

# Population Monitoring and Effects of Grazing on *Calochortus greenei* on the Cascade-Siskiyou National Monument

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## PREFACE

This report is the result of a cooperative Challenge Cost Share project between the Institute for Applied Ecology (IAE) and a federal agency. IAE is a non-profit organization dedicated to natural resource conservation, research, and education. Our aim is to provide a service to public and private agencies and individuals by developing and communicating information on ecosystems, species, and effective management strategies and by conducting research, monitoring, and experiments. IAE offers educational opportunities through 3-4 month internships. Our current activities are concentrated on rare and endangered plants and invasive species.

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Cover Photo: Rob Massatti, IAE

## EXECUTIVE SUMMARY

*Calochortus greenei* is a species of concern in southern Oregon and northern California. Permanent large-mammal exclosures paired with open (unfenced) controls were established in 2003 to assess the influence of herbivory on population dynamics of *Calochortus greenei* and associated plant communities within the Cascade-Siskiyou National Monument, an area of unique ecological diversity in southwest Oregon. Another set of exclosures designed to exclude all mammals (small and large), but allow insect access, were established in 2007. Plots are located in three study areas that span the range of recent cattle utilization intensity occurring on the monument (all cattle grazing ceased in 2009). Historically the Colestine area was essentially ungrazed, Oregon Gulch experienced moderate to low utilization, and Agate Flat received the highest intensity of use. Large-mammal exclosure-control pairs are located in Colestine, Agate Flat and Oregon Gulch. All-mammal exclosures are located in Colestine and Agate Flat. Primary findings in 2009, after large-mammal exclosures have been in place six years, and the all-mammal exclosures have been in place two years are outlined below.

- At Agate Flat, the large-mammal exclosures have had significant positive effects on trends in *C. greenei* leaf length and width. The all-mammal exclosures also resulted in larger plant size in 2009 as compared to controls.
- At the Colestine study areas, trends in *C. greenei* size and reproduction were similar between controls, large-mammal exclosures and all-mammal exclosures.
- In Oregon Gulch, fencing did not have significant effects on plant size or reproduction.
- The frequency of early season leaf herbivory at Agate Flat and Colestine was similar between the all-mammal and large-mammal exclosures. Excluding small mammals did not appreciably reduce herbivory to leaves, and neither exclosure type reduced damage frequency below 50%; insects may contribute a significant proportion of leaf damage.
- The frequency of herbivory on developing flowers in June was similar between all plots in Agate Flat, but was reduced in the all-mammal and large-mammal exclosures in Colestine compared to controls. Excluding small mammals did not result in greater reductions in early season floral herbivory than just excluding large mammals.
- At Agate Flat, damage to mature flowers and developing fruits and fruit set were similar across all exclosures and controls.
- At Colestine, damage to mature flowers and developing fruits was somewhat lower in the all-mammal exclosures than the controls. The proportion of intact fruit set was significantly greater in the all-mammal exclosures, intermediate in the large-mammal exclosures, and lowest (near zero) in the controls, suggesting insects, small and large mammals all contribute to fruit damage in Colestine.
- Trends in frequency and cover of plant community functional groups (e.g., grasses, forbs, shrubs) were statistically similar between fenced and unfenced plots regardless of site with one exception; cover and frequency of exotic grasses may be decreasing in Colestine.
- Population viability analyses incorporating climatic variation as well as herbivore effects will be conducted at the conclusion of the study (2014).

To develop management guidelines and create future conservation strategies for this species, it is crucial to determine the long-term impacts of cattle utilization, native mammal and insect herbivory on *C. greenei*. Since *C. greenei* has a complex life-history that includes dormancy, and this species is likely influenced by climatic variation, we recommend continuing this demographic study through 2014, to best inform management actions in the Cascade-Siskiyou National Monument.

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## INTRODUCTION

### Status

*Calochortus greenei* S. Wats., Greene's mariposa lily, is listed by the United States Fish and Wildlife Service (USFWS) as a federal species of concern, and is proposed for listing as a threatened species in Oregon. It is also a Bureau of Land Management (BLM) special status species.

### Background

*Calochortus greenei* occurs in grassland, shrubland and oak woodland habitats on both sides of the California-Oregon border. Its range also extends south into the Shasta Valley (Brock 1996). A portion of this area is included in the Cascade-Siskiyou National Monument (CSNM; Figure 1). The monument, which is primarily managed by the BLM, is an area of unique ecological diversity with species and influences from the Great Basin, Cascades, and Siskiyou Mountains.



**Figure 1.** *C. greenei* monitoring in the Cascade-Siskiyou National Monument

Many areas supporting *Calochortus greenei* have been influenced by livestock, and are experiencing substantial invasion by non-native species. Open areas within *C. greenei* habitat that were likely once dominated by native bunchgrasses including Roemer's fescue (*Festuca roemerii* ssp. *klamathense*) are now dominated by exotic grasses, such as bulbous blue grass (*Poa bulbosa*) and medusa head (*Taeniatherum caput-medusae*). Substantial yellow starthistle (*Centaurea solstitialis*) populations occur on Agate Flat, one of the study areas with *Calochortus greenei* on the monument. Starthistle populations also line the I-5 corridor near the California border, which is adjacent to the Colestine study area, described later in this report.

*Calochortus greenei* is an herbaceous perennial member of the Liliaceae (Lily family). Plants are 10-30 cm tall, with a large basal leaf 0.5-3 cm wide that is glaucous on both surfaces. Leaves typically begin to senesce as the plants flower. Flowers are large and showy, with pinkish-purple petals, which are extremely hairy on their inner surface. Flowers may be accompanied by small stem leaves. *C. greenei* flowers are likely pollinated by small native bees, honey bees and bumble bees, but may also be visited by butterflies, beetles and other insects (Brock 1988). Fruits develop in mid-summer, are approximately 2-2.5 cm long, and contain many 4-6 mm long seeds (Figure 2). Plants may also reproduce vegetatively through bulb offsets, but this has not been well documented.

Compared to associated species in the same plant communities, *C. greenei* blooms and remains green relatively late in the season. Leaves may be eaten by various organisms from early spring, when its leaves emerge, through mid-summer. The principle herbivores appear to



**Figure 2.** Mature *C. greenei* capsules.

be insects, deer, rodents and livestock. Reproduction of *C. greenei* may be limited by intensive browsing of vegetative and reproductive structures. To develop management guidelines, and create future conservation strategies for this species, it is crucial to determine the long-term impacts of deer, rodent and cattle utilization on *C. greenei*. Since *C. greenei* has a complex life-history that includes dormancy, a multi-year demographic study utilizing permanent plots (some fenced and some unfenced) is necessary to assess the influence of herbivory on its population dynamics, and inform management actions in the Cascade-Siskiyou National Monument.

## Objectives

The objectives of this report are to:

- Describe population monitoring methods and plant community assessments for *Calochortus greenei* and associated plant communities on the Cascade-Siskiyou National Monument.
- Summarize population trends and plant community data for the sixth year of study.
- Evaluate influences of exclosures on *C. greenei* and associated plant communities.

## METHODS

### Study Areas

Three study areas within the Cascade-Siskiyou National Monument were selected in 2003 to establish long-term monitoring and grazing study plots for *Calochortus greenei* and associated plant communities: Agate Flat (Figure 3), Oregon Gulch (Figure 4), and Colestine (Figure 5). These study areas contain the largest populations of *C. greenei* on the monument, and also span the range of recent cattle utilization intensity occurring on the monument, although livestock grazing ceased in 2009. Until 2009, the Colestine area was essentially ungrazed (except for stray cattle from California), Oregon Gulch experienced moderate to low utilization, and Agate flat received the highest intensity of utilization. Quantitative data regarding utilization is lacking. For directions to all plots, see Appendix 1.

### Sampling design

In 2003, fifteen pairs of 2 m x 2 m large-mammal exclosures and controls were established in *C. greenei* populations, five in each of the three study areas (Figure 6-Figure 9; Menke and Kaye 2003). Plots were placed to contain as many *C. greenei* plants as possible and to maximize the similarity in microsite and plant community within plot pairs. Within the plot pairs, one plot was randomly assigned (by a coin toss) to be fenced in a 3 m x 3 m stockwire (~2 in x 5 in grid) exclosure (Figure 10), and the other plot was left unfenced (Figure 11). All plots were marked with rebar pounded into the ground at the corners of the plot, tagged with a metal tag, positioned with a GPS unit (Table 1), and photographed.

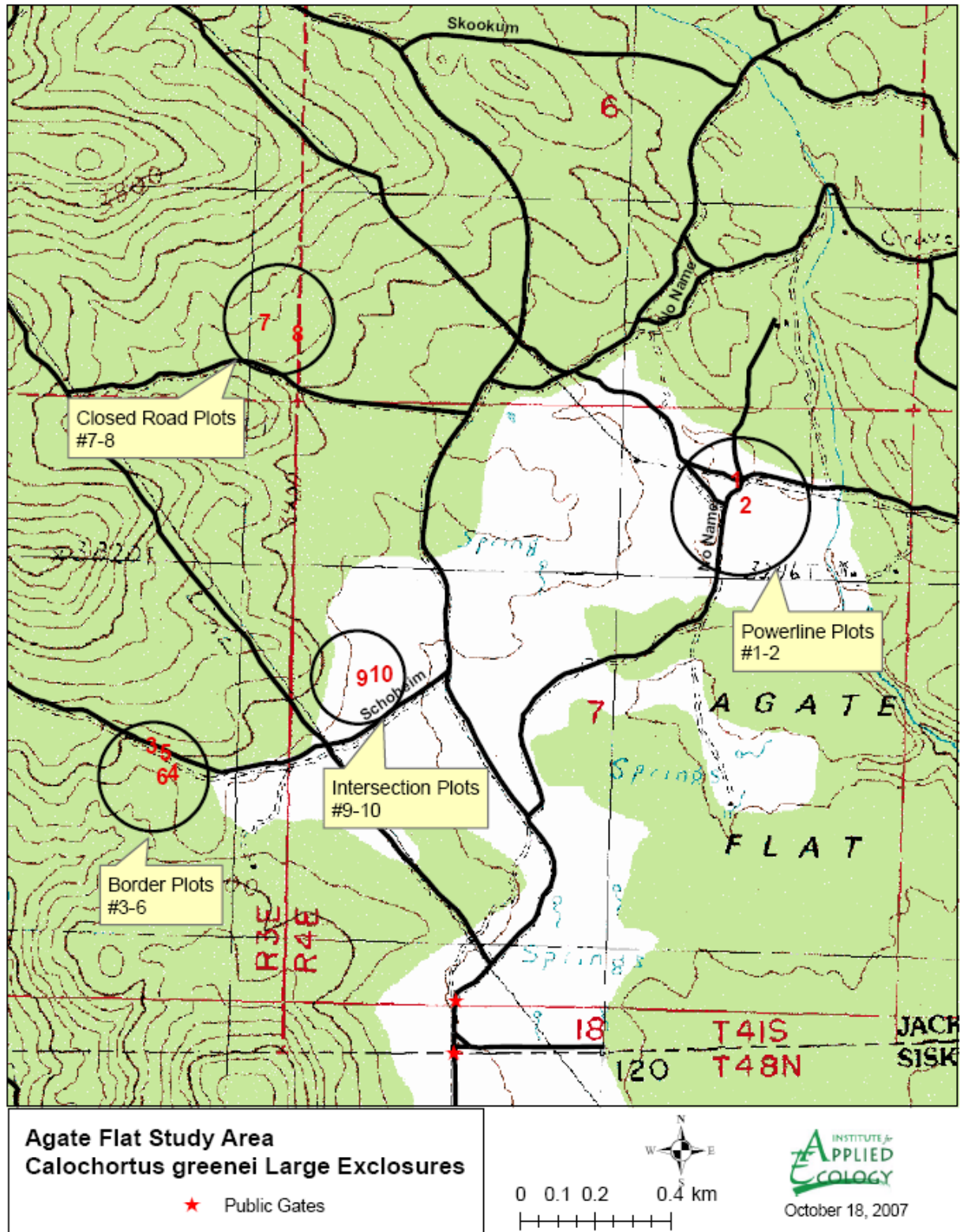


Figure 3. Location of plots 1-10 in the Agate Flat study area.

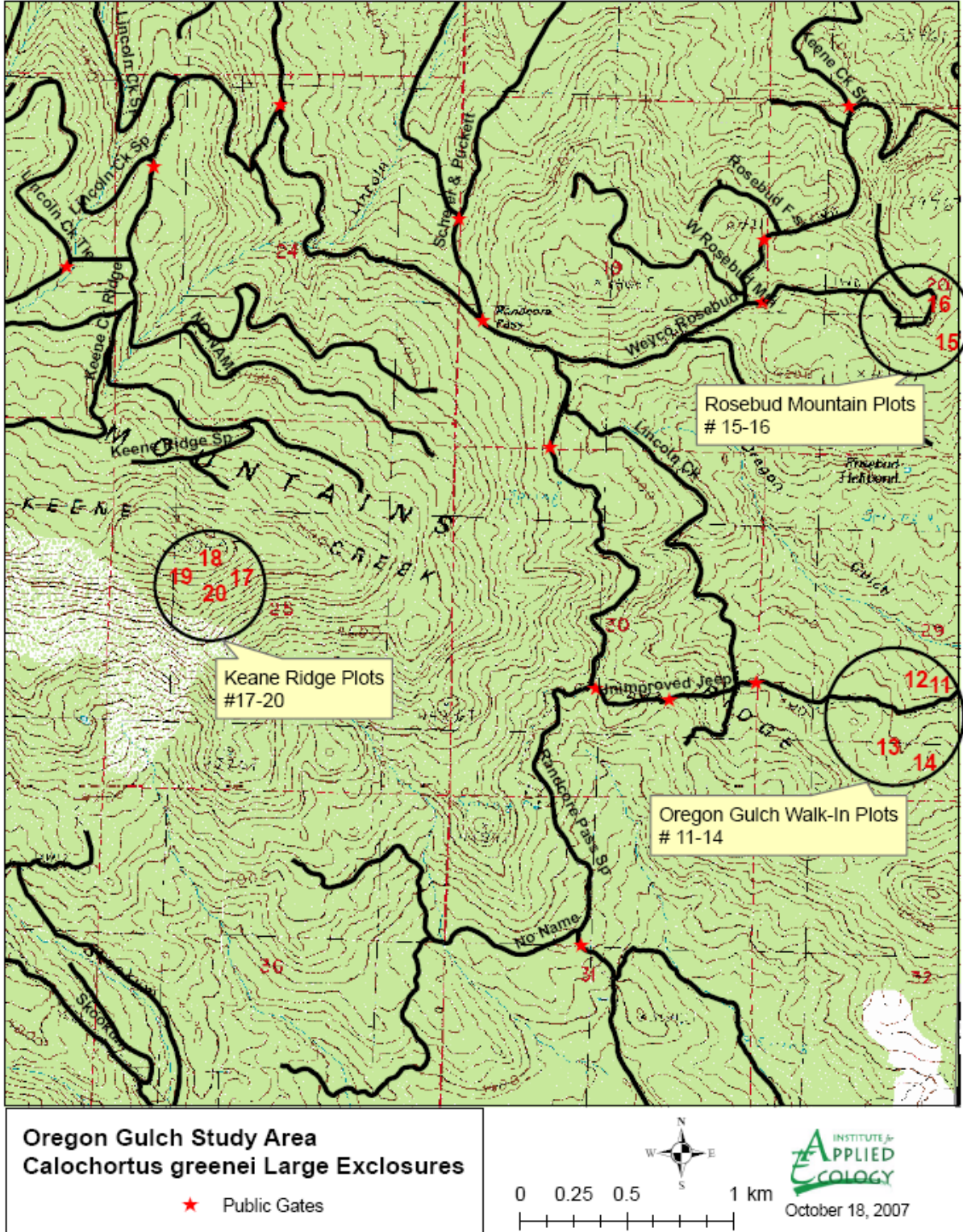
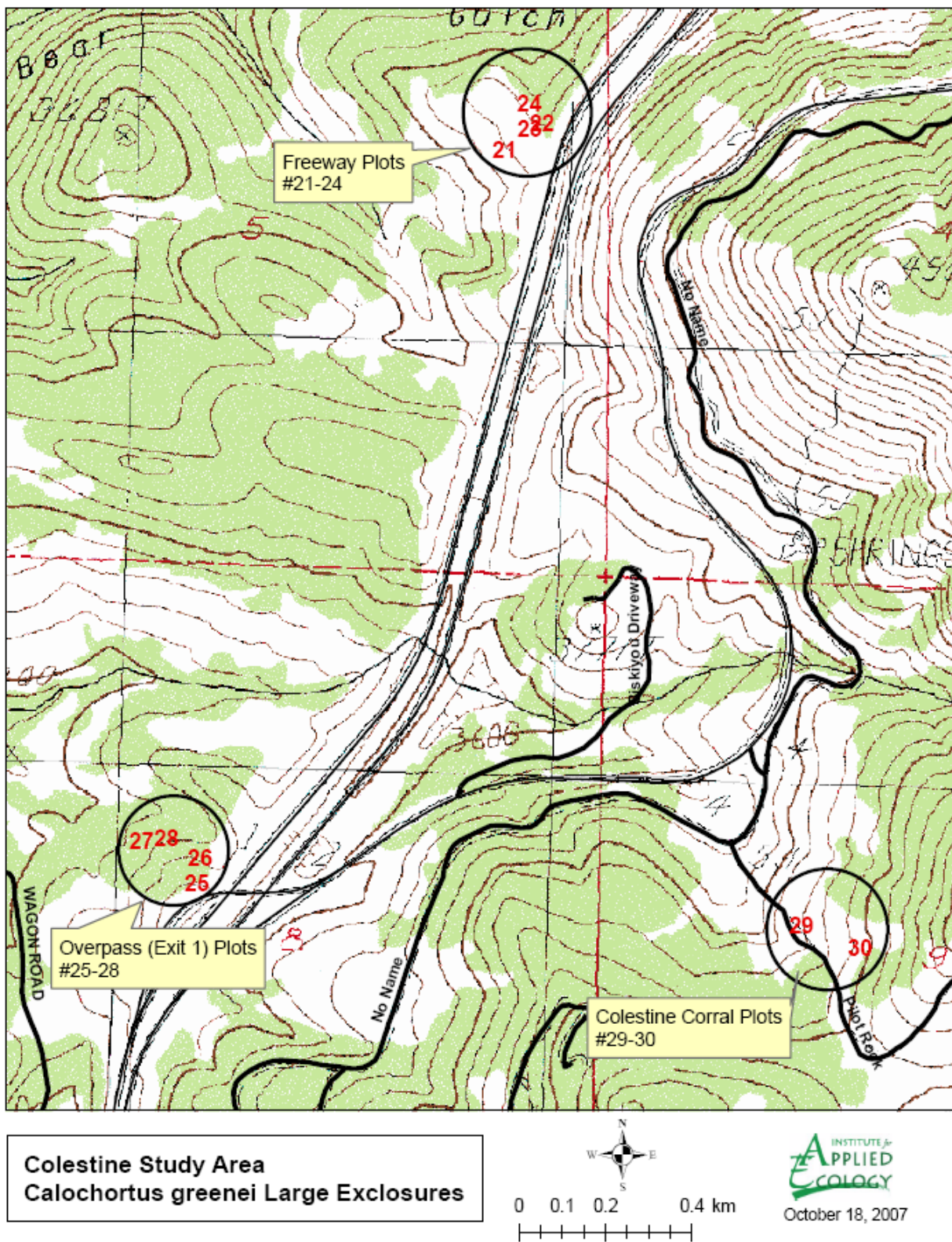
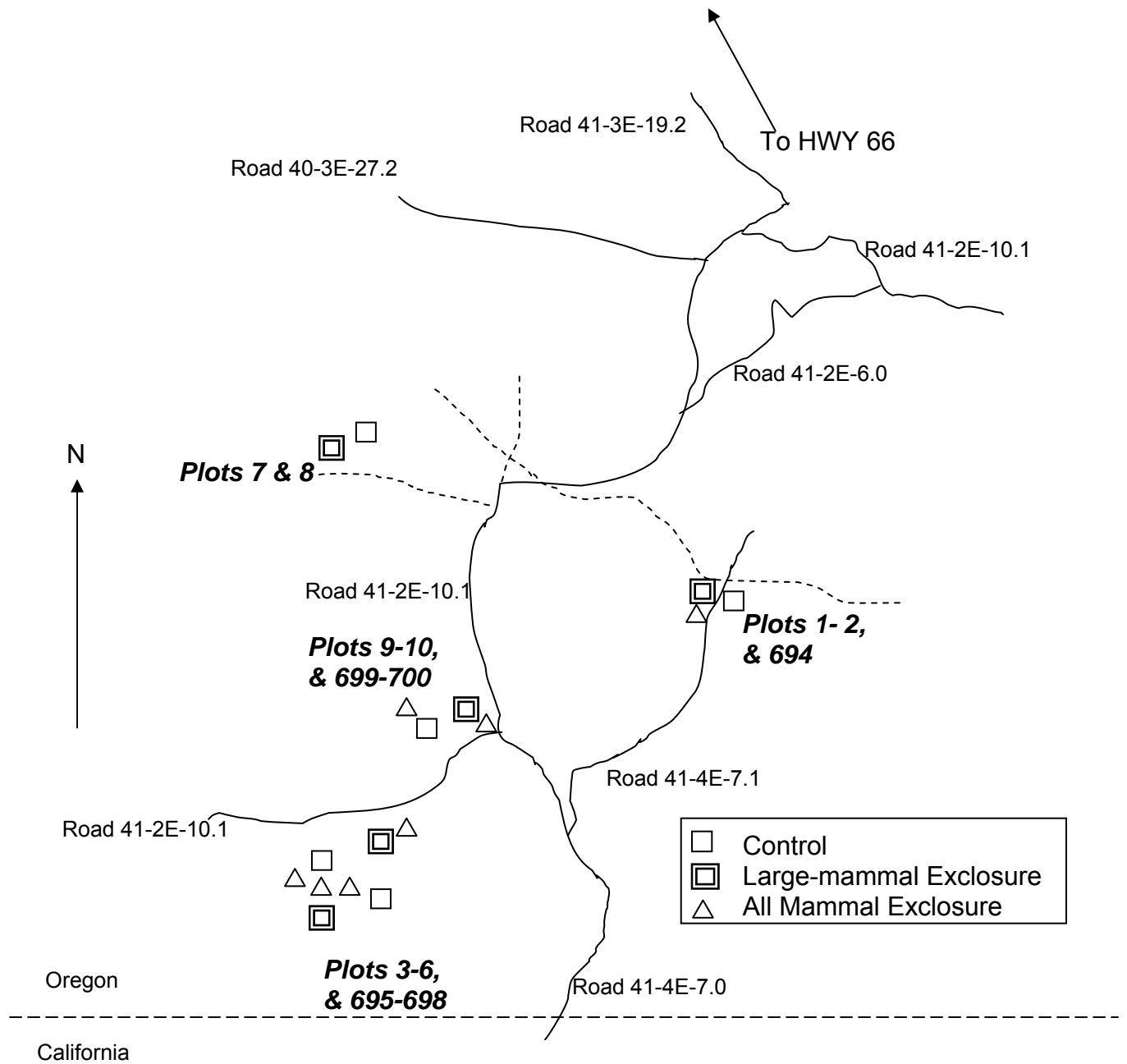


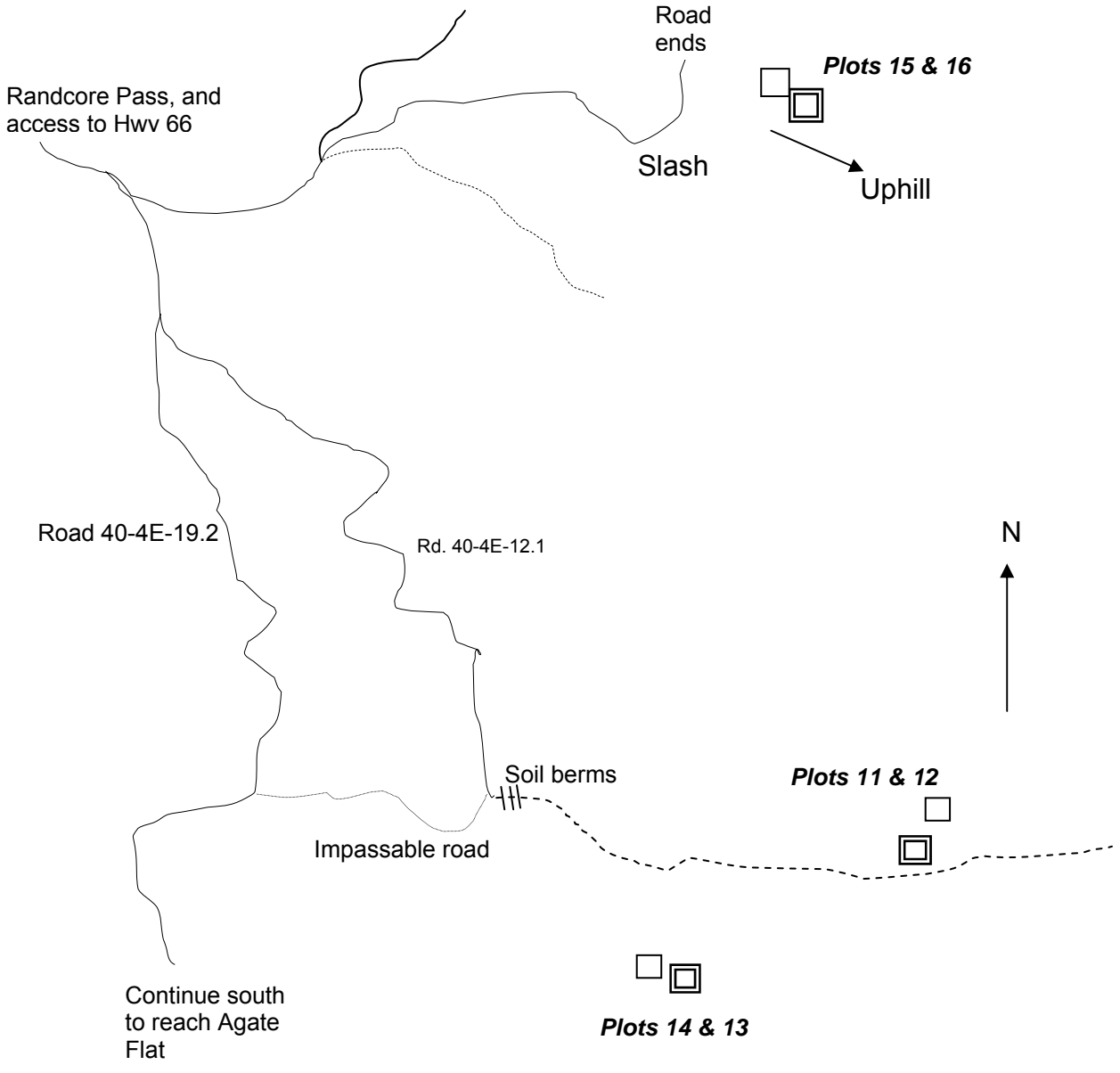
Figure 4. Location of plots 11-20 in the Oregon Gulch study area.



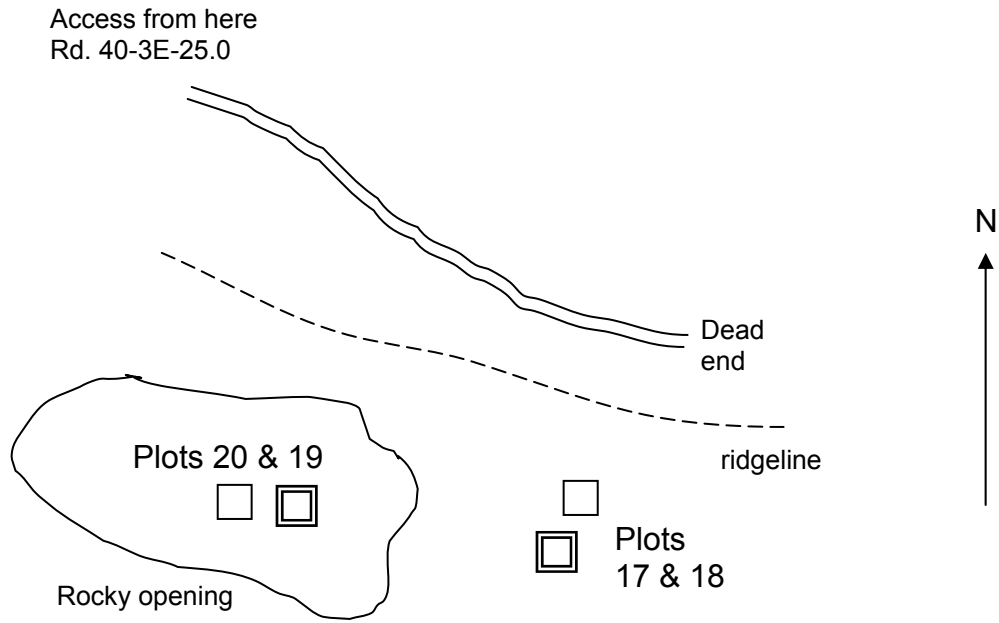
**Figure 5.** Location of plots 21-30 in the Colestine study area.



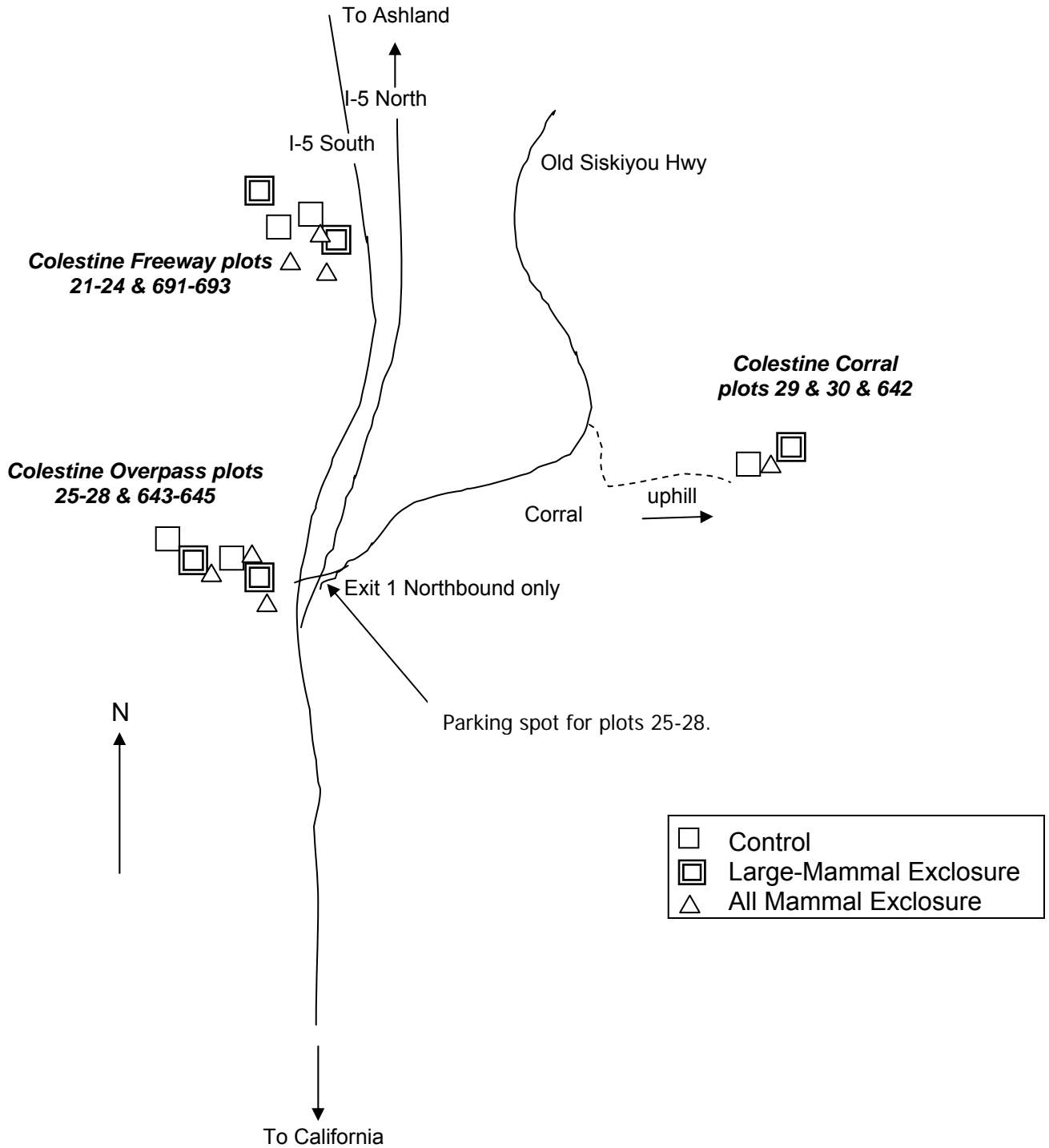
**Figure 6.** Sketch map of controls, large-mammal and all-mammal exclusion locations in Agate Flat.



**Figure 7.** Sketch map of Oregon Gulch walk in plots 11-14 and plots 15 & 16 on Rosebud Mountain. Double squares represent fenced plots.



**Figure 8.** Sketch map of plots 17-20 on Keane Ridge. Follow flagging up and over ridge to reach plots. Double squares represent fenced plots.



**Figure 9.** Sketch map of control, large-mammal and all-mammal exclosure locations in Colestine study area.



**Figure 10.** 2 m x 2 m *Calochortus greenei* large-mammal enclosure, marked with rebar at the four corner posts, and fenced by a 3 m x 3 m enclosure (Oregon Gulch Walk in, Plot 13).



**Figure 11.** Unfenced (control) 2 m x 2 m *C. greenei* plot, marked with rebar and the four corner posts.

### Plant measurements and mapping

In each large-mammal enclosure and control, each individual *C. greenei* plant was mapped (Sample datasheet 1). A 1 m x 1 m quadrat frame with string/wire dividers was used to determine the coordinates of all *C. greenei* plants in each quarter of the 2 m x 2 m plots. We used a coordinate system in which the origin was in the southwest corner of the plot. To mark this corner in fenced plots, it was tagged on the exterior of the enclosure, and in control plots this corner was tagged on the rebar post (Table 1).



**Figure 12.** *C. greenei* demographic and plant community data collection in Oregon Gulch study area enclosures.

We measured the length and width of each *C. greenei* leaf in all plots between 22-26 June 2009 (early summer sampling). With reproductive plants, plant height and flower/bud number were also recorded. Plants were in bud, and no open flowers were observed in plots. We noted herbivory on leaves and flower buds. As possible, we classified herbivory as by mammals when plants were browsed in a clipped manner or as by insects when leaves or flowers had holes or other signs of herbivory that did not appear to be a result of larger animals. In some cases, it was difficult to differentiate between mammal and insect herbivory, and it was also generally impossible to separate mammal herbivory by deer, cattle or rodents.

Between 10-12 August 2009 (late summer sampling), we revisited all plots to determine how many *C. greenei* flower buds were actually matured into capsules. We relocated plants that were in bud on the earlier field visit, and counted matured (filled), aborted, and eaten or damaged capsules. In some cases, we found that plants had produced additional buds/flowers after our first visit. Frequently we found that entire flowering stems had been removed, suggesting some sort of animal damage, but making it impossible to determine how many flowers were matured into capsules or aborted. In this case, we could only record that there had been some sort of reproductive structure and that it was damaged.

**Table 1.** *Calochortus greenei* large-mammal exclosure and control locations, numbers, treatments and tag numbers. GPS coordinates are NAD 27, UTM Zone 10. Plots between horizontal lines are paired.

		Plot		Tag	
		#	Treatment	#	GPS- 2004
Agate Flat Study Area	Powerline Plots	1	Exclosure	544	550284 4652241
		2	Control	545	550312 4652193
	Border Plots	3	Exclosure	537	548804 465146
		4	Control	538	548799 4651442
		5	Control	539	548774 4651462
		6	Exclosure	430*	548769 4651420
	Closed Road Plots	7	Exclosure	535	549069 4652604
		8	Control	536	549095 4652614
	Intersection Plots	9	Control	542	549357 4651666
		10	Exclosure	541	549370 4651667
Oregon Gulch Study Area	Oregon Gulch Walk in	11	Exclosure	546	551576 4656190
		12	Control	547	551571 4656213
		13	Exclosure	553	551451 4655894
		14	Control	552	551453 4655898
	Rosebud Mtn.	15	Control	554	551604 4657971
		16	Exclosure	555	551625 4657980
	Keane Ridge	17	Control	548	548238 4656685
		18	Exclosure	549	548247 4656680
		19	Exclosure	550	548120 4656601
		20	Control	551	548111 4656601
Colestine Study Area	Colestine Freeway	21	Exclosure	527	532879 4653498
		22	Control	429**	532890 4653522
		23	Control	526	532859 4653499
		24	Exclosure	525	532850 4653534
		25	Exclosure	532	532146 4651736
	Colestine Overpass	26	Control	531	532149 4651768
		27	Exclosure	530	532093 4651790
	Colestine Corral	28	Control	529	532090 4651793
		29	Control	533	533624 4651633
		30	Exclosure	534	533681 4656126

\* Tag lost (previously #540 and #591) and replaced in 2005 and 2006.

\*\* Tag lost (previously #528) and replaced in 2006.

*Calochortus tolmiei* frequently co-occurs with *C. greenei*. Fresh specimens of the two species can be distinguished by their leaf surfaces; *C. greenei* is glaucous on both sides, whereas *C. tolmiei* is glaucous on only one side. Most mature *C. tolmiei* leaves are also narrower than those of *C. greenei*. In addition, the capsules of *C. tolmiei* tend to mature earlier than those of *C. greenei*, and their stems and capsules tend to nod, while *C. greenei* stems bearing capsules tend to remain upright. Because both species are frequently animal damaged or drying out at the time of sampling, it is often difficult to tell them apart. To avoid confusion between *C. tolmiei* and *C. greenei* when the two species occurred in the same plot, we mapped the locations of the *C. tolmiei* plants as well, and labeled them on the datasheets. Identifications are re-checked in each year of monitoring; some individual identifications have been confirmed and others are still unconfirmed.

### Plant community sampling

To describe the plant communities in which *C. greenei* occurs, and detect changes over time in fenced and unfenced plots, we collected data on cover and frequency of associated species in the *C. greenei* plots (Sample datasheet 2). In the southwest (tagged) quarter of each plot, we recorded the percent cover of each species, rock, bare soil, and plant litter using a 1 m x 1 m quadrat frame divided into a grid of 25 20 cm x 20 cm squares. We used the quadrat frame in all four quarters of the plot to determine the percent frequency (out of a total of 100 20 cm X 20 cm squares) of the following functional groups: native perennial grasses, annual grasses (including *Poa bulbosa*, which is actually an exotic perennial), forbs, shrubs, bare soil and cow manure.

### All-mammal exclosure establishment

In 2007, we established a total of 14 1 m x 1 m all-mammal exclosures, with seven in Colestine and seven in Agate Flat (Table 2). Exclosures were placed to contain at least six *C. greenei* plants, and were located as close to existing fenced-unfenced pairs as possible. The all-mammal exclosures have sides constructed of hardware cloth (0.5 in grid) attached to 3/8 in rebar, and are approximately 2 ft high. The lids of the exclosures were constructed of 3 in x 2 in grid wire (Figure 13). Numbered metal tags were used to identify each exclosure in the southwest corner. The goal of the exclosures is to allow insect access while eliminating small (and large) mammal access to plants. This will allow us to evaluate the frequency and intensity of small mammal and insect impacts to *C. greenei* plants.

*C. greenei* plants in all-mammal exclosures were mapped, measured, and examined for herbivory damage starting in 2008. Plant community data were not taken in the all-mammal exclosures.



**Figure 13.** 1m x 1m all-mammal exclosure at Agate Flat.

**Table 2.** All-mammal exclosure locations and tag numbers. GPS coordinates are NAD 27, UTM Zone 10.

Study Area	Tag #	Location	2007 GPS	
Agate Flat	700	By intersection near plots 9 & 10.	549536	4651673
	699	Adjacent to plots 9 & 10.	549352	4651655
	698	Adjacent to fenced plot 5.	548776	4651449
	697	Downhill (south) from unfenced plot 5.	548779	4651438
	696	East of rodent exclosure 697, SE of unfenced plot 5.	548788	4651436
	695	South west of and adjacent to fenced plot 3.	548805	4651452
	694	Adjacent to fenced plot 1.	550277	4652220
Colestine	693	Upslope (S) from fenced plot 21.	532883	4653469
	692	Downslope (N) from fenced plot 21.	532883	4653497
	691	Adjacent to unfenced plot 23.	532862	4653486
	645	Uphill from unfenced plot 26	532152	4651751
	644	In small opening (flagged) towards freeway from downhill plot pair (27 & 28).	532133	4651755
	643	Above fenced plot 25.	532152	4651715
	642	Just uphill from unfenced plot 29.	533629	4651627

## Data analysis

Our goals for data analysis in 2009 are to evaluate relationships between the study areas, fencing treatments, and variables of interest in this study. When multiple comparisons were made during analyses, we employed a Bonferroni correction, such that the chance of detecting a difference when there is no difference between groups did not increase. For each set of analyses, we divided the standard P-value to achieve statistical significance ( $\alpha=0.05$ ) by the number of variables tested per study area. For example, if five plant size variables were compared between fenced and unfenced plots within a study area, only P-values  $<0.01$  would be considered significant. P-values smaller than the standard cut-off for statistical significance (0.05) should still be considered strongly suggestive of trends. All P-values from analyses are included in Appendix 5. We examined each study area separately, since each area is subject to different recent grazing intensities (Agate Flat the highest intensity, Oregon Gulch intermediate, and Colestine minimal intensity).

### ***Trends over time in large-mammal exclosures***

#### Plant Abundance

To determine whether the *C. greenei* plants in large-mammal exclosures were more likely to successfully reproduce or be non-dormant, we compared the change (pre-exclosure in 2003 - six yr post-exclosure in 2009) in total plant abundance per plot between large-mammal exclosures and controls in each study area using two sample t-tests.

#### Plant Measurements and Reproductive Output

The objective of analyzing these measurements was to determine if plants protected by exclosures, both large-mammal and all-mammal exclosures, were larger, more likely to flower or produced more flowers. We compared trends in plant measurements between controls and large-mammal exclosures using two sample t-tests in each study area. P-values  $< 0.01$  were considered significant.

#### Herbivory

Data on frequency of vegetative herbivory (any grazing to leaf structures) and reproductive structure herbivory (damage to buds, flowers or capsules) were analyzed to determine if plants

in exclosures had reduced levels of herbivory. In 2003, reproductive structure damage was only assessed in early summer (June), but beginning in 2004, reproductive structure damage, including the number of capsules that were damaged per plant, was assessed again in late summer (late July or August; Menke and Kaye 2004). We used two sample t-tests to evaluate the significance of fencing effects on changes between 2003 and 2009 in frequencies of vegetative herbivory and early summer floral herbivory (P-values < 0.025 considered significant). We also compared large-mammal exclosures and controls in frequency of late summer reproductive structure damage in 2009 with two sample t-tests (P-values < 0.025 considered significant). These data were not taken in 2003, therefore pre- and post-fencing treatment comparisons are not possible. Variables which did not meet assumptions of normality and equality of variance were compared with non-parametric Mann-Whitney tests.

### **Single year comparisons including all-mammal exclosures**

As the all-mammal exclosures have only been in place two years, comparisons of trends with the controls and large-mammal plots are not yet possible. Therefore, plant size, reproductive output and herbivory data from 2009 were compared between the all-mammal exclosures, large-mammal exclosures and controls using one-way ANOVA with Bonferroni multiple comparison tests. When data did not meet parametric assumptions, Kruskal-Wallis tests were used.

### **Plant community in large-mammal exclosures and controls**

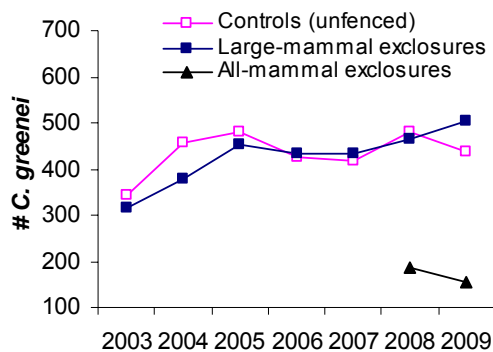
We compared trends in functional group frequency (native perennial grass, annual grass, forb, shrub, bare ground, cow manure) between large-mammal exclosures and controls at each study area using t-tests or Mann-Whitney tests, when data did not meet parametric assumptions (P-values < 0.008 considered significant). We tested the significance of fencing effects on trends in cover (%) of native and exotic forbs, native and exotic grasses, and shrubs at each study area (P-values < 0.01 considered significant).

## **RESULTS & DISCUSSION**

### **Plant Abundance**

#### **Large-Mammal Exclosures**

We mapped and measured a total of 942 *Calochortus greenei* plants in the large-mammal exclosures and controls in 2009



(**Figure 14**). The number of plants per plot ranged from a maximum of 81 to a minimum of

6. The net change in plant abundance between 2003 and 2009 was not significantly influenced by the large-mammal exclosures at any site (all  $P > 0.14$ ). Plant measurement data are included in Appendix 3.

#### **All-Mammal Exclosures**

We mapped and measured a total of 155 *C. greenei* plants in the 14 all-mammal exclosures in 2009. One all-mammal exclosure in Colestine (#642) had clear evidence of small mammal activity, and was excluded from data summary and analysis. The number of plants per exclosure ranged from of 31 to 4. Plant measurement data are included in Appendix 4.

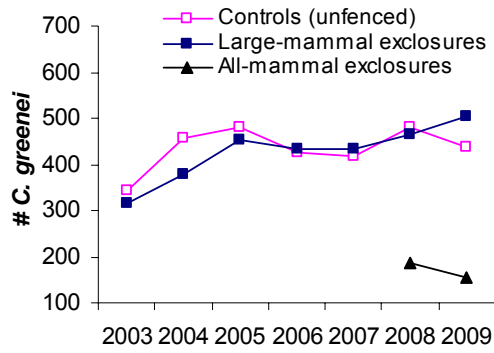
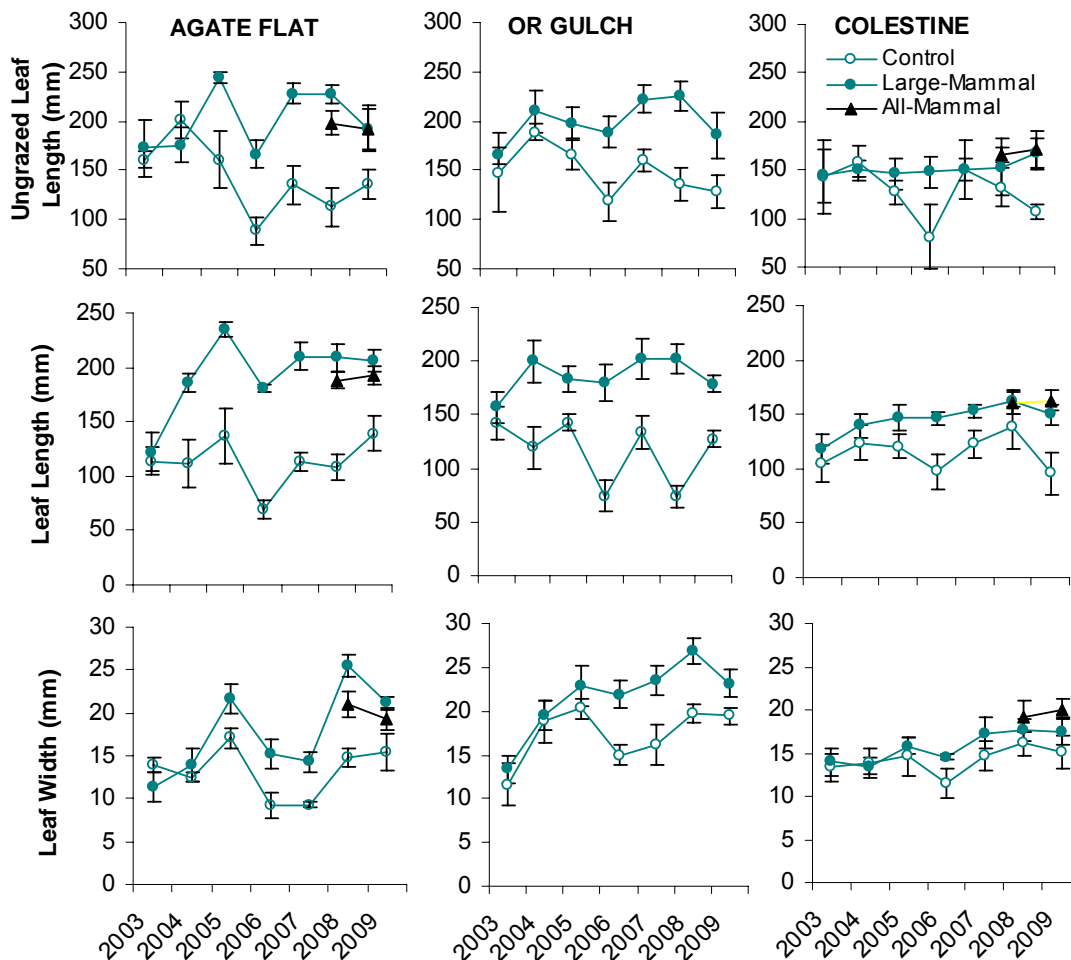


Figure 14 Total number *C. greenei* plants in large-mammal exclosures, all mammal exclosures and unfenced controls in 2003-2009.

## Plant Measurements and Reproductive Effort

### Large-Mammal Enclosures

In Oregon Gulch, which recently had moderate levels of grazing, trends in *C. greenii* plant size (undamaged leaf length, leaf length, leaf width) and flowering (number flowers/plant, percent plants in plot flowering) were similar between large-mammal enclosures and controls (**Error! Reference source not found.** and Figure 16; all  $P > 0.25$ ). At Agate Flat, where there was more grazing use until recently, *C. greenii* leaf width has increased in large-mammal enclosures and remained similar in controls ( $P = 0.01$ ) since enclosures were established in 2003. All other plant variables at Agate Flat had similar trends in and outside of enclosures (all  $P > 0.13$ ). In Colestine, trends in most plant size and flowering were similar (all  $P > 0.06$ ) between large-mammal enclosures and unfenced controls. Leaf length appears to have increased inside enclosures while decreasing outside enclosures, but this trend was not statistically significant ( $P = 0.04$ ,  $P < 0.01$  required for significance after multiple comparisons).



**Figure 15.** Leaf dimensions ( $\pm$ SE bars) in 2003-2009 in the three study areas (Agate Flat, Oregon Gulch and Colestine). Large-mammal enclosures constructed while sampling in 2003. Each study area has five fenced/unfenced plot pairs. All-mammal enclosure data, first sampled in 2008 in Agate Flat and Colestine, with seven plots per study area, are shown.

### **All-Mammal Exclosures**

At Colestine in 2009 (not a trend analysis, differences detected within single year), *C. greenei* in the all mammal exclosures tended to have longer leaves ( $P=0.009$ ) and more flowers ( $P=0.001$ ) than plants in the unfenced controls, but these variables were similar to those observed in the large-mammal exclosures. Other measures of plant size and reproductive effort did not differ between the all-mammal exclosures, large-mammal exclosures and the controls (all  $P>0.09$ ).

At Agate Flat, *C. greenei* in the all-mammal exclosures had longer leaves than the controls ( $P=0.003$ ), but were similar to the large-mammal exclosures. Other measures of plant size and reproductive effort did not differ significantly between groups (all  $P>0.06$ ).

## **Herbivory**

### **Large-Mammal Exclosures**

We examined the effects of the large-mammal exclosures in each study area on the frequency of leaf herbivory (all sources) and reproductive structure damage (Figure 17). Trends in leaf herbivory (all  $P>0.032$ ,  $P<0.025$  required for statistical significance) and June floral herbivory (all  $P>0.2$ ) were similar in fenced and unfenced plots in all study areas. Late summer reproductive structure damage is extremely variable within study areas (Figure 18); protection by large-mammal exclosures increased the likelihood of fruit set in *C. greenei* late in the season at Colestine and Oregon Gulch (both  $P<0.013$ ), but did not result in significant differences at Agate Flat ( $P>0.2$ ).

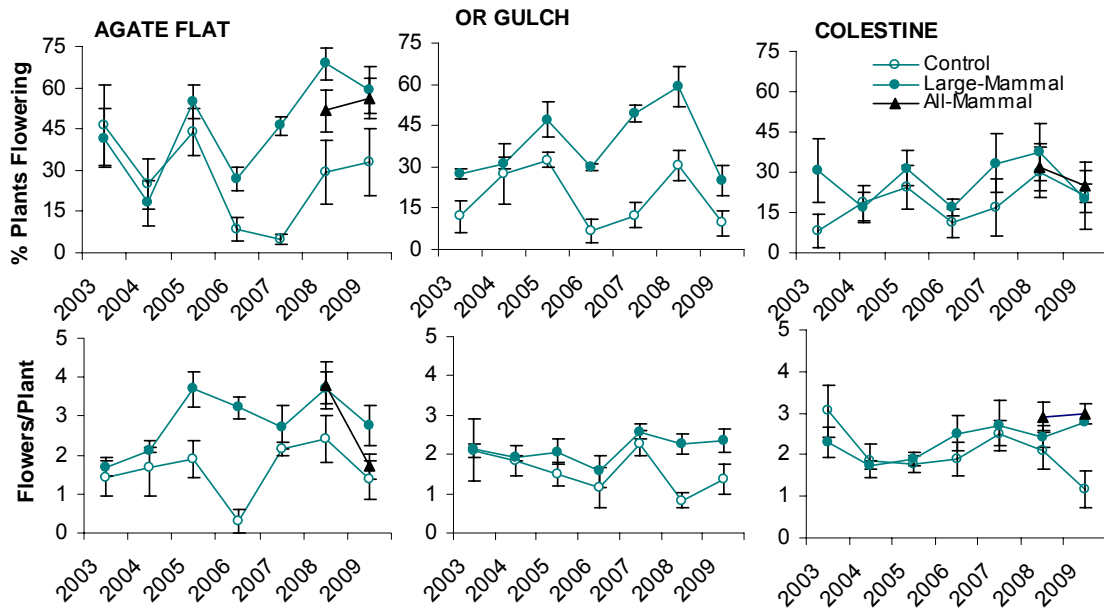
### **All-Mammal Exclosures**

The frequency of June 2009 leaf herbivory at Agate Flat and Colestine was similar between the controls, all-mammal, and large-mammal exclosures (all  $P>0.07$ ); excluding mammals did not reduce herbivory to leaves. As neither the large-mammal nor all-mammal exclosures reduced the frequency of leaf graze to below levels of approximately 50% of the plants per exclosure (Figure 17), it is likely that insects are responsible for significant portion of observed leaf herbivory.

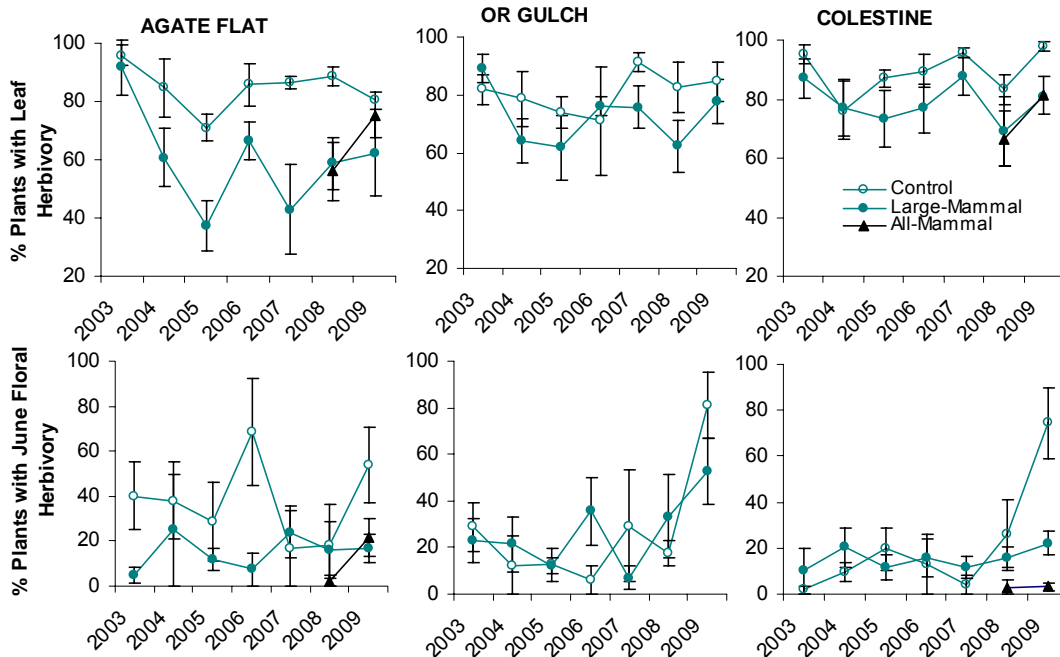
The frequency of herbivory on developing flowers (June floral herbivory) was similar between all plots in Agate Flat ( $P=0.07$ ), but was reduced in the all-mammal and large-mammal exclosures in Colestine ( $P=0.003$ ) as compared to the unfenced controls. Excluding small mammals did not result in greater reductions in early season floral herbivory than just excluding large mammals, suggesting that small mammals do not play a significant role in early season floral herbivory. The all-mammal exclosures reduced damage to almost zero at Colestine and Agate Flat in 2008, but not at Agate Flat in 2009 (Figure 17); the role of insects in early season floral structure damage appears variable across time and between study areas.

In 2008 at Agate Flat, later season floral structure damage (occurring in late June through early August) was significantly lower in the all-mammal exclosures than the controls ( $P=0.025$ ; Figure 18). However, in 2009, there was a steep increase in late season herbivory in the all-mammal exclosures; there was no difference in damage between the controls, all-mammal and large-mammal exclosures ( $P=0.77$ ). The net proportion of intact fruit set was similar between both exclosure types and controls at Agate Flat ( $P=0.15$ ). At Colestine, later season floral structure damage was perhaps lower in the all-mammal exclosures than the controls ( $P=0.027$ ,  $P<0.025$  required for statistical significance). The proportion of intact fruit set was significantly greater in the all-mammal exclosures, intermediate in the large-mammal exclosures, and lowest (near

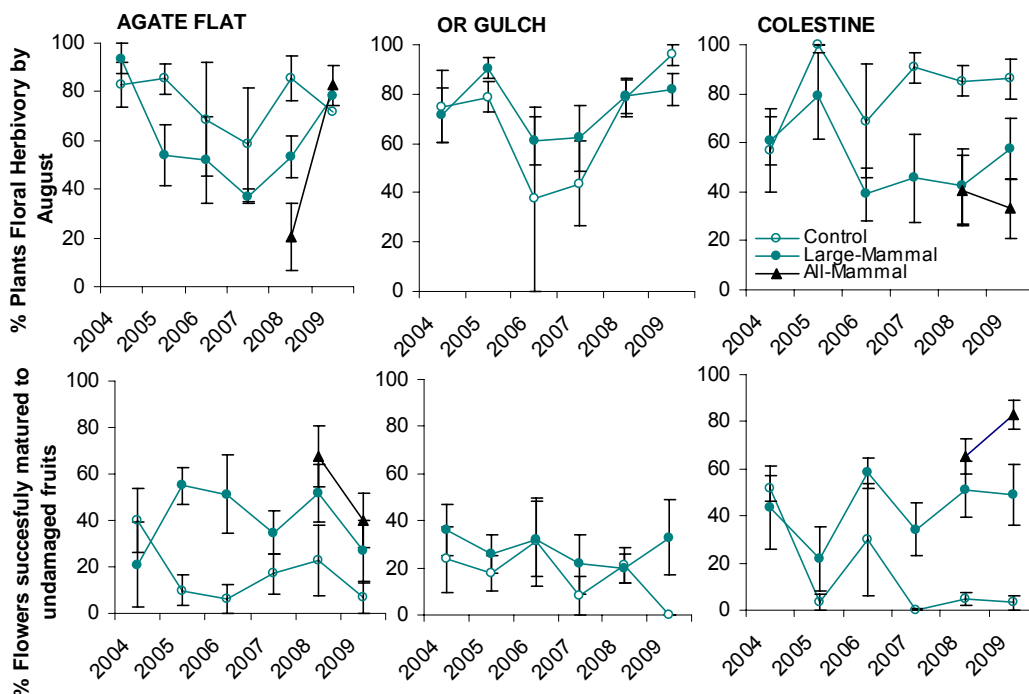
zero) in the controls ( $P=0.0001$ ), suggesting insects, small mammals and large mammals all contribute to fruit damage in Colestine.



**Figure 16.** Mean ( $\pm$ SE bars) percentage of plants flowering and number of flowers per plant in large-mammal exclosures and controls from 2003-2009. Each study area (Agate Flat, Oregon Gulch and Colestine) has five large-mammal exclosure/control pairs. All-mammal exclosure data, first sampled in 2008 in Agate Flat and Colestine, with seven plots per study area, are shown.



**Figure 17.** Mean frequency ( $\% \pm \text{SE}$ ) of *C. greenei* plants with vegetative or floral herbivory in early summer. All-mammal enclosure data, first sampled in 2008 in Agate Flat and Colestine, are shown.



**Figure 18.** Mean frequency ( $\% \pm \text{SE}$ ) of *C. greenei* with reproductive structure herbivory and mean ( $\% \pm \text{SE}$ ) flowers matured to intact capsules in late summer. Data not taken in 2003, therefore pre- and post-fencing comparisons not possible. Data from the all-mammal enclosures, first taken in 2008, in Agate Flat and Colestine, are shown.

## Plant Community

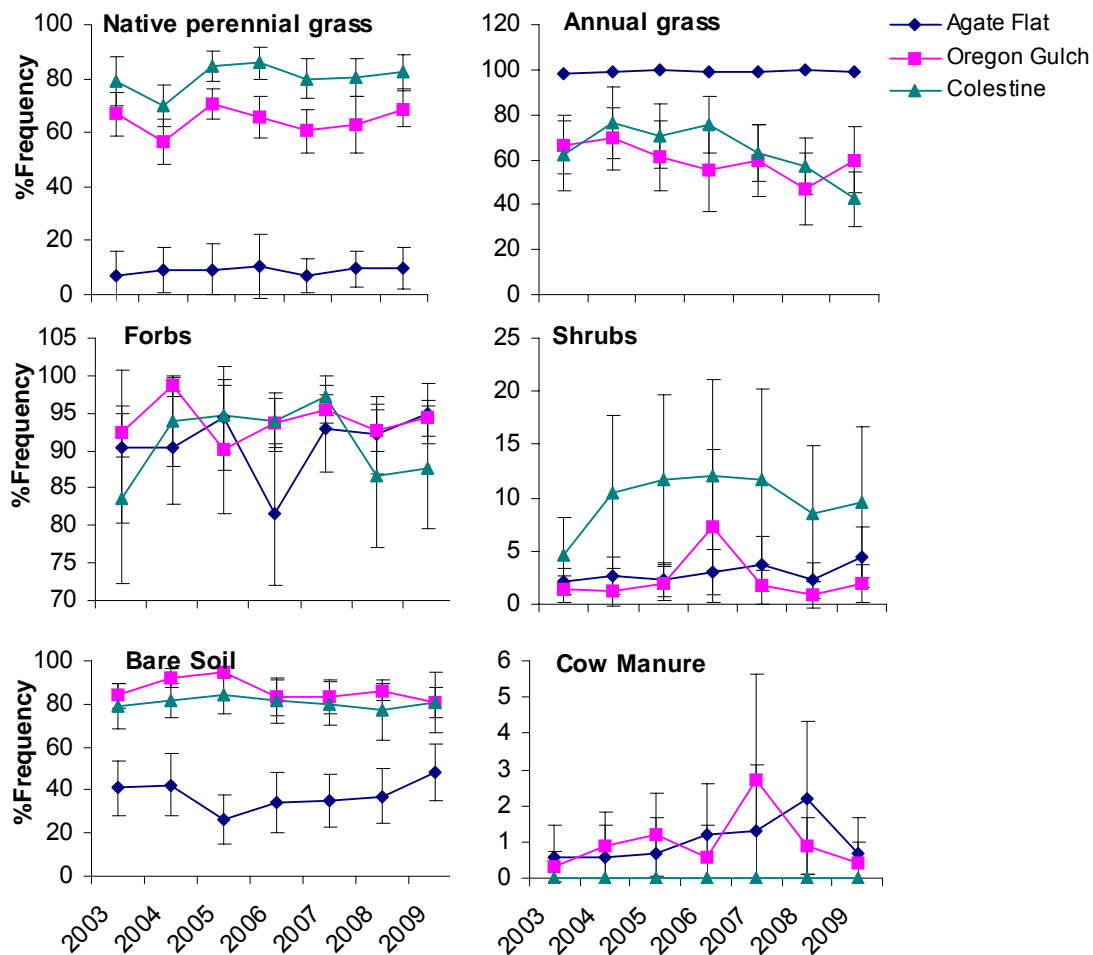
### Functional Group Frequency

#### Study Area Wide Trends

Between 2003 and 2009, the average frequency (in both fenced and unfenced plots) of native perennial and annual grasses, forbs, shrubs, bare soil and cow pies has remained relatively constant (all  $P > 0.01$ ,  $P < 0.008$  required for statistical significance).

#### Comparing Trends in Fenced and Unfenced Plots

There have been few changes in annual and perennial grass, forb, shrub, bare soil and cow manure frequency in plots between 2003 and 2009; trends were similar between fenced and unfenced plots in all study areas (all  $P > 0.08$ ) with one exception; annual grass frequency may be decreasing in Colestine's fenced plots while remaining steady in unfenced plots ( $P = 0.008$ ). The major difference between study areas remains that Agate Flat has much lower perennial grass and bare soil frequency, but much higher annual grass frequency than Colestine and Oregon Gulch (**Error! Reference source not found.**).



**Figure 19.** Mean frequency (% +/- SE) of functional groups in ten plots in 3 study areas in 2003-2009. Large-mammal exclosures and controls not differentiated in graphs.

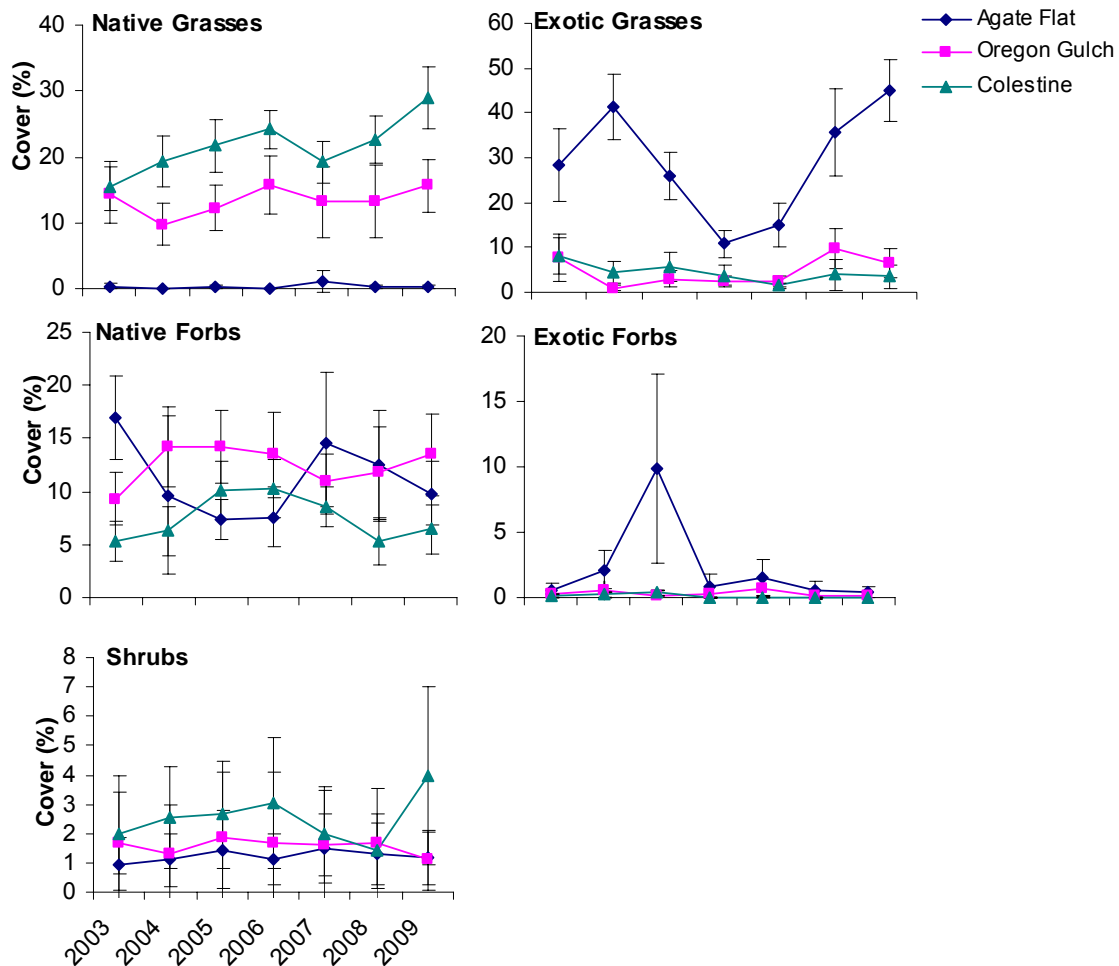
## Species Cover

### Study Area Wide Trends

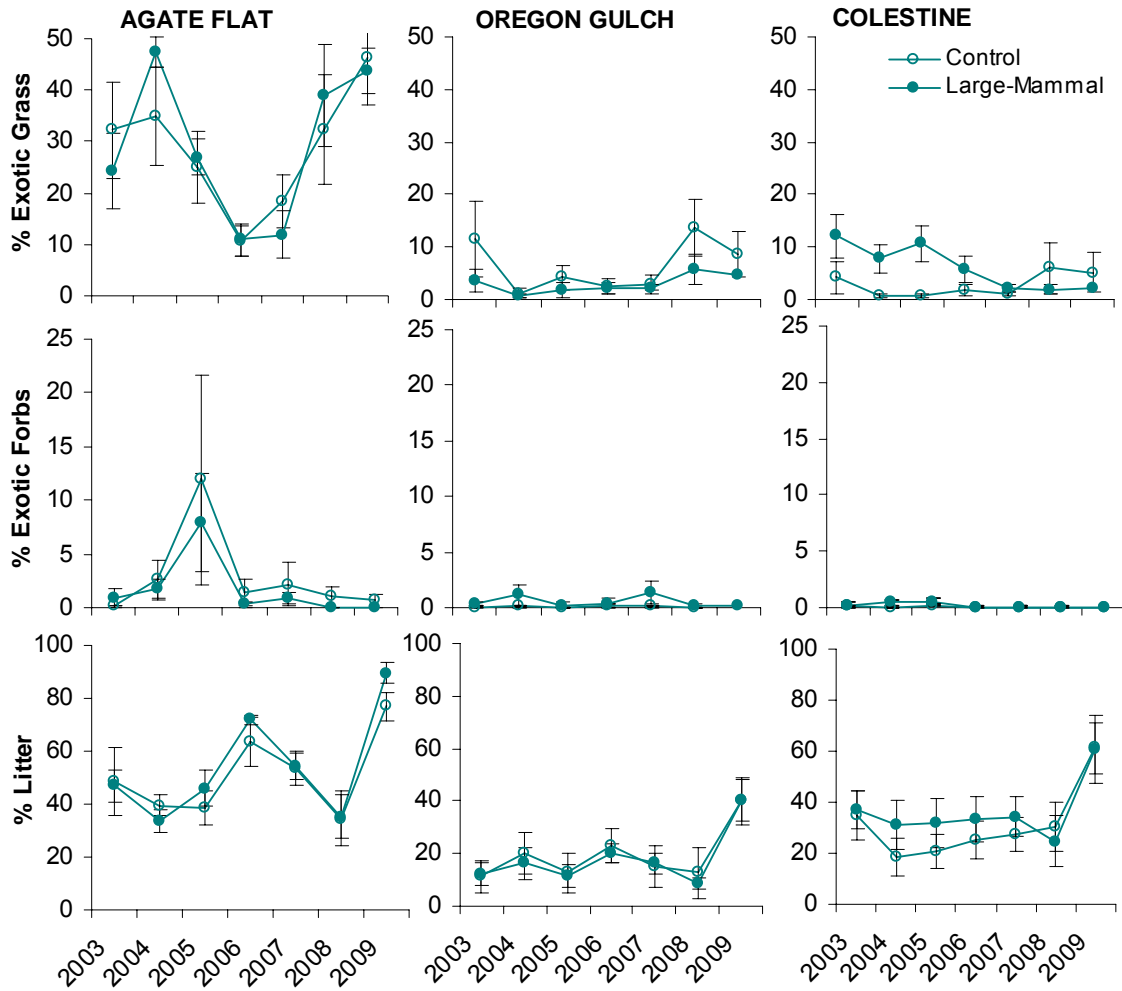
In Agate Flat, when fenced and unfenced plots are combined, it appears that between 2003 and 2009, exotic grass cover has increased ( $P=0.009$ ) while native forb cover may be decreasing ( $P=0.015$ ,  $P<0.01$  required for statistical significance). Native grass, exotic forb and shrub cover have remained similar over time (all  $P>0.37$ ) in Agate Flat. In Oregon Gulch, cover of these functional groups has remained relatively constant (all  $P>0.28$ ), with the exception of native forb cover, which has increased slightly ( $P=0.017$ ,  $P<0.01$  required for statistical significance). In the Colestine study area, native grass cover has increased between 2003 and 2009 ( $P=0.002$ ), while cover of the other functional groups has remained constant (all  $P>0.05$ ).

### Comparing Trends in Fenced and Unfenced Plots

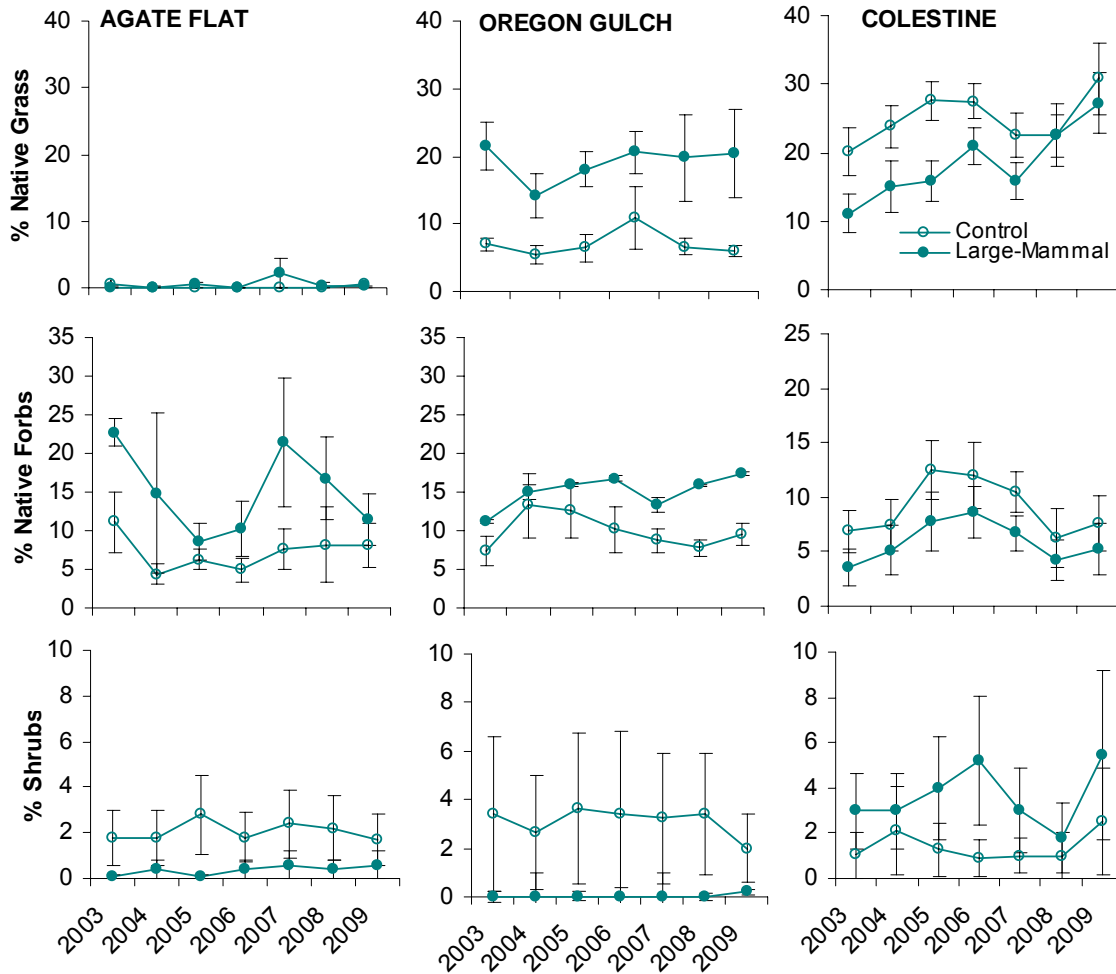
Trends in functional group cover were similar between fenced and unfenced plots in all study areas (all  $P>0.07$ ; Figure 20; Figure 22; **Error! Reference source not found.**), with the exception of a suggestive but not statistically significant decrease in exotic grass cover in fenced plots in Colestine ( $P=0.03$ ,  $P<0.01$  required for significance).



**Figure 20.** Functional group cover (%  $\pm$ SE) between 2003 and 2009 at Agate Flat, Oregon Gulch and Colestine study areas. Large-mammal exclosures and controls not differentiated in graphs.



**Figure 21.** Cover (%  $\pm$ SE) of exotic grasses, forbs and plant litter in large-mammal exclusions and controls between 2003 and 2009 at Agate Flat, Oregon Gulch and Colestine study areas.



**Figure 22.** Cover (%  $\pm$ SE) of native grasses, forbs and shrubs in large-mammal exclosures and controls between 2003 and 2009 at Agate Flat, Oregon Gulch and Colestine study areas.

## CONCLUSIONS & CONTINUING RESEARCH

### Agate Flat

In terms of native species abundance and frequency, the plant community at Agate Flat appears to be in the poorest condition of the three study areas, and this condition is similar between large-mammal exclosures and controls. Native grasses are rare, and annual grasses, especially *Taeniatherum caput-medusae*, dominate in all plots. Accumulation of plant litter has likely influenced cover of other functional groups. A peak in exotic forb cover seen in 2005 has not reappeared, and was likely due to unusually high spring rainfall in 2005 (Western Regional Climate Center 2006). Yellow starthistle is a major threat in this study area, and exotic grass abundance appears to be increasing. Trends suggest that native forb cover may be in decline.

In contrast to the condition of the plant community, the condition of the *Calochortus greenei* at Agate Flat appears similar to the other study areas. The second year of data from the all-mammal exclosures suggest insects are significant agents of leaf herbivory. The role of small in

floral structure herbivory/damage occurring in late June through July, while the plants are maturing fruits, will be clarified with additional years of data.

### Oregon Gulch

The plant community in the plots in Oregon Gulch has a much more prominent native component than plots in Agate Flat. Oregon Gulch plots have less native grass cover but slightly more native forb cover than plots in Colestine. Cover by exotic species in Oregon Gulch plots is low, and appears to be stable; we did not detect any dramatic increases by exotic forbs or grasses this year.

Levels of flowering and numbers of flowers per *C. greenei* plant in Oregon Gulch appear to be fairly stable. At present, *C. greenei* in and out of large-mammal exclosures appear to have similar population vigor and similarly high levels of vegetative and reproductive structure damage to plants. Despite similar levels of early and late season floral structure herbivory, plants inside large-mammal exclosures had greater fruit set than plants in unfenced controls.

### Colestine

The Colestine study area plots have the highest cover of native grasses of those sampled in this project. Cover by exotic species (both grasses and forbs) is low. Trend analyses suggest exotic grass cover may be decreasing in the large-mammal exclosures and increasing slightly in the controls, which may be a result of native animal disturbance outside the exclosures, or enhanced competition by ungrazed and recovering native species inside the exclosures. Study area wide trends suggest native grass cover is increasing in Colestine, which may reflect variation in native grazing use, or be a result of climatic variation.

This year, as was observed the last two years, almost all fruiting structures in Colestine area unfenced control plots had some sort of damage, and fruit set in unfenced control plots was close to zero. Protection provided by the all-mammal exclosures resulted in higher fruit set than the controls, and protection by the all-mammal exclosures resulted in even greater fruit set. This suggests large native mammals, small mammals and insects are active fruit structure grazers in this study area.

In 2009, we determined at least one of the all-mammal exclosures (Figure 24) had been invaded by small mammals (voles), and had to be removed from analyses. This may prove a continuing challenge in the Colestine and Agate Flat study areas.



**Figure 23.** Vole damage observed in Colestine all-mammal exclosure #542 in June 2009.

## CONTINUING RESEARCH

Preliminary population viability analyses, incorporating climatic variation as well as herbivore effects, will be conducted at the conclusion of the study (2014). To develop management guidelines and create future conservation strategies for this species, it is crucial to determine the long-term impacts of utilization by all active herbivores on *C. greenei*. Since *C. greenei* has a complex life-history that includes dormancy, and this species is likely influenced by climatic variation, we recommend continuing this demographic study through 2014, to best inform management actions in the Cascade-Siskiyou National Monument.

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Menke, C.A. and T.N. Kaye. 2003. Population monitoring and grazing research for *Calochortus greenei* on the Cascade-Siskiyou National Monument. Institute for Applied Ecology and Bureau of Land Management, Medford District. 23 pp plus appendices.

Menke, C.A. and T.N. Kaye. 2004. Population monitoring and grazing research for *Calochortus greenei* on the Cascade-Siskiyou National Monument. Institute for Applied Ecology and Bureau of Land Management, Medford District. 23 pp plus appendices.

Western Regional Climate Center 2006. Western U.S. Historical Summaries. Desert Research Institute, Reno, Nevada. <http://www.wrcc.dri.edu/>

## Appendix 1: *Calochortus greenei* Plot Directions

### Agate Flat Study Area (Plots 1-10):

The road to Agate Flat is in increasingly poor condition. To reach these sites, even in summer, requires a four-wheel drive vehicle with good clearance, and a BLM gate key. If plant community sampling is conducted earlier in the year, these sites can only be reached on foot.

From Ashland, take the Highway 66 exit from I-5 and head east. Just before milepost 21, turn right on Mill Creek Road (40 3E 12 Road). If you reach Lincoln, you have gone too far. After 1.4 mi, turn left on Lincoln Creek Road (40 3E 12.1 road on map, not labeled on sign), then after 4.3 mi (total mileage from pavement) veer right towards Agate Flat, and at 4.5 mi, veer right again (19.2 Rd.). You will pass through a locked yellow gate, then at 8.9 miles park at funky no-top tree and walk in about 3/8 of a mile to right on closed road (do not drive on this road!) past a plot set up by P. Hosten on the left, to reach plots 7 and 8, which are about 100 yards off the road on the right (see Figure 8). To reach other plots 3-6, 9 and 10 and 1 and 2, continue on the main road (19.2) until odometer is at 9.3 miles. To reach plots 3-10 turn right on road 41 2E 10.1 until odometer is a 9.4 for 9 & 10, and 9.9 miles for 3-6. To reach plots 1-2, back track to the last intersection (about 0.6 mi) and continue another ~0.5 miles, then turn left on the 41.4E 7.1 road. Go an additional 0.8 miles (will drive past exclosures that look the same as ours but were established by Paul Hosten in areas without *Calochortus*) and look for plots 1 and 2, on opposite sides of the road. If you go too far, you'll reach a gate to private property.

### Oregon Gulch Study Area (Plots 11-20):

#### Plots 11-14 “Walk in Sites”

From Ashland, take the Hwy 66 exit from I-5 and head east. Just before milepost 21, turn right on Mill Creek Road (40 3E 12 Road). After 1.4 mi, turn left on Lincoln Creek Road (40 3E 12.1 road on map, not labeled on sign), then after 4.3 mi (total mileage from pavement) veer right towards Agate Flat. At 4.5 miles veer left, and at 4.9 miles there is a barbed wire fence across the road, which no longer has a gate, so park and start walking here. After about a 1-1.5 miles (20-25 min) walking, you'll reach an area where slash piles were burned on BOTH sides of the road and there is somewhat of a landing on the left side (look for dead ponderosa pines). Look for an old road blocked off by soil berms, and walk in for 10-15 minutes on this road. Plots 11 and 12 will be visible from the road, on the left side. To reach plots 13 and 14, turn right (before you reach 11 and 12) at the red and yellow/black striped flagging on the right side of the road. Head up hill along a drainage, following flagging.

#### Plots 17-20 “Keane Ridge”

From Ashland, take the Highway 66 exit from I-5, and head east. Just before milepost 21, turn right on Mill Creek Road (40 3E 12 Road). After 1.4 miles, stay straight, don't veer left as for Agate Flat. Pass through gate at 1.7 miles. Then at 1.9 miles (total miles from pavement), stay left/straight (private road goes right). After 2.2 miles, keep going straight/left, and at 2.5 miles veer left. At 2.9 miles, stay right, then just between 3.0 and 3.1 miles, take a left turn and go through a yellow locked gate (push down on gate to get it to open). At just over 4.1 miles, pass a heli pond on the right side, and at 4.4 miles, stay right. At 4.5 miles veer right, and at just over 5.1 miles, turn right on the 40-3E-25 road. At 5.5 miles veer left. Keep driving a little further, park at 2nd open area, hike up and over hill on right side, following flagging through oak galleries to the sites.

**Plots 15-16 “Rosebud Mountain”**

From Ashland, take the Highway 66 exit from I-5 and head east. Just before milepost 21, turn right on Mill Creek Road (40 3E 12 Road). After 1.4 mi, turn left on Lincoln Creek Road (40 3E 12.1 road on map, not labeled on sign). After 4.3 mi (total) veer left towards Rosebud (gate), and at 4.6 miles stay left. At 4.9 miles, stay straight/right, and at 5.0 miles take the left fork. At 5.4 miles take the left fork again. Park where possible (road disintegrates) and walk less than an 1/4<sup>th</sup> of a mile past second big slash pile on right, and hike up the hill to right, to bald openings. Fenced plot is just uphill 60 degrees and 75' from the unfenced plot.

**Colestine Study Area (Plots 21-30):****Plots 21-24 “Colestine Freeway”**

From Ashland take I-5 south, and pull off the freeway between mileposts 2 and 3, just past two CHP turnarounds through the center median. Pull off just past metal guardrail. Be sure to leave the BLM research permit on the dash. Hike up the cut bank, and curve up right, through a barbed wire fence. Look for flagging and fencing to find plots. Call Oregon State Patrol Dispatch (541-776-6111) so you don't get tagged and towed.

**Plots 25-28 “Colestine Overpass”**

On I-5, take Exit 1 from the northbound direction (only access is from I-5 north) and park in chain-up pullout at the east end of overpass at top of off ramp. Walk over the overpass, and cross over the guardrail on west side of road, then over a flagged barbed wire fence. Look for enclosure fencing, flagging and fat rattlesnakes.

**Plots 29-30 “Colestine Corral”**

On I-5, take Exit 1 from the northbound direction (can only access from I-5 north), and continue north on the Old Siskiyou Highway past the parking spot for plots 25-28, to the corral turnoff (about 0.5 miles). Take the first right turn, looking for the corral about 100 yards down the road. Park by the corral, and walk east-northeast up an old, washed out, rutted road, then follow flagging to the plots. The fenced plot is slightly uphill from unfenced plot.

## Appendix 2: Sample Datasheets

**Calochortus greenei community plots**

Date:

Names:

Fenced/unfenced:				
STUDY AREA:				
PLOT#				
TAG#				
<i>Calochortus greenei</i>				
<i>Agropyron intermedium</i>				
<i>Bromus japonicus</i>				
<i>Bromus laevipes (carinatus???? orcuttianus?)</i>				
<i>Bromus mollis</i>				
<i>Bromus tectorum</i>				
<i>Danthonia californica (reflexed leaves)</i>				
<i>Danthonia unispicata (ascending leaves)</i>				
<i>Elymus elymoides (Sitanion hystrix)</i>				
<i>Festuca roemerii (idahoensis)</i>				
<i>Koeleria cristata (macrantha)</i>				
<i>Melica subulata</i>				
<i>Poa annua?</i>				
<i>Poa bulbosa</i>				
<i>Poa secunda</i>				
<i>Stipa lemmonii (Achnatherum)</i>				
<i>Taeniatherum caput-medusae</i>				
<i>Vulpia microstachys (Deschampsia danthonioides??)</i>				
unknown Juncaceae				
<i>Agoseris heterophylla</i>				
<i>Allium acuminatum</i>				
<i>Allium siskiyouense</i>				
<i>Allium sp.</i>				
<i>Alyssum alyssoides</i>				
<i>Antennaria microphylla</i>				
<i>Arenaria serpyllifolia ??</i>				
<i>Blepharipappus scaber</i>				
<i>Brodiaea congesta</i>				
<i>Brodiaea elegans</i>				
<i>Calochortus tolmiei</i>				
<i>Calystegia occidentalis ssp. occidentalis</i>				
<i>Centaurea solstitialis</i>				
<i>Clarkia gracilis ssp. gracilis</i>				
<i>Collinsia parviflora- when dry, reddish, persistent capsule?</i>				
<i>Collomia grandiflora</i>				
<i>Crepis sp ?Unknown yellow composite (Lapsana?)</i>				
<i>Cryptantha intermedia</i>				
<i>Cryptogramma crispa?</i>				
<i>Draba verna</i>				
<i>Epilobium sp.</i>				
<i>Eremocarpus setigerus</i>				
<i>Erigeron bloomeri var bloomeri</i>				
<i>Eriogonum umbellatum var polyanthum</i>				
<i>Eriophyllum lanatum</i>				
<i>Erodium cicutarium</i>				
<i>Galium parisiense</i>				
<i>Gilia capitata</i>				
<i>Grindelia sp.</i>				
<i>Horkelia daucifolia</i>				
<i>Lactuca serrolia</i>				
<i>Lomatium dissectum</i>				
<i>Lomatium nudicaule</i>				
<i>Lomatium triternatum</i>				
<i>Lomatium utriculatum</i>				

**Calochortus greenei community plots (Pg. 2)**

Date:

Names:

Fenced/unfenced:				
STUDY AREA:				
PLOT#				
TAG#				
<i>Lupinus argenteus</i>				
<i>Lupinus sp.</i>				
<i>Madia sp. (gracilis?)</i>				
<i>Microseris laciniata</i>				
<i>Microsteris gracilis- dry, 5 carpellate? (aka phlox)</i>				
<i>Minuartia (previously unknown caryophyllaceae?)</i>				
<i>Navarretia sp.</i>				
<i>Orobanche uniflora</i>				
<i>Orthocarpus cuspidatus ssp. cuspidatus (pink)</i>				
<i>Orthocarpus hispidus</i>				
<i>Penstemon roezlii</i>				
<i>Perideridia oregana</i>				
<i>Phacelia heterophylla</i>				
<i>Polygonum douglasii ssp. majus</i>				
<i>Ranunculus occidentalis</i>				
<i>Sedum stenopetalum/radiatum</i>				
<i>Sisyrinchium</i>				
<i>Tragopogon dubius</i>				
<i>Trifolium eriocephalum (whitish, fuzzy head)</i>				
<i>Trifolium sp. (tall?)</i>				
Unknown Asteraceae				
Unknown Caryophyllaceae				
Unk.euphorbiaceae? Tricarpellate, milky sap, wrapping lvs				
Unknown liliaceae				
<i>Veronica sp.</i>				
<i>Vicia americana</i>				
<i>Zigadenous venenosus</i>				
<i>Amelanchier alnifolia</i>				
<i>Ceanothus cuneatus</i>				
<i>Ceanothus prostratus</i>				
<i>Chrysothamnus nauseosus</i>				
<i>Juniperus occidentalis</i>				
<i>Prunus klamathense</i>				
<i>Purshia tridentata</i>				
<i>Quercus garryana</i>				
<i>Rosa sp. (not gymnocarpa)</i>				
<i>Rosa woodsii</i>				
Cedar seedling				
Pinus seedling				
Rock				
Bare ground/soil				
Litter				
TOTAL COVER:				
FREQUENCY				
Perennial grass	/ / /	/ / /	/ / /	/ / /
annual grass	/ / /	/ / /	/ / /	/ / /
Forb	/ / /	/ / /	/ / /	/ / /
Shrub	/ / /	/ / /	/ / /	/ / /
Bare soil	/ / /	/ / /	/ / /	/ / /
Cowpie	/ / /	/ / /	/ / /	/ / /
tree	/ / /	/ / /	/ / /	/ / /



### **Appendix 3: Large-Mammal Exclosure and Control Demographic Data 2009**

See attached file (CAGR 09 Appendix 3.pdf)

## **Appendix 4: All Mammal Exclosure Demographic Data 2009**

See attached file (CAGR 09 Appendix 4.pdf)

## Appendix 5: Details from Data Analyses

This appendix includes detailed output from data analyses. P-values in bold are statistically significant after Bonferroni correction for multiple comparisons. Please see Results and Discussion section for narrative describing results.

Output 1. Comparison of change between 2003 and 2009 in the control and large mammal exclosures. P-values from two sample T-tests or Mann-Whitney tests when data were not normally distributed.

Change between 2003 and 2009					
Year	Data	Site	Control	Large-Mammal	P-value
2009-2003	Plant Abundance	AF	10.20	5.20	0.306
		OG	3.40	12.60	0.251
		CS	5.20	20.40	0.139
	Ungrazed Leaf Length (mm)	AF	-50.61	38.62	0.259
		OG	-1.81	2.02	0.961
		CS	-34.90	21.03	0.460
	Leaf Length (mm)	AF	25.06	83.75	0.127
		OG	-6.96	21.77	0.251
		CS	-9.55	31.20	0.039
	Leaf Width (mm)	AF	<b>1.58</b>	<b>9.85</b>	<b>0.013</b>
		OG	7.83	8.80	0.773
		CS	1.71	3.55	0.462
	% Flowering	AF	-13.39	17.53	0.167
		OG	-2.54	-2.54	1.000
		CS	13.27	-10.30	0.095
	Flower number per plant	AF	-0.04	1.07	0.190
		OG	0.73	0.23	0.598
		CS	-1.49	0.44	0.055
	% June Floral Herbivory	AF	13.67	11.88	0.927
		OG	59.17	29.61	0.205
		CS	46.55	12.82	0.200
% Leaf Graze	AF	-15.18	-17.78	0.914	
	OG	2.66	-11.29	0.167	
	CS	2.57	-6.22	0.032	

Output 2. Comparison of between the control and large mammal exclosures in 2009. P-values from two sample T-tests or Mann-Whitney tests when data were not normally distributed.

			Single Year (2009) Comparison		
Year	Data	Site	Control	Large-Mammal	P-value
2009	% August Floral Graze	AF	71.67	78.44	0.717
		OG	95.83	81.87	0.139
		CS	86.14	57.62	0.118
	% Capsules Surviving	AF	6.67	26.73	0.209
		OG	<b>0.00</b>	<b>32.99</b>	<b>0.011</b>
		CS	<b>3.13</b>	<b>48.81</b>	<b>0.013</b>

Output 3. Comparison between the control, large mammal and all-mammal exclosures in 2009. P-values from One-Way ANOVA or Kruskal-Wallis tests when data were not normally distributed. All-mammal exclosures occur only in Agate Flat and Colestine. Comparisons between just the control and large-mammal exclosures shown in table

Year	Data	Site	Single Year (2009) Comparison			
			Control	Large-Mammal	All-Mammal	P-Value
2009	Ungrazed Leaf Length (mm)	AF	135.77	192.20	191.43	0.122
		OG	128.25	185.43		
		CS	107.10	167.32	161.31	0.141
	Leaf Length (mm)	AF	<b>139.06</b>	<b>205.74</b>	<b>192.63</b>	<b>0.003</b>
		OG	126.95	178.76		
		CS	<b>95.45</b>	<b>149.89</b>	<b>159.81</b>	<b>0.009</b>
	Leaf Width (mm)	AF	15.44	21.14	19.21	0.060
		OG	19.46	23.18		
		CS	15.04	17.50	19.12	0.089
	% Flowering	AF	32.98	59.11	56.01	0.226
		OG	9.55	24.96		
		CS	21.38	20.30	22.82	0.601
	Flower number per plant	AF	1.36	2.77	1.71	0.104
		OG	1.36	2.35		
		CS	<b>1.17</b>	<b>2.80</b>	<b>2.56</b>	<b>0.001</b>
	% June Floral Herbivory	AF	53.83	16.88	21.55	0.070
		OG	80.83	52.44		
		CS	<b>74.59</b>	<b>22.26</b>	<b>3.17</b>	<b>0.003</b>
	% Leaf Graze	AF	80.58	62.41	75.29	0.473
		OG	84.50	77.92		
		CS	97.75	80.86	80.90	0.079
% August Floral Graze	AF	71.67	78.44	82.74	0.771	
	OG	95.83	81.87			
	CS	<b>86.14</b>	<b>57.62</b>	<b>42.62</b>	<b>0.027</b>	
% Capsules Surviving	AF	6.67	26.73	39.88	0.147	
	OG	0.00	32.99			
	CS	<b>3.13</b>	<b>48.81</b>	<b>70.95</b>	<b>0.0001</b>	

Output 4. Comparison of change in plant community functional group frequency between 2003 and 2009 across study areas (all control and large-mammal exclosures combined). P-values from two sample T-tests or Mann-Whitney tests when data were not normally distributed.

Site	Data (Frequency)	Overall change between 2003 and 2009		
		2003	2009	P-Value
Agate Flat	Average of Native Perennial grass	7	9.9	0.170
	Average of annual grass	98.4	98.9	0.453
	Average of Forb	90.5	94.9	0.440
	Average of Shrub	2.1	4.4	0.557
	Average of Bare soil	40.8	48.4	0.286
	Average of Cowpie	0.6	0.7	0.084
Oregon Gulch	Average of Native Perennial grass	66.8	68.8	0.463
	Average of annual grass	66.7	60	0.193
	Average of Forb	92.5	94.3	0.406
	Average of Shrub	1.4	1.9	0.299
	Average of Bare soil	83.9	80.6	0.215
	Average of Cowpie	0.3	0.4	0.084
Colestine	Average of Native Perennial grass	79	82.5	0.590
	Average of annual grass	61.9	42.5	0.012
	Average of Forb	83.7	87.7	0.172
	Average of Shrub	4.6	9.6	0.274
	Average of Bare soil	78.89	80.7	0.973
	Average of Cowpie	0	0	

Output 5. Comparison of change in plant community functional group frequency between 2003 and 2009 between control sand large-mammal exclosures. P-values from two sample T-tests or Mann-Whitney tests when data were not normally distributed.

Year	Site	Data	Change between 2003 and 2009		
			Control	Large-Mammal	P-Value
2009-2003	Agate Flat	Average of Native Perennial grass	-0.4	6.2	0.089
		Average of annual grass	-0.6	1.6	0.082
		Average of Forb	8.6	0.2	0.396
		Average of Shrub	2.2	2.4	0.944
		Average of Bare soil	9	6.2	0.848
		Average of Cowpie	0.2	0	0.347
	Oregon Gulch	Average of Native Perennial grass	2.2	1.8	0.944
		Average of annual grass	0.2	-13.6	0.157
		Average of Forb	0.4	3.2	0.530
		Average of Shrub	1	0	0.296
		Average of Bare soil	-0.4	-6.2	0.265
		Average of Cowpie	-0.6	0.8	0.199
	Colestine	Average of Native Perennial grass	-0.8	7.8	0.525
		<b>Average of annual grass</b>	<b>-3.2</b>	<b>-35.6</b>	<b>0.008</b>
		Average of Forb	2.6	5.4	0.632
		Average of Shrub	0.2	9.8	0.316
		Average of Bare soil	-3.4	3.5	0.746
		Average of Cowpie	0	0	

Output 6. Comparison of change in plant community functional group cover between 2003 and 2009 across study areas (controls and large-mammal exclosures combined). P-values from two sample T-tests or Mann-Whitney tests when data were not normally distributed.

Site	Data (Cover)	Overall change between 2003 and 2009		
		2003	2009	P-Value
Agate Flat	Average of Exotic grass cover	<b>28.225</b>	<b>44.99</b>	<b>0.009</b>
	Average of Native grass cover	0.35	0.33	0.959
	Average of Exotic Forb Cover	0.52	0.37	0.582
	Average of Native Forb cover	16.91	9.83	0.015
	Average of Shrub/woody species	0.95	1.15	0.375
Oregon Gulch	Average of Exotic grass cover	7.61	6.55	0.721
	Average of Native grass cover	14.23	15.65	0.384
	Average of Exotic Forb Cover	0.235	0.16	0.288
	<b>Average of Native Forb cover</b>	<b>9.315</b>	<b>13.45</b>	<b>0.017</b>
	Average of Shrub/woody species	1.7	1.1	0.414
Colestine	Average of Exotic grass cover	8.14	3.63	0.103
	<b>Average of Native grass cover</b>	<b>15.57</b>	<b>28.98</b>	<b>0.002</b>
	Average of Exotic Forb Cover	0.194	0.05	0.366
	Average of Native Forb cover	5.24	6.45	0.339
	Average of Shrub/woody species	2.01	3.99	0.051

Output 7. Comparison of change in plant community functional group cover between 2003 and 2009 between controls and large-mammal exclosures. P-values from two sample T-tests or Mann-Whitney tests when data were not normally distributed.

Year	Site	Data	Change between 2003 and 2009		
			Control	Large-Mammal	P-Value
2009-2003	Agate Flat	Average of Exotic grass cover	14.02	19.51	0.620
		Average of Native grass cover	-0.18	0.14	0.699
		Average of Exotic Forb Cover	0.52	-0.82	0.207
		Average of Native Forb cover	-2.98	-11.18	0.079
		Average of Shrub/woody species	-0.1	0.5	0.376
	Oregon Gulch	Average of Exotic grass cover	-3.04	0.92	0.324
		Average of Native grass cover	3.42	-0.58	0.216
		Average of Exotic Forb Cover	0.02	-0.17	0.163
		Average of Native Forb cover	2.16	6.11	0.173
		Average of Shrub/woody species	-1.4	0.2	0.434
	Colestine	Average of Exotic grass cover	0.98	-10	0.032
		Average of Native grass cover	10.72	16.1	0.399
		Average of Exotic Forb Cover	-0.188	-0.1	0.712
		Average of Native Forb cover	0.74	1.68	0.719
		Average of Shrub/woody species	1.52	2.44	0.738