

**OREGON DEPARTMENT OF AGRICULTURE  
NATIVE PLANT CONSERVATION PROGRAM**

**Annual Program Performance Report  
for Howell's Mariposa Lily:  
*Calochortus howellii***

**2012 Monitoring and Population Stability Evaluation**

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for  
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## Introduction

### *Howell's mariposa lily*

Restricted to the Illinois River drainage in the Siskiyou Mountains of southwestern Oregon (Josephine County), populations of *Calochortus howellii* occur in a narrow band extending from the Eight Dollar Mountain area south to near Oregon Mountain, a short distance north of the California line. Plants bloom in late spring and are perhaps the showiest of several *Calochortus* species occurring in the area, with robust specimens ranging up to 50 cm tall or more (though plants typically range from 20-30 cm; Figure 1). Plants



**Figure 1.** A *Calochortus howellii* plant in flower at the Selma site.

arise from subterranean bulbs, although individuals may not produce flowering stalks every year. Consequently, populations are comprised primarily of non-flowering individuals (and potentially non-emergent individuals) in any given season. The soils supporting *C. howellii* populations are ultramafic in origin, consisting of colluvium and residuum derived directly from serpentinite and peridotite deposits. The species is a serpentine endemic, occurring only on soils with low calcium to magnesium ratios (Fredricks 1986).

Populations occupy exposed, rocky slopes (often south or west facing), generally at elevations below 650 m, and are scattered among the sparse vegetation that typifies serpentine regions (Figure 2). Despite its narrow distribution and edaphic specificity, *C. howellii* may occur in several local plant community types, with sites dominated by a fairly wide range of ultramafic-tolerant taxa such as *Achnatherum lemmonii*, *Ceanothus pumilus*, *Danthonia californica*, *Festuca rubra*, *Melica geyeri*, *Pinus jeffreyi*, *Quercus vaccinifolia*, and several *Arctostaphylos* species (Fredricks 1986). Sites are seasonally moist, but can be very dry by mid-summer.

## **Conservation status**

*Calochortus howellii* was listed as Threatened by Oregon Department of Agriculture (ODA) in 1995, and is considered to be a Species of Concern by U.S. Fish and Wildlife Service. It is regarded as endangered throughout its range by the Oregon Natural Heritage Information Center (ORBIC 2010). Although *C. howellii* continues to be listed as Threatened (rather than Endangered) by ODA, the conservation status of this species may be more in question today than 21 years ago. A narrow endemic, with most populations occurring on private lands lacking administrative protection, *C. howellii* is currently threatened by the potential for mining in serpentine areas and the increasingly common specter of competition from serpentine-tolerant weed infestations. Additionally, the affect of incidental disturbances such as road building, grazing, and fire suppression activities on the hydrology of the seasonal wetland habitat preferred by this species is not known – these activities may degrade sites to the point that they are no longer suitable for *C. howellii*. Although the number of known populations has increased since listing, and populations on public land receive protection, ongoing or periodic monitoring is needed to keep knowledge regarding the status and stability of this species up-to-date.



**Figure 2.** *Calochortus howellii* shares its unique habitat at the Selma site with other uncommon serpentine endemic species.

## ***Transition matrix modeling***

Transition matrix modeling is an effective and widely used method of evaluating demographic data. Transition matrices are constructed by calculating the proportion of individuals that make the transition from one stage to another each year, and the fecundity of each stage. Results are then summarized in a matrix, and various statistics are calculated. The most commonly calculated statistic derived from the transition matrix is the dominant latent root of the matrix, lambda ( $\lambda$ ), which represents the finite rate of population increase after a stable size distribution has been reached. An increasing population has a  $\lambda > 1.0$ ; a  $\lambda < 1.0$  indicates a decreasing population, and  $\lambda = 1.0$  denotes one with a stable growth rate (Fiedler et al. 1998). Statistics associated with  $\lambda$  provide information on the stage structure of the population, the relative contribution of each stage to future population growth, and the impact of each matrix transition on the calculated growth rate (Caswell 1989).

Calculations of  $\lambda$  and other derived values are useful to compare populations, environments or stages. Transition matrix models have been used to improve the understanding of the unusual life history of *Arisaema triphyllum* (Bierzychudek 1987), provide insights into the metapopulation dynamics of *Pedicularis furbishiae* (Menges 1990, Menges 1998), and allow for the comparison of the life history of rare and common species of *Calochortus* (Fiedler 1987). Population viability statistics derived from a transition matrix are especially valuable for evaluating the persistence of a series of populations in different habitats (Damman and Cain 1998) or under different management regimes (Nantel et al. 1996, Kaye et al. 2001).

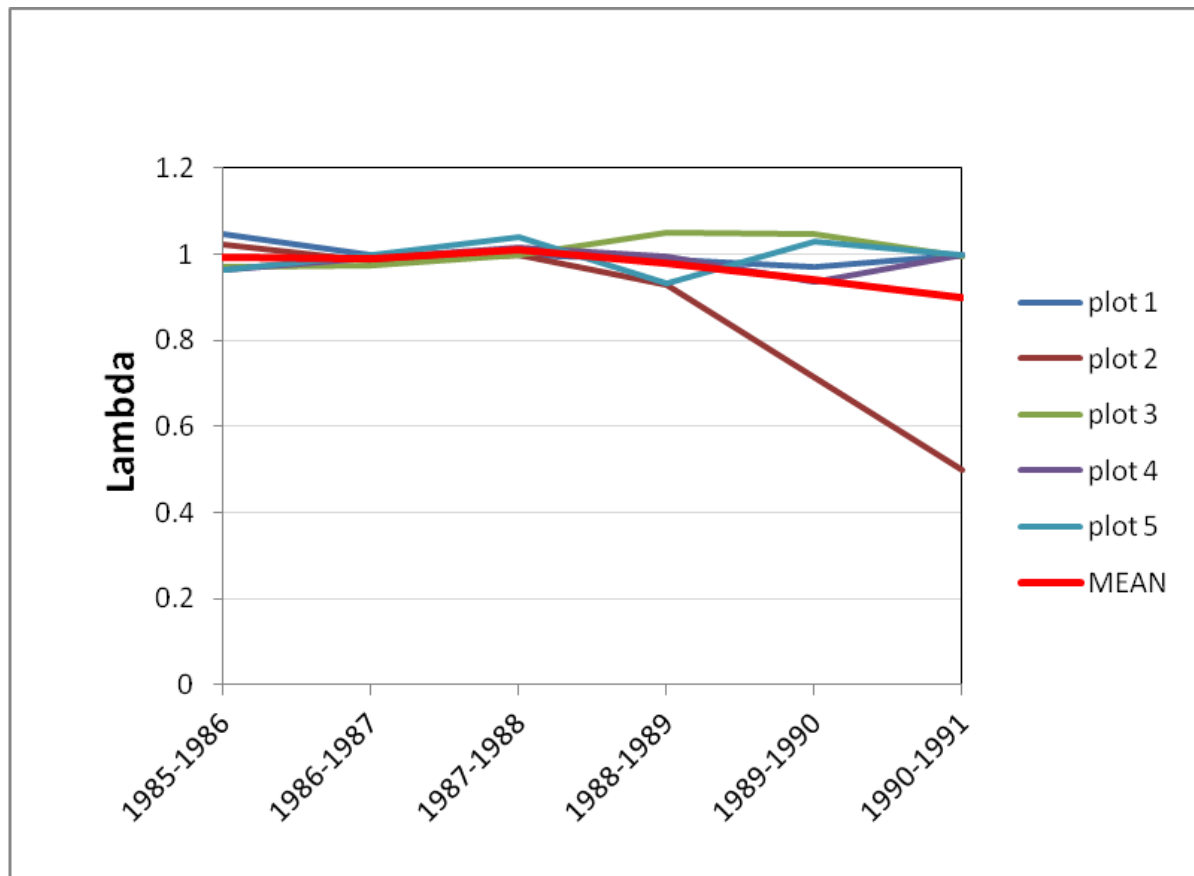
## ***History of demographic studies at Eight Dollar Mountain***

In 1983, Nancy Fredricks (Ph.D. student at Oregon State University at the time, and later Forest Botanist for the Gifford-Pinchot National Forest), established a long-term demographic study of a population of *Calochortus howellii* located southwest of Eight Dollar Mountain (Fredricks 1986, Fredricks 1992, Fiedler et al. 1998). Five large plots, each 25m<sup>2</sup>, were established on gentle slopes just west of the Illinois River (Mariposa Meadow site, in Day's Gulch Botanical Area, Rogue-Siskiyou National Forest). This population was selected because it was "among the most vigorous and densest known," and plots were set up to

incorporate the range of microhabitats occupied by *C. howellii* at this location, which was situated within the heart of the species' range. Beginning in 1983, the location of each individual plant was plotted, with monitoring of these plants continuing for the next eight years. Reproduction, recruitment, and mortality were evaluated, and considerable information was also amassed on the life history of the species. Dr. Fredricks used size-classified transition matrices to summarize demographic data and calculate  $\lambda$  for each transition in each plot. Based on an extensive data set and using matrix modeling methodology, she was able to make predictions regarding the stability of the species at this site.

By tagging and tracking *C. howellii* plants in the five plots, she learned that this species is long-lived and slow growing, and exhibits overall low mortality and low recruitment. No seedlings emerging over the course of the study ever advanced to the reproductive stage, and older non-reproductive plants also grew very slowly. The length of time needed for *C. howellii* plants to reach reproductive maturity, despite nearly a decade of monitoring, was never determined. Natural predation was an episodic but significant factor in the overall population stability at the site, with pocket gophers, deer, and insect herbivores affecting mortality rates as well as reproductive effort (through loss of flowers, capsules, and seeds). The percentage of plants producing capsules varied greatly during the Fredricks study, from 30% in 1983 to 1.4% in 1989 and 1990.

Dr. Fredericks' demographic study produced a picture of general stability for *C. howellii* at the Mariposa Meadow site, with an overall mean  $\lambda$  of 0.99 (averaged for all plots and six transition years). However,  $\lambda$  varied among plots and among years, with one plot in particular exhibiting a precipitous drop in numbers; this decline was hypothesized to be due to an increase in rodent activity (Figure 3).



**Figure 3.** Lambda ( $\lambda$ ) for six transitions in five plots at the Mariposa Meadow site. The last two values for Plot 2 drop sharply, reducing the mean for the population overall. Data from Fredricks 1992.

Fredericks' data also underscored the vulnerability of the species by revealing its slow growth, very limited recruitment, and susceptibility to reproductive limitation and seed loss due to insect herbivory and grazing. Considering this delicate balance, it is natural to wonder how the dynamics of this population may have changed over the years since the original study ended. Have population numbers remained stable or declined? Are the predications Fredericks made validated by current plot censuses? Does ground-level herbivory significantly affect population census numbers? If the population has declined, is it possible to ascertain if the decline is due to management actions, or from natural factors such as predation? How does Fredericks' well-studied population compare with others in the vicinity?

## Study objectives

- ❖ Resample the plots originally set up by Fredricks in 1983, and to evaluate the current number of plants present within study plots in regard to the predictions made in her work.
- ❖ Monitor a series of comparable plots installed in 2006 on land managed by Bureau of Land Management, to evaluate the species at more than one location.
- ❖ Provide information complementary to the Population Viability Analysis of *C. howellii* by evaluating reproductive output, seed germination rates and the potential for recruitment.

## Methods

### *Plot locations*

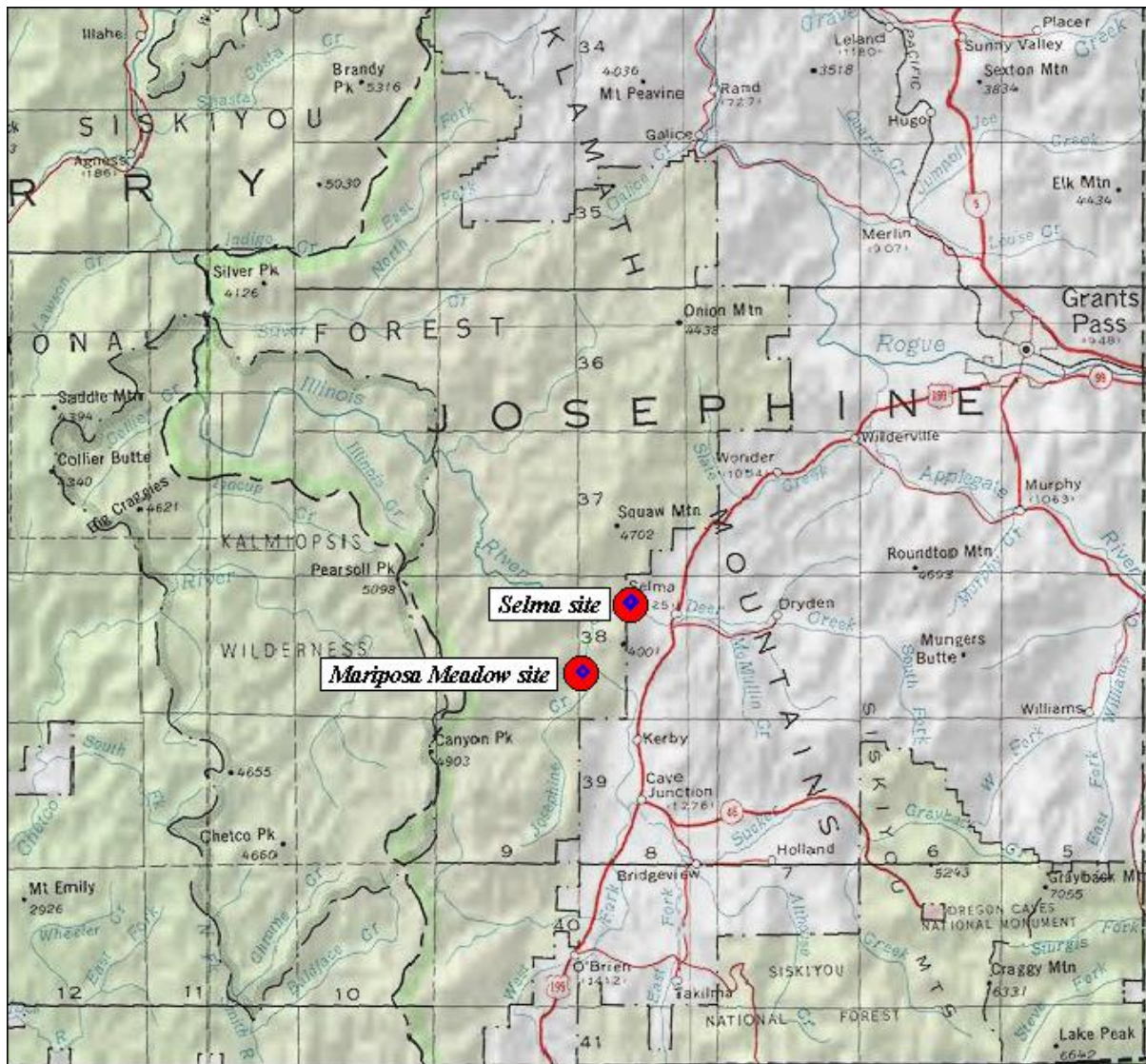
In 2006, four of the original five plots set up by Fredericks in 1983 were relocated. In addition, a second series of plots, with the same dimensions as those at Mariposa Meadow, were established approximately two miles directly west of Selma, in an area with several observed *C. howellii* populations (Figure 4). This site is located on land administered by the Bureau of Land Management (BLM), and is quite similar to the site of the Fredricks study. Details of plot setup and initial data collection are described in Meinke et al. 2007, Meinke and Amsberry 2008, and Amsberry and Meinke 2010. (See Appendices A-D for plot locations and associated species.)

Plot set-up followed a similar protocol at both the Mariposa Meadow and Selma sites. At the Mariposa Meadow site, the original marker stakes for the previously established plots were located in 2006, and new rebar was set in place for each corner. Because the soil here can be rather “spongy” due to a shallow water table, the orientation of the previous plots had shifted slightly (i.e., the original corner posts have slightly moved and the plots are no longer perfectly square). However, our reestablishment of the plots using new corner stakes



approximates the size and orientation of the original plot locations. Each macroplot measures 5 m x 5 m and consists of 25 microplots, each a meter square.

The precise locations for the four new plots at the Selma site were selected arbitrarily, and the immediate locale was subjectively chosen based on the presence of several *C. howellii* clusters. The plots were arranged over an area comparable in size to the study area at the Mariposa Meadow site.



Map created with TOPO!® ©2003 National Geographic ([www.nationalgeographic.com/topo](http://www.nationalgeographic.com/topo))

**Figure 4.** Location of the two study sites in Josephine County, Oregon. See appendices for specific site locations.

## ***Plot census data collection and analysis***

For the first five years, plot census data collection at both sites consisted of mapping all plants in each of 25 microplots in each 5x5 meter macroplot, identifying the life history stage of each plant, observing the presence of any herbivore-related damage, and assessing the potential for plants to disperse seeds (Meinke et al. 2007). In 2011 and 2012, locations of individual plants were no longer mapped, but all plants in each plot were counted and evaluated for reproductive maturity and the presence of herbivory (Figure 5). Because the original Plot 3 at Mariposa Meadow was never relocated, and Plot 4 at Selma (set up in 2006) was not re-located after 2007, data from these plots are not included in data analysis for among year comparisons, or included in population viability analyses. In order to accurately evaluate the life history stage of each plant (reproductive or vegetative), and collect data on capsules and seeds, plot censuses were completed in late June, when plants were in fruit.

Population viability analyses (PVA) were completed by Tom Kaye (Institute for Applied Ecology, Corvallis, Oregon) using SHUFFLE to calculate extinction probability and LAMS to calculate stochastic lambda, both using matrix selection techniques. All modeling was conducted in MATLAB using data collected in 1983-1991 by Nancy Fredericks.

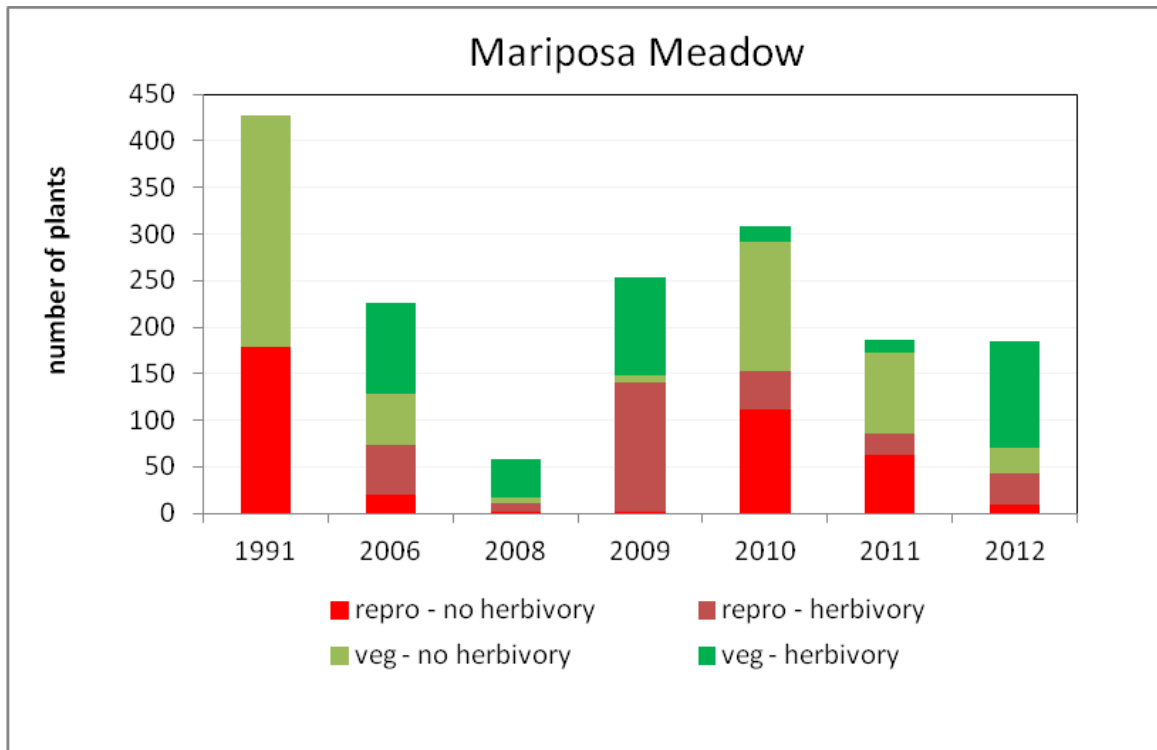


**Figure 5.** Monitoring *C. howellii* plots involves the careful identification of plants and evaluation of reproduction and herbivory.

# Results

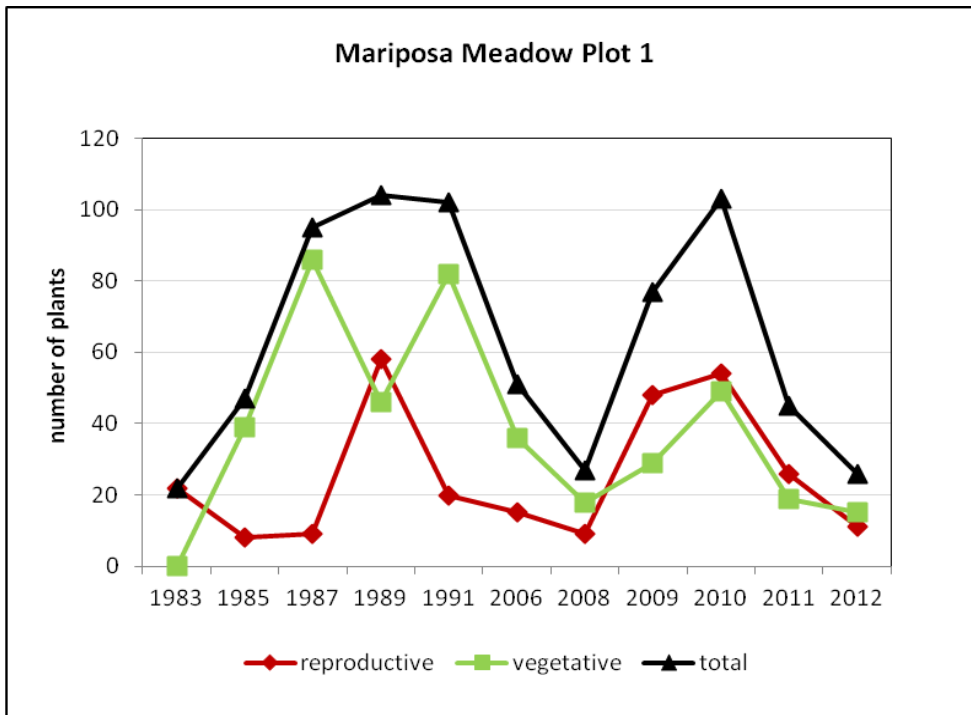
## *Mariposa Meadow plot summary*

In 2012, although the total number of plants observed remained stable, the number and proportion of browsed plants increased (Figure 6). Since plot monitoring began again in 2006, the total number of plants observed has been less than the count from the final year's total in the Fredricks' study in 1991. Plant numbers for all plots at Mariposa Meadow in 2006 were nearly 50% below the count from 1991, with an additional decrease in numbers between 2006 and 2008. However, in 2009, emergent plant totals rebounded to levels slightly above those seen in 2006 and increased again in 2010 (Figures 6-10). In 2011 the total number of plants decreased below the amount observed in 2006, but the number of browsed plants remained fairly low during late season monitoring in June.

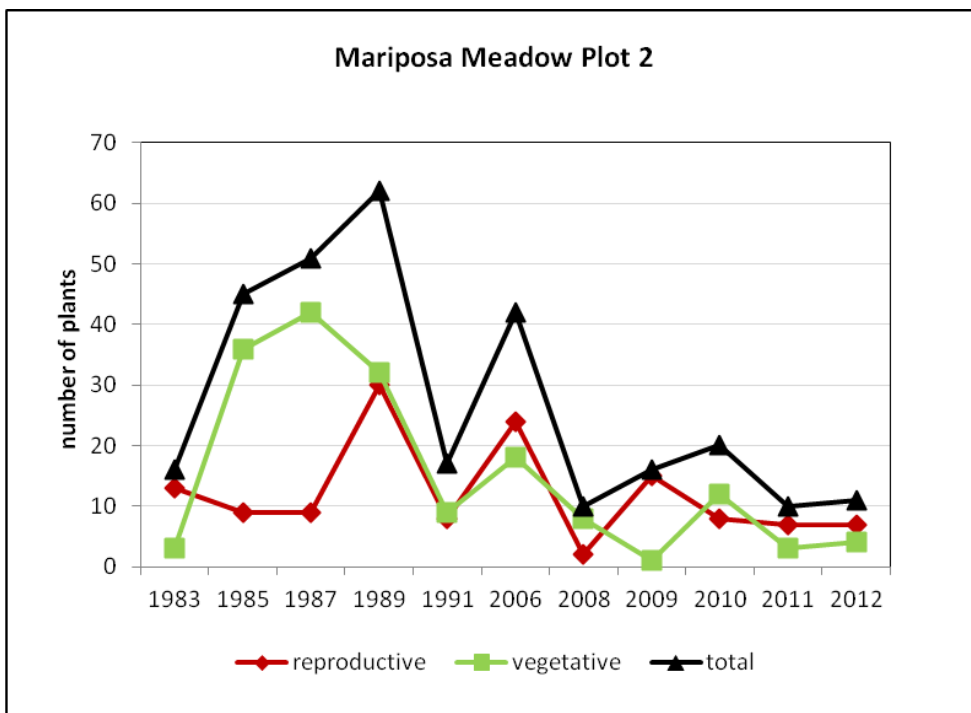


**Figure 6.** Numbers of plants in the plots at the Mariposa Meadow site declined between the completion of the Fredricks study in 1991 and the initiation of our study. (In 1991, browsed plants were not differentiated from plants that did not show evidence of herbivory; 1991 data from Fredricks 1992). Since the initiation of our study, the number of plants fluctuated each year, potentially due to periodic emergence and ground level predation.

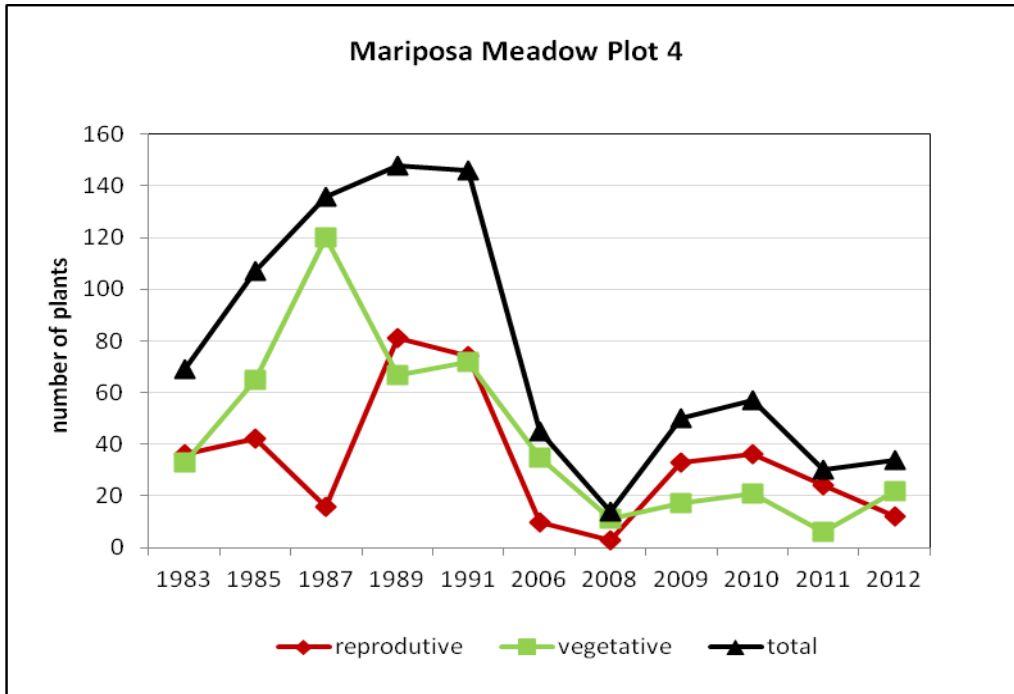
In 2012, the number of reproductive and vegetative plants in Plot 1 decreased, resulting in overall fewer plants than observed in 2009-2011 (Figure 7). This count represents the second lowest number of plants since monitoring began in 1983, with fewer reproductive than vegetative individuals. The number of reproductive plants in Plot 2 remained stable, with the slight increase in vegetative plants resulting in a slight increase in total plants (Figure 8). Interestingly, although Plot 2 had the lowest mean  $\lambda$  (Figure 3), it was the only plot with an increase in plant numbers between 1991 and the initiation of our study in 2006 (Figure 8). The number of observed plants declined in this plot in 2008 to approximately the level observed in 1991, and with slight fluctuation, has remained relatively stable since then. In Plots 4 and 5, a decrease in the number of reproductive plants was offset by increases in the number of vegetative plants, yielding overall increases (Figure 9 and 10). Despite the increase in the number of plants in Plot 4, the total count remains below the 2009 and 2010 counts, yet above the low point of 2008. In this plot, and in Plot 1, the number of reproductive plants has been more than the number of vegetative individuals since 2008: this trend reversed in 2012 (Figures 7 and 9). In Plot 5, the number of vegetative plants continued to trend up and increased markedly more in 2012 than in the previous two years (Figure 10). The number of reproductive plants in Plot 5 continued to decline, and decreased to the lowest levels recorded since 2008. Although the number of observed plants increased in three of the four plots monitored in 2012, this was offset by the decrease of observed plants in Plot 1, resulting in overall fewer plants in monitored plots than were observed in 2011. To date, monitoring data exhibit a great deal of variability, and do not elucidate any profound general trends.



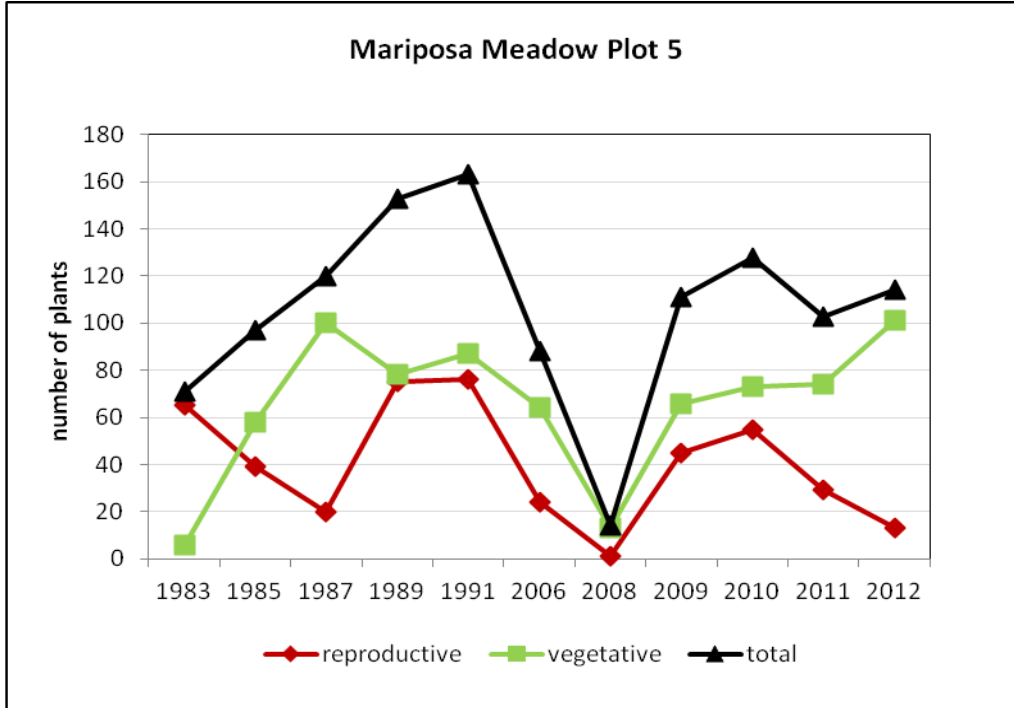
**Figure 7.** The number of vegetative and reproductive plants continued to decrease in 2012, reaching the second lowest level since monitoring began.



**Figure 8.** In 2012, the number of plants in Plot 2 remained near the low level recorded in 2008.



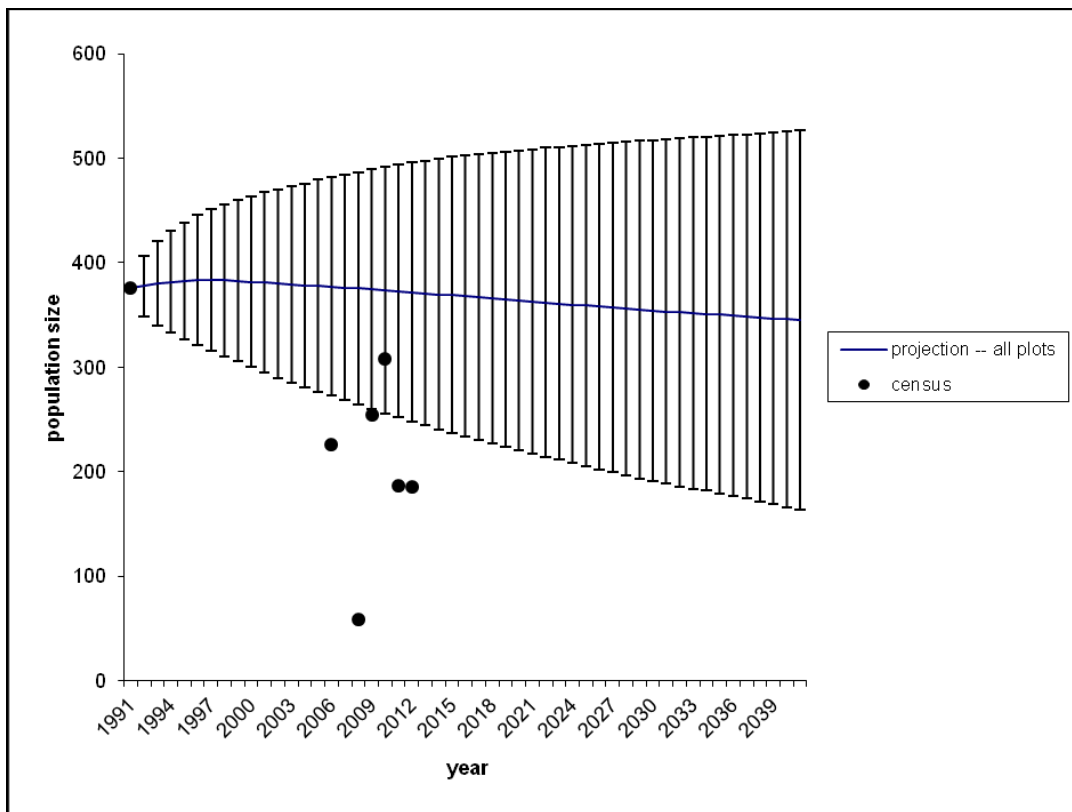
**Figure 9.** The number of reproductive plants continued to decline in 2012, but the number of vegetative plants increased to a level greater than the number of reproductive plants for the first time since 2008, resulting in an overall slight increase.



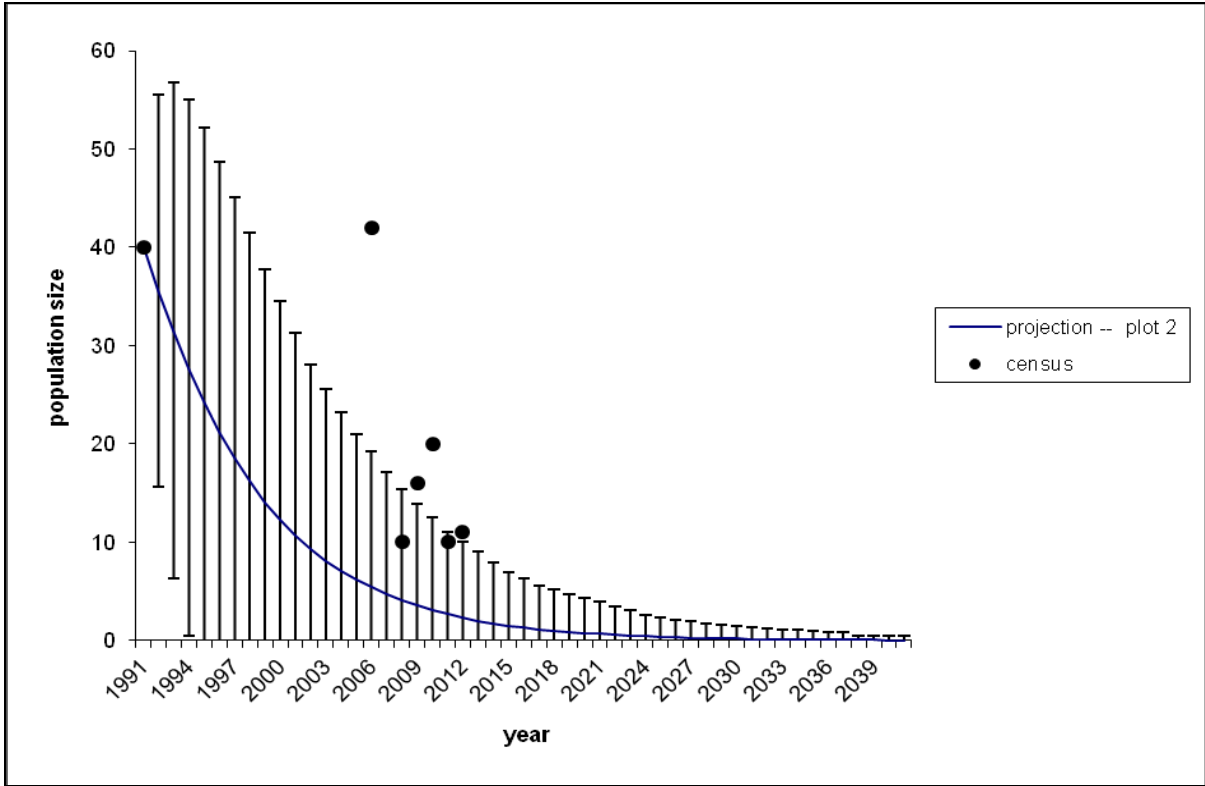
**Figure 10.** The number of reproductive plants continued to decrease in 2012, but the number of vegetative plants continued increasing, resulting in an overall increase of plants in the plot.

## Population viability analyses

The population viability analysis model developed from Fredericks 1983-1991 data did not correctly predict population trends as measured from 2006-2012 at the Mariposa Meadow site. The model overestimates population size when compared to actual census data (collected from the four locatable plots) during the course of our study with the exception of the 2010 census (Figure 11). Data from the six years of our study document widely fluctuating population numbers, making evaluation of any potential trends difficult. Additional years of monitoring may provide sufficient data to confidently predict population trends or may document continuing variability. The model also underestimates the population in Plot 2 for four of the six years measured (Figure 12).



**Figure 11.** Mariposa Meadows total census numbers (for Plots 1, 2, 4 and 5 combined) during the course of our study, with the exception of 2010, do not fall within confidence intervals (two standard deviations above and below the mean) for projected population size. However, low sample sizes may be due to lack of observation of plants due to ground level herbivory or periodic emergence and non-emergence. Data from Fredericks 1992, PVA completed by T. Kaye.



**Figure 12.** Mariposa Meadows Plot 2 census counts in 2006, and 2009, 2010 and 2012 do not fall within confidence intervals (two standard deviations above and below the mean) for projected population size. The census of the plot in 2008 and 2011 both represent a number predicted by the model. Data from Fredericks 1992, PVA completed by T. Kaye.

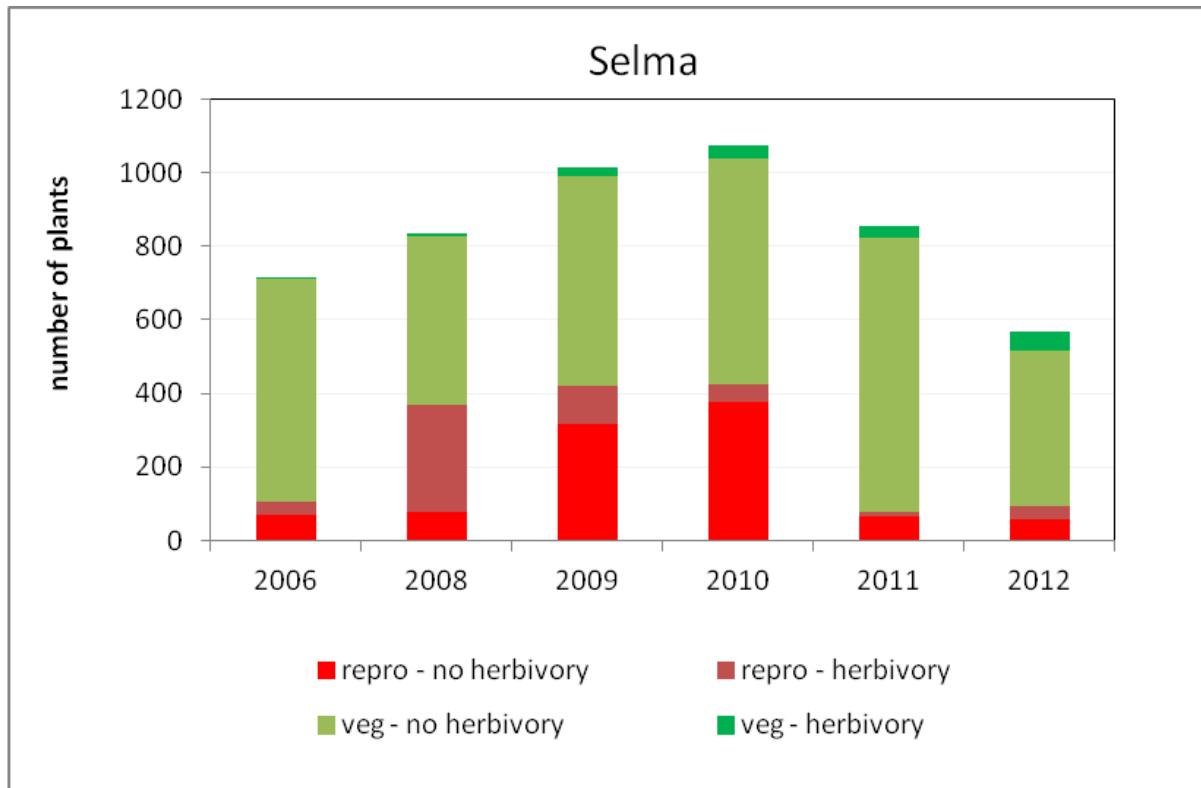


**Figure 13.** Monitoring at the Mariposa Meadows site revealed that fewer *C. howellii* plants are persisting in the plots than the Fredericks' population viability analysis model predicted.



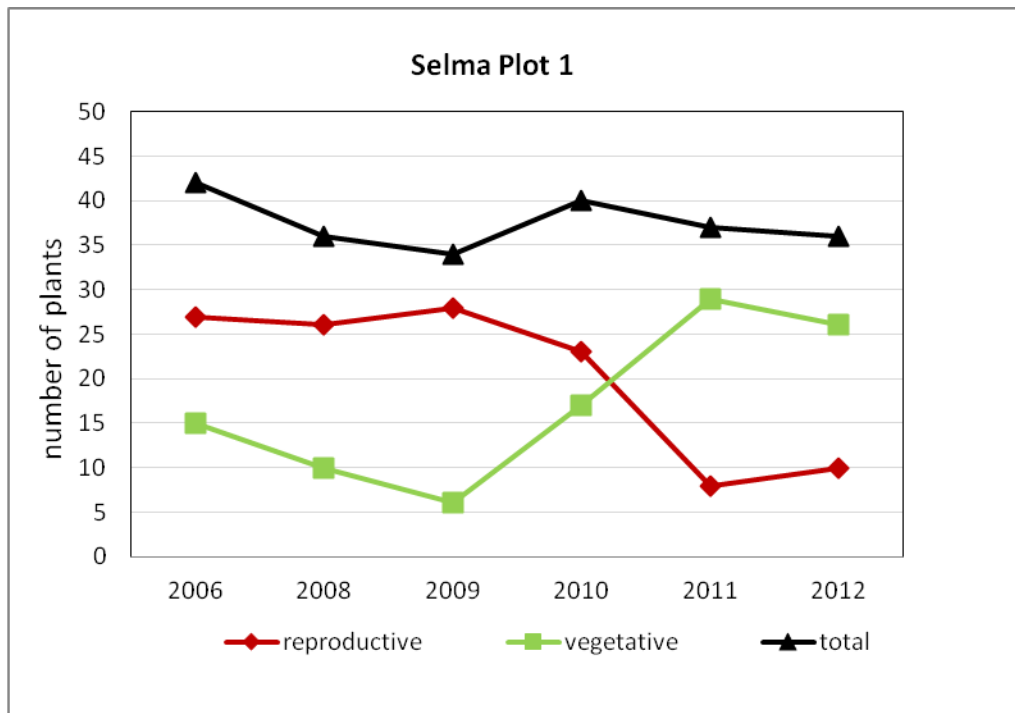
## Selma plot summary

Although the number of plants in plots in the Selma site increased between 2006 and 2010, in 2011 and 2012 population size declined, with fewer plants observed in 2012 than at the initiation of the study (Figure 14). The decreases in the overall number of plants observed in 2011 and 2012 coincide with a marked decrease in the number and proportion of reproductive plants. After low levels of observed herbivory in 2011, the number of both vegetative and reproductive browsed plants increased in 2012. In general, lower proportions of browsed plants are observed in the Selma site compared to Mariposa Meadows.

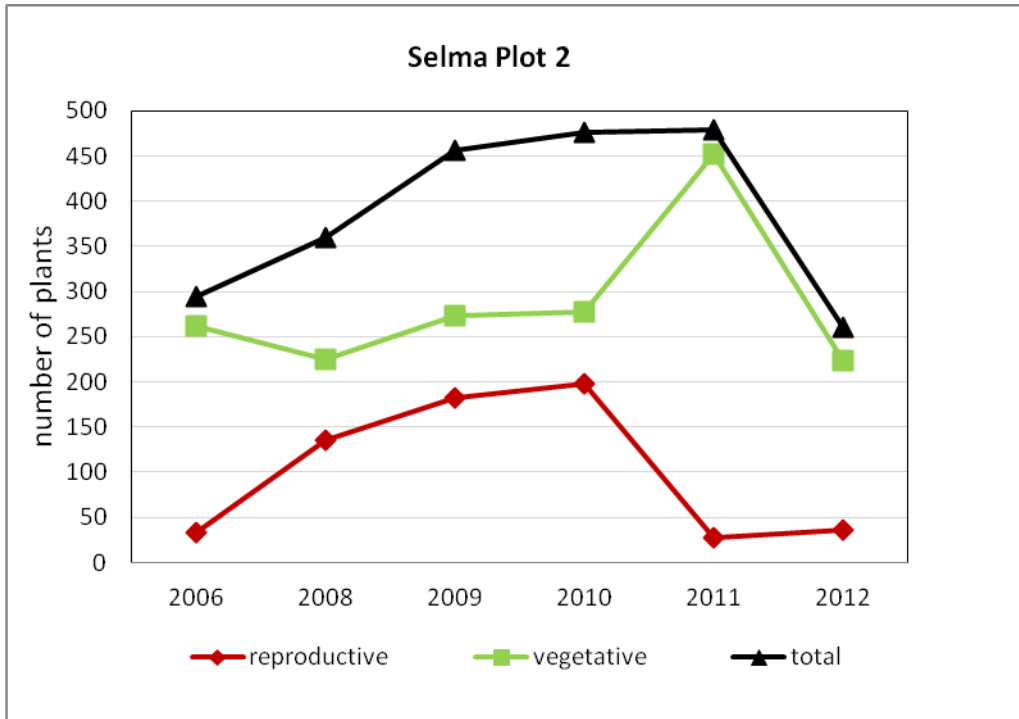


**Figure 14.** The increase in the total number of *C. howellii* plants observed in plots at the Selma site from 2006 to 2010 has been followed by a decline in 2011- 2012 to the lowest total count since monitoring began. In contrast to 2011, many fewer vegetative plants were observed in 2012, while the number of reproductive plants remained relatively stable, although low. The number of browsed plants also increased in 2012.

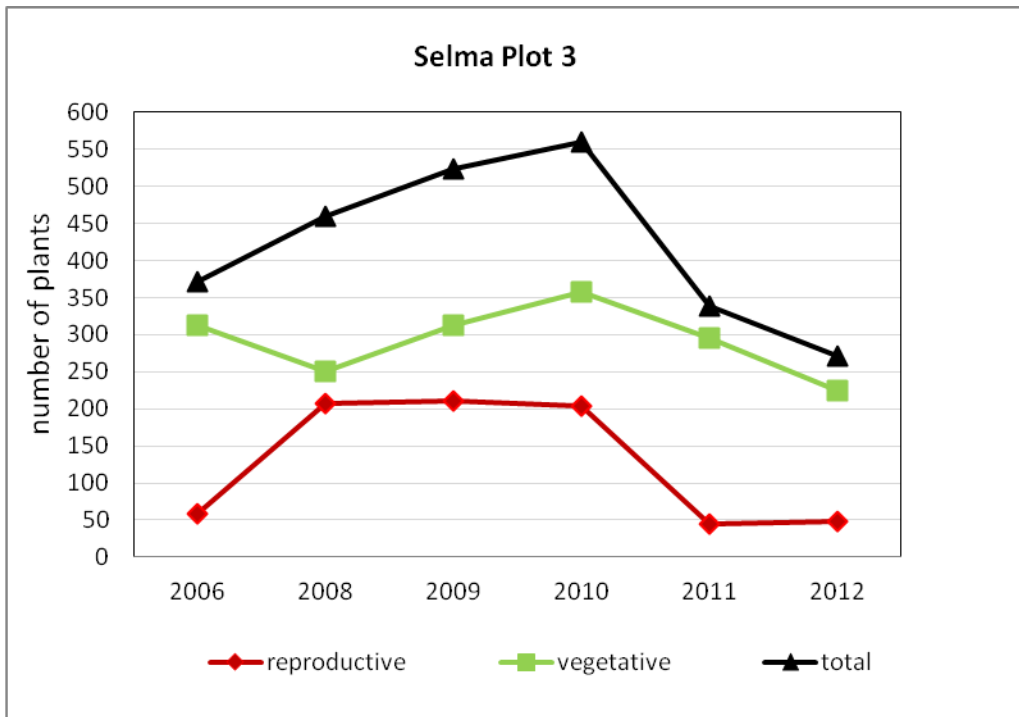
The total number of plants observed in each of the three plots decreased in 2012 (Figure 15-17). The total observed plants in Plot 1 decreased only slightly as a result of a slight decrease in the number of vegetative plants offset by a lesser increase in reproductive plants. In 2011 the number of reproductive plants fell below the level of the vegetative plants and that relationship was repeated in 2012. In Plot 2, the overall number of plants observed decreased as a result of a large decrease in the number of vegetative plants (to their lowest count since monitoring began). This marked decrease comes after an exceptionally high count of vegetative plants in 2011. The number of reproductive plants in Plot 2 increased only slightly in 2012 after a marked decrease in 2011. The number of plants in Plot 3 continued to decrease in 2012 as a result of a continued decline in the number of vegetative plants and only a slight increase in reproductive individuals.



**Figure 15.** The total number of plants declined slightly as a result of a decrease in the number of vegetative plants combined with a minor increase in reproductive plants.



**Figure 16.** The total number of total plants declined drastically due to a sharp decrease in the number of vegetative plants.



**Figure 17.** Vegetative plant numbers dropped in 2012, resulting in fewer total plants.

## Howell's mariposa lily on TV!

In 2012, the Mariposa Meadows population of *Calochortus howellii* was featured on Oregon Field Guide, a popular television series covering agriculture, natural history and outdoor recreation on Oregon Public Broadcasting (Figure 18).

<http://watch.opb.org/video/2296035657/>

This program segment focused on threats to Oregon's agriculture and native flora created by the escape of an experimental crop plant (*Alyssum murale*), and highlighted Howell's mariposa lily as an example of the unique

Southern Oregon wildflowers that are potentially at risk due to invasions of this weed.

<http://earthfix.opb.org/multimedia/slideshows/how-a-nickel-mining-scheme-brought-an-invasive-flo/>

After an initial bit of stage fright, the lilies performed admirably, and they are looking forward to future acting engagements.



**Figure 18.** OPB reporter Amelia Templeton was captivated by the beautiful mariposa lilies.

## Discussion

Our data from the Mariposa Meadow site corroborated Fredricks' observations that, despite stability throughout much of her study (a mean  $\lambda$  of 0.994 for the first three transitions), the population size of *Calochortus howellii* here had begun to decline near the end of her data collection period. There were almost 50% fewer plants (in Plots 1, 2, 4 and 5) observed in 2006 than were reported in 1991 at the end of her study, and the smallest population size to date (58 total plants) was observed in 2008. The numbers of plants rebounded to above 2006 levels in 2009 and 2010, then subsequently declined in 2011 and 2012 to the lowest point since 2008.

Although the cause for this decline in population size in Frederick's study was not immediately apparent, several factors were put forth as potential explanation for the reduction in the number of emergent plants. Repeated herbivory of buds, flowers and capsules may have resulted in continued reproductive failure, with subsequent lack of seedling recruitment. Our documentation of low capsule production in 2011 lends credence to this theory. Herbivory of *Calochortus* plants is common, with "the fate of the majority of the flowers and fruits produced is to be either completely grazed, or to experience ovule abortion due to sawfly larvae damage" (Fiedler et al. 1998). When herbivore pressure on flowers and fruits is relatively low, reproductive values rise accordingly, contributing to the episodic reproduction observed in many species in this genus (Fiedler 1987, Fredricks 1992, Miller et al. 2004). Because reproductive failure in *Calochortus* is slow and difficult to detect in the field, it is difficult to distinguish threats to long term population persistence from a "chance run of failures between rare bouts of success" (Fiedler et al. 1998). Multiple year datasets are needed in order to accurately evaluate the status of populations or taxa which exhibit this strategy.

Periodic dormancy of a portion of the bulbs in a given site may also contribute to a perceived decline in population numbers. Fredricks initially reported apparent bulb dormancy in her plots (Fredricks 1986). However, after further investigation, she felt that these "dormant" bulbs had actually emerged at the start of the growing season, but had been grazed at ground level prior to observation. A later investigation of dormancy in *Calochortus lyalli* and *C.*

*macrocarpus* documented that 2%-26% plants in the study populations experienced single-year dormancy, and up to 4% experienced multiple-year dormancy. Dormancy may be a response to herbivory during the previous growing season, may be caused by poor environmental conditions in the current or prior year, or may be related to events (such as fungal infection or herbivory) occurring between the sprouting of the bulb and the emergence of shoots above the ground (Miller et al. 2004.)

However, data gathered from our plots in 2010 and 2011 suggest that the most likely explanation of periodic non-emergence is the one initially proposed by Fredericks – that is that bulbs are not truly dormant, but instead emerge, only to be immediately grazed. See Groberg et al. 2011a and Groberg et al. 2011b for details on the effects of ground level herbivory on census results. Lack of consideration of the effect of ground level herbivory at the time censuses are completed could contribute to inaccurate documentation of population numbers. However, because the degree of ground level predation did not differ much between the Selma and Mariposa Meadow sites, herbivory probably doesn't contribute to the differences in population dynamics between sites.

Although periodic non-emergence may be contributing to the low numbers of plants observed at the Mariposa Meadow site, mortality of bulbs has probably also occurred. Mortality may be due to the habitat becoming less suitable in response to hydrologic variation related to climate change (soil becoming drier), or to natural or anthropogenic changes that have created new conditions no longer appropriate for *C. howellii*. A changed environment may be resulting in adult mortality, inability of plants to reproduce (possibly due to lack of pollinators), or lack of habitat for seedling recruitment. Although no habitat alteration was immediately apparent during our years of field visits, a review of current and past management may elucidate a subtle but biologically significant change.

Our application of statistics from the Fredericks study demonstrates the potential value of transition matrices in predicting population stability or decline. More than twenty years after the end of the study, the monitored population of *C. howellii* at Mariposa Meadow has continued a trend of decline as expected. However, decline was initially much more severe than predicted by our PVA model, with all but the 2010 census numbers falling below

confidence intervals for the expected population value. In addition to falling below the confidence interval, the population sizes have fluctuated widely rather than decreased steadily.

A more detailed plot-by-plot look at the Fredricks predictions exhibits additional discrepancies. According to the PVA model, the plants within Plot 2 should be present at lower levels than they actually occurred. Although our census numbers from 2008 and 2011 fall within the predicted range, in all other years the population is larger than predicted. Because many years of data are needed to incorporate the complex variation characteristic of biological systems, development of a model that includes sufficient information to make accurate predictions can be daunting. Data from our study highlight the difficulties inherent in developing accurate PVA models, and the need for long-term datasets in order to create models that sufficiently capture population variation.

Meaningful evaluation of variable demographic data can also be confounded by the differing statistics that can result from various methods for developing and interpreting transition matrices. The recent use of matrix modeling and population viability analysis in interpreting a dataset of wolf population numbers after reintroduction resulted in two vastly different models (Theberge et al. 2006). The accompanying recommendations for achieving population stability were also quite different, sparking a heated debate between the two research groups (Patterson and Murray 2008). Other researchers have cautioned against basing conservation decisions solely on population viability analysis statistics (Taylor 1994, Fiedler et al. 1998), and suggest incorporating natural history information into threat assessment models.

After three years of a steady increase in numbers, the population at the Selma site began to decline in 2011 and continued to do so in 2012. In addition to a reduction in the number of total plants, the number of reproductive plants declined sharply in 2011 with only a slight rebound in 2012. Reproductive output data from 2010 and 2011 documented low reproduction and a decline in the number of potential recruits at both sites. This lack of reproduction has probably resulted in a decrease in actual recruitment in both populations

(Groberg et al. 2011b). This reduced recruitment, combined with a steady level of mortality, is likely responsible for the decreasing number of plants at the Selma site.

The high seed germination rates observed during the course of our study corroborate earlier documentation of germination rates “near 100%” under laboratory conditions (Fredericks 1986), and indicate that seed germination is not a limiting factor in the recruitment of *C. howellii*. However, even under ideal growing conditions in the OSU greenhouses and nursery yard, few of these seedlings matured to produce bulbs. Seedling mortality is likely to be even higher under natural field conditions. Data on reproductive output, seed germination, and bulb development provide explanations for the relative importance of these life history stages and processes as identified by PVA, and identify opportunities for adaptive management to improve recruitment in rare plant populations.



## Management recommendations

- ❖ Refine population size estimations and distributions to better inform future adaptive management strategies.
- ❖ Continue monitoring both sites. Data on emergence, reproduction and herbivory have varied widely to date – additional years of information will help reduce variability and allow accurate identification of trends in these two populations.
- ❖ Target capsule predation as a way to augment new recruits in the population. The low survival rate of the seedlings suggests that a large amount of seed must be produced in order for surviving recruits to enter the population. Fenced plots would prevent grazing and potentially allow many more reproductive plants to form capsules.

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## Appendices

**Appendix A.** Location of the four plots at Mariposa Meadow used in this study (Cave Junction, OR 1986).

**Appendix B.** Location of the four plots at the Selma site used in this study (Eight Dollar Mountain, OR 1986).

**Appendix C.** Coordinates, exposure and elevation of the two study sites.

	GPS Coordinates (NAD 83) for plots	Exposure	Elevation (m)
<b>Mariposa Meadow</b>		Southeast	425-465
<b>Selma</b>		South	410-470

**Appendix D.** Associated species at the two study sites.

<b>Mariposa Meadow</b>	<b>Selma</b>
<i>Achnatherum lemmonii</i>	<i>Achnatherum lemmonii</i>
<i>Arabis aculeolata</i>	<i>Arctostaphylos viscida</i>
<i>Arctostaphylos viscida</i>	<i>Allium amplexens</i>
<i>Allium amplexens</i>	<i>Aspidotis densa</i>
<i>Aspidotis densa</i>	<i>Balsamorhiza deltoidea</i>
<i>Balsamorhiza deltoidea</i>	<i>Balsamorhiza sericea</i>
<i>Balsamorhiza sericea</i>	<i>Brodiaea elegans</i>
<i>Brodiaea elegans</i>	<i>Brodiaea hyacinthina</i>
<i>Brodiaea hyacinthina</i>	<i>Castilleja pruinosa</i>
<i>Calocedrus decurrens</i>	<i>Carex sp.</i>
<i>Carex mendocinensis</i>	<i>Calochortus tolmiei</i>
<i>Calochortus tolmiei</i>	<i>Calochortus uniflorus</i>
<i>Calochortus uniflorus</i>	<i>Camassia leichtlinii</i>
<i>Camassia leichtlinii</i>	<i>Danthonia californica</i>
<i>Ceanothus cuneatus</i>	<i>Deschampsia cespitosa</i>
<i>Ceanothus pumilus</i>	<i>Eriophyllum lanatum</i>
<i>Danthonia californica</i>	<i>Festuca rubra</i>
<i>Deschampsia cespitosa</i>	<i>Hieracium parryi</i>
<i>Eriogonum nudum</i>	<i>Horkelia sericata</i>
<i>Eriophyllum lanatum</i>	<i>Lithophragma parviflora</i>
<i>Festuca rubra</i>	<i>Melica geyeri</i>
<i>Hastingsia alba</i>	<i>Microseris howellii</i>
<i>Horkelia sericata</i>	<i>Mimulus guttatus</i>
<i>Lithophragma parviflora</i>	<i>Penstemon laetus</i>
<i>Melica geyeri</i>	<i>Perideridia oregana</i>
<i>Microseris howellii</i>	<i>Phlox speciosa</i>
<i>Mimulus guttatus</i>	<i>Pyrocoma racemosa</i>
<i>Penstemon laetus</i>	<i>Pinus jeffreyi</i>



**Mariposa Meadow****Selma**

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*Pyrocoma racemosa*

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*Rhamnus californica*

---

*Pinus jeffreyi*

---

*Rhus diversiloba*

---

*Ranunculus occidentalis*

---

*Senecio canus*

---

*Rhamnus californica*

---

*Viola cuneata*

---

*Rhus diversiloba*

---

*Viola halli*

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*Senecio canus*

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*Zigadenus venenosus*

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*Viola cuneata*

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*Viola halli*

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*Zigadenus venenosus*

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