DEVELOPMENT OF THE SANTA ROSA VERNAL RESERVE SYSTEM.

VI. THIRD AND FIFTH YEAR RESPONSES OF MARGIN AND UPLAND HABITATS TO MOWING AND PHYTOMASS REMOVAL

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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, Smith and Miller 1998). This report describes the third and fifth year results of experiments for restoring vernal pools and swales on the Santa Rosa Plain, emphasizing 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).

The first experimental treatments were implemented 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 on three SRVRS properties (Cramer, FEMA, and Haroutunian), marked, sampled and treated. Five blocks at each site included two habitats (coastal prairie uplands and vernal pool/swale margin) and each habitat-sub-block (5 X 30 m) had three treatment plots; control, mowed with phytomass removal (Mr), and mowed without phytomass removal (mulched – Mm). Each plot was treated for five years, concluding in 2004. We tested the hypothesis that seasonal mowing with phytomass removal reduces non-native grass cover and thus improves habitat quality in the long-term for native plants, especially those of conservation interest. This treatment could work by depleting soil nitrogen levels (a disadvantage for non-native annual grasses with low nitrogen use efficiencies), improving soil surface microenvironment (e.g. light, temperature), and prolonging soil

moisture for native species that are more nitrogen-use efficient. We also collected phytomass and soil chemistry data during Fall 1999, Spring 2000, and Summers 2002 and 2004 in all 90 plots. These results are not included in this report.

After five years of treatment the results suggest that mowing with phytomass removal can significantly decrease cover of the very invasive, non-native *Lolium multiflorum* in both margin and upland habitats, as well as increase cover of some native graminoids and forbs in either habitat. Specifically, over the period 2000 to 2004; 1) dominant species richness was unaffected by either Mm or Mr treatments, 2) vegetation quality improved (i.e. shifted towards natives) in the margin habitat by 24 to 43% with Mr treatment relative to controls (Mm effects were insignificant) and either improvement or degradation observed in the upland habitat (depending on year), 3) there were no consistent shifts in guilds with treatment in either habitat (in part because some non-native graminoids increased while others decreased (e.g. *Vulpia* replaced *Lolium*), 4) taxon-specific responses were consistent regardless of habitat, with *Lolium multiflorum* decreasing (>50% reduction with Mr), *Vulpia bromoides* increasing (especially with Mm), *Danthonia californica* increasing (especially with Mr), *Lasthenia glaberrima* and *Limnanthes vinculans* usually increasing (but never decreasing), thatch decreasing (either treatment), and others inconsistent (e.g. *Pleuropogon californicus, Juncus phaeocephalus, Eleocharis macrostachya*). Quadrat-based data also suggest that if a seed bank is present, the Mr treatment can increase the density and cover of vernal pool characteristic (VPC) species, especially *Lasthenia glaberrima* and to a lesser extent *Limnanthes vinculans*.

Therefore, this five-year study concludes that mowing with phytomass removal, even if done only one time a year (late spring, early summer), can improve the overall quality of vernal pool and coastal prairie vegetation of the Santa Rosa Vernal Reserve System. A program of regular treatment, perhaps operated as a large-scale, hay baling enterprise, could be used to shift cover from non-native to native and thus provide better habitat for VPC species. It should be considered as a practical surrogate to livestock grazing in a landscape that is rapidly transitioning from rural to suburban. Other treatments, such as controlled burns and hand-applied herbicides, are also beneficial and should be considered as essential, supplemental tools in an ecosystem enhancement or intensive care management regime. The question of who will coordinate and execute the regimes on SRVRS properties remains unresolved. Lack of consistent, long-term management is second only to rapid development as a threat to the conservation of vernal pools and their unique species on the Santa Rosa Plain.

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DEVELOPMENT OF THE SANTA ROSA VERNAL RESERVE SYSTEM.

VI. THIRD-YEAR RESPONSE OF MARGIN AND UPLAND HABITATS TO MOWING AND PHYTOMASS REMOVAL

Bruce M. Pavlik, Cassie Pinnell and Sarah Vroom

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. For example, 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 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.

This report describes the sixth and final phase of management experiments that had begun in 1999. It contains data on the third and fifth year responses to mowing and phytomass removal treatments within 90 permanent plots on the Santa Rosa Plain, emphasizing measurement of post-treatment vegetation responses to mowing with mulching (Mm) and mowing with phytomass removal (Mr). Point frames were used to document cover dominants, supplemented with quadrat-based estimates of absolute cover, density and frequency for vernal pool characteristic (VPC) taxa, including the federally-endangered *Limnanthes vinculans*. The objective is to detect shifts in plant cover from non-native to native (for dominant species) and from sparse to abundant (for rare species).

SUMMARY OF THESE MANAGEMENT EXPERIMENTS, 1998-2004

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 a 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 mulching (Mm) and mowing with phytomass removal (Mr). Mowing with phytomass removal (i.e. raking on a small scale, haying and baling on a large scale) could be a practical, potentially profitable management tool for improving native vegetation and water quality (through nitrogen removal) 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 phase (Pavlik et al. 2001) reported on the first full sampling of the 90 permanent plots (spring 2000) after a single treatment the year before (summer 1999).

There were several significant changes observed in the composition and structure of SRVRS vegetation in response to mowing with phytomass removal. 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. Some non-natives were significantly reduced (e.g. *Lolium multiflorum*), some natives enhanced (e.g. *Danthonia californica*), while others were unaffected (e.g. *Limnanthes vinculans*). The upland (coastal prairie) habitat appeared to respond more than the margin (vernal pool edge) habitat, but differences in initial conditions between properties (e.g. native cover, abundance of rare species) precluded strong, consistent patterns from emerging.

To detect the responses of rarer, unevenly distributed vernal pool characteristic (VPC) species (e.g. *Limnanthes vinculans, Lasthenia glabberima, Blennosperma bakeri*), a patch-intercept sampling method was designed and performed during May 2001 (Pavlik et al. 2003). No treatment effects were detected, indicating that cover by patches of VPC taxa had not become more extensive because of the first- or second-year (1999 or 2000) Mm or Mr treatments. We believed that low seasonal precipitation, combined with only two years of treatment, contributed to the lack of significant response of VPC taxa.

Other studies designed to test "intensive care" techniques for restoration of SRVRS properties were contained in the 2003 report. They determined that mowing was an ineffective form of control of teasel (*Dipsacus fullonum*) and fennel (*Foeniculum vulgare*), and it appears to compound the problem of teasel invasion by promoting germination. Therefore, mowing is not recommended as a management tool for reducing populations of these invasive plants. Fire was also found to be ineffective as most individuals began to resprout within 10 days post-burn. Control of teasel was achieved with hand application of a 0.75% solution of Rodeo® to rosettes and adults in at least three successive years. Fennel was very resistant to control by at Rodeo® at the concentrations tested, even though densities of large and small plants were almost halved when compared to control plots. Consequently, mechanical removal should be used on established plants, followed by hand application of a 1.50% solution of Rodeo® on subsequent resprouts. Pool bottoms heavily infested with pennyroyal (*Mentha pulegium*) can be treated with a hand application of a 1.50% solution of Rodeo® to achieve control. The application should be done in early fall, because most late flowering, pool bottom natives will have already set seed and senesced (e.g. *Eryngium aristulatum*) while pennyroyal remains active and susceptible. The high intensive fire that could not control teasel apparently had a strong, positive effect on the *Limnanthes vinculans* population along the margin of a large pool on the FEMA property. In the spring following the burn, which had only 69% of normal precipitation, the floral display in the burned area was both dense and extensive. Fire appears to be a 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.

During phase five of the management experiments (Pavlik et al. 2005a), we had repeated the VPC sampling technique in spring 2003 and initiated a demographic experiment in fall 2003 that was completed in spring 2004. Again, no consistent treatment effects were detected across all properties, indicating that cover by patches of VPC taxa had not become universally more extensive because of four consecutive years of Mm or Mr treatments (1999 through 2002). However, *Limnanthes vinculans* increased with both mowing treatments on the FEMA property (up to 5% cover compared to 0.7 % in control plots), while *Lasthenia glabberima* increased with Mr treatments on the Cramer and FEMA properties (14 to 30 %, compared to 5 to 9 % in control plots). Initial conditions (e.g. low abundance prior to first treatment) had a profound impact on comparisons between properties, with Haroutunian having entire swales (experimental blocks) devoid of VPC subpopulations during the five-year project. When propagules of *Limnanthes vinculans* were reintroduced into demographic plots within these swales, treatment effects emerged. These effects (enhanced germination, seed production) depended strongly on whether the swale had intact hydrology (with a long inundation period) that deterred seedling predation by the non-native slug *Derocereus reticulatum*. Slug predation decreased plant survivorship from 90% to 40% in swales with intact and altered hydrology, respectively. The Mr treatment, combined with short inundation period (due to altered drainage), may have promoted slug access to *Limnanthes* seedlings and subsequent high mortality. Although slugs were subsequently found at other SRVRS properties (e.g. Cramer), their overall impact on VPC taxa such as *L. vinculans* is unknown. No previous work on the vernal pools of Santa Rosa, or California for that matter, has identified slugs as a conservation concern or as a deterrent to restoration.

OPERATIONAL MODEL

Current efforts to preserve the vernal wetlands of the Santa Rosa Plain must compensate for the effects of fragmentation, degradation, and invasion on biological diversity, even after preserves have been established. For example, populations of *Limnanthes vinculans* and *Lasthenia burkei* have apparently declined by several orders of magnitude at the Todd Road Reserve (Figure 1 in Pavlik et al. 2000) 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.* 1994), 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). But these management techniques are becoming difficult to implement in a rapidly suburbanizing landscape. 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). Hence, we have chosen to investigate 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).

How will mowing affect changes in vegetation quality? Mowing with phytomass removal in late spring could favor perennial grasses in margin and upland habitats by collecting and removing a high proportion of this year's crop of annual grass and weed seed (e.g. *Lolium*). Perennial grasses will also be cut and have seeds removed, but established individuals should have improved growth and/or survivorship over the first summer (higher soil moisture) and next growing season (higher light, soil moisture).

Removal of phytomass could also lower available soil nitrogen, thus favoring species with high nitrogen-use efficiency (e.g. native perennial grasses) over species with low nitrogen-use efficiency (often non-native annuals, Claassen and Marler 1998). We speculate that more than a century of eutrophication has occurred across the Santa Rosa Plain because of agricultural inputs, sewage water discharge and atmospheric deposition. Transport of nutrients, especially nitrogen, by water would promote growth of plants with high nitrogen requirements (and low nitrogen-use efficiency). This could differentially affect pools, swales and their margins where non-native grasses invade and come to dominate in the absence of grazing. Depletion of nitrogen, either by removal with phytomass or promotion of denitrifying bacteria could possibly shift the "competitive balance" back towards a higher diversity of less aggressive plant species (Wedin and Tilman 1996, Choi and Pavlovic 1998). Lowering annual grass cover and competition in the upland could also allow the spread of native margin plants because adjacent soils would be relatively moister and the canopy more open. To the extent that annual grasses are also mowed in the upper part of the margin, direct competition with rare annuals such as *Limnanthes vinculans* and perennials, such as *Pleuropogon,* will be reduced and native plant growth could be improved. Removal of material that adds to the thatch and inhibits germination of annuals in the margins may also benefit the natives, but could possibly benefit annual weeds as well.

The mowing treatments attempt to indirectly manipulate soil nitrogen levels. We suppose that during the first year after mulching the germination of all annuals, both native and non-native could be inhibited, leading to a short-term decrease in *Limnanthes vinculans*, as well as *Avena, Lolium* and other non-native grasses. If the native seed bank is any more long-lived than that of the non-natives, the native seeds should persist. However, mulching will provide a readily decomposed, immediate carbon source for soil bacteria, including denitrifiers. The population of denitrifying bacteria should grow and effectively compete with the plants for available soil nitrogen and eventually release it to the atmosphere (Keller and Friese 1998). Thus, the soil should have reduced availability of nitrogen, putting annual plants in drier (e.g. upland) habitats at a disadvantage relative to perennials. This could eventually retard the growth of non-natives, and open the canopy to native perennials. If vernal pool characteristic (VPC) species, such as *Limnanthes vinculans* are adapted to more open, low-nitrogen soils, they should benefit from lower competition microsites that lack high nitrogen and aggressive non-native grasses.

We see a clear need for site-specific management prescriptions that mitigate the effects of fragmentation, disruption, degradation, and invasion, and thus enhance conditions that conserve native plant species richness and ecosystem integrity within the SRVRS. Our operational model attempts to link management techniques (e.g. mowing, mowing with phytomass removal) with ecosystem functions (e.g.

productivity, nitrogen availability) and the maintenance of biological diversity (e.g. population performance of rare plants, structure of natural vegetation).

METHODS AND MATERIALS

Third and Fifth-Year Results of the Primary Restoration Experiment: Effects of Mowing and Phytomass Removal on Vegetation Composition[1]

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

[1] All sections of the Methods and Materials for the years 2002 and 2004 are consistent with the Methods and Materials of the year 2000.

evenly distributed; *Limnanthes vinculans* (see Pavlik et al. 2000 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, altered 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). 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 large effort needed to perform the sampling, mowing, and raking, we decided to use five blocks per property (15 total), each consisting of 2 habitat sub-blocks. 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 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.

The start location for establishing a block *in situ* used a 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). During fieldwork in mid-April 1999, a marking stake was established by blindly tossing a survey arrow behind the back within the pre-determined quarter. From the arrow a path perpendicular to the pool/swale margin was established (Figure 1). 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. A meter tape pulled parallel to the margin for 90 meters delineated the pool margin strip (= sub-block) 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 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. 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 evenness 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.

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, Vulpia bromoides* and *Bromus hordeaceus*) and natives (e.g. *Danthonia californica*).

All field assistants received advanced training or had expertise in the identification of plants and vegetation sampling (see Appendix A). 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.

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 (50 or 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 colored flags to carefully 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) 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 scientific 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 25 x 25cm pvc quadrat was used to provide additional information on their density and cover. If there were only a few, scattered VPC individuals inside the quadrat, all were counted and total % cover was visually estimated 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 in the spring of 2002 and 2004 (3 properties X 5 blocks/property X 2 habitats/block X 3 plots/habitat X 20 subsamples/plot X 10 pin hits/subsample. Field sampling occurred at the apparent peak of vegetative growth and during maximum floral display of most plant taxa. 5

teams sampled Haroutunian in two full days (16-17 May), Cramer by 6 teams in 3 days (21-23 May) and FEMA by 6 teams in 3 days (24-25 May), for a total of 688 person-hours in the field.

Data Handling and Analysis

The data handling and analysis methods for 2002 and 2004 were consistent with those used in 2000.

A relational database for the Santa Rosa Vernal Reserve System was constructed to hold vegetation and rare plant data gathered with the pin-point sampling method. Based on this sampling method, the database was constructed to record each hit separately by using the four letter taxon name abbreviation. A data entry form mirrored the field data sheets to simplify data-entry. It took a team of two people approximately 30 hours each to enter and quality check the data.

The database was designed using Microsoft Access to reduce repetitive entry and storage of complex information. Access employs multiple, single topic tables that can be linked to create data entry forms, complex queries, and allows for additional fields to be added to the database in the future. The database currently contains eight separate tables of which only two contain field data. The other six are "look-up tables" used to track characteristics of each species, site, pool, and property. The two data entry tables are for cover (TBLCOVER) and density (TBLDENSITY). The six look-up tables include habitat (TBLKHABITAT), pool (TBLKPOOL), property (TBLKPROP), species (TBLKSPECIES), treatment (TBLTREAT), and location (TBLLOCATION).

We queried the database for data summaries by asking for pin hits of species stratified according to property, block, habitat, and treatment. This "first cut" would allow computation of live relative cover (% of 200 total hits, Mueller-Dombois and Ellenberg 1973) for a given species in each of the 90 permanent plots (e.g. % cover by *Limnanthes vinculans* in the Mr plot of the margin habitat in block 2 at Cramer). The measurement of live relative cover (referred to as "cover" in this report) using a point frame is widely regarded as the most consistent and objective method available (Barbour et al. 1980). Species richness was determined by tallying the number of taxa per site or habitat regardless of how many pin hits each represented. Often the point frame method might not detect low-growing and extremely sparse taxa that are recorded in ocular quadrats by observant field botanists. Therefore, we distinguish species richness estimates from point frame data as SR_d (species richness by canopy dominants). Both cover and SR_d data were exported into Microsoft Excel for statistical analysis by creating a "worksheet" for each property. We also entered the quadrat data for density, absolute cover (live) and frequency data for VPC's and calculated another set of abundance indicators.

The stratified analysis presented in this report never combines data from different habitats. Properties are kept separate because each has different initial vegetation and hydrological features (see above) that would result in differential responses to treatment. This is also true for blocks within each property, some of which lack seed banks of target species (e.g. *Limnanthes vinculans*) and could not be expected to produce target species cover within the first year regardless of treatment (i.e. dispersal is limiting). Therefore, the probability of having a statistically-significant, across-property response to treatment, or even a significant across-block response is low at this early stage of our restoration experiment. We believe that similar trends within and between properties constitute some evidence of treatment effects and so the analysis and display of this first-year data will emphasize the search for such trends. It begins with 1) species richness of canopy dominants, then 2) determines the proportion of canopy cover that is contributed by native taxa (a measure of vegetation quality), 3) further divides cover into four "management guilds" (non-native graminoids, non-native forbs, native graminoids and native forbs), 4) displays the cover by taxon (the 14 taxa that contribute >80% of the total relative cover), and 5) ends with the quadrat-based estimations of density, absolute cover, and frequency by VPC taxa.

RESULTS 2002 (Third Year)

Dominant Species Richness

Dominant species richness (SRd) was not statistically different between the pool margin and upland plots for 2002 (Table 1), both averaging about 13 taxa/plot, varying only slightly between treatments. In the margin plots there was no consistent effect of either treatment (Mm or Mr). However, in the upland plots there was a non-significant trend of increasing SRd (Co to Mm to Mr).

In 2002, a total of 58 taxa were recorded by pin hits in the margin habitat (32 native (55%)), compared to 53 taxa (25 native (47%)) in the upland plots (for all three properties combined, see Appendix C).

Canopy Cover by Native Taxa (Vegetation Quality)

Native taxa represented an average of 64% of the cover in margin plots (Table 2) and 28% in upland plots on the three properties. Margin and upland plots both showed a trend of positive responses to treatments when all three properties were combined. Margin Mr plots averaged 24% more native cover than control plots, while margin Mm plot averaged 2% more native cover than Co plots. Upland Mr plots averaged 49% more native cover than Co when all three properties were combined, and upland Mm plots averaged 44% more native cover than Co.

When properties were considered separately, pool margins at Cramer had the highest native cover, but showed the least response to treatments. However, the uplands at Cramer showed the greatest response to treatment, where native cover was increased by 44% by mowing (Mm) and 60% by mowing and raking (Mr). FEMA margin plots showed the highest response to treatments of all the margin plots. Native cover was increased by 23% by mowing (Mm), and 55% by mowing and raking (Mr). FEMA uplands also responded to treatment, with a 45% more natives at both Mm and Mr plots, as compared to control plots.

Haroutunian plots showed a less consistent trend, with a reduction of native cover by 15% at margin Mm plots, but an increase of 27% at margin Mr plots. Haroutunian upland plots showed an increase of native cover by 40% at Mm plots and an increase of 30% at Mr plots.

Analysis by Management Guild

Grouping the 15 most dominant taxa from each habitat into four "management guilds" allows a non-specific analysis of treatment effects. These management guilds include: non-native graminoid, non-native forb, native graminoid, and native forb. In 2002, the "native graminoid" guild contributed the largest proportion (36-60%) of the margin habitat at Cramer and FEMA properties (Table 3). This guild was dominated by mostly *Pleuropogon californicus*. The "non-native graminoid" guild contributed only (14-32%) at Cramer and FEMA. However, the non-native graminoid guild contributed the most cover of the margin habitat at Haroutunian (30-44%). This guild was dominated by *Lolium multiflorum* and *Vulpia bromoides*[2], which covered from 34-120% more than the native graminoid guild (20-25%) at this property. The native forb guild covered only 2-13% at all three properties, and the non-native forb guild covered 1-6%.

FEMA was the only property that showed consistent treatment effects, with native graminoids increasing from 36% at the control (Co) plots to 60% at the mowing with phytomass removal (Mr) plots, non-native graminoids decreasing from 27% at Co to 14% at the Mr, and native forbs increasing from 5% at Co to 13% at Mr. At Cramer, the percent cover of non-native graminoids and native graminoids did not differ significantly between Co and Mr plots. However, the percent cover of native forbs nearly doubled from 6% in Co plots to 11% in Mr plots. At Haroutunian the percent cover of non-native graminoids decreased from 37% at Co to 30% at Mr plots, however, no trends were observed within the other guilds.

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[2] *Vulpia bromoides* was recorded as both *Vulpia octoflora* (native graminoid) and *Vulpia myuros* (non-native graminoid) in the 2000 data. We have subsequently correct the mistake in this report.

The upland habitat of all three properties was dominated by the non-native graminoid guild (41-83%) due to large contributions of *L. multiflorum* and *Vulpia bromoides*. Native graminoids contributed no more than 5% at all three properties. Non-native forbs at Cramer and Haroutunian contributed only 1-6%, however at FEMA they shared 32-37% of the cover. Native forbs contributed less than 5% of cover at all three properties. Management guilds of the upland habitat did not show consistent responses to treatment. However, the non-native graminoids did display weak trends of decrease with mowing and phytomass removal (Mr) at FEMA (45% at Co to 41% at Mr) and Haroutunian (83% at Co to 78% at Mr). Native graminoids showed a trend of increase with treatment at Cramer (1% at Co to 3% at Mr). There was no consistent, or statistically significant, trend of damage to native graminoid populations at any of the properties.

<u>Taxon-Specific Responses</u>

Margin Habitat

In the 2002, the main responses to treatment within the margin habitat were observed within the non-native graminoid guild. *Lolium multiflorum* showed a decrease with treatment at both FEMA and Haroutunian properties (no trend was observed at Cramer which had a low *L. multiflorum* cover in all plots). At both properties, the cover of *L. multiflorum* was reduced by about 50%, from a 23 to 29% mean cover in Co plots to a 11-12% mean cover in Mr plots (Table 4). At all three properties the lower growing non-native graminoid, *Vulpia bromoides*, showed a 17-200% increase with treatment (maximum of 16% mean cover). On both Cramer and FEMA, *V. bromoides* responded more strongly to Mm than Mr treatment, indicating that mulching favored this non-native.

At FEMA, the native graminoid *Pleuropogon californicus* showed a positive response to treatments, shifting from 18% mean cover in Co plots to 36% mean cover in Mr plots. The populations appeared unaffected by treatment at Haroutunian, and a non-significant trend of decrease from 37% in Co plots to 31% in Mr plots at Cramer.

Within the native forb guild, *Lasthenia glabberima* showed a positive response to treatment at all three properties, though the strongest response was shown at FEMA and Cramer properties ranging from 2-3% mean cover in Co plots to 5% mean cover in Mr plots. *Limnanthes vinculans* also showed a trend of increase at Cramer, from 3% mean cover in Co plots to 5% mean cover in Mr plots. None of the native forb populations showed a significantly negative response to treatments.

Thatch cover declined at all three properties with treatment, ranging from 5-10% in Co plots to 1-3% in Mr plots.

Upland Habitat

Within the upland habitat, some of the most dramatic taxon-specific responses occurred within the non-native graminoid guild. Mean cover of *Lolium multiflorum* reduced with treatment at Cramer and Haroutunian, from 26% mean cover in Co plots to 11% mean cover in Mr plots. No trend was observed at FEMA. Mean cover of *Vulpia bromoides* increased with treatment at all three properties, but responded more strongly to Mm than to Mr treatments. Mean cover of *V. bromoides* shifted from 15% in Co plots to 26% in Mm plots. *L. multiflorum* and *V. bromoides* contributed more than

50% of cover within the non-native graminoid guild, with the exception of Haroutunian, which had more *Bromus*. Other non-native graminoids, including *Bromus hordeceus* and *Bromus diandrus,* contributed more than 30% of cover at Haroutunian, showed a trend of decrease with treatment (Table 4).

Within the native graminoid guild, *Danthonia californica,* showed a trend of increase with treatment at Cramer and FEMA. *Hordeum brachyantherum* showed no response to treatment. Native forb taxa did not noticeably respond to treatment, nor did the non-native forbs. There was no significant, or consistent, decrease of native taxa percent cover with treatment. Thatch cover dropped with treatment, ranging from 4-14% in Control plots to 0.4-2% in Mr plots.

RESULTS 2004 (Fifth Year)

Dominant Species Richness

In 2004, SRd was greatest in pool margin plots (Table 5), averaging 13 taxa/plot. Margin Mm and Mr plots showed a significantly higher species richness than Co plots, both averaging 14 taxa/plot, as compared to 11 taxa/plot per Co plots. For all three properties, species richness increased with treatment in the margin plots, though there was no significant difference between mowing (Mm) and mowing with raking (Mr) treatment plots. In the upland plots the average species richness was 11 taxa/plot. For all three properties, there was no significant increase with treatment.

In 2004, 64 taxa were recorded in the margin plots (29 were native (45%)), compared to 54 taxa in the upland plots (24 native (44%)). (For all three properties combined see Appendix D).

Canopy Cover by Native Taxa (Vegetation Quality)

Native taxa contributed an average of 42% cover in the margin plots, and 6% in the upland plots when all three properties were combined. Native cover increased in margin plots with treatment. When values for all three properties were combined, margin plots with mowing and mulching (Mm) averaged 8% more native cover than control plots. Margin plots with mowing and phytomass removal (Mr) averaged 43% more native cover than control plots. Upland plots did not show any increase of native taxa cover with treatment. When all three properties were combined, native cover decreased by 44% in upland Mm plots, and by 32% in upland Mr plots.

When properties were considered separately, FEMA margin plots showed the most positive response to treatment, with Mm plots having a 13% increase and Mr plots showing a 56% increase of native cover. Haroutunian also showed a noticeable increase of 63% more native cover than margin Control plots at both Mm and Mr plots. None of the properties showed a consistent increase with treatment at the upland plots, however, at each property the Mr plots had higher native cover than the Mm plots.

Analysis by Management Guild

Grouping the 15 most dominant taxa from each habitat into four "management guilds" allows a non-specific analysis of treatment effects. These management guilds include: non-native graminoid, non-native forb, native graminoid, and native forb. In 2004, the non-native graminoid guild was dominated by *Lolium multiflorum* and *Vulpia* *bromoides.* This guild contributed the highest percentage of cover (40-56%) in both the control (Co) and in the mowing with mulching (Mm) margin plots at all three properties. However, the native graminoid guild contributed the highest percentage of cover (36-38%) in the Cramer and FEMA mowing with phytomass removal (Mr) plots. This guild was dominated by *Pleuropogon californicus.*

For all three properties, there was a significant decrease of non-native graminoid cover with treatment, with percent cover ranging from 44-56%% in Co plots to 25-30% in Mr plots. The only property that showed a trend of increase in native graminoids with treatment was FEMA, where this guild shifted slightly from an average of 29% in Co plots to 36% in Mr plots. There was no significant trend of treatment effects on native graminoids at Cramer and Haroutunian. Non-native forbs contributed 2-8% of cover at all three properties. This guild showed a trend of decrease with treatment at both Cramer and FEMA properties. The native forb guild contributed 2-16% at all three properties. This guild showed an increase with treatment at all three properties, with the strongest increase at FEMA from an average of 5% at Co plots to 16% at Mr plots.

In upland plots, the non-native graminoid guild, dominated by mainly *L. multiflorum* and *Vulpia bromoides* contributed the majority of cover at all three properties (57-90%). All other guilds contributed less than 5% at all three properties (the remaining cover being mostly thatch or bare ground). There were no consistent treatment effects at the guild-level in the upland plots.

Taxon-Specific Responses

Margin Habitat

In 2004, the margin non-native graminoid guild was dominated by *Lolium multiflorum* and *Vulpia bromoides* (Table 8). Mean percent cover of *L. multiflorum* decreased with treatment. The most significant decrease was observed at Cramer property, from 35% at Control plots to 12% at Mr plots. A similar but weaker trend was observed at both FEMA, (44% in Co to 32% in Mr), and Haroutunian plots (31% in Co and 25% in Mr). The response of the shorter grass, *Vulpia bromoides,* to treatment was less consistent. Mean percent cover increased with treatment at Cramer, remained the same at FEMA, and decreased at Haroutunian.

The margin native graminoid guild was dominated by *Pleuropogon californicus*, which did not show a response to treatment. The other native graminoid taxa, mainly *Juncus phaeocephalus* and *Eleocharus macrostachya*, contributed less than 10% of the mean percent cover, and did not show consistent responses to treatment.

The taxa of the margin non-native forb guild each contributed less than 5% cover to the plots. Within that small representation, *Rumex crispus,* showed a non-significant trend of decrease with treatment at Cramer and Haroutunian. *Dipsacus fullonum* was only observed at FEMA plots. At that property it showed a trend of decrease with treatment.

Within the margin native forb guild, *Eryngium aristulatum* showed a trend of increase with treatment at all three properties. *Lasthenia glaberrima* showed a strong response to treatment at all three properties, increasing mean percent cover from less

... 1-3% at Mm plots, and 1-8% at Mr plots. Neither *Limnanthes*

th... of *Downingia concolor* showed any consistent responses to treatments.

Upland Habitat

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than 1% at Co plots, to 1-3% at Mm plots, and 1-8% at Mr plots. Neither *Limnanthes vinculans* nor *Downingia concolor* showed any consistent responses to treatments.

Upland Habitat

The 2004 non-native graminoid guild in the upland habitat was comprised mainly of *Lolium multiflorum* and *Vulpia bromoides* (Table 8). On all three properties, mean percent cover of *L. multiflorum* decreased with treatment (17-55% in Co to 2-49% in Mr). Mean percent cover of *V. bromoides* appeared to respond positively to the Mm treatment (9-26% in Co and 13-54% in Mm), and responded positively (though less) to Mr treatments (9-55%). Other taxa with a mean percent cover over 10% included *Avena barbata, Bromus hordeaceus,* and *Bromus diandrus.* Of these three, *A. barbata* was the only taxa to respond positively on all three properties to treatment, and appeared to benefit most from Mm treatment (1-6% in Co, 13-44% in Mm, 3-39% in Mr). *B. diandrus* showed a trend of decrease in response to treatment (3-29% in Co, 5-18% in Mm,2-15% in Mr). *B. hordeaceus* did not show a consistent response to treatment.

The upland native graminoid guild in 2004 was comprised mainly of *Danthonia californicus* and *Hordeum brachyantherum*. Both of these taxa had less than 5% mean cover on all three properties. *D. californicus* showed a positive response to treatment, though on some properties did better with Mm than Mr (0-0.4% in Co, 0.5-4% in Mm, 1.2-1.8% in Mr). *H. brachyantherum* did not show a consistent response to treatment.

The 2004 upland non-native forb guild taxa each contributed less than 3% mean cover. The only taxa to suggest a response to treatment was *Vicia sativa*, which had a general trend of decline with treatment (0.1-1.4% in Co, 0.1-1% in Mm, 0-0.5% in Mr).

The 2004 upland native forb guild taxa each contributed less than 2% mean cover, and did not show any consistent response to treatment.

Thatch cover showed a trend of decline with treatment (1-5% in Co, 0.5-1% in Mm, 0-2% in Mr).

Quadrat-based Assessments of VPC Taxa

Although the quadrat-based responses of VPC taxa were statistically insignificant in 2004 (Table 9), there were positive trends observed when density and cover data were compared to those measured in 2000 (after only one year of treatment). In some treated plots that had been completely devoid of *Limnanthes vinculans* when treatments began in 1999 (e.g. Cramer Block 1), densities of 62 to 100 plants/m2 were observed in mowed plots (slightly higher in Mr). At the same time, no plants were observed in the control. A similar pattern was observed for *Lasthenia glabberima* (e.g. Cramer Block 4), in which density rose from 0 in 2000 to at least 90 plants/m2 in 2004. Control density declined from 20 plants/m2 to 0 during the same time period. In these cases, it is most likely that treatment improved conditions for germination and establishment of plants from an existing, quiescent seed bank.

If data from the three properties are combined, then significant improvements in the density and cover of *Limnanthes vinculans* and *Lasthenia glabberima* were twice as liked to occur in treated plots (either Mm or Mr) compared to control plots. To compensate for the lack of a seedbank during the five years of the project, plots in swales that had no plants of either species (21 and 12, respectively) were excluded from the analysis. Of the 24 margin plots in swales with *Limnanthes vinculans*, 50% showed a significant increase (2004 vs. 2000) if mowed, compared to 12% for controls. The improvement in control plots was presumably due to changes in other variables (e.g. rainfall, decreased predation). Of the 33 margin plots in swales with *Lasthenia glabberima*, 33% showed a significant increase (2004 vs. 2000) if mowed, compared to 6% for controls.

DISCUSSION

The average dominant species richness (SRd) for all three properties showed a trend of increase with treatment in both upland and margin, for both 2002 and 2004. In the upland habitat, the Mr plots had a higher SRd than either Mm or Co. In the margin plots there was not a noticeable difference between the Mm and Mr treatments, but both were higher than Co. This implies that treatment does not reduce dominant species richness, and may contribute to an increased species richness. Across all three properties, a total of 61 taxa registered hits in the margin and 56 in the upland for 2002 (after 3 years of treatment). In 2004 (5 years of treatment), 66 taxa registered hits in the margin and 54 in the upland. Both of these years show an increase from 2000 (1 year of treatment), in which only 49 taxa registered hits in the margin and 40 in the upland. In 2004, the number of taxa registered showed a trend of increase with treatment, showing a total of 64 taxa in Co plots, to 67 in Mm plots to 68 in Mr plots (for margin and upland combined).

When plant cover was analyzed by overall quality (percent native cover) the results suggested significant treatment effects. Throughout the five years of treatment, the margin plots showed a significant increase in percent native cover.
After one year of treatment (2000), native cover in Co margin plots was not significantly different than that in Mm or Mr plots. However, after three years of treatment (2002), the mean percent cover of native plants across all three properties increased by 25% with treatment (Co compared to Mr) in the margin habitat. After the fifth year of treatment (2004), margin habitat Mr plots had a 43% higher native cover than Co. All Mm treated plots had a percent native cover between the Co and Mr plots.

The upland plots showed an increase after three years of treatment, but exhibited a decrease after the fifth year. After one year of treatment, native cover in Co plots was not significantly different than that in Mm or Mr plots. However, after three years of treatment (2002), the mean percent cover of native plants across all three properties increased by 49% with treatment (Co to Mr) in the upland habitat. After the fifth year of treatment (2004), the Mr plots had a 32% lower percent native cover than Co plots. With the exception of the 2004 upland plots, all Mm treated plots had a percent native cover ranging between the Co and Mr plots. The 2004 upland response could be the result of an ecological response to environmental factors outside of the parameters of the experiment (i.e. promoted by differences in temperature patterns or hydrology), which are suggested by the universally low percent cover of native upland plants on all three properties, regardless of treatment (mean $<10\%$ in 2004, as compared to mean $> 20\%$ in 2002). Overall, the results of the experiment indicate that mowing with phytomass removal increases percent cover of native plants in both upland and margin habitats.

When the percent cover was analyzed by management guild (non-native graminoids, native graminoids, non-native forbs, and native forbs), the results from 2002 and 2004 suggest that mowing with phytomass removal can significantly reduce non-native cover in the margin plots, but may have less of an impact on upland plots. Native cover increased with Mr treatment at FEMA throughout the five years of treatment, though the other two properties showed a less strong response. Results did not indicate clear trends in the upland plots at any properties. This is partly due to the increase of non-native *Vulpia bromoides*, which seemed to compensate for the decrease in cover by non-native *Lolium multiflorum*.

Taxon-specific responses to treatment were best observed within the non-native graminoid guild. *Lolium multiflorum* decreased significantly with treatment across all three properties in both habitats. This decrease was accompanied by an increase in non-native graminoid *Vulpia bromoides* with treatment. *V. bromoides* is a shorter grass than *L. multiflorum*, it produces less thatch and may be less of an inhibitor to other native plants than *L. multiflorum*).

Native graminoids such as *Pleuropogon californicus* and *Danthonia californica* showed some trends of increase, though the responses were not significant in 2004 as they had been in previous years. There were no significant negative impacts of treatment observed on native taxa.

Some VPC taxa responded consistently to treatment while others did not. *Lasthenia glabberima* increased significantly after three years of treatment (2002) in plots where it had already been present and continued to respond well after five years of treatment (2004). *Limnanthes vinculans* did not demonstrate as strong of a response to treatment, though it either showed a trend of increase or no response at all. The lack of response to treatment could be due to an insufficient or non-existent seed bank in almost half of all margin plots (21/45). The reintroduction of *L. vinculans* seeds to the Haroutunian property in 2003 (Pavlik et al 2005) demonstrated that treated plots in hydrologically intact pools had a 10% higher rate of germination than control plots. This reinforces the argument that the lack of VPC response to treatments has more to do with the lack of a seed bank than the lack of a beneficial effect of those treatments. Furthermore, no significant negative treatment effects were ever observed on any VPC taxa. The significant response of *L. glabberima* and the improved germination of reintroduced seeds of *L. vinculans* suggest that mowing with phytomass removal has beneficial effects on VPC taxa.

SUMMARY AND MANAGEMENT RECOMMENDATIONS

Attempts to restore native vegetation and populations of rare and endangered vernal pool plants on the Santa Rosa Plain must accept a large number of uncontrollable variables that will ultimately determine the strength, direction and rate of improvements. These include annual variations in precipitation and temperature, differences in the initial condition of the vegetation and populations among properties, species-specific responses that may not be concordant (e.g. what is beneficial to one is detrimental to another) and unanticipated outcomes that stem from our imperfect knowledge of the ecosystem and its component species.

Although one of the years of this project had above normal rainfall (35.1 inches in 2003, compared to the 30.7 inch average), all other years were at or below normal (29.9" in 2000, 20.6" in 2001, 31.1" in 2002, and 29.4" in 2004). Below normal precipitation favors upland species that would normally be excluded from pool margins, especially as the period of inundation is contracted in late winter and early spring. Some lack of treatment effects would thus be expected, especially for vernal pool characteristic (VPC) species during years with unfavorable hydrology.

The effects of initial conditions, especially variations in vegetation composition and VPC seed bank size among properties would also determine the observed responses to treatment. Some of the swales chosen for installation of experimental blocks never produced plants of some species, including *Limnanthes vinculans* and *Lasthenia glaberrima*. Native graminoids were very unevenly distributed, if at all present, especially where heavy livestock grazing or plowing had historically occurred (e.g. north Cramer, north Haroutunian). When reintroduced to vacant swales at Haroutunian (Pavlik et al. 2005), seeds of *L. vinculans* germinated well and eventually produced abundant seeds (especially in Mr treated plots). Therefore, improvements to habitat quality made by mowing with phytomass removal should precede inoculation with seeds of VPC taxa.

Not all species, even those in the same management guild, responded the same with respect to treatment. For example, the annual non-native *Lolium multiflorum* was strongly inhibited regardless of treatment, habitat or property (Table 10). However, the annual non-native *Vulpia bromoides* and *Avena barbata* both responded favorably, with the latter species strongly promoted in the upland habitat.

Therefore, to reduce *Lolium* with mowing is to accept increases in these two species. Fortunately, only *Lolium* is likely to be in pool margins and bottoms (Pavlik et al. 2000 Tables 4 and 9), so that focusing treatment on these habitats will minimize this particular trade-off. Some VPC taxa appeared to be strongly promoted by mowing with phytomass removal in the margin habitat (e.g. *Lasthenia glabberima* and *Eryngium artistulatum*), while others were either neutral or weakly promoted (*Limnanthes vinculans*). Some of the weakness, however, may be due to a depleted or non-existent seedbank, as discussed above. A rather large number of species were unaffected by either treatment during the project. Some of these are native (e.g. *Pleuropogon californicus*) that will, fortunately, persist while others are non-native (e.g. *Dipsacus fullonum, Mentha pulegium*) that will, unfortunately, persist. Other intensive care tools (e.g. herbicide or hand removal) will need to be applied to remove the latter (Pavlik et a. 2003).

There were surprises that arose during the course of this project, some pleasant, others not so. For example, the rapid responses of *Lolium multiflorum* and *Danthonia californica* after only one year of treatment (Pavlik et al. 2001) were unanticipated, and foreshadowed patterns we would see throughout the project. But the slow and equivocal response of the primary target species, *Limnanthes vinculans*, was disappointing. Some of this was due to low precipitation and strong differences in initial conditions among plots (see above), but still there seemed to be some other constraints on the response of this taxon that could not simply be due to habitat quality. Perhaps high rates of slug predation (Pavlik et al. 2005), yet another unpleasant surprise, impose strong limits on population growth that have yet to be evaluated in most swales and pools of the Santa Rosa Plain. Such unexpected results will require an ongoing program of adaptive management of SRVRS properties in order to be addressed, mitigated for, and overcome. Without it, these properties will slowly loose the species and ecosystem features that inspired acquisition for conservation purposes.

Nevertheless, after five years of treatment the results of this management experiment suggest that mowing with phytomass removal significantly decreases cover of the very invasive, non-native *Lolium multiflorum* in both margin and upland habitats, as well as increases cover of some native graminoids and forbs in either habitat. Specifically, over the period 2000 to 2004; 1) dominant species richness was unaffected by either Mm or Mr treatments, 2) vegetation quality improved (i.e. shifted towards natives) in the margin habitat by 24 to 43% with Mr treatment relative to controls (Mm effects were insignificant) and either improvement or degradation observed in the upland habitat (depending on year), 3) there were no consistent shifts in guilds with treatment in either habitat (in part because some non-native graminoids increased while others decreased (e.g. *Vulpia* replaced *Lolium*), 4) taxon-specific responses were consistent regardless of habitat, with *Lolium multiflorum* decreasing (>50% reduction with Mr), *Vulpia bromoides* increasing (especially with Mm), *Danthonia californica* increasing (especially with Mr), *Lasthenia glaberrima* and *Limnanthes vinculans* usually increasing (but never decreasing), thatch decreasing (either treatment), and other species inconsistent (e.g. *Pleuropogon californicus, Juncus phaeocephalus, Eleocharis macrostachya*). Quadrat-based data also suggest that if a seed bank is present, the Mr treatment can increase the density and cover of vernal pool characteristic (VPC) species, especially *Lasthenia glaberrima* and to a lesser extent *Limnanthes vinculans*.

Therefore, this five-year study concludes that mowing with phytomass removal (Mr), even if done only one time a year, can improve the overall quality of vernal pool and coastal prairie vegetation of the Santa Rosa Vernal Reserve System. A program of regular treatment, perhaps operated as a large-scale, hay baling enterprise, could be used to shift cover from non-native to native and thus provide better habitat for VPC species. It should be considered as a practical surrogate to livestock grazing in a landscape that is rapidly transitioning from rural to suburban. Other treatments, such as controlled burns and hand-applied herbicides, are also beneficial and should be considered as essential, supplemental tools in an ecosystem enhancement or intensive care management regime. The question of who will coordinate and execute the regimes on SRVRS properties remains unresolved. Lack of consistent, long-term management is second only to rapid development as a threat to the conservation of vernal pools and their unique species on the Santa Rosa Plain.

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Table 1. Dominant species richness (SRd) within two habitats (margin and upland) on three properties (Cramer, FEMA and Haroutunian) of the SRVRS, May 2002 Treatments (Con, Mr, Mm) were made in June and July, 1999 through 2001. Mean and standard errors shown (n=5, 1000 pin hits), all = properties combined for each treatment (n=15, 3000 hits).

margin

	Cramer	SE	**FEMA**	SE	**Hart**	SE	**All**	SE
control	10.2	1.4	13.0	1.4	13.2	2.4	12.1	1.0
Mm	13.4	0.9	13.8	1.6	14.0	1.8	13.7	0.8
Mr	14.6	1.9	11.2	1.2	13.2	1.8	13.0	1.0

upland

	Cramer	SE	**FEMA**	SE	**Hart**	SE	**All**	SE
control	9.6	0.9	14.0	1.9	11.0	2.1	11.0	1.0
Mm	10.0	0.5	13.4	1.3	12.8	2.2	12.1	0.9
Mr	12.4	1.3	14.8	1.2	13.0	1.7	13.4	0.8

Table 2. Vegetation quality (% native cover) within two habitats (margin and upland) on three properties (Cramer, FEMA and Haroutunian) of the SRVRS, May 2002. Treatments (control, Mm, Mr) were made in June and July, 1999 through 2001. Mean and standard errors shown (n=5, 1000 pin hits). All = properties combined for each treatment (n=15, 3000 hits). C+H = Cramer and Haroutunian combined for each treatment (N=10, 2000 hits).

margin

		Cramer	SE	**FEMA**	SE	**Hart**	SE	**All**	SE	**C+H**	SE
control											
	% native	71.2	15.5	53.1	10.2	51.8	11.1	58.7	6.3	61.5	9.7
Mm											
	% native	69.7	5.8	65.5	10.2	45.0	4.6	60.1	7.6	57.4	12.4
Mr											
	% native	70.7	3.8	82.2	6.2	65.9	10.9	72.9	4.8	68.3	2.4

upland

		Cramer	SE	**FEMA**	SE	**Hart**	SE	**All**	SE	**C+H**	SE
control											
	% native	32.8	7.9	16.5	4.5	15.5	4.5	21.6	5.6	24.2	8.6
Mm											
	% native	47.2	6.0	24.2	7.6	21.7	4.4	31.0	8.1	34.5	12.7
Mr											
	% native	52.5	6.3	24.0	7.9	20.2	3.2	32.2	10.2	36.3	16.1

Table 3. Cover (%) by management guilds within two habitats (margin and upland) on three properties (Cramer, FEMA and Haroutunian) of the SRVRS, May 2002. Mean are shown (n=5, 1000 pin hits).

margin

	Cramer	FEMA	Hart
control			
% non-native graminoid	22.3	26.8	36.7
% non-native forb	1.7	5.7	1.6
% native graminoid	44.9	35.9	25.2
% native forb	5.6	4.9	8.0
Mm			
% non-native graminoid	31.5	24.9	44.2
% non-native forb	2.4	2.5	1.5
% native graminoid	43.0	45.3	19.7
% native forb	6.7	8.6	2.3
Mr			
% non-native graminoid	24.4	13.9	29.6
% non-native forb	3.1	3.1	0.6
% native graminoid	40.5	60.3	22.9
% native forb	11.5	13.0	9.0

upland

	Cramer	FEMA	Hart
control			
% non-native graminoid	63.3	45.2	83.1
% non-native forb	4.5	36.5	2.6
% native graminoid	1.2	0.0	2.9
% native forb	0.5	2.5	0.0
Mm			
% non-native graminoid	78.0	49.2	83.1
% non-native forb	2.1	34.3	6.2
% native graminoid	2.9	2.5	5.0
% native forb	0.1	1.8	0.0
Mr			
% non-native graminoid	65.5	41.4	78.3
% non-native forb	1.2	32.4	2.3
% native graminoid	2.9	0.7	2.5
% native forb	0.3	0.7	0.0

Table 4. Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA, and Haroutunian) of the SRVRS, May 2002. Means and SE are shown (n=5, 1000 pin hits).

Margin Control	**Cramer**	SE	**FEMA**	SE	**Haroutunian**	SE
Non-Native Graminoid						
Hordeum marinum	0.9	0.6	0.3	0.2	6.3	1.9
Lolium multiflorum	9.7	5.1	24.7	5.9	22.6	5.8
Polypogon maritimus	0.0	0.0	0.0	0.0	0.0	0.0
Vulpia bromoides	11.7	4.9	1.8	1.4	7.8	3.3
Non-Native Forb						
Convolvulus arvensis	0.6	0.5	0.4	0.4	0.4	0.2
Dipsacus fullonum	0.0	0.0	2.0	0.9	0.0	0.0
Mentha pulegium	0.7	0.5	1.0	0.8	0.0	0.0
Rumex crispus	0.4	0.3	1.3	0.5	1.2	1.0
Native Graminoid						
Eleocharus macrostachya	2.5	1.3	4.8	3.1	2.0	12.0
Juncus phaocephalus	5.5	2.3	12.8	5.7	1.3	0.6
Pleuropogon californicus	36.9	11.1	18.3	8.2	21.9	9.0
Native Forb						
Downingia concolor	0.0	0.0	0.1	0.1	0.1	0.1
Eryngium aristulatum	0.9	0.9	1.7	0.9	2.5	1.5
Lasthenia glabberima	1.6	0.9	0.8	0.7	5.4	4.7
Limnanthes vinculans	3.1	0.9	2.3	2.3	0.0	0.0
Thatch	9.8	1.6	8.9	1.7	5.1	1.7

Table 4 (cont.). Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA, and Haroutunian) of the SRVRS, May 2002. Means and SE are shown (n=5, 1000 pin hits).

Margin Mm	**Cramer**	SE	**FEMA**	SE	**Haroutunian**	SE
Non-Native Graminoid						
Hordeum marinum	0.9	0.5	0.1	0.1	4.7	2.8
Lolium multiflorum	14.3	3.4	19.7	5.4	28.8	8.4
Polypogon maritimus	0.0	0.0	0.0	0.0	0.0	0.0
Vulpia bromoides	16.3	5.6	5.1	2.4	10.7	3.1
Non-Native Forb						
Convolvulus arvensis	1.9	1.9	0.4	0.4	0.9	0.5
Dipsacus fullonum	0.0	0.0	0.7	0.7	0.0	0.0
Mentha pulegium	0.2	0.2	0.8	0.7	0.0	0.0
Rumex crispus	0.3	0.1	0.6	0.4	0.6	0.3
Native Graminoid						
Eleocharus macrostachya	1.8	0.5	6.7	3.8	1.1	0.8
Juncus phaocephalus	9.2	3.6	15.4	5.9	3.4	2.3
Pleuropogon californicus	32.0	8.0	23.2	7.9	15.2	6.5
Native Forb						
Downingia concolor	0.0	0.0	0.2	0.2	0.1	0.1
Eryngium aristulatum	0.2	0.1	5.4	1.9	0.7	0.5
Lasthenia glabberima	1.8	1.0	2.5	2.4	1.5	0.9
Limnanthes vinculans	4.7	1.6	0.5	0.5	0.0	0.0
Thatch	6.0	2.4	3.7	0.9	2.1	0.8

Table 4 (cont.). Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA, and Haroutunian) of the SRVRS, May 2002. Means and SE are shown (n=5, 1000 pin hits).

Margin Mr	**Cramer**	SE	**FEMA**	SE	**Haroutunian**	SE
Non-Native Graminoid						
Hordeum marinum	0.3	0.2	0.1	0.1	1.6	2.5
Lolium multiflorum	10.4	4.0	10.5	3.8	11.7	4.6
Polypogon maritimus	0.0	0.0	0.0	0.0	0.0	0.0
Vulpia bromoides	13.7	6.8	3.3	1.5	16.3	5.2
Non-Native Forb						
Convolvulus arvensis	2.2	2.2	0.0	0.0	0.4	0.3
Dipsacus fullonum	0.0	0.0	1.0	1.0	0.1	0.1
Mentha pulegium	0.9	0.8	1.1	0.4	0.1	0.1
Rumex crispus	0.0	0.0	1.0	0.8	0.0	0.0
Native Graminoid						
Eleocharus macrostachya	1.9	0.8	8.2	3.4	2.3	0.8
Juncus phaocephalus	8.0	3.8	15.8	8.1	1.0	0.4
Pleuropogon californicus	30.6	7.6	36.3	8.1	20.5	9.9
Native Forb						
Downingia concolor	0.0	0.0	0.9	0.8	0.3	0.3
Eryngium aristulatum	1.4	0.8	6.1	1.7	1.8	1.5
Lasthenia glabberima	5.1	2.4	5.0	1.9	6.9	5.4
Limnanthes vinculans	5.0	1.7	1.0	0.9	0.0	0.0
Thatch	2.7	0.7	2.4	1.1	1.2	0.7

Table 4 (cont.). Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA, and Haroutunian) of the SRVRS, May 2002. Means and SE are shown (n=5, 1000 pin hits).

Upland Control	**Cramer**	SE	**FEMA**	SE	**Haroutunian**	SE
Non-Native Graminoid						
Avena barbata	2.1	1.4	0.0	0.0	6.5	3.8
Briza minor	0.4	0.4	1.3	0.3	0.3	0.3
Bromus diandrus	6.1	4.1	5.3	3.7	21.0	8.4
Bromus hordeceus	6.3	1.7	6.0	3.2	15.3	7.8
Hordeum marinum	0.3	0.2	1.7	1.1	1.7	1.2
Lolium multiflorum	20.7	6.5	21.5	4.2	29.9	6.2
Vulpia bromoides	27.4	7.9	9.4	3.9	10.3	3.4
Non-Native Forb						
Convolvulus arvensis	0.5	0.3	0.7	0.7	0.7	0.4
Dipsacus fullonum	0.0	0.0	4.0	2.9	0.0	0.0
Rumex crispus	0.2	0.0	0.3	0.3	0.0	0.0
Vicia sativa	3.8	3.7	31.5	10.6	1.7	0.6
Native Graminoid						
Danthonia californica	0.0	0.0	0.0	0.0	0.5	0.3
Hordeum brachyantherum	1.2	0.8	0.0	0.0	1.1	1.1
Native Forb						
Chlorogalum pomeridianum	0.5	0.4	2.3	1.2	0.0	0.0
Ranunculus pusillus	0.0	0.0	0.0	0.0	0.0	0.0
Thatch	14.4	3.9	3.7	1.0	4.1	1.1

Table 4 (cont.). Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA, and Haroutunian) of the SRVRS, May 2002. Means and SE are shown (n=5, 1000 pin hits).

Upland Mm	**Cramer**	SE	**FEMA**	SE	**Haroutunian**	SE
Non-Native Graminoid						
Avena barbata	5.1	3.8	1.7	0.8	8.4	2.8
Briza minor	0.2	0.1	1.5	1.0	0.4	0.4
Bromus diandrus	1.9	1.9	0.8	0.6	30.9	15.0
Bromus hordeceus	2.9	0.8	3.8	0.9	8.8	4.0
Hordeum marinum	0.9	0.8	2.0	1.7	1.5	0.9
Lolium multiflorum	8.7	3.9	22.2	9.9	11.5	3.3
Vulpia bromoides	58.3	8.5	17.2	9.0	21.6	8.0
Non-Native Forb						
Convolvulus arvensis	0.8	0.7	0.4	0.4	0.6	0.6
Dipsacus fullonum	0.0	0.0	0.2	0.2	0.0	0.0
Rumex crispus	0.0	0.0	0.3	0.3	0.0	0.0
Vicia sativa	1.3	1.3	33.4	6.8	2.0	0.8
Native Graminoid						
Danthonia californica	2.5	2.5	1.8	1.8	1.8	1.7
Hordeum brachyantherum	0.4	0.4	0.7	0.7	1.1	1.1
Native Forb						
Chlorogalum pomeridianum	0.1	0.1	2.0	0.8	0.0	0.0
Ranunculus pusillus	0.0	0.0	0.0	0.0	0.0	0.0
Thatch	2.6	0.6	1.7	1.2	0.6	0.4

Table 4 (cont.). Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA and Haroutunian) of the SRVRS, May 2002. Means and SE are shown (n=5, 1000 pin hits).

Upland Mr	**Cramer**	SE	**FEMA**	SE	**Haroutunian**	SE
Non-Native Graminoid						
Avena barbata	2.4	0.9	0.8	0.8	11.3	3.0
Briza minor	1.2	0.9	1.9	1.3	1.2	0.7
Bromus diandrus	1.6	1.0	1.3	1.3	22.2	7.7
Bromus hordeceus	1.6	0.3	7.7	4.1	10.6	7.4
Hordeum marinum	0.3	0.2	1.4	0.9	0.9	0.7
Lolium multiflorum	6.3	5.0	20.5	4.3	15.0	3.8
Vulpia bromoides	52.1	7.3	7.8	2.1	17.1	2.3
Non-Native Forb						
Convolvulus arvensis	0.6	0.6	0.3	0.3	1.2	0.5
Dipsacus fullonum	0.0	0.0	2.9	2.0	0.4	0.0
Rumex crispus	0.0	0.0	0.2	0.2	0.0	0.0
Vicia sativa	0.6	0.6	29.0	7.9	0.7	0.5
Native Graminoid						
Danthonia californica	1.5	1.3	0.0	0.0	2.2	1.4
Hordeum brachyantherum	1.4	1.4	0.7	0.7	0.3	0.3
Native Forb						
Chlorogalum pomeridianum	0.3	0.2	0.7	0.5	0.0	0.0
Ranunculus pusillus	0.0	0.0	0.0	0.0	0.0	0.0
Thatch	1.9	0.6	0.4	0.3	0.5	0.3

Table 5. Dominant species richness (SRd) within two habitats (margin and upland) on three properties (Cramer, FEMA and Haroutunian) of the SRVRS, May 2004. Treatments (control, Mm, Mr) were made in June and July, 1999 through 2003. Mean and standard errors shown (n=5, 1000 pin hits), all = properties combined for each treatment (n=15, 3000 hits).

margin

	Cramer	SE	**FEMA**	SE	**Hart**	SE	**All**	SE
control	10.4	1.1	11.8	1.2	12.0	1.1	11.4	0.6
Mm	15.0	1.4	13.2	1.7	15.4	0.6	14.5	0.7
Mr	13.6	1.0	14.6	0.7	14.8	2.1	14.3	0.8

upland

	Cramer	SE	**FEMA**	SE	**Hart**	SE	**All**	SE
control	9.2	0.6	13.4	1.2	10.2	1.2	10.9	0.7
Mm	9.2	1.5	11.6	1.4	12.0	0.7	10.9	0.8
Mr	10.4	0.4	13.6	1.0	10.2	1.1	11.4	0.6

Table 6. Vegetation quality (% native cover) within two habitats (margin and upland) on three properties (Cramer, FEMA and Haroutunian) of the SRVRS, May 2004. Treatments (control, Mm, Mr) were made in June and July, 1999 through 2003. Mean and standard errors shown (n=5, 1000 pin hits). All = properties combined for each treatment (n=15, 3000 hits). C+H = Cramer and Haroutunian combined for each treatment (N=10, 2000 hits).

margin

		Cramer	SE	FEMA	SE	Hart	SE	All	SE	C+H	SE
control											
	% native	48.0	13.4	37.3	13.3	22.8	7.9	36.0	7.3	35.4	12.6
Mm											
	% native	37.3	6.5	42.2	12.0	37.5	12.5	39.0	1.6	37.4	0.1
Mr											
	% native	58.7	8.3	58.1	8.8	37.2	13.5	51.3	7.1	48.0	10.8

upland

		Cramer	SE	FEMA	SE	Hart	SE	All	SE	C+H	SE
control											
	% native	11.2	7.4	9.4	2.7	5.1	2.4	8.5	1.8	8.1	3.0
Mm											
	% native	8.3	2.5	4.3	1.2	1.6	0.8	4.7	1.9	4.9	3.3
Mr											
	% native	8.5	5.4	6.2	2.2	2.7	0.8	5.8	1.7	5.6	2.9

Table 7. Cover (%) by management guilds within two habitats (margin and upland) on three properties (Cramer, FEMA and Haroutunian) of the SRVRS, May 2004. Mean are shown (n=5, 1000 pin hits).

margin

	Cramer	FEMA	Hart
control			
% non-native graminoid	47.6	46.7	56.3
% non-native forb	4.9	7.8	2.6
% native graminoid	43.1	29.4	13.8
% native forb	4.4	5.0	2.1
Mm			
% non-native graminoid	48.5	40.3	41.7
% non-native forb	4.0	4.3	3.8
% native graminoid	25.3	30.1	16.8
% native forb	5.0	6.8	5.2
Mr			
% non-native graminoid	30.6	25.4	26.3
% non-native forb	3.5	2.2	3.0
% native graminoid	38.0	36.3	14.4
% native forb	4.8	16.1	5.5

upland

	Cramer	FEMA	Hart
control			
% non-native graminoid	56.8	80.7	84.8
% non-native forb	1.8	3.9	2.8
% native graminoid	1.3	2.0	1.8
% native forb	0.2	1.7	0.0
Mm			
% non-native graminoid	87.1	74.2	90.0
% non-native forb	2.6	2.3	3.5
% native graminoid	4.3	1.3	1.3
% native forb	0.0	0.7	0.0
Mr			
% non-native graminoid	84.4	81.2	89.6
% non-native forb	2.7	4.3	3.5
% native graminoid	3.4	1.8	2.4
% native forb	0.1	2.1	0.0

Table 8. Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA, and Haroutunian) of the SRVRS, May 2004. Means and SE are shown (n=5, 1000 pin hits).

Margin Control	Cramer	SE	FEMA	SE	Haroutunian	SE
Non-Native Graminoid						
Hordeum marinum	0.7	0.7	0.9	0.9	3.9	1.2
Lolium multiflorum	35.1	12.4	44.3	13.8	31.4	9.2
Polypogon maritimus	0.0	0.0	0.1	0.1	0.0	0.0
Vulpia bromoides	8.0	5.2	1.4	0.7	21.0	10.0
Non-Native Forb						
Convolvulus arvensis	1.3	0.0	1.7	1.0	1.2	0.6
Dipsacus fullonum	0.0	0.0	2.8	2.3	0.0	0.0
Mentha pulegium	0.5	0.2	0.7	0.7	0.0	0.0
Rumex crispus	2.0	0.8	2.6	1.2	1.4	0.9
Native Graminoid						
Eleocharus macrostachya	4.2	2.0	2.4	2.2	2.2	1.1
Juncus phaocephalus	6.4	3.9	6.4	3.3	0.8	0.7
Pleuropogon californicus	29.6	9.0	20.6	9.0	10.8	6.2
Native Forb						
Downingia concolor	0.0	0.0	0.0	0.0	0.0	0.0
Eryngium aristulatum	0.4	0.3	3.8	1.6	1.2	1.0
Lasthenia glabberima	0.3	0.2	0.9	0.7	0.9	0.8
Limnanthes vinculans	3.0	1.2	0.3	0.3	0.0	0.0
Thatch	3.1	1.7	1.4	1.0	3.4	1.5

Table 8 (cont.). Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA, and Haroutunian) of the SRVRS, May 2004. Means and SE are shown (n=5, 1000 pin hits).

Margin Mm	**Cramer**	SE	**FEMA**	SE	**Haroutunian**	SE
Non-Native Graminoid						
Hordeum marinum	2.2	0.5	0.3	0.3	6.0	1.5
Lolium multiflorum	19.3	3.6	38.0	10.4	22.1	6.5
Polypogon maritimus	0.0	0.0	0.6	0.5	0.0	0.0
Vulpia bromoides	27.0	10.7	1.4	0.5	13.6	4.0
Non-Native Forb						
Convolvulus arvensis	2.0	1.3	0.6	0.2	1.7	0.6
Dipsacus fullonum	0.0	0.0	1.7	1.2	0.0	0.0
Mentha pulegium	2.0	2.0	0.4	0.2	0.0	0.0
Rumex crispus	1.5	0.5	1.6	1.4	2.1	0.6
Native Graminoid						
Eleocharus macrostachya	2.3	0.6	5.1	2.5	1.7	0.7
Juncus phaocephalus	3.3	3.3	7.1	3.3	1.4	0.9
Pleuropogon californicus	19.7	3.3	17.9	7.0	13.7	8.0
Native Forb						
Downingia concolor	0.0	0.0	0.0	0.0	0.0	0.0
Eryngium aristulatum	2.1	1.6	4.3	1.3	2.0	1.3
Lasthenia glabberima	1.2	1.1	2.5	1.3	3.2	2.5
Limnanthes vinculans	1.7	0.4	0.0	0.0	0.0	0.0
Thatch	0.7	0.5	0.4	0.3	0.9	0.2

Table 8 (cont.). Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA, and Haroutunian) of the SRVRS, May 2004. Means and SE are shown (n=5, 1000 pin hits).

Margin Mr	**Cramer**	SE	**FEMA**	SE	**Haroutunian**	SE
Non-Native Graminoid						
Hordeum marinum	1.9	0.8	0.7	0.3	1.4	0.5
Lolium multiflorum	12.1	4.1	23.1	7.7	24.9	8.7
Polypogon maritimus	0.1	0.1	0.2	0.2	0.0	0.0
Vulpia bromoides	16.5	4.7	1.4	1.0	16.4	5.0
Non-Native Forb						
Convolvulus arvensis	2.7	1.5	0.6	0.4	2.4	1.0
Dipsacus fullonum	0.0	0.0	0.6	0.6	0.0	0.0
Mentha pulegium	0.8	0.7	1.0	0.9	0.2	0.2
Rumex crispus	0.7	0.2	4.4	2.3	0.4	0.2
Native Graminoid						
Eleocharus macrostachya	2.3	1.3	5.5	2.2	2.1	1.2
Juncus phaocephalus	7.0	3.0	9.7	4.7	0.2	0.1
Pleuropogon californicus	28.7	6.3	21.1	3.4	12.1	9.6
Native Forb						
Downingia concolor	0.0	0.0	0.1	0.1	0.0	0.0
Eryngium aristulatum	3.7	2.5	8.0	2.5	2.8	0.8
Lasthenia glabberima	1.1	1.8	8.0	2.2	2.7	2.1
Limnanthes vinculans	2.9	1.5	1.3	1.2	0.0	0.0
Thatch	0.5	0.4	1.1	0.3	1.2	0.8

Table 8 (cont.). Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA, and Haroutunian) of the SRVRS, May 2004. Means and SE are shown (n=5, 1000 pin hits).

Upland Control	**Cramer**	SE	**FEMA**	SE	**Haroutunian**	SE
Non-Native Graminoid						
Avena barbata	1.6	1.1	0.8	0.5	5.9	2.1
Briza minor	0.0	0.0	2.5	0.4	0.1	0.1
Bromus diandrus	29.0	17.4	2.9	1.8	19.6	6.8
Bromus hordeceus	9.1	3.3	9.3	3.8	10.7	3.1
Hordeum marinum	0.2	0.1	0.5	0.5	1.9	0.8
Lolium multiflorum	16.9	8.1	55.5	5.9	27.3	5.9
Vulpia bromoides	26.2	12.3	9.2	2.4	19.3	6.3
Non-Native Forb						
Convolvulus arvensis	0.7	0.4	1.0	0.7	2.2	0.6
Dipsacus fullonum	0.0	0.0	1.1	0.6	0.0	0.0
Rumex crispus	0.0	0.0	0.1	0.1	0.2	0.0
Vicia sativa	0.6	0.5	1.4	0.8	0.1	0.1
Native Graminoid						
Danthonia californica	0.2	0.2	0.4	0.3	0.0	0.0
Hordeum brachyantherum	1.1	0.5	0.0	0.0	1.1	0.7
Native Forb						
Chlorogalum pomeridianum	0.2	0.2	1.7	1.0	0.0	0.0
Ranunculs pusillus	0.0	0.0	0.2	0.2	0.0	0.0
Thatch	0.9	0.6	1.5	0.9	4.6	2.3

Table 8 (cont.). Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA, and Haroutunian) of the SRVRS, May 2004. Means and SE are shown (n=5, 1000 pin hits).

Upland Mm	Cramer	SE	FEMA	SE	Haroutunian	SE
Non-Native Graminoid						
Avena barbata	13.8	5.9	15.3	6.4	33.8	6.9
Briza minor	0.4	0.3	0.6	0.6	0.7	0.3
Bromus diandrus	9.3	7.4	4.9	1.9	17.7	6.1
Bromus hordeceus	5.2	3.1	10.2	1.9	5.8	2.3
Hordeum marinum	1.1	0.9	2.1	1.9	1.1	0.8
Lolium multiflorum	3.3	2.8	41.1	8.6	4.3	1.0
Vulpia bromoides	54.0	12.4	13.3	2.9	26.6	8.8
Non-Native Forb						
Convolvulus arvensis	1.5	1.0	0.3	0.2	1.6	0.9
Dipsacus fullonum	0.0	0.0	0.4	0.3	0.2	0.2
Rumex crispus	0.0	0.0	0.3	0.3	0.0	0.0
Vicia sativa	0.1	0.1	0.4	0.3	1.0	0.5
Native Graminoid						
Danthonia californica	4.0	3.3	0.8	0.7	0.5	0.3
Hordeum brachyantherum	0.3	0.3	0.5	0.3	0.8	0.8
Native Forb						
Chlorogalum pomeridianum	0.0	0.0	0.7	0.4	0.0	0.0
Ranunculus pusillus	0.0	0.0	0.0	0.0	0.0	0.0
Thatch	0.5	0.2	0.9	0.4	0.9	0.7

Table 8 (cont.). Cover (%) by dominant taxa within each management guild for two habitats (margin and upland) on three properties (Cramer, FEMA and Haroutunian) of the SRVRS, May 2004. Means and SE are shown (n=5, 1000 pin hits).

Upland Mr	**Cramer**	SE	**FEMA**	SE	**Haroutunian**	SE
Non-Native Graminoid						
Avena barbata	5.4	1.7	3.2	1.8	39.1	7.8
Briza minor	1.0	0.4	3.2	1.6	2.0	1.1
Bromus diandrus	9.5	8.0	1.9	1.5	15.1	4.0
Bromus hordeceus	11.4	4.4	14.3	1.1	7.7	6.3
Hordeum marinum	1.1	0.7	0.7	0.6	1.3	1.1
Lolium multiflorum	1.5	0.9	48.8	6.0	6.6	1.5
Vulpia bromoides	54.5	10.7	9.1	3.5	17.8	5.5
Non-Native Forb						
Convolvulus arvensis	1.3	1.1	0.2	0.2	2.4	1.0
Dipsacus fullonum	0.0	0.0	2.8	2.4	0.8	0.8
Rumex crispus	0.0	0.0	0.1	0.1	0.0	0.0
Vicia sativa	0.0	0.0	0.5	0.4	0.0	0.0
Native Graminoid						
Danthonia californica	1.8	1.3	1.2	0.8	1.4	0.6
Hordeum brachyantherum	0.6	0.6	0.1	0.1	0.5	0.5
Native Forb						
Chlorogalum pomeridianum	0.1	0.1	1.6	1.5	0.0	0.0
Ranunculus pusillus	0.0	0.0	0.0	0.0	0.0	0.0
Thatch	1.8	1.1	0.4	0.1	0.0	0.0

Table 9. Quadrat-based estimates of density (#/m2), cover (% abs live) and frequency (# occurences/20 subsamples X 100) for VPC taxa, SRVRS, May 2004.

Cramer 5/18-20/2004		Limnanthes vinculans					Blennosperma bakeri			Downingia concolor			Lasthenia glabberima				
		Den / SE		Cov /SE		Freq	Den / SE	Cov / SE	Freq	Den / SE	Cov / SE	Freq	Den / SE		Cov /SE		Freq
Block 1	Control	0.0		0.0		0	0.0	0.0	0	0.0	0.0	0	0.0		0.0		0
	Mm	**62.5**	37.5	**6.0**	4.0	10	0.0	0.0	0	0.0	0.0	0	0.0		0.0		0
	Mr	**100.0**	20.0	**7.8**	1.4	25	0.0	0.0	0	0.0	0.0	0	0.0		0.0		0
Block 2	Control	160.0	55.0	11.0	5.6	35	0.0	0.0	0	0.0	0.0	0	0.0		0.0		0
	Mm	**397.5**	57.5	**38.5**	6.8	50	0.0	0.0	0	0.0	0.0	0	**165.0**	62.5	7.6	4.7	25
	Mr	**237.5**	27.5	**23.1**	1.8	70	0.0	0.0	0	0.0	0.0	0	110.0	57.5	1.8	0.8	50
Block 3	Control	**300.0**	90.0	**29.0**	7.4	50	0.0	0.0	0	0.0	0.0	0	0.0		0.0		0
	Mm	**265.0**	80.0	**26.4**	9.0	35	0.0	0.0	0	0.0	0.0	0	260.0	127.5	**20.0**	8.2	25
	Mr	**362.5**	77.5	**37.8**	6.9	45	0.0	0.0	0	0.0	0.0	0	**125.0**	32.5	**11.2**	1.2	20
Block 4	Control	**100.0**	27.5	**5.2**	1.8	20	0.0	0.0	0	0.0	0.0	0	75.0	0.0	2.0		5
	Mm	**135.0**	42.5	**7.2**	1.8	45	0.0	0.0	0	0.0	0.0	0	**90.0**	17.5	**9.0**	5.3	25
	Mr	**82.5**	35.0	4.7	3.1	30	0.0	0.0	0	0.0	0.0	0	**132.5**	37.5	**5.8**	2.0	30
Block 5	Control	**90.0**	15.0	**12.2**	2.9	50	0.0	0.0	0	0.0	0.0	0	**100.0**	25.0	7.5	2.5	10
	Mm	**300.0**	200.0	**30.0**	20.0	10	0.0	0.0	0	0.0	0.0	0	137.5	112.5	5.5	4.5	5
	Mr	90.0	35.0	**15.0**	5.8	15	0.0	0.0	0	0.0	0.0	0	180.0	82.5	7.4	3.5	25

Bold indicates a significant increase (Mann- Whitney U test, $P< 0.05$), box indicates a decrease or extirpation compared to May 2000.

Table 9. Quadrat-based estimates of density (#/m2), cover (% abs live) and frequency (# occurences/20 subsamples X 100) for VPC taxa, SRVRS, May 2004.

FEMA 5/18-20/2004		**Limnanthes vinculans**					**Blennosperma bakeri**					**Downingia concolor**					**Lasthenia glabberima**				
		Den / SE		**Cov /SE**		**Freq**	**Den / SE**		**Cov / SE**		**Freq**	**Den / SE**		**Cov / SE**		**Freq**	**Den / SE**		**Cov /SE**		**Freq**
Block 1	Control	0.0	0.0	0.0	0.0	0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mm	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	162.5	137.5	36.0	34.0	10
	Mr	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	75.0		4.0		5
Block 2	Control	137.5	40.0	9.1	2.4	40	0.0		0.0		0	0.0		0.0		0	118.7	47.5	6.8	2.0	20
	Mm	0.0		0.0		0	0.0		0.0		0	112.5	87.5	22.5	7.5	10	0.0		0.0		0
	Mr	**220.0**	55.0	**23.0**	6.8	45	0.0		0.0		0	0.0		0.0		0	**205.0**	47.5	**22.5**	5.7	65
Block 3	Control	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	75.0		25.0		5
	Mm	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mr	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	**137.5**	12.5	**25.0**	5.0	10
Block 4	Control	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mm	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mr	**87.5**	12.5	3.0	2.0	10	0.0		0.0		0	0.0		0.0		0	**225.0**	67.5	**11.6**	2.9	40
Block 5	Control	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mm	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	**245.0**	55.0	**35.8**	8.2	45
	Mr	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	**235.0**	22.5	**43.0**	6.0	25

Bold indicates a significant increase (Mann- Whitney U test, P< 0.05), box indicates a decrease or extirpation compared to May 2000.

Table 9. Quadrat-based estimates of density (#/m2), cover (% abs live) and frequency (# occurences/20 subsamples X 100) for VPC taxa, SRVRS, May 2004.

Haroutunian 5/18-20, 2004		Limnanthes vinculans					Blennosperma bakeri					Downingia concolor					Lasthenia glabberima				
		Den / SE		Cov /SE		Freq	Den / SE		Cov / SE		Freq	Den / SE		Cov / SE		Freq	Den / SE		Cov /SE		Freq
Block 1	Control	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mm	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mr	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
Block 2	Control	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mm	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mr	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
Block 3	Control	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mm	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mr	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
Block 4	Control	0.0		0.0		0	**42.5**	7.5	**6.7**	1.7	15	0.0		0.0		0	**130.0**	20.0	**25.0**	5.3	45
	Mm	0.0		0.0		0	**250.0**	0.0	**37.5**	2.5	10	25.0		1.0		5	137.5	27.5	11.3	4.1	30
	Mr	0.0		0.0		0	**368.8**	127.5	**37.5**	5.2	20	0.0		0.0		0	**100.0**	37.5	**12.5**	6.0	20
Block 5	Control	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0	0.0		0.0		0
	Mm	**100.0**	75.0	**8.0**	7.0	0	**30.0**	5.0	**302.0**	6.5	30	0.0		0.0		0	**120.0**	15.0	**12.8**	3.4	90
	Mr	0.0		0.0		0	**62.5**	7.5	**10.3**	2.4	75	25.0		1.0		5	145.0	15.0	**12.7**	2.1	90

Bold indicates a significant increase (Mann- Whitney U test, P< 0.05), box indicates a decrease or extirpation compared to May 2000.

Table 10. Overall effectiveness of Mm and Mr treatments on species of upland (coastal prairie) and margin (vernal pool edge) habitats based on data gathered during five years (2000 to 2004) in 90 permanent plots on three SRVRS properties (Cramer, FEMA, Haroutunian). ++ = significant, consistent increase in cover, + = insignificant trend towards increasing cover, -- = significant, consistent reduction in cover, - = insignificant trend towards decreasing cover. 0 = no consistent trend.

UPLAND

	Mm	Mr
Non-Native Graminoid		
Avena barbata	++	++
Briza minor	0	+
Bromus diandrus	-	-
Bromus hordeceus	-	0
Hordeum marinum	0	0
Lolium multiflorum	--	--
Vulpia bromoides	++	+
Non-Native Forb		
Convolvulus arvensis	0	0
Dipsacus fullonum	0	+
Rumex crispus	0	0
Vicia sativa	0	-
Native Graminoid		
Danthonia californica	++	++
Hordeum brachyantherum	0	0
Native Forb		
Chlorogalum pomeridianum	0	0
Ranunculus pusillus	0	0
Thatch	--	--

MARGIN

	Mm	Mr
Non-Native Graminoid		
Hordeum marinum	0	0
Lolium multiflorum	-	--
Vulpia bromoides	+	+
Polypogon maritimus	0	0
Non-Native Forb		
Convolvulus arvensis	0	0
Dipsacus fullonum	0	0
Rumex crispus	-	-
Mentha pulegium	0	0
Native Graminoid		
Eleocharus macrostachya	0	0
Juncus phaeocephalus	0	+
Pleuropogon californicus	0	0
Native Forb		
Downingia concolor	0	0
Eryngium aristulatum	+	++
Lasthenia glabberima	0	++
Limnanthes vinculans	0	0
Thatch	--	--

APPENDIX A:

Instructions to field assistants

Restoring Vernal Pool Vegetation at the SRVRS

Team: 2 people - a reader and a writer

Equipment:
- 1 pin frame sampler
- 1 quadrat sampler
- 1 50 m tape
- 4 survey arrows
- # 2 pencil
- clip board
- unknown specimen kit

Paperwork:
- block data sheet notebook
- plot maps
- species list

Organization:

Each team will be assigned a block to sample. A block is a pool or swale already marked and treated as part of our restoration experiment. Each block contains two habitats, upland and margin (Figure 1). Each habitat has a 90 m long strip that has already been divided into three plots: a control plot (C or Con), a mowed-mulched plot (Mm) and a mowed-raked plot (Mr). Plots are 30 m long and 5 m wide. The start of the 90 m strip is called the "initial boundary" and is marked by 4 two inch pvc stakes permanently driven into the ground. Other pvc stakes mark the location of the upslope edge of each strip. You will sample all plots in your block (3 margin + 3 upland).

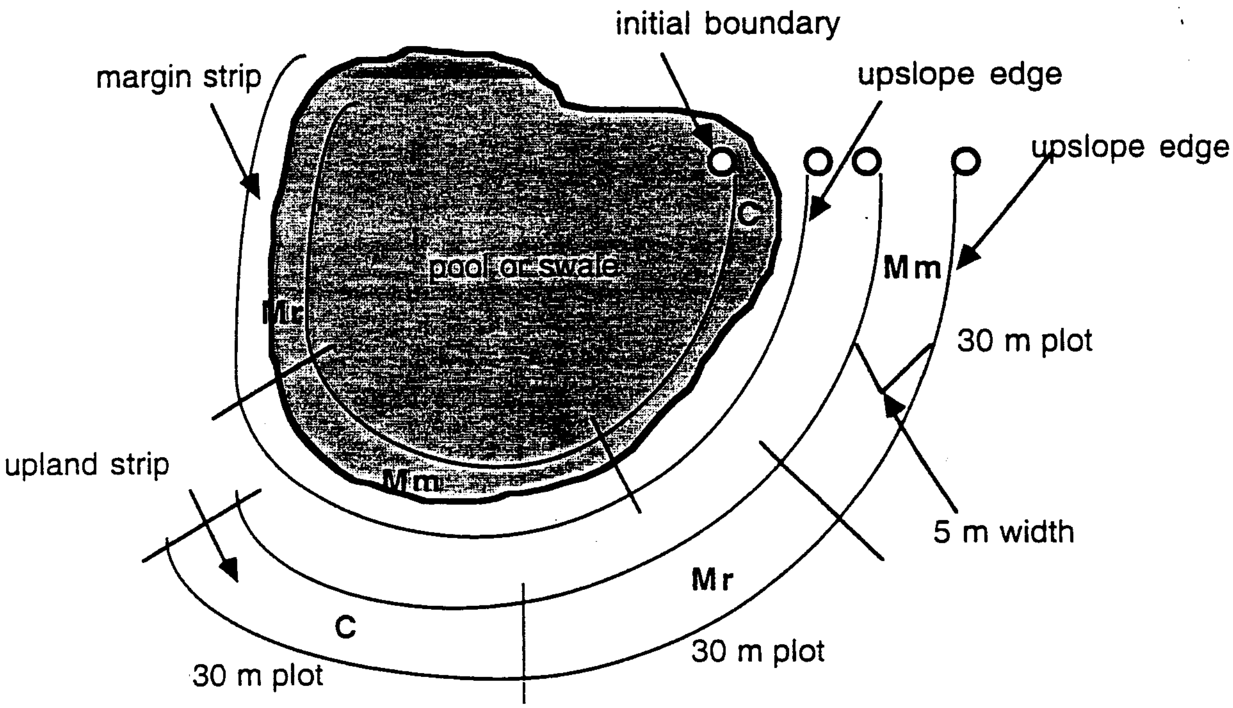

Figure 1. Block design for a vernal pool consisting of two habitat strips (pool margin and upland) each 90 m long. Position of the initial boundary was randomly assigned and each treatment (C= control, Mm= mowed and mulched, Mr=mowed and raked) was randomly assigned.

To Begin:

1) Approach the strips carefully so as not to step into them before sampling. Locate the initial boundary and all four pvc markers. Remember that the lowest two (with respect to the pool topography) are 5 m apart and define the margin strip, and the upper two are also 5 m apart and define the upland strip (Figure 1).

2) Stake the tape with its 0 m mark at the upslope pvc marker for the margin strip. Walking on the outside of the strip, lay the tape out to define the upslope edge using the other pvc stakes or the colored flags. When you come to 30 m, pull the slack out of the tape and stake it down.

3) Consult your maps to determine if this first 30m plot of the margin is a control plot, Mm plot or Mr plot. **Double check.**

4) The writer will remove the proper set of datasheets from the notebook and clip them to the clipboard. **Double check.**

To Sample:

5) The writer tells the reader the position and upper/lower designation on the datasheet, beginning with the lowest position number (e.g. 7 m).

6) The reader carries the pin frame along the upper edge and finds the position (e.g. 7 m) on the tape. If the designation is U (upper), then the frame is carefully set into the plot a short distance from the tape (knot on the locator string). The line of pins are perpendicular to the tape and all pins are raised .

7) **The reader always enters the plot and stands on the side of the frame facing the lowest position numbers** (e.g. 6 m side, not the 8 m side). That way unsampled vegetation does not get stomped.

8) Beginning with the upslope pin (# 1, the one furthest from the pool), the reader slowly lowers it until it makes first contact with a leaf, stem, or flower. The reader calls out the scientific name of the species contacted and the writer records its abbreviation. (e.g. *Limnanthes vinculans* is recorded as LIVI in the slot for pin #1). If there is wind, wait until you can determine which leaf/flower would be touched if it were not in motion.

9) What if you don't recognize the species? Ask a rovering expert, or designate it as unknown "A". Immediately take a complete specimen, tape it to the unknown card and label it. Use the same "name" throughout your sampling and show your specimen to a rover when possible.

10) What if the pin hits bare ground? Record "BARE". Thatch or wood? Record "THAT" A fallen leaf, just resting on the canopy? Remove it and record the next pin hit.

11) Repeat for all 10 pins in this subsample. Raise the pins when done.

12) If between the legs of the pin frame there are any vernal pool dicots (e.g. LIVI, DOCO, PODO), lay the quadrat sampler (20 X 20 cm) in the center of the legs.
For individuals inside the quadrat, count them all and tell the writer the species, the number of individuals and the total % absolute cover for the species. The writer writes the these on the inset of the datasheet for that species.

13) Stretch the downslope locator string (the one with the taped end). Now move the pin frame so it is in place to get the second subsample for that position (pins 11-20).

14) Repeat steps 7-12.

15) Put a red flag into the ground to mark this position along the tape and leave it in place when you leave.

16) Move onto the second position indicated by the random numbers on the datasheet. If the designation is L (lower), then the frame is carefully set into the plot a longer distance from the tape (end of the knotted locator string).

17) Repeat steps 6-15.

18) Do a total of 10 positions (20 subsamples) in a plot. Put another red flag into the ground to mark the position of the last sample along the tape and leave it in place when you leave.

19) **Writer does a check when a plot is finished:**

> a) All datasheets completely filled out for the plot and returned to block notebook.
>
> b) Two red flags in the first and last positions.

20) Move on the the next plot in the same strip. You will need to reposition the tape so that the new 0m is at the previous 30 m position.

21) Repeat steps 2-19 for the other two plots in the margin habitat and the other three plots in the upland habitat

22) **Writer checks to see that when a block is completely sampled there should be six sets of data sheets (margin C, Mm, Mr and upland C, Mm, Mr).**

To Sample Soil:

23) Obtain a large zip-lock bag for each of the 6 plots in your block. Use a water-proof "sharpie" to write on the upper right of each bag the property (C, F or H), block # (1, 2, 3, 4, or 5) and the treatment (Con, Mm, or Mr). For example, Cramer block one, control would be "C - 1" and then below that "Con".

24) Revisit the first treatment plot in your block. Locate the red flag for the first position. At a point between the areas sampled by the point frames (you can tell by your stomps), exposed the mineral soil (i.e. remove thatch) and drive the bulb planter into the soil (5 cm deep). Pull it out and empty into the appropriate bag.

25) Repeat at the second flag for the treatment plot, combining the sample with the other in the same bag. Seal the bag, break apart the chunks, and place it into a container shielded from the sun (e.g. backpack, cooler, shopping bag).

26) Repeat for the other 5 treament plots in your block. Leave the red flags in place.

27) Check that you have 6 bags for your block when done, each with a unique label. Return these to the main sample cooler.

APPENDIX B:

Field datasheets for point frame sampling

Property: C F H **Block:** 1 2 3 4 5

SRVRS 2004

Date ______________
Data by ____________

habitat treat position U/L pin # pin hit species

---

margin **Con** _____ _____

sp	#ind	%cov	pin #	pin hit species
			1 uphill	
			2	
			3	
			4	
sp	#ind	%cov	5	
Livi			6	
Podo			7	
Doco			8	
Lagl			9	
Blba			10	
			11 uphill	
			12	
			13	
			14	
sp	#ind	%cov	15	
Livi			16	
Podo			17	
Doco			18	
Lagl			19	
Blba			20	

margin **Con** _____ _____

sp	#ind	%cov	pin #	pin hit species
			1 uphill	
			2	
			3	
			4	
sp	#ind	%cov	5	
Livi			6	
Podo			7	
Doco			8	
Lagl			9	
Blba			10	
			11 uphill	
			12	
			13	
			14	
sp	#ind	%cov	15	
Livi			16	
Podo			17	
Doco			18	
Lagl			19	
Blba			20	

Property: C F H **SRVRS 2004** **Date** ______________
Block: 1 2 3 4 5 **Data by** ____________

habitat	treat	position	U/L	pin #	pin hit species
margin	**Mm**	____	____	**1** **uphill**	____________
				2	____________
				3	____________
				4	____________
sp	#ind	%cov		5	____________
Livi				6	____________
Podo				7	____________
Doco				8	____________
Lagl				9	____________
Blba				10	____________
				11 **uphill**	____________
				12	____________
				13	____________
				14	____________
sp	#ind	%cov		15	____________
Livi				16	____________
Podo				17	____________
Doco				18	____________
Lagl				19	____________
Blba				20	____________
margin	**Mm**	____	____	**1** **uphill**	____________
				2	____________
				3	____________
				4	____________
sp	#ind	%cov		5	____________
Livi				6	____________
Podo				7	____________
Doco				8	____________
Lagl				9	____________
Blba				10	____________
				11 **uphill**	____________
				12	____________
				13	____________
				14	____________
sp	#ind	%cov		15	____________
Livi				16	____________
Podo				17	____________
Doco				18	____________
Lagl				19	____________
Blba				20	____________

Property: C F H **SRVRS 2004** **Date** ______________
Block: 1 2 3 4 5 **Data by** ____________

habitat treat position U/L pin # pin hit species

---

margin **Mr** _____ ____

sp	#ind	%cov	pin #	pin hit species
			1 uphill	
			2	
			3	
			4	
sp	#ind	%cov	5	
Livi			6	
Podo			7	
Doco			8	
Lagl			9	
Blba			10	
			11 uphill	
			12	
			13	
			14	
sp	#ind	%cov	15	
Livi			16	
Podo			17	
Doco			18	
Lagl			19	
Blba			20	

margin **Mr** _____ ____

sp	#ind	%cov	pin #	pin hit species
			1 uphill	
			2	
			3	
			4	
sp	#ind	%cov	5	
Livi			6	
Podo			7	
Doco			8	
Lagl			9	
Blba			10	
			11 uphill	
			12	
			13	
			14	
sp	#ind	%cov	15	
Livi			16	
Podo			17	
Doco			18	
Lagl			19	
Blba			20	

Property: C F H
Block: 1 2 3 4 5

SRVRS 2004

Date ______________
Data by ______________

habitat	treat	position	U/L	pin #	pin hit species
Upland	**Con**	____	____	**1 uphill**	______________
				2	______________
				3	______________
				4	______________
sp	#ind	%cov		5	______________
Livi				6	______________
Podo				7	______________
Doco				8	______________
Lagl				9	______________
Blba				10	______________
				11 uphill	______________
				12	______________
				13	______________
				14	______________
sp	#ind	%cov		15	______________
Livi				16	______________
Podo				17	______________
Doco				18	______________
Lagl				19	______________
Blba				20	______________
Upland	**Con**	____	____	**1 uphill**	______________
				2	______________
				3	______________
				4	______________
sp	#ind	%cov		5	______________
Livi				6	______________
Podo				7	______________
Doco				8	______________
Lagl				9	______________
Blba				10	______________
				11 uphill	______________
				12	______________
				13	______________
				14	______________
sp	#ind	%cov		15	______________
Livi				16	______________
Podo				17	______________
Doco				18	______________
Lagl				19	______________
Blba				20	______________

Date ____________

Data by ____________

SRVRS 2004

Property: C F H

Block: 1 2 3 4 5

habitat	treat	position	U/L	pin #	pin hit species
Upland	Mm	____	____	1 uphill	
				2	
				3	
				4	
				5	
				6	
				7	
				8	
				9	
				10	
				11 uphill	
				12	
				13	
				14	
				15	

sp	#ind	%cov
Livi		
Podo		
Doco		
Lagl		

Property: C F H

Block: 1 2 3 4 5

SRVRS 2004

Date ______________

Data by ____________

habitat	treat	position	U/L	pin #	pin hit species
Upland	**Mm**	_____	____	**1** uphill	____________
				2	____________
				3	____________
				4	____________
sp	#ind	%cov		5	____________
Livi				6	____________
Podo				7	____________
Doco				8	____________
Lagl				9	____________
Blba				10	____________
				11 uphill	____________
				12	____________
				13	____________
				14	____________
sp	#ind	%cov		15	____________
Livi				16	____________
Podo				17	____________
Doco				18	____________
Lagl				19	____________
Blba				20	____________
Upland	**Mm**	_____	____	**1** uphill	____________
				2	____________
				3	____________
				4	____________
sp	#ind	%cov		5	____________
Livi				6	____________
Podo				7	____________
Doco				8	____________
Lagl				9	____________
Blba				10	____________
				11 uphill	____________
				12	____________
				13	____________
				14	____________
sp	#ind	%cov		15	____________
Livi				16	____________
Podo				17	____________
Doco				18	____________
Lagl				19	____________
Blba				20	____________

Property: C F H **SRVRS 2004** **Date** ____________
Block: 1 2 3 4 5 **Data by** ____________

habitat | treat | position | U/L | pin # | pin hit species

Upland **Mr** _____ _____

			pin #	pin hit species
			1 uphill	
			2	
			3	
			4	
sp	#ind	%cov	5	
Livi			6	
Podo			7	
Doco			8	
Lagl			9	
Blba			10	
			11 uphill	
			12	
			13	
			14	
sp	#ind	%cov	15	
Livi			16	
Podo			17	
Doco			18	
Lagl			19	
Blba			20	

Upland **Mr** _____ _____

			pin #	pin hit species
			1 uphill	
			2	
			3	
			4	
sp	#ind	%cov	5	
Livi			6	
Podo			7	
Doco			8	
Lagl			9	
Blba			10	
			11 uphill	
			12	
			13	
			14	
sp	#ind	%cov	15	
Livi			16	
Podo			17	
Doco			18	
Lagl			19	
Blba			20	