Effect of different grazing regimes on *Viola pedunculata* populations at King Ranch - 2010

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SUMMARY

This report discusses second year results of a study that investigates how specific changes to the grazing regime at King Ranch affects cover of *Viola pedunculata,* the larval food plant of the Callippe silverspot butterfly. In 2007, we established plots in six clusters of three plots each at widely spaced locations on the ranch, with three clusters on each of two common soil types. Cover in these plots was read in spring 2007 and 2008 to serve as a baseline. One plot in each cluster was excluded from grazing early in the grazing season in 2009 and 2010. A second plot in each cluster was excluded from grazing late in the season in 2009 and 2010. The plots excluded from grazing did not differ in *V. pedunculata* cover or grass cover compared to plots which had not been excluded from grazing. Although grass cover and vegetation height were negatively correlated with *V. pedunculata* cover, excluding plots from grazing for short periods did not result in *V. pedunculata* cover differences. Vegetation height and cover were correlated with precipitation during the growing season. Due to the interactions that exist between grazing impacts and weather, we recommend that the study be continued for at least two to three more years, so that treatment effects can be assessed over a wider range of weather conditions. A longer study duration would also allow for assessment of possible cumulative effects that may develop over time.

INTRODUCTION

The native California golden violet or johnny jump-up (*Viola pedunculata*) is the sole larval food plant of the Callippe silverspot butterfly (*Speyeria callippe callippe*), a federally-listed endangered species. There is a general consensus, based primarily on anecdotal observations, that *V. pedunculata* populations in annual grasslands are generally favored by some level of grazing. However, no controlled studies have been conducted to determine how to optimize grazing patterns to maximize *V. pedunculata* cover in Callippe silverspot habitat.

In 2007, as part of the Callippe Silverspot Habitat Enhancement Planning project, we designed a grazing study for the Solano Land Trust (SLT) King / Swett Ranches. This study tests whether specific changes in the grazing regime used at the ranches would increase the cover of *V. pedunculata* and reduce grazing-related damage to *V. pedunculata* in areas where populations of these plants occur.

In April 2007, we established plots for the study and assessed the cover of *V. pedunculata* within all plots to provide baseline data prior to the start of differential grazing treatments. Although differential grazing treatments were originally expected to begin in early 2008, funding to begin the study was not available by that time. Because the start of the study was delayed until 2009, we reassessed baseline cover levels of *V. pedunculata* within the plots in April 2008 to provide a recent baseline prior to the start of the grazing treatments. In addition, having baseline cover levels measured in multiple years prior to the onset of experimental treatments allowed us to examine the amount of variation that can occur from year to year in response to variations in weather, the "standard" grazing regime, and other factors, such as gopher activity. Given the year to year variability inherent in the annual grassland vegetation type, the additional year of baseline data provided a better basis for interpreting treatment-related differences that may occur in the study.

This report updates our previous report with data from 2010, the second year in which the differential grazing regimes were applied to study plots.

METHODS

Plots

We established six clusters of matched plots at widely spaced locations at the King ranch in spring 2007. Each cluster has three plots which were matched to the degree possible for slope, aspect, soil type, and vegetative cover, especially the cover of *V. pedunculata*. The plot clusters are distributed on two soil types (*figure 1*), one derived from igneous rock (Toomes stony loam=ToG2) and the other from siltstone (Milsholm loam=Mme). Three plot clusters (9 plots total) are on each soil type.

Each individual plot is square, 7.6 m (25 ft) long on each side (58 m^2= 625 ft^2=0.014 acre). We cryptically marked the plots in 2007 by driving a 15 cm long carriage bolt topped with a 4 cm diameter fender washer into the ground at each corner. Bolts were driven into the ground, so that the washer and bolt head were flush with the soil surface. These inconspicuous ground-level markers do not attract the attention of cattle; this prevents the development of unusual grazing patterns around markers. The corner markers were relocated using a combination of GPS coordinates, measured azimuths between plot corners, and a metal detector to detect the plot corner bolts.

In fall 2008, short sections of galvanized pipe were driven in to the ground at the corners of the plots that were assigned to be excluded from grazing. These pipe sections were pinched closed on one end, which was driven into the ground, leaving the open pipe end protruding 10-15 cm above the ground surface. The pipe sections served as sockets into which inverted T-posts were placed. These sockets were about (10 cm) high, too low and inconspicuous to serve as attractants to cattle. The sockets for first grazing drop out period plots were painted white to help identify the plot treatments.

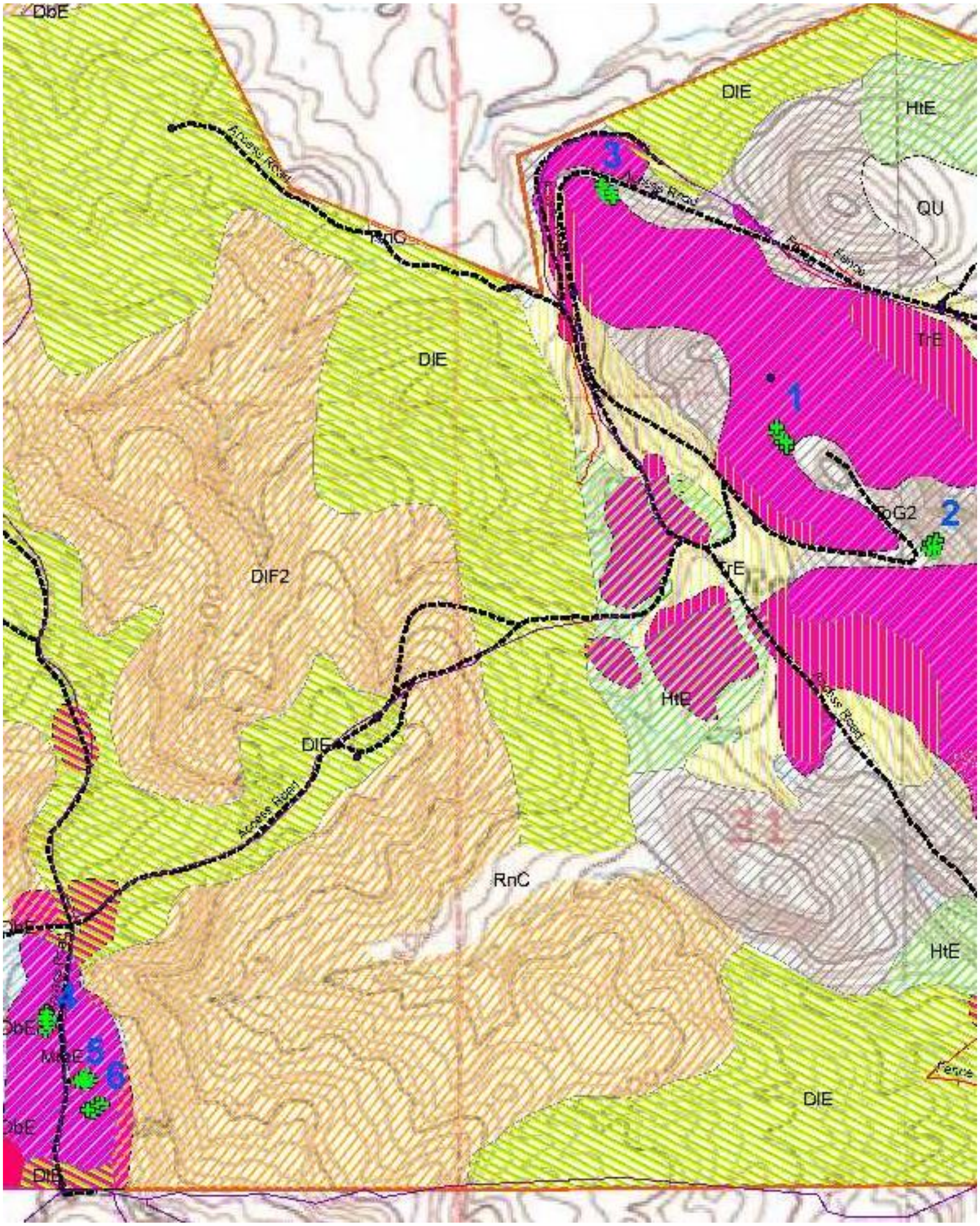


Figure 1. Plot cluster locations. The six plot clusters are represented by the green crosses and are numbered in blue. Soil types are shown with hatching. Magenta color indicates areas where *V. pedunculata* has been mapped. Roads, boundaries, soil type and *V. pedunculata* polygons from SLT King-Swett GIS layers. Background contours from USGS 7.5 min quadrangles Cordelia and Fairfield South.

Grazing treatments

One plot in each cluster was unfenced all season long and served as the control, i.e., no difference from the grazing regime currently in use. The other two plots in each cluster were fenced at different times to exclude cattle. One of these plots was fenced early in the season, and the other was fenced later in the season. The experimental exclusion periods and the overall grazing regime for the ranch, which was the same as the nonexclosed control, is shown in Table 1 below.

In 2010, grazing treatments were assigned to the same plots as in 2009 with one exception. In 2009, plot 6-2 had the early exclosure treatment and plot 6-1 had the late exclosure treatment. In 2010, these treatments were inadvertently reversed. Data analyses were adjusted to account for this reversal. For the continuation of the study, the plot assignments used in 2010 should be used.

Table 1. Grazing regime for King Ranch for the 2008-2009 and 2009-2010 grazing seasons, showing exclosure periods for the two experimental treatments and vegetation assessment dates.

	Treatment	**2008-2009**	**2009-2010**
Stocking levels	Control treatment	26 Dec 2008 – 27 Feb 2009 123 cows/115 calves 27 Feb – 7 May 2009 251 cows/ 243 calves 23 May – 15 June 2009 372 cows	27 Jan – 11 Feb 2010 165 cows/166 calves 11 Feb – 14 May 2010 215 cows/216 calves
	Early grazing exclosure period (drop 1)	23 Dec 2008 – 5 Mar 2009	4 Feb – 23 or 24 Mar 2010
	Late grazing exclosure period (drop 2)	26 Mar 2009 - 7 May 2009	29 Apr 2010 - 14 May 2010
Viola cover assessment		23 Mar 2009	7 Apr 2010

From the beginning of the 2008-09 grazing season through 5 March 2009 portable electric fencing was used to exclude cattle from the exclosed treatments. The fencing was attached to the four inverted T-posts in each plot corner and a single fiberglass post placed midway between each pair of posts. Three strands of nylon/metallic fence conductors were placed around each plot which were energized with a battery powered unit. Early in the season, cattle quickly learned to avoid the fencing. As a result, we did not see evidence of excessive use or tracking around the fence perimeters, which can occur around non-electrifed exclosures.

As the first grazing season progressed, the electric fences became less effective at keeping cattle out of the plots. In February and March 2009, cattle knocked down the fencing in plot cluster 5. During the second exclosure period the electric fences were frequently breached. By 8 April 2008, the fences on the plots in the eastern portion of the ranch (plot clusters 1-3) were replaced with barbed wired and by May, the electric fencing for the remaining plots on the western side had been replaced by barbed wire. By the end of exclosure period 2 (7 May 2009), no cattle paths had developed around any of the fenced plots.

In 2010, the plots were exclosed using barbed wire from the beginning of the first exclosure period. Many of the plots developed partial to complete tracks around the fenced plots (*figure 2*).

Figure 2. Example of cattle tracks around a fenced exclosure on 7 April 2010. Walking stick marks one corner of the plot.

Cover measurements

Methods for assessing cover within the plots were described previously (Bernhardt and Swiecki 2007). Briefly, we used a modified point-intercept method to assess plant cover, using a minimum of 100 sample points per plot. Starting in 2008, we used ropes to mark the opposite sides of each plot during data collection. Sample points (10-12 per row) were spaced at roughly even intervals along each of the 10 rows demarcated by evenly-spaced flags on the ropes. The plot area assessed for cover was buffered in about 2 ft from the plot edges; we anticipated that installation and removal of fencing during the study could disturb this buffer area somewhat. In addition, with the switch away from electric fencing, cattle can reach under the barbed wire fencing and graze this buffer area.

We used a high-intensity green laser pointer mounted an upright PVC frame (Bernhardt and Swiecki 2007) to project the sample point down to the vegetated layer. *V. pedunculata* hits were scored if the laser dot point intersected any part of a *V. pedunculata* plant. Because we are interested in total cover of *V. pedunculata*, a hit was scored on this species if it was under the laser dot, even if the dot intercepted grasses or forbs overlying the *V. pedunculata*. We used a first hit convention (uppermost plant illuminated by the laser dot) to score cover for plants other than *V. pedunculata*.

Annual assessments of cover were made 10-12 April 2007, 3-7 April 2008, 23 March 2009 and 7 April 2010. Cover measurements were made earlier in 2009 than in other years because plant maturity was advanced due to low spring precipitation up to that point.

Vegetation height measurements

We used a falling plate meter (Bernhardt and Swiecki 2007) to measure the average vegetation height within the plots. The falling plate was also used to compress vegetation to obtain an estimate of residual dry matter. In 2007 and 2008, height measurements were made at nine locations in each plot which were approximately evenly spaced throughout the plot. In 2009 and 2010, we increased the number of height measurements per plot to 16, distributed roughly in a 4 $\times$ 4 grid that covered the plot area inside of a buffer of about 1 m around the plot edges. Readings of average plant height and the height of compressed vegetation were made at each spot.

Residual dry matter

The relationship between residual dry matter and vegetation height was established in 2009. To calibrate height measurements against residual dry matter (RDM), we selected patches of vegetation that were representative of vegetation heights measured at a given plot cluster. Patches were adjacent to plots or within 1 m of the edge within exclosed plots. We measured the total and compressed heights of vegetation in these patches with the falling plate meter. After these measurements were made, a square 30 cm metal frame was set down around the area measured. Vegetation within the frame was clipped to within 1 cm of the ground and placed in paper bags for drying to a constant weight in a drying oven. The weight of each sample was recorded and compared with height measurements to develop a relationship between height and RDM.

Data analysis

Data for 2010 were entered into a database that also contained 2007, 2008, and 2009 cover data and 2008 and 2009 vegetation height data. We transformed percent cover data to the arcsine of the square root of percent cover prior to analysis to help normalize the data distribution. Analysis was performed using JMP® 10 statistical software. Unless otherwise noted, effects or differences were considered significant at $P \leq 0.05$.

RESULTS

Rainfall

Total rainfall for the first 3 years in which we collected cover data (2006-2009) was relatively low (*table 2*, *figure 3*) compared to the 2005-2006 season. Most of the 2008-2009 precipitation fell in February. Prior to February 2009, only 10.9 cm of rainfall had been recorded for the season, but 18 cm of rainfall fell in February. March 2009 was also dry overall (5.6 cm rainfall). Rainfall was also low in the February-March period in 2010. Most of the 2009-10 season rainfall fell in October 2009 and January 2010.

Table 2. Rainfall totals at CIMIS station 123 in Suisun Valley.

Rainfall year	Rainfall total (cm) Oct-Mar	Rainfall total (cm) Oct-Jan	Rainfall total (cm) Feb-Mar
Oct 2005 – Mar 2006	76.4	49.8	26.6
Oct 2006 - Mar 2007	27.4	14.7	12.7
Oct 2007 - Mar 2008	32.6	26	6.6
Oct 2008 - Mar 2009	34.5	10.9	23.6
Oct 2009 - Mar 2010	51.6	37.9	13.7

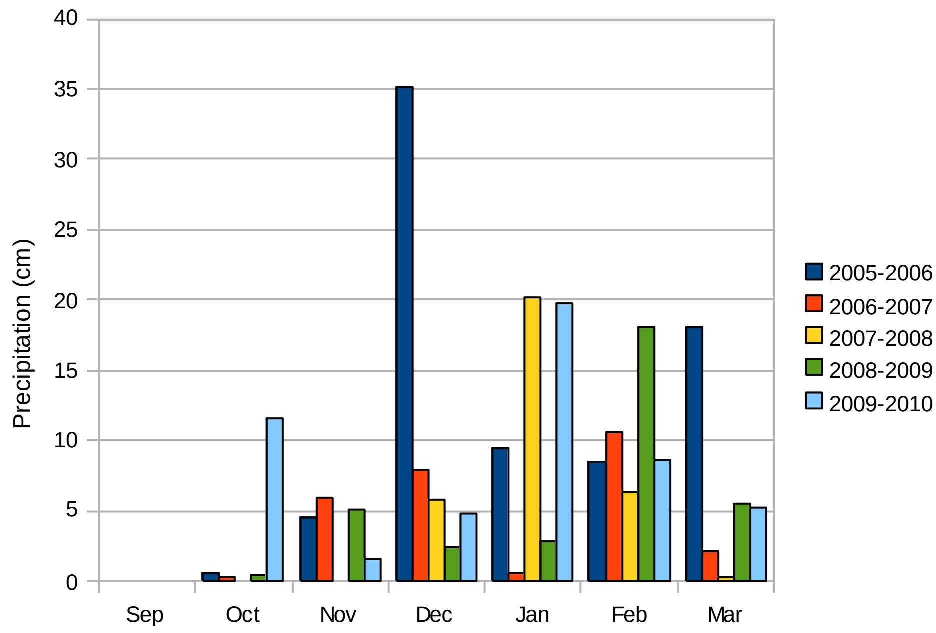


Figure 3. Rainfall totals by month at CIMIS station 123 in Suisun Valley.

Vegetation heights and residual dry matter

Spring vegetation height measurements made in 2009, both average (noncompressed) heights and compressed (drop) heights, were strongly correlated with vegetation dry weights (*figure 4*). Noncompressed vegetation heights showed a stronger correlation with dry weights than did compressed heights. Low drop heights were difficult to measure accurately in some plots because soils were uneven or rocky, which increased the error associated with those readings. Because average vegetation heights showed the best correlation with dry weight, we used this variable as the indicator of total plant biomass.

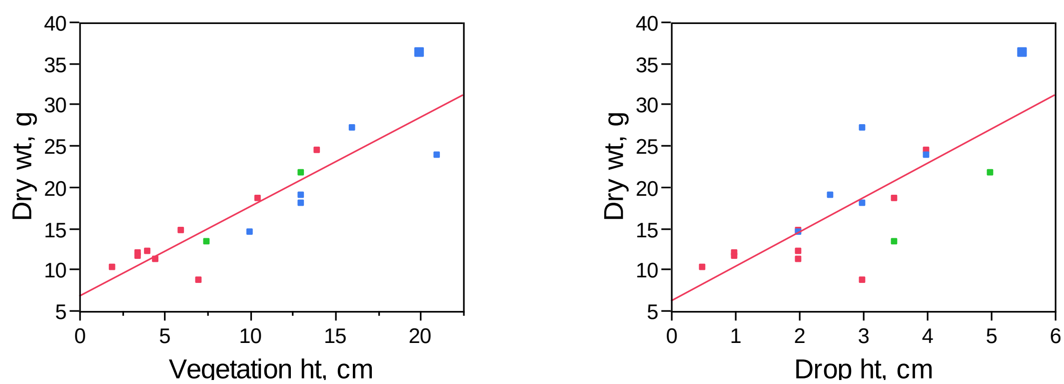


Figure 4. Comparison of dry weights and average vegetation heights (left) and compressed vegetation height (drop height, right). Vegetation height R^2= 0.8183, P<0.0001, compressed foliage height R^2=0.6856, P<0.0001. Colors indicate samples collected on different dates in 2009.

Effect of grazing treatments on vegetation

In 2009, vegetation height was collected multiple times over the season to assess grazing impact on height growth and total biomass (RDM). Although vegetation heights differed somewhat between different grazing regimes in 2009 (*figure 5),* the differences are not significant if all plots are analyzed, due to the high amount of variability in the data. Plots in cluster 1 had very shallow soils with low height growth irrespective of the grazing regime. If the plots in cluster 1 are excluded from the analysis, the late season grazing exclusion shows a significant effect on vegetation height.

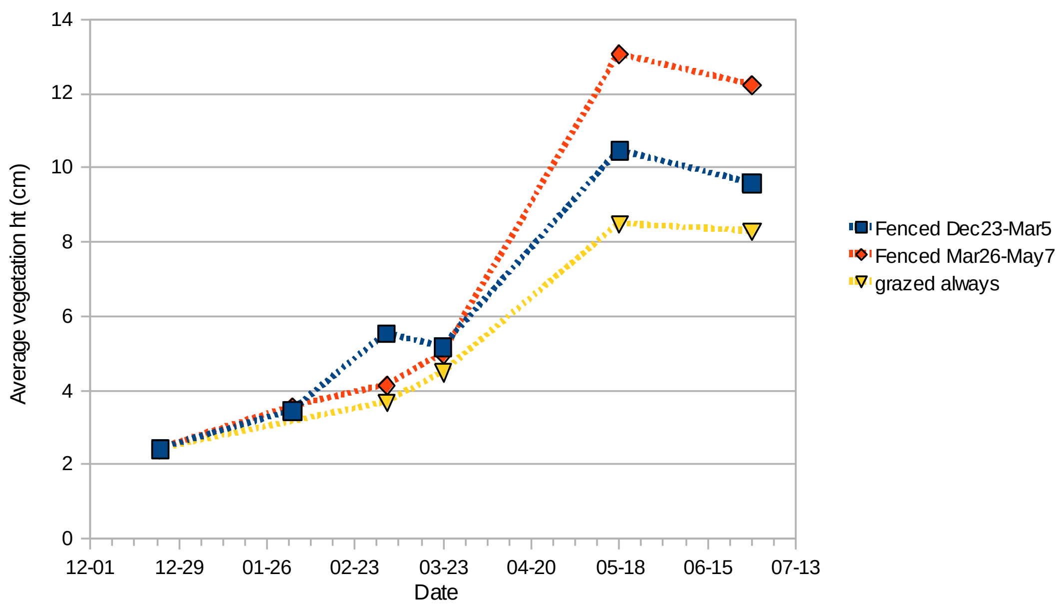


Figure 5. Average vegetation heights measured during the 2009 grazing season. The fenced treatments were fenced to exclude cattle from the plots during the dates shown in the graph legend. Graph excludes data from plot 5-0, an early season exclosed plot whose fence was breached before the end of the exclusion period.

Vegetation height in 2010 was collected on 7 April, about 2 weeks after the fencing was removed from the early exclosure period plots (exclosed 4 February to 23-24 March 2010). In the 7 April 2010 measurements, vegetation heights in plots excluded from grazing did not differ from the height of vegetation in plots that had been grazed for the entire time. Furthermore, June 2009 vegetation height was not a significant predictor of vegetation height in April 2010. These results indicate that removing plots from grazing for short periods resulted in only small and transient changes in vegetation height and total plant biomass. In addition, the exclosure treatments had no significant effect on grass cover in 2009 or 2010.

Other factors affecting vegetation growth

Productivity in plots was correlated from year to year (*figure 6*). Vegetation height in April 2008 was correlated with vegetation height in March 2009 ($R^2 = 0.35$, $p=0.01$ with one outlier excluded), and vegetation height in March 2009 was correlated with height in April 2009 (R^2=0.28, p=0.02). In the three years for which we have collected vegetation height data, average height appears to be strongly related to rainfall totals (R^2=0.39, p<0.0001, *figure 7*), but this relationship is also influenced by the amount of grazing pressure applied in each year.

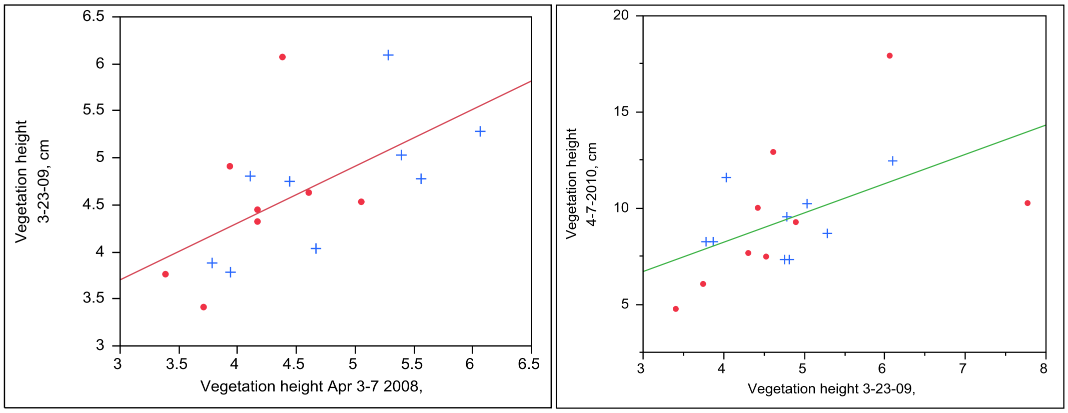


Figure 6. Relationship between vegetation height in spring in successive years. Note differences in scales. Symbols indicate soil types: += Toomes stony loam (igneous origin), ToG2, •= Milsholm loam (sedimentary origin).

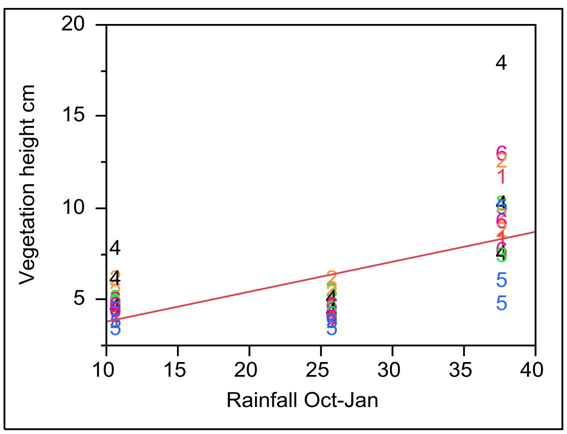


Figure 7. Relationship between vegetation height and October-January rainfall. Numbers represent plot clusters shown in Figure 1.

Effect of grazing on Viola pedunculata *cover*

Statistical analysis showed no significant effect of the first grazing exclosure period on *V. pedunculata* cover in either 2009 or 2010. The late grazing exclosure period in 2009 also had no significant effect on *V. pedunculata* cover in 2010. Mean *V. pedunculata* cover in each plot during the spring sampling dates is shown in Figure 8. The 2007 and 2008 *V. pedunculata* cover data serve as a baseline; different grazing treatments were not imposed until the 2009 grazing season. In general, *V. pedunculata* cover in all plots in the same cluster showed similar trends in cover change, with greater *V. pedunculata* cover in 2007 and 2009 and less in 2008 and 2010. Plots in cluster 4 are an exception to this trend and did not show an increase in *V. pedunculata* in 2009.

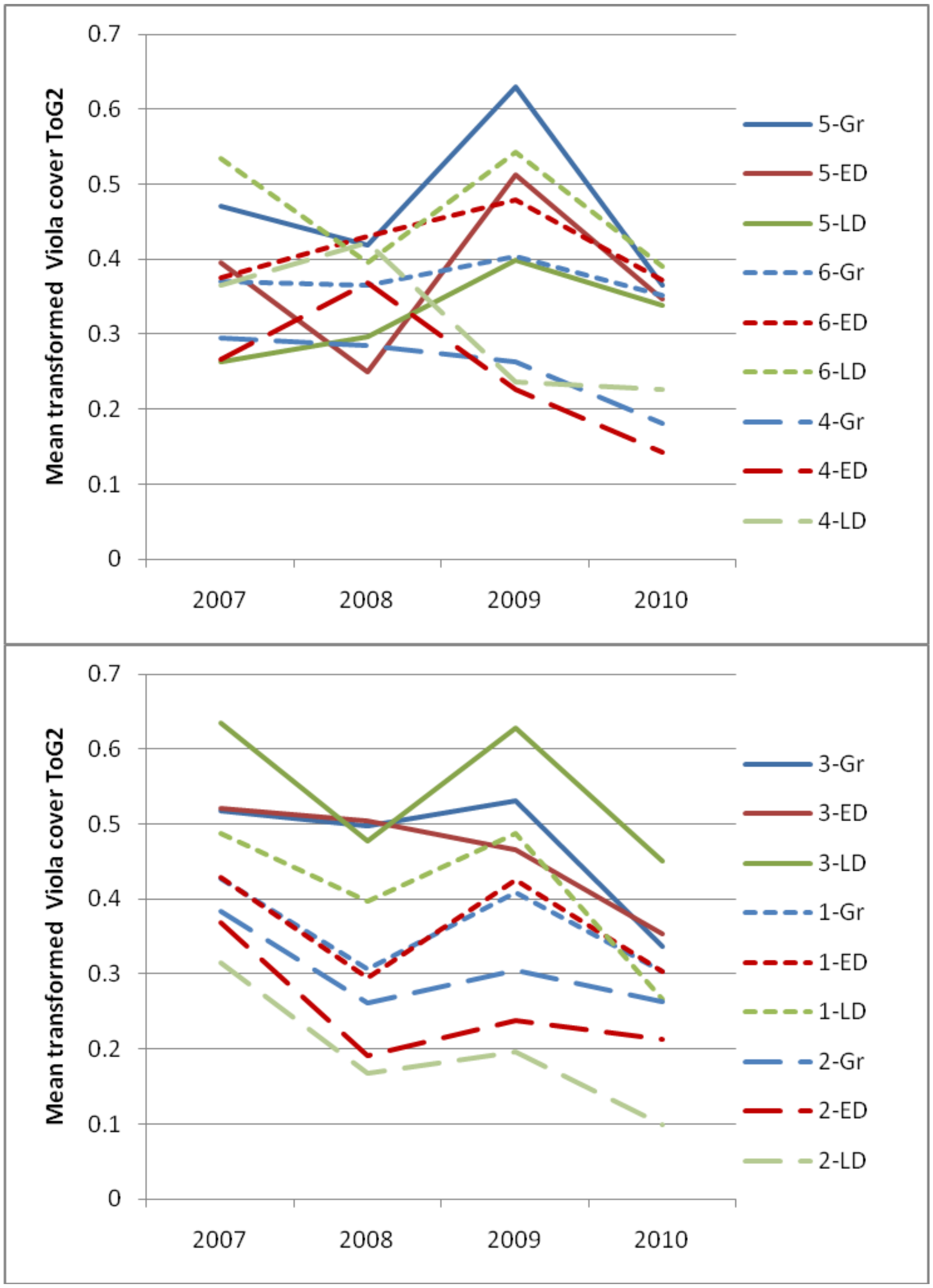


Figure 8. *Viola pedunculata* cover (arcsine of the square root of percent cover) in each plot (number indicates plot cluster) on Milsholm loam (sedimentary origin, top) and Toomes stony loam (igneous origin, bottom) soil types. Gr=standard grazing regime; ED = early exclosure period; LD = late exclosure period: ED and LD treatments were applied only in 2009 and 2010.

Other factors related to Viola pedunculata *cover*

Figure 9 shows how overall cover of grasses, forbs, *V. pedunculata*, and bare soil have varied over the four years of data collection on the two soil types. Cover of *V. pedunculata* differed across the two soil types only in 2007. Since that time, mean cover on the two soil types has not differed. However, *V. pedunculata* cover on the Toomes stony loam generally has shown greater variation between plots, especially in 2008 and 2010 (*figure 8*).

Cover of grass and other forbs has varied significantly by year and soil type, based on repeated measures ANOVA. Overall, Toomes stony loam supports greater forb cover and has more bare soil than does Milsholm loam, which has greater grass cover overall. The cover of other forbs was not significantly correlated with *V. pedunculata* cover, but grass cover showed a negative correlation (R^2=0.18, p=0.0002) with Viola cover (*figure 10*).

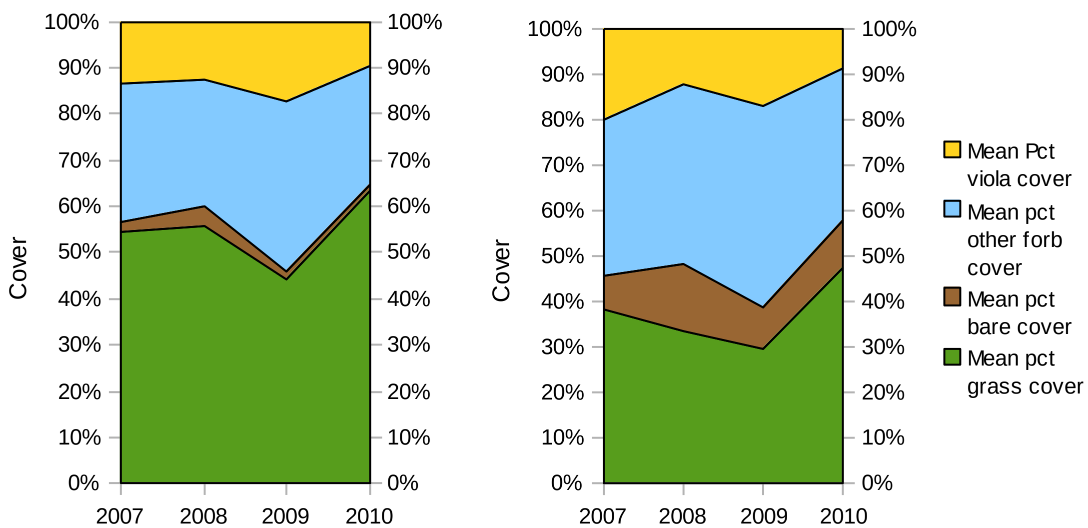


Figure 9. Average percent cover measured in spring of each year for *V. pedunculata*, other forbs, grass, and bare soil in plots on Milsholm loam (sedimentary origin, left) and Toomes stony loam (igneous origin, right) soil types.

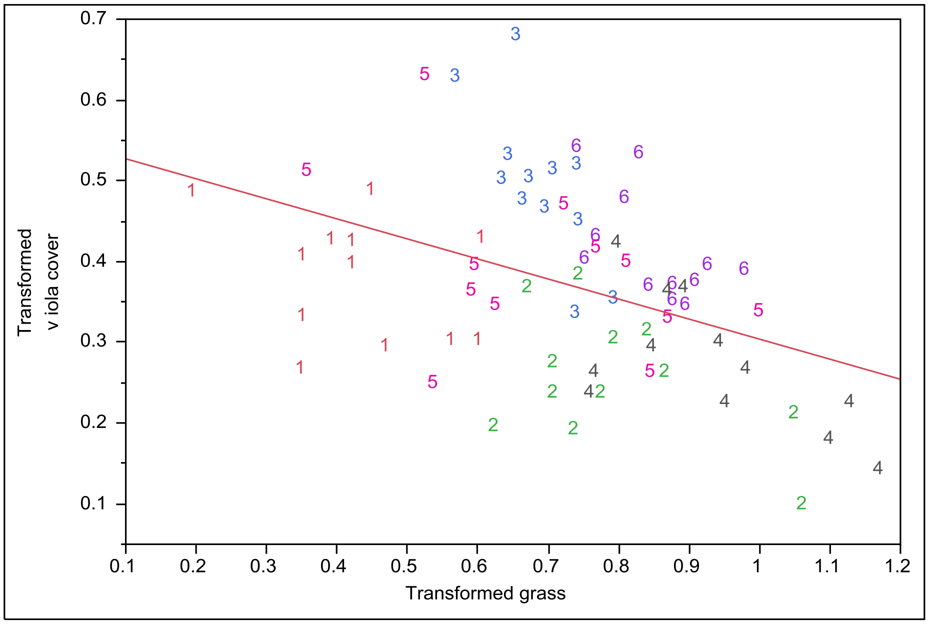
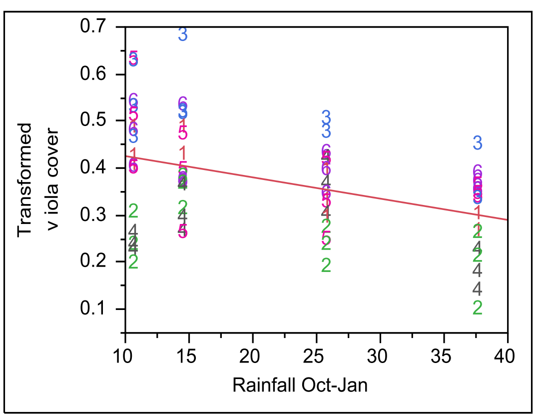


Figure 10. Correlation between V. pedunculata cover and grass cover (both arcsine transformed) for 2007 through 2010 in all plots ($R^2=0.18$, $p=0.0002$). Numbers represent plot clusters 1 through 6 shown in Figure 1.

Cover of *V. pedunculata* and grass were significantly related to early season rainfall (*figure 11*). A three-way analysis of variance shows that *V. pedunculata* cover is negatively correlated with grass cover and October-January rainfall, and that plot cluster is also a significant source of variation (model $R^2=0.69$; grass cover $p=0.04$, plot cluster $p<0.0001$, Oct-Jan rainfall= 0.0002).



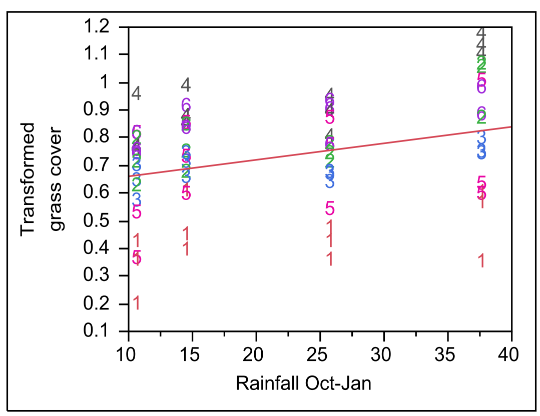


Figure 11. Mean cover (arcsine transformed) of *V. pedunculata* (left; R^2=0.17 p=0.0004) and grass (right; R^2=0.10 p=0.008) by early season (Oct-Jan) rainfall totals. Numbers represent data from plot clusters shown in Figure 1.

Vegetation height

Viola cover was negatively correlated with vegetation height (both variables measured on the same date each year, *figure 12*). The significance of this correlation is primarily due to the inclusion of the 2010 data, which had relatively large variation in vegetation height represented among the various plots. Individual year correlations for 2008 and 2009 were not significant. In both of those years, vegetation was uniformly short in almost all plots.

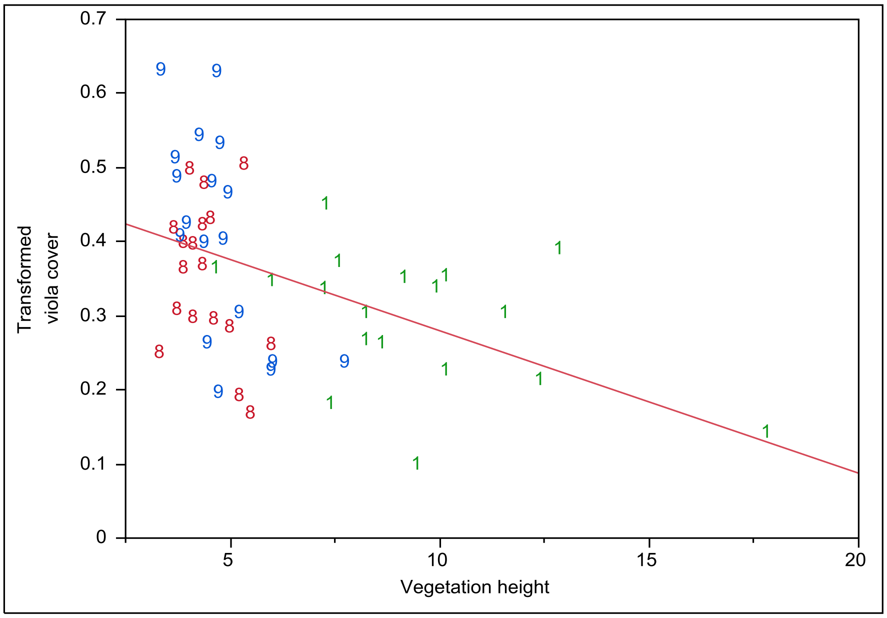


Figure 12. *V. pedunculata* cover (arsine transformed) by vegetation height (R^2=0.22 p=0.0003). 8 = 2008, 9 = 2009, 1=2010.

Discussion

Cover of *V. pedunculata* has varied in plots from year to year. Most of this variation appears to be associated with differing rainfall levels in the four years. Early season rainfall was relatively more abundant in 2008 and 2010, which appears to have favored grass biomass and cover at the expenses of *V. pedunculata* cover. Early season rainfall has been shown in other studies to be positively correlated with vegetation growth in annual grasslands (Murphy 1970). Changes in the cover of other forbs were not correlated with changes in *V. pedunculata* cover.

Although increasing grass cover and height appears to suppress *V. pedunculata* cover, interrupting grazing for the short periods used in this study did not change *V. pedunculata* cover in 2009 and 2010. The relatively short periods of grazing exclusion had only minor effects on vegetation height/biomass and no effect on grass cover. If trampling or other early season grazing impacts have potentially adverse effects on the survivorship of Callippe silverspot larvae early in the growing season, avoiding grazing during this period could potentially be used to mitigate such negative effects without adversely impacting *V. pedunculata* cover.

Because all study plots are grazed, variation in vegetation height from year to year is influenced by the amount of grazing pressure in a given year as well as rainfall amounts. In the normal management of King Ranch, the cattle stocking rate and timing of cattle grazing varies from year to year and is not tightly controlled to achieve a uniform impact on wetter or drier years. In this type of system, it is not possible to completely separate the effects of grazing and rainfall on vegetation height. Nonetheless, by observing the effects of specific grazing exclusion periods over a number of years, it is possible to determine whether those exclusions have an impact on vegetation outcomes of interest, including *V. pedunculata* cover.

To date, this study includes only two years of differential grazing treatments. Because rainfall has a strong effect on annual grassland vegetation, additional years of observations under different rainfall regimes are needed to see whether results will be consistent across a wider range of weather conditions and corresponding grazing pressures. We recommend that the study be continued for at least 2-3 more grazing seasons, so that a wide range of weather conditions are represented in the data set. If trends seen to date are consistent across a wider range of rainfall conditions, we can be more confident that the effects are repeatable and representative.

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