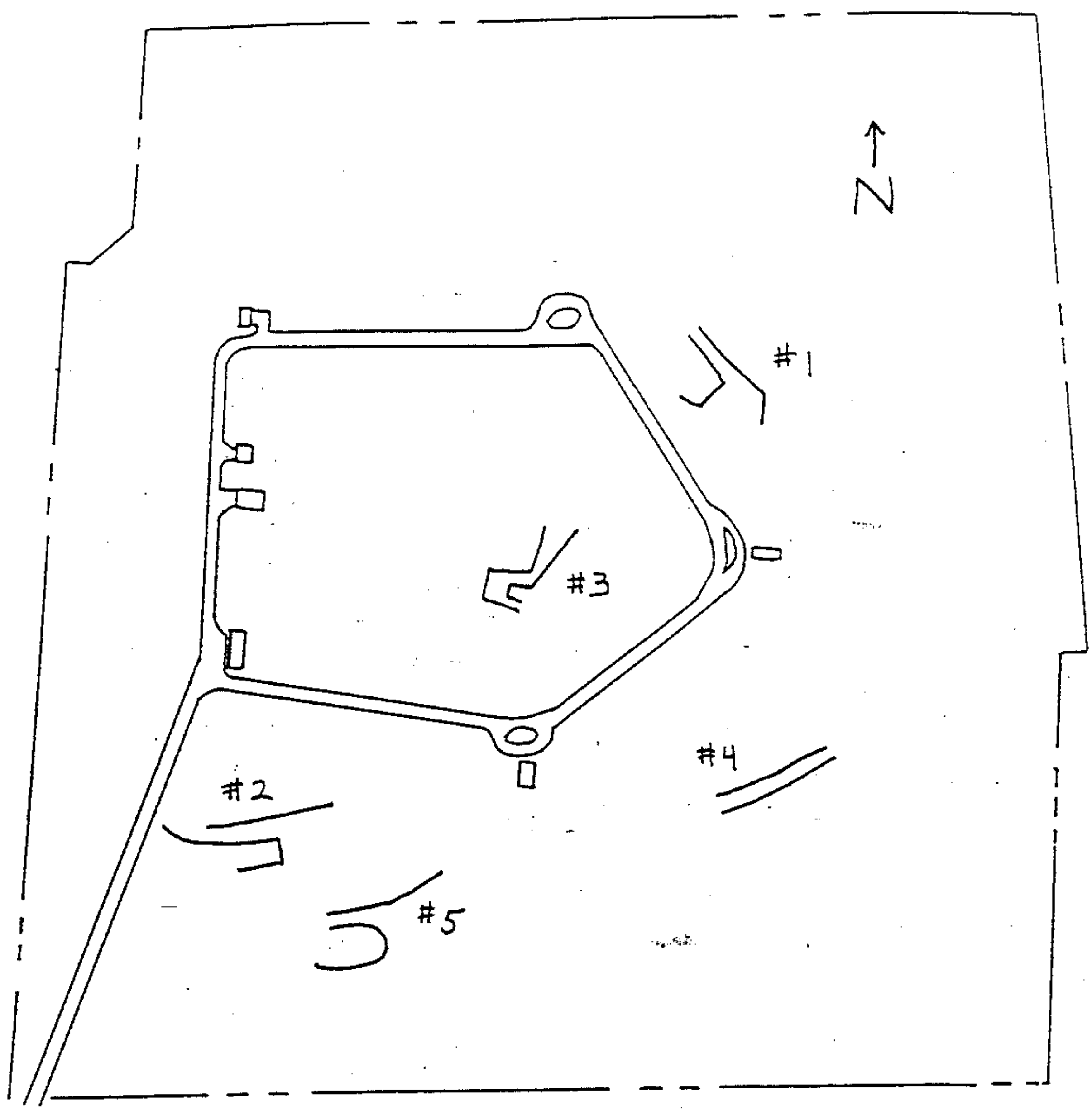


Cramer 4
all segments 30 m



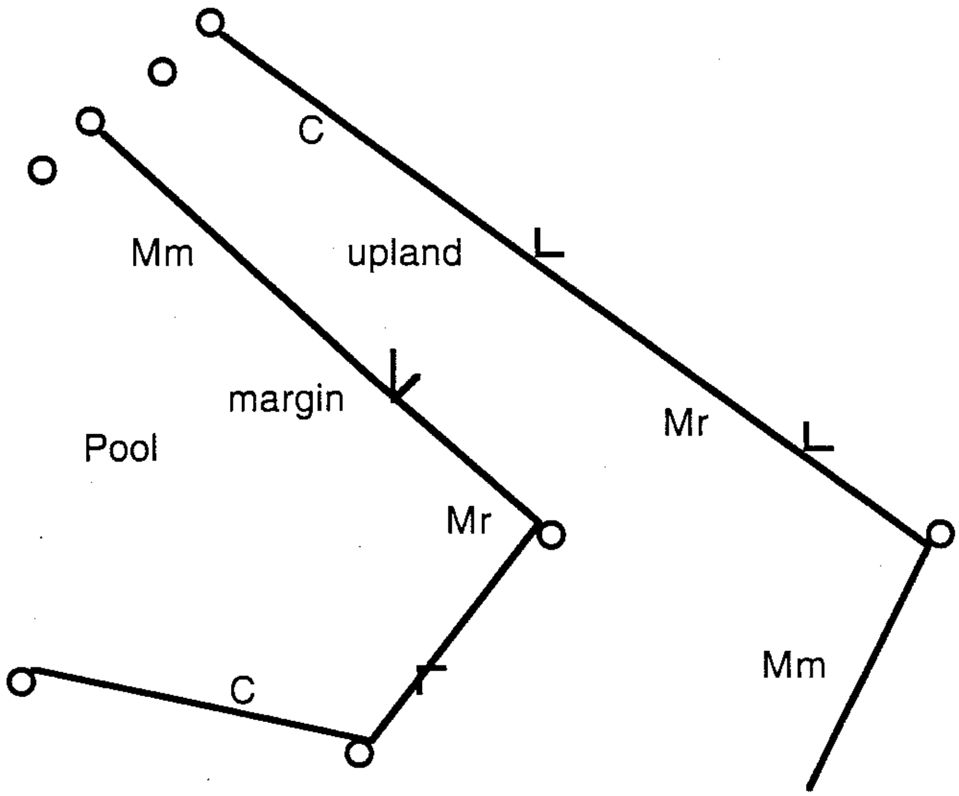
Cramer 5
all segments 30 m



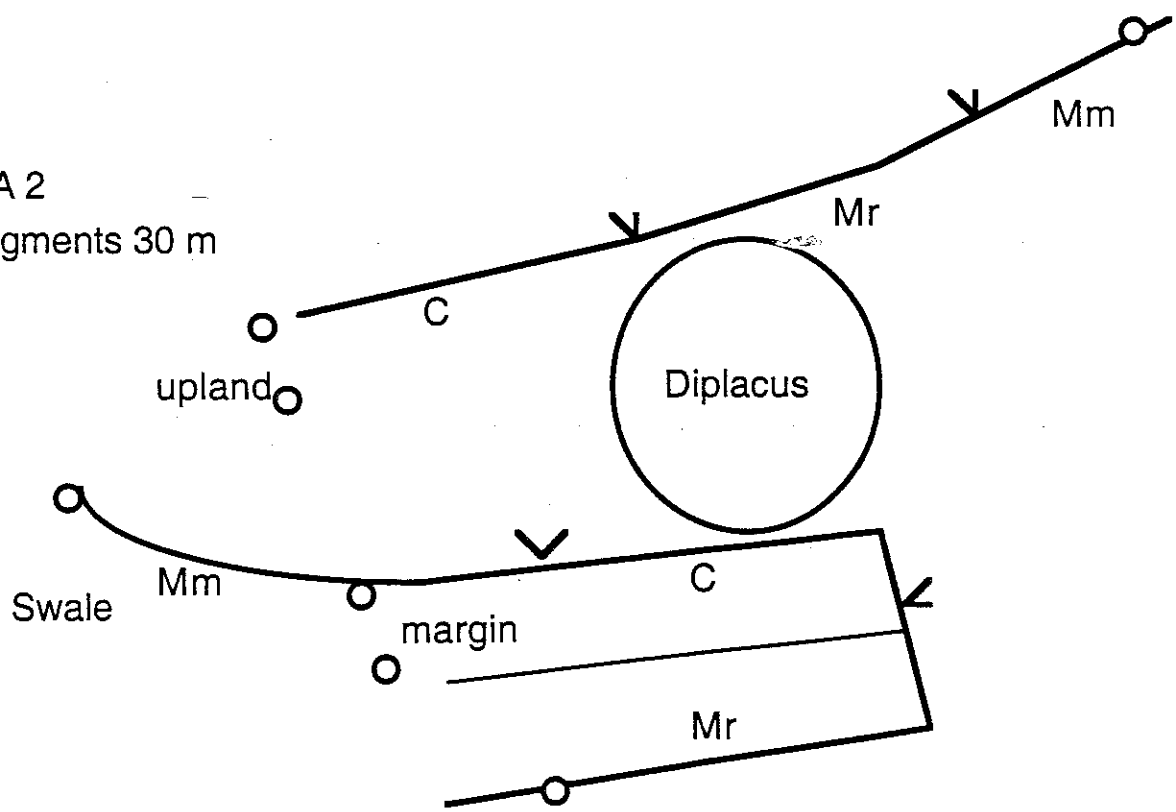


Location of experimental blocks 1-5 on the FEMA property. Scale is one inch = 300 feet (approx.). Base map is U.S. Army Corp of Engineers (1968). see Pavlik et al. (1998) for reference.

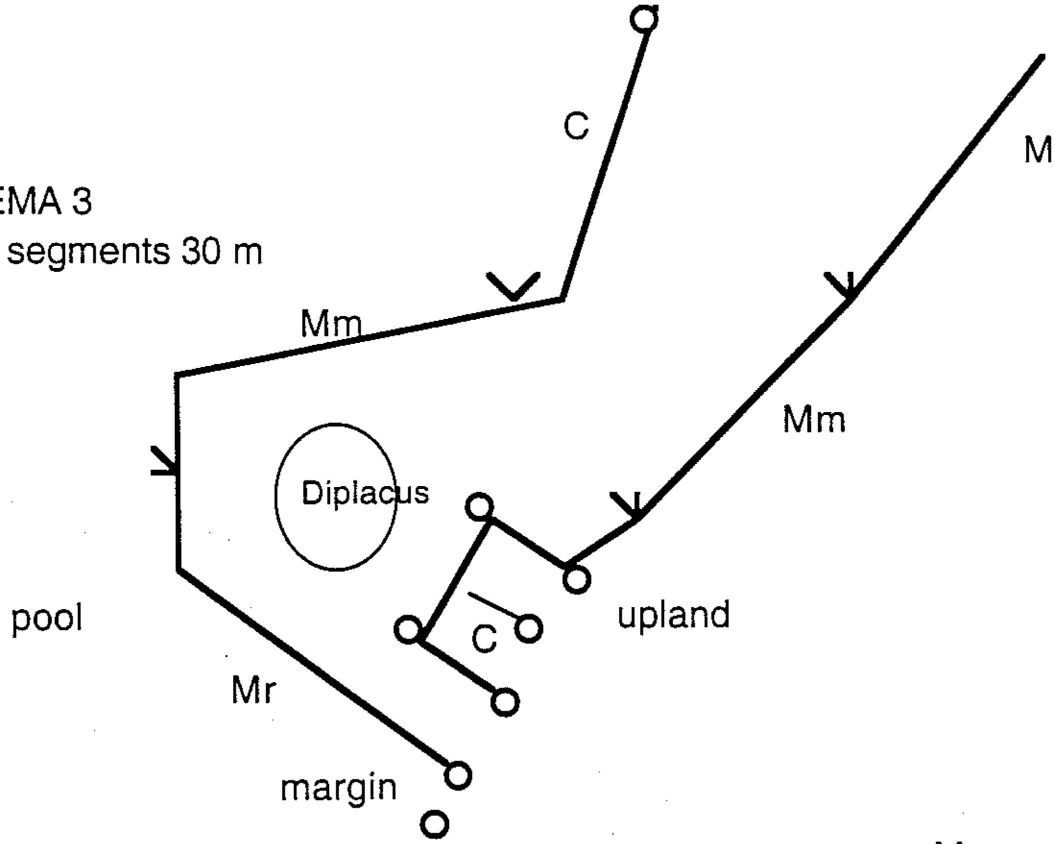
FEMA 1
all segments 30 m



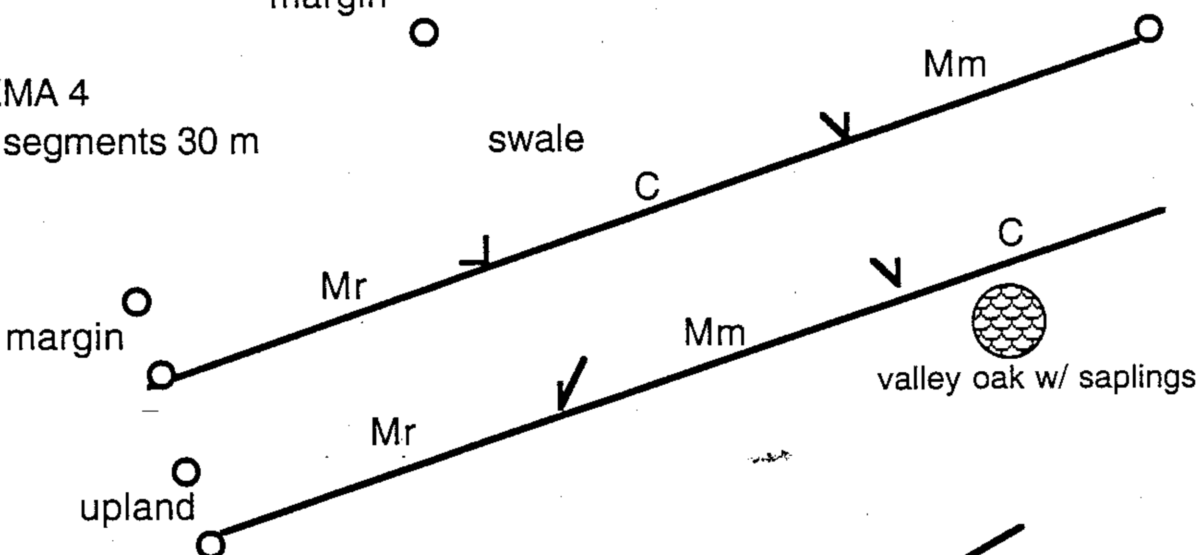
FEMA 2
all segments 30 m



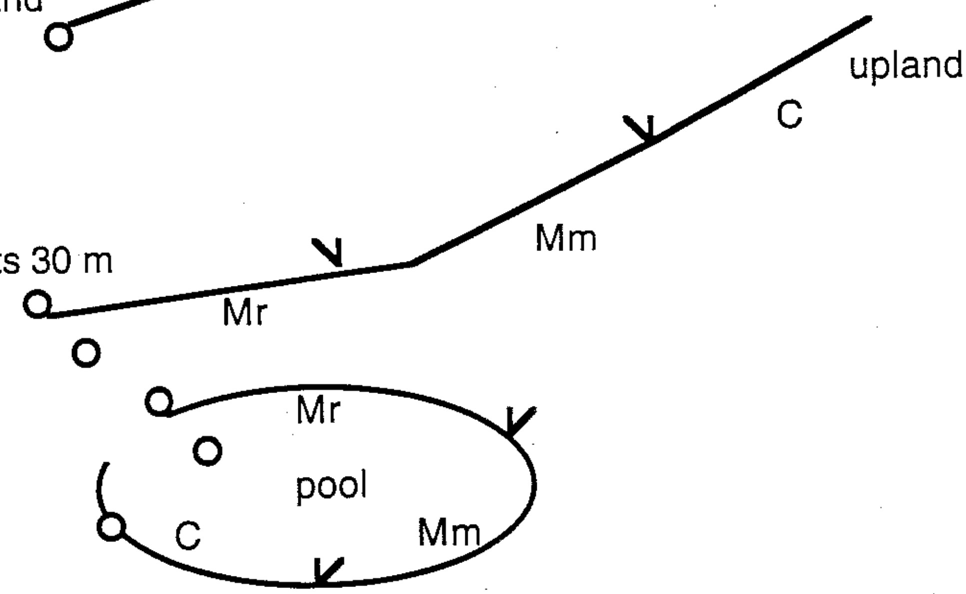
FEMA 3
all segments 30 m

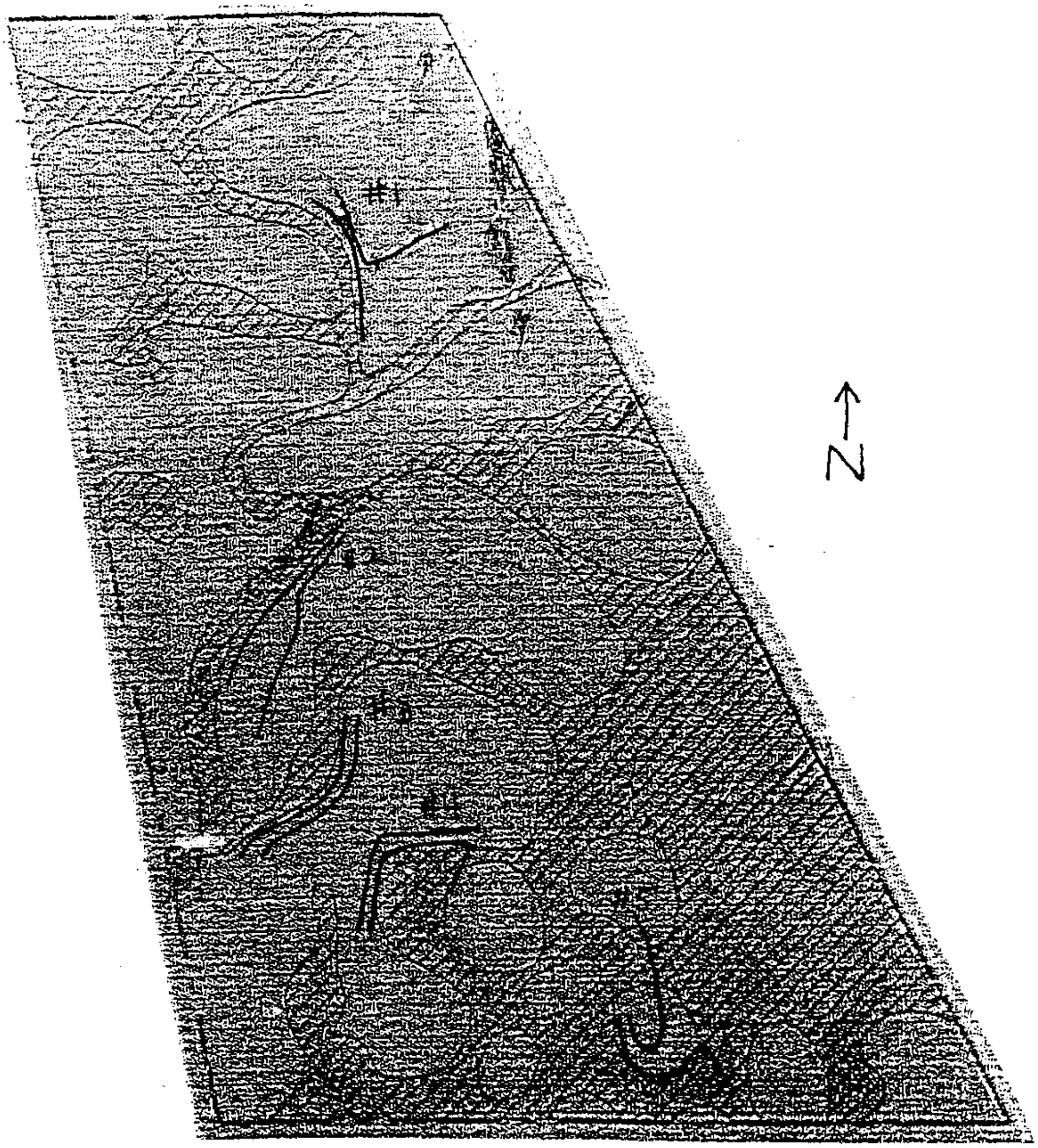


FEMA 4
all segments 30 m



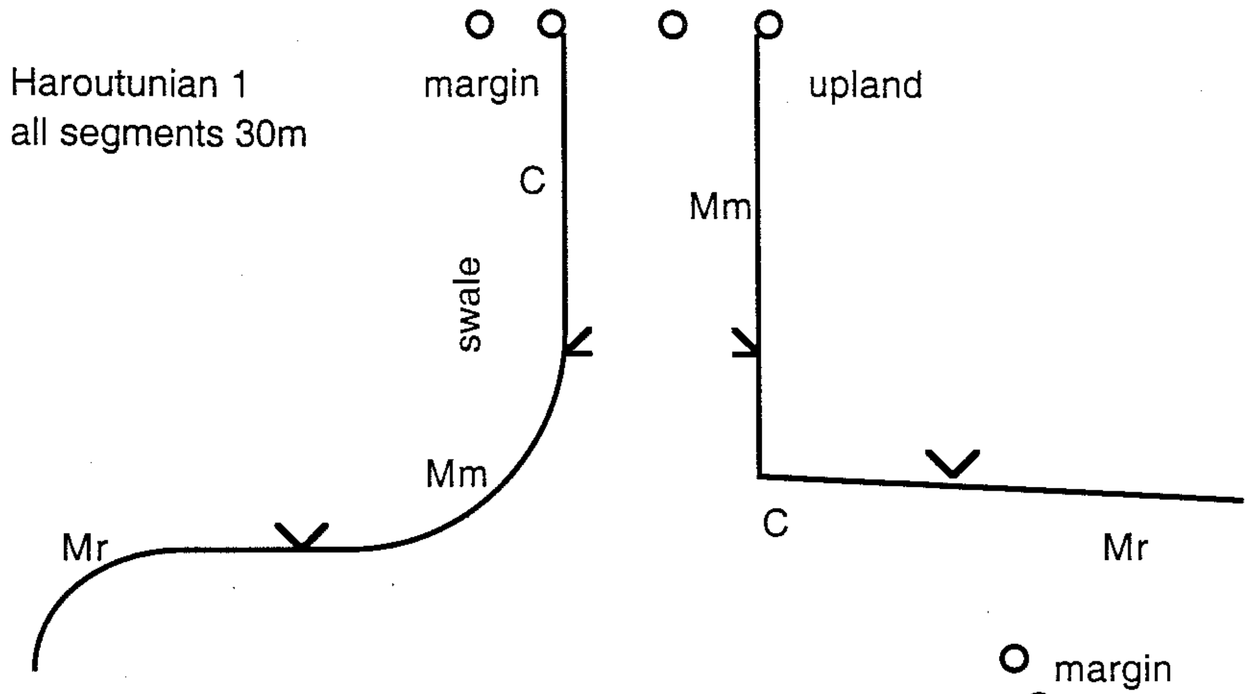
FEMA 5
all segments 30 m

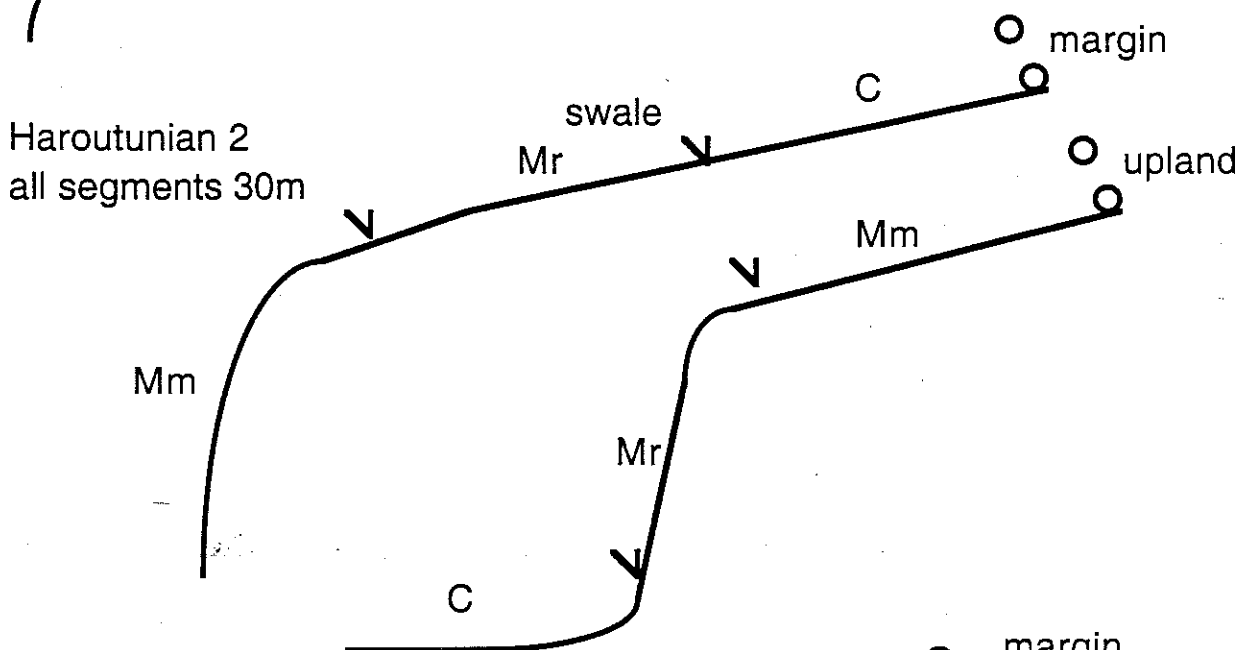


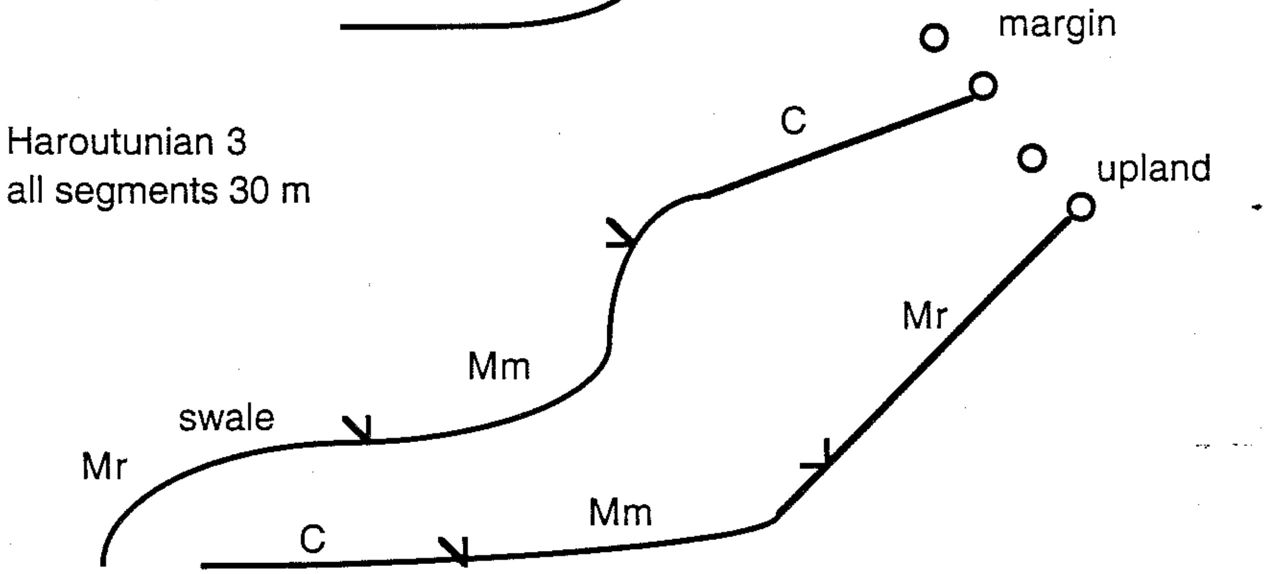


N

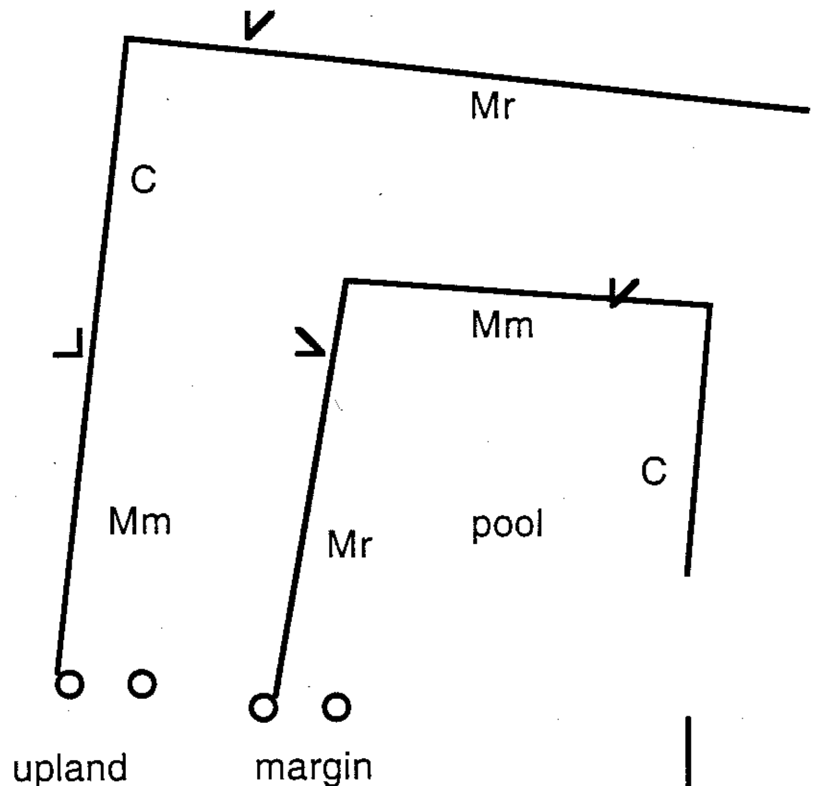
Location of experimental blocks 1-5 on the Haroutunian property. Scale is one inch = 100 feet (approx.). Base map is by M. Waaland (1996). see Pavlik et al. (1998) for reference.


Haroutunian 1
all segments 30m
margin
upland
C
Mm
swale
Mm
Mr
C
Mr

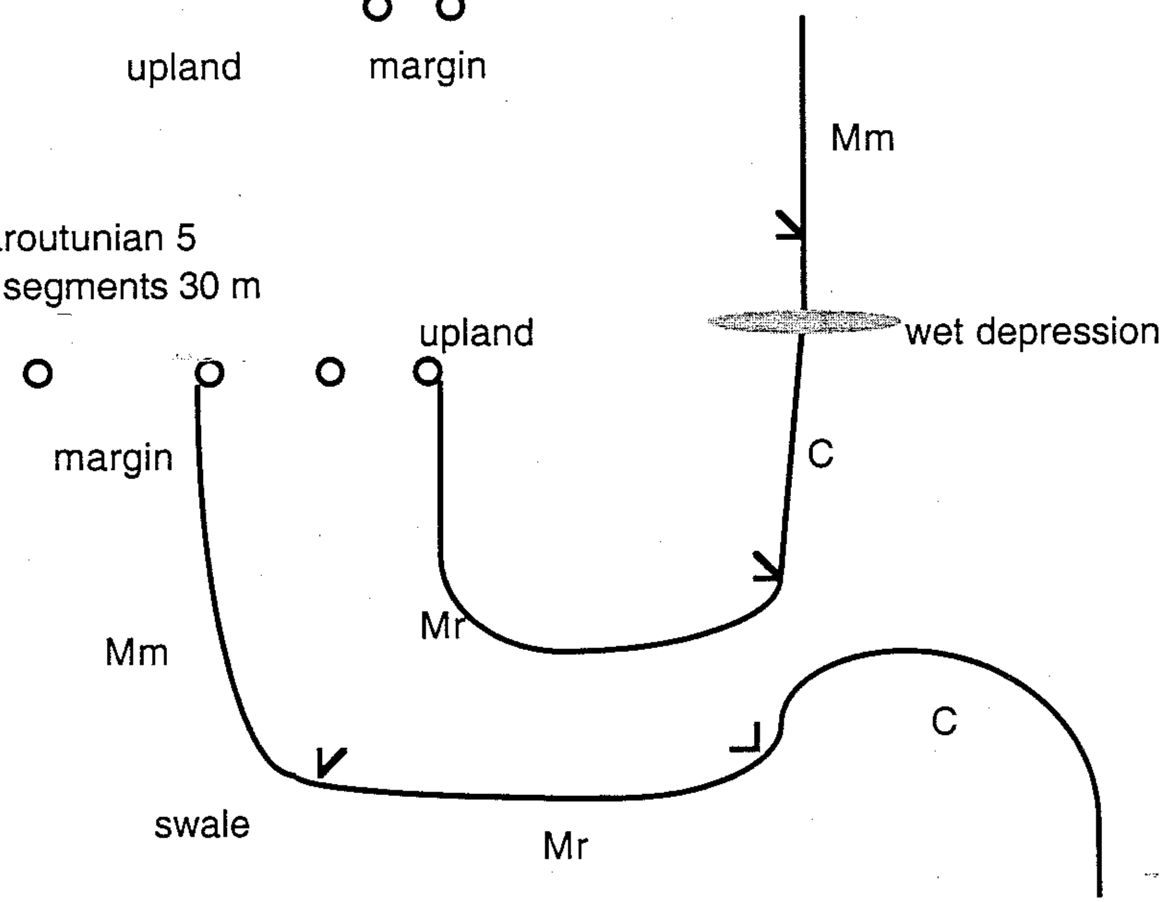

margin
C
swale
Haroutunian 2
all segments 30m
Mr
upland
Mm
Mm
Mr
C


margin
C
Haroutunian 3
all segments 30 m
upland
Mr
Mm
swale
Mr
Mm
C

Haroutunian 4
all segments 30m



Haroutunian 5
all segments 30 m



APPENDIX E:

Rare Animals Associated with Experimental Pools and Swales

- Life Histories and Occurrence on SRVRS Properties
- Standard Protocols for Survey

Appendix E

Rare Animals Associated with Experimental Pools and Swales

Life history information was compiled on the rare fauna of the Santa Rosa vernal pools and swales. Sources included CDFG files (Yountville Office), unpublished reports (Eakins and Wilcox 1996), field guides (Stebbins 1972, Eriksen and Belk 1999), and government documents (e.g. CH2M Hill 1995, USFWS 1994). We concentrated on the taxa most commonly noted during the phase I examination of SRVRS property information (Pavlik et al. 1998), specifically; *Ambystoma tigrinum californiense* (California Tiger Salamander), *Rana aurora draytonii* (California Red-Legged Frog), and *Linderiella occidentalis* (California Linderiella, a fairy shrimp).

Cursory field surveys were also conducted within all blocks on the three experimental properties (Cramer, FEMA, and Haroutunian) prior to sampling and plot treatment, on May 18, 20, 21, 27 and 28, 1999. Conditions on the first three days were warm and dry; air temperatures ranged between 68-76^{0} F and the majority of pools (13/15) had no standing body of water (although the soil surface in the center could be moist or have puddles). Conditions on the evenings of the last two days were cool and humid; air temperatures after sunset ranged between 50-60^{0} F, with overcast skies. Surveys lasted a maximum of 10 minutes per pool (depending mostly on its size) and included one one-minute stationary position. A standard, grid-like search pattern was walked and all visible and audible signs of the target taxa were recorded. Temporary captures were used only for immediate identification and release. No specimens were collected and early season surveys were not conducted, so this can only be considered a preliminary attempt to know the fauna of the experimental sites.

Life Histories and Occurrence on SRVRS Properties

California Tiger Salamander (CTS)

The California Tiger Salamander (*Ambystoma tigrinum californiense*) is a state "Species of Special Concern" and a candidate for federal listing by the U.S. Fish and Wildlife Service (CH2M Hill 1995). This animal inhabits oak savannas and annual grasslands of central and coastal California. Much of the range has been reduced due to habitat destruction. Adults spend their lives underground or in burrows of ground squirrels, badgers and gophers. They emerge from these dens during the winter rains (between November and March) to feed, migrate to courting grounds and court and mate. Females then lay eggs in vernal pools or other quiet, semi-permanent water sources. The eggs hatch into larvae and can grow a few inches long within 2-3 weeks, usually in January or February. Larvae undergo 3 to 4 months of development before metamorphosis, after which they seek out mammalian burrows and deep cracks in which to reside during the summer. In the case that underground burrows are not available, the CTS will seek out loose soil in which to burrow or may take up residence in rotting logs or fallen branches.

Adult CTS individuals are most vulnerable to restoration activities during pre-mating migration and post-metamorphosis burrow seeking. Although sampling and plot treatments would not occur in mid-winter, they do occur during the post-spring peak of burrow seeking. Sampling at this time should be done with caution, but the use of mowing or fire for treatments at this time will require additional surveys to ensure that animals are not present above ground. Developing CTS eggs and larvae are extremely fragile during their vernal pool or swale residence and no disturbance of inundated habitat should take place.

Our surveys of the Cramer, FEMA, and Haroutunian properties prior to vegetation sampling and treatment did not yield any signs of CTS. Furthermore, none of the occurrence reports from the CDFG files include sightings of this species on these properties. However, reports have been filed for CTS within a 5-mile radius and the habitat appears suitable for this animal.

California Red-Legged Frog (CRLF)

The California Red-Legged Frog (*Rana aurora draytonii*) is a state "Species of Special Concern" and is listed as a "Threatened" species by the U.S. Fish and Wildlife Service. This animal is widespread in the coastal drainages of California, associated with wetlands and streams that provide quiet pools and slow-moving water (CH2M Hill 1995). It requires a surrounding vegetation that is dense and shrubby for foraging and breeding. It is unclear whether this animal burrows or hibernates during the winter months, but breeding occurs from early spring through July. Large clusters of eggs are attached to the stems and leaves of shoreline vegetation just below the surface of the water. CRLF eggs and larvae require 11-20 weeks of standing water to complete development (CDFG Rarefind Reports). Other phenological data regarding egg or tadpole development are not available.

Adult CRLF individuals are most vulnerable to restoration activities during late spring-early summer breeding. Sampling at this time should be done with caution, but the use of mowing or fire for treatments at this time will require additional surveys to ensure that animals are not present above ground. As with other amphibians, the egg stages are extremely sensitive to disturbance and care should be taken to avoid pools or swales with standing water.

Our surveys (including nocturnal auditory attempts) did not yield any evidence for the occurrence of this species on our experimental properties (although the Striped Pacific Chorus Frog was quite abundant). In addition, CRLF did not appear on occurrence reports from the CDFG for the Santa Rosa or Sebastopol quadrangles. However, one sighting of this taxon was reported for the Cotati quadrangle in the extreme southern portion of the Santa Rosa Plain. Moreover, the presence of apparently suitable habitat at the Cramer, FEMA, and Haroutunian properties requires some degree of caution during restoration activities.

California Linderiella Fairy Shrimp

A study conducted by CDFG of 18 vernal pools in the Santa Rosa Plain revealed the presence of at least 53 species of aquatic invertebrates (Eakins and Wilcox 1996). Three state-listed "Endangered" species (conservancy fairy shrimp, longhorn fairy shrimp, and vernal pool tadpole shrimp), as well as one state-listed "Threatened" species (vernal pool fairy shrimp) were all determined to reside within these pools.

The California Linderiella fairy shrimp (*Linderiella occidentalis* - Anostraca), a candidate for listing with the U.S. Fish and Wildlife Service, is also associated with pools throughout Sonoma County and the Santa Rosa Plain (CH2M Hill 1995). Very little species-specific data are available on any fairy shrimp, so we discuss herein the life-history traits of freshwater fairy shrimp in general.

The four species of fairy shrimp mentioned above are endemic to vernal waters in the Central Valley, coast ranges, and a limited number of pools on the Santa Rosa Plain. Each species is confined to freshwater and none are found in the ocean. The distribution of these shrimp may be partially dependent upon the turbidity of pools; conservancy fairy shrimps are known to primarily inhabit highly turbid waters, longhorn fairy shrimp are found in clear and turbid grass-bottomed pools and tadpole shrimp are found in clear to highly turbid water. California Linderiella are absent from running waters (CH2M Hill 1995) and are tolerant of turbidity, high temperature and low oxygen levels (Eriksen and Belk 1999).

Fairy shrimp feed on algae, bacteria, rotifers, and protozoa within the pools. Tadpole shrimp also filter-feeding on organic sediment within pools, and some are known to scavenge and feed on small animals (including frog tadpoles).

Fairy shrimp reproduce sexually, and females carry eggs within a ventral brood sac. These eggs are either dropped to the floor of a pool or remain within the female's body until she dies and sinks to the bottom. Tadpole shrimp are known to reproduce via egg fertilization and/or parthenogenesis. Fecundity rates are unavailable for all species, but are generally low. It may be inferred that other species of shrimp reproduce in a similar fashion, although confirming data are unavailable. For example, the California freshwater shrimp (*Syncaris pacifica*) reproduce only once per year. Fertilized eggs form cysts as a means of protection against winter elements and to aid dispersal. Cysts are resistant to heat, drying, cold, and desiccation. Wind disperses cysts to surrounding pools or swales. Eggs or cysts hatch in newly watered pools and growth into reproductive adults is rapid. Hatching, mating and egg bearing can occur as early as September for the California freshwater shrimp, whose range surrounds and includes the Santa Rosa Plain. Therefore, it is reasonable to assume similar reproductive rates and timing for California Linderiella within pools in the Santa Rosa Plain.

Several life history traits of fairy shrimp would contribute to their vulnerability within pool and swale ecosystems. Shrimp are necessarily susceptible to dramatic population shifts by the sensitivity of their egg and reproductive phases to environmental conditions. Temperature, dissolved oxygen levels, predation and water quality are major factors that affect juvenile and adult survivorship. Because much of the vernal pool habitat within the Santa Rosa plain has been destroyed or modified, the chances of cysts dispersing between favorable habitats is reduced are low. It is unclear whether restoration activities within and around the pools (e.g. trampling and restoration treatments) would be detrimental. It is reasonable to assume that, due to their filter-feeding techniques, shrimp are highly susceptible to alterations of water quality. Consequently, winter or early-spring manipulations should be avoided to minimize impacts to standing waters.

Our surveys for fairy shrimp occurred too late in the year, when there was relatively little standing water in the pools. Consequently, we don't have pool (block) -specific information on the occurrence of California Linderiella. These was evidence of clam shrimp (especially at Cramer) earlier in the season, indicating potential habitat for fairy shrimp in general.

Standard Protocols for Survey

California Tiger Salamander

According to the California Department of Fish and Game, the proper aquatic survey techniques for the California Tiger Salamander are as follows:

> A standard aquatic survey requires two separate aquatic surveys during one calendar year. The first survey should be collected between March 15 and April 15 and the second between April 15 and May 15. There shall be at least 15 days between surveys. Surveys should not begin prior to March 15 in order to reduce disturbance to eggs and to facilitate larval identification. Surveys for eggs should not be conducted. Every suspected breeding location must be sampled twice during the same season if the initial visit was negative. Surveys initiated after 15 May can not be used to report negative findings because larvae may metamorphose by this time. Standard aquatic surveys must be performed at all potential breeding sites for two calendar years to support a negative finding.
>
> CTS larvae, particularly small sizes under 35 mm (total length), are fragile and captured individuals should remain in nets only long enough to record an approximate total length measurement before being released. All other pool fauna should be treated with similar car. Sampling should cease once presence has been determined in order to minimize disturbance of pool flora and fauna.
>
> In areas that contain numerous pools, the sampling effort should focus on pools expected to hold water for at least 10 weeks, which is approximately the minimum necessary for larvae to reach transformation. It is important to collect data regarding the type and quality of each pool sampled. At a minimum this data should include the date and time, location, type and quality of water body (i.e. vernal pool, seasonal wetland, artificial impoundment, etc.),

dimension and depth of pond, water temperature, turbidity, presence of aquatic vegetation (submergent and emergent), introduced species, and vertebrates present. Photographs of pools and adjacent upland areas are helpful and copies should be included in the final report.

All ponds should be initially sampled using D-shaped, long-handled dipnets (typically 30 cm [12 inches] or larger), with 3 mm (1/8-inch) mesh or smaller. Most shallow ponds approximately 3 m (10 feet) in diameter or smaller can be completely sampled with dipnets. Sample approximately 50 percent of the surface area of the pond by spacing dipnet sweeps accordingly from one end of the pool to the other in order to sample different depths.

If fairy shrimp or tadpole shrimp are located, sampling should cease until the animals are identified to species. Return fairy shrimp immediately back to the pond. Empty nets as completely as possible before sampling different pools in proximity in order to minimize inadvertent transfer of fairy shrimp and other species. For the same reasons, nets should be thoroughly rinsed before proceeding to the next study site to ensure that pool fauna are not transferred from one region to another.

Freshwater Shrimp Species

Fairy shrimp have been collected in vernal pools in the months of from December to May. According to the Courtside Village Endangered Species Management Plan, the protocol for aquatic invertebrate sampling is as follows:

Sampling in selected pools should be conducted every two weeks when the pools and other ponded wetlands contain standing water. Each sample should be a drag sample collected with a triangular aquatic net, nine inches on a side, and obtained over wither a single eight-foot length covering the full range in water depth (for swales) or a pair of four-foot lengths for vernal pools where a single drag would not sample to full depth range. In the latter case, the separate samples should be combined. Before sampling, turbidity should be assessed qualitatively. Then, the samples should be collected, labeled, and preserved in a plastic jar to which 10 percent formalin will be added in a volume equal to that of the sample. A dye should be dissolved in the sample solution to facilitate identification.

Organisms should be identified to genus and estimates made of the number of genera present and the number of individuals per genus and higher taxonomic group (cladocerans, copepods, ostracods, fairy shrimp, dragonflies, water beetles, etc.). Most identifications should be made using a dissecting scope but some small forms (i.e. nematodes, mites, worms) can be whole-mounted and viewed under a compound scope. When necessary, organisms which are unidentifiable or whose taxonomic identity is in question should be sent to experts, if such experts are known.