DEVELOPMENT OF THE SANTA ROSA VERNAL RESERVE SYSTEM.

IV. EXPERIMENTAL MANIPULATIONS TO IMPROVE RARE PLANT POPULATIONS AND ECOSYSTEM QUALITY

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Prepared for

Region 3
California Department of Fish and Game
P.O. Box 47 Yountville, CA 94599

and

Plant Conservation Program
California Department of Fish and Game
1416 Ninth Street
Sacramento, CA 95814

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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 et al. 1998, 2000, 2001). This report describes second and third year responses of rare plants and vegetation of the vernal pools and swales of the Santa Rosa Plain to experimental management, 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) the responses of rare plant cover to mowing and removal in spring 2001, 3) collection of vegetation response to mowing and removal in 2002, and 4) responses of selected exotic plants (*Dipsacus fullonum, Foeniculum vulgare* and *Mentha pulegium*) to mowing, herbicide and fire treatments.

We collected 18,000 pin-hit data points from the 90 plots on the Cramer, FEMA, and Haroutunian properties in May 2002. These data are currently being entered into our Access database for analysis of vegetation response. Anecdotally, we observed dramatic differences on some properties (Cramer, Haroutunian), apparently related to treatment. Patches of *Limnanthes vinculans* and *Blennosperma bakeri* were more extensive and obviously showier in mowed and raked (Mr). Overall, the observed trends are desirable, and indicate that ongoing treatment is warranted.

A patch-intercept sampling method was designed and performed to detect responses of the vernal pool characteristic (VPC) taxa during May 2001. No treatment effects were detected, indicating that cover by patches of VPC taxa did not become more extensive because of the first or second-year mowing or mowing with phytomass removal. We believe that low seasonal precipitation, combined with only two years of

treatment, contribute to the lack of significant response of VPC taxa. This sampling will be repeated in 2003.

Mowing was shown to be an ineffective form of control of teasel and fennel, and it appears to compound the problem of teasel invasion by promoting germination. Therefore, we do not recommend mowing as a management tool for reducing populations of these invasive exotic plants.

We recommend that in areas heavily infested with teasel, especially along the margins of pools and swales, that hand application of a 0.75% solution of Rodeo® be used in at least three successive years. Fennel appears to be very resistant to control by at Rodeo® the concentrations tested, even though densities of large and small plants were almost halved when compared to control plots. Consequently, we believe that mechanical removal, perhaps combined with herbicide treatment, may be more effective than herbicide alone. We therefore recommend that in areas heavily infested by fennel, especially along roads, that mechanical removal be used on established plants, followed by hand application of a 1.50% solution of Rodeo® to subsequent resprouts. We also recommend that in pool bottoms heavily infested with pennyroyal, hand application of a 1.50% solution of Rodeo® be used to achieve control. The application should be done in early fall, because most late flowering, pool bottom natives will have already set seed (e.g. *Eryngium aristulatum*) while the target remains susceptible.

Despite complete incineration of green teasel shoots, plants were not killed and began resprouting within 10 days of the burn. Densities of adults and rosettes were the same as in adjacent, unburned areas, with the latter easily exceeding 1000/100 m^2. Consequently, fire is not only an ineffective form of control, it may compound the problem of teasel invasion. The same high intensive fire that could not control teasel apparently had a strong, positive effect on the *Limnanthes vinculans* population along the margin of a burned pool. In the spring following the burn, which had only 69% of normal precipitation, the floral display of this VPC in the burned area was both dense and extensive. We suspect that fire is very effective for improving populations of some VPC taxa, but is largely an impractical tool because of the suburbanized landscape of the Santa Rosa plain.

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DEVELOPMENT OF THE SANTA ROSA VERNAL RESERVE SYSTEM.

IV. EXPERIMENTAL MANIPULATIONS TO IMPROVE RARE PLANT POPULATIONS AND ECOSYSTEM QUALITY

Bruce M. Pavlik, Alison Stanton and Tyson Holmes

INTRODUCTION

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 data collected using scientific approaches and statistical analyses of outcomes. Treatment variables (e.g. mowing, fire, selective herbicides) are chosen according to the best available information for the taxa or habitat in question. Field observations, greenhouse studies, or inference from related ecosystems, provide testable hypotheses for the first round of experimental trials. These initial choices may only provide incomplete data sets for restoring a target population or community, but the experiments will provide new information and identify additional variables or treatments to test in subsequent trials. 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 experimental data collection 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 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 (Pavlik et al. 2000) provided a quantitative description of baseline vegetation at three SRVRS properties (Cramer, FEMA and Haroutunian). A total of 360 samples (720 subsamples using a bipartite quadrat) were collected from 15 pools or swales and included bottom, margin and upland habitats. The samples were used to provide species composition and structural data that could help focus restoration efforts on the most important target taxa. We also installed the first management experiment (using 90 permanent plots in two habitats on three properties) 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).

The third report (Pavlik et al. 2001) described the first year responses to mowing and phytomass removal treatments within 90 permanent plots on the Santa Rosa Plain, and included the following major components: 1) Measurement of post-treatment vegetation using point frames for cover dominants and quadrat-based assessments of vernal pool characteristic (VPC) taxa, including the federally-endangered *Limnanthes vinculans*. The objective was to detect shifts in plant cover from non-native to native (for dominant species) and from sparse to abundant (for rare species). 2) Quantitative description of how Mm and Mr treatments affect phytomass and soil chemistry after treatment (Fall 1999) and after the first growing season (Spring 2000). 3) An initial set of recommendations regarding Mm and Mr treatments for restoring vernal pool and swale vegetation on the Santa Rosa. We found that one year after a single experimental treatment there were several significant changes observed in the composition and structure of SRVRS vegetation. The few significant changes in % native cover, % cover by certain taxa, standing phytomass, and soil chemistry were generally in the right direction, of sufficient magnitude, and consistent with our operational ecosystem model. We recommended continuation of the treatments, accompanied by alternating monitoring schemes that emphasized either the whole-vegetation responses (using point frame sampling) or the VPC responses (using a patch-intercept method especially designed for detecting patchy distribution patterns with variable plant densities).

Herein we report on the responses of vernal pool margin and upland habitats to second and third year treatments of mowing and mowing with phytomass removal. The second year responses were those of VPC taxa, while third year responses were those of the vegetation as a whole. Specifically, the components of this work included; 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) the responses of rare plant cover to mowing and removal in spring 2001 (year two), 3) collection of vegetation response to mowing and removal in 2002 (year three), and 4) responses of selected exotic plants (*Dipsacus fullonum, Foeniculum vulgare* and *Mentha pulegium*) to mowing, herbicide and fire as spot-treatment management techniques. A subsequent report will include the analysis of 2002 vegetation data, including soil chemistry responses.

METHODS AND MATERIALS

Primary Restoration Experiment: Data Collection on the Third Year Responses of Vegetation to 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, taxonomy follows Hickman 1993). 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 Pavlik et al. 2000, 2001 for additional descriptions of the species and their habitats).

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 (see Pavlik et al. 2000 for additional descriptions of the properties).

Design and Establishment of a Block Design

A randomized block design was selected for this first restoration experiment because of the anticipated ecological heterogeneity, both natural and anthropogenic, among selected SRVRS properties. Power analysis was performed for three properties having equal quantities of blocks (Holmes 1998, T. Holmes, pers. comm. 2 Feb 1999, additional details in Pavlik et al. 2001). 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 sub-block (the apparent edge of vernal pool or swale vegetation) and an upland sub-block (coastal prairie). Block locations were determined by assigning numbers to every pool or swale feature on a wetlands delineation map for each property. We excluded numbered pools/swales in areas that had less than 50% live cover during 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.

Details of the block design and field marking is found in Pavlik et al. (2001).

Mowing and Phytomass Removal

Each 5 X 90 m margin or upland strip within a given block contained three 5 X 30 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 (treatment year 1), on four days between 7 July and 18 July 2000 (treatment year 2), and on three days between 9 July and 14 July 2001 (treatment year 3). 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).

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 evenness of raking among and within blocks. Raking was by far the most time-consuming and arduous part of the treatment process.

Post-Treatment Vegetation Sampling

At each of the three properties, the post-treatment vegetation in the plots was sampled in two habitat zones; 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 margin as the sloping edge zone adjacent to the pool bottom, 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*).

All field assistants received advanced training or had expertise in the identification of plants and vegetation sampling (see Appendix A of Pavlik et al. 2001). We conducted on-site recognition drills each morning new assistants arrived at a property. These activities included quizzes on fresh material and examination of variations in our field herbaria. Quizzes were repeated until all responses were correct. In addition, we assembled the plot frames and practiced sampling to ensure similar, high levels of competency among the assistants. At the end of each sampling day we again conducted quizzes to check identifications and make any necessary corrections to data sheets. In May 2002 we used 5 teams of two field assistants to complete the sampling in three long days.

A team of two trained field assistants (a reader and a writer) was assigned a block to sample, each with upland and margin strips containing three plots each (control (C or Con), mowed-mulched (Mm) and mowed-raked (Mr)). Teams were instructed to approach the strips carefully so as not to step into them before sampling. A measuring tape (100 m length) was staked with its 0 m mark at the upslope pvc marker (at the initial boundary) for the margin strip. Walking on the outside of the strip, a team member laid the tape taut using other pvc stakes or flags to precisely define the upslope edge.

Plot maps were double checked to determine if the first 30m plot of the margin was a control, Mm or Mr plot. The writer removed the proper set of preprinted datasheets (Appendix B of Pavlik et al. 2001) from a property notebook and secured them to a clipboard. The writer told the reader the position and upper/lower designation on the datasheet (filled out ahead of time using a set of random numbers), beginning with the lowest position number (e.g. 7 m). The reader carried a 10-pin, pvc sampling frame along the upper plot edge and located the position (e.g. 7 m) on the tape. If the designation was U (upper), then the frame was carefully set into the plot a short distance (0.75 m) from the tape (marked with a knot on the locator string). If the designation was L (lower), then the frame was set into the plot 1.5 m from the tape (end of the knotted locator string). The line of vertical pins was perpendicular to the tape and all pins (each 1.0 mm in diameter) were initially raised. The reader always entered and stood in the plot on the side of the frame facing the lowest position numbers (e.g. 6 m side, not the 8 m side) so that unsampled vegetation was not disturbed.

Beginning with the upslope pin (# 1, the one furthest from the pool), the reader slowly lowered it until it made first contact with a leaf, stem, or flower. The reader called out the name of the species contacted and the writer recorded its four letter abbreviation (e.g. *Limnanthes vinculans* is recorded as LIVI in the data slot for pin #1). If there was wind, the reader waited until she or he could determine which leaf/flower would be touched if there was no motion. If the species could not be identified, the writer could ask a roving expert, or designate it as unknown "A". In case of the latter, the writer took a complete specimen, taped it to a blank unknown card and labeled it. The same "name" was used throughout the team's sampling and the specimens were kept until collected as a voucher for later identification or cross-checks between teams. If the pin hit bare ground the record was "BARE" and if it hit thatch or wood it was recorded as "THAT". Fallen leaves resting on the canopy were removed and the pin trajectory was maintained until contact. This was repeated for all 10 pins in the subsample.

If the area between the legs of the pin frame contained any rooted vernal pool characteristic (VPC) taxa (e.g. *Limnanthes vinculans, Blennosperma bakeri, Pogogyne douglasii* ssp. *parvifolia, Downingia concolor,* and Lasthenia *glabberima*), a 0.125 m^2

wooden quadrat was used to provide additional information on their density and cover. The quadrat was centered within the base of the point frame and used to count all rooted individuals and to estimate total % cover for each species.

When a subsample was finished the downslope locator string was stretched and the pin frame positioned to get the second subsample (pins 11-20) for that position along the upper edge. All steps were repeated and the frame moved to the next position along the tape. A total of 10 positions (20 subsamples) were used per plot. Before moving to the other two plots in the margin habitat and the other three plots in the upland habitat, the writer would check to see that all data sheets were filled out completely before returning them to the property notebook. All unknown vouchers were sealed in bags until all teams met at the end of the day to cross-check names and to be retested on identification of all species encountered. Corrections to datasheets, if any, were made immediately to ensure the highest possible consistency among teams.

A total of 18,000 pin "hits" were recorded between 16 May and 18 May of 2002 (3 properties X 5 blocks/property X 2 habitats/block X 3 plots/habitat X 20 subsamples/plot X 10 pin hits/subsample) to detect vegetation responses to the third year (2001) treatments. Field sampling occurred at the apparent peak of vegetative growth and during maximum floral display of most plant taxa.

Data Handling and Analysis

The vegetation data for spring 2002 was collected and will be analyzed within Microsoft Access database. Details can be found in Pavlik et al. 2001 and in a subsequent report (Pavlik et al. 2004).

Primary Restoration Experiment: Second Year Responses of Vernal Pool Characteristic Plants to Mowing and Phytomass Removal

Alternating with the point frame sampling (for detecting responses of the vegetation), we designed and performed patch-intercept sampling (for detecting responses of the vernal pool characteristic (VPC) taxa) during May 2001 (after second year treatment in July 2000). The sampling method and data analysis were designed for taxa that occurred in a few, isolated, discrete, often elongate patches (0.5-1 m wide, and > 2 m long) along the margins of vernal pools and swales. The densities of plants within patches is uniform from patch interior to edge, and high enough that individual plants cannot be easily distinguished from one another. Taking these spatial population characteristics into account allowed the development of an efficient field sampling method based upon cover interceptions with a sample rod. The rod will be randomly placed within the 30 m long plots, but a more even dispersion achieved using stratification (10 strata, each 3 m long). At the random position within each stratum, the summed length of a VPC's cover intercepted by the rod will be measured.

The VPCs included were *Limnanthes vinculans, Blennosperma bakeri, Pogogyne douglasii* ssp. *parvifolia, Downingia concolor,* and Lasthenia *glabberima*. Previous analyses established strong correlations between VPC abundances (e.g. Figures 4 and 5 in Pavlik et al. 2001), meaning that responses of these taxa to mowing and phytomass removal were probably indicating of responses of taxa that were not in our experimental plots (e.g. *Lasthenia burkei*).

Field Sampling

The sampling unit (pole) was a rigid piece of half inch PVC pipe, 4.0 m long, with 10 cm graduations marked along one side. It was positioned perpendicular to the margin plot's edge, and thus more likely to intercept a VPC patch (which generally are elongated as concentric circles parallel to the water's edge). Care was taken to ensure the bottom end of the pole was aimed at the pool or swale center (where water depth would be greatest). A random numbers table was used to generate 10 positions, each between 0 and 300 cm (3 m), and these positions ensured the pole would be laid randomly, but throughout each plot. Because plots were 5 m wide with 0.5 m buffers on the upper and lower edges, the pole spanned the entire treatment area.

Each team of field assistants had a pole, meter stick, datasheet and block maps. The meter stick was used to measure the total length (cm) of each VPC's patch (cover) as intercepted by the rod. For purposes of uniformity between teams, the following definitions were adopted: A patch was defined as two or more VPC plants within 10 cm of each other. A gap between patches was defined as a section of the linear dimension greater or equal to 10 cm that contains no VPC plants. The linear dimension of patches of each VPC were recorded separately and not lumped. All strata in a plot were completed by a team before moving on to another treatment plot in the same block.

During the 2001 field season (in response to the second year, 2000, treatments) the sampling was completed on six field days between 16 May and 11 June. VPC plants were in full flower, transitioning to fruit production, at that time.

Data Analysis

Analysis was "double hurdle" in the sense that a first analysis was conducted to compare the percentage of pools/swales observed to be occupied by the VPC taxa and then a second analysis was performed on proportion relative cover among those pools/swales where the VPC taxa were observed.

A permutation test (Good 1994, Edgington 1995) was employed to compare proportion of occupied pools/swales among sites. The two-tailed test statistic *S* for this test was the sum of squared deviations around the observed mean proportion of pools/swales occupied across the three sites $\bar{x}$:

$$S = \sum_{i=1}^{3} (x_i - \bar{x})^2 \quad .$$

Among those sites where the species was observed, mean proportion relative cover and its standard error were estimated assuming a multistage design (Thompson 1992) with pools/swales serving as the first stage and sampling positions within treatment strips serving as the second stage.

Hypothesis concerning proportion relative cover were tested by fitting a linear mixed effects model (Pinheiro and Bates 2000) to the data from those sites where the VPC taxa were observed. Swale, swale by treatment interaction, and sampling positions within treatment strips were random effects while site, treatment, and site by treatment served as fixed effects. Explicit incorporation of heteroscedasticity (Pinheiro and Bates 2000) within and among sites in the modeling significantly improved model fit. Estimation employed restricted maximum likelihood. All random effects were approximately normally distributed.

Development of Management Tools: Controlling Exotic Plants with Mowing, Herbicide, and Fire

Mowing

We established three replicate plots, each 10 X 10 m, in a stand of *Dipsacus fullonum* (teasel) and three in a stand of *Foeniculum vulgare* (fennel) on the FEMA property during June 2000. Each corner was flagged, along with corners of contiguous plots that would serve as controls. Plants of both species had new, erect stems exceeding 4' in height, bearing open flowers. The teasel population also consisted of 1 year old rosettes. The treatment plots were then mowed to 3" tall, leaving cut material in place. Plots were visited in June 2001 to determine if mowing had any deleterious effects on the populations of these two weeds.

Herbicide

We established nine plots in a stand of *Dipsacus fullonum* (teasel), nine in a stand of *Foeniculum vulgare* (fennel), and six in a stand of *Mentha pulegium* (pennyroyal) on the FEMA property during September 2000. The teasel and pennyroyal plots were 1 X 1 m, while fennel plots 2 X 2 m. In each case, one set of three plots were random designated as controls, while the other sets were assigned one of two herbicide concentrations: either 0.75 or 1.5% solutions, as indicated by the manufacturer for controlling herbaceous perennial weeds (only 1.5% was tested for pennyroyal). Specifically, we used the wetland-approved herbicide Rodeo® (25 ml/gal for 0.75%, 50 ml/gal for 1.50%) and LI-700 surfactant (20 ml/gal). Application was done with a hand pump sprayer to more than half of the leaves on an adult plant.

Surfaces were wet but there was little or no run-off, and a total of 3.5-4 l was applied to all nine plots of each species.

To monitor the effects of the herbicide solutions, we tracked all plants in the experimental plots. For teasel, the number of adult (bolted and flowered, 2nd year) and juvenile (rosette, 1st year) individuals inside the nine plots were counted separately at the time of application and one year later. For fennel, the number of large, old ($\geq$ 10 reproductive stems) and younger, smaller (<10 repro stems) individuals were counted in the plots. The results were expressed in a transition matrix, where each value indicates the probability of one stage in the life history (e.g. a teasel rosette) to transition into the same stage (e.g. for a rosette to persist as a rosette) or into another stage (e.g. to become a reproductive teasel adult) under the treatment conditions after one growing season. Pennyroyal, being a rhizomatous perennial, was tracked by estimating the number of patches (clumps of stems) and the total % absolute cover of the species within the plots.

Fire

During July 2000 an apparently intense fire swept unevenly across the eastern portions of the FEMA property. It had been started by illegal fireworks and was controlled by the local fire department. Parts of FEMA Block 1 were incinerated, as were several extensive stands of teasel. We established two plots within burned teasel stands, each 10 X 10 m, to observe this weed's response to fire. Immediately after the burn, there was no live plant material showing above ground (e.g. rosettes, leaves), and very little thatch or organic debris on the surface (mostly mineral soil and ash). Only charred stalks of adult teasels marked the locations of plants prior to the burn.

RESULTS

Primary Restoration Experiment: Data Collection on the Third Year Responses of Vegetation to Mowing and Phytomass Removal

In May 2002 we collected 18,000 pin-hit data points from the 90 plots on the Cramer, FEMA, and Haroutunian properties. These data are currently being entered into our Access database for analysis. The responses of dominant species richness (SR_d), canopy cover by native taxa (vegetation quality), trends in management guilds (e.g. non-native graminoids, native graminoids), and specific taxa (including VPCs such as *Limnanthes vinculans*) will be reported in early 2004, as will trends in soil chemistry.

Anecdotally, we observed dramatic differences on some properties (Cramer, Haroutunian), apparently related to treatment. Patches of *Limnanthes vinculans* were more extensive and obviously showier in mowed and raked (Mr) plots at Cramer. This was easy to see in Block 2, where the control plot remained dominate by a tall canopy of *Pleuropogon californicus* and *Lolium multiflorum* (Figure 1). In Cramer Block 1, large numbers of *Limnanthes vinculans* appeared in mowed-mulched (Mm) and Mr plots where there had been none observed during the last three years. The control plot remained devoid of VPC taxa. At Haroutunian, *Blennosperma bakeri* became so abundant in the Mr plots of Blocks 4 and 5 that it was intercepted by our pin frame sampling for the first time. In previous years, and in the control plots of the current year, this VPC was very sparse and usually senescent by May. These improvements were less obvious at the FEMA property, where altered hydrology in some blocks (e.g. #3) is shifting the vegetation away from vernal pool and towards a wetland dominated by *Juncus phaeocephalus*. Overall, the observed trends at Cramer and Haroutunian are desirable, and indicate that ongoing treatment is warranted.

Primary Restoration Experiment: Second Year Responses of Vernal Pool Characteristic Plants to Mowing and Phytomass Removal

In May 2001 (the spring after the second year treatment) we applied the patch-intercept sampling technique to VPC taxa for the first time. Rainfall had only been 69% of normal, and pools were completely dry by 10 May. Many VPC's were already senescent, and the floral displays of *Limnanthes vinculans, Downingia concolor,* and Lasthenia *glabberima* had been relatively sparse, both between blocks and within plots. The proportion of pools/swales observed to be occupied by *Limnanthes vinculans* varied from 0.8 for Cramer to 0.4 for Haroutunian (Figure 2). Permutation testing found that proportions did not differ significantly among sites ($S = 2$, $p = 0.96$). This means that experimental blocks had an equal chance of supporting *Limnanthes vinculans* among properties.

In those blocks where observed, estimated mean proportion relative cover of *Limnanthes vinculans* exceeded 0.3 in Cramer but was less 0.1 in Haroutunian (Figure 3). Mixed modeling found proportion relative cover to differ significantly among sites ($F = 7.16$, $p = 0.03$). Different site histories, including degree of isolation, hydrological alteration, grazing, and agricultural activities could account for these differences (Pavlik et al. 2000). However, treatment ($F = 0.77$, $p = 0.49$) and treatment by site ($F = 2.17$, $p = 0.13$) effects were not statistically significant at this time. We believe that low seasonal precipitation, combined with only two years of treatment, contribute to the lack of significant response of VPC taxa. This sampling will be repeated in 2003.

Development of Management Tools: Controlling Exotic Plants with Mowing, Herbicide, and Fire

Mowing

Mowed stands of *Dipsacus fullonum* (teasel) had mean densities that were equivalent to densities in adjacent unmowed areas. Adult plants ranged in density from 4-36/100 m^2, while unbolted rosettes ranged from approximately 250-1000/100 m^2 in the spring following treatment (May 2001). Low rosettes were not damaged by the mower blades, and more may have been stimulated to form from seeds germinating during the wet winter (Figure 4). Consequently, mowing is not only an ineffective form of control, it appears to compound the problem of teasel invasion.

Mowed stands of *Foeniculum vulgare* (fennel) appeared to have the same density before and after mowing, but new stems appeared smaller in diameter and shorter overall. Unlike the case of teasel, mowing does not appear to increase fennel where it has become established, but it also seems ineffective as a control tool.

Herbicide

A single light application of a 0.75% solution of Rodeo® was very effective in reducing the transition probabilities of teasel rosettes (Table 1). Established, one-year-old rosettes (R_1) of this strict biennial had a 0.80 probability of transitioning to an adult in the control plots, but a 0.00 probability of do so when treated with either concentration of herbicide. Production of new rosettes (R_0) from germinating seeds was not, however, affected (R_0 to R_1 probabilities ranged from 0.51 to 0.80 regardless of treatment). Therefore, it appears there is little residual affect of Rodeo® and that successive years of application will be needed until the seed bank is exhausted. Overall, the densities of adult and rosette teasels in the herbicide plots were less than half of those in the control plots in the spring following treatment. We therefore recommend that in heavily infested areas, especially along the margins of pools and swales, that hand application of a 0.75% solution of Rodeo® be used to control teasel in at least three successive years.

In contrast to teasel, the single light application of a 0.75% solution of Rodeo® was not effective in reducing the transition probabilities of established fennel plants of different sizes (Table 1). In control plots, the transition probabilities within size categories exceeded 0.90, indicating that this long-lived herbaceous perennial grows slowly (a small plant with less than 10 stems does not become a large plant with more than 10 stems in less than a year), but surely. This was reduced to 0.49 when small plants were treated with the 0.75% solution and only 0.62 when the concentration was doubled. In large plants the 0.75% solution reduced the probability to 0.75 while the 1.50% solution reduced it to 0.42. Fennel appears to be very resistant to control by at Rodeo® these concentrations, even though densities of large and small plants were almost halved when compared to control plots. Consequently, we believe that mechanical removal, perhaps combined with herbicide treatment, may be more effective than herbicide alone. We therefore recommend that in heavily infested areas, especially along roads, that mechanical removal be used on established fennel, followed by hand application of a 1.50% solution of Rodeo® to subsequent resprouts.

When compared to control plots, the 1.50% solution of Rodeo® appeared to effectively control pennyroyal in the bottoms of pools (Table 2). Control plots had 6-15 patches of pennyroyal stems, producing 15-25% cover in the plots. Plots treated with herbicide had 0-3 clumps, with <2% cover in the spring (May 2001) following treatment (September 2000). The reductions were still apparent two years later (May 2003), although some regrowth had occurred. We therefore recommend that in heavily infested pool bottoms that hand application of a 1.50% solution of Rodeo® be used to achieve control. The application should be done in early fall, because most late-flowering, pool bottom natives will have already set seed (e.g. *Eryngium aristulatum*) while the target remains susceptible.

Fire

Despite complete incineration of green teasel shoots, the plants were not killed and began resprouting within 10 days of the burn. After two months the rosettes were about 10 cm diameter and would go on to become reproductive adults less than a year later. Densities of adults and rosettes were the same as in adjacent, unburned areas, with the latter easily exceeding 1000/100 m^2. Consequently, fire is not only an ineffective form of control, it may compound the problem of teasel invasion.

However, it should be noted that the same fire apparently had a strong, positive effect on the *Limnanthes vinculans* population along the margin of a burned pool. In the spring following the burn, which had only 69% of normal precipitation, the floral display of this VPC in the burned area was both dense and extensive (Figure 6). While patches of *Limnanthes vinculans* in other, unburned, areas were rather sparse, those associated with this fire were quite impressive.

SUMMARY AND MANAGEMENT RECOMMENDATIONS

1) We collected 18,000 pin-hit data points from the 90 plots on the Cramer, FEMA, and Haroutunian properties in May 2002. These data are currently being entered into our Access database for analysis. Anecdotally, we observed dramatic differences on some properties (Cramer, Haroutunian), apparently related to treatment. Patches of *Limnanthes vinculans* were more extensive and obviously showier in mowed and raked (Mr) plots at Cramer.. At Haroutunian, *Blennosperma bakeri* became so abundant in the Mr plots of Blocks 4 and 5 that it was detected by our pin frame sampling. Overall, the observed trends at Cramer and Haroutunian are desirable, and indicate that ongoing treatment is warranted.

2) We designed and performed patch-intercept sampling for detecting responses of the vernal pool characteristic (VPC) taxa during May 2001 (after second year treatment in July 2000). The sampling method and data analysis were designed for taxa that occurred in a few, isolated, discrete, often elongate patches along the margins of vernal pools and swales. No treatment effects were detected, indicating that cover by patches of VPC taxa did not become more extensive because of the first or second-year mowing or mowing with phytomass removal. We believe that low seasonal precipitation, combined with only two years of treatment, contribute to the lack of significant response of VPC taxa. This sampling will be repeated in 2003.

3) Mowing was shown to be an ineffective form of control of teasel and fennel, and it appears to compound the problem of teasel invasion by promoting germination. Therefore, we do not recommend mowing as a management tool for reducing populations of these invasive exotic plants.

4) We recommend that in areas heavily infested with teasel, especially along the margins of pools and swales, that hand application of a 0.75% solution of Rodeo® be used in at least three successive years. Fennel appears to be very resistant to control by at Rodeo® the concentrations tested, even though densities of large and small plants were almost halved when compared to control plots. Consequently, we believe that mechanical removal, perhaps combined with herbicide treatment, may be more effective than herbicide alone. We therefore recommend that in areas heavily infested with fennel, especially along roads, that mechanical removal be used on established plants, followed by hand application of a 1.50% solution of Rodeo® to resprouts. We also recommend that in pool bottoms heavily infested with pennyroyal, hand application of a 1.50% solution of Rodeo® be used to achieve control. The application should be done in early fall, because most late-flowering, pool bottom natives will have already set seed (e.g. *Eryngium aristulatum*) while the target remains susceptible.

5) Despite complete incineration of green teasel shoots, plants were not killed and began resprouting within 10 days of the burn. Densities of adults and rosettes were the same as in adjacent, unburned areas, with the latter easily exceeding 1000/100 m^2. Consequently, fire is not only an ineffective form of control, it may compound the problem of teasel invasion.

6) The same high intensive fire that could not control teasel apparently had a strong, positive effect on the *Limnanthes vinculans* population along the margin of a burned pool. In the spring following the burn, which had only 69% of normal precipitation, the floral display of this VPC in the burned area was both dense and extensive. We suspect that fire is very effective for improving populations of some VPC taxa, but is

largely an impractical tool because of the suburbanized landscape of the Santa Rosa plain.

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Table 1. Transition probabilities for teasel (*Dipsacus fullonum*) and fennel (*Foeniculum vulgare*) populations treated with two concentrations (0.75 and 1.50%) of the herbicide Rodeo. Teasel stages are Ro (new rosette from germinules), R1 (one year old rosette), A (adult, reproductive and bolted). Fennel stages are Ro (new rosette from germinules), small adult (with < 10 stems/plant), large adult (≥ 10 stems). _ = transition not observed.

TEASEL

Control

	Ro	R1	A
Ro	_	0.80	_
R1	_	0.28	0.80
A	_	_	0.00

0.75%

	Ro	R1	A
Ro	_	0.51	_
R1	_	0.00	0.00
A	_	_	0.00

1.50%

	Ro	R1	A
Ro	_	0.75	_
R1	_	0.00	0.00
A	_	_	0.00

FENNEL

Control

	Ro	< 10 st	≥ 10 st
Ro	_	_	_
R1	_	0.95	0.05
A	_	_	1.00

0.75%

	Ro	< 10 st	≥ 10 st
Ro	_	_	_
R1	_	0.49	0.02
A	_	_	0.70

1.50%

	Ro	< 10 st	≥ 10 st
Ro	_	_	_
R1	_	0.62	0.00
A	_	_	0.41

Table 2. Patch numbers and % absolute cover for pennyroyal (*Mentha pulegium*) populations treated with a 1.50% solution of the herbicide Rodeo. Patches are clusters of stem.

	2000 September		2001 April	
	# patches	**% cover**	**# patches**	**% cover**
Control				
plot 1	14	25	10	20
2	10	15	15	18
3	15	25	6	20
mean ± SD	13.0 ± 2.2	21.7 ± 4.7	10.3 ± 3.4	19.6 ± 0.9
1.50%				
plot 1	12	20	0	1
2	15	25	2	2
3	9	20	3	2
mean ± SD	12.0 ± 2.4	21.6 ± 2.4	1.7 ± 1.2	1.7 ± 0.5

Figure 1. Cramer Block 2 with mowed-raked (Mr) plot in foreground and control (C) plot arched around the left margin of the pool. Mr plot dominated by *Limnanthes vinculans* (white flowers) and *Pleuropogon californicus* and *Lasthernia glaberrima*, while the control plot is dominated by *Pleuropogon californicus, Lolium multiflorum, Vulpia myuros* and *Juncus phaeocephalus*). April 2001.

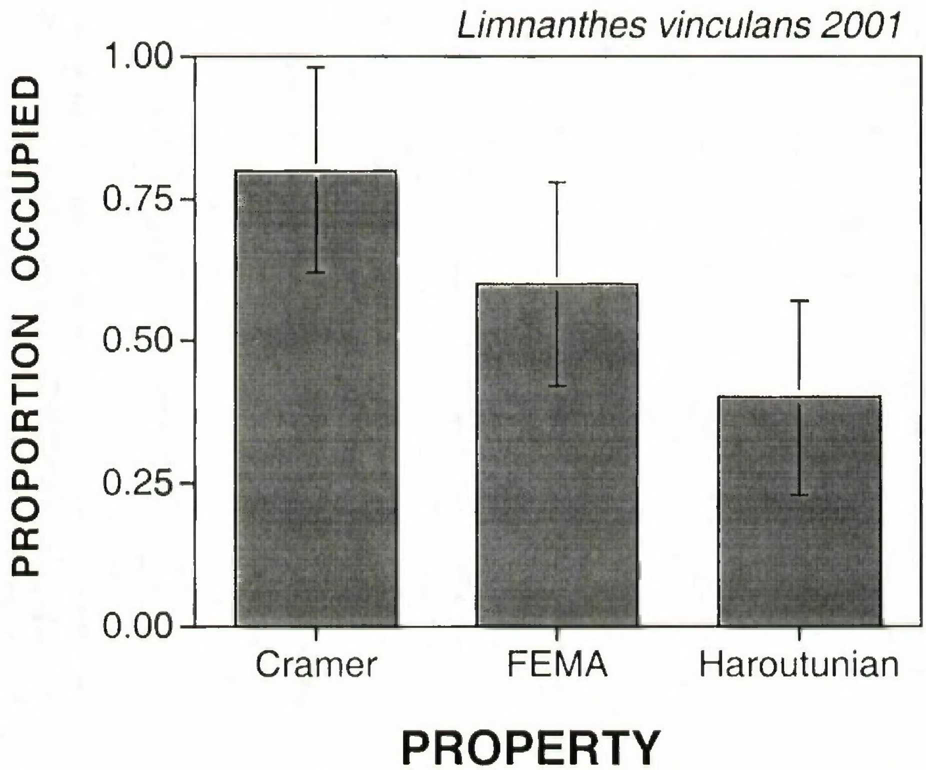

Figure 2. Proportion of pools/swales occupied by Limnanthes vinculans on each of the experimental properties, May 2001. Shown + 1 SE of the proportion.

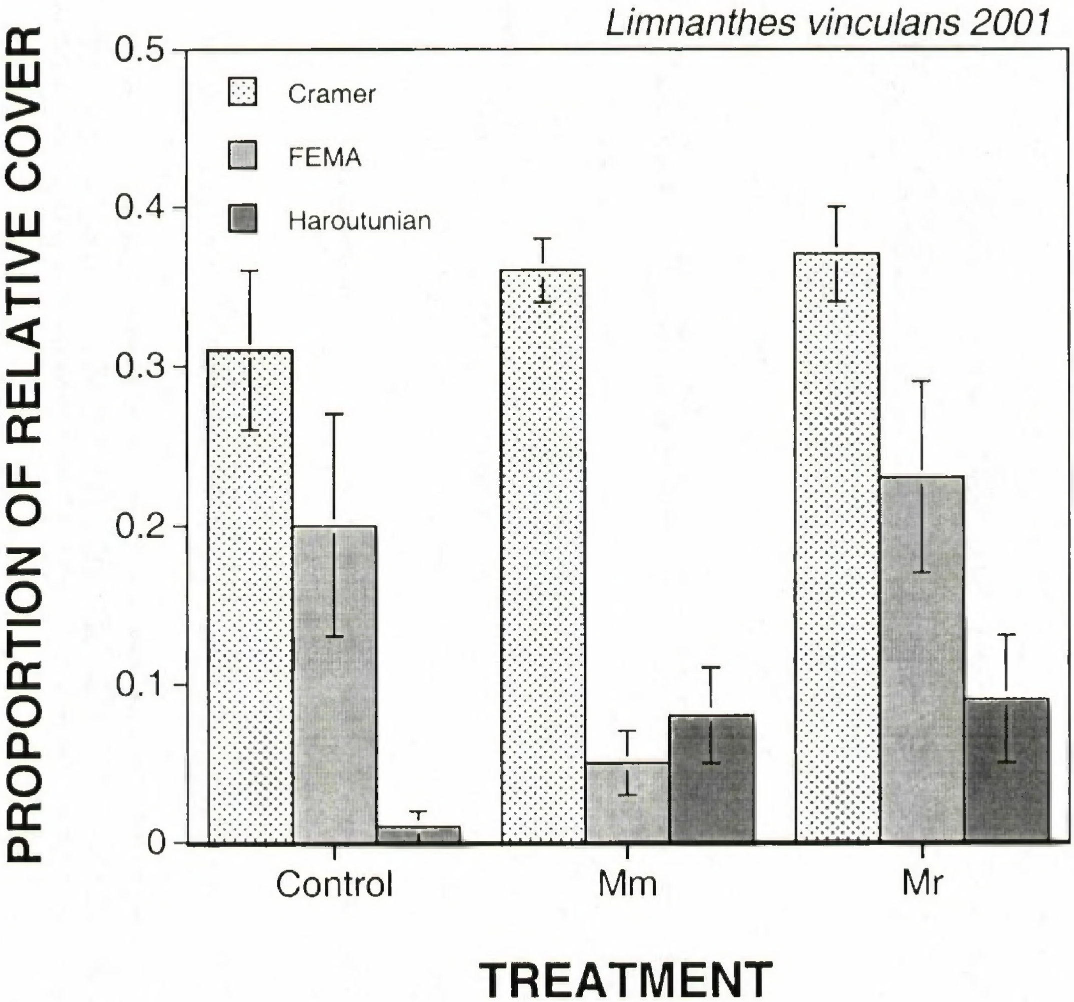

Figure 3. Proportion of relative cover of patches of Limnanthes vinculans by property and treatment, May 2001. Shown + 1 SE.

Figure 4. (upper). Mowed 10 X 10 m teasel plot on the FEMA property, July 2000.

(lower). Same plot, April 2001, prior to bolting. Note high density and large size of teasel rosettes.

Figure 5. (upper). Burned stand of teasel on the FEMA property, July 2000.

(lower). Teasel resprouting two months after the burn, September 2000.

Figure 6. Stand of *Limnanthes vinculans* in April 2001, after the July 2000 burn at the FEMA property.