

Serpentine Vegetation Management Project

2007

FINAL REPORT

Stuart B. Weiss, David H. Wright, and Christal Niederer

Creekside Center for Earth Observation

27 Bishop Lane, Menlo Park, CA 94025

tel: 650-854-9732, fax: 650-644-3355

e-mail: stu@creeksidescience.com

<http://www.creeksidescience.com>



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Cover photo: Bay checkerspot butterflies mating near the experimental blocks on Coyote Ridge, north of Kirby Canyon, in spring of 2006.

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SUMMARY AND CONCLUSIONS

We report on a 3-year project to evaluate and make recommendations regarding vegetation management methods and grazing impacts on serpentine habitat in Santa Clara County (initiated 2004, completed 2007). We conducted an experimental vegetation management trial, and made observations on serpentine vegetation across different grazing and other vegetation management regimes (intersite and burn studies). This work tracked cover of all plant species found. With respect to particular rare species, we also performed a simulated herbivory experiment on *Streptanthus albidus* ssp. *peramoenus* (a sister subspecies of the federally endangered Metcalf Canyon jewelflower, *S. a. albidus*) and made observations on the federally endangered Santa Clara Valley dudleya (*Dudleya setchellii*). Developing vegetation management information and applying it in adaptive land management are priority tasks for recovery of the bay checkerspot butterfly, Santa Clara Valley dudleya, Metcalf Canyon jewelflower, and other species.

Vegetation management trial: This experiment looked at vegetation response to seven treatments: 1) no grazing or trimming, 2) 2-inch trim early, 3) 4-inch trim early, 4) 2-inch trim late, 5) 4-inch trim late, 6) partial grazing, and 7) ambient grazing. The trimming treatments simulated the vegetation removal of grazing under more controlled conditions, varying intensity and timing to test those factors.

Two strong signals were apparent in the data from our experimental vegetation management trial: a moisture signal and a “smothering” signal. The moisture signal was apparent in a switch between 2006 and 2007 results in the relative performance of *Lolium multiflorum* and other nonnative annual grasses versus perennials. Note that 2005 and 2006 were almost ideal years for annual grass growth, with extended rains that led to high grass production. In contrast, in the drier year 2007, *Lolium* decreased to cover values less than the baseline 2005 data. *Bromus hordeaceus* was not hit so hard by the dry conditions, but overall nonnative annual grass values fell back significantly in 2007. Native perennials, including geophytes, appeared unaffected or even benefited under the drier conditions, perhaps in response to reduced activity of annuals. While drought is not under the control of local land managers, the occasional dry year or multi-year drought offer opportunities for managers to take advantage of reduced annual grass cover.

The “smothering” signal refers to the consistent pattern of heavy growth of nonnative grasses when not controlled by grazing or other management – with the consequent crowding out, outcompeting, or overshadowing of native annuals including those important to the bay checkerspot butterfly. A common consequence of such heavy annual grass growth is development of thatch, which adds to the strong smothering effect by inhibiting annuals’ germination and growth. The smothering signal dominated our ungrazed, untrimmed treatment which, after heavy early annual grass growth (2006), developed significant thatch cover, high residual dry matter plus litter, and reduced species richness. This treatment was clearly the worst for plants that constitute habitat for the bay checkerspot butterfly.

While there did not appear to be one vegetation management treatment that was “best” for all native species, vegetation functional groups, or measures such as species richness, “better” treatments include grazing, 2-inch trims, and early trims, all of which resulted in lower thatch and lower nonnative annual grass cover, more native forbs and more goldfields (*Lasthenia*) and tidy tips (*Layia*), especially in wetter years.

Intersite comparisons: We established transects to sample species composition across different grazing regimes and a variety of sites, with a consistent set of transects for 2005 through 2007. With the advent of an uncontrolled burn in 2004 at one of our sites, we were able to compare grazing and burning effects around the Santa Clara Valley.

The intersite comparisons largely confirmed the moisture effects and smothering effects found in the experimental trial. We also found strong effects of the Tulare Hill burn. *Plantago erecta*, *Castilleja densiflora*, and species richness in 2005 all were significantly higher in the burned area, thatch was removed, and nonnative annual grass cover was initially lower. The habitat improvements were brief, mostly being gone or insignificant by the third year post-burn. Grazing post-burn helped prolong the benefits of burning, for example for *Plantago*, *Lasthenia*, and native species richness.

Significant differences between grazing regimes were found but were not always easy to interpret, and are probably dependent on seasonal weather patterns. The variety in plant and abiotic responses to management that these differences stem from can be useful to the land manager in making sure that a diversity of conditions is available for a diverse set of species or species groups, even if exact causes of the differences are not always yet fully understood.

Studies of *Dudleya setchellii*: We undertook what we believe to be the first density comparison of this patchily distributed, endangered dudleya in paired quadrats on either side of a 1.2 km fence dividing grazed and ungrazed habitat, and found no significant difference. *Dudleya* inflorescences on the ungrazed side did tend to be slightly taller, and this difference was consistent enough to be statistically significant. Since taller plants had been shown to produce more flowers on average, these data suggest a small increase in seed output among plants on the ungrazed side.

Looking regionally at patches of dudleya on grazed and ungrazed sides of fencelines, and at a burned area, we concluded that there are significant differences between the level of damage from herbivores to dudleya inflorescences across fencelines. However, which side of the fence sustained the most damage – grazed or ungrazed – varied from location to location. At both Kirby Canyon area locations – grazed winter-spring – there was less damage on the grazed side, while at a Tulare Hill site – grazed spring to fall – there was more damage on the grazed side. A plausible explanation is that damage is caused extremely locally (on a scale of a few meters, e.g. by ground squirrels) and is idiosyncratic with respect to fencelines; but it is possible cattle could play a role damaging young inflorescences at a vulnerable point in the spring.

Damaged inflorescences usually bore no flowers, as opposed to an average of 20 to 35 flowers on undamaged inflorescences in 2005 and 2006. We found no evidence of branching of inflorescences below the break, or of new inflorescences developing to replace broken ones, so we conclude that herbivores do substantially damage annual reproductive output of dudleya. The plants are perennial, however, and might be capable of compensating with additional reproductive effort in a future year.

***Streptanthus albidus* response to clipping:** An experiment with heavy to severe simulated herbivore damage confirmed our observations from 2005 that the subspecies *S. a. peramoenus*, and by inference perhaps the endangered subspecies *albidus* as well, is flexible in the face of moderate damage, but adversely impacted by severe damage. Severely clipped plants had higher mortality, were smaller, and had fewer seed pods and lower seed production than moderately damaged plants. Naturally occurring damage by herbivores is readily seen in the field, and occurs in ungrazed as well as grazed areas. Possible culprits in causing herbivore damage to the subspecies include ground squirrels, leporids (rabbits and hares), cattle, deer, and elk.

Serpentine vegetation management recommendations: We provide general and specific recommendations for conservation managers of Santa Clara County serpentine lands. Briefly, hands-on management is necessary in our region to limit nonnative species and obtain management objectives. Grazing and controlled burning are both useful tools for the management toolbox, and grazing is for all practical purposes a must for bay checkerspot butterfly habitat in Santa Clara County. Site constraints and objectives allowing, using different management protocols on different portions of the site will enhance diversity and spread risk. Monitoring of sites is essential to know how management is affecting targets and progress toward objectives.

INTRODUCTION

This report presents the results and recommendations of a 3-year project to evaluate vegetation management methods and grazing impacts on serpentine habitat in Santa Clara County, California. Our work has been funded by the Habitat Restoration Program of the U.S. Fish and Wildlife Service. Developing this information and applying it in adaptive land management are priority tasks for recovery of the bay checkerspot butterfly, Santa Clara Valley dudleya, Metcalf Canyon jewelflower, and other species (USFWS 1998). Our field work was conducted on Coyote Ridge east of Highway 101, a conservation area in the Kirby recovery unit for bay checkerspot butterfly, on Tulare Hill, and at other significant serpentine preserves in the county.

Serpentine grasslands in Santa Clara County support multiple listed and rare species, including the bay checkerspot butterfly (*Euphydryas editha bayensis*), Santa Clara Valley dudleya (*Dudleya setchellii*), Metcalf Canyon jewelflower (*Streptanthus albidus albidus*), and Opler's longhorn moth (*Adela oplerella*). Table 1 provides a list of species of interest that rely on this habitat. Many are endemic to serpentine sites, and the federally listed species are endemic to Santa Clara County or nearly so.

A critical need in order to recover species and restore habitat on serpentine soils in Santa Clara County is to build adaptive vegetation management strategies. This need is identified in the USFWS 1998 final Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area¹, and the results of strategy development are needed for habitat management of preserved serpentine sites² (USFWS 1998). Our objective is to provide land managers with information they need on serpentine vegetation response to management alternatives, so that they can more effectively implement their own vegetation management programs for conserving rare species.

In this report we show that nonnative cover severely impacts native plant communities, and that several vegetation management approaches are effective in reducing nonnative plant cover. Different management approaches affect some native plant species differentially. Grazing effects on listed endangered plants are complex, and appear to include both positive and negative components. Timing of grazing may affect the balance of effects. Controlled burning offers another vegetation management tool. Our data and discussion address the effects and tradeoffs of burning. Finally, we present recommendations for serpentine grassland land managers as indicated by our work, notably that large properties should be managed in a patchwork of different techniques to promote biological diversity and to avoid putting all conservation eggs into one "management basket."

¹ Priority 1 tasks, number 5.16 and 5.24 (USFWS 1998, p. IV-27 to 28, 33, 35)

² Priority 1 task 3.1 (USFWS 1998, p. IV-16)

Table 1. Special Status Species and Species of Interest in the Area of the Project

Common Name	Scientific Name	Status ³	Comments
bay checkerspot butterfly	<i>Euphydryas editha bayensis</i>	FT	largest core population, critical habitat
Opler's longhorn moth	<i>Adela oplerella</i>	FSC	
Santa Clara Valley dudleya	<i>Dudleya setchellii</i>	FE, CNPS 1B	rocky serpentine areas
Metcalf Canyon jewelflower	<i>Streptanthus albidus</i> ssp. <i>albidus</i>	FE, CNPS 1B	white flowers
Most beautiful jewelflower	<i>Streptanthus albidus</i> ssp. <i>peramoenus</i>	FSC, CNPS 1B	pink-purple flowers
smooth lessingia	<i>Lessingia micradenia</i> var. <i>glabrata</i>	FSC, CNPS 1B	
serpentine linanthus	<i>Linanthus ambiguus</i>	CNPS 4	
dwarf plantain	<i>Plantago erecta</i>		food plant of bay checkerspot
purple owl's clover	<i>Castilleja densiflora</i>		food plant of bay checkerspot
exserted paintbrush	<i>Castilleja exserta</i>		food plant of bay checkerspot
California cream cups	<i>Platystemon californicus</i>		food plant of Opler's longhorn moth
tidy-tips	<i>Layia gaillardiioides</i> ⁴		nectar plant, bay checkerspot
California goldfields	<i>Lasthenia californica</i>		nectar plant, bay checkerspot
desert-parsley	<i>Lomatium</i> spp.		nectar plant, bay checkerspot
wild onion	<i>Allium serra</i>		nectar plant, bay checkerspot
sea muilla	<i>Muilla maritima</i>		nectar plant, bay checkerspot
false babystars	<i>Linanthus androsaceus</i>		nectar plant, bay checkerspot
intermediate fiddleneck	<i>Amsinckia intermedia</i>		nectar plant, bay checkerspot

³FE=federally endangered, FT=federally threatened, FSC=federal species of concern. CNPS codes refer to California Native Plant Society lists.

⁴ We and others have previously reported this species as *Layia platyglossa*; however, we have since determined the species to be *Layia gaillardiioides*.

DESCRIPTION OF STUDY AREA

All work was conducted in serpentine grassland habitats in Santa Clara County, California, USA. The vegetation is essentially treeless, dominated by grasses and forbs, with unusual abundance of native and endemic species relative to highly invaded non-serpentine California grasslands. These habitats have been grazed by cattle for many decades, quite possibly since the arrival of the Spanish. The soils of our study areas typically are mapped as Montara series, a serpentine or ultramafic soil series in Santa Clara County. A general description of this type of habitat can be found in the introduction of the Recovery Plan for Serpentine Soil Species of the San Francisco Bay Area (USFWS 1998) or on the USDA-Natural Resources Conservation Service website at: <http://ortho.ftw.nrcs.usda.gov/cgi-bin/osd/osdname.cgi>.

Our vegetation management trial on Coyote Ridge was located in the Kirby Conservation Area north of the Kirby Canyon Landfill (approximately UTM Zone 10, 617,600 easting, 4,117,500 northing, WGS84 datum, USGS Morgan Hill 7.5" quad). The area is grazed at 1 cow-calf per 10 acres in winter and spring (personal communication, rancher Tony Pierce), with some oversight by Waste Management, Inc. consultants to ensure good habitat conditions for bay checkerspot. This grazing generally results in low vegetation heights and low residual dry matter that favor the butterfly's low-stature host plants. Most-beautiful jewelflower studies were carried out north of the Kirby Conservation Area access road in a gently sloping area of coarse, gravelly serpentine soil with scattered rock outcrops.

Tulare Hill, rising from the Santa Clara Valley between Coyote Ridge and the Santa Teresa Hills, was another important study area (USGS Morgan Hill and Santa Teresa Hills quads). Vegetation studies, including burn comparisons, were conducted there. About half of Tulare Hill experienced an uncontrolled burn in late May 2004, starting at the railroad tracks and spreading south. We established paired transects across the burn line in addition to already established plant transects and have since followed the results of that burn. Previous work (Weiss and CH2M Hill 2003, 2004) had established that fall burns were ineffective for reducing nonnative cover and increasing native cover. This accidental burn provided a unique opportunity to assess the short and longer-term impacts of a late spring burn.

We examined vegetation differences in different grazing paddocks to evaluate effects of differences in grazing management. By pairing transects on adjacent sides of a fence, we minimized differences due to such non-grazing factors as slope, aspect, and soils. Fencelines in serpentine grassland in the Kirby area and on Tulare Hill were evaluated. Ungrazed areas behind certain fencelines at Kirby have been ungrazed since 1986. A large paddock on United Technologies property, adjacent to and north of the Kirby Conservation Area, has been grazed in summer-fall at the same stocking rate. Ungrazed areas at Tulare Hill have been fenced off since 2001. Fencelines separating different grazing management regimes (winter-spring vs. summer) also are present near Kirby.

MATERIALS AND METHODS

Vegetation management trial

This experimental trial had seven treatments in a randomized block design. Two grazed treatments were: (1) ambient grazing (winter-spring), and, (2) partial grazing exclusion (fencing opened or closed to try to reach 4-inch vegetation height). Within complete grazing-exclusion fencing were the five remaining treatments: (3) untrimmed (None), (4) trimmed to 2 inches through the spring (2E), before most grass seed maturation, (5) trimmed to 2 inches after most grasses senesced (2L), (6) trimmed to 4 inches early (4E), and, (7) trimmed to 4 inches late (4L).

We fenced the grazing exclusion plots in late fall of 2004 before substantial annual plant growth, and added the partial grazing exclusion fencing on March 15, 2005, when cattle were present. Two blocks (each about 40 by 40 feet) of plots were established to avoid pseudo-replication. Each half-meter by half-meter plot was staked and numbered. In the grazing exclusion area, plots were randomly assigned to vegetation management treatments.



Photo: One of two grazing exclusion blocks established in fall 2004 on Coyote Ridge.

We trimmed early season treatments as needed in the spring of each year to maintain target vegetation height. Simulated late-grazing plots were trimmed in June or July after most grass seed heads had shattered and dispersed their seed. We trimmed plots using battery-powered hedge-trimmers, and trimmed 20 cm horizontally outside each plot to reduce edge effects. Approximate average vegetation height was recorded in each plot before the first trimming of the year.

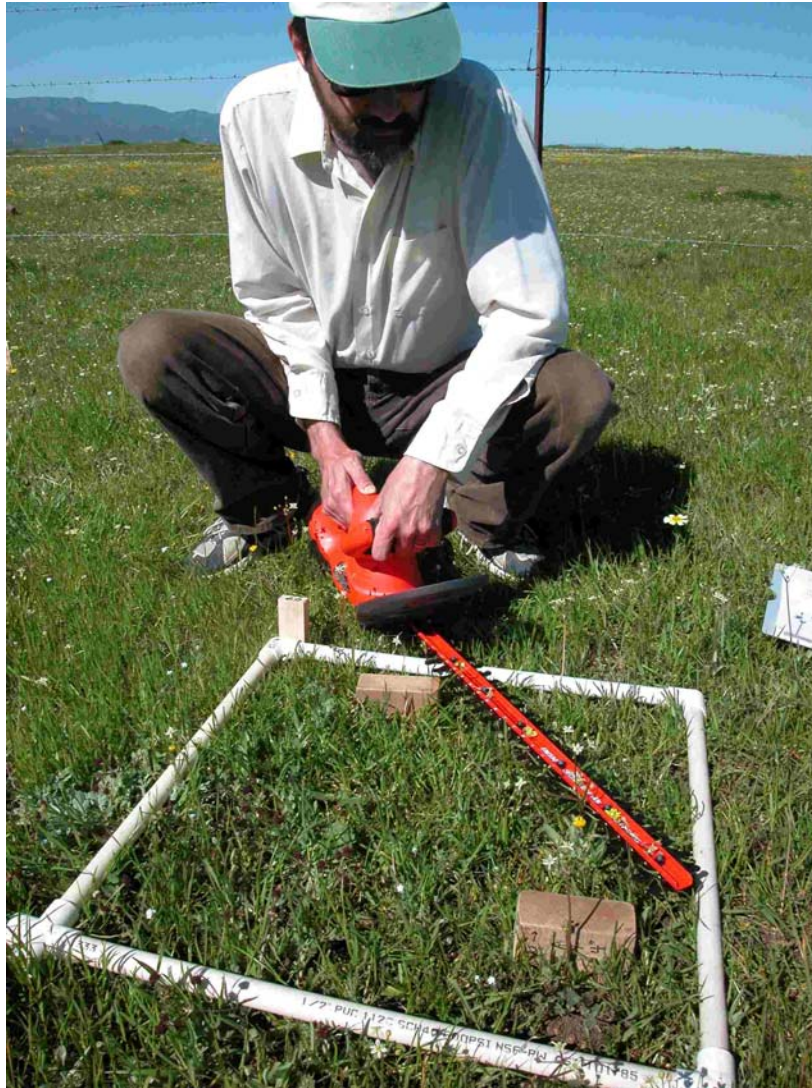


Photo: David Wright trimming a 2-inch early trim, grazing exclusion plot on March 15, 2005. The PVC quadrat shows the size of the sample area; an additional 2 dm on all sides of the plot are trimmed to minimize edge effects. The wood blocks are temporarily placed to standardize the height of cut. The wooden stake at upper left marks and identifies the plot. The fence in the background excludes cattle grazing.

We quantified plant percentage cover in each plot by plant species, and also recorded percent cover of litter or thatch, bare ground, and rocks. Plant cover was recorded in April of each year at a point when many species were flowering. Cover estimates used a scale of: 0, 1, 2, 5, 10, 20, 30, 40, ..., 100%.

On August 27, 2007, we collected and composited 2 sub-samples of residual vegetation (above 0.5 cm above ground level) plus litter from the 20-cm wide border of each plot. Each sub-sample was from an area 5 by 20 cm, so the composite sample area covered 200 cm². Samples were air-dried in Sacramento, CA, examined, any excess soil removed, and the dry vegetation plus litter weighed to the nearest 0.01 g. This measure differs from a conventional residual dry matter (RDM) measurement because it includes accumulated plant litter or thatch. We determined it to be important to include thatch because it is an influential factor in plant growth in the plots.

The responses in cover of individual species in plots between years were analyzed as differences from 2005 to 2006 (2006 report) and 2005 to 2007 in log₁₀ (cover+1) transformed data, using JMPin 4.0 (SAS Institute). This is the equivalent of a one-way repeated measures ANOVA, with treatment as a fixed factor. Individual hostplant and nectar species, key annual grasses, and functional groups (perennial grasses, perennial forbs, annual forbs, annual grasses, and geophytes⁵) were analyzed.

Intersite Comparisons

We established transects to sample species composition across different grazing regimes and a variety of sites, with a consistent set of transects for 2005 through 2005. Transects were 50 m long, and ten 0.5 x 0.5 m quadrats spaced 5 m apart were sampled for percent cover of plant species and bare ground, as described above. Transects were set within various parts of the gradient from warm to cool slopes to represent local habitat diversity. Grazing regimes included ungrazed, winter-spring, spring and fall, and summer-fall. In some cases transects are paired across fencelines to minimize uncontrolled differences due to factors such as slope, aspect, soils, and localized species distributions; so in previous reports we have sometimes called these data “cross-fence comparisons.” All data were log₁₀ transformed for one-way ANOVA. Tabular and graphical data report untransformed values.

Cross burn line (May 2004) comparisons on Tulare Hill were done in a similar manner, and we were able to sample unburned-ungrazed, burned- ungrazed and burned-grazed. There were not sufficient areas to adequately sample unburned–grazed parts of Tulare Hill.

Dudleya herbivore damage

We quantified damage to dudleya plants across fencelines separating different grazing regimes at four locations in July, 2005, and measured plants within a recent burn area in one location. The samples on either side of the fences were within 50 m of one another in visually similar habitat; and plants within 1 m of the fence were not included, to avoid

⁵ A geophyte is a plant that has bulbs, corms, tubers, or similar underground structures. The California poppy (*Eschscholzia californica*) and blue-eyed grass (*Sisyrinchium bellum*) are two common examples. While technically a type of perennial forb, here geophytes are calculated separately from that category.

areas of potential heavy trampling by cattle. We counted and measured inflorescences, and counted flowers on selected inflorescences to relate inflorescence size to reproductive potential. Damage to inflorescences was recorded, and observations of evidence of potential herbivore activity were made.

Dudleya fenceline comparison

On June 26 and 27, 2007, we counted dudleya clumps⁶ and dudleya inflorescences in paired quadrats along both sides of a 1.2 km fenceline transect separating the Kirby Canyon Landfill (ungrazed) from grazed management areas to the north. Quadrats were 20 m long parallel to the barbed-wire fence, located 2 m away from the fence to avoid fenceline artifacts (trampling, grazing through the fence), and extended an additional 5 m perpendicular to the fence (20 x 5 m = 100 m² or 0.01 ha). In all a total of 1.2 ha of habitat was intensively surveyed along the fenceline.

Quadrats were continuously arrayed along the fence except where disturbed habitat or obvious non-habitat intervened (e.g., landfill edge, a road, a riparian corridor), allowing a density estimate in this habitat. Pairing quadrats served to minimize differences among quadrats caused by non-management factors such as slope, aspect, or soil characteristics. To investigate possible differences in reproductive success under different grazing regimes, in each quadrat containing dudleya inflorescences a sample of up to 10 inflorescences (the first 10 encountered) was measured for height and stalk diameter (in cm and in hundredths of mm, respectively). These data were compared with correlations we have recorded between numbers of flowers and inflorescence height and diameter in *Dudleya setchellii*.

***Streptanthus albidus* ssp. *peramoenus* clipping experiment**

In an area of moderate density of *S. a. peramoenus* north of the Kirby ridge access road (approx. 830 ft. elevation), we conducted an experiment to examine the jewelflower's response to simulated herbivore damage. Previous observations suggested the plants were quite tolerant of light to moderate damage (see our 2005 report). On May 8, 2006, plants above a minimum size were identified and tagged, and each plant randomly assigned to one of 3 clipping treatments: (1) no clipping; (2) the main stem cut off at half of its height; or (3) the main stem cut off close to the ground but just above the first healthy leaf. A total of 90 plants were tagged, with 30 in each treatment.

The jewelflower plants were harvested (cut off at ground level and bagged) on July 20, 2006, and were measured, dried, weighed, and their seed pods counted.⁷

⁶ Determining individual dudleya plants or rosettes is not practicable in the field; for purposes of this study we defined a "clump" as a rosette or a contiguous cluster of rosettes with at most one inflorescence. If a contiguous cluster of dudleya had more than one inflorescence, it was counted as the same number of clumps as its number of inflorescences.

⁷ After counting, seed pods were given to the Santa Clara Valley chapter of the California Native Plant Society (Jean Struthers) for their work in educating people about native plants and native plant gardening.

RESULTS AND DISCUSSION

Observations of bay checkerspot butterflies

No bay checkerspot larvae were observed during project vegetation management activities, and none were directly impacted. We observed bay checkerspot adults flying in the project vicinity on Coyote Ridge in the Kirby habitat area (cover photo). Bay checkerspot larvae were observed but not disturbed during intersite comparison vegetation sampling on Coyote Ridge.

Vegetation Management Trial

In 2005 we collected baseline data for all plots in their initial, grazed state, and began the management trial treatments (fencing, trimming).



Photo: Vegetation inside the grazing exclusion fencing was visibly higher toward the end of the first growing season (July 27, 2005; compare vegetation in background). Trimmed trial plots are visible as shorter patches amid the high grass.

Effects of the treatments on vegetation were evident in average-height estimates made before the first 2006 trimming (Figure 1). In mid-April 2006, about 9 months after the late trim treatment of 2005, vegetation was shortest in the grazing treatments and taller in the ungrazed treatments – tallest in the untrimmed treatment. In 2007, we adjusted our partial grazing treatment – keeping the cows out a bit more – to try to parallel the 4-inch trim treatments. As a result, the vegetation in partial grazing plots was taller in spring 2007 than in 2006.

In both years, ambient grazed areas had the shortest cover: 4-8 cm (1.6-3.1 inches), and ungrazed, untrimmed plots had the tallest: 12-16 cm (4.7-6.3 in). That the modest height reductions achieved by trimming treatments had significant effects on native and nonnative plant species suggests that these effects may have been mediated by thatch as well as by plant height. Thatch development through plant litter deposition is addressed below.

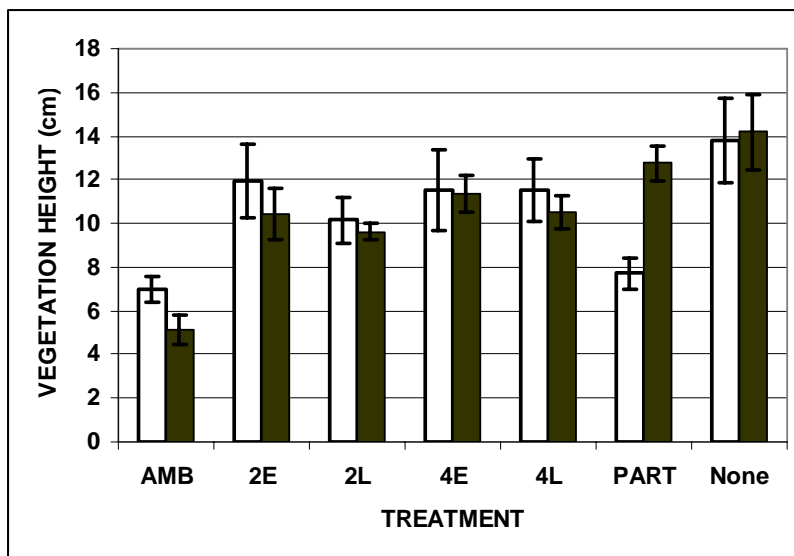


Figure 1. Average vegetation height (and 95% confidence intervals) in the plots in April 2006 (top panel) and 2007 (lower panel) before trimming. Treatment combinations are: “AMB” = ambient grazing, 2 and 4 stand for 2- or 4-inch trim, E and L stand for early and late trimming, “PART” = partial grazing, “None” = ungrazed and untrimmed.

Our results for the spring of 2006 (first year post-treatment) were reported in our 2006 Interim Report (attached), and can be summarized as follows. The springs of 2005 and 2006 were relatively wet. Grassland composition was affected strongly by the different treatments in the first year. In general, annual grasses – primarily nonnative – and annual forbs – primarily native – showed significant differences among treatments, and the perennial components did not. *Lolium multiflorum* (Italian ryegrass) dominated the annual grass component response: it was reduced by the ambient and partial grazing treatments and increased strongly in the late-trim (both 2-inch and 4-inch) and ungrazed, untrimmed treatments. *Lolium* in early trim treatments was relatively unchanged from 2005 to 2006. Annual forbs generally declined in all treatments except ambient grazing.

This result was consistent with a competitive interaction with nonnative annual grasses. For example, *Lasthenia californica* increased in 2006 in ambient grazing plots, where *Lolium* declined, but *Lasthenia* declined in ungrazed, untrimmed plots and in 2-inch early plots. *Layia gaillardoides* declined under all treatments except ambient and partial grazing, again, where *Lolium* declined. We noted that many flowerheads of both *Lasthenia* and *Layia* were trimmed in the early trim treatments. Unlike perennials in general, *Muilla maritima* did show a significant treatment response, increasing in early trim and partial grazing plots, despite trimming of its inflorescences in 2-inch early and often 4-inch early plots.

In the remainder of this section we discuss our 2007 results in the vegetation management experimental trial. Compared to 2005 and 2006, 2007 was a dry year, with resulting decreases in cover of annuals, both native and nonnative, across all treatments. However, native perennial cover increased (grasses, forbs, and geophytes), suggesting a relative improvement in the competitive status of native perennials in dry years. At the same time, the effects of grazing on the plant community were less noticeable.

As in previous years, there were substantial differences between experimental blocks, so the block design served to control for place-to-place variation due to block differences. Block effects were seen for *Layia*, *Muilla*, *Lolium*, *Bromus hordeaceus*, annual grass, perennial grass, geophytes, annual forbs, perennial forbs, and species richness. Generally, the east block on a slight northeast-facing slope had higher grass cover and less forb cover than the west block on the relatively flat ridgetop.

Bay checkerspot butterfly host and nectar plants. Cover of *Plantago erecta*, the primary larval host plant of the bay checkerspot, remained low in 2007 (<1% on average: Figure 2). Apparently the impact of *Plantago* defoliation by high densities of postdiapause larvae at this particular site in 2002-2004 is persisting over several years. No treatment responses were detected at these low cover levels, but *P. erecta* response to grazing and fire will be considered in another section of this report.

Castilleja densiflora cover declined overall in 2007, and cover values remained too low to detect any significant response to treatments (Figure 3). *Castilleja densiflora* and *Castilleja exserta* are vital secondary larval host plants for pre-diapause bay checkerspot larvae (*C. exserta* did not occur in the plots). We noted that the 2-inch early trim often removed inflorescences of *C. densiflora*. In contrast, grazing cattle do not appear to feed on these inflorescences, which frequently grow up without damage in well-grazed areas. We also generally have observed that these *Castilleja* species germinate and grow more abundantly in wetter years.

California goldfields (*Lasthenia californica*), an important nectar plant, showed significantly different responses to management treatments. While *Lasthenia* decreased in all treatments in the face of dry 2007 conditions, the ungrazed, untrimmed treatment showed the most dramatic decrease, and *Lasthenia* decreased least in the ambient grazing, 2-inch late, and 4-inch early trims (Figure 4, $p = 0.0003$).

Layia gaillardoides also decreased across all treatments (Figure 5), with a significant difference among treatments ($p = 0.0057$). *Layia* in the partial grazing treatment stayed low over time, while the 4-inch late trim plots showed the largest decrease (these plots also had the highest baseline).

Cover of *Muilla maritima*, a perennial geophyte and a nectar plant, increased in many plots in 2007, with a significant treatment effect (Figure 6; $p = 0.001$). The 4-inch early trim showed the largest increase, while ambient grazing gave the lowest cover over time. This is consistent with a grazing effect on vegetative parts of the plant. Leaves of *Muilla* and many geophytes in this habitat are grass-like and closely intermingled with grass. In our experience, cattle do not appear to graze directly on inflorescences or fruits of *Muilla*, although it is possible that grazing might damage some inflorescences early in their growth initiation. On the other hand, in our 2006 results, damage to *Muilla* inflorescences in the trimmed plots did not adversely affect abundance of these perennials in the short term (1 year), and in the 2007 (2-year) results there were no significant adverse effects of trimming. Effects resulting from impacts to reproduction and recruitment to the perennial population, however, would likely take up to a generation to observe.

Grasses and thatch. The annual grasses showed varied responses. *Lolium* cover decreased significantly at all sites except for the partially grazed (Figure 7; $p < 0.01$). This was somewhat countered by an increase in *Bromus hordeaceus* (Figure 8). The dry conditions of 2007 appeared to constrain *Lolium* relative to *B. hordeaceus* (*Lolium multiflorum* is well known as a moisture-loving species). The most significant increases in *B. hordeaceus* cover were in the two late trimming treatments ($p = 0.0024$), showing that early trimming or grazing pressure, before seed maturation, is needed to keep *B. hordeaceus* cover down.

Annual grasses combined usually accounted for 35 to 60 percent of plant cover in the plots (Figure 9 [the native annual grass *Vulpia microstachys* makes only a very small and occasional contribution to cover, with no significant patterns among treatments: Figure 11]). Analyzing annual grasses combined, in 2007 annual grass was near 2005 baseline levels in the ambient and partial grazing treatments, declined in early trim treatments – particularly the 2-inch early – and increased in late trim treatments.

Perhaps counterintuitively, annual grasses also declined significantly in the ungrazed, untrimmed plots. This decrease in live annual grass was explained by thatch buildup in these unmanaged areas (Figure 10). While annual grass recruited more competitively in thatch than annual forbs (see below), heavy thatch still reduced annual grass recruitment and cover. Thatch was significantly higher in the fenced, no trim plots than in any other treatment in 2007 (average 37% cover vs. less than 10% in other treatments; $p < 0.0001$). Quantitative data were not collected on thatch in 2005, but we observed that thatch was initially near zero cover throughout all plots. Plots were installed in a grazed area that had very little thatch in 2005, similar to the low levels observed in the ambient grazed plots shown in 2007.

Perennial grass cover increased in all treatments in 2007, with no significant treatment effects (Figure 12). We interpret this general increase as showing a relative competitive advantage of the perennials in a dry year following wet years.

Forbs and geophytes. Geophytes increased in all treatments in 2007 except for ambient grazing. Differences in geophyte cover among treatments were driven primarily by increased growth of *Chlorogalum pomeridianum* (soaproot) in the absence of grazing within the plots (Figure 13; $p < 0.0001$). Annual forbs generally decreased in 2007, with no significant treatment effects (Figure 14). Perennial forb cover, however, increased across the board, likely in response to reduced competition from annuals in this dry year. The smallest increase was in the partially grazed plots (Figure 15). These species were able to recruit in the thatch-laden ungrazed, untrimmed plots, but we observed a tendency for successful plants in these situations to be larger and more elongated than usual, as a result of growing through the thatch.

Species richness and aboveground biomass. Species richness declined dramatically in the fenced untrimmed plots over the study (reduction of about 30 to 40 percent; Figure 16; $p < 0.001$). In all other treatments species richness remained about the same over time. Richness of native species only, excluding exotics, showed the same response (Figure 17).

Total aboveground biomass, living and dead, was measured as residual dry matter plus litter (RDML). This was only measured in 2007, and reflects plant aboveground growth and competition as well as the extent to which litter or thatch may inhibit germination and growth of plants. There were significant differences among the management treatments (Figure 18, $p = 0.002$), with the highest RDML in the ungrazed, untrimmed plots and significantly reduced RDML in the ambient grazed, partial grazed, and 2-inch late trim treatments.

Significance levels in response from 2005 to 2007 among treatments noted by:
 N.S. (not significant), * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, □ = 2005, ■ = 2007. Mean \pm SE.

Bay checkerspot host and nectar plants:

Figure 2. Mean *Plantago erecta* cover, N.S.

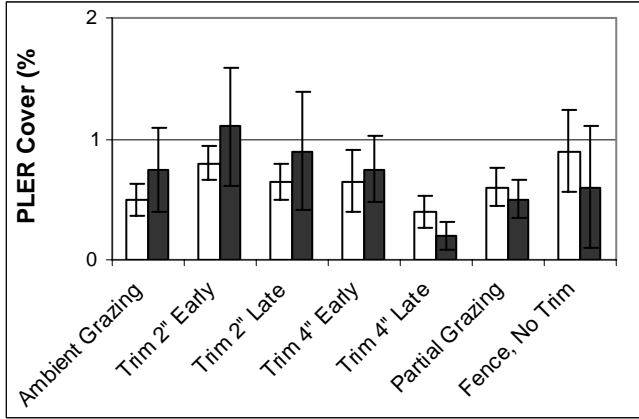


Figure 3. Mean *Castilleja densiflora* cover, N.S.

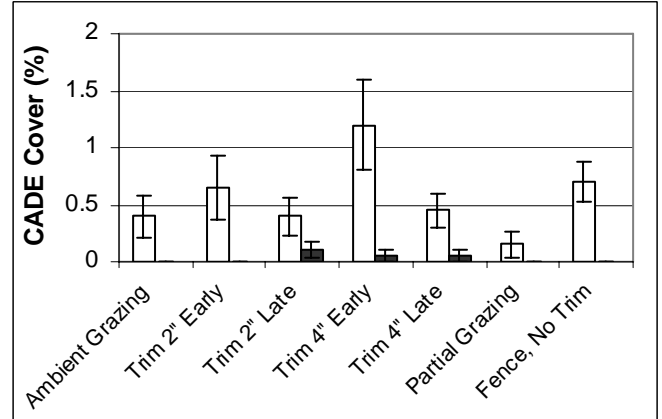


Figure 4. Mean *Lasthenia californica* cover***

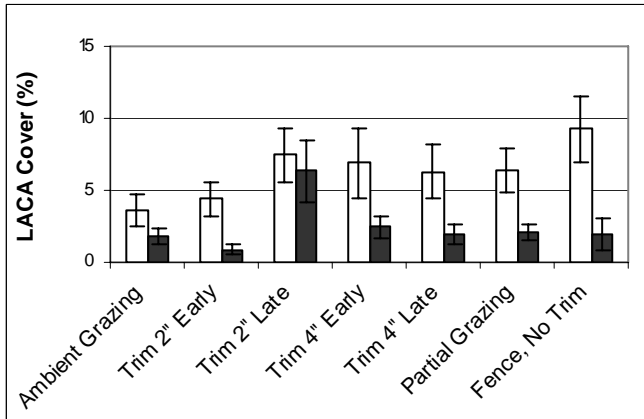


Figure 5. Mean *Layia gaillardoides* cover**

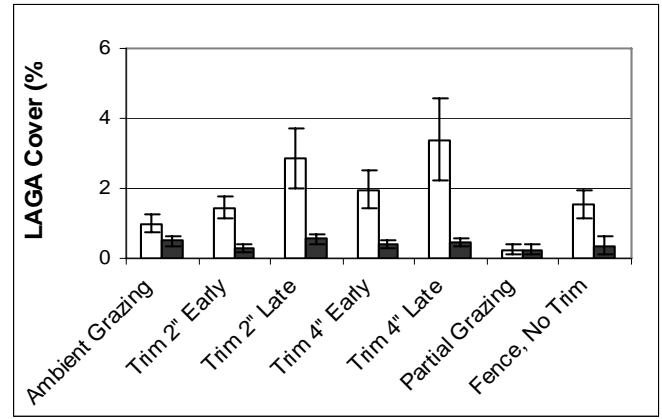
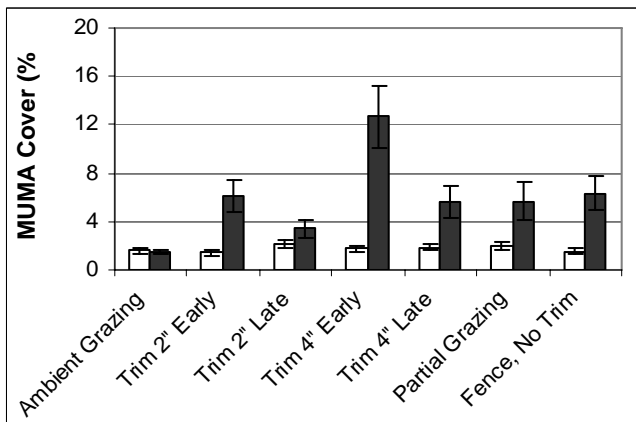


Figure 6. Mean *Muilla maritima* cover***



Grasses:

Figure 7. Mean *Lolium multiflorum* cover**

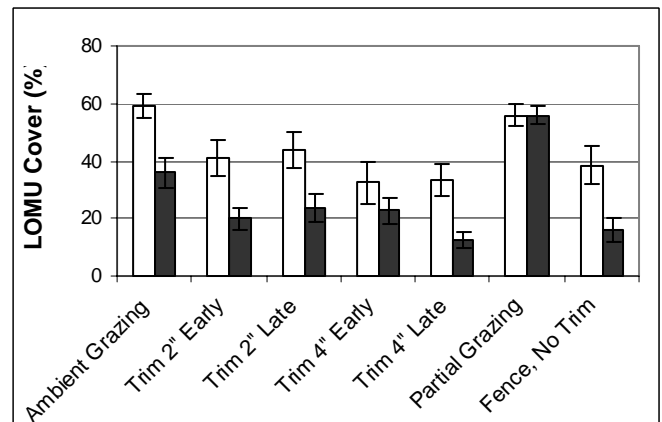


Figure 8. Mean *Bromus hordeaceus* cover***

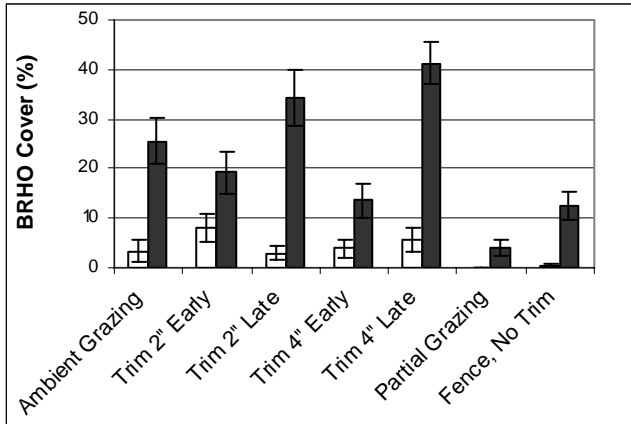


Figure 9. Mean nonnative annual grass cover**, with Welch ANOVA for unequal variances

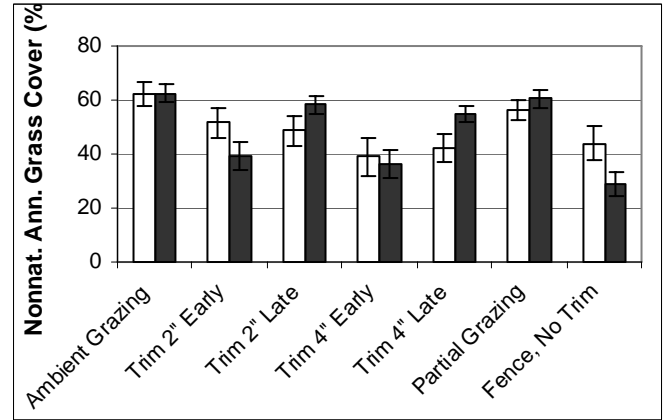


Figure 10. Mean thatch cover, 2007***

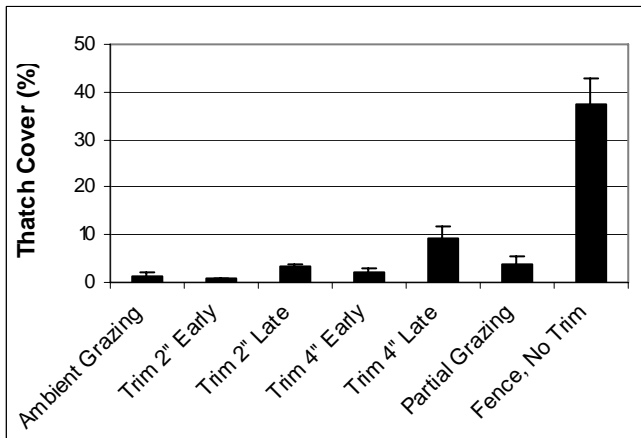


Figure 11. Mean *Vulpia microstachys* cover, N.S.

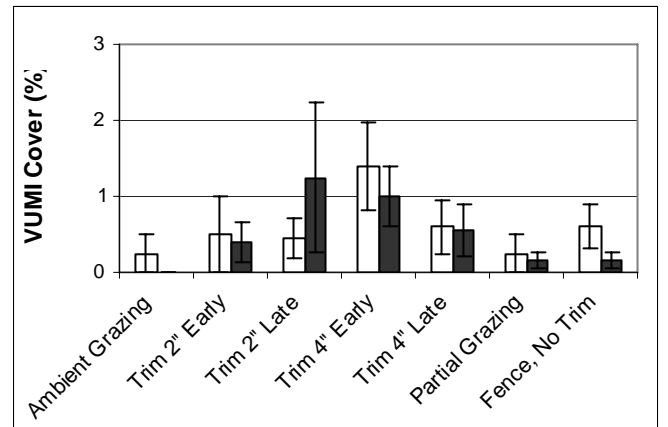
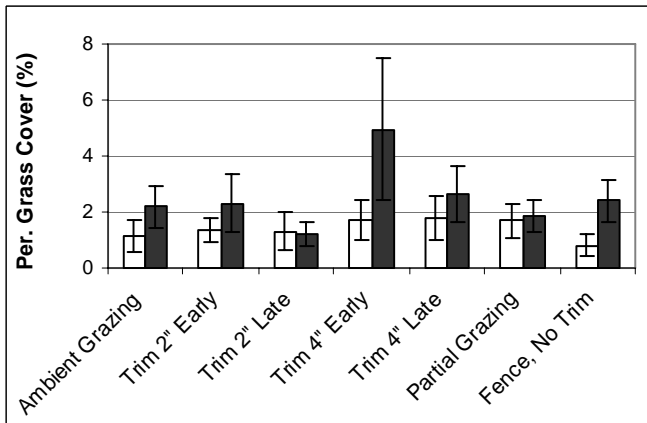


Figure 12. Mean perennial grass cover, N.S.



Other functional groups:

Figure 13. Mean geophyte cover***

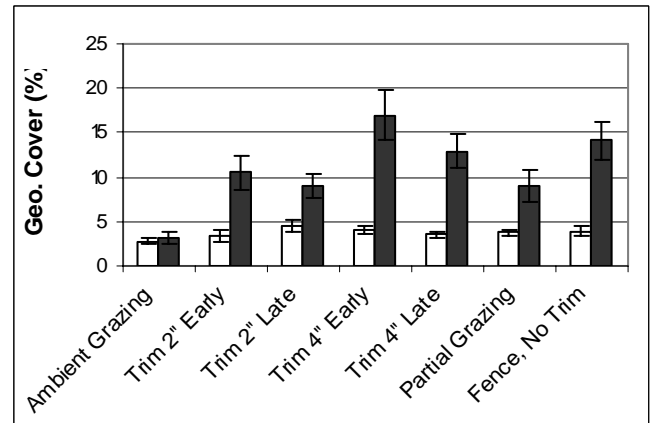


Figure 14. Mean annual forb cover, N.S.

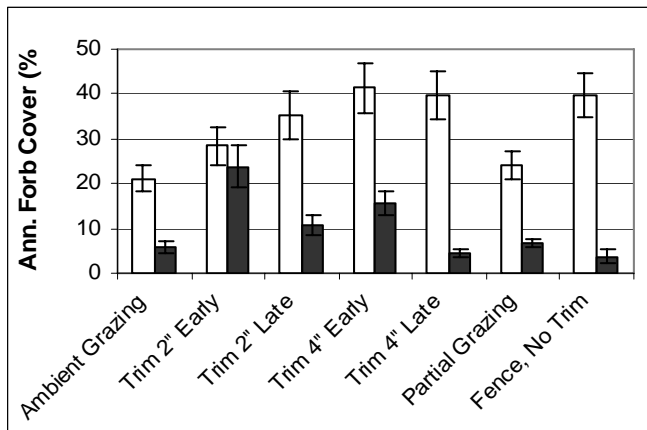
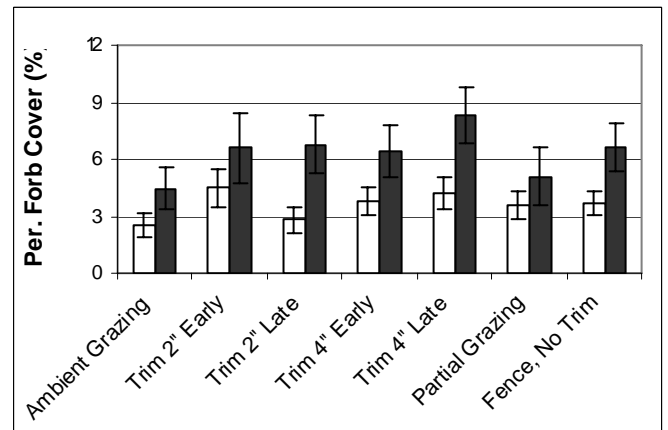


Figure 15. Mean perennial forb cover*



Species richness:

Figure 16. Mean total species count***

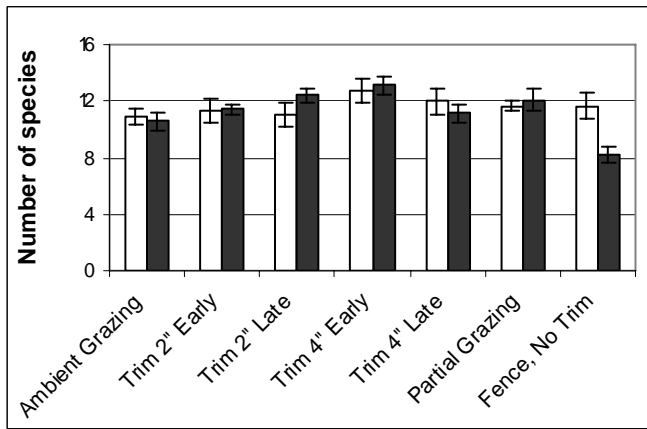
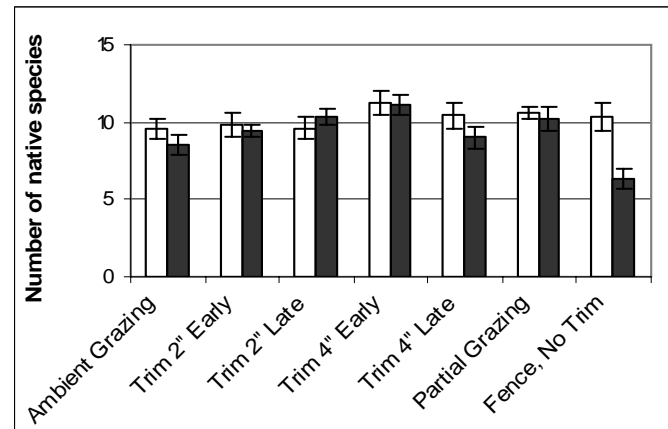
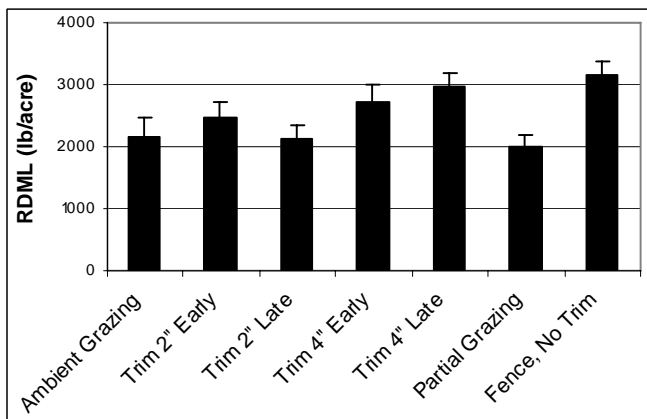


Figure 17. Mean native species count***



Residual dry matter + litter:

Figure 18. RDM + litter per treatment**



Discussion of vegetation management trial. Two strong signals are apparent in the data from our experimental vegetation management trial: a moisture signal and a “smothering” signal. The moisture signal is apparent in the switching between 2006 and 2007 results in the relative performance of *Lolium multiflorum* and nonnative annual grasses versus perennials. Note that 2005 and 2006 were almost ideal years for annual grass growth, with extended rains into May that led to high forage production. The “smothering” signal refers to the consistent pattern of heavy growth of nonnative grasses when not controlled by grazing or other management – with the consequent crowding out, outcompeting, or overshadowing of native annuals important to the bay checkerspot butterfly. A common consequence of such heavy annual grass growth is development of thatch, which adds to the strong smothering effect by inhibiting annuals’ germination and growth.

In 2005-2006, a wetter year, *Lolium* and other nonnative annual grasses grew abundantly: the dominant *Lolium* increased from nearly 40% cover to over 60% in the ungrazed, untrimmed plots. In contrast, in the drier year 2007, *Lolium* decreased to cover values less than the baseline 2005 data, typically to values around 20% cover. *Bromus hordeaceus* was not hit so hard by the dry conditions (least of all in late-trimmed plots), but overall nonnative annual grass values fell back approximately to 2005 values. Perennials, including geophytes, appeared unaffected or even benefited under the drier conditions, perhaps in response to reduced activity of annuals. This response of perennials could rely on stored reserves from the previous, wetter year(s), and might not persist for long under a prolonged drought. Nevertheless, it seems clear that perennials, which are predominantly native in this habitat, may benefit in competition with nonnative annual grasses from intermittent or even frequent dry years. While drought is not under the control of local land managers, the occasional dry year or multi-year drought offer opportunities for reduced grass cover.

The smothering signal was clear in the ungrazed, untrimmed treatment (fence, no trim), which, after heavy early annual grass growth (2006), developed significant thatch cover, high residual dry matter plus litter, and reduced species richness. The late-trim treatments also experienced a flush of *Bromus hordeaceus* growth, presumably because these treatments allowed seeding. The 4-inch late trim treatment also showed substantive thatch development and low annual forb cover comparable to the ungrazed, untrimmed treatment.

While there did not appear to be one vegetation management treatment that was “best” for all native species, vegetation functional groups, or measures such as species richness, the untreated (fence, no trim) plots were clearly the “worst” treatment for many species. These “unmanaged” plots showed significantly higher thatch, and significantly lower species richness and *Lasthenia californica* cover. These plots had low cover of annual grass in 2007, which is explained by the increasing amounts of thatch and dry conditions. While lack of management and development of thatch in the ungrazed, untrimmed treatment did not appear to harm geophytes or perennial grasses or forbs in 2007, it is not clear that effects on perennials would remain equally benign over time, especially in wetter years or with excess nitrogen deposition. “Better” treatments include grazing, 2-

inch trims, and early trims, all of which resulted in lower thatch and lower nonnative annual grass cover, more native forbs and more *Lasthenia* and *Layia*, especially in wetter years (2006 report). Analysis suggests moderately heavy grazing (to 4-8 cm vegetation height; RDM roughly 2000 pounds per acre [thatch is negligible in these circumstances]) may adversely impact geophytes in general, and *Muilla maritima* in particular. However, native annuals appear relatively sensitive to trimming timing or vegetation height, with 2-inch trim being better than 4-inch and early trim better than late in both 2006 and 2007. The intersite comparisons (below) place these results in context.

Intersite Comparisons

Intersite (“cross-fenceline”) results for 2005 were presented in our 2005 report (attached). Our 2005 results can be summarized as follows:

Grazing regimes had substantial effects on plant composition in 2005. *Plantago erecta* was reduced in the ungrazed (UG) areas. *Castilleja* of either species were patchy and low in density and did not differ detectably among grazing regimes (winter-spring vs. spring-fall), but were totally absent from the ungrazed areas. *Lasthenia*, *Layia*, and *Muilla* – all bay checkerspot nectar plants – were highest under winter-spring grazing (WS), followed by spring-fall (SF), and lowest in ungrazed sites. *Lolium* and total annual grass cover were highest in UG, and lowest in WS. Species richness at the quadrat level was highest in WS, followed by SF, and lowest in UG.

The initial post-burn effects of the 2004 burn on Tulare Hill were substantial. *Plantago*, *Castilleja densiflora*, and species richness in 2005 all were significantly higher in the burned area. Nectar sources did not differ detectably. *Lolium* and total annual grass cover were higher in the unburned areas, and grazing reduced *Lolium* and total annual grass cover on the burned areas (BG<BUG).

Data from plots in additional serpentine grassland sites in south San Jose are included here for our 2005-2007 comparisons. We were able to contrast different grazing regimes (grazed vs. ungrazed, and timing of grazing) and followed the vegetation of a burned area. Table 2 below lists the management regimes for each group of plots. Our experimental trial plots, discussed above, were near the KC-WS plots.

Table 2. Intersite comparison information and abbreviations.

Name	Full Name	Site	Management	Elevation
TH-BG	Tulare Hill	Tulare Hill	2004 burn; Grazed, spring-fall	Low
TH BUG	Tulare Hill	Tulare Hill	2004 burn; Ungrazed	Low
TH UBUG	Tulare Hill	Tulare Hill	Unburned; Ungrazed	Low
LE-SF	Los Esteros	Coyote Ridge	Grazed, spring and fall	Low
VTA-WS	Valley Transportation Authority	Coyote Ridge	Grazed, winter-spring	Mid
KC-WS	Kirby Canyon	Coyote Ridge	Grazed, winter-spring	High
UTC-SF	United Technologies Corp.	Coyote Ridge	Grazed, spring and fall	High

Bay checkerspot butterfly host and nectar plants. *Plantago erecta* responded negatively to lack of management at Tulare Hill (TH-UBUG), but responded positively to burning (TH-BUG) or burning and grazing (TH-BG) (Figure 19; no comparable unburned grazed area was available to sample). *Plantago* cover was the lowest observed regionally at Tulare Hill's ungrazed and unburned transect, whereas the Tulare Hill grazed and burned site had highest cover values. Cover declined at the burned sites as the vegetation redeveloped post-fire, and declined particularly steeply in the ungrazed burn site. The Coyote Ridge sites showed a diversity of year to year responses that suggest differences due to grazing timing and/or elevation.

Castilleja cover (Figure 20) showed some similarities with *Plantago*, with lowest cover regionally at the Tulare Hill ungrazed unburned site and the low elevation Los Esteros site on Coyote Ridge. Again there was interesting diversity in performance of the mid and high elevation Coyote Ridge sites: in 2005 the winter-spring grazed Kirby Canyon site had the highest cover, while in 2006 (both wetter years) the spring-fall grazed UTC site was highest. In 2007, a dryer year, *Castilleja* had lower cover at all sites.

Lasthenia cover dropped at all sites, showing a similar pattern to the experimental plots (Figure 21). We suggest the dry year as the main factor in average cover decreases; and the differences in cover at the three Tulare Hill sites suggest management regimes to be important as well. The lowest cover was again found on the unmanaged Tulare Hill site, with the highest Tulare Hill cover found on the grazed and burned site. It is interesting that, from 2005 to 2006, *Lasthenia* cover increased only in the burn sites, and declined more rapidly in the ungrazed burn site from 2006 to 2007 than in the grazed burn area.

Layia gaillardoides cover appears too sporadic to quantitatively detect regional patterns (Figure 22).

Allium continuously showed very low cover across the board, with mixed increases and decreases in 2007. We noted that two burned plots on Tulare Hill showed an immediate post-fire spike in *Allium* cover, but densities have since receded (Figure 23).

Muilla also had low cover. There did not appear to be a clear trend based on grazing regime (Figure 24).

Grasses and thatch. Perennial bunchgrasses generally showed slight decreases, contrasting with the slight increases in most of the experimental treatments (Figure 25). The highest cover was found at Kirby Canyon, and the lowest cover was found at VTA. There were no notable management effects, even though the most common perennial grass, *Nassella pulchra*, sometimes increases after (repeated) fires (DiTomaso & Johnson 2006).

Burning clearly altered the cover of annual grasses, which are dominated by nonnatives. Unlike unburned sites, which saw either little change or decreases in annual grass cover from 2005 to 2007, the Tulare Hill burn sites both saw significant increases in cover (Figure 26). The lowest annual grass cover was at Kirby Canyon; Tulare Hill continues to have the highest annual grass cover. In 2007 for the first time, the Tulare Hill ungrazed, unburned parcel did not have the highest annual grass cover. This can be explained by its high thatch cover (see below), as this unmanaged parcel has reached a point where thatch buildup limits even annual grass recruitment. Annual grasses have continued to increase on the other Tulare Hill sites, to the point where they are now all comparable.

Of the annual grass species, *Lolium multiflorum* cover was lowest at Kirby Canyon and Tulare Hill burned and grazed (Figure 27). There did not appear to be a pattern based on elevation or management regime. The three sites where *Lolium* declined most also showed the greatest thatch development (TH-BUG, TH-UBUG, LE-SF).

Bromus hordeaceus had its highest cover and largest increases at all the Tulare Hill sites, even in the presence of grazing (Figure 28). The *B. hordeaceus* cover at the grazed, burned site has continued to increase well beyond its preburn cover of 16% in 2004 (not shown) to its current 39%. *B. hordeaceus* cover is relatively low on Coyote Ridge, but the experimental plots there suggest that *B. hordeaceus* did well relative to *Lolium* in the dry year of 2007. These plots also showed that *B. hordeaceus* may be less impacted by thatch than *Lolium*. However, the burned grazed Tulare Hill plots did not have severe thatch buildup (Figure 30). The reason that *B. hordeaceus* has increased so greatly at all the Tulare Hill sites requires further investigation.

Vulpia cover was highest at the burned sites on Tulare Hill (Figure 29). It otherwise showed no clear pattern among elevation or management regimes. Its largest increase was at UTC.

Thatch appeared to follow an elevational gradient, with the exception of relatively low thatch buildup on the Tulare Hill burned and grazed parcel (Figure 30). The Tulare Hill ungrazed unburned area showed severe thatch buildup, at 20% cover in 2007. The elevational gradient could also be a nitrogen deposition gradient, since most nitrogen source pollution is at lower elevations in the San Jose and the Santa Clara Valley – or a temperature/rainfall gradient, as temperature decreases and precipitation generally increases with elevation. All sites had increased thatch in 2007 over 2006, which is probably due to 2006 being a relatively wet year, and plant production in the 2006 growing season became thatch in 2007.

Other functional groups. The Tulare Hill sites had the least geophyte cover. Kirby Canyon had the highest. Differences among other Coyote Ridge sites did not seem to follow elevation or grazing regime (Figure 31). Cover increased notably at UTC, making it more similar overall to the other Coyote Ridge sites. Geophyte cover at burned Tulare Hill sites declined over 2005-2007 while other sites remained similar or had increases in cover, suggesting that post-fire vegetation succession may have been suppressing geophytes.

Perennial forbs had higher cover on Coyote Ridge (Figure 32). With 2007's increase at UTC and a decrease at VTA, perennial forbs now follow an elevational gradient. Tulare Hill sites remain lowest in cover, where the postfire spike at the burned, ungrazed plots has disappeared.

There were regional declines in annual forb cover, most likely due to the dry year (Figure 33). The lowest annual forb cover was at Tulare Hill's unburned, ungrazed site. Tulare Hill's grazed and burned site has more annual forb cover than Los Esteros and VTA, otherwise the data suggest a gradient with increasing elevation of increasing annual forbs. Again, this could be a gradient of decreasing nitrogen deposition or decreasing temperature/increasing precipitation.

Like other annual forbs, legumes decreased across sites (Figure 34). Even the highest cover in 2007, at Kirby Canyon, was low at 3%. A weak elevational gradient among sites may be present. A spike in legume cover on Tulare Hill disappeared in the second postfire year.

Species richness and combined plant cover. Coyote Ridge had the highest native species richness, which in 2007 generally fit an elevational gradient (Figure 35). Tulare Hill was least diverse, and showed a significant decline at the burned, ungrazed site. This site is now similar in native species richness to the unburned, ungrazed site, showing the positive effect of burning was short-lived. Both burned sites declined in richness as vegetation redeveloped post fire, whereas unburned sites generally showed increasing richness per quadrat or remained similar from 2005 to 2007.

Percent cover of all native species combined had a downward trend over the study (Figure 36). Tulare Hill burned, ungrazed and unburned ungrazed stand out as having the lowest native cover. Tulare Hill grazed and burned, and ungrazed and burned sites

showed large declines, along with VTA. Kirby Canyon and UTC had highest native cover. High native cover was largely associated with lower nonnative cover, rather than with less thatch or bare ground. For example, native cover was highest at Kirby Canyon and lowest at unburned, ungrazed Tulare Hill, and annual grasses were lowest at Kirby Canyon and high at unburned, ungrazed Tulare Hill (compare Figures 36 and 26). Also, declines in native plants from early high values at both grazed and ungrazed Tulare Hill 2004 burn sites were mirrored by strong increases in annual grass cover as vegetation succession proceeded in the years after burning.

Most sites were steady or showed slight declines in total cover of all live plants (Figure 37). No site jumps out as having much more or less cover than another. This is one of the few measured parameters that did not show obvious differences between management regimes, even under different annual climate conditions. This apparent ‘equilibrium’ may be ascribed to the competitive tradeoff between native species and nonnatives – predominantly annual grasses).

Abiotic. Coyote Ridge sites had the most bare ground, and Tulare Hill sites had the least (Figure 38). The Tulare Hill sites have not shown significant differences in bare ground among the different management regimes, despite the considerable differences in thatch, for example. There were large increases in bare ground at the winter-spring grazed sites (Kirby Canyon and VTA) in 2007, which was a dry spring. The only substantive decrease in bare ground in 2007 was at Tulare Hill’s grazed and burned parcel, probably due to its large increase in annual grass. The Los Esteros site showed a large, unexplained increase in bare ground from 2005 to 2006, which was paralleled to a lesser degree by the other spring-fall grazed site, UTC.

See Table 2 for site abbreviations. Mean \pm SE.

Bay checkerspot host and nectar plants:
Figure 19. Intersite comparison, *Plantago erecta*

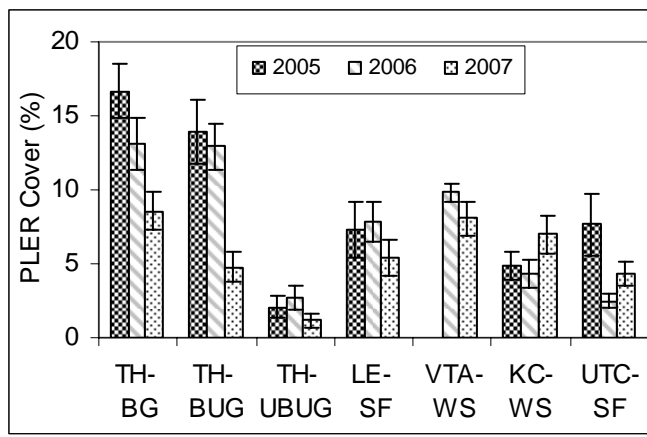


Figure 20. Intersite comparison, *Castilleja* spp.

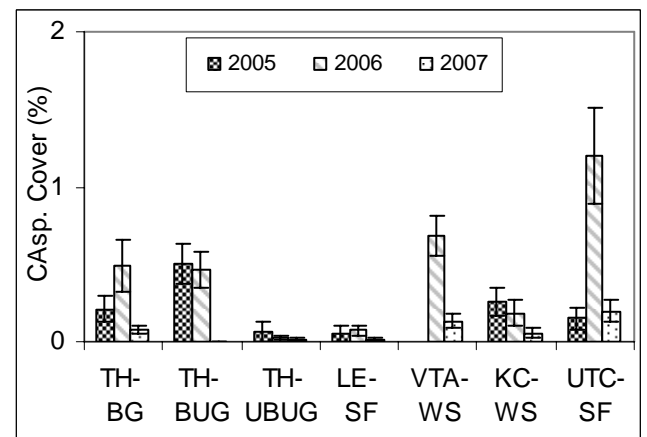


Figure 21. Intersite comparison, *Lasthenia californica*

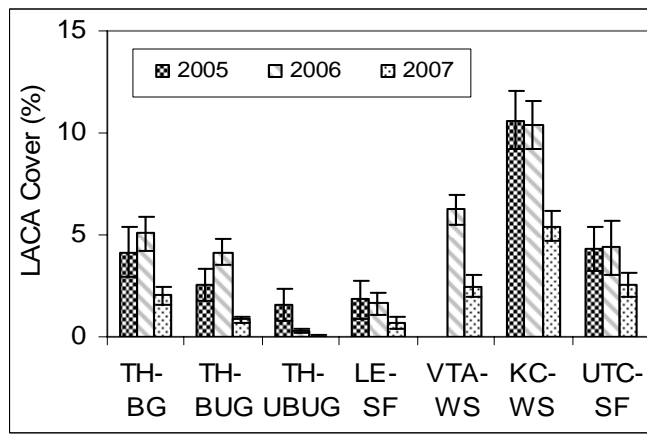


Figure 22. Intersite comparison, *Layia gaillardoides*

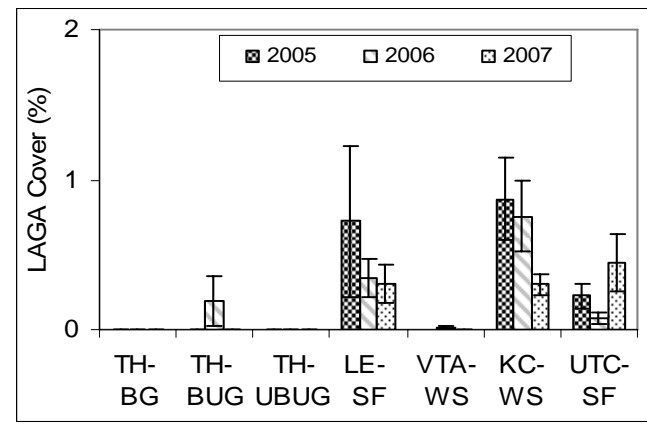


Figure 23. Intersite comparison, *Allium serra*

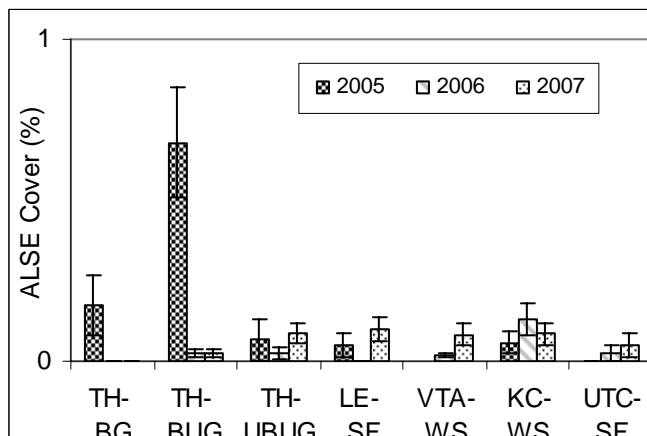
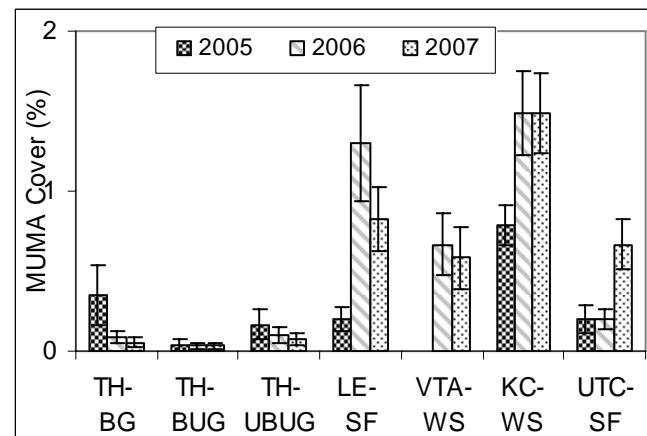


Figure 24. Intersite comparison, *Muilla maritima*



Grasses and thatch:

Figure 25. Intersite comparison, perennial grass

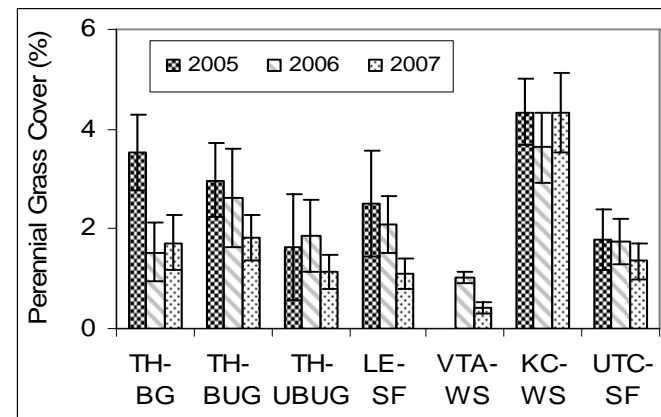


Figure 26. Intersite comparison, annual grass

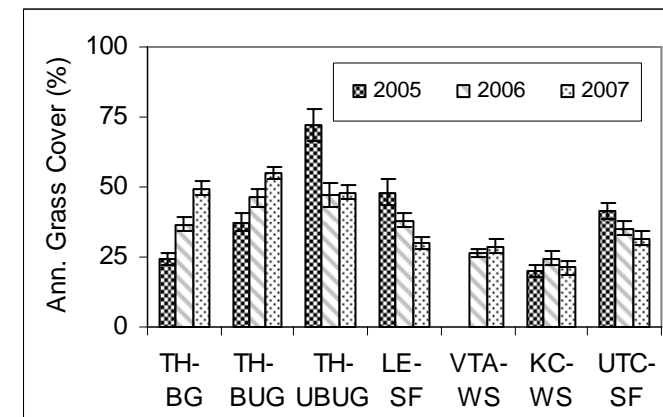


Figure 27. Intersite comparison, *Lolium multiflorum*

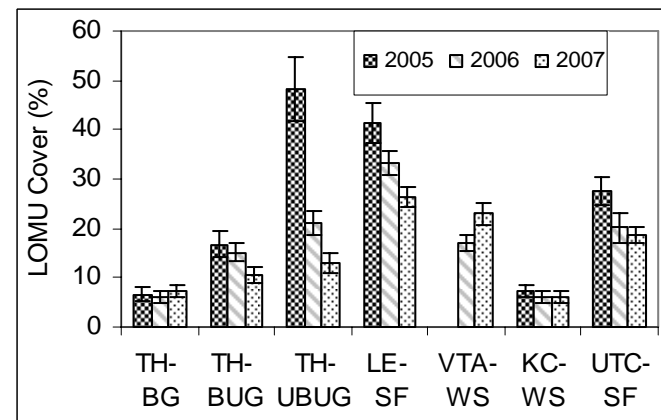


Figure 28. Intersite comparison, *Bromus hordeaceus*

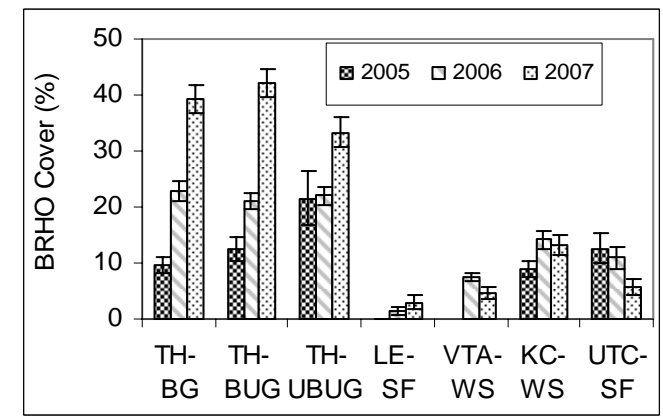


Figure 29. Intersite comparison, *Vulpia* spp.

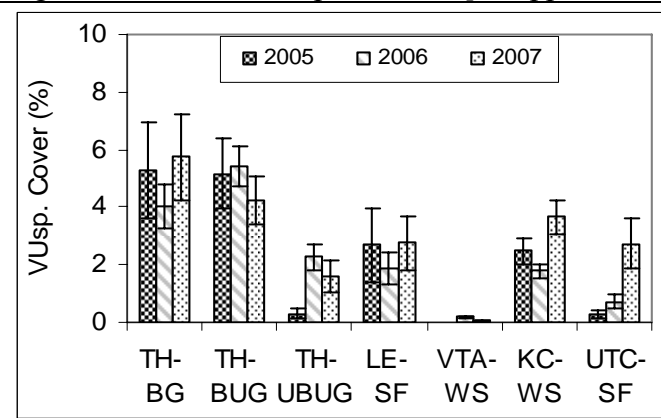
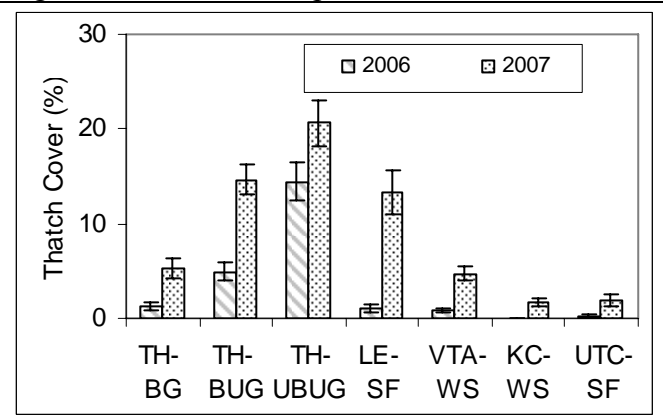


Figure 30. Intersite comparison, thatch



Other functional groups:

Figure 31. Intersite comparison, geophytes

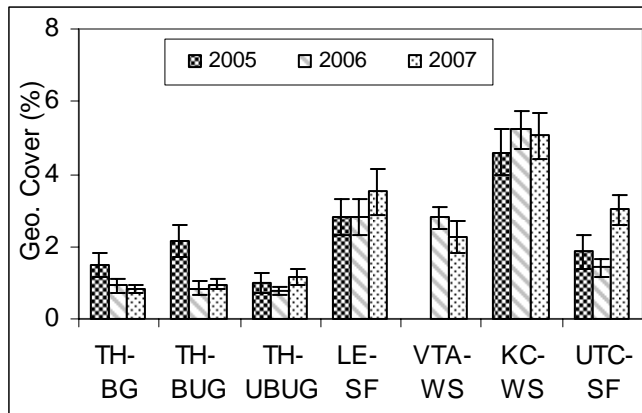


Figure 32. Intersite comparison, perennial forbs

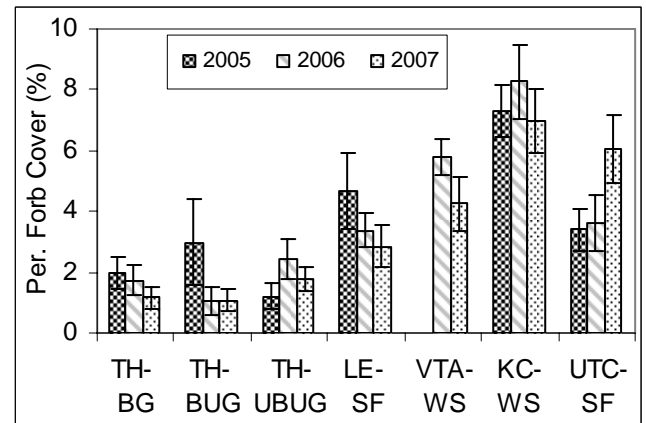


Figure 33. Intersite comparison, annual forbs

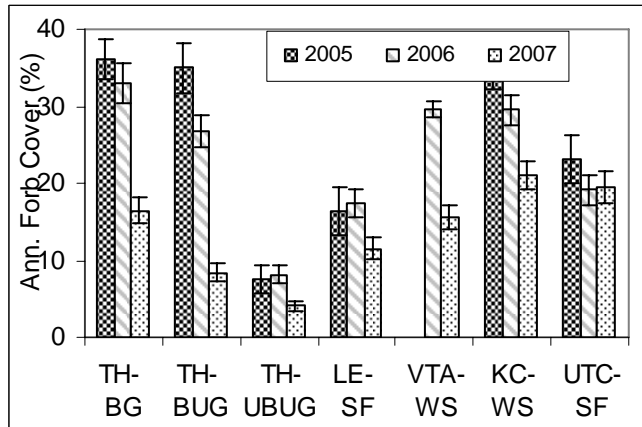
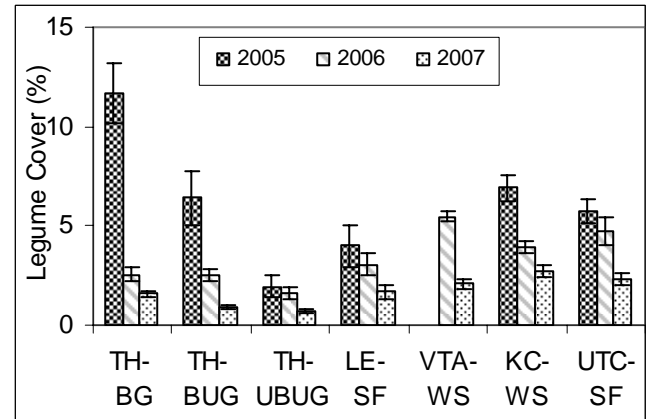


Figure 34. Intersite comparison, legumes



Species richness and overall plant cover:

Figure 35. Intersite comparison, native species richness per quadrat (0.25 m²)

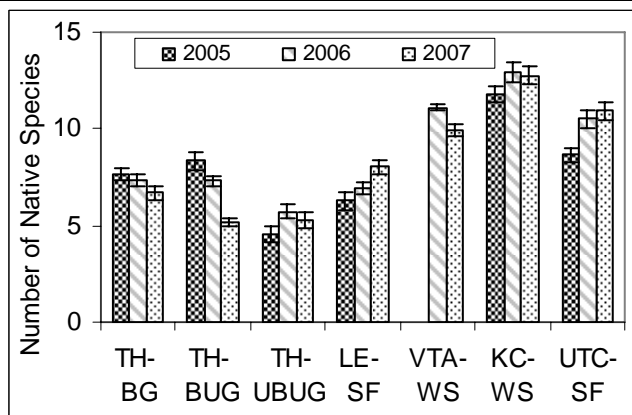
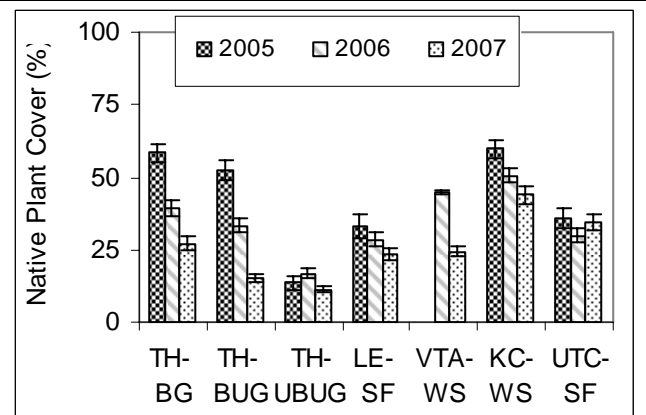
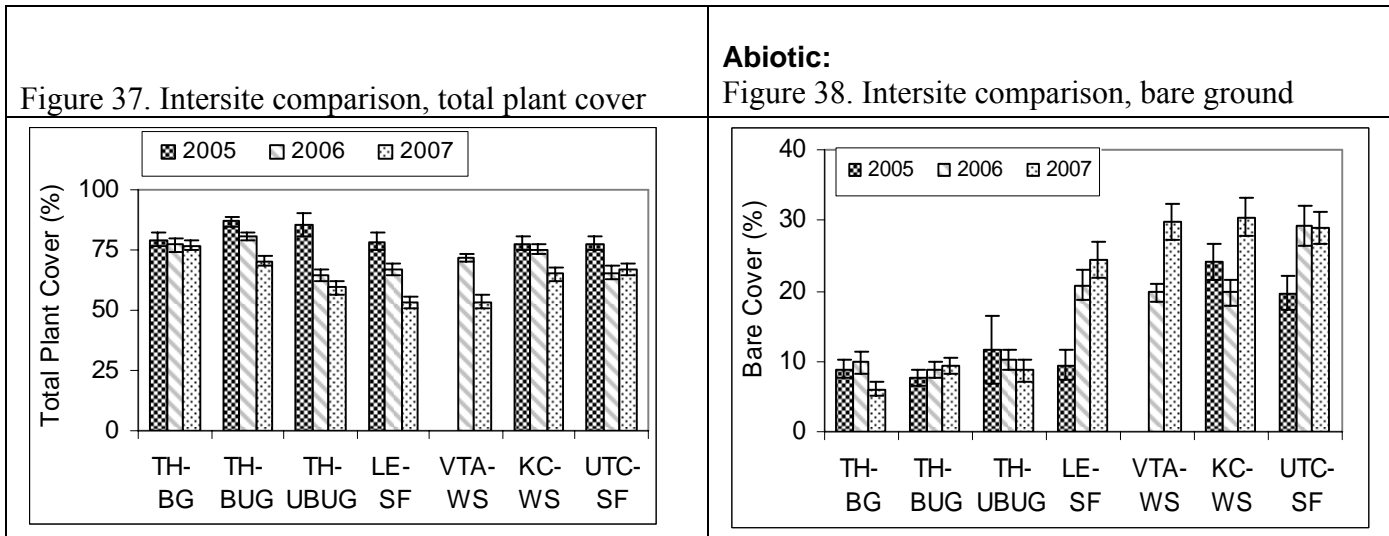


Figure 36. Intersite comparison, native plant cover





Intersite comparison discussion. Burn effects were some of the strongest observed (neglecting rainfall patterns, which are not in the control of local land managers). Burning resulted in increased cover of bay checkerspot butterfly host plants *Plantago erecta* and *Lasthenia californica*, and reduced cover of nonnative annual grasses and thatch that impair native species. The positive effects of burning were short-lived, however, and effects on the vegetation components discussed above and on annual forbs, legumes, native species richness, and combined native plant cover were greatly reduced or indiscernible by 3 years after the fire.

The ungrazed sites, both at Tulare Hill, continue to deteriorate. The ungrazed, unburned site continues to have the poorest habitat quality, with the lowest native plant cover, low species richness, lowest *Plantago*, lowest *Lasthenia*, lowest annual forbs, lowest legumes, and high annual grass and highest thatch. Three years after burning, the ungrazed, burned site is no longer significantly better in habitat quality than the ungrazed, unburned site, whereas grazing has maintained lower thatch and higher *Plantago*, *Lasthenia*, and annual forbs in the grazed burned site. Given these results, grazing is clearly an important vegetation management tool at these sites.

Annual grasses largely held steady at Coyote Ridge sites, but increased at the previously burned sites at Tulare Hill. This was driven by an increase in *Bromus hordeaceus*. The increases in *Bromus hordeaceus* at Tulare Hill might have been mitigated by earlier grazing pressure. The experimental plots show *B. hordeaceus* cover increasing with late trimming (or presumably grazing). The Tulare Hill rancher has been contacted and asked to increase early grazing pressure.

Significant differences between grazing regimes were not difficult to find but were not always easy to interpret. Further, such differences are probably strongly dependent on seasonal weather. For example, bare ground increased in the two winter-spring grazed sites from 2006 into the dry 2007 period while the two spring-fall grazed sites showed no significant change. In the wet 2005 to 2006 period, the spring-fall grazed sites showed

substantial increases in bare ground while the Kirby Canyon winter-spring grazed site did not. Such variety in plant and abiotic responses to management can be useful to the land manager in making sure that a diversity of conditions is available for a diverse set of species, even if exact mechanisms are not always yet fully understood.

As with the vegetation management experimental trial, the annual moisture signal was strong in the intersite data. The 2007 dry conditions led to decreases across all sites for annual forbs, including bay checkerspot host and nectar plants.

Kirby Canyon continues to have the highest overall habitat quality, with the highest annual forb, perennial forb, and perennial grass cover; the lowest annual grass cover; and the highest native species richness and cover. However, we note that bay checkerspot butterfly populations have been high in both WS and SF grazing regimes on Coyote Ridge over the years, not always simultaneously (S. Weiss unpublished data and Kirby Canyon Butterfly Trust Annual Report).

Dudleya Herbivore Damage

Substantial numbers of inflorescences of the endangered Santa Clara Valley dudleya showed damage in our July 27-29, 2005 sampling, many apparently from herbivory (Figure 39). The average rate of damage of inflorescences across all sites was approximately 40% ($n = 778$). We observed evidence of several herbivores potentially contributing to the damage in the immediate vicinity of the dudleya plants: cattle, ground squirrels, pocket gophers, and leporids (hares and rabbits). Other species, such as woodrats, voles, deer, and elk cannot be excluded. The location of sampling sites is shown in Figure 40.



Figure 39. A dudleya cluster in middle upper right shows numerous inflorescences severed at approximately the same level. To the left, against the rock outcrop, is a single intact inflorescence, and another from the same base has fallen over and is lying to the far left. There are a number of dudleya rosettes in the picture that lack any inflorescence. The yellow strip is 17 cm long.

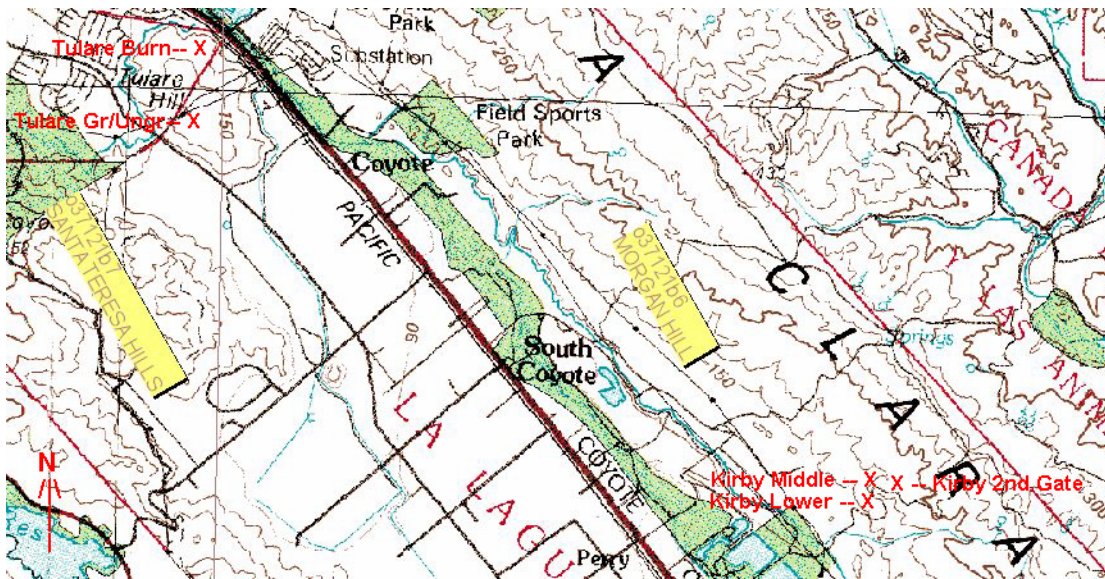


Figure 40. Project area showing dudleya sampling locations, in red. The map spans the Santa Clara Valley between San Jose and Morgan Hill; USGS 7.5'' quadrangle names are shown in yellow. Scale: from side to side the map portrays an area approximately 10.5 km wide. Base map: <http://casil.ucdavis.edu/mapsurfer/>.

Table 3 shows the frequency and proportion of broken inflorescences on grazed and ungrazed sides of fencelines. In two of three comparisons where testing was possible, the proportion damaged was significantly different on opposite sides of the fence (chi-squared tests), and in the third case the difference was suggestive.

Table 3. Broken vs. intact dudleya inflorescences across fencelines at 4 sites					
	Kirby Middle			Kirby 2 nd Gate	
	Intact	Broken		Intact	Broken
Ungrazed	54	39 (42%)	Ungrazed	none	found
Grazed	41	16 (28%)	Grazed	80	59 (42%)
	$X^2 = 2.92$ df=1, P~0.09				
	Kirby Lower			Tulare Hill	
	Intact	Broken		Intact	Broken
Ungrazed	73	68 (48%)	Ungrazed	49	7 (12.5%)
Grazed	70	29 (29%)	Grazed	14	91 (87%)
	$X^2 = 8.65$ df=1, P<0.005			$X^2 = 84.3$ df.=1, P<0.001	

However, the direction of the difference varied with location. At both Kirby locations there was less damage on grazed side, while at Tulare Hill there was more damage on the grazed side. Tulare Hill was grazed spring through fall, while Kirby was grazed winter-spring. Dudleya inflorescences develop and may be attractive as forage in late spring. We observed patterns of damage suggestive of cattle or ungulate grazing (e.g., clusters of inflorescences all severed at the same level with a similar angle of cut; Figure 39, above). Other damage was consistent with small mammals, and we observed rodent burrows among rock outcrops, pocket gopher mounds and pocket gopher activity in soil around rock outcrops, ground squirrel or rabbit trails, and rabbit scat. We did observe some physically caused breakage, e.g., by wind, usually leaving the inflorescence lying nearby, but there was no reason to expect such breakage to differ across fencelines.

Did herbivore damage actually impair dudleya reproduction? Figures 41 and 42 show that damaged inflorescences usually bore no flowers, whereas most intact inflorescences had more than 10 flowers and the average was between 25 and 35 flowers. We looked for but saw no evidence of branching of inflorescences below the break, or of new inflorescences developing to replace broken ones. The plants are perennial, however, and might be capable of compensating somewhat with additional reproductive effort in a future year.

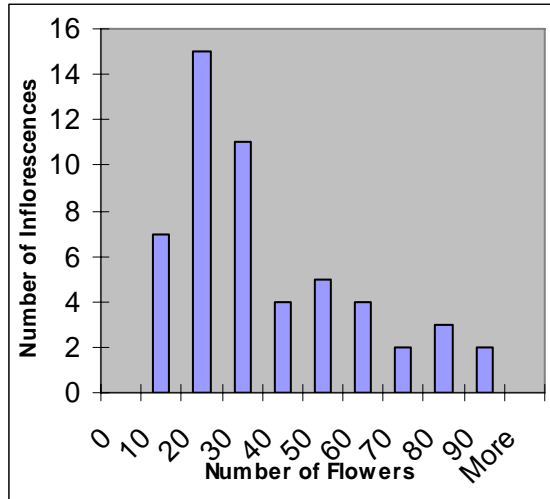


Figure 41. Histogram of number of flowers on intact inflorescences in 2005. The frequency axis indicates the number of inflorescences bearing the number of flowers on the x-axis. This figure is based on a non-random sample used to construct Figure 43, and over-represents large and small inflorescences, but the general pattern is clear, as is the contrast with the much reduced reproductive potential of damaged inflorescences (Figure 42).

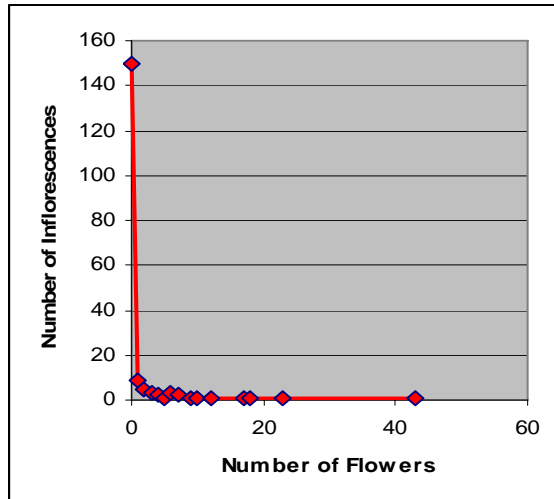


Figure 42. Histogram of number of flowers on broken inflorescences. The great majority bore no flowers; the average number was 1.1 flowers.

Larger inflorescences produced more flowers (Figure 43), and our visual observations indicated they also produced more fruit. We did not dissect fruits to count seeds.

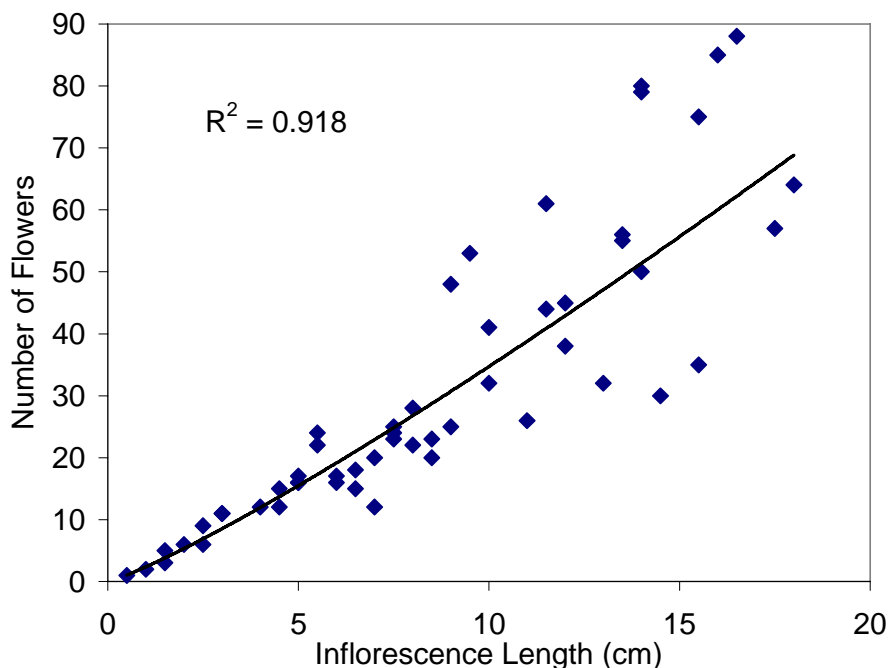
Dudleya setchellii: no. of flowers vs. inflor. length, 2005

Figure 43. Flower production increased significantly with increasing inflorescence length in *Dudleya setchellii*. The regression equation is $\log_{10}(n \text{ flowers}) = 1.1652 * \log_{10}(\text{inflor cm}) + 0.3752$.

We measured inflorescence lengths across fencelines and in a burned area in two locations, at Kirby and at Tulare Hill (Table 4). Inflorescences were significantly smaller on the grazed side at Tulare Hill, and did not appear adversely affected in the burn area. There was no significant difference in inflorescence length on grazed and ungrazed sides of the fence at the Kirby middle site. The difference at across the Tulare Hill fenceline corresponds, according to the equation of Figure 43, to a difference of about 9 flowers per inflorescence (23 grazed vs. 32 ungrazed) – potentially a reduction of about 28% in reproductive output due to inflorescence size difference.

Table 4. *Dudleya* inflorescence length comparisons (average, confidence interval, in cm)

		Kirby Middle		Tulare Hill	
		Average	(95% C.I.)	Average	(95% C.I.)
Ungrazed		7.3	(6.33 – 8.18)	Burn	10.0 (8.97 – 10.94)
Grazed		8.1	(7.02 – 9.22)	Ungrazed	9.3 (8.32 – 10.33)
				Grazed	6.9 (5.76 – 8.02)
Ungrazed vs. grazed t-test:			Ungrazed vs. grazed t-test: P = 0.0033*		
P = 0.24*					

* two-tailed, unequal variances

Dudleya fenceline density comparison

Our sampling of 120 paired 0.01 ha quadrats on the grazed and ungrazed sides of a 1.2 km fenceline in June 2007 did not show any strong effect of grazing on *Dudleya setchellii* in the Kirby Canyon area.

Overall, 30 percent of quadrats contained dudleya (36 of 120), at an average density of about 5 clumps per 0.01-hectare plot (median 0 clumps). There was no difference in frequency of occurrence of dudleya on the grazed versus ungrazed side of the fence (18 of 60 in both grazed and ungrazed: 18 of 60). Dudleya were patchy and clumped spatially, as is to be expected from their clustering on rock outcrops, so that – despite the separation of the paired quadrats by 4 meters – dudleya were more likely to be present on one side of the fence if they were also present on the other (chi-square 11.85, $P < 0.001$). Numbers of dudleya did not differ significantly in the paired quadrats (Table 5; sign test, $P > 0.10$, two-tailed).

Table 5. Difference in number of <i>Dudleya</i> : <u>Grazed minus Ungrazed</u>	Frequency: number of quadrats
more neg. than -20	3
-11 to -20	4
-1 to -10	4
Same (both zero)	35
1 to 10	11
11 to 20	1
more than 20	2

Nor did numbers of inflorescences differ between grazed and ungrazed pairs (sign test, $P > 0.10$, two-tailed). On average, about 77% of total dudleya counted had inflorescences in 2007 (see Materials and Methods for information on how dudleya clumps were counted).

There were some, but small, indications of differences in reproductive effort between grazed and ungrazed habitat. Inflorescences averaged slightly taller on the ungrazed side of the fence (15.9 vs. 14.3 cm: $t = 2.815$, $df = 233$, $P < 0.01$ two-tailed), paralleling the 2005 result at Tulare Hill. Stem diameters were not significantly different ($t = 1.017$, $df = 233$, $P > 0.20$ two-tailed), suggesting inflorescences on the ungrazed side were slightly more slender for their height.

If we assume other factors remain equal and plug the height and diameter measurements for each inflorescence into a multiple regression on flower production obtained from our work in the area in 2006, we can obtain an estimate or index of flower productivity for each inflorescence. The regression equation is:

$$\log_{10}(\text{number of flowers}) = 0.05140 * \text{height} + 0.06900 * \text{diameter} + 0.13259 ,$$

with height in units of cm and diameter in mm. This regression accounted for about 90% of the variation in flower number among a sample of plants ($n = 23$ inflorescences). The diameter term was not statistically significant, but we include it here because we believe based on field observations that a larger sample would prove it to be important.⁸ When flower production of the dudleya in grazed and ungrazed quadrats is estimated in this way, we find that estimated flower production per inflorescence was slightly higher among plants on the ungrazed side (average \log_{10} of estimated flower number = 1.0471 versus 0.9604). The estimated arithmetic means are 12.9 and 11.1 flowers per inflorescence in ungrazed and grazed habitat, respectively. This difference was primarily due to the inflorescences being slightly taller on the ungrazed side.

Given these results that grazing had no or little effect on dudleya numbers or reproduction, it is important to ask how heavily the Kirby area is grazed. In general the winter-spring grazing regime in the Kirby Landfill area could be described as moderately intensive, but from spot to spot grazing intensity varies considerably depending on accessibility to cattle, e.g. due to steep slopes or fence corners; or depending on stocking patterns. In the most accessible areas the vegetation was grazed to an average height of perhaps 6-10 cm, but in some areas we noted tall grass and thatch even on the grazed side of the fence. Nevertheless, in all areas there was a visual difference in grassland vegetation between the grazed and ungrazed sides, with the ungrazed side generally being taller and denser.

***Streptanthus albidus* studies**

In observations associated with a preliminary *Streptanthus albidus* ssp. *peramoenus* clipping experiment (see our 2005 report), we learned that the most-beautiful jewelflower appears to be flexible in the face of physical damage. The plants readily branch and, unlike the dudleya, send out new inflorescence branches in response to loss of the apex. Stems and leaves are similarly colored, the leaves are rather small and sparse, and the stems may be photosynthetically active, all of which mean that clipping even two-thirds of the leaves is not a very severe event for *S. a. peramoenus*. On the other hand, we observed that jewelflower stems nipped off essentially to ground level – by whatever herbivore – were somewhat common in the field at Kirby. The cast of potential culprits among herbivores is quite large, but this kind of severe damage did occur in ungrazed and extremely steep areas (presumed inaccessible to cattle) as well as in grazed areas.

Therefore, in 2006 our *Streptanthus* work looked at more severe simulated herbivory impacts, including complete removal of all plant parts above the first healthy leaf. Since branching occurs from the leaf axils, this would presumably leave at least one active site for branch bud development. An “intermediate” treatment chopped off the plants at half their initial height. (By chance, our randomly assigned cohort of unclipped control plants

⁸ For example, stem diameter appears to correctly reflect flower production when dudleya that are shaded by rocks or vegetation produce long, slender inflorescences with fewer flowers than expected solely on the basis of height. Further data also might refine this coefficient's value.

averaged smaller in initial height than the 30 intermediate treatment plants, while plants to be severely clipped averaged in between in initial height -- Table 7).

As in 2005, we noted significant interrelationships between plant size and reproductive variables (Figure 3). Taller and heavier plants carried more seed pods, and also had longer pods on average.

Severely clipped plants were significantly harmed by the treatment, with reduced size and weight at harvest compared to the unclipped control plants (Table 7). The average length of seed pods was significantly shorter on severely clipped plants relative to controls (Table 7). In 2005 we established that seed production per pod is closely and approximately linearly related to seed pod length (number of seeds = pod length (mm) x 0.755 – 17.3; accounting for nearly 88% of the variance: see our 2005 report, attached), so reduced pod length translates to reduced seed output per pod.

In many other *Streptanthus albidus peramoenus* responses, we observed what has been called compensatory growth (or even over-compensation) or productivity stimulation following damage to the plant. In other words, in many cases the intermediate clipping treatment equaled or exceeded the undamaged controls in final size and reproductive output. Plants in the intermediate clipping treatment had low mortality (Table 6). We observed productivity stimulation in seed pod production, and plant height and weight at harvest also qualify since the plants reached sizes comparable to control plants despite being reduced by half in height 74 days earlier (Table 7).

Table 6. Mortality at harvest in *Streptanthus albidus peramoenus* experimental treatments, 2006. Ratios in parentheses (e.g., 8/30) reflect the number dead divided by the total number of plants, live and dead, found at harvest. There is significant variation in mortality among treatments ($P = 0.0014$, Fisher's Exact Test, 2-sided), which is most strongly expressed in the difference between the intermediate clipping treatment and the severe clipping treatment.⁹

Treatment:	A—Control (unclipped)	B—Intermediate (clipped at half of initial height)	C—Severe (clipped above lowest green leaf)
Percent Mortality:	27 % (8/30)	7 % (2/27)	52 % (14/27)

⁹ It may be easier to find live than dead plants; if so mortality could be underestimated in treatments where not all 30 plants were found (i.e., the intermediate treatment might be more similar to the controls than the table reflects).

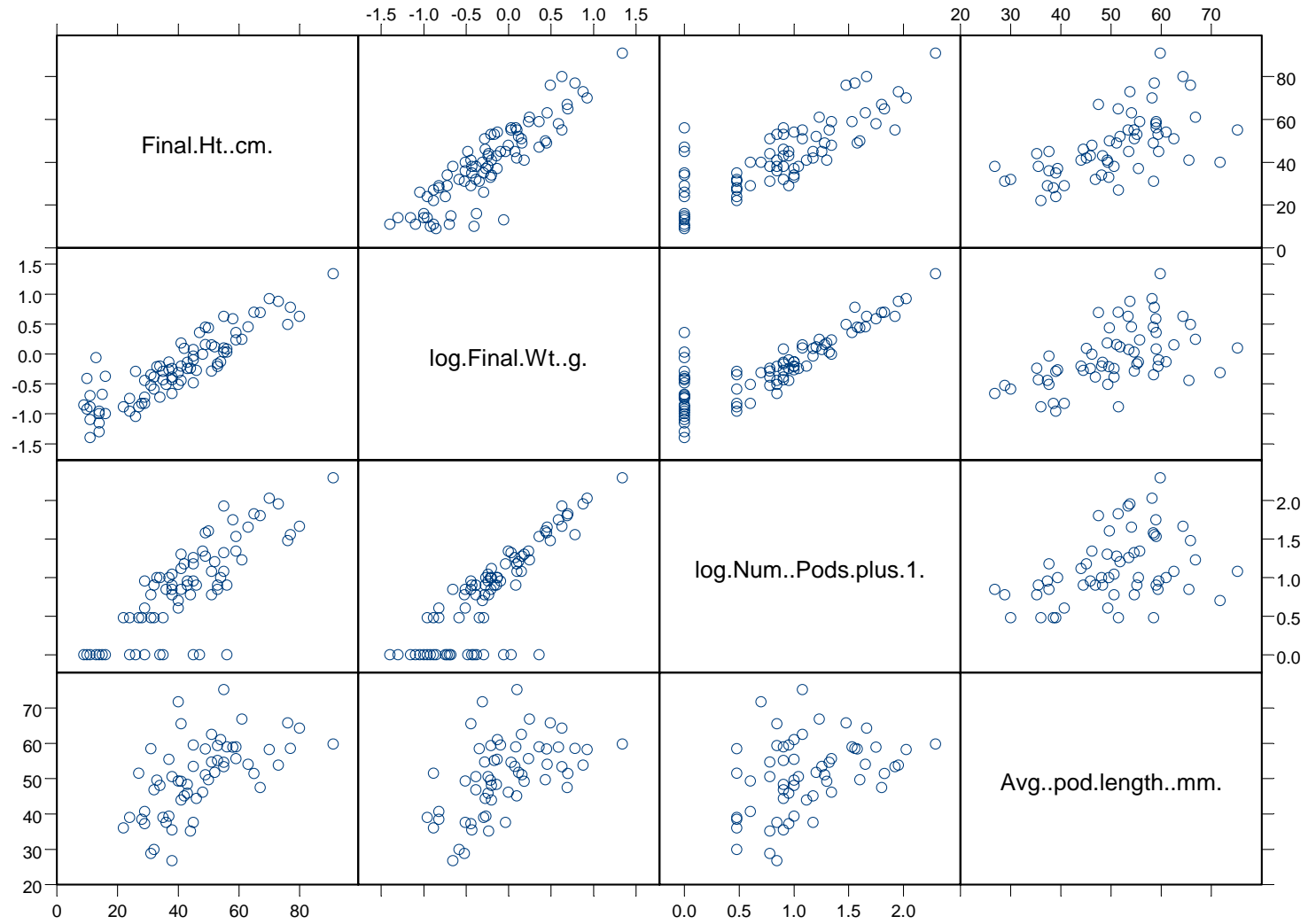


Figure 3 (previous page) – Scattergrams of relationships between several plant size and reproductive measures for *Streptanthus albidus peramoenus*. Plants from all treatments of the 2006 experiment are included (n = 83 plants for most variables; n = 60 plants for plots of average pod length). Height, logarithm of weight, and log(number of pods + 1) are strongly correlated (all $r > .83$). Correlations with average pod length are weaker ($r = .337$ to $.583$), but all relationships shown are still significantly non-zero, $P < .01$, two-tailed.

Table 7. Comparison of *Streptanthus albidus peramoenus* experiment treatments; arithmetic means (and 95% confidence interval) except as noted. Within rows, means followed by the same letter are not significantly different at $P = 0.05$.

Measure	A—Control (unclipped)	B—Intermediate (clipped at half of initial height)	C—Severe (clipped above lowest green leaf)
Initial height (cm)	33.2 a (29.1--37.3)	42.1 b (36.9—47.2)	39.5 ab (34.2—44.8)
Final height (cm)	46.2 b (40.4--51.9)	48.5 b (41.8--55.2)	24.1 a (18.8—29.3)
Stem diameter (mm)	1.87 a (1.54—2.20)	2.43 a (1.98—2.88)	2.07 a (1.68—2.45)
Final weight (g)*	0.642 b (0.412—0.998)	1.188 b (0.730—1.932)	0.265 a (.175--.400)
Number of seed pods per plant*	5.0 a (2.61—9.03)	13.6 b (7.74—23.48)	1.7 a (0.70—3.35)
“ “ omitting plants dead without fruit*	10.6 ab (6.5—16.7)	17.1 b (10.5—28.5)	7.0 a (4.0—11.8)
Average seed pod length, per plant (mm)	53.2 b (47.9—58.5)	51.3 ab (47.4—55.2)	41.5 a (39.6—49.8)
Cumulative pod length production per plant (mm of pods)*	98 ab (31—300)	502 b (211—1190)	14.5 a (3—50)
“ “ omitting plants dead without fruit*	525 ab (318--864)	826 b (484--1420)	294 a (158--547)

*Data have non-normal distribution; therefore values presented are geometric means (back-transformed means and back-transformed 95% confidence intervals of log-transformed data). Statistical tests performed on appropriately transformed data.

An important bottom-line for this annual plant is total seed production. Since seed production is strongly linearly related to pod length, we can measure total seed production at harvest by the aggregate length of all seed pods on the plant. We estimated this by multiplying the total number of pods on a plant by the average length of pods on that plant (calculated from measuring 10 pods per plant, systematically selected from all areas of the plant--or all pods if there were 10 or fewer), obtaining the cumulative length

of pods produced by each plant. Cumulative pod length was highly variable but was greatest in the intermediate clipping treatment and lowest in the severe clipping treatment, with the control plants not significantly different from either extreme (Table 7).

Pollination. In addition to these contributions to the reproductive biology of *Streptanthus albidus peramoenus*, on June 6, 2005, along the Kirby Conservation Area access road between the first (west) and second gates, one of us (DHW) observed several bumblebees busily visiting a large number of open *S. a. peramoenus* flowers. One was captured and identified as *Bombus melanopygus* (“*edwardsii*” color form [black rather than reddish hair on abdominal tergites 2 and 3]; thanks to Dr. Robbin Thorp, UC Davis, for help confirming the i.d.). Bumblebees often are considered to be effective pollinators. Thorpe et al. (1983) reported *B. “edwardsii”* visits species in the genus *Streptanthus*, as well as *Platystemon* and *Ceanothus* (the endangered *Ceanothus ferrisiae* occurs in this vicinity). *Bombus vosnesenskii* also is reported to visit *Streptanthus*. Conservation of *S. a. peramoenus*, and *S. a. albidus* by extension, may well depend on adequate conservation of surrounding nesting and foraging habitat for pollinators such as bumblebees.

***Streptanthus* clipping experiment discussion.** Our effort to simulate herbivory – clipping – was a double-edged sword for *Streptanthus albidus* ssp. *peramoenus*. Levels of clipping we consider rather dramatic (decapitation at half the plant height) appeared to have little effect or even to stimulate growth and seed production. Compensatory growth or growth stimulation in response to herbivory is a phenomenon researched and discussed at length by McNaughton and colleagues (e.g., McNaughton 1985). On the other hand, severe clipping (to near ground level), not unlike damage from herbivory seen in nature, seriously damaged *S. a. peramoenus* reproductive success, as estimated by seed output – though it did not always prevent it.

These results may also apply to the most beautiful jewelflower’s endangered sister subspecies, the Metcalf Canyon jewelflower, *Streptanthus albidus albidus*. However, several caveats should be borne in mind, particularly regarding growth response to herbivory. Annual plant response to herbivory likely is sensitive to environmental conditions (2006 had abundant rains in the *Streptanthus* growing season, which may have facilitated a stronger compensatory response) and to the timing of herbivory (would severely clipped plants have fared better if clipped earlier in the season?). Clipping may not provide a completely accurate simulation of herbivory; and we still need better information on the sources and frequency of herbivore damage on *Streptanthus albidus* in the field.

MANAGEMENT RECOMMENDATIONS

Our recommendations are developed for managers of serpentine grasslands in Santa Clara County, California:

- 1) Serpentine grassland in Santa Clara County is a spatially diverse and temporally dynamic ecosystem. Many ecological responses to grazing and fire are contingent on interactions between weather year, site history, topoclimate (warm versus cool slopes and elevational differences in temperature and precipitation) and other factors beyond the control of the manager. Managing for a static endpoint is unlikely to be fruitful and maintaining habitat within a historical range of variability is a more realistic goal.
- 2) The nitrogen deposition in the Santa Clara Valley mandates that vegetation on serpentine grassland reserves must be actively managed. Our work indicates that “hands-off” is not a viable option for conservation of many serpentine species.
- 3) Have clear site objectives and a thorough baseline of vegetation information for the site. Management will differ depending on whether, for example, you are managing for bay checkerspot butterfly habitat or for native perennials, and on what species are present on site in what abundances. It is common to have multiple objectives for a site but sometimes competing objectives point to contradictory management methodologies. Therefore an overarching (e.g., ecosystem) goal or purpose is often useful in resolving conflicts.
- 4) Grazing is the most common vegetation management option:
 - a. We have only examined cattle grazing. Other stocking options should be approached with caution and prior testing.
 - b. Any areas that serve as bay checkerspot butterfly habitat must be grazed. There is a 2-3 year window before annual grass invasion, primarily *Lolium multiflorum* and *Bromus hordeaceus*, and thatch buildup seriously impair habitat value for the butterfly. Grazing generally enables native forbs to compete and preserves dramatic wildflower displays.
 - c. A mixture of grazing regimes and seasonal rotation of grazing will spread risks and opportunities across large landscapes and provide flexibility for ranchers. There are many different timing regimes for grazing that provide for butterfly habitat value. In Santa Clara County in most years a moderate stocking rate – 1 cow with calf or 1 bull per 10 acres allows for full utilization of grass over the season.
 - d. The existing grazing monitoring by the ranchers – observation of animal weight gains, forage availability, and range conditions so that the maximum amount of grass biomass is removed in any given season without permanent damage – appears to provide effective feedback to avoid overgrazing and undergrazing, at least in terms of bay checkerspot butterfly habitat.
 - e. Grazing effectively destroys and prevents production of thatch.

- f. Some grazing pressure early in winter appears necessary to maintain *Bromus hordeaceus* and to a lesser extent *Vulpia microstachys* since these grasses mature earlier than *Lolium*.
 - g. If the species is present, monitor for grazing damage to *Dudleya setchellii* inflorescences and if necessary keep stock off when inflorescences are attractive to grazers
- 5) Controlled burns should also be considered as part of a suite of serpentine vegetation management methods:
 - a. Late-spring fire has short-term (1-2 year) effects, generally positive for native diversity and cover and negative for annual grasses. After 3 years, however, ungrazed areas lose habitat quality.
 - b. The thatch removal by fire, both spring and fall, is an important component of restoration of degraded sites. Later fires (fall season) remove thatch but are not expected to reduce non-native grass seed germination and growth.
 - c. Late-spring fire is being tested for control of barbed goatgrass (*Aegilops triuncialis*) on Coyote Ridge.
 - d. Late-spring fire will not have adverse effects on bay checkerspot butterfly hostplants and nectar sources, but may prove problematic for *Streptanthus albidus* subspecies, which are annual and beginning to flower at that time. Effects of fire on *Dudleya setchellii* are mitigated by its perennial habit and lack of fuel around rock outcrops where it lives.
 - 6) Grass-specific herbicides and mowing may provide viable management options, especially for constrained parcels where regular grazing or burning are difficult, or for invading pest plants like barbed goat grass.
 - 7) Conservation management should also address maintaining suitable habitat (including nesting) conditions for a broad suite of pollinators. Watering and fertilization must be avoided.
 - 8) Manage with a diversity of techniques to the extent the site and objectives will allow. Different species or groups of species often respond differently to management techniques (e.g., those that increase versus those that decrease in response to short-interval fires; those that prefer low grazing intensity and those that fare better in close-grazed habitat). Keeping a diversity of taxa healthy on your parcel(s) is likely to be enhanced by using more than one—perhaps several—management methods simultaneously, each in a different portion of the property.
 - 9) Monitor annually to know how your management is affecting targets and progress toward objectives. Also monitor representative species, sentinel and sensitive species, functional groups, and species diversity so that you can detect early changes in the larger picture.

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CONTACT INFORMATION

Stuart Weiss
27 Bishop Lane
Menlo Park, CA 94025
(650) 854-9732
Stu@creeksidescience.com

David Wright
1573 49th Street
Sacramento, CA 95819
(916) 739-8906
(425) 696-3265 fax
dwrighteco@calweb.com

Christal Niederer
(650) 655-6677
christal@creeksidescience.com

EXPENDITURE SUMMARY

Allocated funds for the project were \$64,800 for 2006 and 2007

Personnel: \$63,010.54
Travel : \$ 1,789.46
Supplies : \$ 0

No major property was purchased during the project.

DATA APPENDICES

Files provided in electronic format on CD.

SUMMARY OF EXPENDITURES FOR 2007

Personnel and salaries: