EFFECTS OF GRAZING ON UPLAND VEGETATION AT JEPSON PRAIRIE PRESERVE, SOLANO COUNTY, CA

Progress report 1: first year (2004-2005) results

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EXECUTIVE SUMMARY

This progress report presents results from the first year of a three-year study that examines the effects of different grazing regimes on vegetation at the Jepson Prairie Preserve. The purpose of this study is to test whether the current sheep grazing regimes can be altered to increase cover of native plants in areas that are currently weed-dominated without adversely affecting areas that are currently dominated by native species. Weedy plants, especially exotic grasses, predominate on the relatively high mound or upland areas of the Preserve, whereas native species typically predominate in low lying areas.

Starting in January 2005, three adjacent field at the Preserve were grazed according to three different grazing regimes. The grazing regimes differ with respect to when, how long, and how many sheep are present in each field. In each field, we established eight clusters of study plots. Each cluster included plots in both high (weed-dominated) and low (generally native dominated) positions. Adjacent grazed and nongrazed (fenced) plots were set up in both high and low positions in each cluster. By comparing forage heights in paired grazed and nongrazed plots at approximately monthly intervals, we were able to assess the pattern of forage removal over time at each plot. This pattern is referred to as the grazing profile for a given plot. Due to the uneven nature of grazing within fields, we found that grazing profiles commonly varied between plots within a field, i.e., between plots that had the same overall grazing regime.

First-year data showed that adjacent high and low plots within fields were grazed at different intensities by sheep. Weed-dominated high plots were grazed preferentially in winter months when the low-lying native-dominated areas were periodically flooded. As the season progressed and the exotic grasses began to dry out and set seed in the high plots, sheep preferentially grazed the native-dominated low plots.

A baseline assessment of native and exotic cover and species diversity within plots was conducted in late April 2004 prior to the start of the experiment. Plant cover was reassessed in April 2005. Low plots that were grazed during the peak spring bloom period in late March and April 2005 lost native cover and gained exotic cover compared to the baseline assessment. This effect was not seen in high plots or in low plots that were not grazed during this period.

After one growing season, plots excluded from grazing had considerably more residual dry matter (RDM) in August than did plots that were grazed. However, native cover and native species diversity did not differ significantly between grazed and nongrazed plots.

INTRODUCTION

Grazing and fire are the two main management tools available for managing grassland vegetation at Jepson Prairie Preserve. However, due to the numerous constraints on controlled burning, grazing is the only vegetation management method that is currently applied to most fields each year. Although grazing is widely acknowledged as a critical management input, the Jepson Prairie Management Committee and others have been concerned for some time that the current grazing practices may not be optimized for the Preserve's vegetation management objectives.

Although grazing may appear to be a simple process superficially, the use of grazing to accomplish specific vegetation management objectives at Jepson Prairie is a fairly complex problem. To begin with, vegetation in the preserve as a whole and within each pasture is a mosaic of species that vary considerable over relatively short distances. Species complexes tend to differ as a function of soils and microtopography. Higher mound/upland microsites are usually dominated by exotic species and lower swale/pool/playa microsites are commonly dominated by native species. Furthermore, while some weedy and native species occur in both of these general soil/microtopography units, other species are largely restricted to one unit or the other. Also, some species are widely distributed throughout the preserve whereas others, such as the introduced weed purple star thistle, are currently limited to certain areas near the point(s) of introduction.

Environmental and management influences across the preserve also vary across space and time. Especially in semiarid and arid regions, annual vegetation is highly influenced by rainfall and temperature profiles that vary from year to year. Weather influences can easily outweigh the effects of management inputs, including grazing, in any given year (Jackson and Bartolome 2002). Weather interacts with edaphic factors, management factors, and the seed bank to increase the overall variation in vegetation outcomes. In other words, a given set of management inputs could have a variety of different effects on vegetation depending on environmental factors.

To further complicate matters, grazing cannot be considered to be a uniform or fixed effect either within years or between years. Grazing records from Jepson Prairie indicate that pastures which nominally receive a given grazing prescription show considerable variation in the time periods that animals are present and actual stocking rates. Such variation is unavoidable, give the influence of annual weather conditions on the plant phenology and the spatio-temporal distribution of available forage throughout the reserve. In addition, because sheep tend to move as flocks, the large pastures at Jepson are not grazed uniformly in space and time. As sheep move throughout the pasture, a mosaic of local grazing intensities and timings develop over the pasture. Furthermore, as noted in the grazing plan (Jepson Prairie Management Committee 1999), sheep (and other grazers) show varying levels of selectivity when they graze. At any given time, preferred species are likely to be grazed more intensely than non-preferred species. Hence, the amount of time that sheep remain in an area, and the impact that they have on different species within an area, are influenced by the existing vegetation at the time that the animals encounter it.

Because Jepson Prairie has a long history of grazing, it is reasonable to assume that all of the common species that occur at the reserve can tolerate some level of grazing. The use of grazing as a management tool to manipulate species composition at Jepson Prairie relies on the hypotheses that within this complex of grazing-tolerant species (a) varying the timing and/or intensity of grazing impacts will differentially affect the competitive abilities of certain species and (b) this change in competitive advantage will alter the total cover achieved by various species. The purpose of this study is to determine if we can identify a grazing regime or regime(s) that will reduce cover of exotic species and increase cover of native species beyond levels achieved by the currently-used grazing regimes. The six hypotheses being addressed in this study are listed in Table 1.

Table 1. Hypotheses and related questions addressed in this study

Hypothesis	Questions addressed
(1) Changes in the initial and final vegetation states for a given growing season will vary with the seasonal grazing profile.	Within the range of grazing patterns tested, are some patterns superior to others?
(2) Grazing profile variables that include a temporal element (timing of grazing impact) will be better predictors of vegetation change outcomes than variables that only measure total biomass removal.	How important is the timing of grazing relative to total biomass removal?
(3) Weed-dominated and native-dominated experimental units will show different responses to grazing variables.	What grazing patterns are associated with positive or negative changes in weedy patches? What grazing patterns are associated with positive or negative changes in native-dominated patches?
(4) Different grazing profiles are likely to occur between weed- and native-dominated experimental units within plot clusters	Do sheep show consistent grazing preferences based on the composition of the vegetation over the grazing season? If so, are they more pronounced at certain times during the season?
(5) Thatch /mulch accumulation/removal will vary with grazing profiles.	Which grazing profiles are associated with desired thatch management goals?
(6) Compared with nongrazed units, grazed units will have lower weedy cover and increased native species cover.	Is grazing necessary to suppress weeds and maintain native species cover?

This study was initiated in 2004, at which time baseline data was collected. Differential grazing regimes were initiated in 2005 and will continue through 2007. This report presents results based on the baseline (2004) and first year (2005) results. Additional data collection and analysis will occur in 2006 and 2007. The study is funded by a grant from the California Bay Delta Authority with support from the Solano County Water Agency.

METHODS

The overall design of the experiment has been described previously (Swiecki and Bernhardt 2004). Some of the methods described previously have been modified as needed to adapt to field conditions. Updated procedures are presented in this section.

The experiment was established in three adjacent pastures, known as field 20East or east eucalyptus (EEuc); field 19East or east north section 24 (EN24); and field 18East or east south section 24 (ES24). Using GIS software that showed the boundaries of the study pastures, we used randomly-selected coordinates to establish an initial candidate cluster location in each pasture. Subsequent candidate cluster locations were generated by filling each field with non-overlapping circles 75 m in radius. Coordinates of the center point of each circle, each at least 150 m from an adjacent point within a pasture, were uploaded to a GPS receiver (Garmin® GPS76).

Between April 20 and May 1, 2004, we used the GPS to locate the plot cluster areas in the pastures. Upon reaching a candidate cluster location, we determined whether we could establish three plots (1 m^2 each) in native dominated areas (generally pools or swales, i.e., low microtopographic positions) and three plots in exotic dominated areas nearby (generally uplands or mounds , i.e., high microtopographic positions). If suitable plots could be not be found within about 20 to 30 m of the preselected coordinates, the candidate area was rejected and we proceeded to another point. We continued inspecting candidate locations until we had eight plot clusters in each pasture. The final distribution of the selected cluster locations is shown in Figure 1.

The six plots in each cluster are in relatively close proximity to each other to ensure that all plots within each cluster had the same potential grazing exposure. The separation between plots in a cluster ranges from less than a meter (e.g., between adjacent high or low plots) to about 28 m (maximum distance between high and low plots in a single cluster). Given the size of the flocks used on these fields (about 140 to 560 head in 2005) and the fact that sheep tend to be somewhat attracted to the exclosures, plots within a given cluster had the same potential exposure to the flock as it moved around the field.

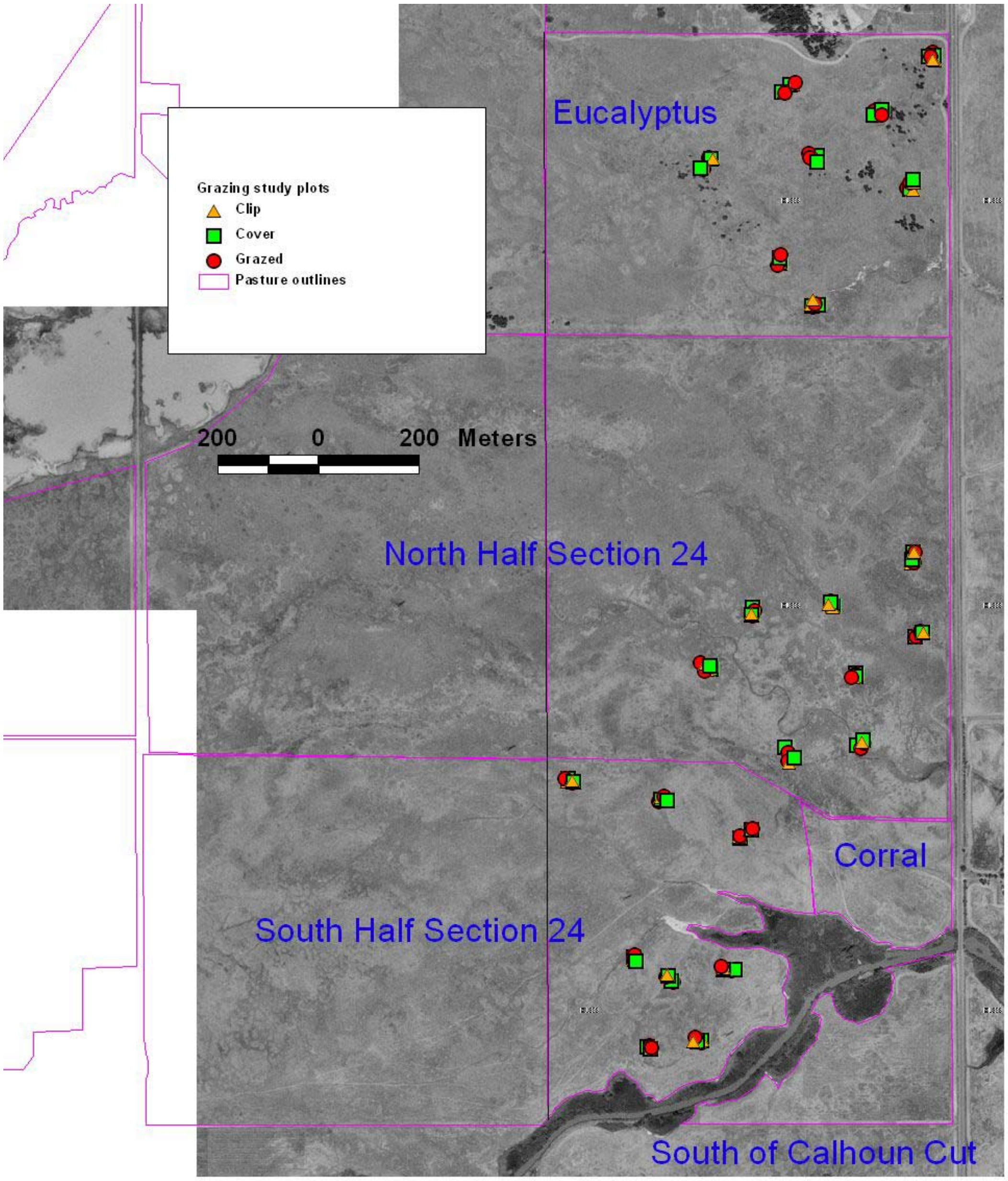


Figure 1. Plot cluster locations. The different symbols indicate different plot types (grazed, nongrazed cover, nongrazed clip) within the clusters.

Plot setup

Within each cluster, each set of three plots (high or low) was matched to the degree possible for vegetation characteristics, including plant height, species composition, and cover. The three plot types designated in low (swale/pool) and high (upland) halves of each cluster were:

Grazed plot: exposed to grazing; used to measure cover and composition changes and thatch accumulation in the presence of grazing.

Nongrazed cover plot: excluded from grazing by fencing; used to measure cover and composition changes and thatch accumulation in the absence of grazing (i.e., multiyear nongrazed control). The exclosures for cover plots are larger than 1 m^2 to allow collection of nongrazed residual dry matter samples from inside of the exclosure but outside the area used to measure cover.

Nongrazed clip plot: excluded from grazing by fencing; used as reference plot to estimate the amount of forage removal occurring each month in the matched grazed plot. Forage in this plot was manually clipped as needed at each observation date to maintain average forage height within 5 cm of the average forage height in the grazed plot.

It was generally much easier to pick out two closely matched plots than three matched plots. If three nearly identical plots could be established, plots types were assigned randomly. For plot sets that were less closely matched, the two plots that were most closely matched for vegetation height and density were assigned to the grazed and nongrazed clip plots treatments.

Two diagonal plot corners were marked by driving 15 cm long carriage bolts topped with 4 cm diameter fender washers into the ground so that the washer was flush with the soil surface. The legs of the 1 meter square point frame that is used to collect cover data fit directly over the carriage bolts, so the frame can be positioned in the same exact location for all measurements using the frame.

Differential-corrected GPS coordinates were recorded for each plot. We also recorded distances and azimuths between the three plots in each half of the cluster to aid in relocation.

In October 2004, personnel from Solano Land Trust (SLT), and the University of California Davis, working with inmates from Delta Camp (a joint effort of the California Department of Corrections and the California Department of Forestry and Fire Protection), constructed exclosures around the nongrazed cover plots and the nongrazed clip plots. Exclosures are composed of 4 steel T-posts surrounded by 122 cm tall, 14 gauge galvanized welded wire mesh (5 by 10 cm) fence fabric The fence fabric is secured to the posts with plastic cable ties, which are readily removed when removal of the cage is necessary.

Grazing

SLT subdivided the large pastures in which the plots were located by installing north-south cross fencing prior to the beginning of experimental grazing. All plots are located in the easternmost pastures created by the cross fencing. The initial grazing plan for the pastures is shown in Figure 2 and was developed by SLT and members of the Jepson Management Committee. The actual grazing regime implemented on each pasture (i.e., timing of livestock introduction and removal and stocking rates) was determined from grazing records provided by Burrows Hamilton.

East eucalyptus (field 20E, EEuc) was to be grazed according to one of the two grazing regimes currently in use at the preserve; the other two plans were new. The grazing regime in EN24 (field 19E) was intended to have a higher grazing intensity, with a target of 560-784 kg/ha (500-700 lb) of residual dry matter (RDM) per acre at the end of the grazing season. The grazing regime in ES24 (field 18E) consisted of discrete pulses intended to target specific growth stages of exotic annuals. The second pulse was timed to impact medusahead and the two final pulses were specifically targeted to control yellow starthistle (YST). However, YST was not present in any of the study plots in any field.

In the 2004-2005 growing season, grazing began in January 2005. Burrows Hamilton supplied his actual grazing records for the study pastures in October 2005, after all grazing for the season was completed.

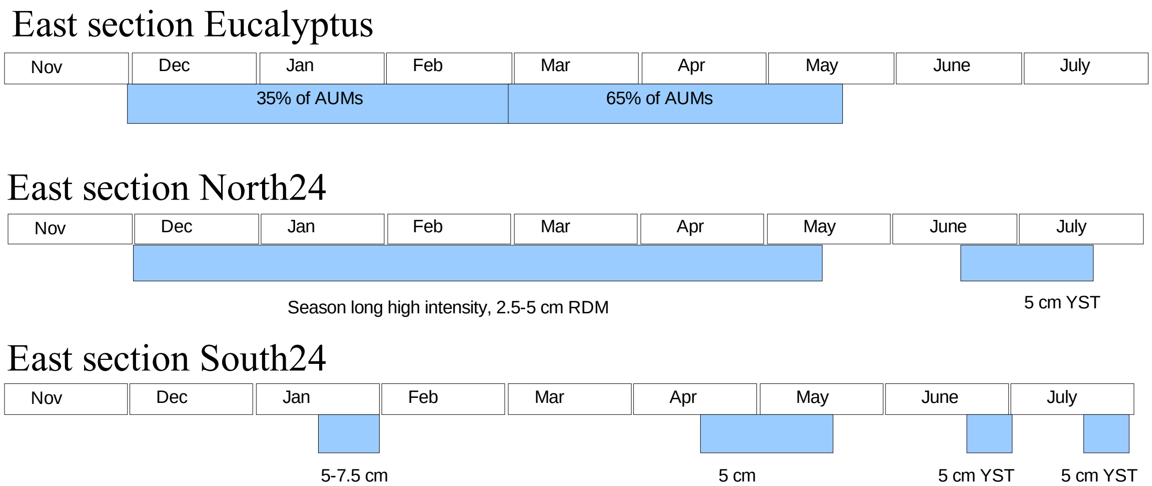


Figure 2. Grazing plan for the 2004-2005 grazing season. The plan for east eucalyptus pasture called for a total of 75 AUM/acre for the season, allocated as shown. The plan for EN24 called for a total of 120 AUM/acre for the season; the target forage heights are shown in the figure. This plan also called for a late grazing pulse to suppress yellow starthistle (YST). The plan for ES24 called for discrete periods of grazing to reduce forage heights to those shown.

Data collection

Grazing impact measurements

To estimate grazing impacts over the growing season in grazed plots, forage height measurements were made in both grazed and nongrazed clip plots over the following dates: January 4-6, February 14-18, March 16-17, April 19-27, and August 10-18. At each observation period, average forage height was measured at five locations in each plot (center and four corners) using a modified falling plate meter (Barnhart 1998, Rayburn and Lozier 2003). The clear plastic plate of the meter was 25 cm square and was attached to a metal tube which was nested in a calibrated measuring rod (*fig. 3*).

Average standing forage height at each measured location was estimated as the height at which about half of the plants under the plate contacted the bottom of the plate. The plate and attached tube (mass=1.2 kg) was then lifted about 30 cm above the maximum forage height and allowed to drop freely; a second measurement was then made on the forage compressed by the falling plate/tube assembly. Because the dropped plate measurement is affected by plant density as well as plant height, it provides a better estimate of total forage biomass than does average forage height.

Figure 3. Falling plate meter in grazed plot.

If the average forage height in the nongrazed clip plot exceeded that of the paired grazed plot by 5 cm or more, forage in the nongrazed clip plot was mowed to match the height of the grazed plot. We used a battery-operated string trimmer to mow the clip plot. After mowing, the forage height in the clip plot was remeasured as noted above.

Spring assessments

In April of 2004, near the time when native spring annual forb cover was maximal, a baseline assessment was conducted on all plots as described below. Plots were also photographed at this time. In 2004, plots were assessed between April 20 and May 1. These assessments were repeated in 2005 between April 19 and April 27. Comparisons between the 2004 baseline and 2005 data constitute the results of the first full year of the study.

For the nongrazed cover plots and the grazed plots, we estimated plant cover by species using a square, evenly-spaced 100 point grid. A laser-based point frame was mounted over the plot, using the bolts placed in the plot corners to maintain a consistent placement of the frame over a given plot. A high-intensity green laser pointer mounted on a sliding bracket suspended over the plot was used to highlight each of the 100 points. We recorded whether the laser dot fell on bare soil, thatch (dried plant material from the previous or older growing season), or current-season plant species. Sample point hits were identified to species for all native species and for exotic forbs. Sample point hits on exotic grasses were differentiated only into categories of medusahead or other exotic grasses. Cover was assessed on a first hit basis, so total cover for the plot sums to 100%.

In addition, for all plots, we noted all plants species visible within the plot. For each plant species present within the sample frame area we also noted the phenological stage (vegetative, bolting, flowering, seed formation, senescent, dead). We also noted the dominant species within each plot. Average forage height and compressed forage height were also measured in all plots at this time, using the falling plate meter as described above.

Summer assessments

In August 2004 and 2005, after grazing for the season was complete, we revisited each plot and noted the presence and cover of summer annuals that were not visible in April.

Residual dry matter (RDM) was estimated using a clipped and weighed sample from an area that was visually matched to have the same RDM as the plot but was not located within the plot itself. For grazed plots, the sample was collected from a nearby area outside of the plot. For the nongrazed plots, the sample was collected from within the area excluded from grazing, but outside of the area in which cover was measured. A square 30 cm metal frame was used to delimit the area from which the RDM sample was clipped.

In addition, the falling plate meter was used to measure average forage height and compressed forage height at five points in each plot as described above. Mulch or thatch height was also measured at five points in each plot using a measuring tape. Mulch was defined as RDM that had carried over from the previous year and was distinguished from current season RDM by its more weathered appearance and typically grayish rather than brown color.

After all evaluations were made, the nongrazed clip plots were mowed and raked to match the height and approximate RDM of the paired grazed plots so that grazed and nongrazed clip plots would be matched with respect to RDM at the start of the upcoming growing season.

Data analysis

Calculation of grazing impact — For the first reading in January, the difference between forage heights in the grazed and nongrazed clip plots was used directly to calculate the grazing impact to that point (Equation 1). Grazing impacts were expressed as the percent of the potential forage height growth removed.

$$grazing\ impact_{January} = \frac{(height_{nongrazed} - height_{grazed})}{(height_{nongrazed})} \times 100 \qquad \text{(Equation 1)}$$

For all other time intervals, grazing impacts for grazed plots were calculated as shown in Equation 2; t_1 and t_2 represent the start and end of the grazing interval, respectively. If nongrazed clip plots were mowed at the start of a time interval, forage height after mowing was used as the initial (t_1) nongrazed forage height

$$\textit{grazing impact}_{t_1 \rightarrow t_2} = \frac{(t_2\,height_{nongrazed} - t_1\,height_{nongrazed}) - (t_2\,height_{grazed} - t_1\,height_{grazed})}{(t_2\,height_{nongrazed})} \times 100$$

(Equation 2)

Based on the limits of accuracy of our average forage height measurements, differences in forage heights of less than 2.5 cm were set to zero for purposes of data analysis.

Development of grazing profiles— We defined the grazing profile for a given plot as the series of grazing impact scores for that plot from each observation interval. We used hierarchical clustering to group plots with similar grazing profiles. Ward's minimum variance method was used for clustering. This method tends to join clusters with few observations and is strongly biased toward producing clusters with similar numbers of observations.

To create grazing profiles that were appropriate for the analysis of spring cover data (measured in April), grazing impact data for the period April to August was not used in hierarchical clustering. In addition, grazing impacts in the January evaluation were not used to develop clusters for the low plots because only two of these plots showed any measurable grazing impact at this time. Grazing profiles were used to test experimental hypotheses 1-5.

We used JMP® statistical software (SAS Inc., Cary NC) for data summary and analysis. Unless otherwise indicated, effects or differences are referred to as significant if $p \leq 0.05$. Effects of year and grazing variables were tested using repeated measures analysis of variance. We used appropriate variance-stabilizing transformations on percent and count data (arcsine and square root transformations, respectively) prior to analysis of variance or regression analyses. Paired t-tests were used for specific comparisons between paired observations.

RESULTS AND DISCUSSION

Overall grazing regimes and impacts

Figures 4, 5, and 6 summarize the planned and actual grazing regimes as well as the measured forage height growth and grazing impacts in plots located in each of the three study fields. The 2003-2004 grazing for each field is also plotted for comparative purposes.

Differences between 2003-2004 and 2004-2005

Overall grazing records show that all three pastures were grazed differently in 2004-2005 than they were in 2003-2004 (*fig. 4-6, 7*). Hence, vegetation responses in the 2004-2005 season in both grazed and non-grazed plots may be influenced by carryover effects related to the different 2003-2004 grazing regimes. In 2004-2005, field 20E (EEuc) was grazed for only two short periods in January and February 2005, whereas it was grazed in five months in 2003-2004, including two periods during the peak spring bloom period (about March 15 to April 30) (*fig. 3, 7*). In contrast, fields 19E (EN24) and 18E (ES24) were both grazed more intensely overall in 2004-2005 than in 2003-2004 (*fig. 5-7*). Also, ES24 was grazed during the peak spring bloom period in 2004 whereas EN24 was not (*fig. 7*). The situation was reversed in 2005. In fact, EN24 was the only field grazed during the peak spring bloom period in 2005.

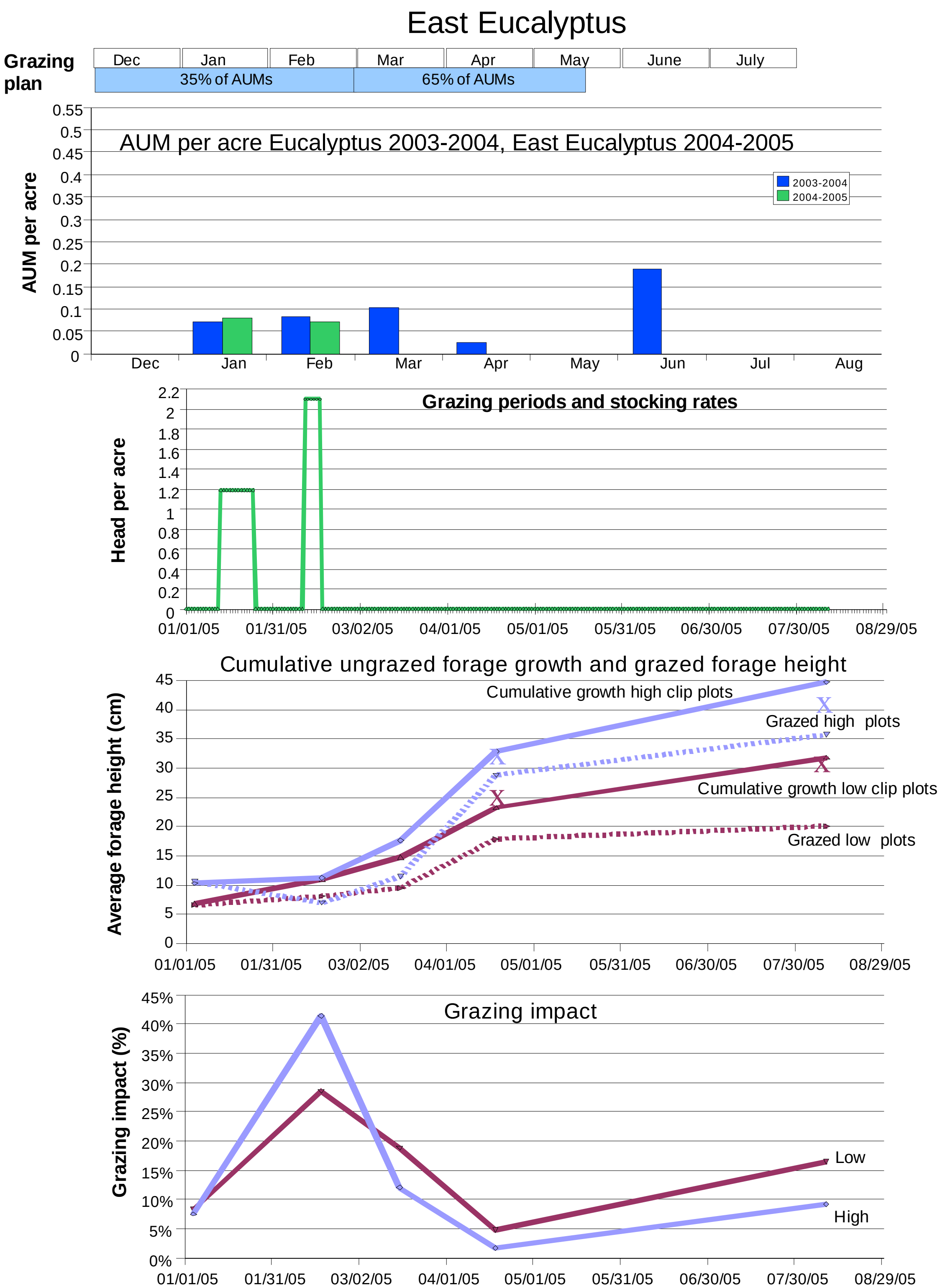


Figure 4. Planned and actual grazing in field 20E (east eucalyptus, EEuc). From top to bottom: grazing plan; reported AUM/acre for 2003-2004 and 2004-2005 seasons; 2004-2005 grazing periods and stocking rates; measured average forage height, calculated cumulative forage growth potential (based on ungrazed clip plots), heights in nongrazed cover plots (X's); grazing impact, as percent reduction in forage height.

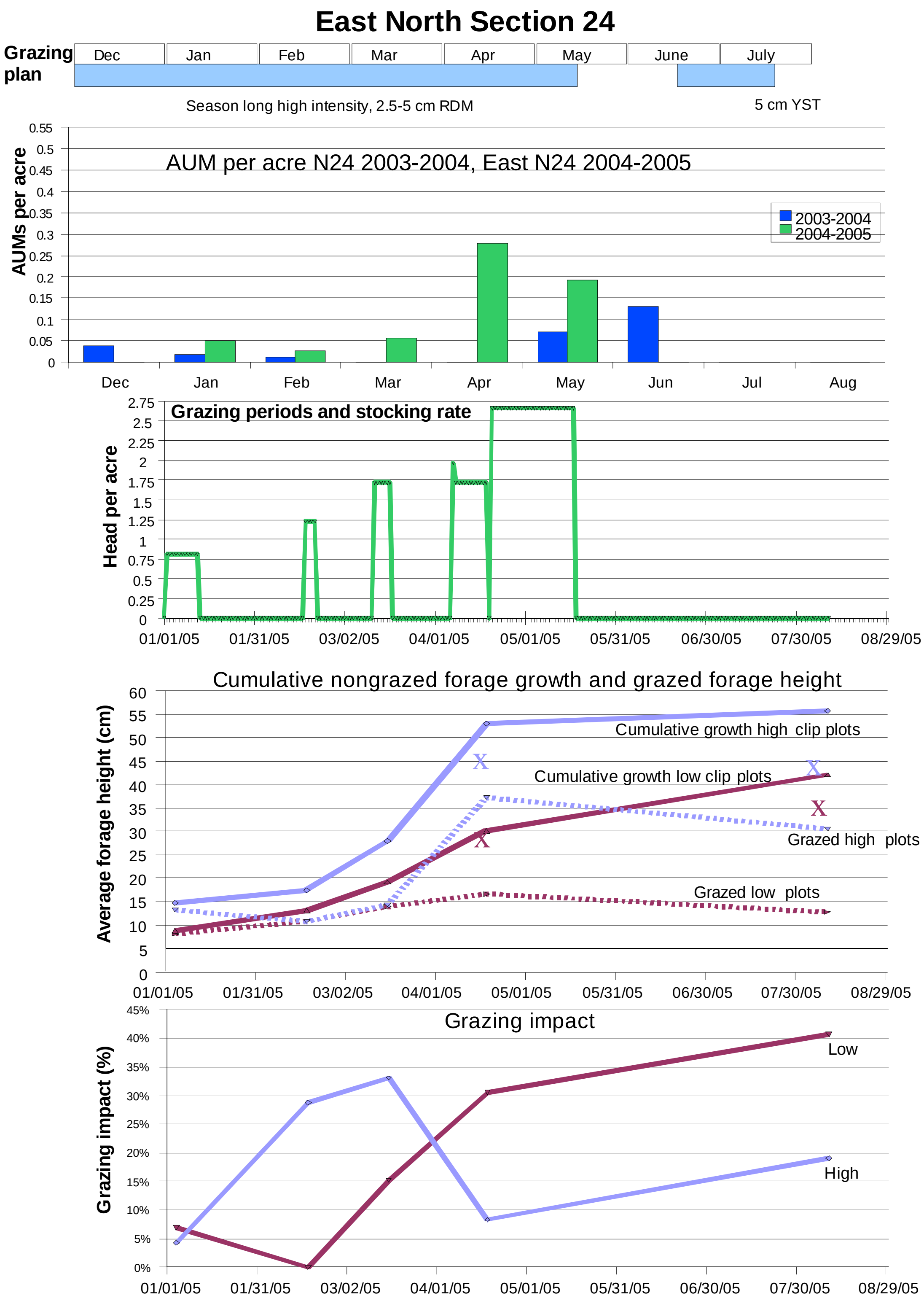


Figure 5. Planned and actual grazing in field 19E (east north section 24, EN24). From top to bottom: grazing plan; reported AUM/acre for 2003-2004 and 2004-2005 seasons; 2004-2005 grazing periods and stocking rates; measured average forage height, calculated cumulative forage growth potential (based on ungrazed clip plots), heights in nongrazed cover plots (X's); grazing impact, as percent reduction in forage height.

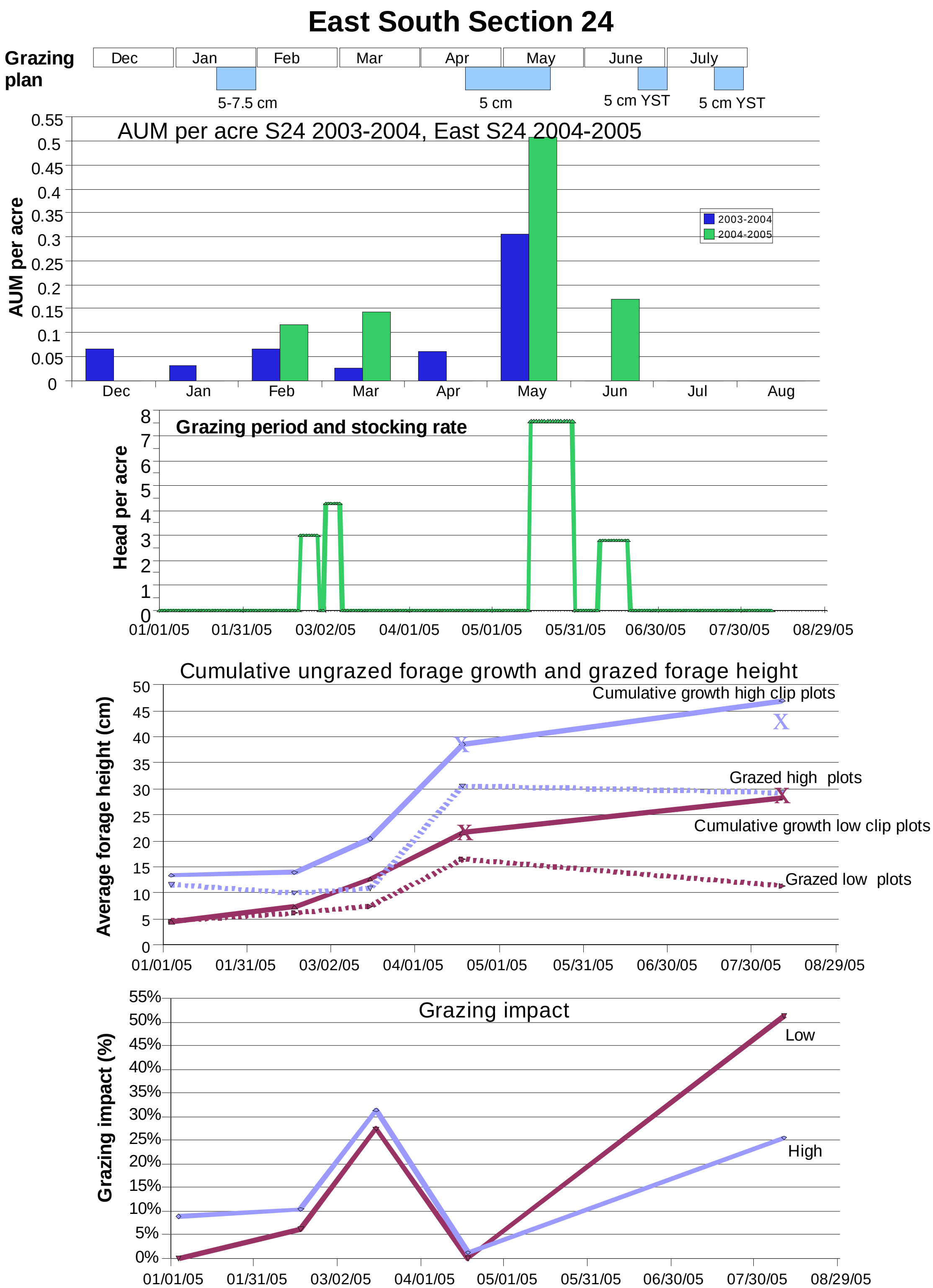


Figure 6. Planned and actual grazing in field 18E (east south section 24, ES24). From top to bottom: grazing plan; reported AUM/acre for 2003-2004 and 2004-2005 seasons; 2004-2005 grazing periods and stocking rates; measured average forage height, calculated cumulative forage growth potential (based on ungrazed clip plots), heights in nongrazed cover plots (X's); grazing impact, as percent reduction in forage height.

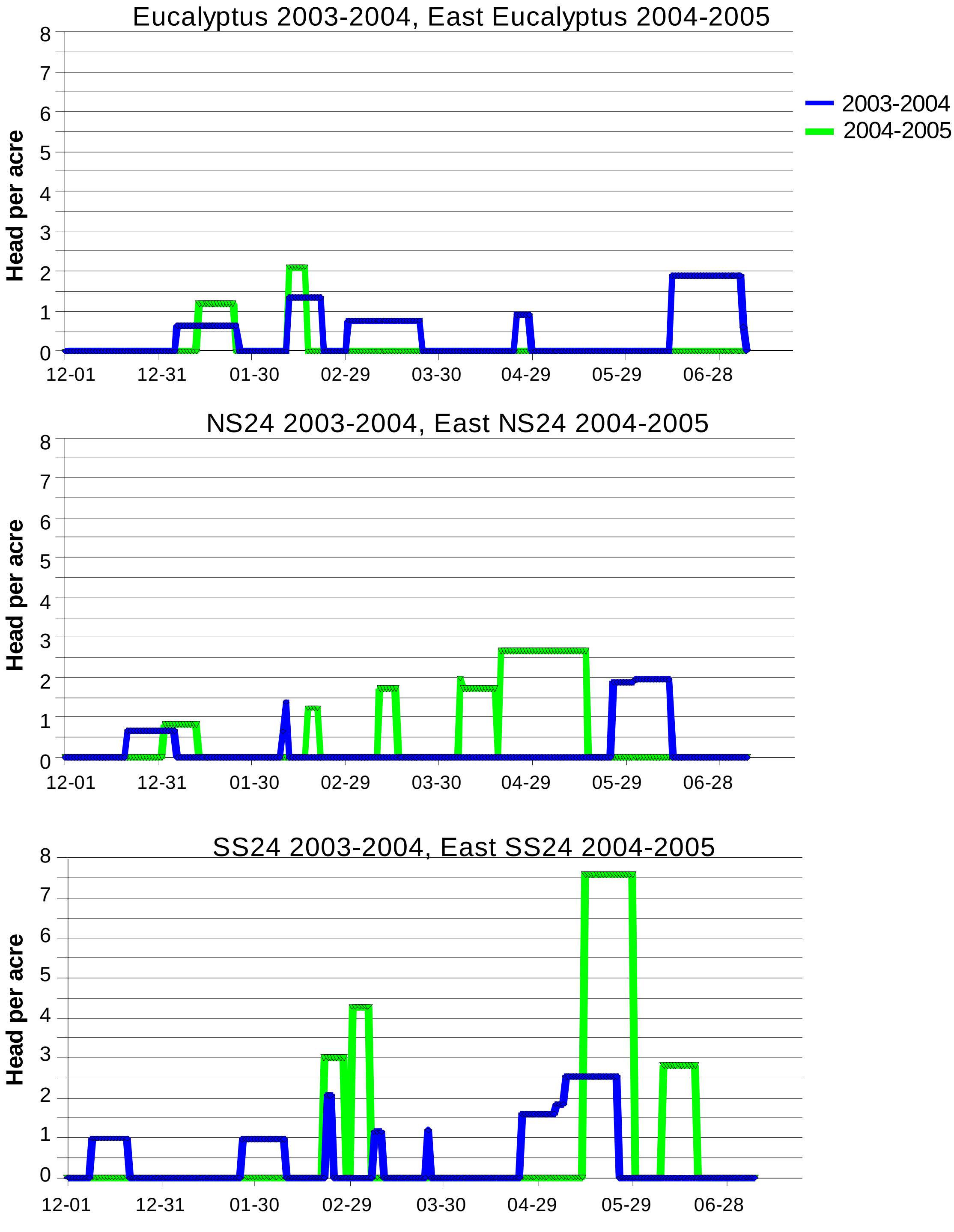


Figure 7. Periods of grazing and overall stocking levels in head per acre in the three study pastures in the 2003-2004 (burgundy line) and 2004-2005 (blue line) grazing seasons. The overall field areas were greater in 2003-2004 than in 2004-2005 because new cross fences were added between the two seasons. The head per acre calculation uses the pasture acreage that applies for each season. Note that the y-axis scale differs in the three graphs.

Actual grazing versus the grazing plans

Field 20E (EEuc) — The grazing plan for EEuc was one of two standard grazing regimes currently specified for use on the preserve. However, 2004-2005 grazing records show that this field was grazed considerably less than specified in the grazing plan (*fig. 4*). All grazing in this field occurred between the January 4 and February 17 evaluations, and the greatest seasonal grazing impact was measured in the February evaluation. The low grazing impact calculated for March probably represents a carryover effect from the previous month; grazed and trampled vegetation in the grazed plots apparently grew at a slightly slower rate than the vegetation in the mowed but nongrazed clip plots. The slight grazing impact measured between April and August in the absence of sheep grazing probably represents the combined action of native herbivores (e.g., rabbits) and loss of dry matter due to wind. Both of these processes are likely to impact the exposed grazed plots to a greater degree than the caged nongrazed clip plots. The overall effect was that the 2004-2005 grazing regime in EEuc was the lowest-intensity regime tested (17.7 AUM or 0.15 AUM/acre for the entire season), consisting of moderate early spring grazing only. Grazing intensity up to the point of the April plant cover evaluation was 17.7 AUM or 0.15 AUM/acre. It was less intense than either of the current nominal grazing regimes used at the preserve.

Field 19E (EN24) — The grazing plan for EN24 (*fig. 2*) was intended to be a more intensive version of the standard regime that was slated for EEuc. The overall grazing period was similar, but the intensity was supposed to be substantially greater, maintaining forage height at 2.5 to 5 cm over most of the grazing season. As executed, grazing occurred in a series of pulses in every month from January to May, with a relatively long and intense period of grazing during the latter portion of the spring bloom. The actual 2004-2005 season grazing in EN24 matched the plan well with respect to timing (*fig. 5*), although the June-July pulse did not occur. However, the intensity (106.3 AUM or 0.6 AUM/acre for the entire season) was insufficient to maintain forage near the average height / RDM target (*fig. 5*). Average forage heights in both high and low plots were above the target throughout the season, with the greatest deviation occurring during the late spring growth flush between the March and April evaluations. Grazing intensity up to the point of the April plant cover evaluation was 72.5 AUM or 0.41 AUM/acre. In effect, the grazing regime that occurred in this field was actually much closer to the regime that was intended for EEuc. Hence, we can consider the grazing in this field to be representative of one of the existing standard regimes, rather than a new regime as originally intended.

Field 18E (ES24) —The grazing plan for ES24 called for a series of relatively intense grazing pulses (*fig. 2*). The plan called for grazing to an average forage height of 5 to 7.5 cm in late January, and to 5 cm from mid-April through mid-May and again in June and July. The June and July pulses were to be timed to yellow star thistle phenology. Although actual grazing did occur in pulses, the timing was different from that specified in the plan (*fig. 6*). Perhaps the most notable deviation from the plan was that no grazing occurred during the peak spring bloom period. The overall grazing intensity in this field (67.6 AUM or 0.94 AUM/acre for the entire season) was the highest among the three fields on an area basis. However, grazing intensity through April was only 18.7 AUM or 0.26 AUM/acre, intermediate between levels used in EEuc and EN24. Average forage height was maintained near target levels through the March evaluation, but was higher than specified by the plan at the end of the grazing season despite relatively intensive grazing in late May and an additional pulse in June. The overall 2004-2005 grazing regime in this field differs from the standard regimes used at the preserve and was characterized by moderate to intense pulses of early and late season grazing, with no grazing during the peak bloom period.

Seasonal patterns of forage growth and grazing impact

By summing the growth increments for each interval measured in the nongrazed clip plots, we were able to calculate the potential cumulative height growth for the entire growing season for high plots (blue lines) and low plots (maroon lines) (*fig. 4-6*). In all pastures, the greatest increment of forage height growth occurred between the March and April evaluation dates. This was primarily associated with the growth of exotic grasses, especially in the high plots. Most of the forage height growth in the April-August evaluation period presumably occurred by the end of May, before soil moisture was depleted.

The actual end-of-season forage heights in the nongrazed cover plots were generally similar to the calculated cumulative heights for the low plots, but they were less than the cumulative heights for the high plots (compare X's and solid lines on the average forage height graphs in *fig. 4-6*). This difference reflects the fact that exotic grasses in the nonmowed cover plots (X's), reached their maximum heights and stopped growing. In the mowed clip plots, grasses regrew after each mowing and did not have the opportunity to stabilize at their maximum height until after the April evaluations.

Based on paired t-tests of high and low plots within clusters, both total forage height reduction and grazing impact (percent reduction in height relative to that attained by the matched nongrazed clip plot for a given time interval) were significantly greater in high plots than in adjacent low plots among plots that were grazed during the observation intervals between January and March (*fig. 4-6, 8*).

Presumably, forage removal is affected by both plant phenology, and seasonal flooding. During the wet winter months, forage removal from low plots is likely to be affected by rainfall and subsequent inundation of the pools and swales. Figure 9 shows the temporal correspondence of rainfall and monthly data collection periods, along with the water depth measured at each period. Low areas filled rapidly after rainfall, but the relatively shallow pools and swales dried out after periods with little or no rain. The low plot areas also dried out more slowly early in the season than they did later in the season.

Figure 9 shows that grazing impacts to low plots were less than the impacts to high plots for fields that were grazed during or shortly after periods of substantial rainfall which flooded the low plots. In the field, we observed that the sheep tended to avoid standing water during the late winter months. The fact that sheep do not like to stand in water was previously noted in the Jepson Prairie Grazing Plan (Jepson Prairie Management Committee 1999). Although vegetation in the low areas was less likely to be grazed early in the season due to flooding, exotic grasses on the high areas were still vegetative and were readily grazed by the sheep.

As the fields dried out in the spring, the sheep no longer avoided the pool and swale areas where the low plots were located. In addition, many of the exotic grasses (e.g., ripgut brome, medusahead) on the uplands became less palatable as they began to flower, set seed, and senesce (*fig. 10*). Forage height measurements clearly show that sheep preferentially grazed in the low plots in the late spring months. In the March-April interval, both overall height reduction and grazing impact due to grazing were significantly greater in low plots than in the high plots (paired t-test of plots from fields grazed during this period) (*fig. 4-6, 8*). This trend persisted into the final observation interval (April-August), although only paired differences in the percent grazing impact were significant; total height reduction did not differ significantly between paired high and low plots.

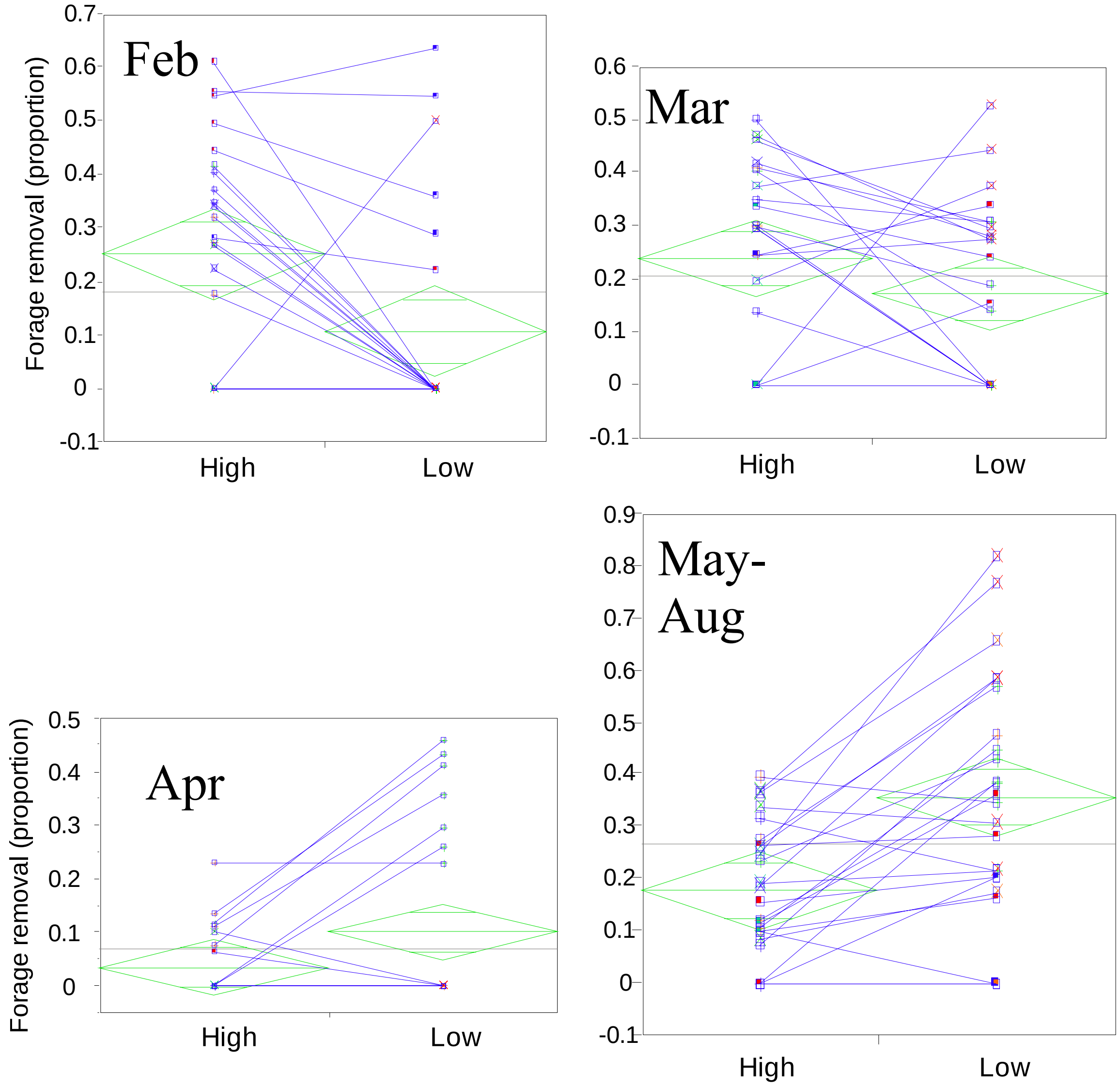


Figure 8. Proportion of forage height removed by grazing in high and low plots, measured in February, March, April, and August. Each line connects a high and low plot pair from the same cluster. The horizontal line in each graph represents the overall average. The center line of each diamond represents the mean for the position (high or low). The vertical extent of each diamond represents the 95% confidence interval based on a pooled variance of both the high and low positions. n=24 plots in each position.

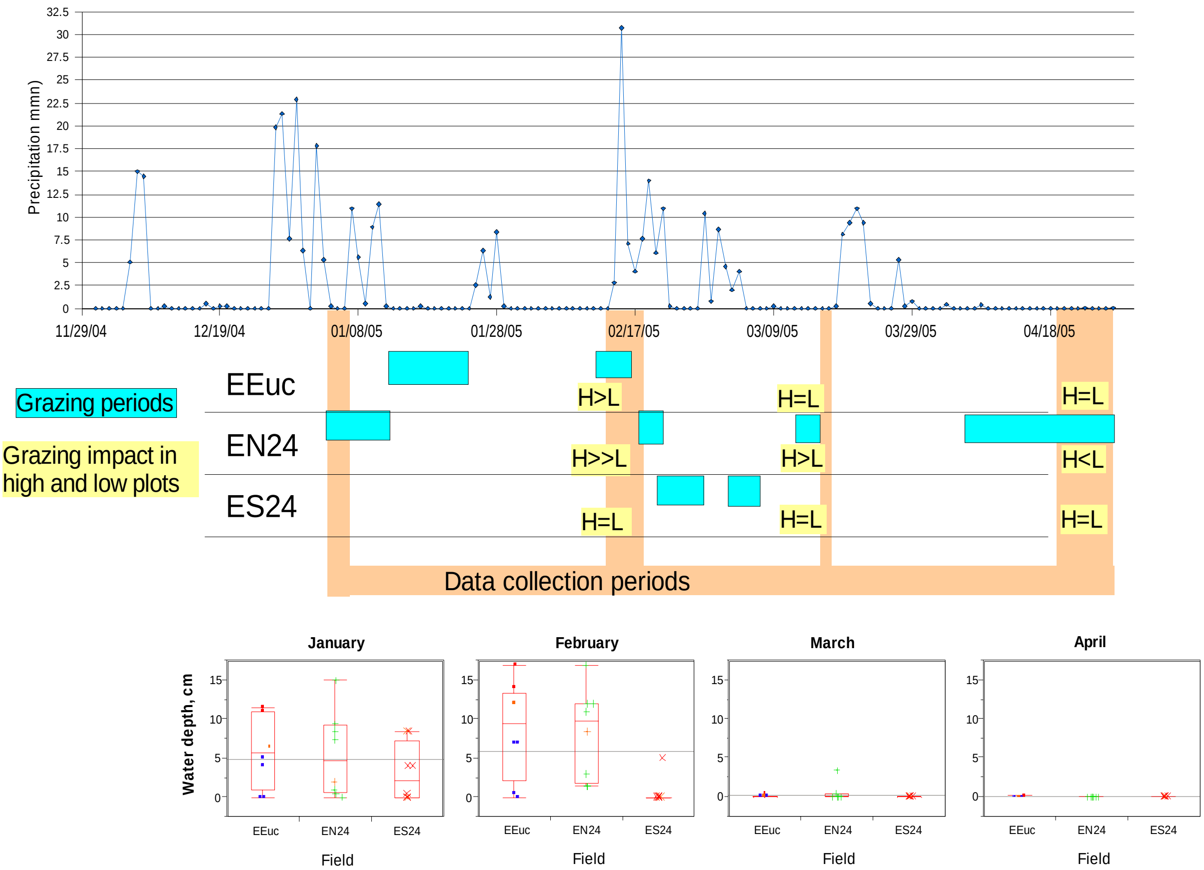


Figure 9. Temporal relationships between rainfall (top graph); grazing periods, and relative grazing impacts in high (H) and low (L) plots in EEuc, EN24, and ES24 (middle); and water depth (bottom) measured in low plots at evaluation dates in January, February, March, and April. Rainfall data are from CIMIS station 122 (Hastings Tract) located about 2.4 km northwest of the study area. Turquoise bars show time periods when sheep were present in the fields. Time intervals during which data were collected are shown by orange bars extending from the x-axis of the rainfall graph. Overall grazing impact trends for the January – February and February – March evaluation intervals are coded as follows: H>L greater impact in high plots than paired low plots; H>>L much greater impact in high plots than paired low plots; H=L similar level of impact in paired high and low plots; H<L greater impact in low plots than paired high plots. Box plots for water depth readings in the low plots at the three evaluation dates show actual depths (points), median (center line of box) and the first and third quartiles (outer edges of boxes). Lines beyond boxes extend to furthest data point that falls within 1.5× the interquartile range. The disparity in water depths for the February readings are related to the timing of measurements relative to rain. All but one plot in ES24 were evaluated before the first rain event in February; all other plots were evaluated after this rain, which refilled most the dry or nearly dry pools and swales.

Figure 10. Sheep preferentially grazing in swales in field 19E (EN24) on April 25, 2005.

Grazing profiles

As we had anticipated, grazing impact varied not only between high and low plots within clusters, but also among plots of a given microtopographic position within each field. For example, Figure 11 shows the individual grazing profiles for the eight high grazed plots in ES24. Although many plots within the field had similar grazing profiles, levels of grazing impact among the plots at each evaluation date varied substantially. It is also apparent from Figure 11 that the monthly and season-long grazing impact averages for the field are poor descriptors of the grazing impacts that individual plots experienced.

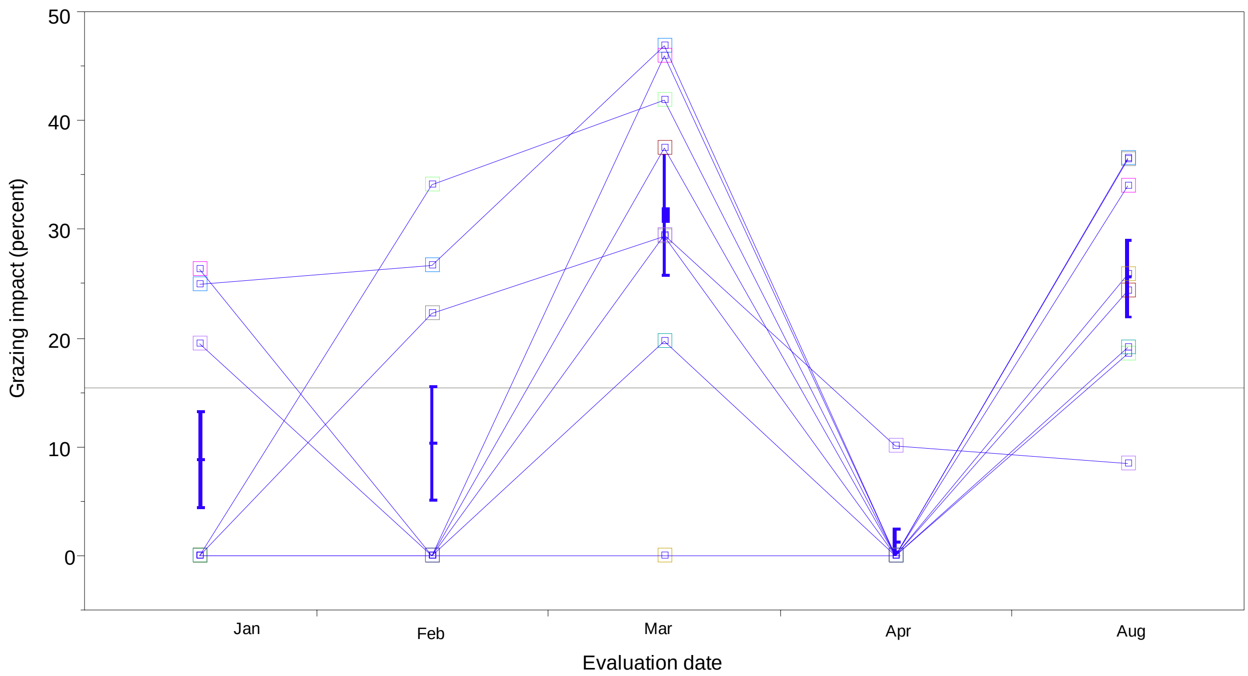


Figure 11. Percent grazing impact (forage height reduction as percent of current height) and grazing profiles for high plots in field 18E (ES24). Horizonal line is the overall season average. Overall means and standard errors for each evaluation date are shown by the vertical error bars.

We used Ward's method for hierarchical clustering to group plots with similar seasonal grazing profiles irrespective of the pasture in which they were located. This allowed us to develop a single variable that described the overall timing and magnitude of grazing impacts over the season and grouped plots that were similar with respect to these impacts. Because of the many differences that existed between high and low plots, hierarchical clustering was performed separately on plots in these two different microtopographic positions.

Figure 12 shows the hierarchical clustering dendrograms and Figure 13 shows the resulting average grazing profiles that were used for subsequent analyses. Five overall grazing profiles were defined for high plots and four were defined for the low plots based on hierarchical clustering. We selected a cutoff for hierarchical clustering that provided a minimum of four plots per grazing profile. Four of the nine grazing profiles consisted of plots from a single field, whereas the others included plots from two or more fields. Average grazing impact by month for each overall grazing profile is shown in Figure 13.

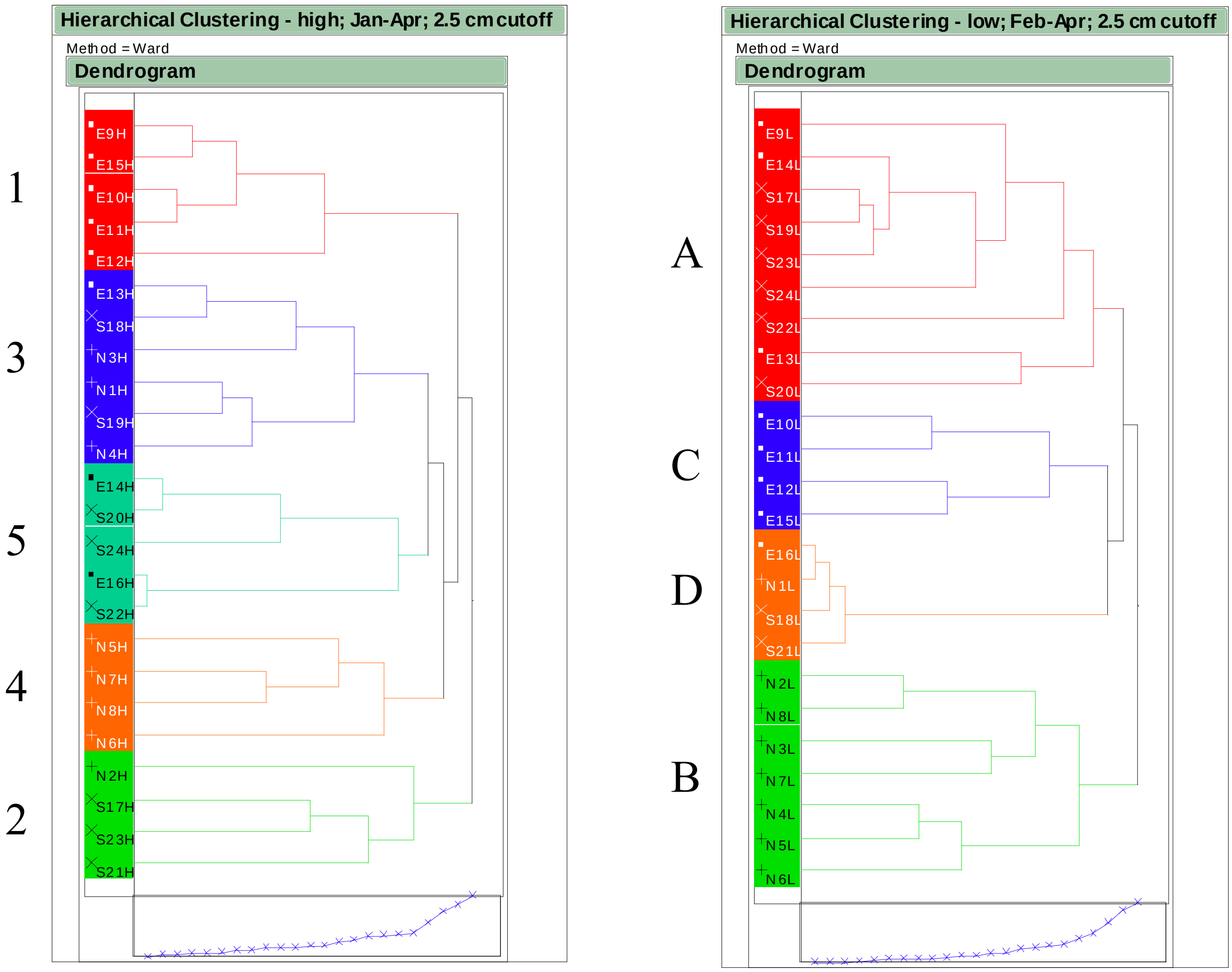
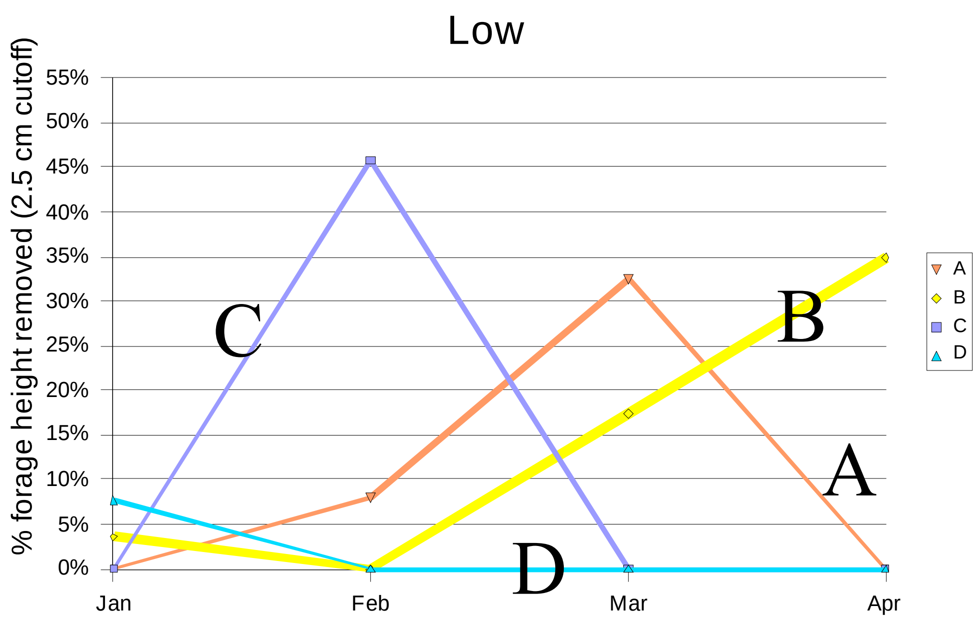


Figure 12. Hierarchical clustering diagrams of grazing impacts for high (left dendrogram) and low (right dendrogram) plots. Plots are identified by plot cluster number: plots in EEuc begin with E and are marked by ■, those in EN24 begin with N and are marked by +, and those in ES24 begin with S and are marked by ×. Within high and low plots, hierarchical clusters are marked by colors.



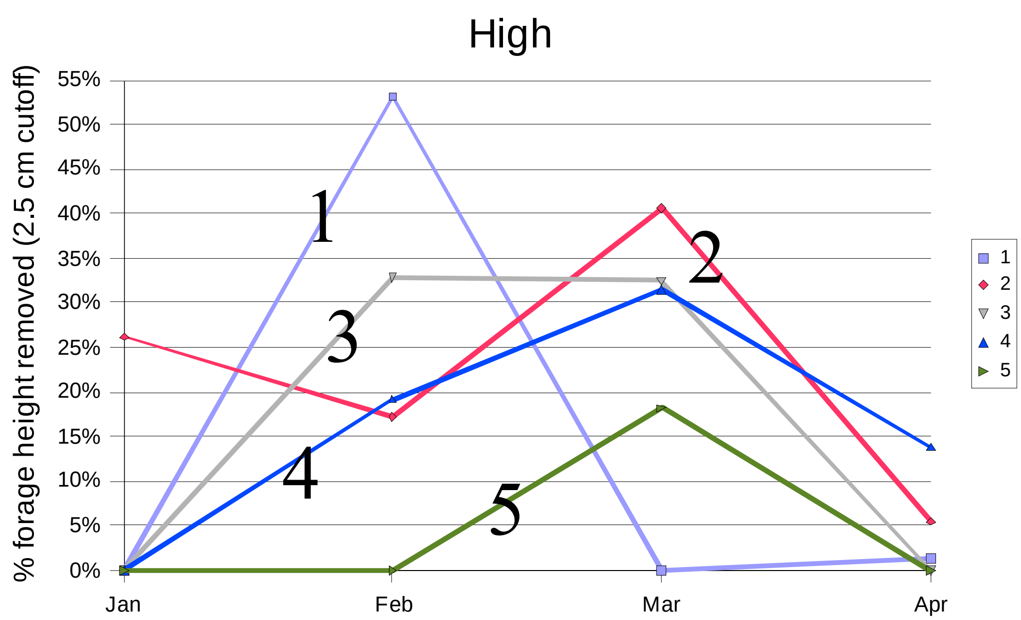


Figure 13. Average percent forage removed by month for each grazing profile, developed by hierarchical clustering, for low (top graph) and high (bottom graph) plots.

Grazing profiles C (low) and 1 (high), which occurred only in plots located in EEuc were nearly identical, but the remaining grazing profiles for the high and low plots were dissimilar (*fig. 13*). All occurrences of grazing profile C in low plots occurred in plot clusters where the high plots showed grazing profile 1 (*fig. 14*). However, in the other plot clusters, the grazing profiles in paired low and high plots were not consistently matched (*fig. 14*). This shows that sheep were utilizing forage from adjacent high and low plots differently as the season progressed.

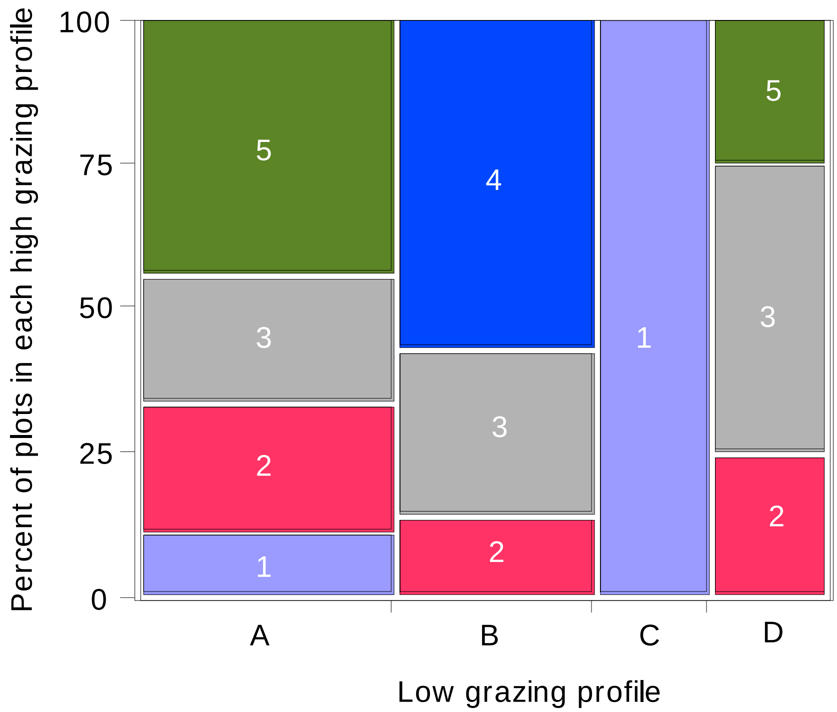


Figure 14. Co-occurrence of grazing profiles among grazed high (upland/mound) and low (pool/swale) plots within plot clusters. Each column is a stacked bar graph showing the percent of high plots in grazing profiles (1-5) occurring with each low grazing profile (A-D). The width of each column is proportional to the number of low plots in each low grazing profile.

Changes in residual dry matter from 2004 to 2005

We used repeated measures analysis of variance of August residual dry matter (RDM) by plot position (high vs. low) and plot type (grazed vs. nongrazed) to determine whether season-end RDM had changed from 2004 to 2005. This overall analysis showed that August 2005 RDM was significantly greater than August 2004 RDM among the nongrazed cover plots but not among the grazed plots (Table 2, *fig. 15*). As expected, RDM was also significantly greater in the high plots than in the low plots overall. Figures 16-20 show examples of plot appearance in April 2004, prior to the start of the experimental grazing treatments, and in April 2005. The pretreatment photo taken in April 2004 was not identified as to plot type (grazed cover, or clip) at the time the photo was taken. Differences in the amount of biomass present in April in the grazed versus the nongrazed plots are most obvious in those clusters grazed in April.

Table 2. Summary of repeated-measures analysis of variance for end-of-season (August) residual dry matter in 2004 and 2005 by plot position (high, low) and plot type (grazed, nongrazed).

Source	df	F ratio	Probability
Between plots			
Position (high, low)	1	182.5034	<.0001
Within plots			
Year	1	64.6505	<.0001
Year × Position	1	0.7245	0.3969
Year × Type (grazed, nongrazed)	1	45.9769	<.0001
Year × Position × Type	1	1.4424	0.2328

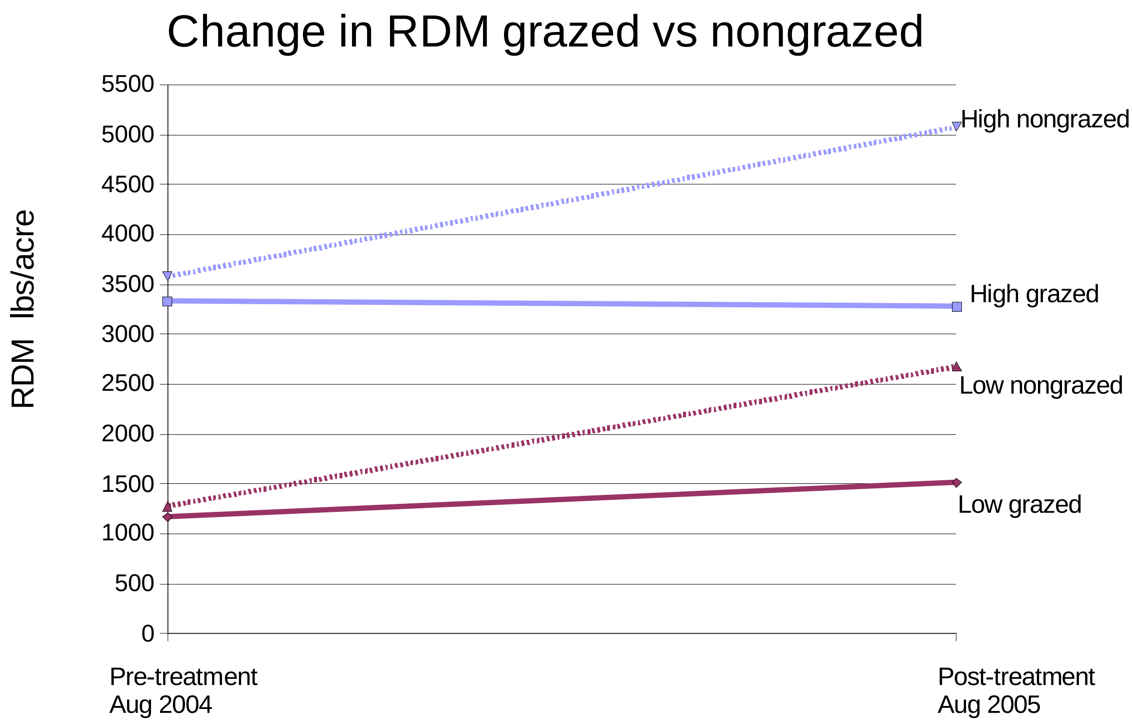
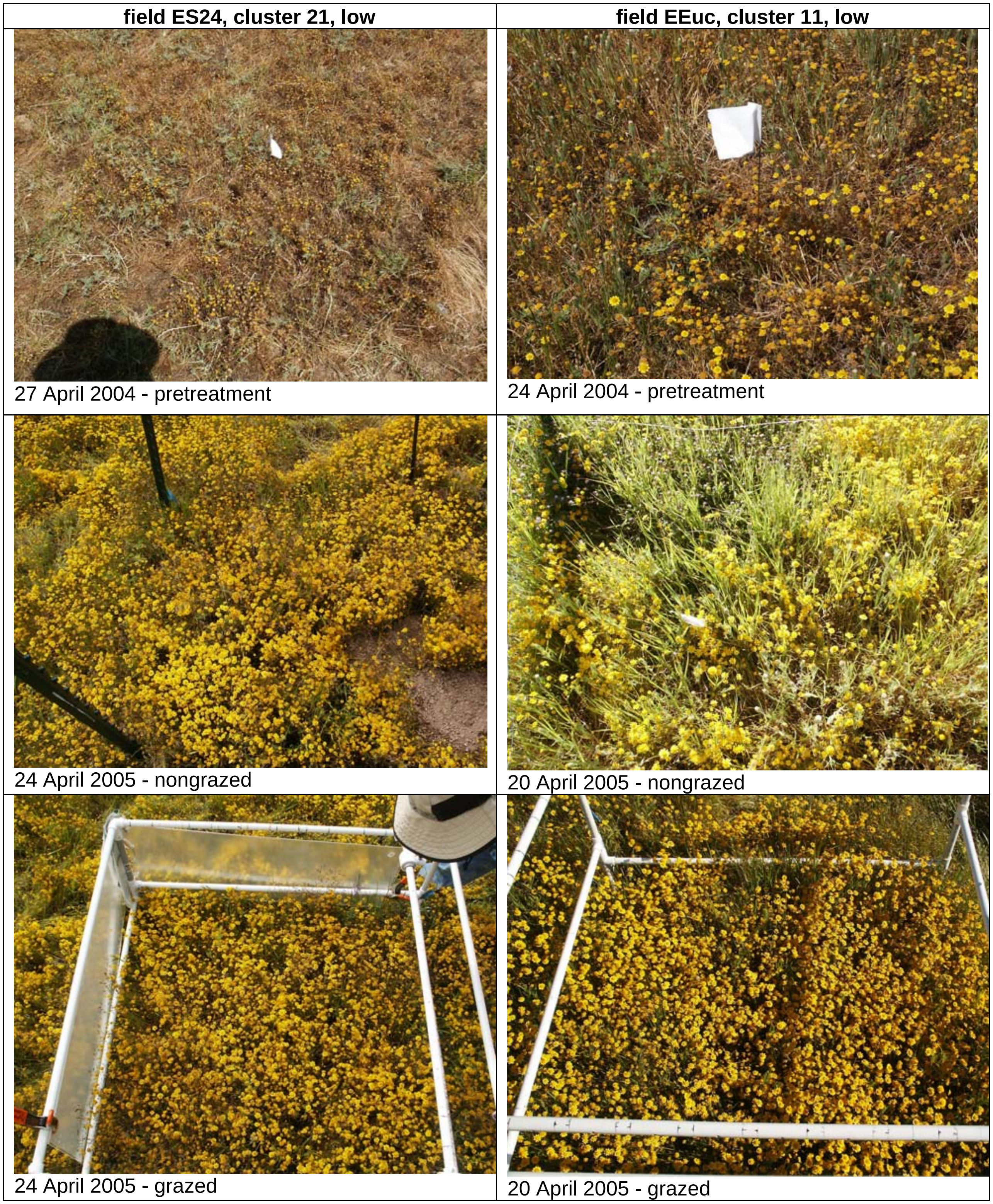


Figure 15. Pre-treatment and post-treatment residual dry matter (RDM) measured in August 2004 and August 2005. For both plot positions (low and high), nongrazed control plots showed a significant increase in RDM levels between the 2004 pretreatment baseline and the 2005 reading after one year of differential grazing.



field ES24, cluster 21, low	field EEuc, cluster 11, low
27 April 2004 - pretreatment	24 April 2004 - pretreatment
24 April 2005 - nongrazed	20 April 2005 - nongrazed
24 April 2005 - grazed	20 April 2005 - grazed

Figure 16. Appearance of selected low plots in spring 2004, before exclosures were erected, and in spring 2005. The grazed plots were assigned to grazing profiles D (cluster 21, left column) and C (cluster 11, right column).

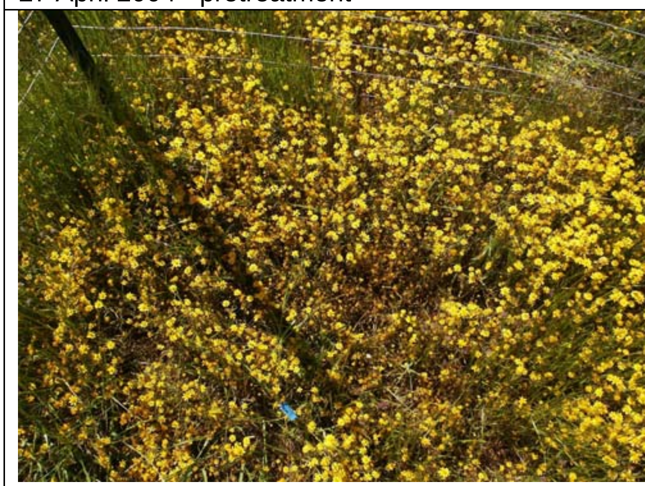
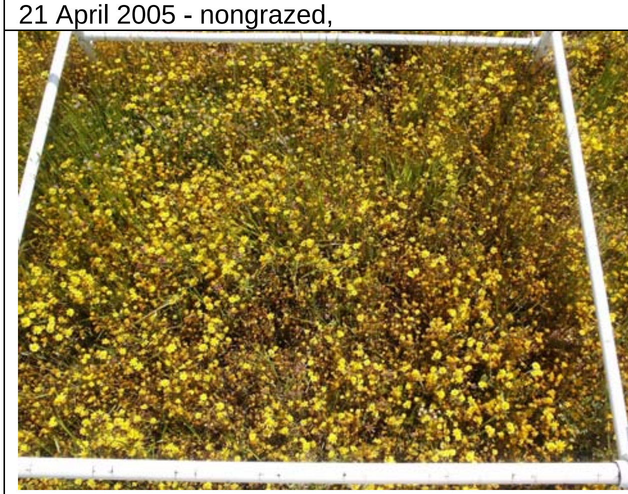
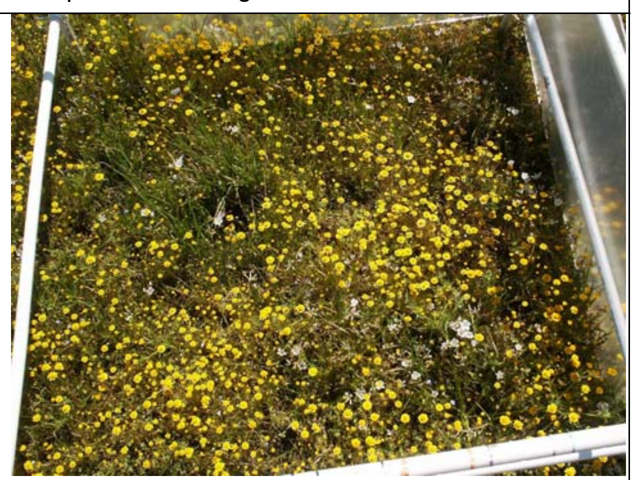
field ES24, cluster 19, low	field EEuc, cluster 13, low
 27 April 2004 - pretreatment	 24 April 2004 - pretreatment
 21 April 2005 - nongrazed,	 20 April 2005 - nongrazed
 21 April 2005 - grazed	 20 April 2005 - grazed

Figure 17. Appearance of selected low plots in spring 2004, before exclosures were erected, and in spring 2005. Grazed plots were assigned to grazing profile A.

field EN24,cluster 6, low	**field EN24, cluster 7, low**
 22 April 2004 - pretreatment	 26 April 2004 - pretreatment
 25 April 2005 - nongrazed	 26 April 2005 - nongrazed
 25 April 2005 - grazed	 26 April 2005 - grazed

Figure 18. Appearance of selected low plots in spring 2004, before exclosures were erected, and in spring 2005. Grazed plots were assigned to grazing profile B.

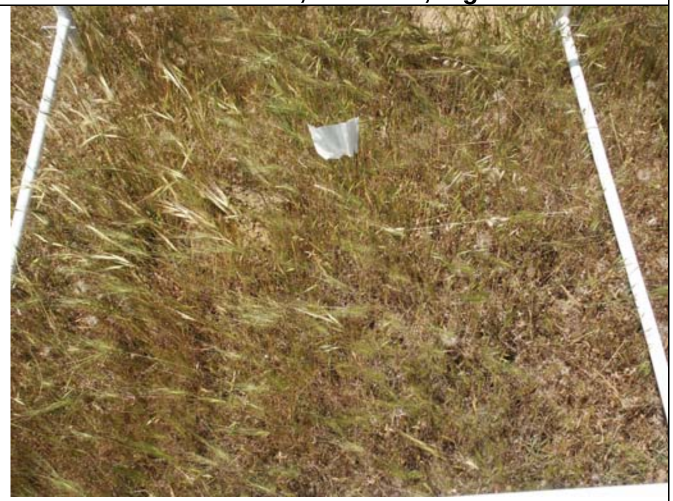
field ES24, cluster 21, high	field EN24, cluster 7, high
 28 April 2004 - pretreatment	 26 April 2004 - pretreatment
 24 April 2005 - nongrazed	 26 April 2005 - nongrazed
 24 April 2005 - grazed	 26 April 2005 - grazed

Figure 19. Appearance of selected high plots in spring 2004, before exclosures were erected, and in spring 2005. The grazed plots were assigned to grazing profiles 2 (cluster 21, left column) and 4 (cluster 7, right column).

field EEuc, cluster 11, high

30 April 2004 - pretreatment

20 April 2005 - nongrazed

20 April 2005 - grazed

Figure 20. Appearance of selected high plots in spring 2004, before exclosures were erected, and in spring 2005. The grazed plot was assigned to grazing profile 1.

April forage biomass, as measured with the falling plate meter, differed significantly between grazing profiles in both low plots (ANOVA p=0.0297) and high plots (ANOVA p=0.0011). In each case, the significance of the difference was associated with a single grazing profile (*fig. 21*). Among the low plots, grazing profile B, which was characterized by relatively intense grazing in most of April, had the lowest overall compressed forage height readings. In the high plots, grazing profile 1 had significantly greater compressed forage height readings than the other grazing profiles. Plots with this profile were only grazed in February in 2005 (*fig. 10*).

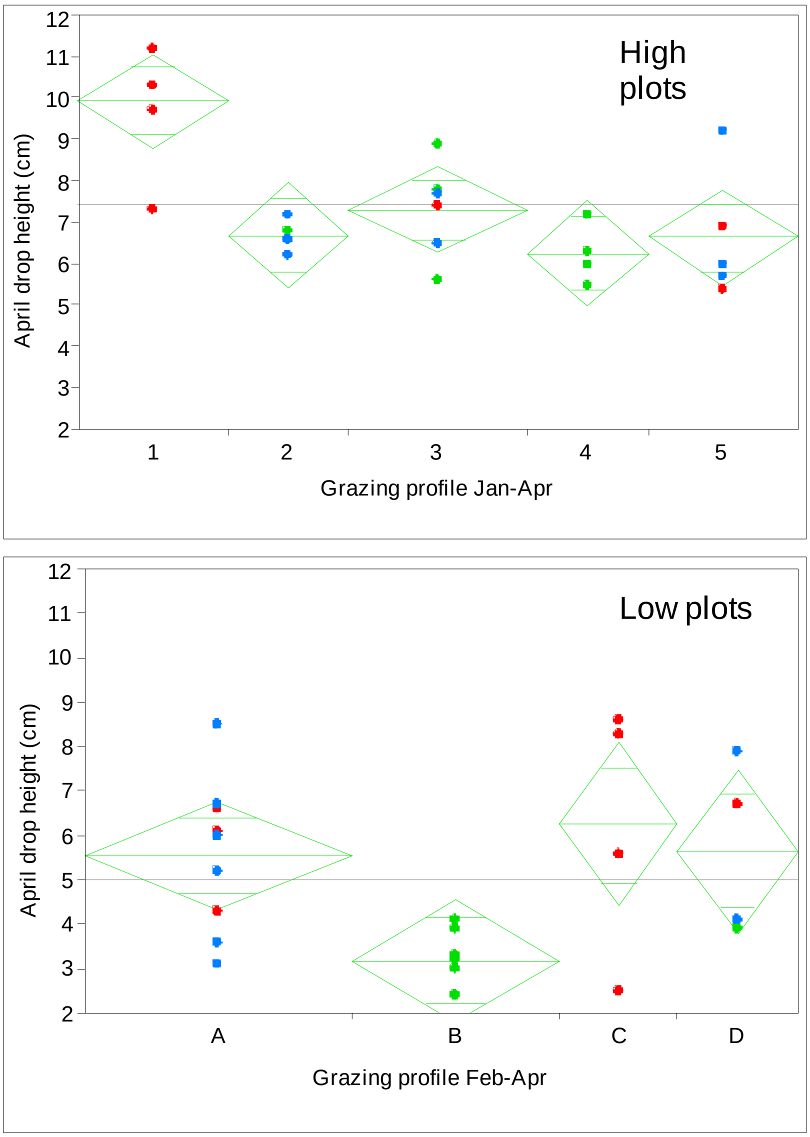


Figure 21. April 2005 compressed forage height readings made with the falling plate meter on grazed plots by position (high/low) and grazing profile. Green points are from EN24, blue from ES24, and red from EEuc. The horizontal line in each graph represents the overall average. The center line of each diamond represents the mean for the grazing profile. The vertical extent of each diamond represents the 95% confidence interval based on a pooled variance of all grazing regimes within the position (high or low). The horizontal spread of each diamond is proportional to the number of plots in each grazing profile.

Although the estimated April biomass was influenced by January through April grazing profiles, these profiles were not significant predictors of August RDM in repeated measures models for either high or low plots This is presumably due, at least in part, to the fact that fields EN24 (*fig. 5*) and ES24 (*fig. 6*) were grazed after the April 2005 evaluation dates. The grazing impact for the April-August time interval was a significant predictor of August RDM in repeated measures models for high and low plots (time × April-August grazing impact interaction significant at p=0.0299 for high plots, p=0.0033 for low plots). The relationship between April-August grazing impact and the change in RDM from 2004 to 2005 is shown in Figure 22. Plots with higher grazing impact in the April-August interval were more likely to have lower August RDM in 2005 than 2004 (i.e., RDM change 2005-2004 is negative). Although both regression lines are significant, the R^2 values are relatively low, suggesting that other factors also affect August RDM. It is also evident from Figure 22 that low plots had greater overall grazing impacts in the April-August interval than did high plots (note different ranges for the x axis in *fig. 22*).

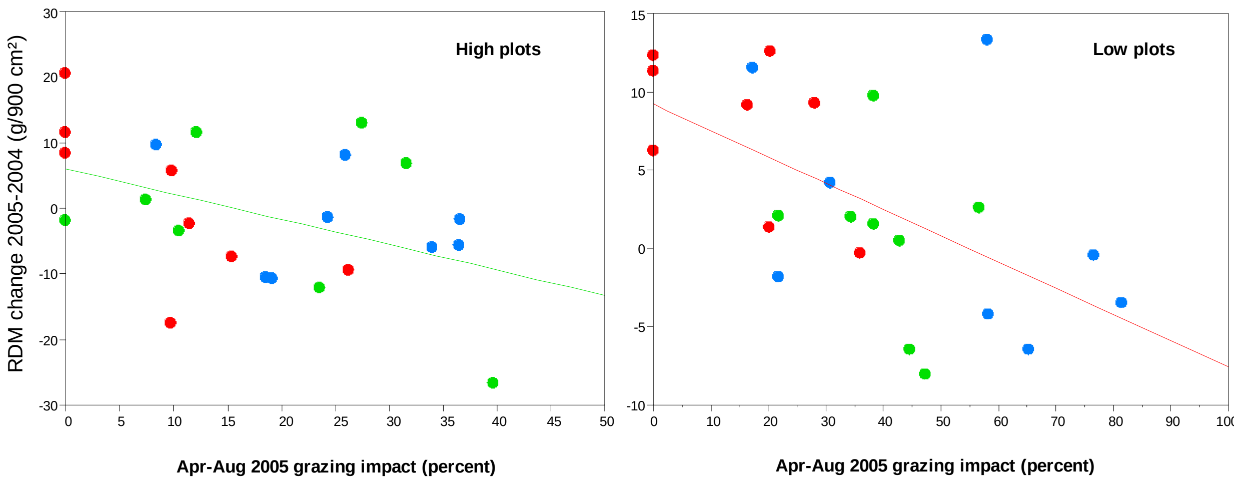


Figure 22. Regression lines for April-August 2005 grazing impact (percent of forage height removed relative to nongrazed clip plot) and RDM change (2005–2004) for high and low plots. Positive values for RDM change indicate higher amounts of RDM in 2005 compared to 2004. Green points are from EN24, blue from ES24, and red from EEuc. Regression lines: high – R^2=0.197, p=0.0299; low – R^2=0.330, p=0.0033.

August 2005 mulch height

Dry matter present at the end of the growing season, especially if it consists of grasses such as medusahead that degrade slowly, has the potential to persist as a layer of mulch through at least the following growing season. Because this mulch can adversely affect the germination and growth of native species, reducing mulch levels is one of the objectives of the current Jepson Prairie grazing plan (Jepson Prairie Management Committee 1999).

Mulch heights in 2005 were significantly greater in nongrazed control plots than in grazed plots for both high and low plots (paired t-test p<0.0001 for high, p=0.0021 for low). Among grazed plots, average mulch heights were significantly greater (t test p<0.0001) in high plots (mean 1.14 cm) than in low plots (mean 0.15 cm). Grazed plot mulch heights in 2005 were also significantly correlated with the amount of mulch and/or RDM present in August 2004 and the amount of grazing that occurred in 2005.

Although most of the variables related to grazing impact are correlated with each other to some degree, certain grazing variables were better predictors of August 2005 mulch heights than others. The sum of grazing impacts for January through August was not a significant predictor of August 2005 mulch height in an analysis of covariance model that included August 2004 mulch height, August 2004 RDM, and plot position (high or low) as predictors. However, field was a significant predictor (p=0.0092) of 2005 mulch heights when substituted for grazing impact in the model. Mulch heights in EEuc were significantly greater than in the other two fields.

Grazing profiles (*fig. 13*) were significant predictors of 2005 mulch height in separate analyses for high (p=0.0008) and low plots (p=0.0010). For both models, the grazing profiles that occurred only in EEuc (high 1 and low C, *fig. 12, 13*) had significantly higher mulch heights than the remaining profiles (*fig. 23*).

In summary, the only effect of grazing on mulch height was seen in plots that were grazed minimally and only early in the season in 2005. These plots showed greater mulch heights than other plots. The remaining plots did not show differences in mulch height attributable to grazing profiles despite the variation in grazing profiles represented.

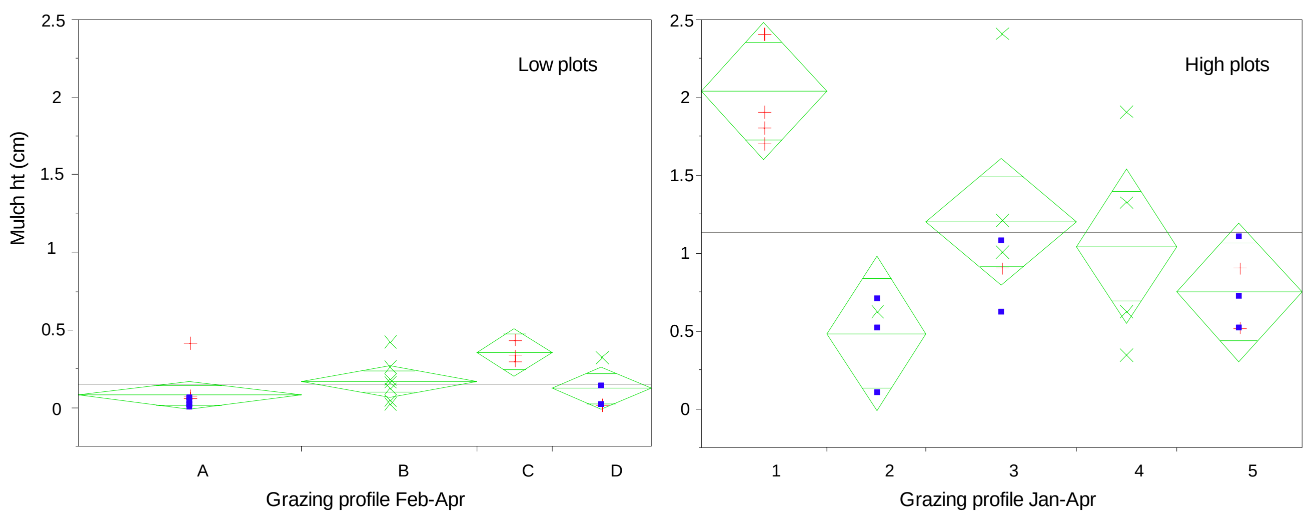


Figure 23. Average mulch heights in grazed plots by grazing regimes in high and low plots. X= plots from EN24, ■= plots from ES24, and += plots from EEuc. The horizontal line in each graph represents the overall average. The center line of each diamond represents the mean for the grazing regime. The vertical extent of each diamond represents the 95% confidence interval based on a pooled variance for all grazing regimes within the position (high or low). The horizontal spread of each diamond is proportional to the number of plots in each grazing profile.

Overall vegetation changes from 2004 to 2005

Repeated measures analysis of variance was used to test whether vegetation parameters changed significantly from spring 2004 to spring 2005 and whether these changes were associated with plot position (high vs. low plots) or the overall presence or absence of grazing (grazed vs. nongrazed cover plots). Vegetation outcomes included overall cover of native and exotic species; cover of vegetation guilds within these groups (grasses and forbs); and species diversity, both overall and within various guilds. Results of these analyses are summarized in Table 3.

Many of the vegetation parameters showed changes from 2004 to 2005, although overall cover of native species did not differ between 2004 and 2005 when considered across both plot positions and plot types (Table 3). Total exotic species cover and cover of both exotic grasses and forbs were greater in 2005 than in 2004, whereas bare soil cover was reduced in 2005 (Table 3). The greater cover of exotic annuals in 2005 is probably at least partly due to the difference in rainfall in the 2004-2005 season (54 cm total) compared with the 2003-2004 season (38 cm total). The 2004-2005 rainy season also began earlier and extended later in the season than did the previous rainy season (*fig. 24*). Early rainfall has been shown to increase growth of forage in annual grasslands in California (Murphy 1970).

Table 3. Probability levels of F tests for repeated measures analyses for vegetation outcomes by plot position (high/low), and plot type (grazed, nongrazed). Factors significant at p≤0.05 are shown in boldface.

	Between plots	***Within plots***			
Source:	**Position**	**Year**	**Year × Position**	**Year × Type**	**Year × Position × Type**
Cover:					
All native species	**<0.0001**	0.2744	0.4376	0.1709	0.6366
Native grasses	**<0.0001**	0.2015	**0.0057**	0.1000	0.7002
Native forbs	**<0.0001**	0.1274	0.1831	0.7523	0.8824
All exotic species	**<0.0001**	**<0.0001**	0.3304	0.0502	0.9468
Exotic forbs	**<0.0001**	**0.0034**	0.0648	0.0655	**0.0185**
Exotic grasses	**<0.0001**	**0.0066**	0.4517	0.0117	0.3954
Thatch	**<0.0001**	**<0.0001**	0.9141	0.3878	0.7343
Bare	**<0.0001**	**<0.0001**	**0.0017**	**0.0292**	0.5228
Counts:					
All native species	**<0.0001**	**0.0044**	0.1481	0.5412	0.2957
Native grasses	**<0.0001**	**0.0457**	**0.0003**	0.2493	0.3147
Native forbs	**<0.0001**	**<0.0001**	**0.0007**	0.7935	0.7178
All exotic species	**<0.0001**	**0.0107**	0.1141	0.2395	0.4145
Exotic forbs	**<0.0001**	0.5248	0.4650	0.2030	0.2167
Exotic grasses	**<0.0001**	**0.0027**	0.0949	0.2392	0.6116

As shown in Table 3, all of the vegetation parameters differed significantly overall between high and low plots. However, plot position had a significant effect on only four outcomes when the change from 2004 to 2005 is considered. Native grass cover declined from 2004 to 2005 in high plots only (*fig. 25*). This change was related to an apparent decrease in salt grass cover in the high plots. The only other native grass commonly found in high plots, *Nassella pulchra,* showed no change in cover between 2004 and 2005. Because salt grass is low growing, overtopping by heavier growth of exotic grasses in 2005 may account for the apparent loss of cover. High plots also showed a small but significant decrease in the number of native grass species per plot and an increase in the number of native forb species per plot (Table 3, *fig. 25*).

Grazed and nongrazed plots showed different changes in exotic grass cover and bare soil cover from 2004 to 2005 (Table 3). Only nongrazed cover plots showed an increase in exotic grass cover from 2004 to 2005 (*fig. 25*). Bare soil cover decreased in both grazed and nongrazed cover plots from 2004 to 2005, but the decrease was greater in nongrazed plots (*fig. 25*).

The only outcome with a significant three way interaction between year, position, and type was exotic forb cover. Only high grazed plots showed a strong increase in exotic forb cover between 2004 and 2005 (from 5 to 14%); all other position by type combinations showed very little change in exotic forb cover across the two years. Most of this effect is related to a few grazed plots that had high levels (about 15 to 50%) of vetch, geranium (*Geranium dissectum*), or exotic clover cover in 2005, but had low cover of these species (1 to 7%) in 2004.

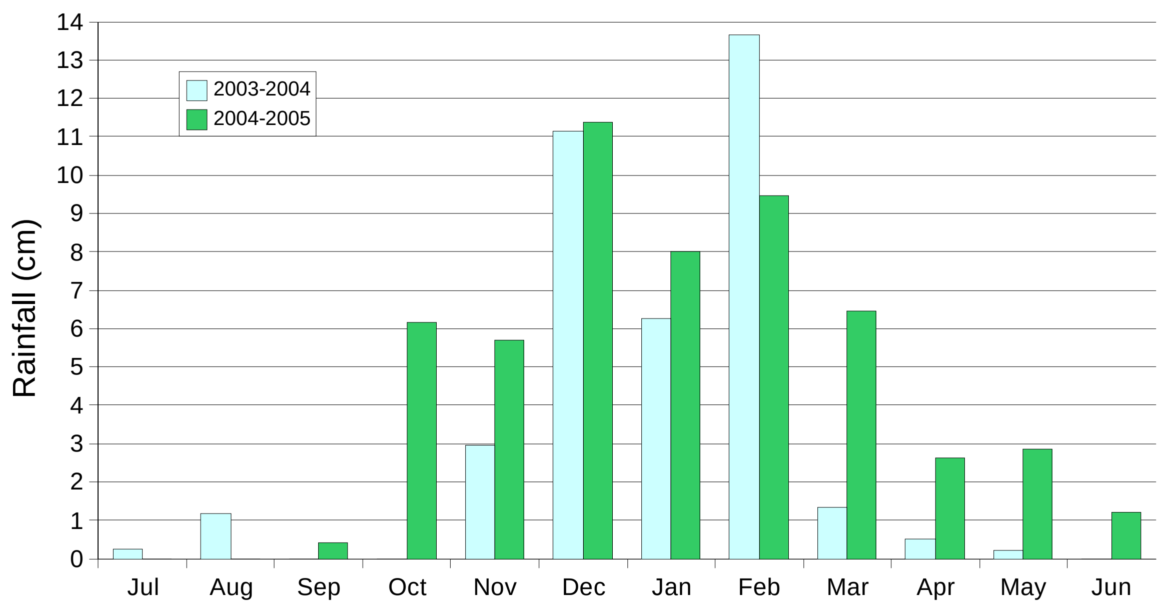


Figure 24. Rainfall measured at the CIMIS station 122 (Hastings Tract), located about 2.4 km northwest of the study area.

These overall analyses emphasize the vegetation differences that exist between the high and low plots. Due to the differences in species composition between the high and low plots, many of the vegetation changes that may be related to rainfall or other weather variables are seen in only the high or low plots. These analyses indicate that after one year, no major changes in plant cover and diversity have developed in the nongrazed cover plots relative to grazed plots even though RDM has increased significantly in the nongrazed plots over this time interval (*fig. 15*).

Vegetation changes and grazing profiles

We also used repeated measures analysis of variance to test whether changes in vegetation parameters from spring 2004 to spring 2005 were associated with the grazing profiles described above (*fig. 13*). Separate analyses were performed for high and low plots because these plots differ greatly with respect to both vegetation parameters and grazing profiles. Vegetation outcomes included overall cover of native and exotic species; cover of vegetation guilds within these groups (grasses and forbs); and species diversity, both overall and within various guilds. Results of these tests are summarized in Table 4.

In the high plots, only one of the vegetation outcomes was significantly associated with grazing profiles. As noted above, grazed high plots showed an overall increase in exotic forb cover that was not seen in nongrazed plots or in the low plots overall (Table 3). Exotic forb cover in the high plots also varied significantly by grazing profile (Table 4). This effect was due to the increase in exotic forb cover in grazing profile 1 (*fig. 13*), which is represented by five plots in EEuc that were grazed only in February (*fig. 12, 13*). This is the same grazing profile that had the highest estimated biomass in April (*fig. 21*). High plots with the remaining grazing profiles showed no change or slight decreases in exotic forb cover. Overall, it appears that the different grazing profiles had little effect on vegetation in the high plots between 2004 and 2005.

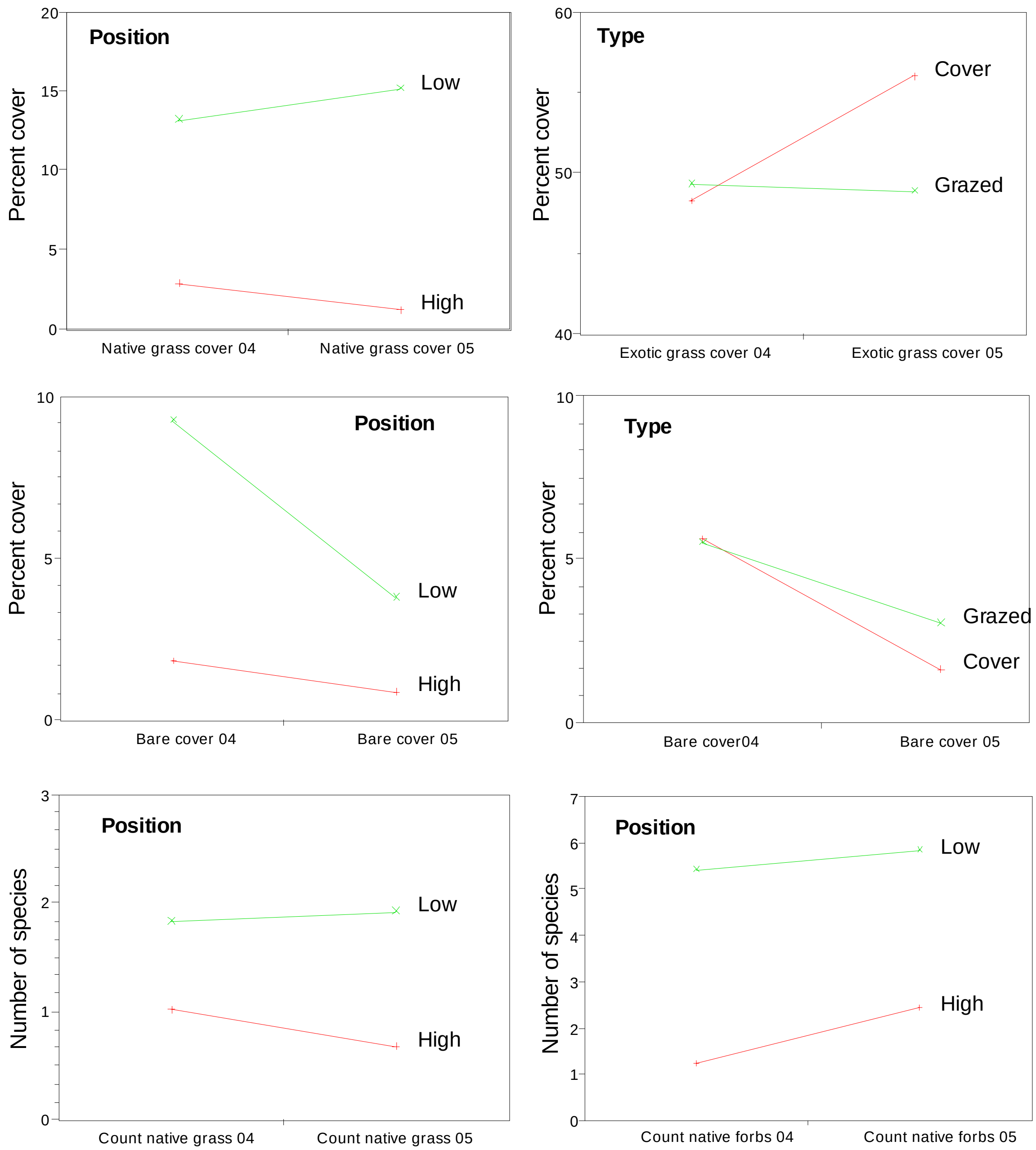


Figure 25. Overall means by plot position (high/low) or plot type (grazed, nongrazed), for native grass cover, exotic grass cover, bare soil cover, count of native grass species, and count of native forb species in 2004 and 2005. The significance levels for these variables in the repeated measures analysis of variance are shown in Table 3.

Table 4. Probability levels of F tests for the year by grazing profile interaction in repeated measures analyses for vegetation outcomes. Grazing profiles are shown in Figure 13. Factors significant at p≤0.05 are shown in boldface.

Source:	**Year by grazing profile**	**Year by grazing profile**
	High plots	**Low plots**
Cover:		
All native species	0.6983	**0.0015**
Native grasses	0.3626	0.5105
Native forbs	0.6309	**0.0051**
All exotic species	0.8968	**0.0158**
Exotic forbs	**0.0098**	0.3786
Exotic grasses	0.2106	**0.0210**
Counts:		
Native grasses	0.4120	0.9543
Native forbs	0.7778	0.1053
Exotic forbs	0.4008	0.7658
Exotic grasses	0.4730	**0.0256**

In contrast, several cover variables and the count of exotic grass species varied significantly by grazing profile in the low plots (Table 4). Overall changes in native and exotic species cover were due to reciprocal changes in the cover of native forbs and exotic grasses seen in plots with grazing profile B (*fig. 26*). Grazing profile B, found only among plots in EN24, was the only profile that included substantial grazing during the peak native forb bloom period in late March and April 2005 (*fig. 7,12,13*). Plots with grazing profile B showed a decrease in native forb cover and an increase in exotic grass cover between 2004 and 2005 which did not occur among plots with the other grazing profiles (*fig. 26*).

As noted earlier, sheep grazed preferentially in the low swale and pool areas in late spring. Based on results from the repeated measures analysis (*fig. 26*) and our field observations, we infer that the sheep preferred the native forbs to the exotic grasses growing in these plots in late spring. The most common exotic grass in the low grazed plots was Italian ryegrass (*Lolium multiflorum*), but medusahead also occurred in about 42% of the low grazed plots, albeit at low cover (less than 1% cover overall in low grazed plots). Furthemore, there was no apparent impact on native grasses in the low plots as a result of this late spring grazing. Sheep did not appear to be grazing *Pleuropogon californicus* heavily at this time, possibly because it was already becoming senescent. The cover of other native grasses in these plots was about 10% or less, so small changes in cover of these species might not have been detected if they occurred.

Although the 2004-2005 change in the average number of exotic grass species in the low plots varied significantly between different grazing profiles, the biological significance of this change is not clear. Grazing profiles B and D showed increases while A and especially C showed decreases in the number of exotic grass species present per plot. However, these changes involve the apparent loss or gain of only a single species on average.

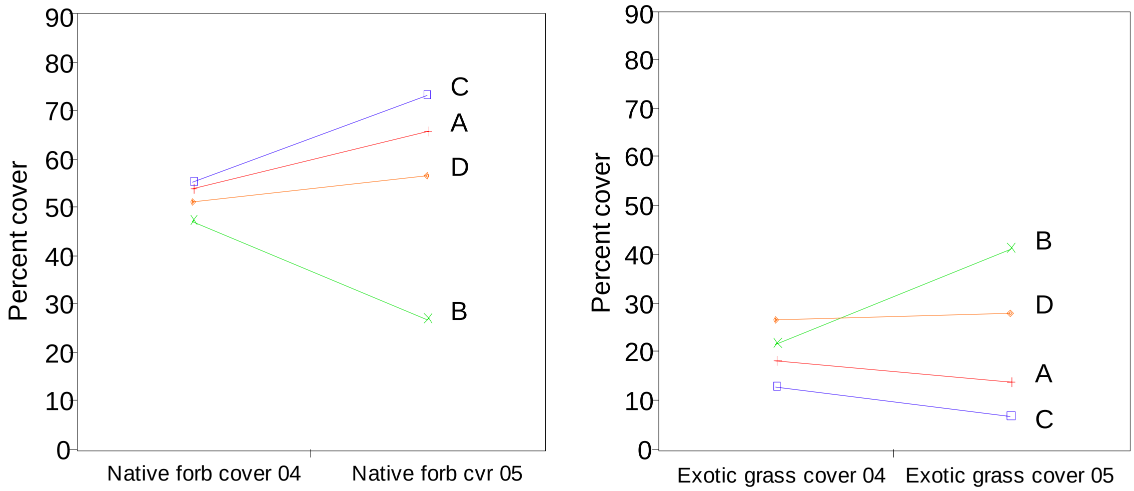


Figure 26. Mean native forb cover (left) and exotic grass cover (right) in 2004 and 2005 for low plots with grazing profiles A-D (see *fig. 13* for grazing profile characteristics).

CONCLUSIONS

Because the new grazing regimes used in this study have only been implemented for one year, the results presented to date should be considered preliminary. Observed results may have been influenced by the grazing regimes that occurred in each field prior to the initiation of the experimental grazing regimes. Furthermore, it is likely that the high amounts of rainfall in 2004-2005 influenced how the vegetation responded to the experimental grazing regimes.

Although the grazing regimes that were used on the fields did not match the original plans, we did end up with three grazing regimes that are of practical interest. Field 19E (EN24) ended up with a regime that was close to one of the standard prescriptions currently in use at Jepson Prairie, and includes grazing during the peak spring bloom period. The grazing regime in field 18E (ES24) included relatively intense grazing pulses before and after the peak spring bloom period, but no grazing during the main bloom period. Field 20E (EEuc) was grazed only early in the season, prior to the main bloom period and had no late season grazing.

After presenting preliminary results to the Jepson Prairie Management Committee, the consensus of the committee was that the grazing regimes used during the 2004-2005 grazing season should be repeated in 2005-2006. The only change is that the grazing intensity in field 20E, which was grazed very lightly in 2005, will be increased by extending grazing to March 15. Burrows Hamilton has indicated that, weather permitting, he should be able to duplicate the 2004-2005 grazing patterns in the upcoming season. Although grazing profiles at individual plots are likely to change somewhat, the overall timing of grazing impacts should be similar. This should allow us to determine whether the effects we observed this year are repeatable under different rainfall conditions.

In this first year's results, the most obvious effect seen was that adjacent high and low plots showed differential grazing impacts that shifted as the season progressed: high plots tended to be grazed more heavily early in the season and lighter late in the season. We believe that this is a fairly robust effect that is likely to occur in most if not all years, although the timing and magnitude of the shift could be affected by weather patterns.

The tendency of sheep to graze the low plots more heavily in the peak bloom period gave rise to the main observed changes in vegetation associated with the different grazing profiles. However, it remains to be seen whether this effect will intensify or diminish after successive years with the same grazing regime.

We also observed that different grazing profiles developed not only between adjacent high and low plots within a field but among plots within a field that had the same topographic position (high or low). This confirmed our underlying hypothesis that a given field receives a mosaic of grazing impacts in any given year. As expected, many plots within fields had similar grazing profiles. However, some plots in different fields were more similar with respect to grazing impacts over time than were plots within a single field. Repeated measurements on these plots over multiple years should show whether some plots may be prone to heavier or lighter grazing impacts due to factors such as their position within the field.

Although an increase in season-end RDM was seen after a single year of exclusion from grazing, no major vegetation shifts have yet been seen in the nongrazed plots. We anticipate that these shifts may well require two or more years to develop. However, it seems possible if not likely that high and low plots will show different types of responses to a prolonged absence of grazing.

Summary of hypothesis and first year results:

Hypothesis 1. Changes in the initial and final vegetation states for a given growing season will vary with the seasonal grazing profile.

First year data support this hypothesis. The most notable effect we observed was that grazing during the spring bloom period decreased native cover relative to the prior year in which no spring grazing occurred. A preliminary conclusion that needs to be confirmed by additional observations is that grazing regimes that include substantial levels of grazing during the spring bloom period will result in less native cover during that year.

Hypothesis 2. Grazing profile variables that include a temporal element (timing of grazing impact) will be better predictors of vegetation change outcomes than variables that only measure total biomass removal.

This hypothesis has not been distinctly addressed to date. However, the underlying question (the importance of the timing of grazing relative to the overall amount of biomass removal) has been addressed in several ways.

First year results show that grazing profiles, which incorporate both timing of grazing and the amount of biomass removed (grazing impact) are significant predictors of some vegetation change outcomes in low plots. However, in the data from this first year, the effect of the grazing profile is confounded with measures of biomass removal. Low grazing profile B, which was associated with the greatest change in native cover (*fig. 26*) also had the greatest biomass removal up to that point in the season (*fig. 21*) and was the only grazing profile that included grazing during the peak bloom period in April.

Biomass removal related to grazing is most commonly assessed by measuring season-end RDM. The relationship between August 2005 RDM and changes in plant cover will be analyzed after the spring plant cover evaluations in 2006. Depending on how the grazing plan is implemented in 2005-2006, season-end RDM could still be confounded with grazing profiles to some degree.

Other first–year results also showed that various vegetation parameters are significantly affected by the timing of grazing impacts. For example, relative grazing impacts to high and low plots changed as the season progressed (*fig. 8,9*). In addition, August 2005 RDM was correlated with April-August grazing impacts but not with grazing impacts earlier in the season. Furthermore, nongrazed controls, which had significantly elevated RDM levels in 2005 compared with all grazed plots (*fig. 15*) showed very little change in vegetation parameters (Table 3). This suggests that the amount of biomass removal alone is less important than the timing of biomass removal.

Hypothesis 3. Weed-dominated and native-dominated experimental units will show different responses to grazing variables.

First-year results support this hypothesis. Vegetation parameters in weed-dominated high plots were generally unchanged in response to the range of grazing profiles tested (Table 4). In contrast, native-dominated low plots showed a decrease in native cover associated with high intensity grazing during the spring bloom period (Table 4).

Hypothesis 4. Different grazing profiles are likely to occur between weed- and native-dominated experimental units within plot clusters.

First-year results support this hypothesis. Grazing profiles differed between most weed-dominated high and native-dominated low plots (*fig. 13, 14*). As noted previously, sheep grazed native-dominated low plots more heavily in April and May but grazed the weed-dominated high plots more heavily during the winter months (*fig. 8, 9*).

Hypothesis 5. Thatch /mulch accumulation/removal will vary with grazing profiles.

First-year results generally support this hypothesis. Analyses of mulch heights showed that plots in EEuc had higher mulch levels in 2005 than other plots. These plots were only grazed early in the season and were grazed lightly overall. Thatch levels were also greater in nongrazed plots than grazed plots overall and much higher in high plots than low plots overall (*fig. 23*).

Hypothesis 6. Compared with nongrazed units, grazed units will have lower weedy cover and increased native species cover.

After one season of exclusion from grazing, no notable changes in plant cover and diversity have developed in the nongrazed cover plots relative to grazed plots (Table 3, *fig. 25*). Although this hypothesis was not supported by results from the first year, additional observations will be needed to determine whether vegetation changes will be seen only after plots have been excluded from grazing for multiple years. RDM has increased significantly in nongrazed plots (*fig. 15*). In plots with high RDM, plant residue could begin to suppress growth of native species in 2006.

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