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Rare Plant Restoration and Monitoring at Lawrence Livermore National Laboratory, Site 300, Project Progress Report, Fiscal Year 2005 and 2006.

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Table of Contents

Section A—*Amsinckia grandiflora* Monitoring and Research

A-1. Introduction A-1
A-2. Methods and Materials....A-3
A-2.1. 2006 Seed Sowing at the Experimental Sites....A-3
A-2.2. Spring Census A-3
A-2.3. *Poa secunda* Persistence....A-5
A-2.4. Fire Frequency (FF) Experiment....A-5
A-2.5. Flashing Subpopulation Biomass Collection....A-6
A-2.6. Predation Monitoring A-6
A-2.7. Lupine Study....A-7
A-3. Results and Discussion....A-8
A-3.1. Spring Census A-8
A-3.2. Flashing Subpopulation Biomass Collection....A-10
A-3.3. Fire Frequency Experiment A-11
A-3.4. Predation Monitoring A-11
A-3.5. Lupine Study....A-11
A-4. Recommendations and Future Work A-11
A-5. References....A-13

Section A—List of Figures

Figure A1. Distribution of large-flowered fiddleneck at Site 300, and large-flowered fiddleneck critical habitat

Figure A2. Summary of experimental treatments at the experimental FL subpopulation.

Figure A3. Summary of experimental treatments at the experimental FF subpopulation.

Figure A4. Nearest neighbor composition of *A. grandiflora* reintroduced population at Lougher Ridge, 2005 (n=173).

Figure A5. Community biomass collected from *A. gradiflora* reintroduced population at Lougher Ridge, 2005 (n=5). Bar are one standard error.

Figure A6. Spring census data of the Site 300 Native Drop Tower population.

Figure A7. Spring census data of the Site 300 experimental FL subpopulation.

Figure A8. Spring census data of the Site 300 experimental FF subpopulation.

Figure A9. Log plot of population size at times of census, shown with rainfall totals over growing season.

Figure A10. Total average biomass for 1998 through 2006.

Figure A11. Biomass of burned vs. unburned FL plots for 1999 through 2006.

Figure A12. Average number of *Poa secunda* plants per plot for each of three burn frequencies.

Figure A13. Cumulative percent granivory in 2005 and 2006 by population and burn.

Figure A14. Predation intensity for all 2005 and 2006 locations.

Figure A15. Native population in Spring 2001 and 2004.

Figure A16. Drop Tower population in 2005 before and after the July wildfire.

Figure A17. Close up of FF and FL experimental populations after the July 2005 wildfire.

Section A—List of Tables

Table A1. FF plots burned in the July 2005 wildfire and prescribed burn schedule following the 2005 wildfire.

Table A2. Community composition of *A. grandiflora* reintroduced population at Lougher Ridge based on nearest neighbor data.

Table A3. Summary of demographic data collected from the Site 300 Drop Tower experimental and native populations and the Lougher Ridge experimental population.

Table A4. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower native and experimental populations: 1997–2001.

Table A5. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower native and experimental populations: 2002–2004.

Table A6. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower native and experimental populations: 2005–2006.

Table A7. Constancy, percent mean cover for all plots in each subpopulation, and I.V. for cover data collected from the native and experimental populations in 2005.

Table A8. Constancy, percent mean cover for all plots in each subpopulation, and I.V. for cover data collected from the native and experimental populations in 2006.

Table A9. Dry biomass by dominant grass type in FL plots at the Site 300 Drop tower experimental population.

Table A10. Density of *Poa secunda* per 1 m^2 plot in the fire frequency experimental subpopulation.

Table A11. Number of of *Amsinckia grandiflora* per 1 m^2 plot in the fire frequency experimental subpopulation.

Section B—*Blepharizonia plumosa* Monitoring and Research

B-1. Introduction B-1
B-2. Methods and Materials....B-3
B-2.1. Site-wide Mapping B-3
B-2.2. Seedling Recruitment Burn Study B-4
B-3. Results....B-5
B-3.1. Site-wide Mapping B-5
B-3.2 Seedling Recruitment Burn Study B-5
B-4. Recommendations and Future Work B-6
B-5. References....B-7

Section B—List of Figures

Figure B1. Location of seedling recruitment transects compared to the distribution of *Blepharizonia plumosa* and *Blepharizonia laxa* in 2001 through 2004.

Figure B2. *Blepharizonia* populations mapped in the fall of 2001 through 2004.

Figure B3. *Blepharizonia* populations mapped in the fall of 2005–2006.

Figure B4. Enlargement of Figure B1. *Blepharizonia* populations mapped in the fall of 2001.

Figure B5. Enlargement of Figure B1. *Blepharizonia* populations mapped in the fall of 2002.

Figure B6. Enlargement of Figure B1. *Blepharizonia* populations mapped in the fall of 2003.

Figure B7. Enlargement of Figure B1. *Blepharizonia* populations mapped in the fall of 2004.

Figure B8. Enlargement of Figure B1. *Blepharizonia* populations mapped in the fall of 2005.

Figure B9. Enlargement of Figure B1. *Blepharizonia* populations mapped in the fall of 2006.

Figure B10. The total area of *Blepharizonia* populations at Site 300 each year compared to rainfall for the previous winter.

Section B—List of Tables

Table B1. Estimated population size and area of *Blepharizonia plumosa* and *Blepharizonia laxa* at Site 300.

Table B2. The number of *Blepharizonia* seedlings observed along five transects surrounding building 801 are shown for the spring prior to a prescribed burn (conducted in June 2005) and the spring following the burn.

Section C—*Eschscholzia rhombipetala* Monitoring

C-1. Introduction.......... C-1
C-2. Methods and Materials C-2
C-2.1. Census C-2
C-2.2. Vegetation Sampling C-2
C-3. Results and Discussion C-3
C-3.1. Census C-3
C-3.2. Vegetation Sampling C-4
C-4. Discussion and Future Work.......... C-4
C-5. References C-5

Section C—List of Figures

Figure C1. Distribution of *Eschscholzia rhombipetala* populations at Site 300.
Figure C2. Distribution of *Eschscholzia rhombipetala* at site 3 in 2005 and 2006.
Figure C3. *Eschscholzia rhombipetala* sites 1 and 2 following the July 2005 wildfire.

Section C—List of Tables

Table C1. Summary of census data collected from sites 1, 2, and 3: 1998–2006.

Table C2. Height, number of floral units (buds + flowers + capsules) per plant, and capsule length for marked *Eschscholzia rhombipetala* plants: 1998–2006.

Table C3. Results of the logistic regression: the effect of vegetation on *Eschscholzia rhombipetala* absence.

Section D—*California macrophylla*

D-1. Introduction D-1
D-2. Methods and Materials D-2
D-2.1. Spring Census D-2
D-3. Results D-3
D-3.1. Spring Census D-3
D-4. Discussion D-3
D-5. References D-4

Section D—List of Figures

Figure D1. 2005 distribution of *California macrophylla* at Site 300.
Figure D2. 2006 distribution of *California macrophylla* at Site 300.
Figure D3. 2005 and 2006 site 1 distribution.
Figure D4. 2005 and 2006 site 2 distribution.
Figure D5. 2005 and 2006 site 3 distribution.
Figure D6. 2005 and 2006 site 4 and 5 distribution.
Figure D7. 2005 and 2006 site 6 distribution.
Figure D8. 2005 absolute percent cover of six vegetation categories at sites 1 – 6 and all sites combined.
Figure D9. 2006 absolute percent cover of six vegetation categories at sites 1 – 6 and all sites combined.
Figure D10. *California macrophylla* populations at site 2 through 6 following the July 2005 wildfire.

Section D—List of Tables

Table D1. Area, elevation, and estimated population size and density of all Site 300 *California macrophylla* populations: 2004-2006.

Table D2. Number of floral units per plant for the six *California macrophylla* populations.

Table D3. 2005 absolute cover recorded in 0.6 m^2 quadrats containing *California macrophylla.*

Table D4. 2005 absolute cover recorded in 0.6 m^2 quadrats without *California macrophylla.*

Table D5. 2006 absolute cover recorded in 0.6 m^2 quadrats containing *California macrophylla.*

Table D6. 2006 absolute cover recorded in 0.6 m^2 quadrats without *California macrophylla.*

Section A
Amsinckia grandiflora Monitoring

Section A
Amsinckia grandiflora
Monitoring and Research

A-1. Introduction

The large-flowered fiddleneck, *Amsinckia grandiflora* (Gray) Kleeb. ex Greene (Boraginaceae), is a rare annual forb native to the California winter annual grasslands. *Amsinckia grandiflora* germinates with the onset of fall or early winter rain, grows vegetatively throughout the winter, flowers in the early spring, and sets seeds and dies prior to the summer drought, a pattern observed in most of the herbaceous species of the California winter annual grasslands (Heady, 1990). Of the fifteen species in the genus recognized by Ray and Chisaki (1957a,1957b), *A. grandiflora* is one of four heterostylous species with highly restricted distributions that are likely ancestors of the weedy, widespread, and homostylous congeners (Ray and Chisaki, 1957a,1957b; Shoen et al., 1997). As a heterostylous species, *A. grandiflora* produces pin and thrum flower forms (also known as morphs). Each individual plant has only one type of flower. An exerted stigma and anthers within the corolla tube characterize pin flowers. Thrum flowers have the opposing morphology, with the stigma within the corolla tube and exerted anthers (Figure A1). Characteristic of the genus, each flower morph has four ovaries at the base of the style, each of which matures into a seed, known as a nutlet. Thus, each flower can produce a maximum of four nutlets.

Amsinckia grandiflora has been recently known from only three natural populations containing individuals numbering from fewer than 30 to several thousand. All natural populations occur on steep, well-drained north facing slopes in the Altamont Hills of the Diablo range, about 30 km southeast of San Francisco, California. The populations occur at low elevations (approx. 300 m) and border on blue oak woodland and coastal sage scrub communities. Two of the natural populations occur at Lawrence Livermore National Laboratory (LLNL) Site 300, a high-explosive testing facility operated by the University of California for the U.S. Department of Energy (DOE). The two natural populations at Site 300 are known as the Drop Tower population and the Draney Canyon population. Located in the north/southwest trending Drop Tower canyon, the Drop Tower population is the larger of the two populations at Site 300 and was the only known population of *A. grandiflora* until 1987. In 1987, the Draney Canyon population was discovered in a north/southwest trending canyon to the west of the Drop Tower canyon. This population is now believed to have been extirpated. In 1993, a large *A. grandiflora* population, known as the Carnegie Canyon population, was discovered on private rangelands near the southeast border of Site 300.

Attempts at establishing two experimental populations have also occurred near Site 300. Adjacent to the southeast border of Site 300 is an ecological reserve owned by the California Department of Fish and Game (CDFG). An attempt was made to establish an experimental population of *A. grandiflora* at this site (known in Pavlik, 1994 as the Corral Hollow population), but no reproductive plants have been observed at this site in recent years, suggesting the establishment was not successful. Also near the southeast border of Site 300 is the privately owned Connolly Ranch. An experimental population at this site was attempted, but failed, possibly due to extremely high rodent activity (Pavlik, 1994). Figure A2 shows the approximate locations of the *A. grandiflora* populations at or near Site 300.

Amsinckia grandiflora was federally listed as endangered in 1985. On May 8, 1985, one hundred and sixty acres of Site 300 surrounding the native Drop Tower *A. grandiflora* population was designated critical habitat by the U.S. Fish and Wildlife Service (USFWS). In 1997, the USFWS published the final recovery plan for the species (USFWS, 1997). On April 28, 2000, the Secretary of the U.S. DOE established the *A. grandiflora* reserve on the 160 acres of critical habitat and signed a memorandum of agreement with the USFWS describing technical services, management and access to the reserve (U.S. DOE, 2000).

Restoration efforts began in 1988 by researchers from Mills College in Oakland, California. These efforts focused on determining the factors necessary for the successful establishment of additional populations of *A. grandiflora* (Pavlik, 1988a,1988b) and have resulted in the establishment of at least one apparently successful experimental population at Lougher Ridge in Contra Costa County (Pavlik, 1994).

Between 1993 and 1995, using funds obtained through a grant from LLNL's Laboratory Directed Research and Development Program, LLNL researchers teamed with researchers from Mills College to further investigate the causes of *A. grandiflora* rarity and to establish an additional population at Site 300. The experimental population was established near the Drop Tower native population on a north-facing slope on the eastern fork of the Drop Tower canyon where it bifurcates around the Drop Tower facility parking lot (Figure A3). This population is known as the Drop Tower experimental population. The Drop Tower experimental population is divided into two portions. The original experimental population is referred to as the flashing (FL) subpopulation because it is surrounded by metal flashing in an attempt to exclude rodents from the population. The Drop Tower experimental population was expanded in 1999 to include 20 additional plots to be used in an ongoing experiment on the effects of prescribed burns on *A. grandiflora* and *Poa secunda.* This newer portion of the Site 300 experimental population is referred to as the fire frequency (FF) subpopulation.

Research on the Drop Tower experimental population and the Lougher Ridge experimental population, and data from management of the Drop Tower natural population indicate that competition from exotic annual grasses contributes to the decline of *A. grandiflora*, and that long term management to reduce exotic annual grass cover and restore and maintain the native perennial bunch grass community is necessary to ensure the persistence of this species (Pavlik et al., 1993; Pavlik, 1994; Carlsen et al., 2000). The USFWS and the U.S. Bureau of Reclamation have provided additional funding.

The goal of the ongoing management of the Site 300 *A. grandiflora* populations is to control the cover of exotic annual grasses while developing techniques to restore native perennial grasslands. The use of controlled burning is being investigated as a tool for developing and maintaining perennial grasslands. The impact of seed predation is also being investigated to determine its impact on the population dynamics of *A. grandiflora*. This report details progress made during the 2005 and 2006 federal fiscal years (October 2005 to October 2006).

A-2. Methods and Materials

A-2.1. 2006 Seed Sowing at the Experimental Sites

Precision planting of *A. grandiflora* seeds was conducted at both Site 300 experimental subpopulations on December 1, 2006 using previously developed methods (Pavlik et al., 1993). The seed sowing was conducted to help maintain the experimental subpopulations by enhancing the seed bank in the existing plots. Planting was conducted in each FF plot and in the bottom three rows of the FL subpopulation.

Planting frames constructed of 0.48 cm thick ply board were used. A grid of holes nominally measuring 3.8 cm and separated by 2.5 cm was cut into the frames. Planting frames used at Site 300 consisted of an 8 × 8 grid of holes. This resulted in 64 being sown into each plot. Planting was conducted by first anchoring the planting frame in place in the plot. Once the planting frames were anchored, each hole was excavated to a depth of about 0.5 cm into the mineral soil. A single seed was placed into each hole. Each seed was then lightly covered with mineral soil and lightly tapped down.

Germination was not measured for this seed sowing effort.

A-2.2. Spring Census

A-2.2.1. Lougher Ridge Spring Census

On April 18, 2005, the Lougher Ridge population of *A. grandiflora* was censused. Each plant found was measured for height and branch number, and the species of the nearest neighbor was recorded. Five randomly located 0.1 m^2 quadrats were placed in the population and aboveground plant biomass was collected from each of these five quadrats. Collected biomass was placed in a drying oven at 60°C on April 20. Biomass was removed from the oven on April 25 and weighed at that time. (Biomass was not collected at Lougher Ridge in 2006.)

A-2.2.2. Drop Tower Spring Census

The census of the FF and FL subpopulations took place on March 31 and April 1, 2005, and on March 30 and April 13, 2006. The native Drop Tower population census was also conducted on April 1, 2005 and on April 13, 2006. Location, morph, plant height, and branch number were recorded for each *A. grandiflora*. Branch number is defined as the number of major branches off the main stem and is equivalent to inflorescence number. Nearest neighbor data were also collected for all *A. grandiflora* observed in the experimental and native populations in 2005 and 2006.

Specific cover estimates were recorded by placing a 60 cm × 60 cm quadrat centered in existing plots (experimental populations) or random locations (native population) at the time of the spring census. In the experimental and native populations, absolute cover was estimated for each species present, bare ground and thatch.

In the experimental Drop Tower population in 2005, cover estimates were taken for 54 of the 55 original 60 cm × 60 cm plots within the FL subpopulation and two additional 60 cm × 60 cm plots (named red flag north and red flag south) in the southeastern corner of the subpopulation. In 2006, cover estimates were taken for the 55 original 60 cm × 60 cm plots within the FL subpopulation.

In the native Drop Tower population in 2005, specific plant cover estimates were taken from three quadrats near the location where *A. grandiflora* has previously occurred in the Carlsen-Gregory subpopulation, and from twelve quadrats randomly placed within the main portion of the native *A. grandiflora* population.

In 2006, cover estimates were recorded from one quadrat centered on the location where *A. grandiflora* was found in the Carlsen-Gregory subpopulation of the native Drop Tower population. 2006 was an extremely wet year; therefore, cover estimates were not recorded in the main portion of the native population to avoid damage to the saturated soil in this area.

A-2.2.3. Estimate of Nutlet Production

The number of nutlets produced by the native populations and the FL and FF experimental subpopulations were estimated using previously developed regression equations. The number of nutlets per plant in the native population was estimated using the regression equation: # nutlets/plant = 3.42 • (shoot length in cm) – 65.46, r = 0.86, $p < 0.01$ (Pavlik, 1991).

The number of nutlets per plant in the experimental population was estimated using the regression equation: # nutlets/plant = 16.81 • (# of inflorescences) – 36.76, r = 0.96, $p < 0.0001$ (unpublished). If the estimated seed production for an individual plant was a negative number, it was defined as zero.

A-2.2.4. Analysis of Nearest Neighbor Data

The frequency of nearest neighbor species and Shannon's Index (H') were calculated for the native population and the FL and FF subpopulations using the formula

$$H' = \sum_{i=1}^{S} \frac{n_i}{n} \ln \frac{n_i}{n}$$

where S is number of different species observed as nearest neighbors, n is the number of individuals observed, and n_i is the number of individuals in the ith species (Shannon and Weaver, 1949).

This diversity index is an expression of the likelihood that two plants picked at random will be of two different species. It not only reflects the number of species present in the sample, but also gives an idea of the evenness of distribution for these species (Ludwig and Reynolds, 1988). The higher the number of species and the more evenly they are distributed, the higher the diversity index.

A-2.2.5. Analysis of the Cover Estimates

Cover data were analyzed by calculating constancy, mean cover and importance value (IV) for each species and for thatch and bare ground. Constancy was calculated by dividing the number of times any one species was observed in a plot or area (referred to as the count) by the total number of plots for that year. Mean cover was calculated by averaging the cover over all plots where each species was found. Importance values for each species were calculated by summing the constancy and mean cover value by species.

A-2.3. *Poa secunda* Persistence

The number of the perennial bunch grasses *Poa secunda* were counted in both the FF and FL subpopulations during the 2005 and 2006 spring censuses to monitor long-term establishment of *Poa secunda*.

A-2.4. Fire Frequency (FF) Experiment

The FF subpopulation consists of twenty plots:

- five control plots that that will not receive prescribed burns after the initial burn in 1998
- five low frequency plots that are burned once every five years
- five medium frequency plots that are burned once every three years
- five high frequency plots that are burned each year

Figure A4 shows the layout of these plots. The population was established by initially burning the entire area of the FF subpopulation in 1998. Perennial bunch grasses *(Poa secunda)* were planted in the center portion of each FF plot in 1999 (Carlsen et al., 2001) and allowed to establish in 1999–2000, as were *A. grandiflora* that were transplanted into the plots. Perennial bunch grasses were planted at the same density in each plot. In 2001, plot burn treatments were selected using a randomized block design. Because of the nature of the burns, it was important that no two plots of the same treatment be adjacent to each other. This extra stipulation for plot selection prevented areas from acting ecologically as larger 2.5 m × 1 m blocks (including the 0.5 m space between plots), rather than the intended 1 m × 1 m areas. Burn treatments began in the summer of 2001. All FF plots, except the control plots, were burned on July 18, 2001, and on June 20, 2002, the high frequency FF plots were burned. Again in June 30, 2003 only the high frequency plots were burned. On June 6, 2004, the high frequency plots were burned again, and the medium frequency plots received their first treatment burn.

On June 11, 2005, a prescribed burn was conducted in the five high frequency plots. One month later on July 18, 2005, a wildfire burned through both the experimental and native *A. grandiflora* populations. The firebreaks created in preparation for the prescribed burn provided some protection from the fire. Thirteen of the 20 FF plots burned in the 2005 wildfire and seven were protected. Twelve of the plots burned in the wildfire were medium frequency, low frequency, and control plots that were not burned in the prescribed burn that was conducted earlier in 2005. Only one of the plots burned in the wildfire (plot O) was also burned during the prescribed burn. Including the prescribed burn and the wildfire, 17 of the 20 FF plots were burned in 2005.

During the 2006 prescribed burned, we attempted to control for the impacts of the 2005 wildfire by burning the three low frequency, medium frequency, and control plots (plots A, C, and D) that were not burned during the 2005 wildfire. After the 2006 prescribed burn, all low frequency plots had been burned twice between 2001 and 2006, and all medium frequency plots and been burned three times between 2001 and 2006 (although not necessary during the same years). All control plots had been burned once either in the 2005 wildfire or 2006 prescribed burn, and the high frequency plots were all burned each year between 2001 and 2006.

A-2.5. Flashing Subpopulation Biomass Collection

Biomass sampling began in 1998 to measure the differences in biomass between burned and unburned plots. Baseline biomass data was collected in 1998, and a prescribed burn was conducted in the southern half of the FL subpopulation later that spring. The southern half of this population was burned again in the spring of 1999, and no burns occurred in the population between 1999 and 2003. On June 6, 2003, the entire FL subpopulation was burned in an effort to increase the success of *A. grandiflora* and *P. secunda* in that area. The entire FL subpopulation was burned again in the July 2005 wildfire.

In 1999 through 2002, five biomass samples were taken within the 1999 burn areas and five samples were taken outside of the 1999 burn area. Starting in 2003, five samples were taken each year throughout the FL subpopulation and these samples were not evenly distributed in the 1999 burn and unburned areas.

Biomass samples (0.1 m^2) were collected from the center of five FL plots on May 23, 2005, and additional five plots on May 24, 2006. These plots were selected using a randomized block design with the additional requirement that biomass samples were not taken in a plot where the biomass had been sampled during the previous two years. Biomass samples were separated into *Poa,* other grass, forbs, and thatch.

A-2.6. Predation Monitoring

Starting in 1998, *A. grandiflora* nutlets were set out each year to monitor levels of seed predation within the experimental population. As in the biomass and *Poa secunda* persistence experiments described above, prior to 2003 the predation experiment was designed to measure differences between burned and unburned groups. Starting in 2003, the goal of the predation experiment shifting to monitoring annual changes in predation instead of differences between burned and unburned groups. In 1999 through 2002, predation monitoring was conducted in two rounds. Round one was conducted before the prescribed burn in the FF subpopulation and round two was conducted after the FF burn. A single round of predation monitoring was conducted in 2005 and 2006.

For each plot included in the predation experiment, a single nutlet was adhered with double-stick tape to each of 25 3.5-inch galvanized nails spaced 10 cm apart in five rows of five nails placed in the center of the existing FF or FL plot. Each nail was pressed into the soil so the nail head was flush with the soil surface.

In 2005, a total of ten grids of nutlet/nails were placed: five in the FF plots and five in the FL plots (Figure A2 and Figure A3). Plots were chosen haphazardly from plots that would not be burned in 2005 and that were not used to study predation in 2003 and 2004. Nutlet/nails were placed in the plots on May 23, 2005. Nails were checked on May 31, June 6, June 13, and September 20 of 2005. On September 20, all nutlet/nails were removed.

In 2006, a total of five grids of nutlet/nails were placed in plots where that would not be burned in 2006 in the FF subpopulation (Figure A3). Nutlet/nails were placed into the plots on May 25, 2006. Nails were checked on May 30, June 6, June 13, and October 3 of 2006. On October 3, all nutlet/nails were removed.

A-2.7. Lupine Study

The lupine study was initiated in the fall of 1999 to investigate the potential effects of *Lupinus albifrons* expansion on the biomass accumulation of *A. grandiflora* competitors. In previous years, *L. albifrons* and dying *L. albifrons* in the native population were mapped and presented graphically (Carlsen et al., 2003). In 2001 through 2004, the extent of *L. albifrons* invasion of the native population was recorded with a photograph.

In 2004, we attempted to boost *A. grandiflora* success at the native Drop Tower population by manually removing *L. albifrons* from the entire native population and reducing grass and thatch buildup in selected plots. The vegetation removal treatment was conducted in approximately one half of the existing native population to allow future comparison of areas receiving the vegetation removal treatment and areas where the vegetation has not been altered.

Treatment areas for reducing grass and thatch buildup were chosen by first dividing the native population into a 3×4 grid using existing fence posts that mark the perimeter of the population. Of the 12 cells, six were chosen for the vegetation removal treatment based on the historic presence of *A. grandiflora* in the cells; the goal was to apply the vegetation removal treatment to half of the areas that historically contained the majority of *A. grandiflora* plants while leaving the other half of these population centers as controls. Figure A6 shows the historic distribution of *A. grandiflora* at the native population with the treatment locations.

All vegetation removal treatments were conducted on September 29, 2004, well after *A. grandiflora* had senesced, and when the soil was dry and stable, so the site could be accessed without the threat of increased erosion due to foot traffic. In the treatment cells, *L. albifrons* was removed by cutting it at its base. The entire treatment cell was also trimmed using a weed whacker to a height of approximately 10 to 12 inches and lightly raked.

All plots were burned in the July 2005 wildfire. All grass and thatch in this area was burned, thus removing all treatment differences between the Drop Tower plots.

A-3. Results and Discussion

A-3.1. Spring Census

A-3.1.1. Lougher Ridge Spring Census

As part of a seed bank enhancement project in the fall of 2002, 4500 seeds were sown into 45 plots at Lougher Ridge in December 2002. This resulted in 206 individuals projected to have produced 1592 nutlets in the spring of 2003. In October 2003, an additional 4500 seeds were sown into the Lougher Ridge population. These seeds produced 868 aboveground plants, which in turn were estimated to produce 8739 nutlets in the spring of 2004. It is these 8739 nutlets and any seeds from previous years' seed banks that produced the aboveground plants censused the spring of 2005.

Over half the plants in the population were senesced at the time of the 2005 census. Plant height averaged 35.4 cm (stdev = 10) and the average number of branches per plant was 1.6 (stdev = 1.3). The tallest plant in the population was 52 cm and there was one individual with 10 branches. The pin:thrum ratio of still-flowering plants was very close to 1 (34:35). The projected seed production of the population was 670 nutlets (using the equation: nutlets/plant = 16.81 • (# of inflorescences) – 36.76, r=0.96 [unpublished data]). Each plant produced an average of 4 seeds (stdev = 16).

Most plants found were clustered and occurred in historic plot locations around metal marker posts. Individuals were leggy and often grew parallel to the ground for tens of centimeters before emerging upright with inflorescences. Even leggy plants, though, tended to have stout stems. The frequency of *A. grandiflora* as its own nearest neighbor (Table A2) indicates the degree to which plants were clumped within the population. Exotic grasses were the most common nearest neighbor (Figure A4), while native forbs and exotic forbs shared the remainder of the community about equally.

Plant biomass in the population was high and dominated by exotic grasses. Plots averaged about 101 g total aboveground biomass (stdev = 34). Most of this biomass was exotic annual grasses (Figure A5), which averaged 73 g (stdev = 21.2) of biomass per plot. Thatch was also quite high at this location with an average of 25.4 g per plot (stdev= 10.8).

A-3.1.2. Drop Tower Spring Census

Population sizes continued to be very small in the Drop Tower native population in 2005 and 2006. In 2005, no *A. grandiflora* were observed in the native Drop Tower population (Table A3, Figure A6). In 2006, the first spring after the wildlife, four

A. grandiflora were found in the native population. All four of these plants were located in the Carlsen-Gregory portion of the native population.

The success of 2002 and 2003 rapid seedbank enhancement efforts continued to be reflected in the size of the FF experimental populations in 2005. The FF subpopulation contained 173 *A. grandiflora* in 2005 and 47 *A. grandiflora* in 2006 in spite of very low estimated seed production in 2003 and 2004 (Table A3, Figure A7). The estimated seed production for the FF subpopulation continued to be low in 2005 (85 seeds) and 2006 (41 seeds).

In contrast, the population size in the FL experimental subpopulation dropped dramatically in 2005 and 2006 compared to 2004. There were no *A. grandiflora* in the FL subpopulation in 2005 and only two plants in 2006. This indicates that the FL subpopulation has not been able to maintain a seedbank without active enhancement efforts the previous year (Table A3, Figure A8). This corresponds with estimates that the plants present in the FL subpopulation were too small to produce many nutlets in 2003 and 2004. Although the 2003 seedbank enhancement project was successful in increasing the population size in the FL subpopulation, these plants were very small. Plants in the FL subpopulation in 2003 were 7.3 cm tall (stdev = 4.0) and unbranched; in 2004 they averaged 13.7 cm tall (stdev 5.3) with very few plants having more than one branch. As result of the small plant size, the FL subpopulation was estimated to produce no seeds in 2003 and fewer than 30 seeds in 2004 (Table A3). Although there were many fewer plants in the native population compared to the experimental populations, the plants in the native population were much larger (18 ± 3.7 cm height in 2003 and 20.7 ± 11.11 cm height in 2004) and, therefore, were estimated to produce more seeds than the experimental populations.

Again in 2006, the two *A. grandiflora* present in the FL subpopulation were not estimated to produce any seed.

When examining population sizes from Draney Canyon, the Drop Tower native population, and the Drop Tower experimental population (Figure A12), it appears that numbers remained stable or increased in the years 1986 to 1996. After 1996, the numbers of all three populations dropped. Draney Canyon had no plants in 1998–2000 and was not surveyed in 2001, 2003, 2005, or 2006. The historic Draney Canyon population site and surrounding areas were surveyed in 2004 and no *A. grandiflora* was observed. While it appears that high rainfall years are detrimental to *A. grandiflora* populations, the effect is either delayed or dependent on multiple years of high rainfall in close proximity. The size of all four populations with total annual rainfall is shown in Figure A9.

A-3.1.3. Nearest Neighbor Data

Composition of nearest neighbors overemphasizes the importance of small, understory plants, but since data collection methods have remained the same over the years, these data are useful in making comparisons among subpopulations and years. Tables A5 and A6 shows the percent species composition of *A. grandiflora* nearest neighbors for both native and experimental populations. Shannon's index (H') of diversity is also shown.

The exotic grasses *Avena* spp., *Bromus diandrus,* and *Bromus hordeaceus* have consistently been among the most common nearest neighbors in the native, FF, and FL subpopulations. Another exotic grass, *Vulpia myuros,* did not occur as a nearest neighbor in the native population in 1997–1998 but has periodically been a common nearest neighbor in the native and experimental populations since 1999. The exotic forb *Erodium cicutarium* is frequently the most common nearest neighbor in the experimental population.

The presence of native forb and grass species, such as *Galium aparine, Collinsia heterophylla*, *Achillea millefolium* and *Poa secunda,* as nearest neighbors in the experimental and native populations has been much more variable. Other native plants that commonly occur as nearest neighbors are *Claytonia parviflora* and *Lupinus bicolor.*

A-3.1.4. Cover Estimates

Cover estimates have been taken in all three populations since 2001. Cover estimates for 2005 are shown in Table A7. *Erodium cicutarium* had the highest IV for the two experimental subpopulations in 2005 (cover was not recorded in the native population in 2005). Several native forbs also had a relatively high IV in the FL subpopulation, including *Clarkia* sp., *Lupinus bicolor,* and *Delphinium* sp. These species had a high IV despite a relatively low overall mean percent cover because they were present in most plots. In the FL and FF subpopulations several native and exotic grasses ranked high in IV. Two grasses, *Avena* sp. and *Poa secunda,* ranked 2nd and 3rd in I.V. in the FF subpopulation, repeating the pattern seen in 2004.

Table A8 shows the cover estimates for 2006 for the FL and FF subpopulations (percent cover was sampled in only one location in the native population in 2006 so IV was not calculated for this population). Again in 2006, *Erodium cicutarium* had the highest I.V. for both experimental populations. The abundance of the exotic forb *E. cicutarium* in the experimental populations is probably a result of the fire frequency in this area. A prescribed burn was conducted in the entire FL subpopulation in 2004, then it was burned again during the 2005 wildfire.

In 2006, the annual grasses were not mature enough to identify to species in many cases at the time of the spring census. These species were recorded in a general “annual grass” category. Grasses at these populations include species of *Avena* and *Bromus,* and this “annual grass” category had the second highest I.V. in the both experimental subpopulations in 2006.

A-3.2. Flashing Subpopulation Biomass Collection

Biomass samples have been collected in the FL plots each year since 1998 to measure the difference in four biomass categories (herb, thatch, *Poa,* and total) between burned and unburned plots and in plot types originally established in 1993. Three types of plots were established in 1993: plots planted with *Poa secunda* at a specified density, plots with existing *Poa secunda,* and plots cleared of all perennial grasses. The planted

Poa and existing *Poa* plots were established at three different densities (low, medium, and high). The original treatment burns were conducted in May of 1998 and 1999.

Changes in total biomass in burned and unburned plots, along with a rainfall graph are shown in Figure A10. These two graphs show a relationship between higher rainfall years and increased biomass as expected. Biomass is also shown in Table A9.

A-3.3. Fire Frequency Experiment

Figure A12 shows the density of *Poa secunda* in the FF plots from 1999 through 2006. The FF plots were originally established in 1999 with 33 *P. secunda* per plot for all fire frequencies. In 2000, the number of *P. secunda* dropped only slightly in all plots (average of 29 *P. secunda* plants per plot), and in 2001, the number of *P. secunda* per plot continued to drop (average of 22 *P. secunda* plants per plot) (Table A10). In the summer of 2001, after *Poa* counts were completed, FF treatment burns began. All plots except the control plots were burned in 2001.

In 2005 and 2006, the abundance of *P. secunda* continued to be lowest in the control plots (Table A10), and low frequency plots have a lower *Poa* frequency then both medium and high frequency plots.

The number of *A. grandiflora* present in plots of each burn frequency is shown in Table A11.

A-3.4. Predation Monitoring

The result of the 2005 and 2006 predation monitoring are shown in Figures A13 and A14. The intensity of predation was high during the first two weeks of monitoring, and dropped during the third week.

A-3.5. Lupine Study

Figure A15a,b shows a photograph of the native population in the spring of 2001–2004. The distribution of *L. albifrons* was similar during those four years, although many of the lupines present had begun to die back. Also, many of the lupines removed in the fall of 2004 as part of the vegetation clearing treatment had died prior to removal.

A-4. Recommendations and Future Work

Seed production at Lougher Ridge has been estimated (this year and previous years) using the equation: nutlets/plant = 16.81 • (# of inflorescences) – 36.76, r=0.96 (unpublished data). However, the reasons for using this equation over the equation: nutlets/plant = 3.42 • (shoot length in cm) – 65.46 are unclear. The first equation was developed for plants growing in the experimental population at Site 300, the second for plants in the native population at Site 300. While on the surface, experimental populations may be more similar to each other, to our knowledge no conditional analyses have been done to determine which equation might be best under different conditions. For example, if the native population equation was developed when most plants in the population had greater than three inflorescences and the experimental population equation was developed for a population in which most plants had only one or two inflorescences, a more accurate use of these projections would be to use each for the plant size range for which they are most accurate, rather than using one equation for one population and one equation for the other. If we had used the native population nutlet output estimator, our estimated seed output would be 9685 for the Lougher Ridge population in 2005, with each plant producing an average of 56 seeds (stdev = 33.7).

Comparative analyses between the Site 300 and Lougher Ridge populations in terms of nutlet production and population maintenance would be helpful in determining post-hoc which end of the range of estimated seed production is the most accurate.

The 2005 wildfire burned the entire native Drop Tower population and FL experimental subpopulation and portions of the FF experimental subpopulations. It was necessary to slightly modify the frequency of prescribed burns in the FF subpopulation to control for the fact that not all FF plots were burned during the wildfire. But, the wildfire did not appear to have any obvious impacts on the success of *A. grandiflora* in any of the Drop Tower populations.

The number of *A. grandiflora* in the native population continues to be very small; there were no plants in the native population in 2005, and in 2006 there were only four plants in the Carlsen-Gregory portion of the native population. This highlights the importance of maintaining the experimental populations and *ex situ* seedbanks for this species.

Amsinckia grandiflora has long been a subject of intense study by botanists and ecologists due to its unique breeding system and extreme rarity. However, even with such a focus, the species continues to decline. *Amsinckia grandiflora* appears to have very narrow environmental requirements, which to date have not been well elucidated.

We know that *Amsinckia grandiflora* has been negatively impacted by the conversion of its habitat from native perennial grasslands to exotic annual grasslands (Pavlik et al., 1993; Carlsen et al., 2000). Controlled burns have been used at the Drop Tower experimental populations in an attempt to control exotic annual grassland and help to maintain a grassland habitat dominated by native perennial grasses, but several limitations to the use of controlled burns to establish native perennial grasslands as habitat for *A. grandiflora* have been identified. First, *A. grandiflora* seeds (also known as nutlets) are relatively large (up to 5 mg) (Carlsen et al., 2002). This may limit dispersal, with most seeds falling near the maternal plants. These seeds are then potentially exposed to the direct effects of fire from the late-spring controlled burns that occur immediately after seed rain. *Amsinckia grandiflora* seeds do not tolerate high temperatures (unpublished data) and thus would not be expected to survive. Those seeds that do escape the direct effects of the fire are at high risk of predation in the area exposed by the controlled burn. Finally, the low number of *A. grandiflora* plants that occur outside the area of the controlled burn, along with the limited seed dispersal potential, limits the source of seeds that could take advantage of the burned area in the following growing season.

A-5. References

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Section A
Figures

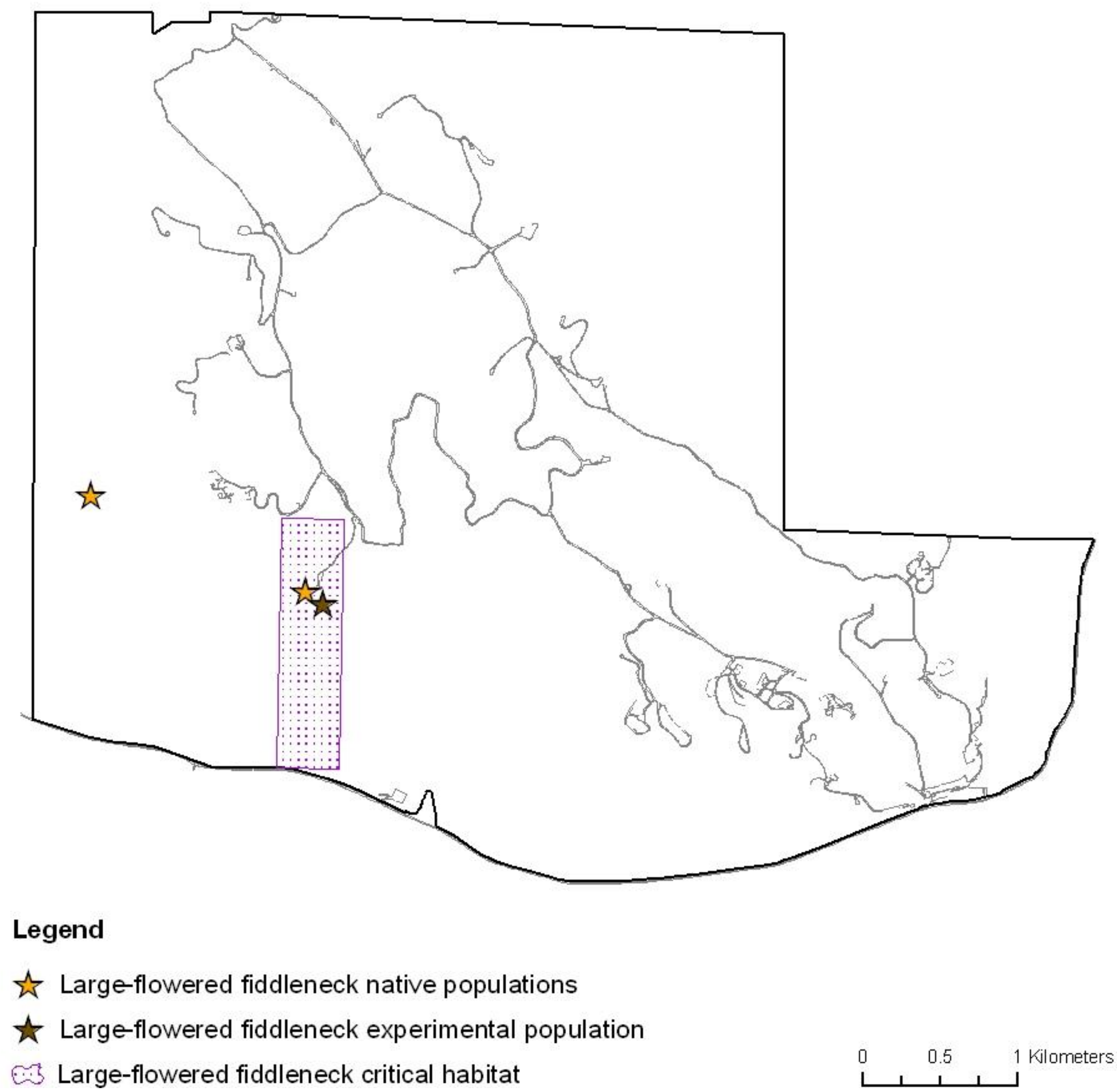


Figure A1. Distribution of large-flowered fiddleneck at Site 300, and large-flowered fiddleneck critical habitat.

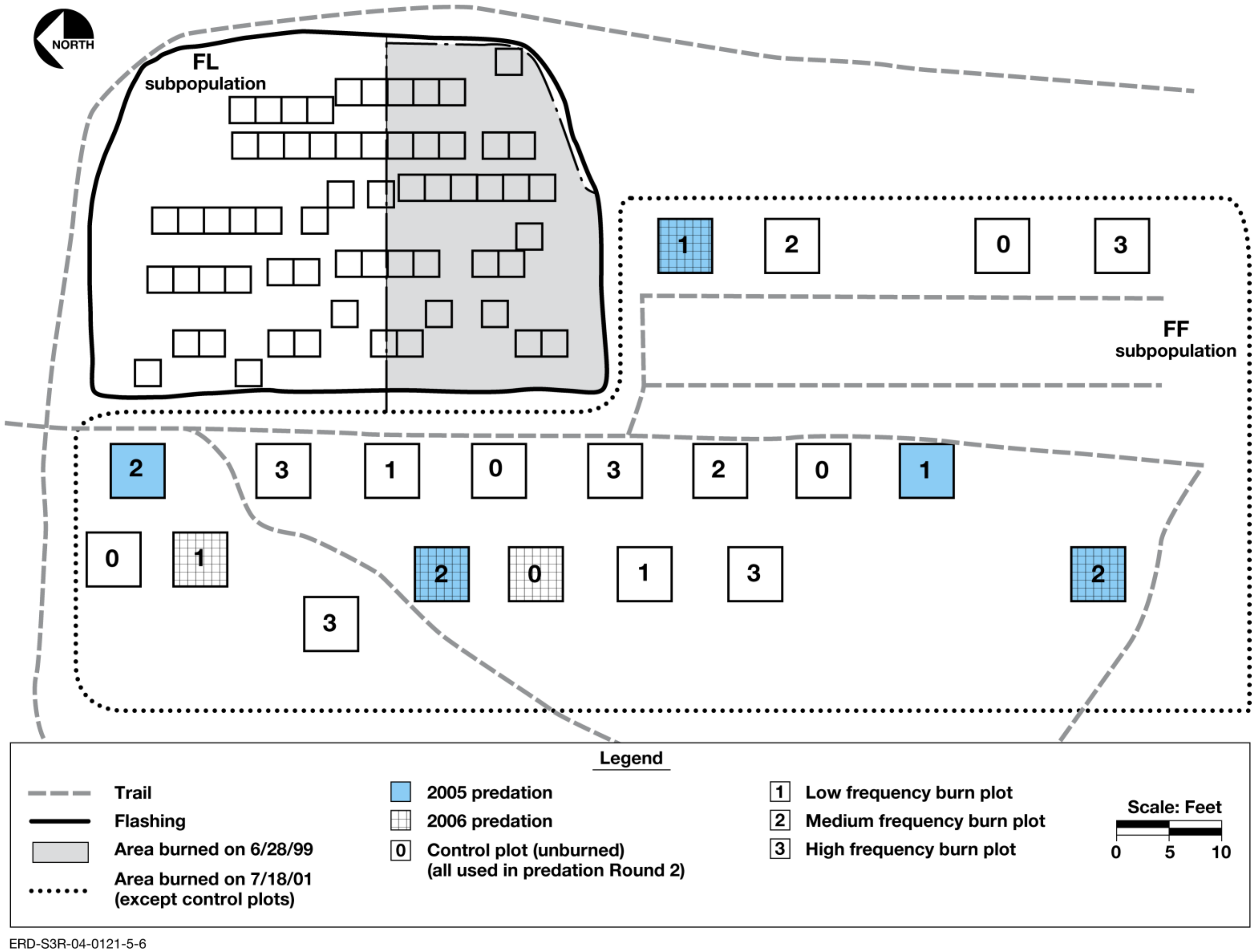


Figure A2. Summary of experimental treatments at the experimental FL subpopulation.

Figure A3. Summary of experimental treatments at the experimental FF subpopulation.

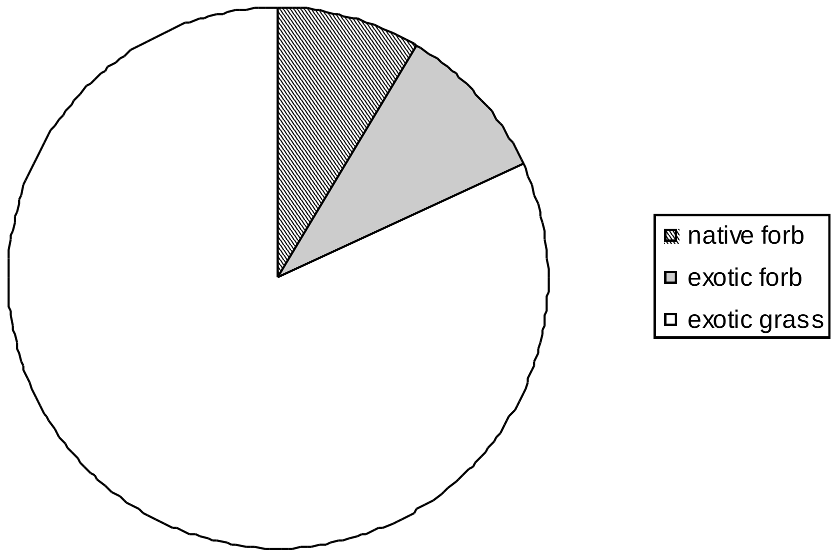


Figure A4. Nearest neighbor composition of *A. grandiflora* reintroduced population at Lougher Ridge, 2005 (n = 173).

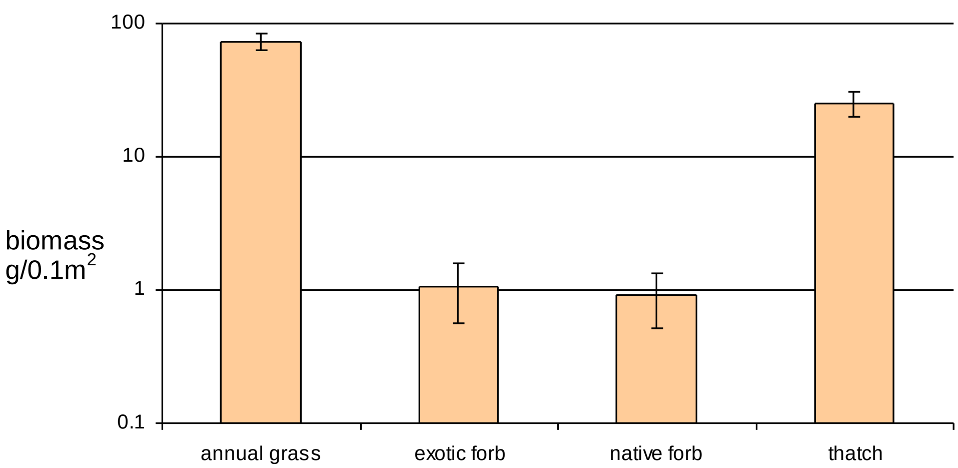


Figure A5. Community biomass collected from *A. grandiflora* reintroduced population at Lougher Ridge, 2005 (n = 5). Bars are one standard error.

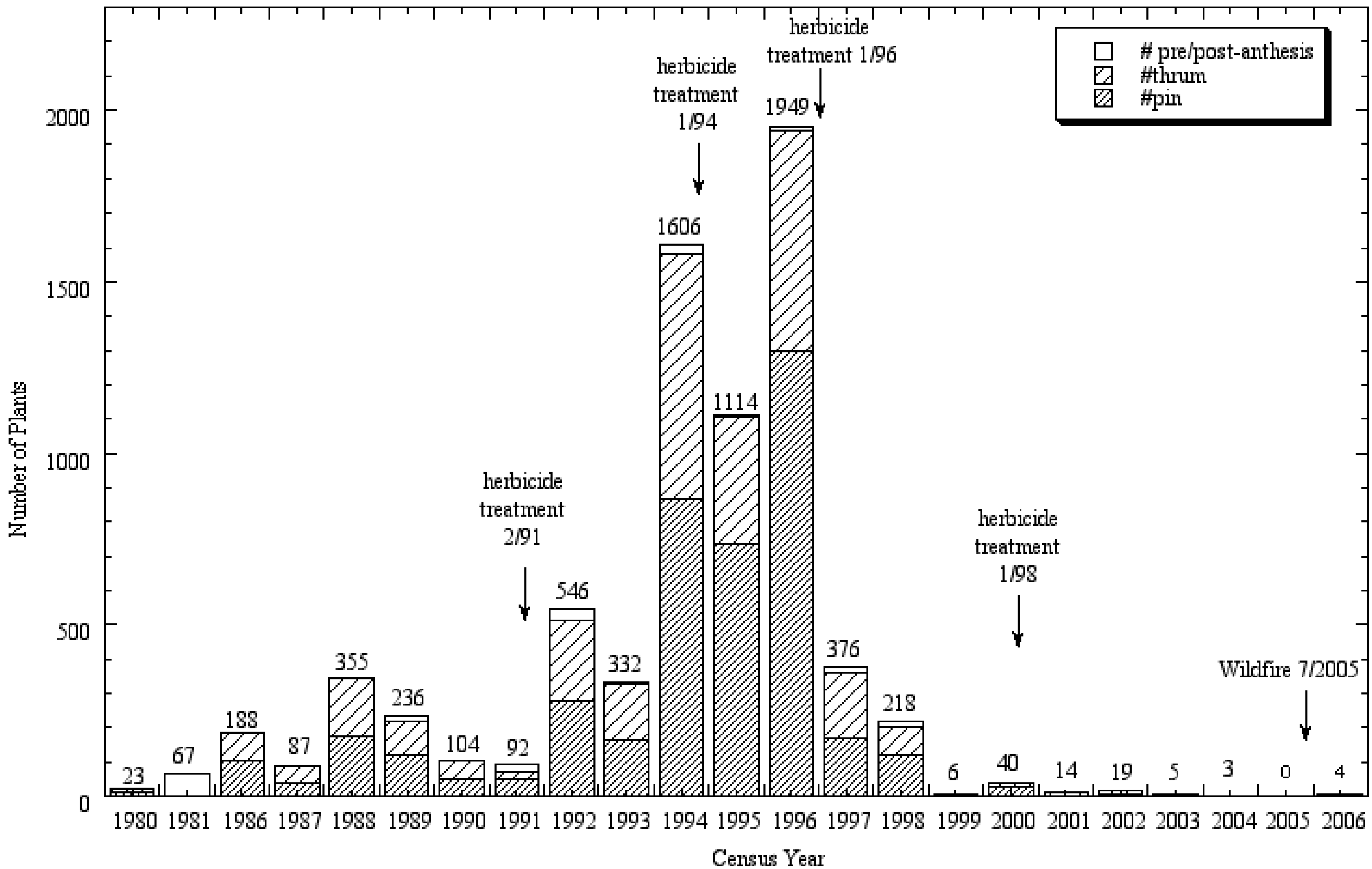


Figure A6. Spring census data of the Site 300 Native Drop Tower population. Total population size is given above each bar. Approximate timing of herbicide treatments is shown.

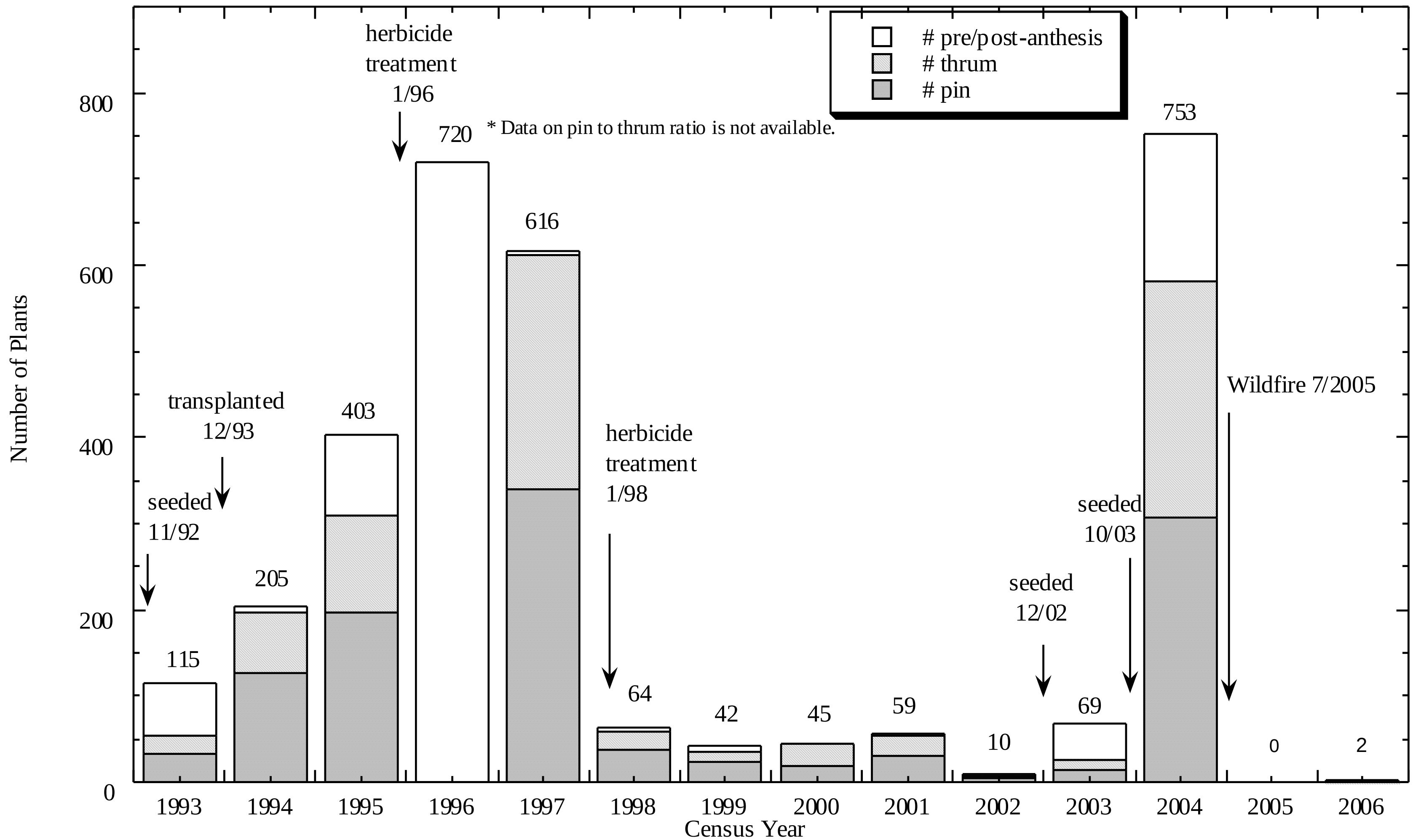


Figure A7. Spring census data of the Site 300 experimental FL subpopulation. Total population size is given above each bar. Approximate timing of all treatments are shown.

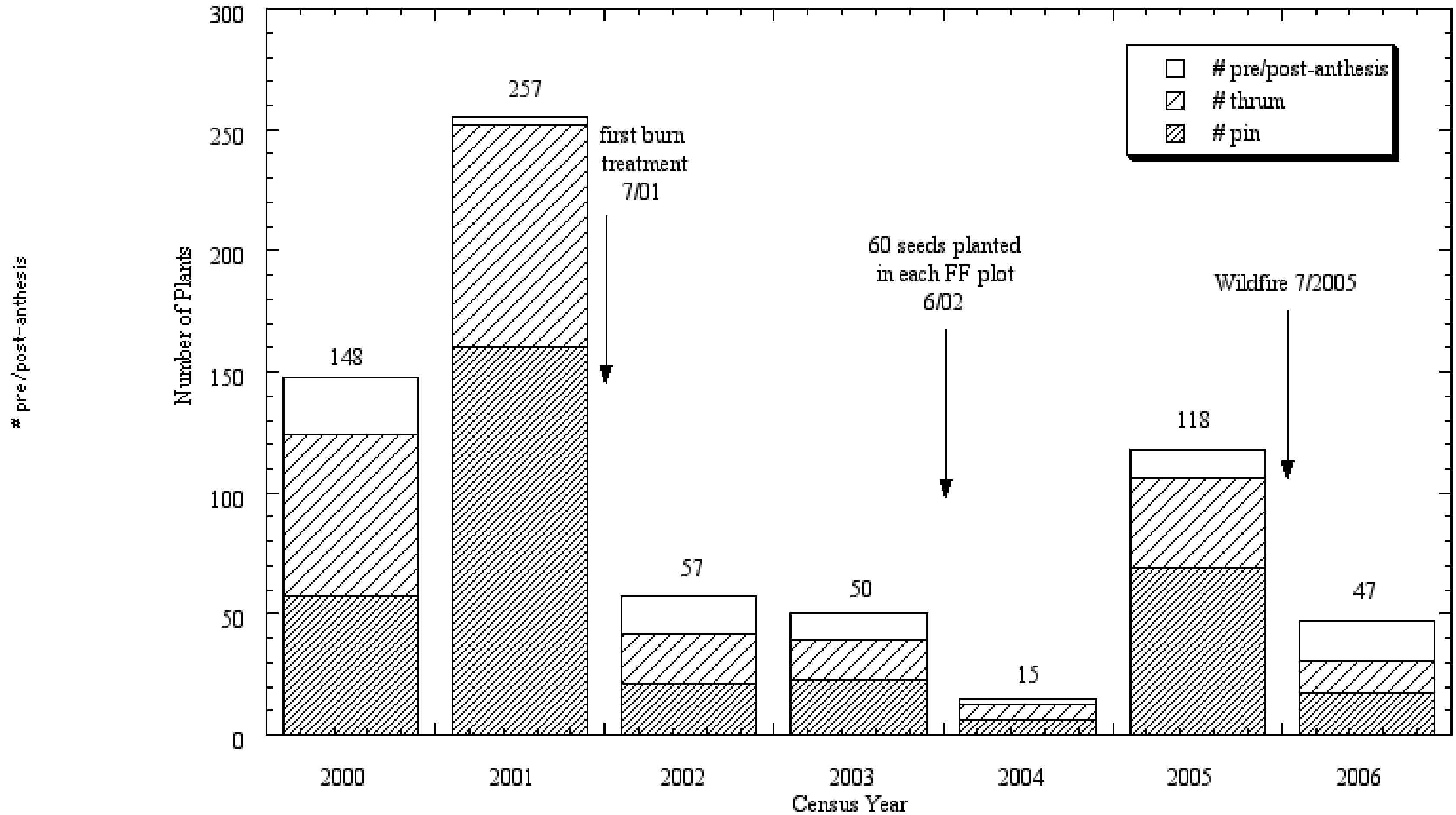


Figure A8. Spring census data of the Site 300 experimental FF subpopulation. Total population size is given above each bar.

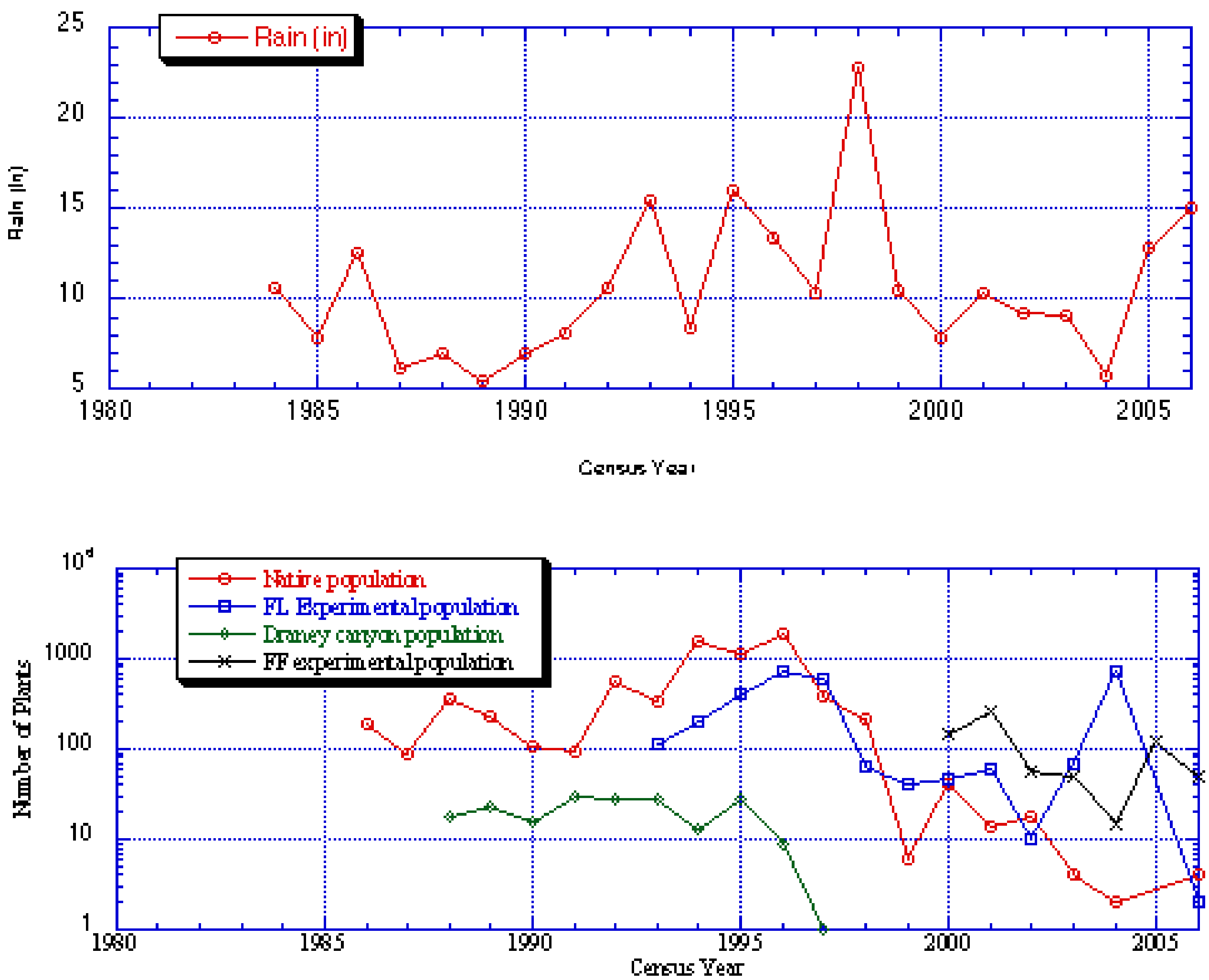


Figure A9. Log plot of population size at time of census, shown with rainfall totals over growing season

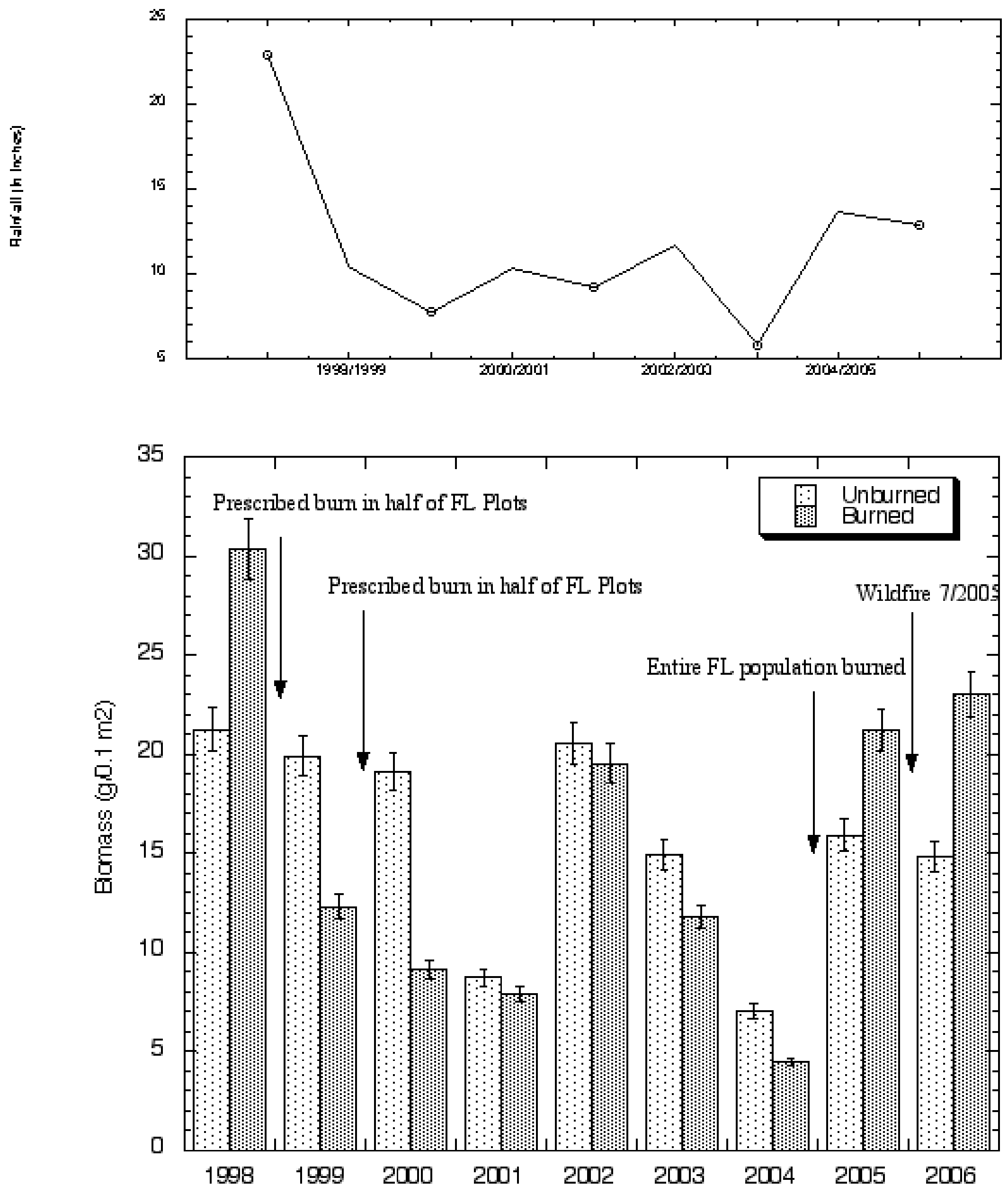


Figure A10. Total average biomass for1998 through 2006. Burned versus unburned refers to the 1998 and 1999 prescribed burns.

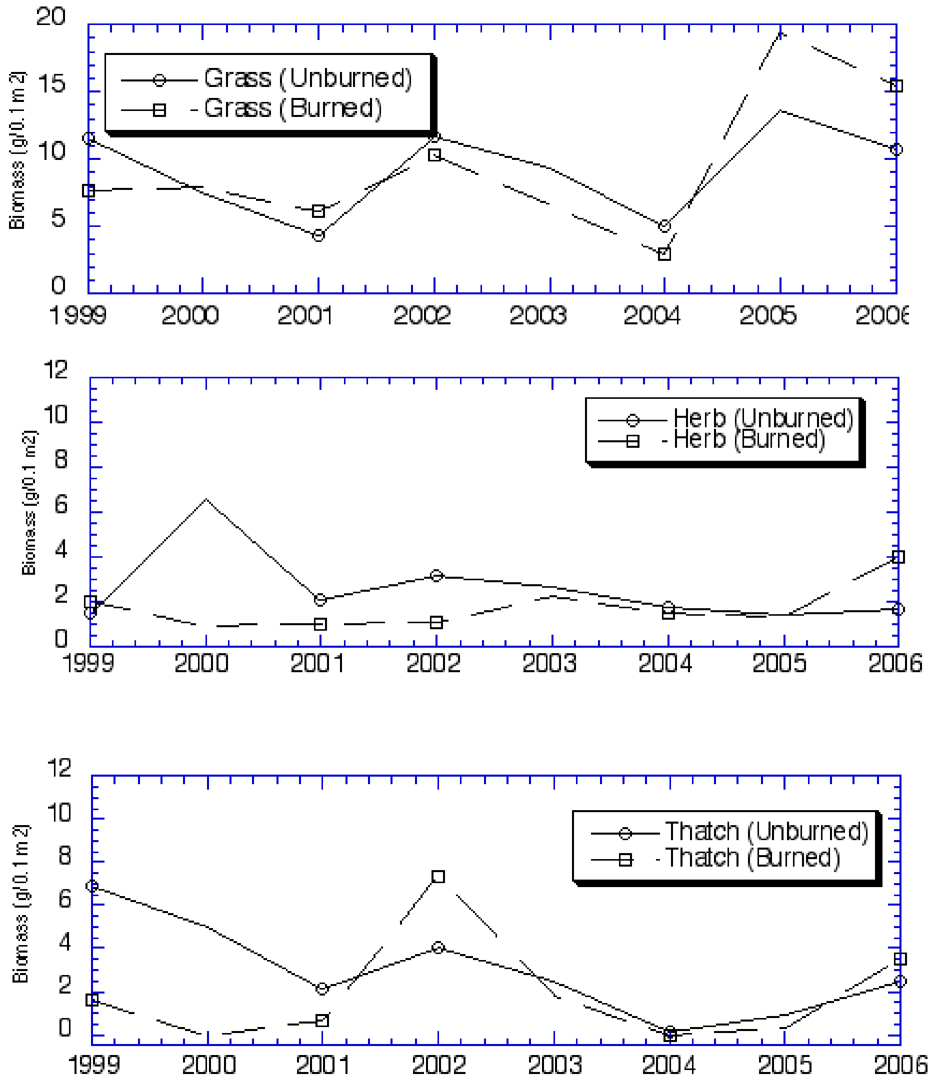
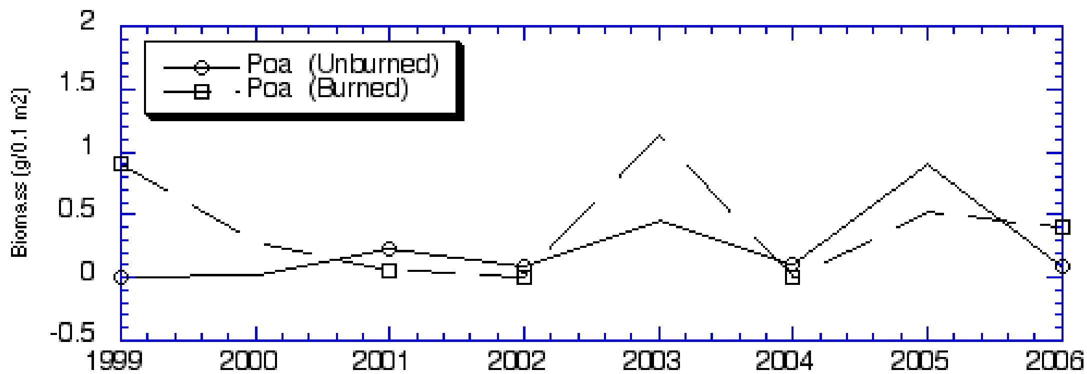


Figure A11 (Page 1 of 2). Biomass of burned vs. unburned FL plots for 1999 through 2006. Bars are one standard error. ++ indicates treatments differ at $p < 0.01$. + indicates treatments differ at $p < 0.05$. N = 5. Burned versus unburned refers to the 1998 and 1999 prescribed burns.



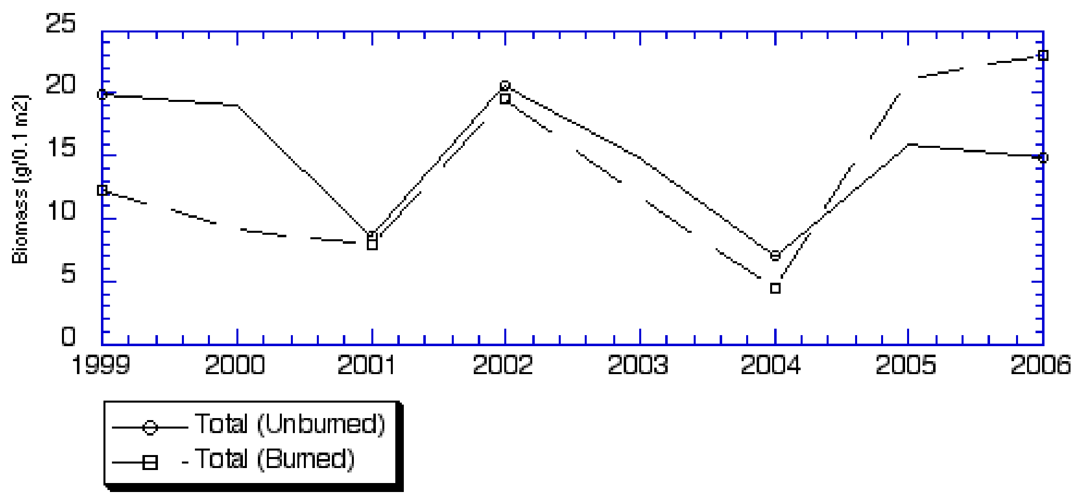


Figure A11 (Page 2 of 2). Biomass of burned vs. unburned FL plots for 1999 through 2006. Burned versus unburned refers to the 1998 and 1999 prescribed burns.

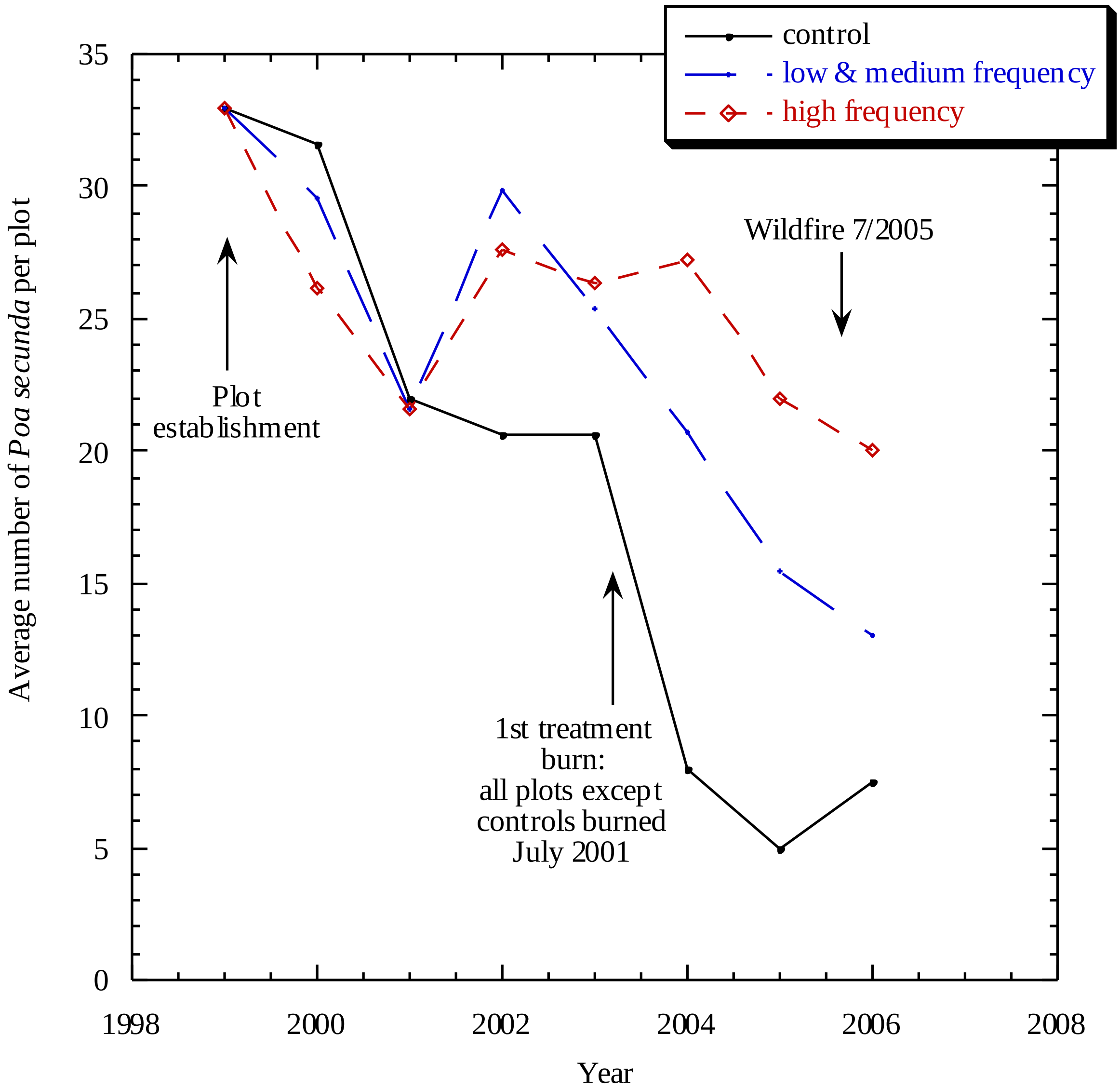
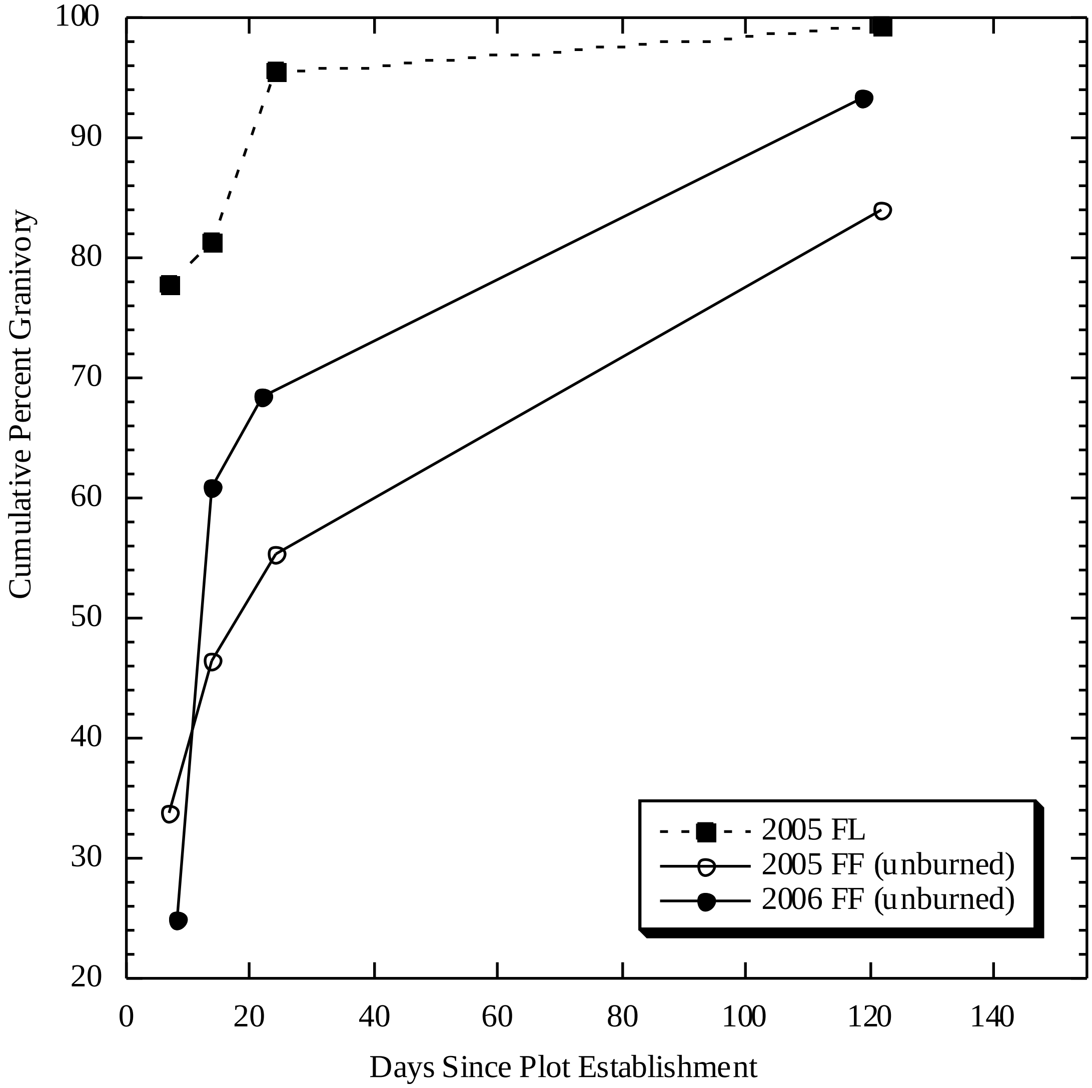


Figure A12. Average number of *Poa secunda* plants per plot for each of three burn frequencies. The low and medium frequency plot are grouped because the medium and low frequency plots were burned at the same rate until summer 2004 when the first medium frequency burn was conducted



Notes:
FL = Flashing Subpopulation
FF = Fire Frequency Subpopulation

Figure A13. Cummulative percent granivory in 2005 and 2006 by population and burn.

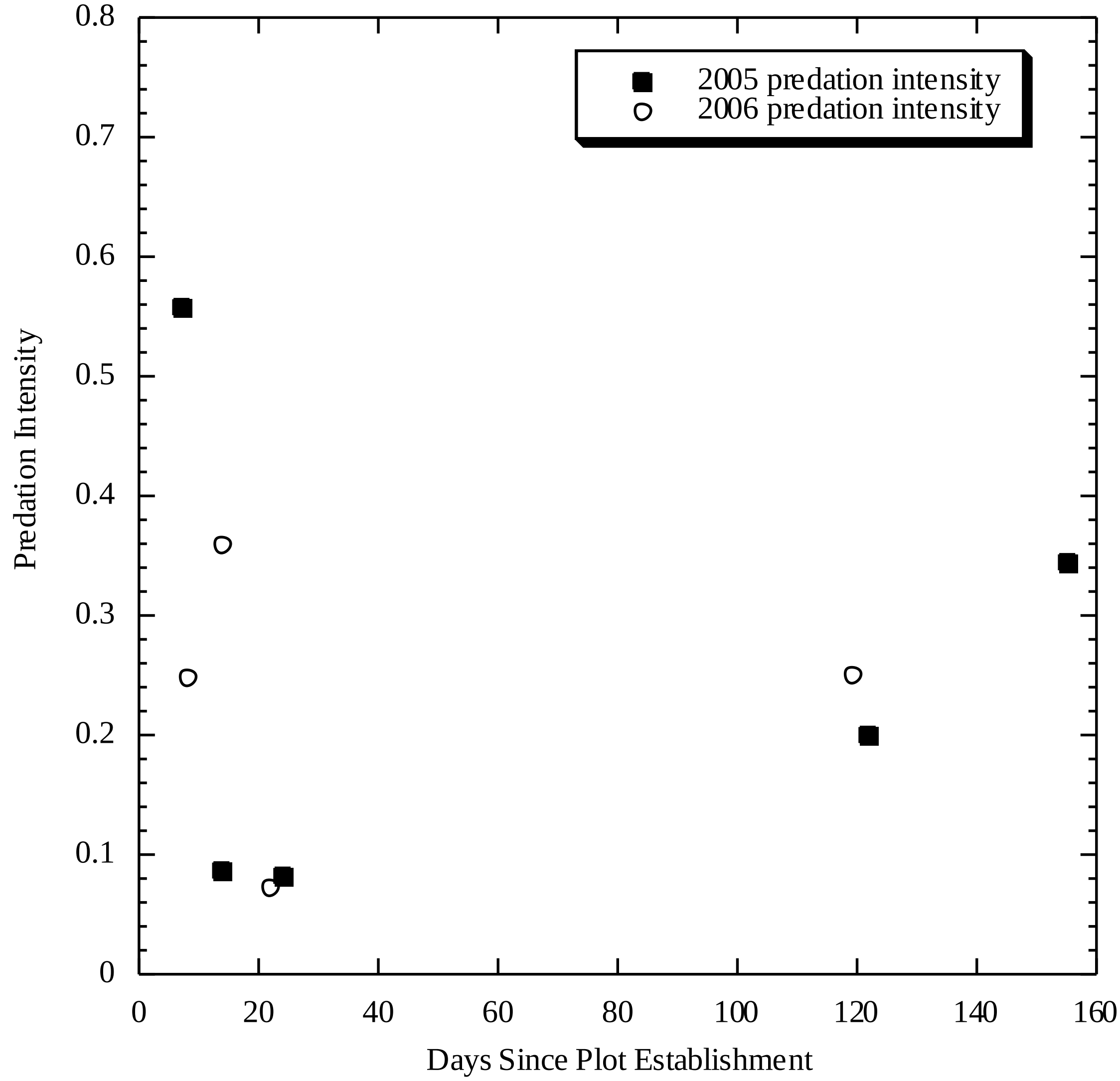
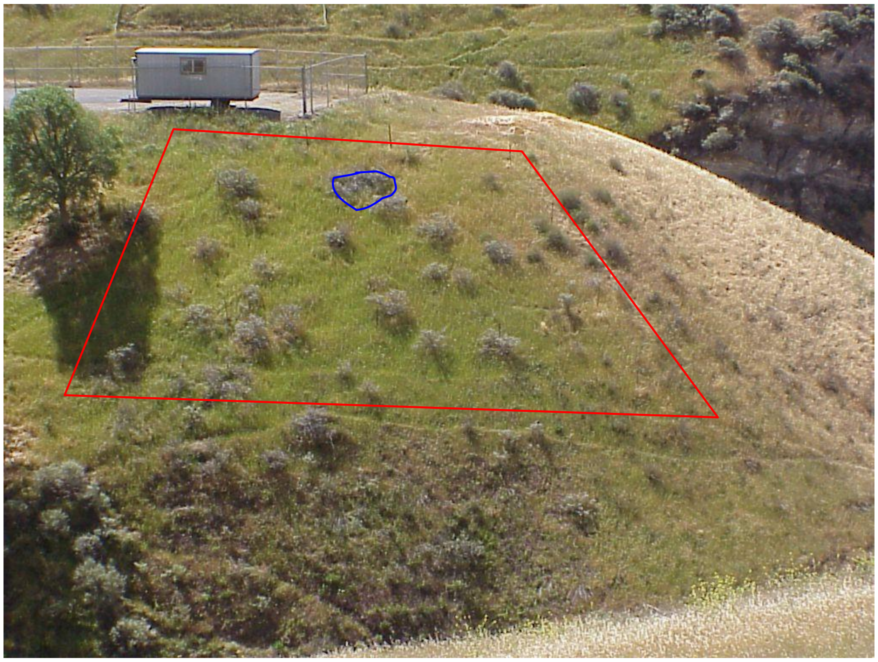


Figure A14. Predation intensity for all 2005 and 2006 locations. (2005 fire frequency and flashing, 2006 fire frequency only)

N



2001

2002

Figure A15 (Page 1 of 2). Native population in Spring 2001 through 2004. Small shrubs are *Lupinus albifrons.* The native population is outlined in red, and the original *Lupinus albifrons* is outlined in blue.

2003

2004

Figure A15 (page 2 of 2). Native population in Spring 2001through 2004. Small shrubs are *Lupinus albifrons.* The native population is outlined in red, and the original *Lupinus albifrons* is outlined in blue.

March 20, 2005

July 20, 2005

Figure A16. Drop Tower populations in 2005 before and after the July wildfire.

July 20, 2005

**No photo available for 2006*

Figure A17. Close up of FF and FL experimental populations after the July 2005 wildfire.

Section A
Tables

Table A1. FF plots burned in the July 2005 wildfire and prescribed burn schedule following the 2005 wildfire.

		2001	2002	2003	2004	2005	2005 wildfire	2006	2007	2008	2009	2010	2011
		1	2	3	4	5		6	7	8	9	10	11
Control													
High Freq.		burn	burn	burn	burn	burn		burn	burn	burn	burn	burn	burn
Med. Freq.		burn			burn					burn			burn
Low Freq.		burn											burn
a	**Med**	burn			burn			burn		burn			burn
b	**High**	burn	burn	burn	burn	burn		burn	burn	burn	burn	burn	burn
c	**Low**	burn						burn					burn
d	**Control**							burn					
e	**High**	burn	burn	burn	burn	burn		burn	burn	burn	burn	burn	burn
f	**Med**	burn			burn		burn			burn			burn
g	**Control**						burn						
h	**Low**	burn					burn						burn
I	**Control**						burn						
j	**Low**	burn					burn						burn
k	**High**	burn	burn	burn	burn	burn		burn	burn	burn	burn	burn	burn
l	**Med**	burn			burn		burn			burn			burn
m	**Control**						burn						
n	**Low**	burn					burn						burn
o	**High**	burn	burn	burn	burn	burn	burn	burn	burn	burn	burn	burn	burn
p	**Med**	burn			burn		burn			burn			burn
q	**Low**	burn					burn						burn
r	**Med**	burn			burn		burn			burn			burn
s	**Control**						burn						
t	**High**	burn	burn	burn	burn	burn		burn	burn	burn	burn	burn	burn

Table A2. Community composition of *A. grandiflora* reintroduced population at Lougher Ridge based on nearest neighbor data.

Nearest neighbor	N	% Occurrence
Bromus diandrus	83	48.3
Lolium multiflorum	37	21.5
Carduus pynocephalus	14	8.1
Avena sp.	14	8.1
Galium aparine	7	4.1
Amsinckia grandiflora	**5**	**2.9**
Bromus hordeaceous	5	2.9
Amsinckia tessellata	3	1.7
unknown grass	2	1.2
Brassica sp.	1	0.6
Medicago polymorpha	1	0.6

Table A3 (Page 1 of 2). Summary of demographic data collected from the Site 300 Drop Tower experimental and native populations and the Lougher Ridge experimental population. (Values are means ± 1 SD)

Population	Total no. of plants	P/T ratio[a]	Average height (cm)	Average no. of branches per plant[b]	Estimated average seed production per plant[c]	Estimated total seed production per population
Spring 1999						
Native	**6**	**all P**	**15.30 ± 7.30**	**1.0 ± 0**	**0**	**0**
FL plots (experimental)	**42**	**2.18**	**13.30 ± 5.41**	**1.02 ± 0.15**	**0**	**0**
Spring 2000						
Native	**40**	**2.16**	**20.13 ± 6.51**	**1.70 ± 1.16**	**10.92 ± 14.44**	**436.98**
FL plots (experimental)	**45**	**0.76**	**16.78 ± 5.52**	**1.32 ± 0.97**	**2.70 ± 10.74**	**121.92**
FF plots (experimental)	**148**	**0.85**	**16.67 ± 5.98**	**2.33 ± 1.55**	**10.54 ± 20.58**	**1560.85**
Spring 2001						
Native	**14**	**0.43**	**17.21 ± 4.09**	**1.0 ± 0**	**1.42 ± 2.35**	**36.40**
FL plots (experimental)	**59**	**1.29**	**13.67 ± 5.09**	**1.0 ± 0**	**0**	**0**
FF plots (experimental)	**257**	**1.74**	**15.74 ± 4.51**	**1.02 ± 0.20**	**0.11 ± 1.22**	**28.27**
Spring 2002						
Native	**19**	**1.14**	**24.69 ± 4.83**	**1.50 ± 0.56**	**9.93 ± 11.13**	**188.7**
FL plots (experimental)	**10**	**1.67**	**15.78 ± 6.39**	**1.0 ± 0**	**0**	**0**
FF plots (experimental)	**57**	**1.00**	**15.15 ± 6.25**	**1.05 ± 0.26**	**0**	**0**
Spring 2003						
Native	**5**	**4**	**18 ± 3.65**	**1.0 ± 0**	**3.18 ± 4.61**	**12.72**
FL plots (experimental)	**69**	**1.27**	**7.30 ± 4.04**	**1.0 ± 0**	**0**	**0**
FF plots (experimental)	**50**	**1.43**	**14.02 ± 4.23**	**1.0 ± 0**	**0**	**0**
Lougher Ridge	**205**	**N/A**	**23.5 ± 9.7**	**N/A**	**N/A**	**1592**
Spring 2004						
Native	**3**	**0 P, 2 T, 1 Bud**	**20.67 ± 11.11**	**1.33 ± 0.58**	**16.37 ± 28.35**	**49.11**
FL plots (experimental)	**753**	**1.12**	**13.69 ± 5.34**	**1.08 ± 0.31**	**0.02 ± 0.50**	**13.67**
FF plots (experimental)	**15**	**0.86**	**17.53 ± 4.71**	**1.2 ± 0.56**	**0.91 ± 3.53**	**13.67**
Lougher Ridge	**868**	**1.59**	**20.74 ± 8.21**	**1.93 ± 2.45**	**50.81 ± 67.93**	**8739.04**

Notes and footnotes appear on following page

Table A3 (Page 2 of 2). Summary of demographic data collected from the Site 300 Drop Tower experimental and native populations and the Lougher Ridge experimental population. (Values are means ± 1 SD)

Population	Total no. of plants	P/T ratio[a]	Average height (cm)	Average no. of branches per plant[b]	Estimated average seed production per plant[c]	Estimated total seed production per population
Spring 2005						
Native	**0**	**0**	**0**	**0**	**0**	**0**
FL plots (experimental)	**0**	**0**	**0**	**0**	**0**	**0**
FF plots (experimental)	**118**	**1.86**	**23.70 ± 1.30**	**1.30 ± 0.59**	**0.72 ± 3.72**	**85.16**
Lougher Ridge	**173**	**0.97, 4 Buds**	**35.43 ± 10.01**	**1.57 ± 1.29**	**3.9 ± 15.92**	**669.5**
Spring 2006						
Native	**4**	**3P, 1Bud**	**28.50 ± 6.19**	**2.00 ± 1.63**	**31.28 ± 22.53**	**128.04**
FL plots (experimental)	**2**	**1T, 1 Bud**	**15.75 ± 6.01**	**1.0 ± 0**	**0**	**0**
FF plots (experimental)	**49**	**1.13, 15 Buds**	**17.69 ± 5.17**	**1.12 ± 0.56**	**0.84 ± 0**	**41.01**
Lougher Ridge	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**

Notes:

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

N = Number of plots.

NA = Not available.

P = Pin-flowered plants.

T = Thrum-flowerd plants.

SD = Standard deviation.

[a] **Calculated using the number of pin versus thrum plants in the entire population. Does not include plants that were senescent or had not flowered at the time of the census.**

[b] **In the native population, branch number was defined as the number of stems branching from the main stem. In the experimental population, branch number was defined as the number of inflorescences per plant.**

[c] **The number of nutlets per plant in the native population was estimated using the regression equation, # nutlets/plant = 3.42* (shoot length in cm) -65.46, r = 0.86, $p < 0.01$ (Pavlik, 1991). If the estimated seed production for an individual plant was a negative number, it was defined as zero. The number of nutlets per plant in the experimental population was estimated using the regression equation, # nutlets/plant = 16.81* (# of inflorescences) -36.76, r = 0.96, $p < 0.0001$ (unpublished). If the estimated seed production for an individual plant was a negative number, it was defined as zero.**

Table A4. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower native and experimental (Exp) populations: 1997–2001.

Species	Native 1997 (%)	Native 1998 (%)	Native 1999 (%)	Exp FL 1999 (%)	Native 2000 (%)	Exp FL 2000 (%)	Exp FF 2000 (%)	Native 2001 (%)	Exp FL 2001 (%)	Exp FF 2001 (%)
Achillea millefolium	5	5	–	–	5	–	–	–	–	–
Allium serra	–	1	–	–	–	–	–	–	–	–
Amsinckia grandiflora	–	–	–	–	–	7	–	–	4	5
Amsinckia tessellata	–	–	–	–	3	5	–	–	4	1
Amsinckia sp.										
Astragalus didymocarpus	–	–	–	–	3	–	–	–	–	–
Avena sp.	18	13	-	7	15	11	24	21	21	21
Bromus diandrus	22	9	17	5	5	2	2	14	2	16
Bromus hordeaceus	31	21	50	33	3	5	1	14	7	7
Bromus madritensis	1	–	–	–	–	–	–	–	–	1
Bromus sp.	–	–	–	–	5	5	28	–	–	–
Castilleja exserta	–	–	–	–	–	–	–	–	–	1
Clarkia sp.	–	3	–	–	5	–	1	7	5	5
Claytonia parviflora	1	1	–	12	–	16	6	–	–	–
Collinsia heterophylla	3	9	17	–	–	–	–	–	–	1
Delphinium hesperium	1	3	–	–	3	2	–	–	–	–
Dichelostemma capitatum	–	–	–	–	–	–	–	–	–	–
Erodium cicutarium	4	5	–	24	18	16	4	21	41	21
Galium aparine	11	23	17	2	5	–	4	7	2	1
Lepidium nitidum	–	–	–	–	–	–	–	–	–	–
Lithophragma affinis	–	–	–	–	–	2	–	–	–	–
Lupinus albifrons	–	1	–	–	–	–	–	–	–	–
Lupinus bicolor	–	–	–	–	–	–	1	–	–	4
Minuartia californica	–	–	–	–	–	–	–	–	–	–
Phacelia tanacetifolia	–	–	–	–	3	–	–	–	–	–
Poa secunda	–	1	–	–	–	–	11	–	5	9
Sonchus sp.	1	-	–	–	–	–	–	–	–	–
Thysanocarpus curvipes	–	–	–	–	–	–	–	–	–	–
Vulpia microstachys	–	–	–	–	–	–	–	–	–	–
Vulpia myuros	–	–	–	10	20	30	11	7	9	5
Unknown dicot	3	3	–	7	8	2	2	7	–	2
Unknown Liliaceae	–	–	–	–	–	–	–	–	–	–
Unknown Poaceae	–	–	–	–	–	–	–	–	–	–
No. of species (S)	12	14	4	8	14	12	12	8	10	15
n	100	129	6	42	39	45	151	14	56	244
Shannon's Index (H')[a]	1.92	2.16	1.31	1.59	2.40	2.14	1.93	1.97	1.80	2.35

Notes:

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

N = Total number of plants.

[a] Shannon and Weaver (1949). $H' = -\Sigma$ (of I = 1 to S) $(n_i/n) * \ln(n_i/n)$ where S is the number of species observed; n is the number of individuals observed; and n_i is the number of individuals in the ith species.

Table A5. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower native and experimental (Exp) populations: 2002–2004.

Species	Native 2002 (%)	Exp FL 2002 (%)	Exp FF 2002 (%)	Native 2003 (%)	Exp FL 2003 (%)	Exp FF 2003 (%)	Native 2004 (%)	Exp FL 2004 (%)	Exp FF 2004 (%)
Achillea millefolium	–	–	–	–	–	–	–	0.27	–
Allium serra	–	–	–	–	–	–	–	–	–
Amsinckia grandiflora	–	22.2	–	–	–	–	–	3.47	–
Amsinckia tessellata	–	–	–	–	–	–	–	–	–
Amsinckia sp.	12.5	–	–	–	–	–	–	0.40	–
Astragalus didymocarpus	–	–	–	–	–	–	–	–	–
Avena sp.	50.0	11.1	21.7	–	12.31	8	33.33	7.87	40
Bromus diandrus	12.5	–	–	25	–	2	33.33	1.87	6.67
Bromus hordeaceus	12.5	–	–	–	1.54	2	–	6.8	
Bromus madritensis ssp. *Rubens*	–	–	–	–	–	–	–	0.13	–
Bromus sp.	–	–	–	–	–	–	–	–	–
Castilleja exserta	–	–	–	–	1.54	–	–	1.07	–
Clarkia sp.	–	–	13.0	–	7.69	6	–	2.13	–
Claytonia parviflora	–	–	–	–	–	–	–	0.13	–
Collinsia heterophylla	–	11.1	–	–	–	–	–	–	–
Delphinium hesperium	–	–	–	–	3.08	–	–	0.53	–
Dichelostemma capitatum	–	–	–	–	–	–	–	0.13	
Erodium cicutarium	–	44.4	21.7	50	36.92	48	–	37.87	46.67
Galium aparine	12.5	–	–	–	–	–	–	0.27	–
Lepidium nitidum	–	–	–	–	–	–	–	0.13	–
Lithophragma affinis	–	–	4.3	–	–	-	–	0.4	–
Lupinus albifrons	–	–	–	–	–	–	–	–	–
Lupinus bicolor	–	–	4.3	–	1.54	–	–	1.07	–
Minuartia californica	–	–	–	–	–	–	–	0.27	–
Phacelia tanacetifolia	–	–	–	–	–	–	–	0.13	–
Poa secunda	–	–	–	–	–	2	–	1.33	2
Sonchus sp.	–	–	–	–	–	–	–	–	–
Thysanocarpus curvipes	–	–	–	–	1.54	–	–	–	–
Vulpia microstachys	–	–	–	–	–	–	–	5.2	–
Vulpia myuros	–	–	30.4	–	24.62	12	33.33	–	6.66
Unidentified dicot	–	–	–	–	–	–	–	0.13	–
Unknown Liliaceae	–	–	–	–	–	–	–	0.13	–
Unknown Poaceae	–	11.1	4.3	25	9.23	20	–	10	–
No. of species (S)	5	5	7	3	10	8	3	26	4
n	8	9	23	4	65	50	3	750	15
Shannon's Index (H')[a]	1.39	1.43	1.68	1.04	1.75	1.53	1.10	2.06	1.08

Notes:

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

N = Total number of plants.

[a] Shannon and Weaver (1949). $H' = -\Sigma$ (of I = 1 to S) $(n_i/n) * \ln(n_i/n)$ where S is the number of species observed; n is the number of individuals observed; and n_i is the number of individuals in the ith species.

Table A6. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower native and experimental (Exp) populations: 2005–2006.

Species	Native 2005 (%)	Exp FL 2005 (%)	Exp FF 2005 (%)	Native 2006 (%)	Exp FL 2006 (%)	Exp FF 2006 (%)
Achillea millefolium	–	–	–	–	–	–
Allium serra	–	–	–	–	–	–
Amsinckia grandiflora	–	–	1.7	–	–	4.1
Amsinckia sp.	–	–	–	–	–	–
Avena barbata	–	11.1	–	–	–	–
Avena fatua	–	–	9.3	–	–	–
Avena sp.	–	11.1	12.7	–	–	18.4
Bromus diandrus	–	–	10.2	–	–	2
Bromus hordeaceus	–	–	14.4	–	–	6.1
Bromus madritensis ssp. *Rubens*	–	–	2.5	–	–	–
Bromus sp.	–	–	–	–	–	–
Castilleja exserta	–	–	0.8	–	–	–
Clarkia sp.	–	–	4.2	–	–	2
Claytonia parviflora	–	–	0.8	–	–	–
Collinsia heterophylla	–	–	–	–	–	–
Delphinium hesperium	–	–	–	–	–	–
Dichelostemma capitatum	–	–	–	–	–	–
Erodium cicutarium	–	11.1	29.7	25	50	36.7
Erodium macrophyllum	–	–	3.4	–	–	–
Galium aparine	–	–	0.8	–	–	–
Lithophragma affinis	–	11.1	–	–	–	-
Lotus wrangelliannus	–	–	–	50	–	–
Lupinus bicolor	–	–	2.5	–	–	–
Minuartia californica	–	–	–	–	–	–
Phacelia tanacetifolia	–	–	–	–	–	–
Poa secunda	–	11.1	–	–	50	8.2
Sonchus sp.	–	–	–	–	–	–
Thysanocarpus curvipes	–	–	–	–	–	–
Vulpia microstachys	–	–	2.5	–	–	–
Vulpia myuros	–	44.4	0.8	25	–	–
Unidentified dicot	–	–	1.7	–	–	–
Unknown Liliaceae	–	–	–	–	–	–
Unknown Poaceae	–	–	1.7	–	–	24.5
No. of species (S)	–	6	18	3	2	7
n	–	9	118	4	2	49
Shannon's Index (H')[a]	N/A*		2.25	1.04	0.16	1.61

Notes:

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

N = Total number of plants.

[a] Shannon and Weaver (1949). H' = - Σ (of *I* = 1 to S) (n_i/n) * ln (n_i/n) where S is the number of species observed; *n* is the number of individuals observed; and n_i is the number of individuals in the *i*th species.

* No *Amsinkia grandiflora* found in at the Native population site

Table A7 (Page 1 of 2). Constancy, percent mean cover for all plots in each subpopulation, and I.V. for cover data collected from the native and experimental populations in 2005.

	Native N = 15				Flashing N=56				Fire Frequency N=20			
	Mean % Cover	Stdev % Cover	Constancy	I.V.	Mean % Cover	Stdev % Cover	Constancy	I.V.	Mean % Cover	Stdev % Cover	Constancy	I.V.
Bare	15.7	9.4	100.0		32.6	25.7	100.0		23.8	23.5	80	
Thatch	22.8	17.3	100.0		10.9	7.4	91.1		12.8	16.6	65	
Achillea millifolium	1.8	2.7	46.7	0.5	0.8	3.2	10.7	0.1	0.5	2.2	5.0	0.1
Allium serra	0.7	1.5	20.0	0.2	-	-	-	-	-	-	-	-
Amsinckia grandiflora*	-	-	-	-	0.2	0.6	7.1	0.1	3.6	5.9	50.0	0.5
Amsinckia menziesii	-	-	-	-	-	-	-	-	0.8	1.2	30.0	0.3
Amsinckia sp.	0.3	0.9	13.3	0.1	1.5	1.5	53.6	0.6	-	-	-	-
Artemisia californica	-	-	-	-	0.1	0.5	3.6	<0.1	0.1	0.6	5.0	0.1
***Avena* sp.**	29.3	12.4	100.0	1.3	15.5	8.3	100.0	1.2	13.5	15.2	75.0	0.9
Blepharizonia sp.	0.5	1.0	20.0	0.2	0.4	1.0	14.3	0.1	-	-	-	-
Bromus diandrus	4.2	6.2	53.3	0.6	3.1	4.9	48.2	0.5	3.5	5.8	40.0	0.4
Bromus hordeaceus	16.7	15.5	80.0	1.0	7.5	7.7	83.9	0.9	9.1	13.2	55.0	0.6
Bromus madritensis* subsp. *rubens	11.2	22.4	80.0	0.9	1.0	1.5	35.7	0.4	0.9	2.5	15.0	0.2
***Camissonia* sp.**	-	-	-	-	0.2	0.7	8.9	0.1	-	-	-	-
Capsella bursa-patoris	-	-	-	-	0.1	0.6	5.4	0.1	-	-	-	-
Castilleja exerta	0.2	0.6	6.7	0.1	3.0	3.2	66.1	0.7	1.6	3.6	30.0	0.3
***Cirsium* sp.**	-	-	-	-	-	-	1.8	<0.1	0.3	0.8	10.0	0.1
***Clarkia* sp.**	0.3	0.9	13.3	0.1	2.5	1.1	91.1	0.9	2.3	2.8	50.0	0.5
***Claytonia* sp.**	0.3	0.9	13.3	0.1	0.1	0.6	5.5	0.1	0.4	1.2	10.0	0.1
Collinsia heterophylla	1.5	3.0	26.7	0.3	-	-	-	-	-	-	-	-
***Delphinium* sp.**	1.2	2.7	26.7	0.3	3.8	5.1	67.9	0.7	0.3	0.8	10.0	0.1
Dichelostemma capitatum	-	-	-	-	0.3	0.8	10.7	0.1	-	-	-	-
Elymus elymoides	-	-	-	-	-	-	-	-	0.8	3.4	5.0	0.1
***Eriogonum* sp.**	-	-	-	-	0.1	0.5	3.6	<0.1	-	-	-	-
Erodium cicutarium	10.3	12.5	80.0	0.9	25.4	12.8	98.2	1.2	16.8	12.1	75.0	0.9
Filago californica	-	-	-	-	0.1	0.7	3.6	<0.1	-	-	-	-
Galium aparine	4.3	4.3	80.0	0.8	0.2	0.6	7.1	0.1	0.1	0.6	5.0	0.1
Grindelia camporum	-	-	-	-	0.1	0.7	3.6	<0.1	1.8	5.9	10.0	0.1
Lepidium nitidum	-	-	-	-	0.1	0.4	1.8	<0.1	-	-	-	-

Table A7 (Page 2 of 2). Constancy, percent mean cover for all plots in each subpopulation, and I.V. for cover data collected from the native and experimental populations in 2005.

	Native N = 15				Flashing N=56				Fire Frequency N=20			
	Mean % Cover	Stdev % Cover	Constancy	I.V.	Mean % Cover	Stdev % Cover	Constancy	I.V.	Mean % Cover	Stdev % Cover	Constancy	I.V.
Lithophragma affine	0.2	0.6	6.7	0.1	2.7	4.5	46.4	0.5	1.0	2.5	20.0	0.2
Lotus wrangelliannus	0.5	1.0	20.0	0.2	0.1	0.7	3.6	<0.1	-	-	-	-
Lupinus albifrons	-	-	-	-	-	-	-	-	0.3	1.1	5.0	0.1
Lupinus bicolor	0.3	0.9	13.3	0.1	5.8	5.2	96.4	1.0	1.8	3.5	35.0	0.4
Marah fabaceus	-	-	-	-	0.1	0.7	1.8	<0.1	0.3	1.1	5.0	0.1
Medicago polymorpha	-	-	-	-	<0.1	0.3	1.8	<0.1	-	-	-	-
Monolopia major	0.2	0.6	6.7	0.1	-	-	-	-	-	-	-	-
Phacelia distans	0.3	0.9	13.3	0.1	<0.1	0.3	1.8	<0.1	-	-	-	-
Poa secunda	1.5	3.0	26.7	0.3	8.8	9.7	71.4	0.8	14.3	12.1	70.0	0.8
Sanicula bipinnata	0.5	1.4	13.3	0.1	-	-	-	-	-	-	-	-
Thysanocarpus curvipes	-	-	-	-	0.3	0.8	10.7	0.1	-	-	-	-
Trifolium sp.	-	-	-	-	<0.1	0.3	1.8	<0.1	-	-	-	-
Unknown Asteraceae	0.5	1.4	13.3	0.1	0.6	2.0	12.5	0.1	-	-	-	-
Unknown Brassicaceae	-	-	-	-	<0.1	0.3	1.8	<0.1	-	-	-	-
Unknown dicot	0.3	0.9	13.3	0.1	1.6	2.8	33.9	0.4	0.8	1.4	25.0	0.3
Unknown Liliaceae	-	-	-	-	0.1	0.7	1.8	<0.1	-	-	-	-
Unknown Poaceae	-	-	-	-	2.1	5.1	17.9	0.2	-	-	-	-
Vulpia microstachys	1.2	2.8	20.0	0.2	21.1	24.7	85.7	1.1	5.8	11.0	35.0	0.4
Vulpia myuros	7.5	9.3	60.0	0.7	-	-	-	-	-	-	-	-

Notes:

Constancy = Number of times a species occurs/total number of plots) × 100.

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

I.V. = Importance values. (Constancy + Mean Cover)/100.

N = Number of plots.

SD = Standard deviation.

*** = No *Amisinkia grandiflora* plants were found at the native population site in 2005**

Table A8 (Page 1 of 2). Constancy, mean percent cover, standard deviation, and I.V. for all plots in the flashing and fire frequency experimental in 2006. Only one cover quadrat was sampled in the native population in 2006 so standard deviation, constancy, and I.V. are not shown.

	Native N=1	Flashing N=55				Fire Frequency N=19			
	% Cover	Mean % Cover	Stdev % Cover	Constancy	IV	Mean % Cover	Stdev % Cover	Constancy	IV
Bare	30	33.0	16.6	100		32.8	17.2	100	
Thatch	10	2.1	1.5	72.7		6.3	5.3	100	
Achillea millifolium	-	0.5	2.0	7.3	0.1	0.8	3.4	5.3	0.1
Amsinckia grandiflora	<5	0.1	0.5	3.6	<0.1	0.9	1.7	26.3	0.3
Amsinckia menziesii	-	0.7	1.4	23.6	0.2	0.1	0.6	5.3	0.1
***Amsinckia* sp.**	-	0.4	0.9	16.4	0.2	0.3	0.8	10.5	0.1
Avena fatua	30	-	-	-	-	-	-	-	-
Bromus diandrus	-	<0.1	0.3	1.8	<0.1	1.8	5.8	15.8	0.2
Bromus hordeaceus	5	0.8	2.5	12.7	0.1	7.4	13.2	47.4	0.5
Bromus madritensisssp. rubens	5	-	-	-	-	-	-	-	-
Castilleja exerta	-	1.8	2.9	43.6	0.5	1.3	1.5	47.4	0.5
Cirsium sp.	-	-	-	-	-	0.7	2.3	10.5	0.1
Clarkia sp.	-	1.5	1.2	61.8	0.6	1.7	1.9	52.6	0.5
Claytonia perfoliata	-	0.4	0.9	14.5	0.1	1.1	1.5	36.8	0.4
Delphinium sp.	-	3.5	5.3	70.9	0.7	0.8	1.2	31.6	0.3
Dichelostemma capitatum	-	0.1	0.7	3.6	<0.1	0.3	0.8	10.5	0.1
Erodium cicutarium	-	28.2	17.8	100.0	1.3	23.3	16.9	94.7	1.2
***Eriogonum* sp.**	-	0.1	0.5	3.6	<0.1	-	-	-	-
***Filago* sp.**	-	<0.1	0.3	1.8	<0.1	0.1	0.6	5.3	0.1
Galium aparine	-	-	-	-	-	0.4	0.9	15.8	0.2
Grindelia camporum	-	0.1	0.5	3.6	<0.1	-	-	-	-
Lithophragma affine	-	1.6	2.0	50.9	0.5	1.3	1.9	36.8	0.4
Lotus wrangelliannus	25	0.1	0.7	1.8	<0.1	-	-	-	-
Lupinus albifrons	-	-	-	-	-	0.4	0.9	15.8	0.2
Lupinus bicolor	-	2.4	1.9	74.5	0.8	1.7	2.8	36.8	0.4

Table A8 (Page 2 of 2). Constancy, mean percent cover, standard deviation, and I.V. for all plots in the flashing and fire frequency experimental in 2006. Only one cover quadrat was sampled in the native population in 2006 so standard deviation, constancy, and I.V. are not shown.

	Native N=1	Flashing N=55				Fire Frequency N=19			
	% Cover	Mean % Cover	Stdev % Cover	Constancy	IV	Mean % Cover	Stdev % Cover	Constancy	IV
Monolopia major	<5	-	-	-	-	-	-	-	-
Phacelia distans	<5	-	-	-	-	-	-	-	-
Poa secunda	-	9.4	9.1	80.0	0.9	13.7	9.1	84.2	1.0
Senecio vulgaria	-	0.1	0.5	3.6	<0.1	-	-	-	-
Thysanocarpus curvipes	-	<0.1	0.3	1.8	<0.1	0.1	0.6	5.3	0.1
Trifolium gracilentum	-	<0.1	0.3	1.8	<0.1	-	-	-	-
Vulpia microstachys	-	4.5	10.9	27.3	0.3	4.6	7.8	63.2	0.7
Vulpia myuros	15	3.0	9.3	14.5	0.2	-	-	-	-
Unknown dicot	<5	2.3	3.9	47.3	0.5	2.9	2.9	66.7	0.7
Unknown Liliaceae	-	0.1	0.5	3.6	<0.1	0.3	0.8	10.5	0.1
Unknown annual grass	-	26.4	13.7	100.0	1.3	25.0	19.2	78.9	1.0
Unknown moss	-	9.3	10.1	85.5	0.9	5.5	15.1	21.1	0.3

Notes:

Constancy = Number of times a species occurs/total number of plots) × 100.

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

I.V. = Importance values. (Constancy + Mean Cover)/100.

N = Number of plots.

SD = Standard deviation.

Table A9. Dry biomass by dominant grass type in FL plots at the Site 300 Drop Tower experimental population. Values are means ± 1 SE.

	Poa secunda plots[a]		Annual grass plots[b]		All plots	
Year	Final dry biomass (g/0.1 m^2)[c]	N	Final dry biomass (g/0.1 m^2)[c]	N	Final dry biomass (g/0.1 m^2)[c]	N
2006	22.66 ± 8.95	3	15.97 ± 1.77	2	19.98 ± 7.36	5
2005	25.24 ± 7.37	2	14.15 ± 4.43	3	18.59 ± 4.84	5
2004	6.32 ± 1.53	2	6.63 ± 1.82	3	6.50 ± 1.28	5
2003	14.1 ± 1.6	3	13.0 ± 4.6	2	13.66 ± 1.31	5
2002	16.58 ± 3.30	3	16.6 ± 3.3	7	18.80 ± 1.57	10
2001	7.3 ± 0.81	5	9.0 ± 1.99	5	8.30 ± 1.04	10
2000	10.6 ± 2.9	5	17.6 ± 4.1	5	14.13 ± 2.52	10
1999	13.5 ± 3.1	5	20.6 ± 8.2	5	16.80 ± 1.97	10
1998	28.5 ± 2.2	6	21.7 ± 5.9	4	25.77 ± 2.74	10
1994	9.9 ± 0.9	13	8.7 ± 0.9	20	NA	

Notes:

FL = Flashing subpopulation.

NA = Not applicable.

N = Number of plots.

SE = Standard error.

[A] Plots established with fixed densities of *Poa* in 1993 and 1994. (Includes plots planted with low, medium and high densities of *Poa*.)

[b] Plots cleared of all perennial grasses 1993 through 1994.

[C] Biomass samples were collected from a 0.1 m^2 area located in the center of each 0.8 m^2 plot. Samples were collected in May 1994, June 1998, May 1999, May 2000, May 2001, May 2002, May 2003, May 2004, May 2005, May 2006.

Table A10. Number of *Poa secunda* per 1 m^2 plot in the fire frequency experimental subpopulation. Values are means ± 1 SD. Italics indicates plots burned the previous year.

		Fire frequency			
	All frequencies N = 20	**Control N = 5**	**Low N = 5**	**Medium N = 5**	**High N = 5**
2006[a,b]	***13.68 ± 9.11***	***7.50 ± 8.66***	***10.00 ± 6.12***	***16.00 ± 11.94***	***20.00 ± 5.00***
2005	**14.5 ± 12.06**	**5.0 ± 5.48**	**11.0 ± 13.42**	***22.0 ± 7.58***	***20.0 ± 12.75***
2004	**19.2 ± 8.7**	**8.0 ± 4.2**	**19.6 ± 6.1**	**21.8 ± 2.9**	***27.2 ± 7.0***
2003	**24.5 ± 8.3**	**20.6 ± 9.4**	**27.2 ± 5.4**	**23.6 ± 6.9**	***26.4 ± 11.4***
2002	**27.2 ± 7.8**	**20.6 ± 6.4**	***29.0 ± 3.4***	***30.8 ± 7.0***	***27.6 ± 10.5***
2001	**21.7 ± 5.3**	**22.0 ± 5.8**	**22.0 ± 5.2**	**21.2 ± 4.1**	**21.6 ± 7.2**
2000	**29.3 ± 6.0**	**31.6 ± 4.4**	**30.0 ± 2.0**	**29.2 ± 1.3**	**26.2 ± 11.4**
1999	**33**	**33**	**33**	**33**	**33**

Notes:

Plots planted in 1999.

Averages broken down by burn frequency (control = unburned, low = burned every fifth year, medium = burned every third year, high = burned every other year). There are five plots for each of the four burn frequencies.

Burn treatments began summer 2001.

N = Number of plots.

SD = Standard deviation.

[a] **4 out of 5 control plots were sampled making the total number of plots 19**

[b] **In July 2005 a wildfire burned both the experimental and native Amsinkia populations**

Table A11. Number of *Amsinckia grandiflora* per 1 m^2 plot in the fire frequency experimental subpopulation. Values are means ± 1 SD.

		Fire frequency[a]		
	All frequencies N = 20	Control N = 5	Low & Medium N = 10	High N = 5
2006[a]	0.62 ± 1.71	1.25 ± 2.89	0.50 ± 1.77	0
2005	3.68 ± 5.93	8.00 ± 8.91	3.00 ± 2.09	0.70 ± 1.57
2004	0.8 ± 1.3	2.2 ± 2.0	0.4 ± 0.5	0
2003	1.3 ± 1.1	2.0 ± 3.5	3.2 ± 2.9	1.6 ± 1.1
2002	2.5 ± 2.7	5.6 ± 4.8	1.0 ± 1.7	2.6 ± 3.7

Notes:

Burn frequencies: Control = unburned, Low = burned every fifth year, Medium = burned every third year, High = burned every other year). There are five plots for each of the four burn frequencies.

Burn treatments began summer 2001.

N = Number of plots.

SD = Standard deviation.

[a] 4 out of 5 control plots were sampled making the total number of plots 19

Section B
Blepharizonia plumosa Monitoring

Blepharizonia plumosa Monitoring and Research

B-1. Introduction

Several populations of *Blepharizonia plumosa* (the big tarplant, known also as *Blepharizonia plumosa* subsp. *plumosa*) were identified during a habitat survey in 1996 at Site 300 (Preston, 1996; 2002). *Blepharizonia plumosa* is an extremely rare late-season flowering annual plant included on the California Native Plant Society (CNPS) List 1B, which includes plants that are rare, threatened, or endangered (CNPS, 2008). Populations have been previously identified in Alameda, Contra Costa, San Joaquin, Stanislaus, and Solano counties (Skinner and Pavlik, 1994). Preston (1996) noted that a population was discovered at Contra Loma Regional Park, south of Antioch in 1979, but that surveys conducted by the East Bay Regional Park District in 1991 were unable to relocate the species. In 1994, several more populations were discovered on private property southwest of Brentwood (CNDDB, 2006). Another small population was found at Chaparral Springs, near Mount Diablo (Preston, 1996). The current status of these populations is unknown. Also, during the 1996 and 2002 habitat surveys of Site 300, a few populations of the more common big tarplant, *Blepharizonia laxa* (also known as *Blepharizonia plumosa* subsp. *viscida*), were found.

The genus *Blepharizonia* has recently been taxonomically revised. Baldwin et al. (2001) found that what had been considered two similar plant subspecies are truly two co-occurring, separate species. *Blepharizonia plumosa* subsp. *plumosa* retained the specific moniker *B. plumosa*, and *B. plumosa* subsp. *viscida* is now known as *B. laxa*. The most current nomenclature for these species will be used throughout this report. Both *B. plumosa* and *B. laxa* are dicots within the family Asteraceae (the sunflower family), and members of the tribe Helenieae (Karis and Ryding, 1994). They are both summer annual forbs, which germinate with the onset of the first substantial fall/winter rains and flower July through October. The plants are heterocarpic, producing dimorphic flowers within the same inflorescence. Disc seeds are produced from the central or disc flowers of the inflorescence and ray seeds are produced from the peripheral ray flowers. The disc flowers are whitish in color while the ray flowers are white with purple veins and deeply three lobed (Bremer, 1994).

Blepharizonia plumosa can generally be distinguished from *B. laxa* by fruit morphology and leaf color (Hickman, 1993; personal observation). The most distinctive characteristic of *B. plumosa* is the pappus of 1.5 to 3 mm in length on the disc fruits. This pappus, sometimes described as plumose (thus the name *plumosa),* contrasts with the very minute pappus of the ray fruits. The plants also have a pale green color, as their foliage is sparsely glandular below the inflorescence. Older plants have many inflorescences on lateral side branches.

Blepharizonia laxa, although also endemic to California, exists in large numbers and has a much larger range that extends farther south into the inner South Coast Ranges including San Benito County (Hickman, 1993). The disc and ray seeds of *B. laxa* appear quite similar and have a short pappus from 0 to 1 mm in length. *Blepharizonia laxa* is much more glandular than *B. plumosa*, giving the plant a more yellow-green color and a much stronger scent. Older plants have inflorescences mostly terminal on slender wand-like, bracted peduncles (Hickman, 1993).

Many areas at Site 300 are annually burned in the late spring/early summer as a means of wildfire control. Although rare outside of Site 300, *B. plumosa* is quite common at Site 300, occurring in large numbers in areas that are routinely burned. This is interesting, for at the time of the annual spring burns at Site 300, the plant is in a green vegetative stage, and thus very susceptible to fire damage. It is possible that the larger Site 300 *B. plumosa* population may be acting as a metapopulation. Smaller subpopulations may be established or extinguished, depending on fire uniformity and intensity. And although fire is potentially fatal to individual *B. plumosa* plants directly in its path, it may provide the amount of disturbance necessary to reduce competition and allow for subpopulation establishment, thus maintaining a metapopulation consisting of ephemeral individual populations.

While common throughout its range, *B. laxa* is less common at Site 300 than *B. plumosa*. *Blepharizonia laxa* populations occur sporadically in both unburned and burned areas. The two species also occur sympatrically in a few locations.

For conservation and management purposes, a thorough understanding of the population dynamics of *B. plumosa* is necessary. *Blepharizonia laxa* is also of interest as comparisons of rare and common congeners can provide important information for rare plant management (Bevill and Louda, 1999; Pantone et al., 1995) and can illuminate differences that affect comparative abundance (Byers, 1998). Therefore, between 1996 and 2001, we collected basic demographic and population biology data on *B. plumosa* and *B. laxa.* Between 1996 and 2001, populations of *B. plumosa* and *B. laxa* were delineated for demographic monitoring purposes. This monitoring showed that *B. plumosa* and *B. laxa* do not survive direct contact with prescribed burns, but survive in small patches of unburned habitat within the burns.

We have begun to discern ecological differences between *B. plumosa* and *B. laxa* (Gregory et al., 2001); however, we cannot yet explain the relative differences in abundance between the two species at Site 300. Therefore, current and future work focus on understanding the population dynamics of *B. plumosa* across the entire site. If indeed *B. plumosa* is acting as a large metapopulation, smaller subpopulations may be of less importance. But we must verify that *B. plumosa* is indeed acting as a metapopulation and understand how it is maintained before we can be certain subpopulations loss will not threaten the overall metapopulation. By continued work with *B. laxa* we will gain a better understanding of the mechanisms controlling the relative abundance of the two species at Site 300.

B-2. Methods and Materials

B-2.1. Site-wide Mapping

Site-wide mapping of *B. plumosa* and *B. laxa* was conducted at Site 300 in 2005 and 2006. In 2005, *Blepharizonia* mapping was conducted on ten days between September 22 and October 11. In 2006, *Blepharizonia* mapping was conducted on six days between September 26 and October 6.

Surveys for *Blepharizonia* were conducted by driving the Site 300 fire trail system at slow speeds while surveying for *Blepharizonia* from the vehicle. In addition, we stopped at vantage points and scanned the landscape with binoculars for *Blepharizonia. Blepharizonia* is one of the few white-flowered plants blooming at Site 300 during the survey, so it is easy to identify using binoculars.

In 2003 through 2006, tarplant mapping was conducted using handheld Trimble XH, and XT GPS units, and population attributes were recorded using a standardized method. For each population mapped, the following information was recorded: the species *(B. plumosa* or *B. laxa)*, an estimate of population size (< 10, 10–50, 50–200, 200–500, 500–1,000, 1,000–5,000, or > 5,000 plants), whether the site was burned or unburned, and population location (roadside, grassland, scrub, or power pole ring).

For 2003 through 2006, all data recorded using the Trimble units was differentially corrected using base stations at Site 300, Mt. Hamilton, or Livermore. The corrected GPS data was then exported to an ArcInfo geodatabase for analysis. Topology errors for each year's data were corrected separately to remove overlapping polygons.

In 2002, all areas of Site 300 were surveyed for flowering *Blepharizonia* populations. All *B. plumosa* and *B. laxa* populations found were manually mapped using a large-scale topographic map (1 in : 600 ft). The number of individuals were either counted or visually estimated for each population mapped. The populations were drawn by hand in ArcGIS using topography, roads, and buildings as reference.

Analysis conducted in this report use population estimates from 2002 through 2006 because data from these years was recorded using comparable methods and the entire site was mapped.

In 2001, only the northeastern portion of the site was mapped using handheld Trimble GPS units. The population size was also estimated for all populations mapped in 2001.

Mapping was also conducted on the following dates between 1996 through 2000.

- 1996 & 1997: On September 27, 1996; October 4, 1996; and September 23, 1997, Robert Preston surveyed the entire site for flowering *B. plumosa* populations and visually estimated population locations and sizes, hand-mapping them on a large-format map (Preston, 2002).
- 1999 & 2000: On October 22 and 29, 1999, and on seven dates between October 20 and November 8, 2000, all areas of Site 300 were surveyed for flowering *B. plumosa* populations. Mapping included a combination of hand-mapping and GPS mapping (using a Trimple GPS unit).

- 2001: On three dates between October 25 and November 8, 2001, the northern and western areas of Site 300 were surveyed for flowering *Blepharizonia* populations. The remainder of the site was not surveyed due to manpower limitations. All *B. plumosa* and *B. laxa* populations found were mapped using a Trimble GPS unit.
- 2002: The number of individuals were either counted or visually estimated for most of the populations that were mapped on seven dates between September 25 and October 30, 2002.
- 2003: Site wide *Blepharizonia* mapping was conducted on October 14–17 and 20, 2003.
- 2004: Site wide *Blepharizonia* mapping was conducted on September 29 and 30, 2004, and October 8 and 15, 2004.

B-2.1.1. Data Analysis

Using the ArcGIS geodatabase created from field data described above the area of the *Blepharizonia* populations at Site 300 for 2001 through 2006 was calculated. Also, minimum and maximum population sizes for all *B. plumosa and B. laxa* at Site 300 were estimated for each year from 2001 through 2006. The minimum estimated population size was calculated by summing the lowest extent of the population size range for each polygon mapped, and the maximum estimated population size was calculated by summing the highest extent of the population size range. For example, if a polygon was given the population size range of less than ten plants, the value one plant was used as the minimum population size for this polygon, and ten plants was used as the maximum population size for this polygon. The minimum and maximum population sizes of *B. plumosa* at Site 300 was calculated by summing these minimum or maximum population sizes for all *B. plumosa* polygons at Site 300 during a particular year.

The population area was compared to the total annual rainfall at Site 300 for 2002 through 2006. Data from 2001 was not used for this comparison because the entire site was not mapped that year. Rainfall for each census year was defined as the rainfall from October 15 prior to the census until the following October 14.

B-2.2. Seedling Recruitment Burn Study

A study was established to attempt to determine if seedling recruitment increased in the years following a prescribed burn. Prior to 2002, the area surrounding Building 801 had routinely been including in the annual Site 300 prescribed burn. After 2001, it was no longer necessary for Site 300 to burn this area. A prescribed burn was conducted in the area surrounding Building 801 in June of 2005 in an effort to increase the *B. plumosa* distribution surrounding Building 801.

In May of 2005 prior to the 2005 prescribed burn, five 300 foot transects were established within the area surrounding Building 801 where the additional prescribed burn was to be conducted. Transects were placed based on the distribution of *B. plumosa* in 2001 through 2004. Transects were placed where *B. plumosa* occurred in at least two of the last four years. The location of these transects is shown in Figure B1.

Prior to the prescribed burn, in May of 2005 the number of *Blepharizonia* seedlings within five feet of either side of the transect were counted. The transects were surveyed again in May 2006, approximately 11 months after the prescribed burn.

A paired t-test was used to compare the number of *Blepharizonia* seedlings found before the prescribed burn to the number found the spring following the prescribed burn.

B-3. Results

B-3.1. Site-wide Mapping

Figures B2 and B3 summarize the results of *Blepharizonia* mapping and/or burning conducted between 2001 and 2006. For maps of the distribution of *Blepharizonia* at Site 300 in previous years, see the FY03/04 annual report (Paterson et al., 2005). The relationship between *Blepharizonia* location and burning is shown in greater detail in the map enlargements that follow the summary maps (Figures B4 through B9).

Table B1 shows that the number of *B. laxa* and *B. plumosa* varies greatly between years. Between 2002 and 2006, the Site 300 *B. plumosa* population fluctuated between a maximum estimated population size of almost 250,000 plants in 2005 to only 10,000 plants in 2006.

The *B. laxa* population size also varied greatly between 2002 and 2006, and showed a similar pattern of variation, as did *B. plumosa.* During years when the *B. plumosa* population was relatively large, the *B. laxa* population was also relatively large, and during years when the *B. plumosa* population was small, the *B. laxa* population was also relatively small. The largest estimated *B. laxa* population size between 2002 and 2006 occurred in 2005 when the maximum estimated population size was approximately 71,000 plants. While the maximum estimated size of the *B. laxa* population was only 754 plants in 2006, the smallest maximum estimated population size recorded was in 2004 at 258 plants.

Figure B10 shows the abundance of both species of *Blepharizonia* compared to rainfall.

B-3.2. Seedling Recruitment Burn Study

Of the five seedling recruitment transects established near Building 801 in 2005, transects 4 and 5 had many more seedlings the spring after the burn compared to the spring prior to the burn. Transect 1 had fewer seedlings the spring after the burn compared to the spring prior to the burn, and transects 2 and 3 remained at a similar number of seedlings. There was not a significant difference in the number of seedlings in May of 2005 compared to May of 2006 ($p = 0.39$). The effect of the burn is likely masked by success of *Blepharizonia* throughout the site. When comparing the population size between 2002 and 2006, both *B. laxa* and *B. plumosa* populations were largest in 2005 and smallest in 2006.

B-4. Recommendations and Future Work

By mapping *B. plumosa* populations on a yearly basis, we are gaining a better understanding of the mechanisms at work controlling the distribution of this species. *Blepharizonia plumosa* is so widespread at Site 300 that mapping over multiple years is required to provide information on the relationship between population presence and burn frequency. Intensity and timing of burning may have profound effects on *B. plumosa* population dynamics and, in the absence of the ability to control these effects, many years of data are needed to shed light on the relationship between *B. plumosa* and the annual burns that occur at the site.

The information gained from monitoring the burn survivorship at Building 850, Elk Ravine, and Building 812 in 2001 and 2002 was useful in interpreting the site-wide data. We have shown conclusively that *B. plumosa* does not survive direct contact with the flames, but rather survives in patches of unburned habitat. However, it is now important to determine if seedling recruitment is enhanced in burned vs. unburned areas. That is, while burning may cause direct mortality of plants in the year of the burn, it may enhance seedling recruitment either through reduction in plant competition or enhanced germination the following year if the area is not burned again. Mapping results from the northeastern portion of the site, near Building 801, suggest this to be the case. As such, we would expect to see a decline in this population over time if the area is not periodically burned.

A study of *B. plumosa* seedling abundance was conducted in the area surrounding Building 801 prior to (May 2005) and following (May 2006) a prescribed burn. The goal of the study was to determine if seedling abundance was increased the year following a prescribed burn. This study was inconclusive in part due to the unusually low *B. plumosa* population size throughout Site 300. The number of seedlings in two of the five transects did dramatically increase in 2006 despite the low site-wide population size indicating that this question warrants more careful study in the future.

Developing a method of measuring burn patchiness would allow us to more clearly understand the fluctuations in population size near Buildings 801 and 851. By mapping unburned patches immediately following controlled burns at Buildings 801 and 851 annually, we would be able to compare the distribution of *B. plumosa* in relationship to the patchiness of the burns and possibly explain why the *B. plumosa* population surrounding Building 851 continues to persist despite annual burns. Mapping burn patchiness may also help to explain population size fluctuations throughout the site.

The importance of gene flow among Site 300 *B. plumosa* locations is unknown. The Site 300 *B. plumosa* population may be acting in one of three ways: (1) a true metapopulation, in that gene flow is semi-restricted, with most of the gene flow occurring within subpopulations and with limited gene flow occurring between subpopulations, (2) one large population, with extensive gene flow occurring between all subpopulations, or (3) many small populations, with no gene flow among them. We have been operating under the hypothesis that the Site 300 *B. plumosa* population is either a true metapopulation (scenario 1) or a single large population (scenario 2). Under either case, the loss of a small subpopulation may not impact the larger Site 300 population depending on its size and location. However, should individual populations be the case (scenario 3), each population is valuable and irreplaceable and theoretically should be protected. The best method to determine the population structure at this level is through molecular and/or genetic analysis of plants from subpopulations across the site. Should funding opportunities arise, this work should be considered.

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Section B
Figures

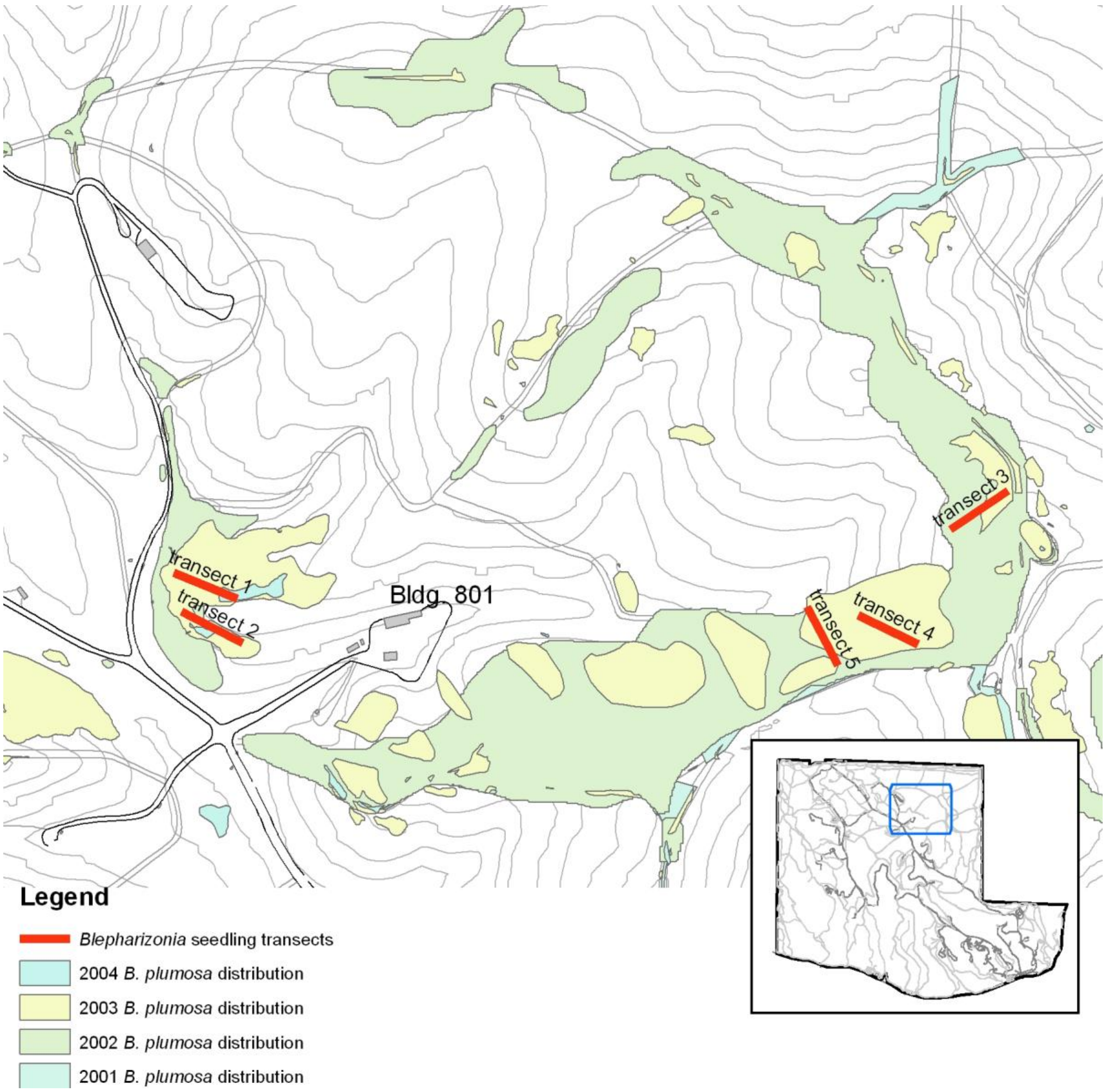


Figure B1. Location of seedling recruitment transects compared to the distribution of *B. plumosa* and *B. laxa* in 2001 through 2004.

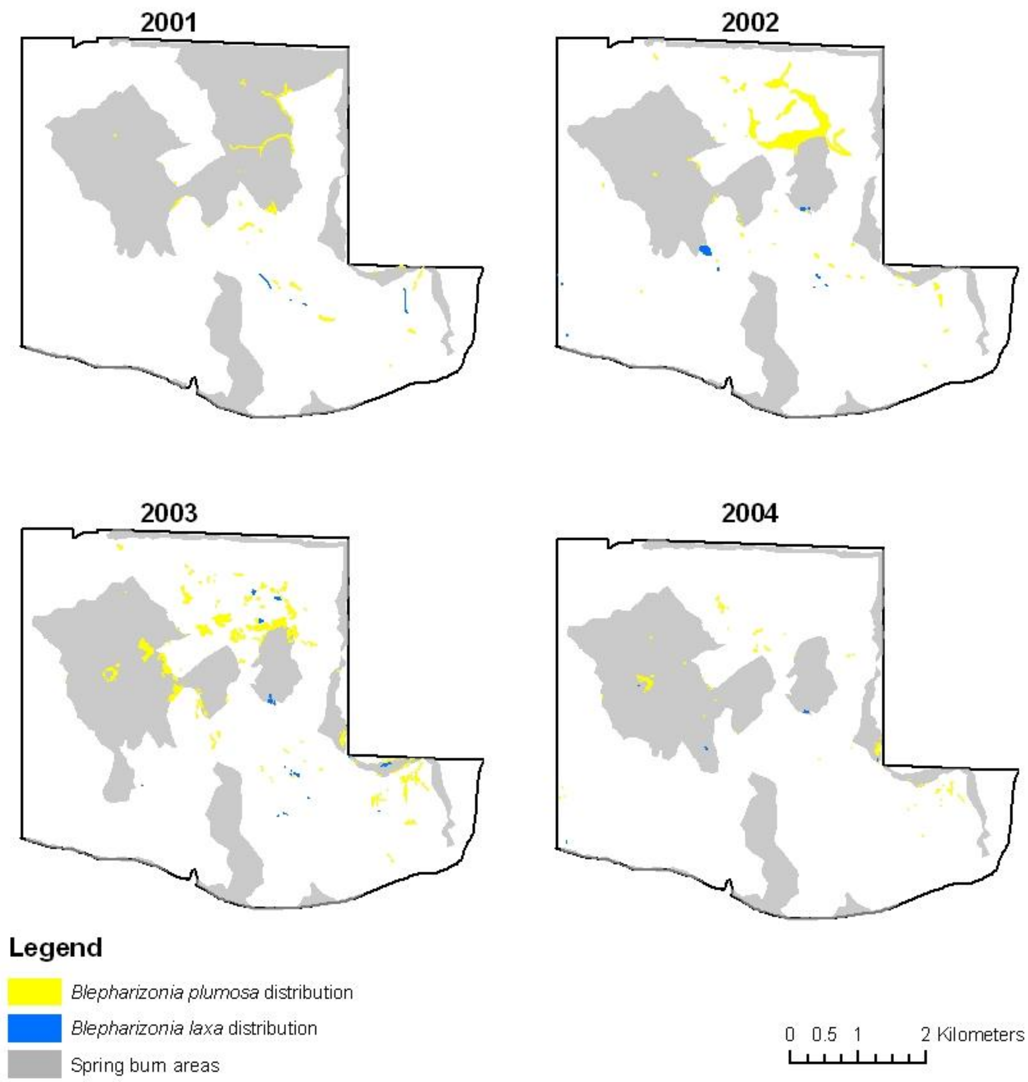


Figure B2. *Blepharizonia* populations mapped in the fall of 2001 through 2004. Spring prescribed burns are also shown. For map enlargements, refer to Figures B4 through B7.

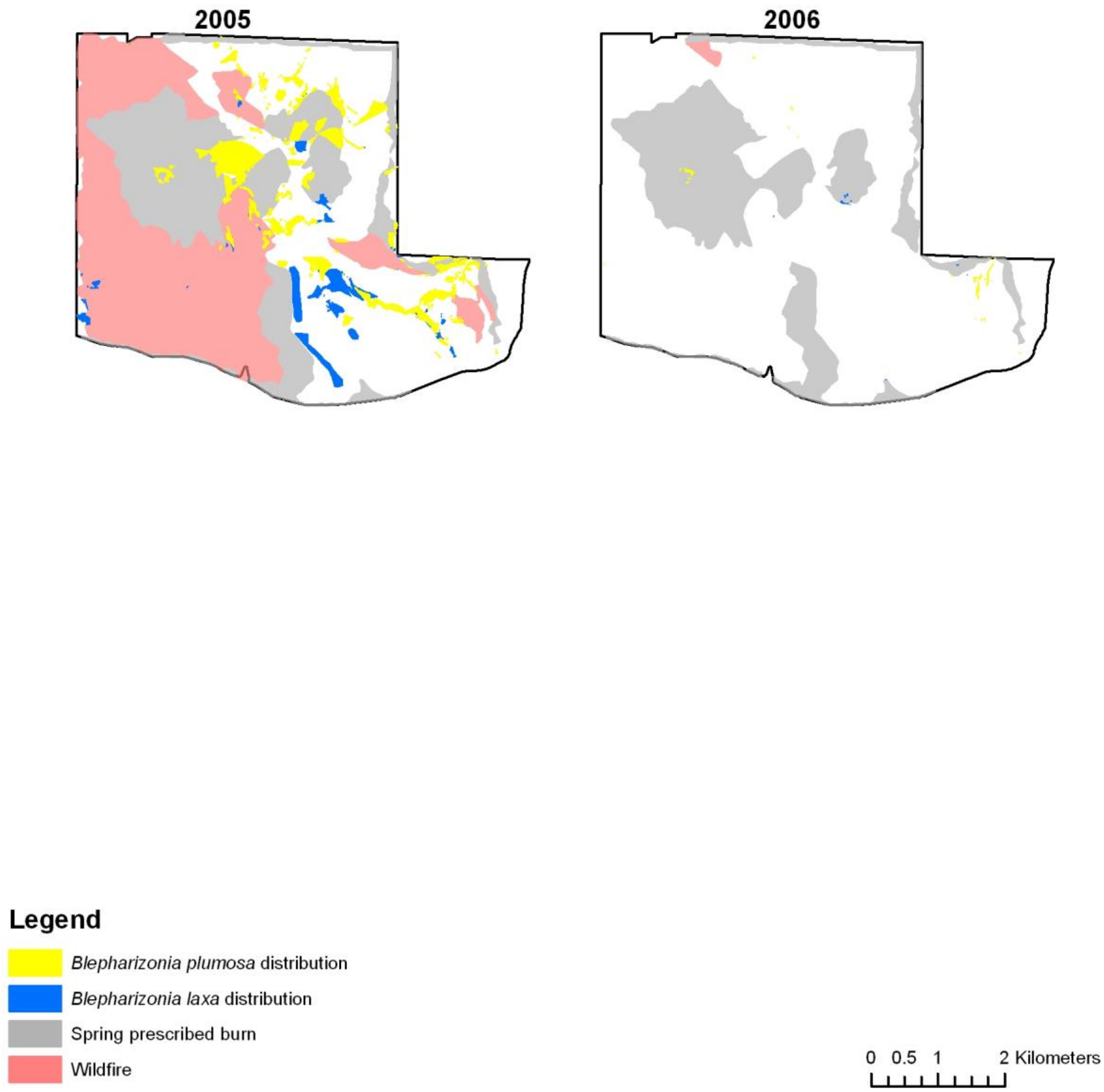


Figure B3. *Blepharizonia* populations mapped in the fall of 2005 and 2006. Spring prescribed burns and wildfires are also shown. For map enlargements, refer to Figures B8 and B9.

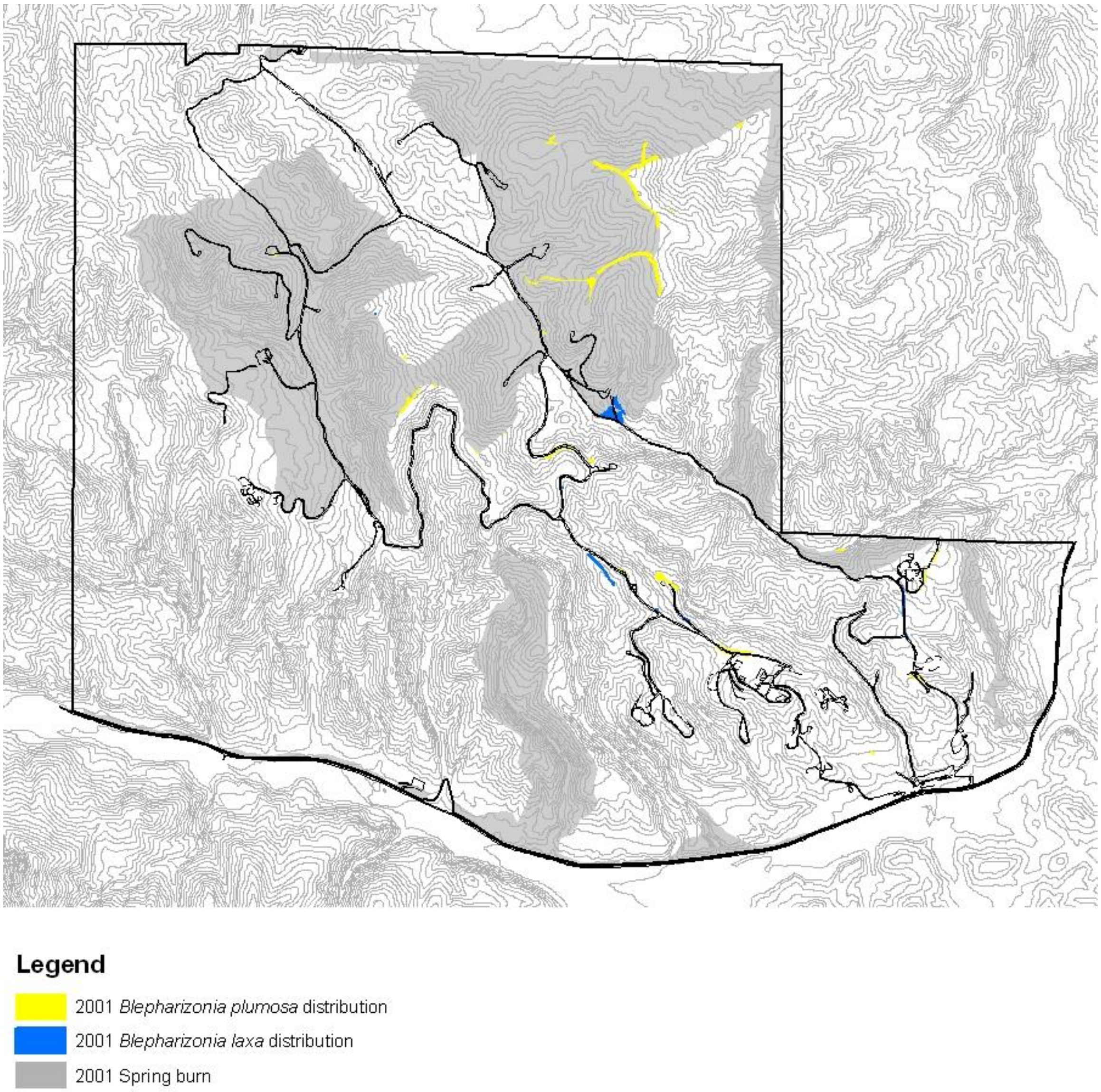


Figure B4. Enlargement of Figure B1 (2001). *Blepharizonia* populations mapped in the fall of 2001. The 2001 prescribed burn is also mapped.

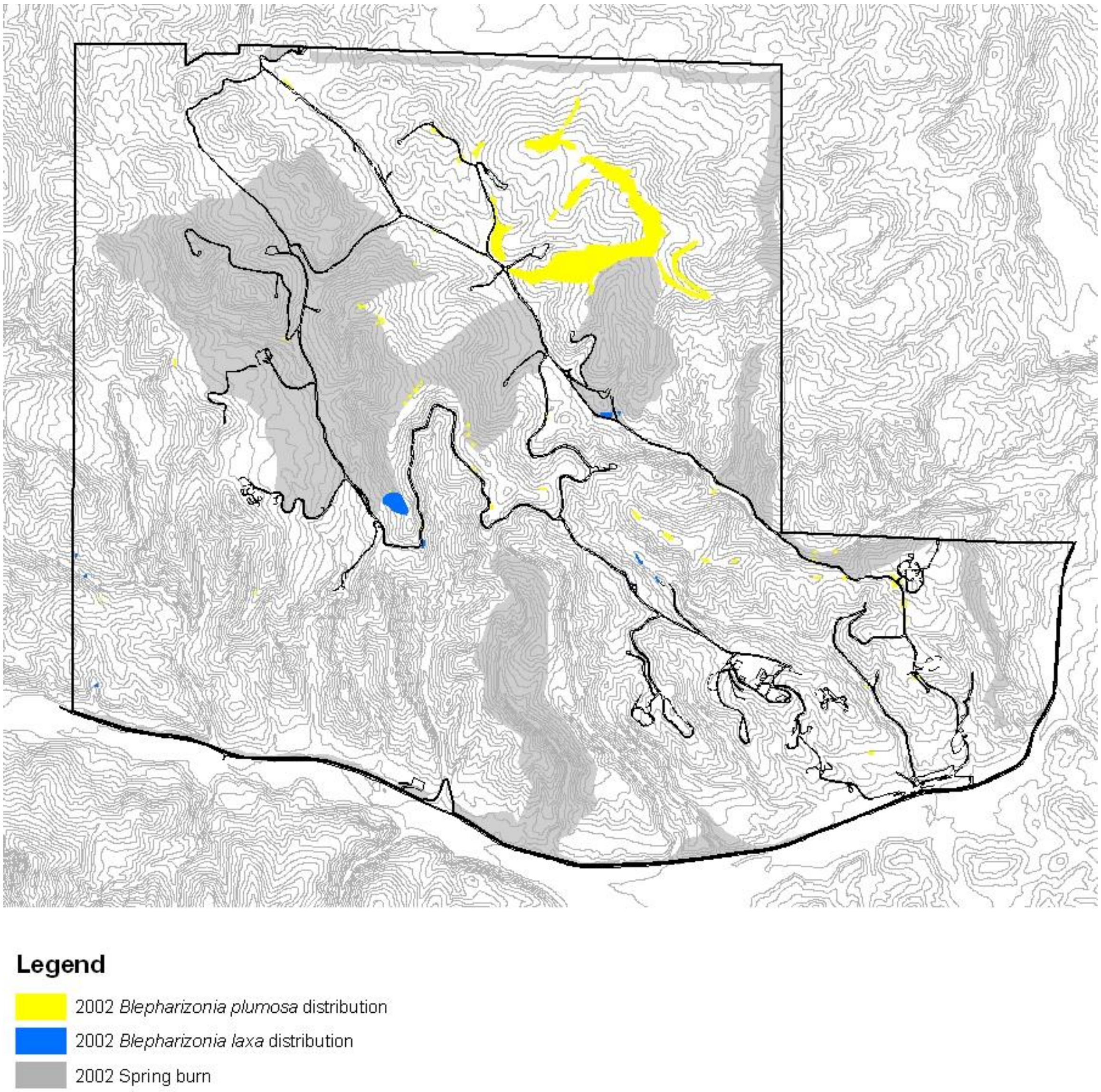


Figure B5. Enlargement of Figure B1 (2002). *Blepharizonia* populations mapped in the fall of 2002. The 2002 prescribed burn is also mapped.

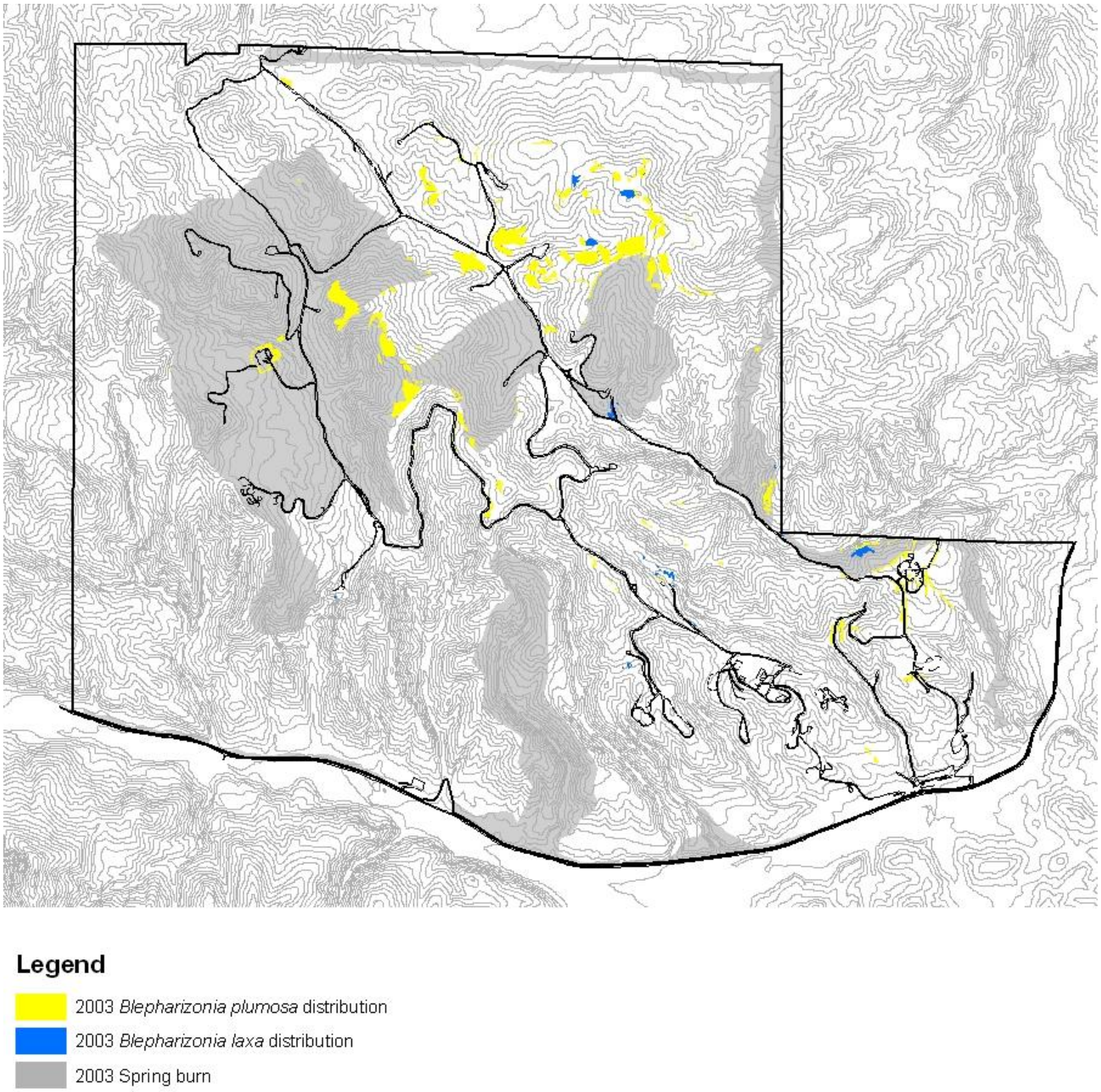


Figure B6. Enlargement of Figure B1 (2003). *Blepharizonia* populations mapped in the fall of 2003. The 2003 prescribed burn is also mapped.

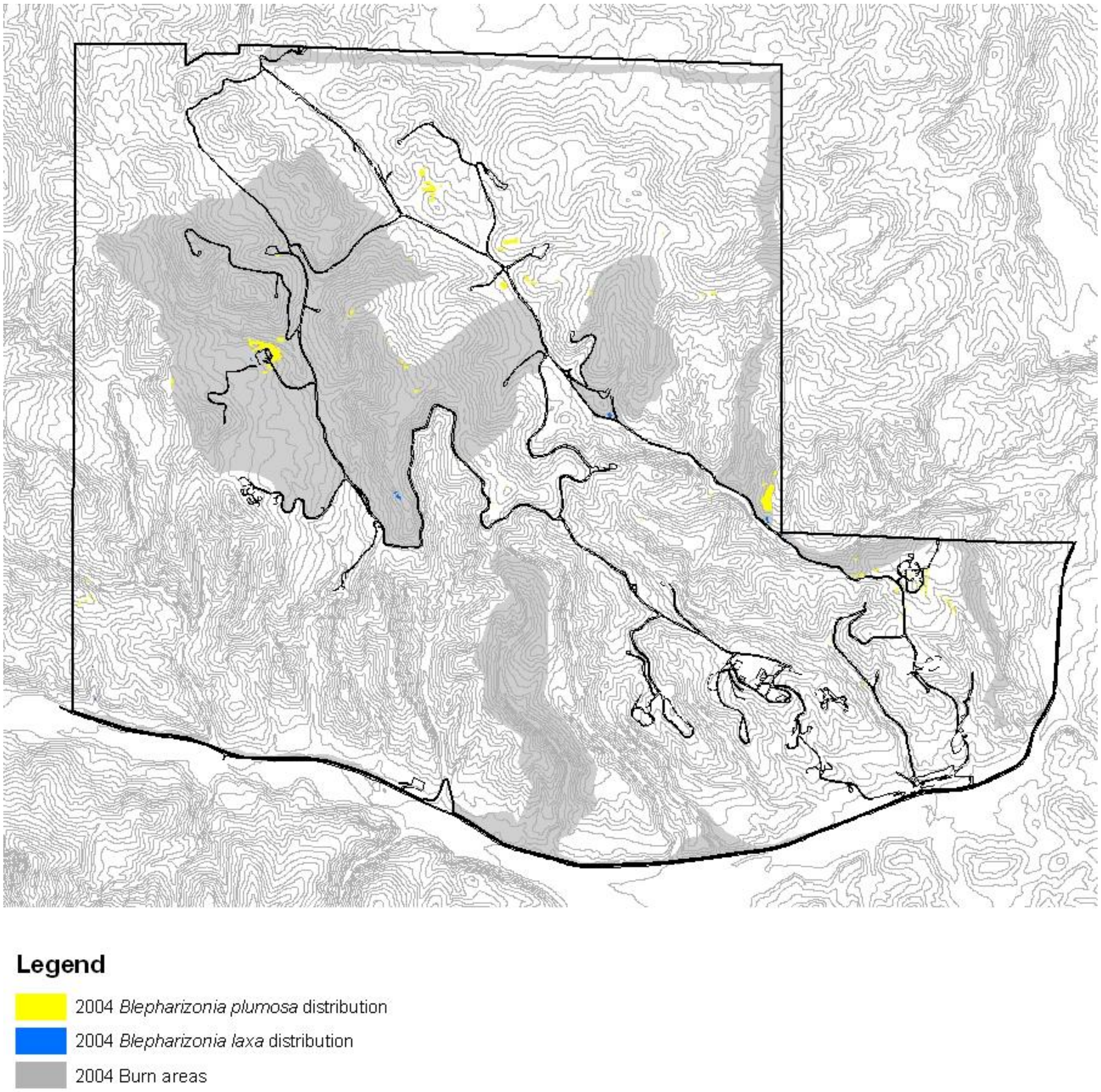
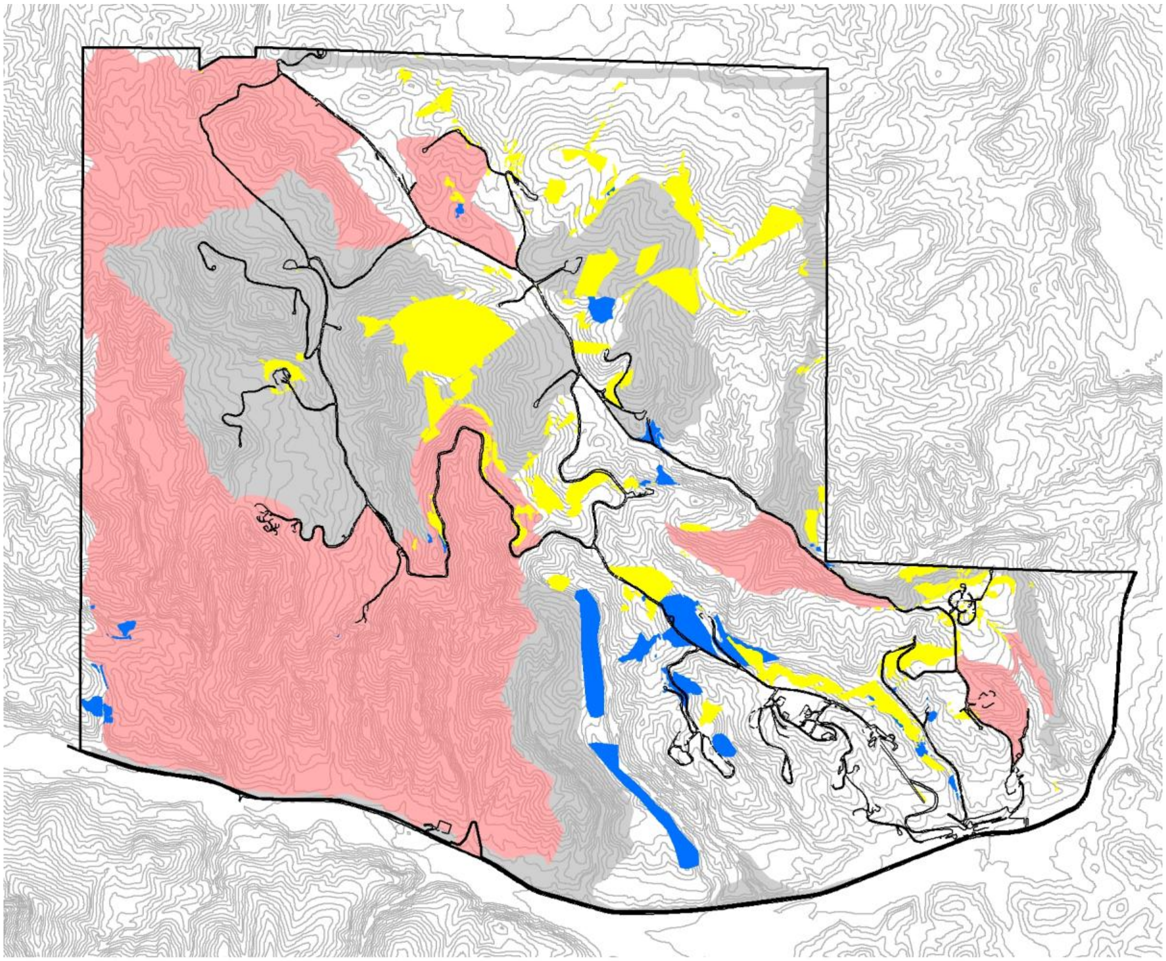


Figure B7. Enlargement of Figure B1 (2004). *Blepharizonia* populations mapped in the fall of 2004. The 2004 prescribed burn is also mapped.



Legend

- 2005 *Blepharizonia plumosa* distribution
- 2005 *Blepharizonia laxa* distribution
- 2005 Prescribed burn
- 2005 Wildfires

Figure B8. Enlargement of Figure B2 (2005). *Blepharizonia* populations mapped in the fall of 2005. The 2005 prescribed burn and wildfires are also mapped.

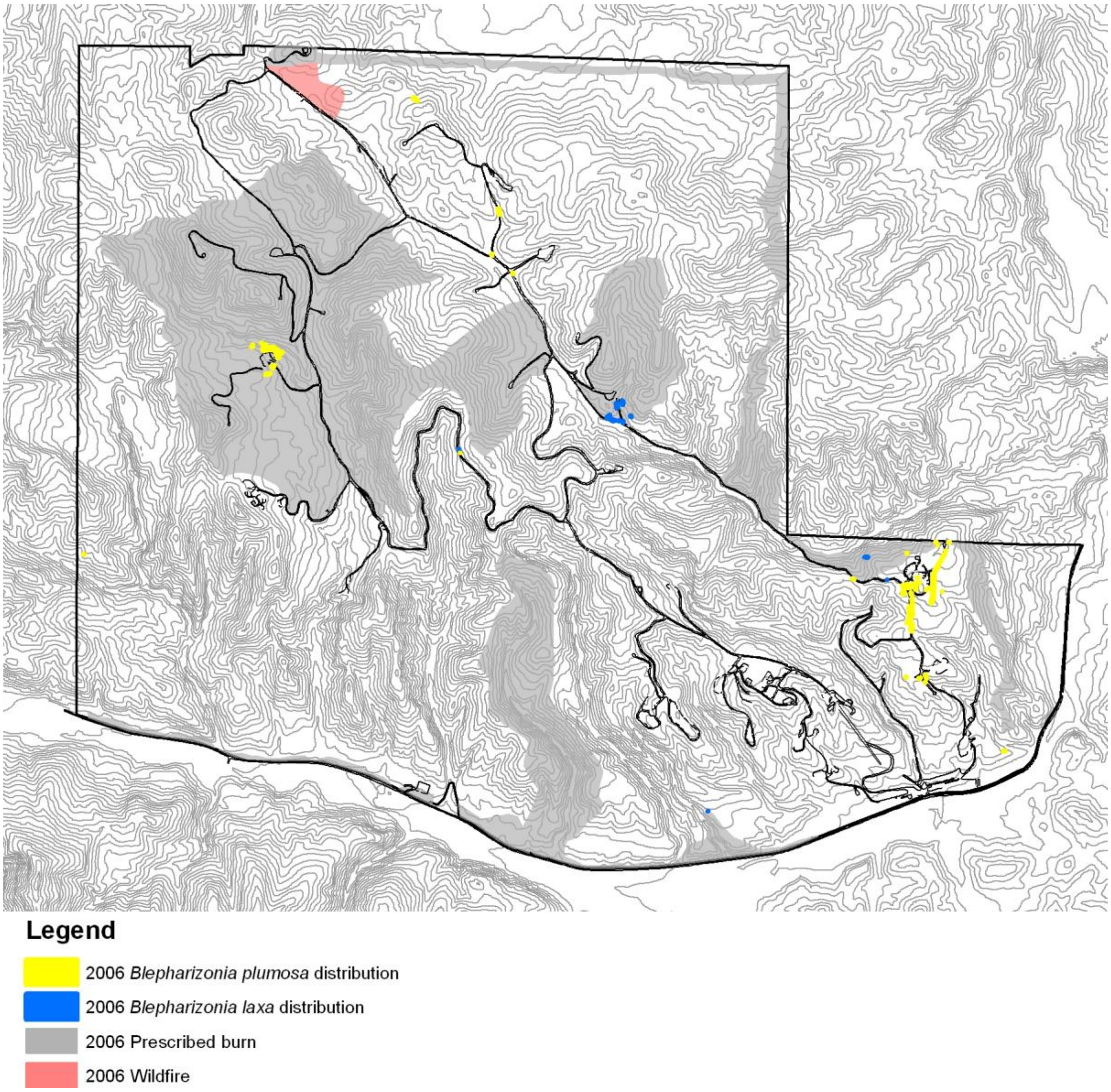


Figure B9. Enlargement of Figure B2 (2006). *Blepharizonia* populations mapped in the fall of 2006. The 2006 prescribed burn is also mapped.

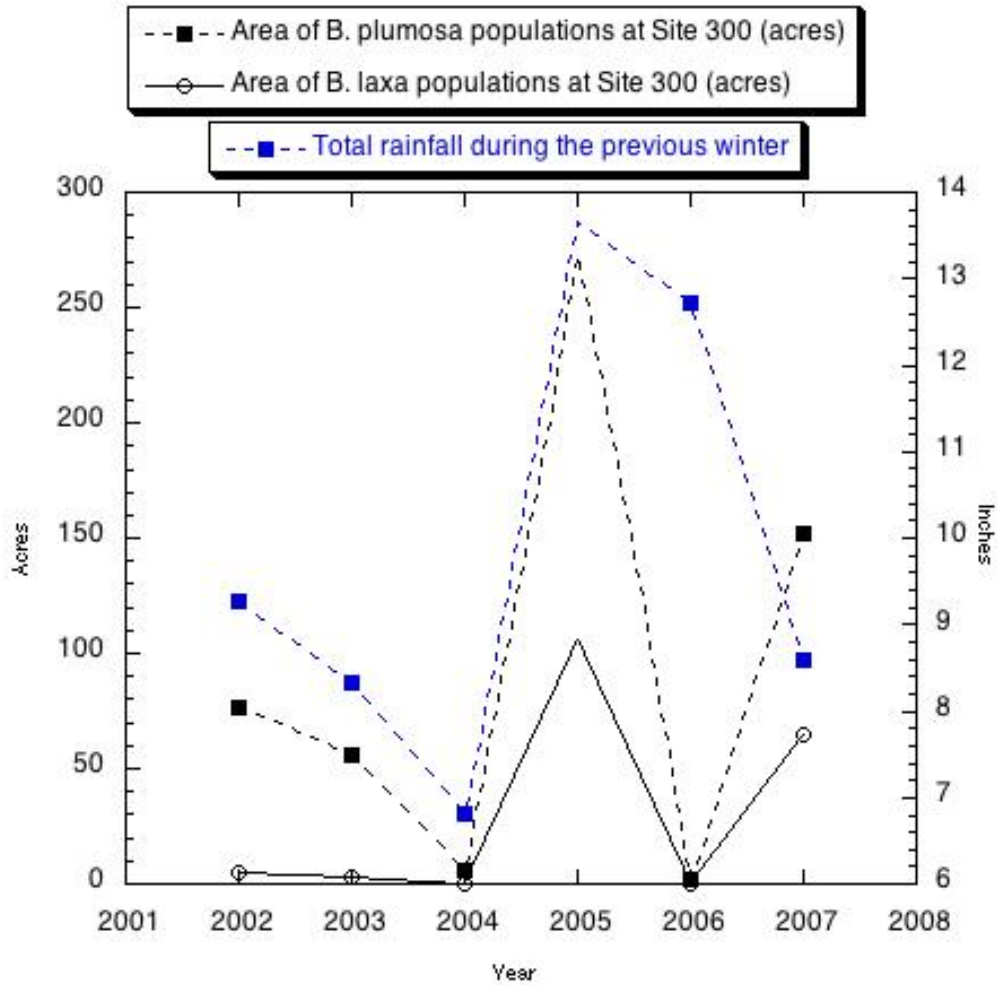


Figure B10. The total area of *Blepharizonia* populations at Site 300 each year compared to rainfall for the previous winter. For example, for 2001 the rainfall includes all rain recorded at Site 300 from September 1, 2000, to August 31, 2001.

Section B
Tables

Table B1. Estimated population size and area of *Blepharizonia plumosa* and *Blepharizonia laxa* at Site 300: 2001-2007.

	B. plumosa					***B. laxa***				
Year	**Minimum estimated population size**	**Maximum estimated population size**	**Maximum estimated population size (Bldg. 801 area only)**	**Area at Bldg 801 (acres)**	**Area (acres)**	**Minimum estimated population size**	**Maximum estimated population size**	**Maximum estimated population size (Bldg. 801 area only)**	**Area at Bldg 801 (acres)**	**Area (acres)**
2001 [a]				**0**	**15.5**			**0**	**0**	**2.7**
2002 [a,b]				**63.2**	**76.3**			**0**	**0**	**4.9**
2003	**57,851**	**160,209**	**61,013**	**24.2**	**56.1**	**1759**	**7721**	**5,700**	**1.8**	**3.5**
2004	**9,806**	**28,304**	**527**	**0.4**	**6.3**	**42**	**258**	**0**	**0**	**0.3**
2005	**95,653**	**247,047**	**5526**	**27.7**	**272.3**	**23,349**	**71,011**	**200**	**0.4**	**105.9**
2006	**2,686**	**10,144**	**100**	**0.1**	**1.8**	**176**	**754**	**0**	**0**	**0.3**

[a] Population size not available for 2001 and 2002
[b] Only the northwest portion of the site was mapped in 2001.

Table B2. The number of *Blepharizonia* seedlings observed along five transects surrounding building 801 are shown for the spring prior to a prescribed burn (conducted in June 2005) and the spring following the burn.

	Transect 1	Transect 2	Transect 3	Transect 4	Transect 5
May 23, 2005 (preburn)	76	30	30	8	6
May 19, 2006 (postburn)	22	28	34	80	156

p = 0.39

Section C
Eschscholzia rhombipetala Monitoring

Section C

Eschscholzia rhombipetala Monitoring

C-1. Introduction

Eschscholzia rhombipetala (the diamond-petaled poppy) is an extremely rare spring-flowering annual plant currently included on the California Native Plant Society (CNPS) List 1B (CNPS, 2008). This species was formerly included on the CNPS List 1A (Skinner and Pavlik, 1994), which includes plants that are presumed extinct. The historic range of this species includes the inner North Coast Range, the eastern San Francisco Bay region, and the inner South Coast Ranges. The last herbarium collections of *E. rhombipetala* were made in 1950 in San Luis Obispo County, and the species has since been presumed extinct. In 1993, a population of *E. rhombipetala* was discovered in the northern part of the Carrizo plain by a plant taxonomist from California Polytechnic State University, San Luis Obispo (Keil, 2001). This population was observed again in 1995 but has not been seen since. At this location, they grow on heavy clay soils that accumulate water in the spring, forming vernal pools. The poppies grow in an ecotone on the higher areas between an *Amsinckia*-dominated mound and a *Layia*-dominated swale, in open patches. They grow as almost an understory to the taller *Lasthenia*, *Phacelia*, and various grasses (Clark, 2000).

Collections of *E. rhombipetala* have been made at Corral Hollow, both in 1937 and in 1949 (Espeland and Carlsen, 2003). A population of *E. rhombipetala* was identified during a habitat survey in 1997 at Site 300 (Preston, 2000). This original population (site 1) is located in the extreme southwest corner of the site (Figure C1). Like the Carrizo plain population, it occurs in an ecotone on heavy clay soils. The ecotone at Site 300 was formed by a landslide within a minor east-west drainage to a major north-south trending canyon. The landslide formed a slump at the bottom of the slide, with sharp scarp faces on the northern and southern sides of the slump. This *E. rhombipetala* population is found on the southern side of the slump (a northwest facing aspect) near the edge of the scarp, some distance into the surrounding grassland, and in the slump itself. The surrounding grasslands are composed primarily of the exotic grasses *Avena* and *Bromus*, with *Sonchus* and *Brassica* species being the primary forbs. The slump contains various grasses, along with another rare plant, *Blepharizonia plumosa* (Section B), as well as *Blepharizonia laxa*.

A second population (site 2) of *E. rhombipetala* was discovered in spring of 2002 in another habitat survey, less than 2.3 km from the first population (Figure C1). This population occurs on a steep, northwest-facing slope on clay soil. While it may occur on an historic slump, the soil of the population area is not noticeably more active than its surroundings. The population at site 2 occurs in a grassland of exotic species similar to that at site 1.

In the spring of 2004, a third population (site 3) was found in the northwestern corner of Site 300 in an area known as Round Valley only 0.4 km from site 2 and 1.7 km from site

1. Unlike sites 1 and 2, this population is found in a relatively flat valley surrounded by small hills. At site 3, *E. rhombipetala* occurs with another rare plant *California macrophylla* (Section D).

Eschscholzia rhombipetala is a small, erect annual, 5 to 30 cm tall. A member of the poppy family (Papaveraceae), it has typical poppy characteristics, but is quite diminutive and thus easily overlooked. The flower's yellow petals are 3 to 15 mm long from a barrel-shaped receptacle, and when in bud, may be erect or nodding, with a blunt or short point. The fruit is a capsule, generally 4 to 7 cm long, containing numerous round, net-ridged black seeds 1.3 to 1.8 mm wide (Clark, 1993).

All Site 300 *E. rhombipetala* populations are located in remote portions of Site 300, outside of the programmatic areas. However, for conservation and management purposes, an understanding of the population dynamics of *E. rhombipetala* is desirable. Therefore, we are collecting census data on the *E. rhombipetala* populations, as well as characterization data on the surrounding plant community. These data will provide information concerning the mechanisms controlling the abundance and distribution of *E. rhombipetala*. The results of this analysis will inform continued monitoring and management activities of the Site 300 *E. rhombipetala* populations.

C-2. Methods and Materials

C-2.1. Census

Eschscholzia rhombipetala populations were censused in 2005 on April 1 (Site 2), April 4 and 6 (Site 3), and April 11 (site 1). In 2006 *E. rhombipetala* populations were censused on April 18 (site 1), April 19 (site 3), and April 27 (site 2). A total estimate of population size was obtained for all three sites. Height, flower number and capsule length were recorded for all three sites. If the population size was small (<50), all *E.rhombipetala* were measured. For larger populations, only those *E. rhombipetala* found within vegetation sampling quadrats were measured (Section C-2.2). For site 1, the geographic feature was record for each *E. rhombipetala*. Site 1 was divided into three different areas based on the geographic feature: slump (SL), scarp (SC), and the surrounding grassland (GR).

C-2.1.1. Data Analysis

Linear regression was performed to examine the relationship between plant height and number of floral units (buds + flowers + capsules) and capsule length for 2005 census data (and previously form 1998, 2000, 2001, 2002, and 2004 census data). Too few plants were present to conduct this analysis with 1999, 2003, and 2006 census data.

C-2.2. Vegetation Sampling

Vegetation community data were collected from 60 cm $\times$ 60 cm plots on the same dates that the populations were censused. For each plot, species were identified, and their percent cover was visually estimated. Percent bare ground and percent thatch cover was also recorded.

Site 1 was divided into three different areas for vegetation sampling: slump, scarp and grassland. Our goal was to measure five vegetation plots with *E. rhombipetala* and five vegetation plots without *E. rhombipetala* in each of the three areas. In some cases, there were less than five locations with *E. rhombipetala.* In 2005, only one location with *E. rhombipetala* was found in the slump; therefore, only one vegetation quadrat was measured with *E. rhombipetala.* Five quadrats containing *E. rhombipetala* were placed at the only locations plants were found in the scarp and grassland area. Additional plots without *E. rhombipetala* were placed haphazardly. In 2006, no *E. rhombipetala* was found at site 1, so only five vegetation quadrats without *E. rhombipetala* were sampled in each of the three areas. These quadrats were placed haphazardly.

For sites 2 and 3, our goal was to measure at least five quadrat containing *E. rhombipetala* and five that did not contain *E. rhombipetala.* At site 2 in 2005, *E. rhombipetala* was found in several locations, so ten quadrats with *E. rhombipetala* and ten quadrats without *E. rhombipetala* were measured. In 2006 at site 2, no *E. rhombipetala* was found. Only five quadrats without *E. rhombipetala* were measured.

At site 3, vegetation sampling locations were chosen randomly. A tape was placed along one side of the population. Quadrats were placed a random number of feet along the tape and a random number of steps into the population. A third random number was used to determine if the plot should contain *E. rhombipetala* or not. Quadrats were placed at the nearest location either containing or not containing *E. rhombipetala*. In 2005 and 2006, five vegetation community quadrat with *E. rhombipetala* and five without *E. rhombipetala* were sampled.

In 2005, capsules were collected at Site 3 to determine the relationship between capsule length and the number of seeds per capsule. Capsules were collected at the time of the spring census and the number of ovules per capsule was recorded. Additional capsules were collected later when the seeds were mature and the number of seeds per capsule was recorded.

C-2.2.1. Data Analysis

Logistic regression was used to determine if there is a relationship between *E. rhombipetala* absence and vegetation cover for six categories of vegetation cover (% bare ground, % thatch cover, % exotic grass cover, % native grass cover, % exotic forb cover, and % native forb cover).

C-3. Results and Discussion

C-3.1. Census

The *E. rhombipetala* population at site 1 and site 2 remained small in 2005 and 2006 (Table C1). In 2005, only 23 *E. rhombipetala* were observed at site 2, and 29 *E. rhombipetala* were observed at site 1. In 2006, no *E. rhombipetala* were observed in site 1 or site 2. In comparison, the *E. rhombipetala* population at site 3 was quite large.

Site 3, contained 554 *E. rhombipetala* in 2005 and 593 in 2006. The distribution of *E. rhombipetala* at site 3 is shown in Figure C2.

Table C2 shows the heights, number of floral units per plant, and capsule length of *E. rhombipetala* by site for 1999 through 2006. The average height *Eschscholzia rhombipetala* was similar at site 1 (9.6 [stdev = 3.1]), site 2 (11.2 [stdev = 3.9]), and site 3 (11.8 [stdev = 3.9]). The average number of floral units per plant was almost three at site 3, compared to an average of less than one floral unit per plant at sites 1 and 2. 2006 plants were smaller and had fewer floral units than 2005 plants. In 2006, *E. rhombipetala* was only found at site 3. These plants had an average height of 5.3 (stdev = 2.0) and an average of 1.2 (stdev = 0.7) floral units per plant.

In 2005, capsules were collected at Site 3 to determine the relationship between capsule length and the number of seeds per capsule. As expected, the number of ovules per capsule and the number of seeds per capsule are clearly related to capsule length. For the relationship of ovule number to capsule length r2 is 0.79 ($p < 0.0001$), and for the relationship of seed number to capsule length r2 is 0.91 ($p < 0.001$). The regression equation explaining the number of seeds produced by capsule length is number of seeds = 5.64 • (capsule length in cm) – 9.59. In the future, this regression equation can be used to estimate the number of seeds produced in each site.

C-3.2. Vegetation Sampling

When cover data from all sites and all years (1999–2006) are combined, *E. rhombipetala* absence is negatively correlated with percent bare ground and native grass cover (negative values for the parameter estimates in Table C4), and positively correlated to thatch, exotic grass cover, and exotic forb cover. *Eschscholzia rhombipetala* is more likely to be found where the vegetation is more open and where native grasses are also present and less likely to be found when thatch cover is high.

C-4. Discussion and Future Work

Site 1 has been censused for nine consecutive years, and site 2 has been censused for five years. These populations continue to follow a similar pattern for *E. rhombipetala* abundance. Since its discovery in 2004, site 3 has been the largest of the three Site 300 *E. rhombipetala* populations containing greater than 350 *E. rhombipetala* each year between 2004 and 2006. In 2006, while there were no *E. rhombipetala* observed in site 1 or 2, 593 plants were found in site 3. This is largest population recorded at site 3 during the three years of censusing the site.

2004 data showed that the new population (site 3) differs from the two older populations (sites 1 and 2) in several ways. Site 3 is found at the bottom of a small stable bowl shaped valley, while sites 1 and 2 are located on steep northwest facing hillsides in areas that are disturbed by slumping soil. *Eschscholzia rhombipetala* at site 1 and site 2 is also often found in association with the native perennial grass, *P. secunda*, while *P. secunda* was not found at site 3. In addition, *E. rhombipetala* at site 3 are larger and have more floral units than plants at sites 1 and 2 (Paterson et al., 2005).

In 1999–2006, using data from all three sites, *E. rhombipetala* absence was linked to less bare ground, less native grass cover, less exotic grass cover, and more thatch, exotic grass, and exotic forb cover. Sites 1, 2, and 3 are very different from one another in terms of vegetation and slope and yet the microhabitats in which *E. rhombipetala* are found are similar among the sites: flowering *E. rhombipetala* plants are found more often when the vegetation is open, exposing bare ground, and when there is less thatch accumulation. Other California forbs have shown similar sensitivity to thatch accumulation, as shown by increased plant performance in thatch removal studies (Meyer and Schiffman, 1999; Heady, 1956). Exotic annual grasses tend to accumulate more thatch than native grasses and as such they may be particularly powerful inhibitors of native forbs. While clipping treatments may reduce the above ground biomass of live exotic grass plants and thus reduce thatch accumulation, results from clipping studies have been mixed (Hayes, 2002). The mixed results from clipping studies and the lack of relationship between *E. rhombipetala* plant presence and live exotic grass cover indicates that the positive connection between *E. rhombipetala* presence and bare ground may be due to more than merely the absence of thatch.

In 2005, comparisons of capsule length and seed and ovule number resulted in regression equations that can be used to estimate seed production. The number of seeds produced per capsule can be estimated by the equation: seeds = 6.28 • (capsule length in mm) – 9.59. The difficulty in using this equation will be in determining the average capsule length at maturity because our census is typically only conducted on one or two days during a the spring when plants are still in flower and many capsules are not yet mature. The use of this equation may require additional analysis to determine the relationship between the capsule length at the time of the spring census compared to the capsule length when fruits are mature.

By continuing to collect size, fecundity and cover data, we hope to identify the environmental factors that positively influence *E. rhombipetala* fitness and create self-sustaining populations. Surprisingly little research has been performed on *Eschscholzia* ecology (Espeland and Myatt, 2001), and little is known about the response of California poppy and its relatives to soil condition, moisture, and inter-specific competition. *Eschscholzia californica* is known to have strong seed dormancy (Fox et al., 1995), but it is unknown if other species in the genus share this characteristic. Because of the extreme rarity of *E. rhombipetala,* we have as yet been unable to collect any data on germination and survivorship for this species.

C-5. References

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Section C
Figures

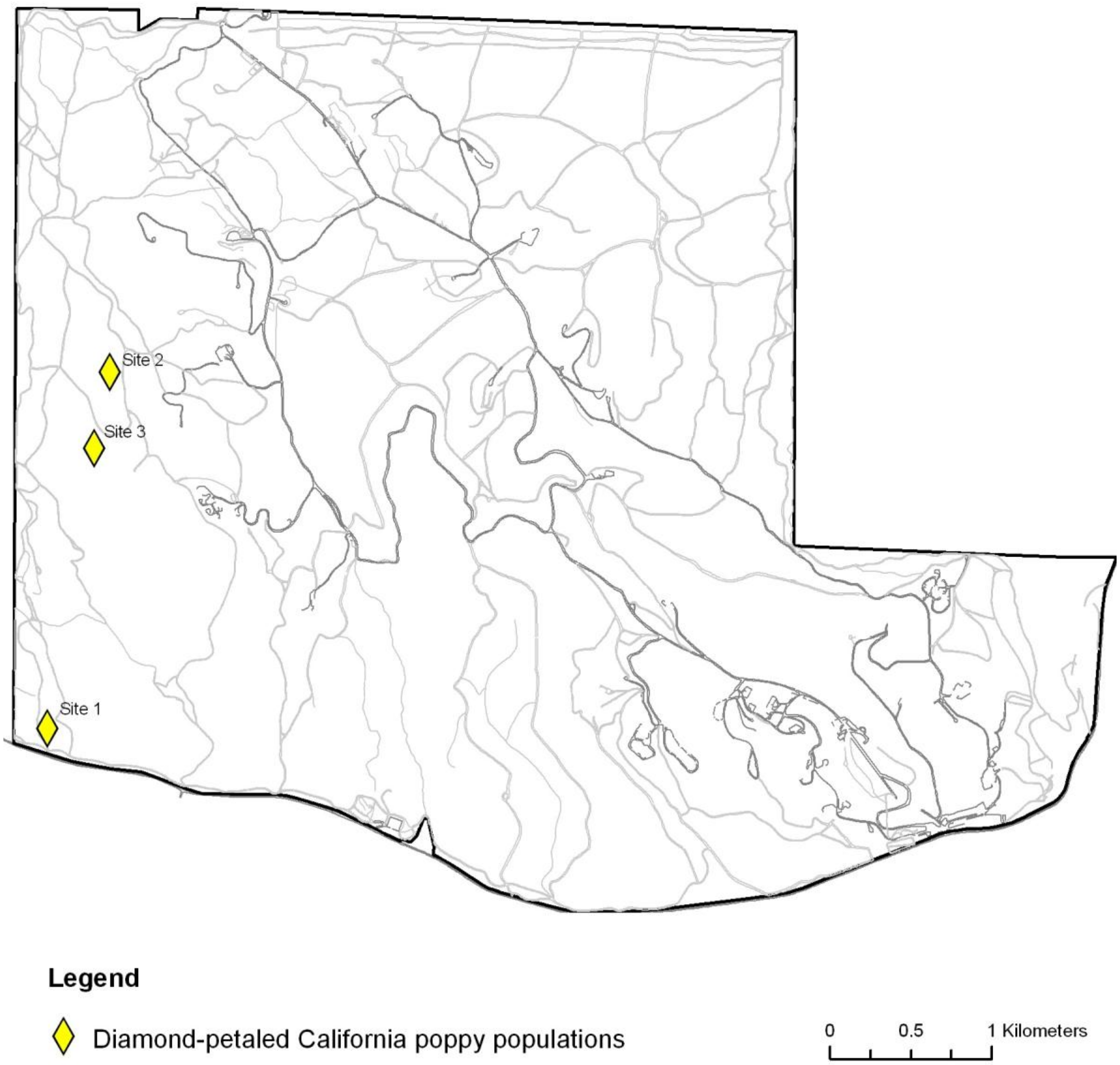

Figure C1. Distribution of *Eschscholzia rhombipetala* at Site 300.

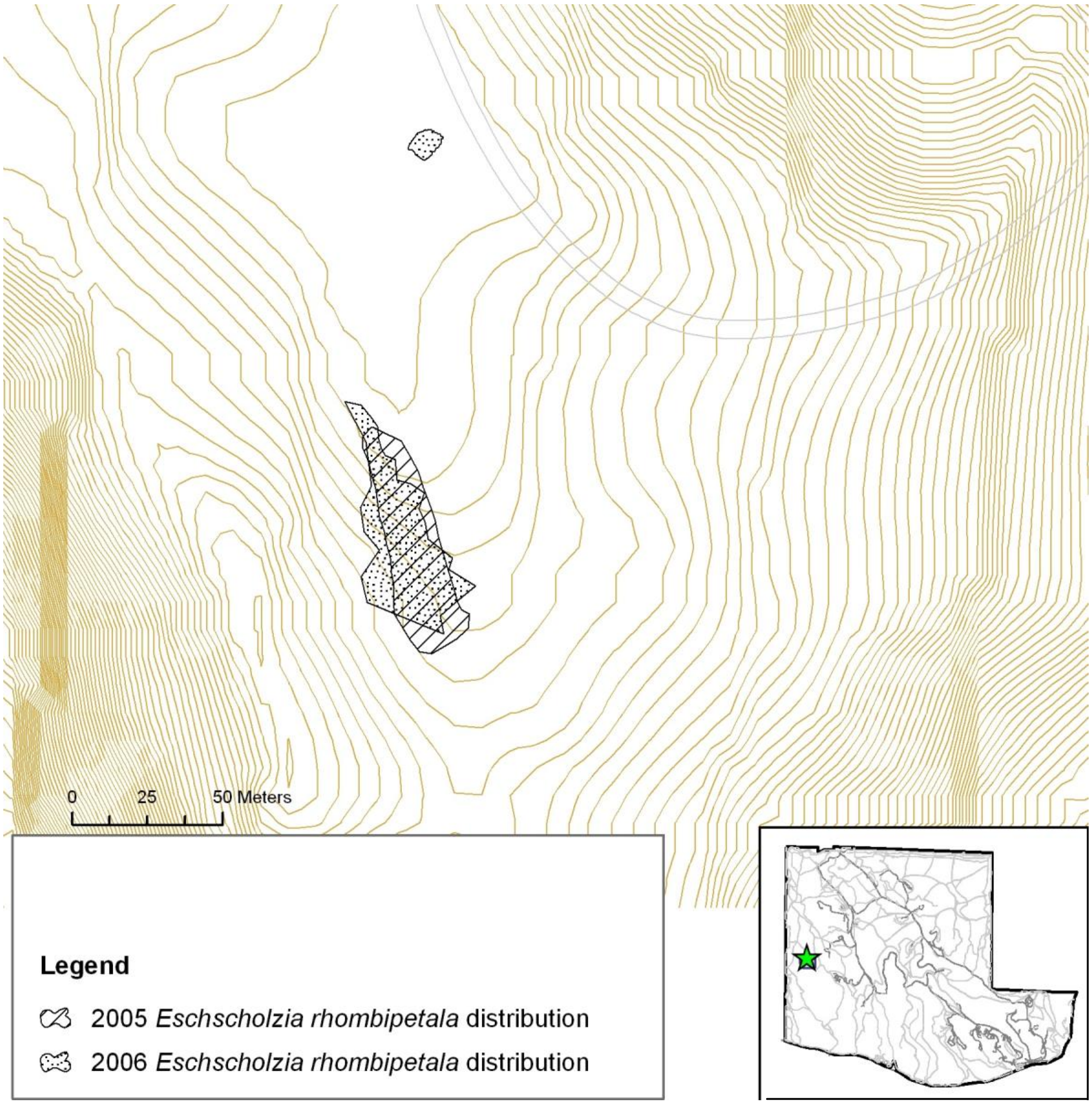

Figure C2. Distribution of *Eschscholzia rhombipetala* at site 3 in 2005 and 2006.

Site 1 – September 2005

Figure C3 (Page 1 of 2). ***Eschscholzia rhombipetala*** **sites 1 through 3 following the July 2005 wildfire**

Site 2 – September 2005

Site 3 – September 2005

Figure C3 (Page 2 of 2). *Eschscholzia rhombipetala* sites 1 through 3 following the July 2005 wildfire

Section C
Tables

Table C1. Summary of census data collected from sites 1, 2, and 3: 1998–2006.

	Site 1				Site 1	Site 2	Site 3
Year	Grassland	Scarp	Slump	Location not recorded	Total	Total	Total
1998	-	-	-	18	18	-	-
1999	-	-	-	9	9	-	-
2000	98	60	115	0	273	-	-
2001	19	107	72	0	189	-	-
2002	74	138	67	0	285	76	-
2003	2	8	0	0	10	2	-
2004	2	14	3	0	19	1	389
2005	7	19	3	29	29	23	554
2006	0	0	0	0	0	0	593

Note:

-Site 2 was first discovered in 2002, and site 3 was first discovered in 2004.

-Site 1 areas were censused separately starting in 2000.

Table C2. Height, number of floral units (buds + flowers + capsules) per plant, and capsule length for marked *Eschscholzia rhombipetala* plants: 1998–2006. All averages are ± one standard deviation.

Site	Date measured	Height (cm)	No. of floral units/plant	N[a]	Capsule length (cm)	N[b]
1	18 Apr 98	7.5 ± 2.8	0.4 ± 0.5	24	2.8 ±1.4	16
1	30 Apr 99	6.0 ± 1.8	0.7 ± 0.7	9	2.1 ± 0.6	6
1	24 Mar 00	5.5 ± 2.1	0.6 ± 0.5	171	2.3 ± 1.4	44
1	30 Mar 01	5.0 ± 2.5	0.3 ± 0.5	189	2.8 ± 1.8	72
1	29 Mar 02	6.8 ± 2.5	1.1 ± 0.7	280	3.4 ± 1.6	73
2	05 Apr 02	8.0 ± 2.1	1.4 ± 0.7	76	3.3 ± 0.3	63
1	25 Mar 03	6.1 ± 2.0	0.7 ± 0.5	10	1.3	1
2	25 Mar 03	4.0 ± 2.8	2.5 ± 0.7	2	N/A	N/A
1	26 Mar 04	7.5 ± 2.6	1.3 ±1.1	19	3.2 ± 1.1	15
2	26 Mar 04	6.2	3	1	7.0	1
3	01 Apr 04	12.0 ± 2.6	2.9 ± 1.9	158	3.9 ± 2	124
1	11 Apr 05	9.6 ± 3.1	0.4 ±1.1	29	3.0 ± 1.3	25
2	01 Apr 05	11.2 ±3.9	0.7 ±0.8	23	3.0 ±1.6	21
3	04 & 06 Apr 05	11.8 ± 2.9	2.9 ± 2.6	554	3.1 ± 1.3	40
3	19 Apr 06	5.3 ± 2.0	1.2 ± 0.7	21	1.5 ± 0.7	20

Notes:

N = Number of plants.
N/A = No capsules present at time of census.
[a] Number of plants measured is the same for the height and number of flower measurements. Plants with no flowers were included in the average.
[b] Number of plants measured for capsule length includes only those plants with capsules.

Table C3. Results of the logistic regression: the effect of vegetation on *Eschscholzia rhombipetala* absence.[a] Site 1: 1999–2006, site 2: 2003–2006, and site 3: 2004-2006.

Covariate x	*p*-value	β[a]	Odds ratio[b]	Confidence interval	Maximum measured x value[a]
Intercept α = 0.347	0.499	–	–	–	–
% bare ground	0.0182	-0.014	0.986	0.975–0.998	98
% thatch cover	0.0457	0.013	1.013	1.000–1.026	100
% exotic grass cover	0.0248	0.011	1.011	1.001–1.021	100
% native grass cover	<0.0001	-0.079	0.924	0.889–0.961	75
% exotic forb cover	0.048	0.021	1.021	1.000–1.042	60
% native forb cover	0.423	-	-	-	-

Note:

– = Model was not significant. Values cannot be reported for β, Odds ratios, Confidence intervals, or Maximum measured x values.

a Model fit (Wald) p < 0.001, n = 439 (289 plots with no *E. rhombipetala*, 150 plots with *E. rhombipetala*). The model is $p/(1-p) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_n x_n$ where p is the probability of *E. rhombipetala* absence from the plot, α is the intercept, β is the parameter estimate, and x is the covariate. In the model, bare ground, thatch, exotic grass, native grass, exotic forb, and native forb covers were used as covariates.

b Odds ratio is probability *E. rhombipetala* absent : probability *E. rhombipetala* present.

.

Section D
California macrophylla Monitoring

Section D
California macrophylla

D-1. Introduction

California macrophylla (Hook. & Arn.) J.J. ALDASORO, C. NAVARRO, P. VARGAS, L. SAEZ AND C. AEDO is an annual or biennial plant with long petioled leaves growing from short stems. Its leaves are reniform and shallowly lobed, and its flowers have white, sometimes with a red tint, petals that are approximately 6 to 8 mm long (Aldasoro et al., 2002). Flowers are ephemeral with petals typically falling off within one day. The fruit body is typically 8 to 10 mm long and divided into five segments, and a portion of the style persists above the fruit body extending 3 to 5 cm (Taylor, 1993).

Based on morphological data *C. macrophylla* has recently been segregated from the genus *Erodium* into the new monotypic genus *California* (Aldasoro et al., 2002). Aldasoro et al. (2002) describes three characteristics that separate *C. macrophylla* from species of *Erodium* (and the genus *Monsonia*): arrangement of stamens, mericarp bristle morphology, and leaf shape. All species in the genus *Erodium* have five fertile stamens and five staminodes. Unlike species of *Erodium*, *C. macrophylla* has five stamens with two lateral wing-like expansions on the filaments and no staminodes. *Erodium* species have a semicircular rim surrounding each bristle on the fruits. *California macrophylla* fruit bristles lack this rim. Finally, unlike *Erodium* species, the leaves of *C. macrophylla* are rounded with a cordate base and subpalmate veins. *Erodium* species have subpinnate or pinnate veins.

Of the six species of *Erodium* that are described in the Jepson Manual, *Erodium macrophyllum (California macrophylla)* is one of two species native to North America. *Erodium texanum* A. Gray is native to the southwestern United States and northern Mexico. The remaining four species are native to Mediterranean Europe or Australia (Taylor, 1993).

In California, *C. macrophylla* is currently known to occur in the Great Valley, San Francisco Bay area, central and south coasts, and the Channel Islands of California (CNPS, 2008). The range of *C. macrophylla* had previously reported to extend from northern California to northern Mexico and southern Utah to the east (Taylor, 1993). Gillespie (2003) argued that reports of *C. macrophylla* in southern Utah were based on mislabeled specimens, and that this species only occurs outside of California in southern Oregon and northern Baja.

California macrophylla is a California Native Plant Society List 1B species, which includes species that are rare or endangered throughout their range (CNPS, 2008). This species was recently moved from List 2 to List 1B by the California Native Plant Society based on Gillespie's research.

In 2002, one population of 200 plants of *C. macrophylla* was observed at Site 300 during a site wide special status plant survey (Preston, 2002). This species was not known to occur at Site 300 prior to 2002, although herbarium specimens from the

1920s and 1930s record *C. macrophylla* presence in the Corral Hollow area and Altamont Hills. Five additional populations of *C. macrophylla* were discovered in 2003 and 2004 during wildlife surveys (van Hattem, 2004). All six populations occur in the far northwestern corner of Site 300 at elevations between 360 m and 450 m. (Figure D1 and D2). Of the six Site 300 populations, populations 1 through 4 occur in annually graded dirt fire trails. These fire trail populations are restricted to disturbed portions of the fire trails that are graded annually in the spring in preparation for prescribed burns that are conducted at Site 300 in May or June.

The remaining two populations (population 5 and 6) occur in grasslands 100 to 500 feet from the fire trails. Both off-road populations occur in areas that are not typically included in the annual prescribed burns at Site 300. Population 5 occurs in a small, relatively level bowl surrounded by small hills. This population occurs with another extremely rare annual forb, *Eschscholzia rhombipetala. Eschscholzia rhombipetala* and *C. macrophylla* have also historically been reported to occur together in San Luis Obispo County (Hoover, 1970). Population 6 is found on a west-facing hillside.

In 2005 and 2006, the abundance and distribution of *C. macrophylla* was recorded for all six Site 300 populations. In addition, the composition of the vegetation community in each population was recorded and the community composition of plots containing *C. macrophylla* were compared to those without *C. macrophylla.*

D-2. Methods and Materials

D-2.1. Spring Census

In 2004, we began censusing *C. macrophylla* sites 1 through 6. Sites 1 through 6 were again censused in 2005 and 2006. The boundaries of each of the six populations were recorded using a Trimble handheld GPS and an estimate of the total population size was made. The dates of the *C. macrophylla* censuses at Site 300 in 2005 and 2006 are shown in Table D1.

Specific plant cover was also measured in each of the six sites. Cover estimates were made using 60 cm × 60 cm quadrats. For populations 2 through 5, approximately ten random locations within each population were chosen for cover estimates. Population 1 has a distribution divided between two adjacent fire trails, and cover was estimated in a total of 20 quadrats (10 on each of the two fire trails). Populations 1 through 4 occur along fire trails and, therefore, have a basically linear distribution. In these four populations, random locations were chosen by laying a tape measure along the linear population (usually along the edge of the fire trail) and sampling at random distances along and into the population from the tape. Site 5 was not located along a fire trail, so the tape was placed along one side of this off-road population and cover measurements were taken at random distances along the tape and into the population. Site 6 includes small isolated patches, and cover measurements were taken from five of the small patches and immediately adjacent to the patches. Half of the quadrats at each population were placed at the nearest spot to these random locations containing *C.*

macrophylla plants, and an equal number of quadrats were sampled from areas within the general distribution of *C. macrophylla* but not containing any *C. macrophylla* plants.

The number of *C. macrophylla* in each population quadrat sampled was recorded in addition to the number of floral units, the height, and the width of each *C. macrophylla* within the quadrat. The area of each of these plants was calculated by multiplying height by width.

D-2.1.1. Data Analysis

Specific cover data was combined into six categories: bare ground, thatch, exotic grasses, native grasses, exotic forbs, and native forbs.

D-3. Results

D-3.1. Spring Census

The size estimates and area of each Site 300 *C. macrophylla* population is given in Table D1. There is not a consistent pattern of variation in population size between years for all the sites. Of the six Site 300 populations, *C. macrophylla* was most abundant at site 1 in 2004 (2200 plants), but site 1 was relatively small in 2005 (380 plants). Contrasting with this, the two off-road sites (5 and 6) were quite small in 2004 (45 plants and 30 plants, respectively) but contained many more plants in 2005 (540 plants and 850 plants, respectively) and 2005 (460 plants and 3850 plants, respectively). The average height, width and area of plants sampled in each population are shown in Table D2.

The overall distribution of *C. macrophylla* at Site 300 in 2005 and 2006 is shown in Figures D1 and D2. The total area *C. macrophylla* sites mapped in 2006 (12,290 m^2 [3.1 acres]) was larger than that mapped in 2005 (7,537 m^2 [1.9 acres]). The distribution of all sites except site 4 increased in 2006 compared to 2004. The distribution of *C. macrophylla* increased in 2006 compared to 2005 at sites 1, 2, and 6; at the three remaining sites the distribution decreased.

The vegetation community composition for 2005 and 2006 is shown in Tables D3 through D6 and Figures D8 and D9. Tables D3 and D5 show the average community composition for plots containing *C. macrophylla,* and Tables D4 and D6 show the average community composition for plots without *C. macrophylla.*

D-4. Discussion

In 2004, four previously unknown populations of *C. macrophylla* were discovered at Site 300 despite the fact the site-wide botanical surveys had been conducted in 1986 and 2002 (Preston, 2002; Biosystems, 1986). In 2005 and 2006 additional small patches of *C. macrophylla* were found near existing sites. It is possible that *C. macrophylla* seeds are being moved around the site during grading of the fire trails, resulting in new populations of *C. macrophylla* in suitable fire trail locations.

In our 2003/2004 research and monitoring report (Paterson et al., 2005), we found that there are significant differences in the community composition of the fire trail populations compared to the grassland populations. The fire trail populations had more bare ground and less thatch as would be expected in an area that is annually graded. There was also significantly less exotic grass cover in the fire trail population compared to the grassland populations.

In a recent study, Gillespie and Allen (2004) found that weeding (manually removing an exotic species) had a positive effect on *C. macrophylla* emergence survival and fecundity, and that exotic grasses competitively suppress *C. macrophylla.* In our study, fire trail populations did have a decreased exotic grass cover compared to areas outside of the fire trails. This decreased annual grass cover could, at least partially, contribute to the success on *C. macrophylla* in the fire trails

Although *C. macrophylla* clearly appears to benefit from the disturbance caused by the annual grading of the fire trails, it is not associated with frequently burned sites as are several other native species at Site 300. Five of the six populations occur in areas that have not been burned for ten or more years.

Although large portions of the Site 300 grasslands are burned annually in the spring to decrease the threat of wildfire, five of the six *C. macrophylla* populations occur in areas that are not routinely burned. Population 1 is the only one of the six populations that occurs within are area where annual prescribed burns are conducted. Even though site 1 is within an annual burn area, the fire trails are graded annually to provide a firebreak, and the actual fire trails where *C. macrophylla* occurs do not have enough fuel to burn although the areas adjacent to the fire trails are burned.

In July of 2005, a large wildfire occurred across the western portion of Site 300 that impacted all six sites. Photographs of the six *C. macrophlla* populations immediately following the wildfire are shown in Figure D10. *California macrophylla* survived in all known sites after the wildfire, and the distribution of *C. macrophylla* increased in 2006 (post burn) compared to the spring of 2005 (pre burn) especially in off road areas. If time allows, future research will focus on comparing pre-burn and post-burn community composition and *C. macrophylla* distribution and abundance.

D-5. References

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Section D
Figures

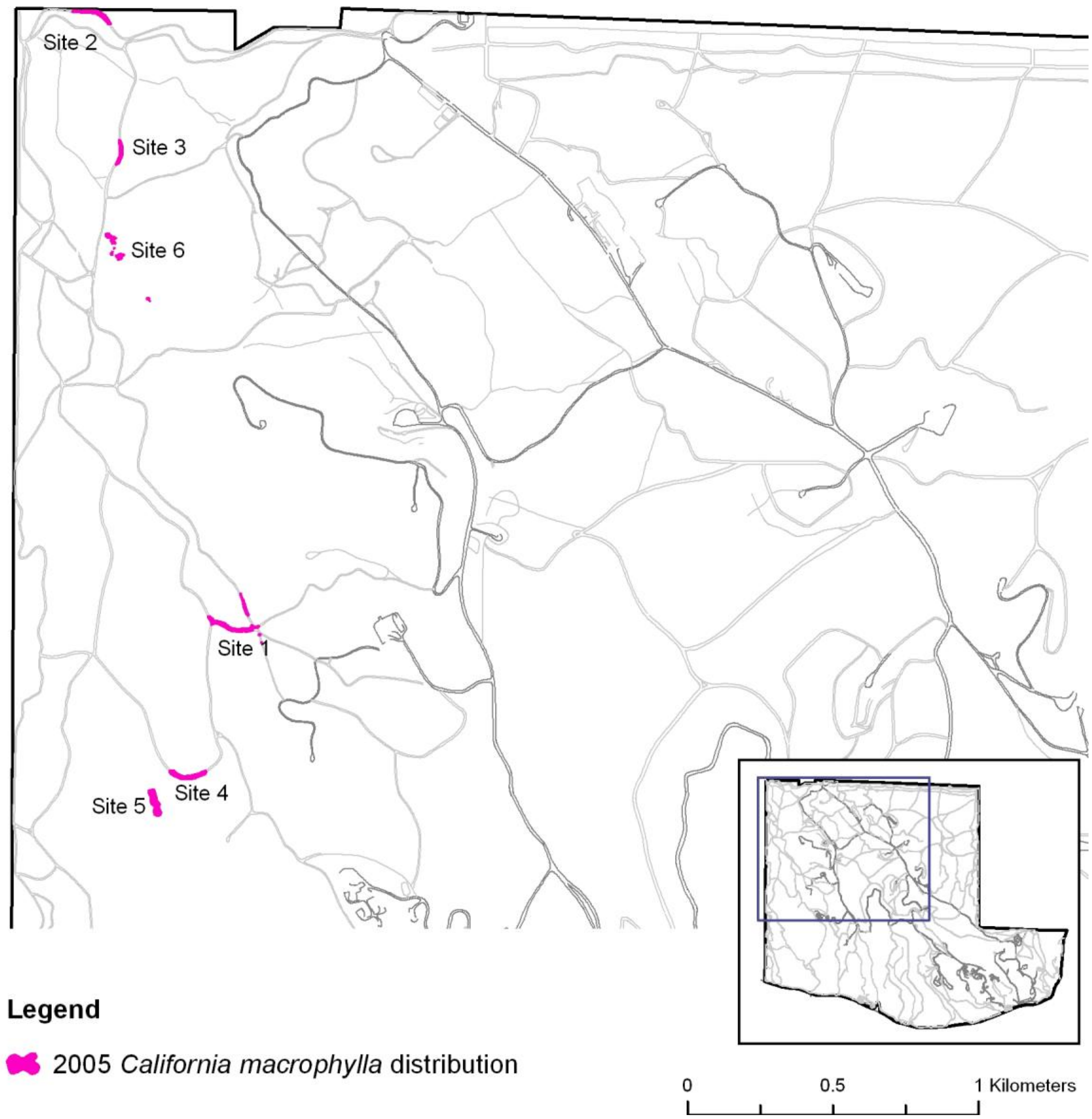

Figure D1. 2005 distribution of *C. macropylla* at Site 300.

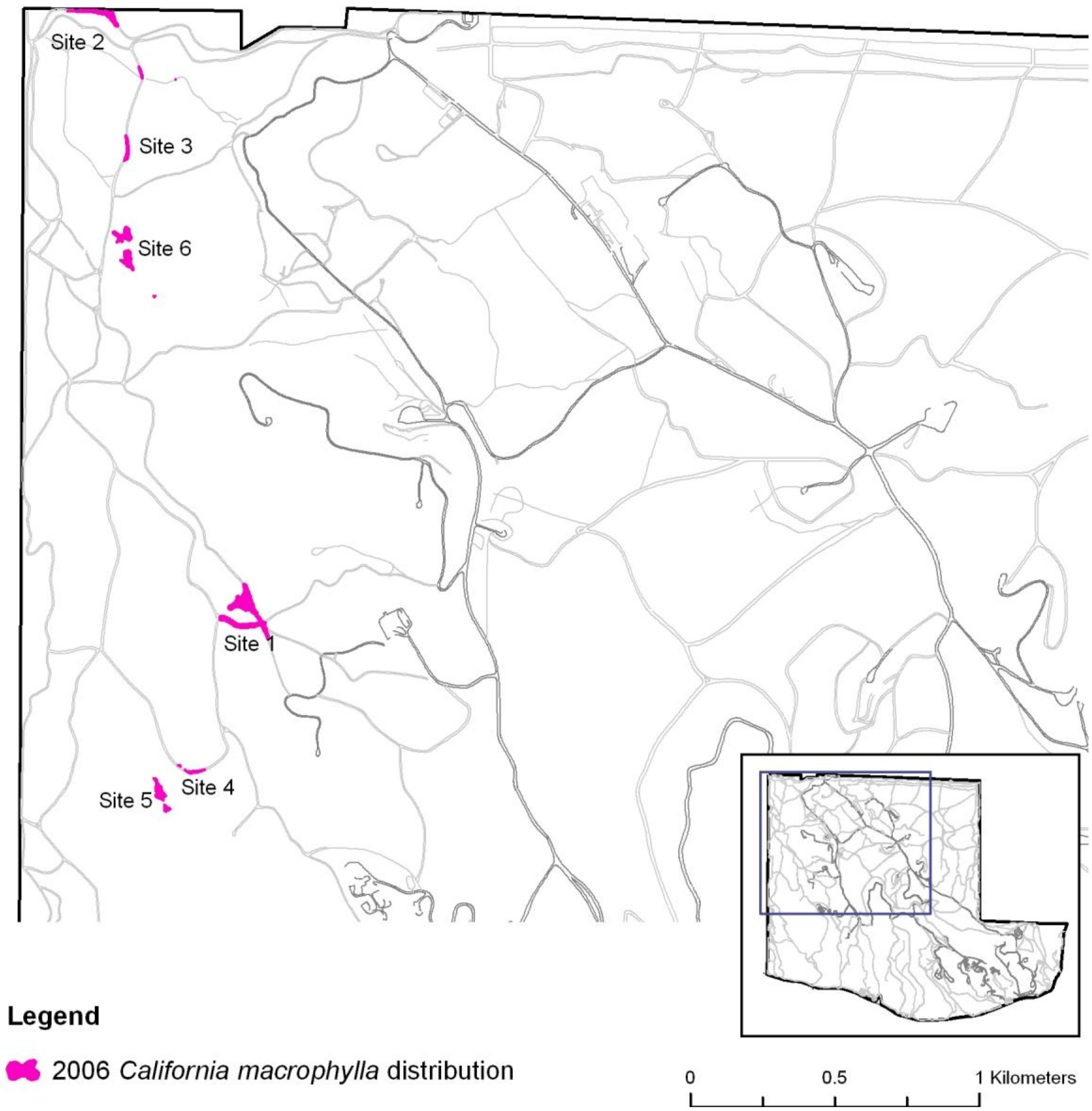

Figure D2. 2006 distribution of *C. macropylla* at Site 300.

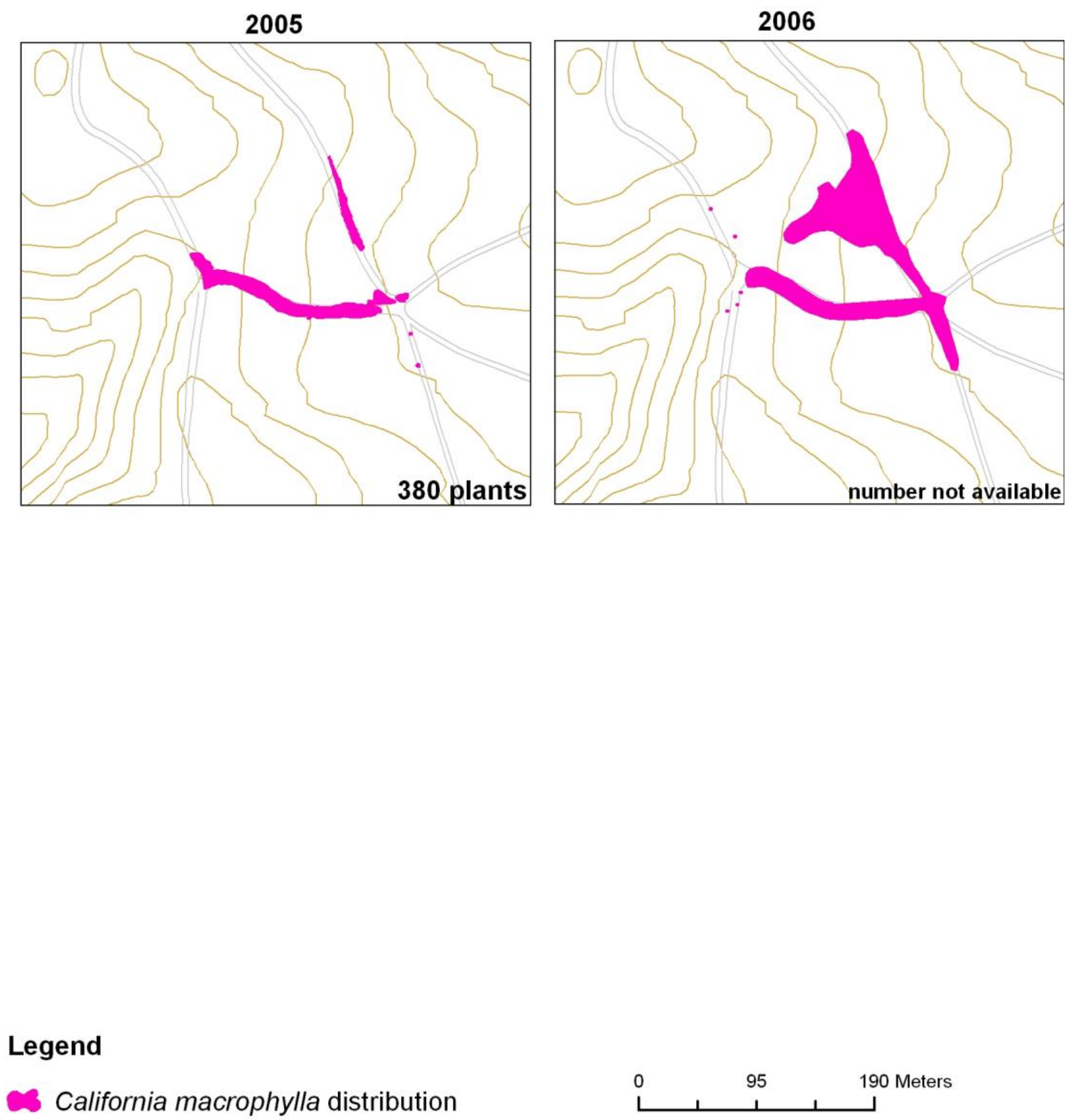

Figure D3. 2005 and 2006 site 1 distribution.

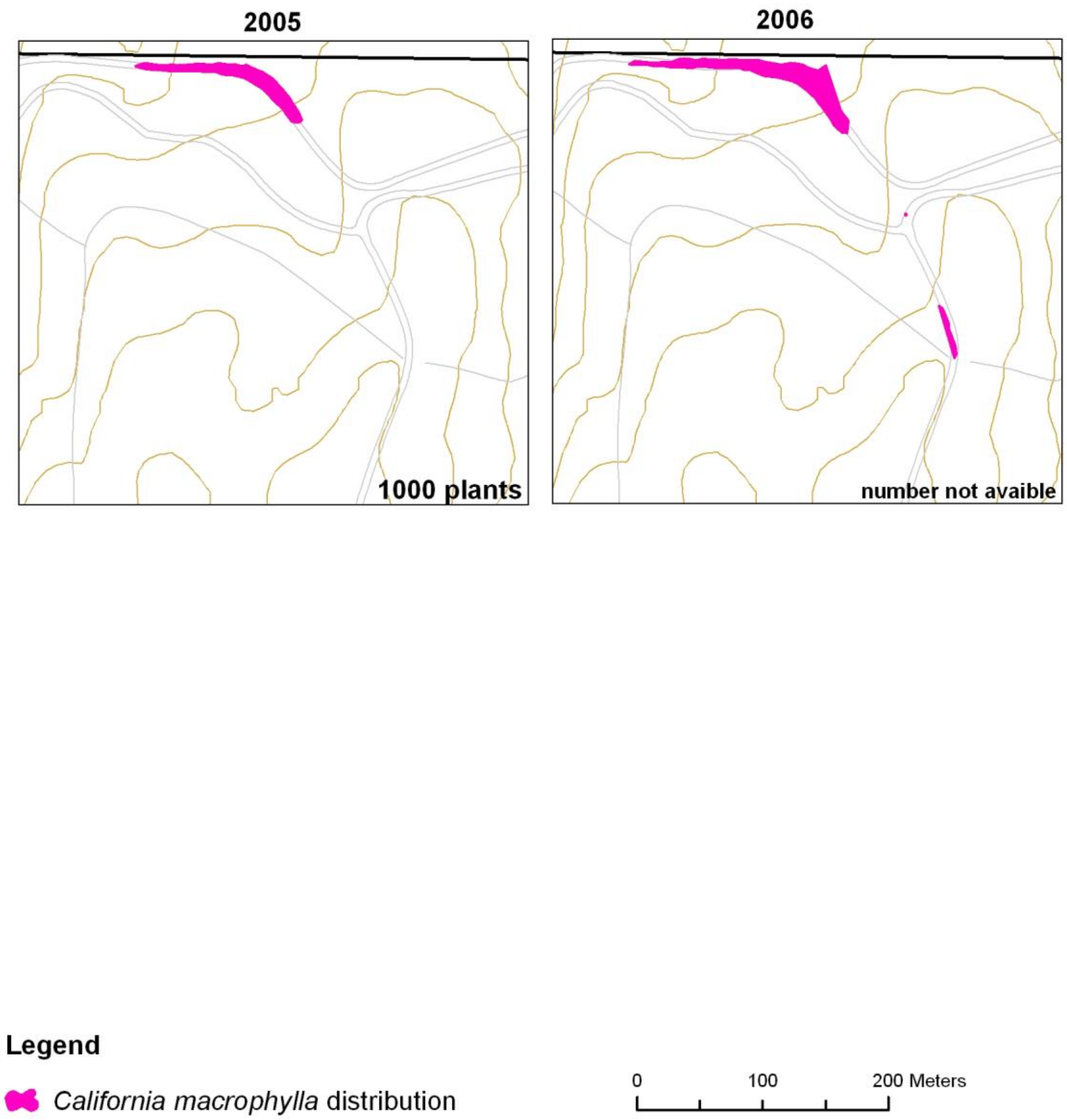

Figure D4. 2005 and 2006 site 2 distribution.

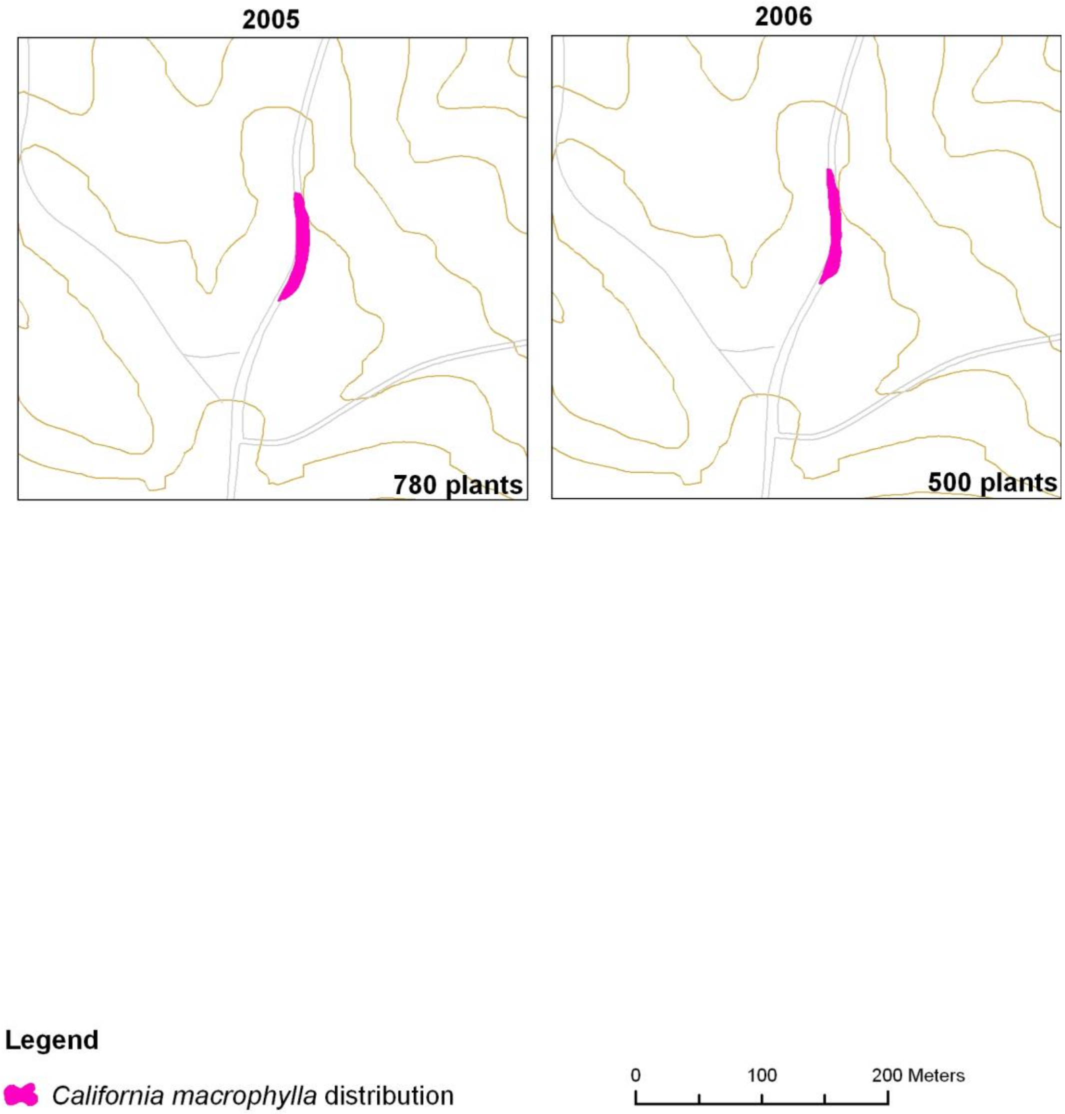

Figure D5. 2005 and 2006 site 3 distribution.

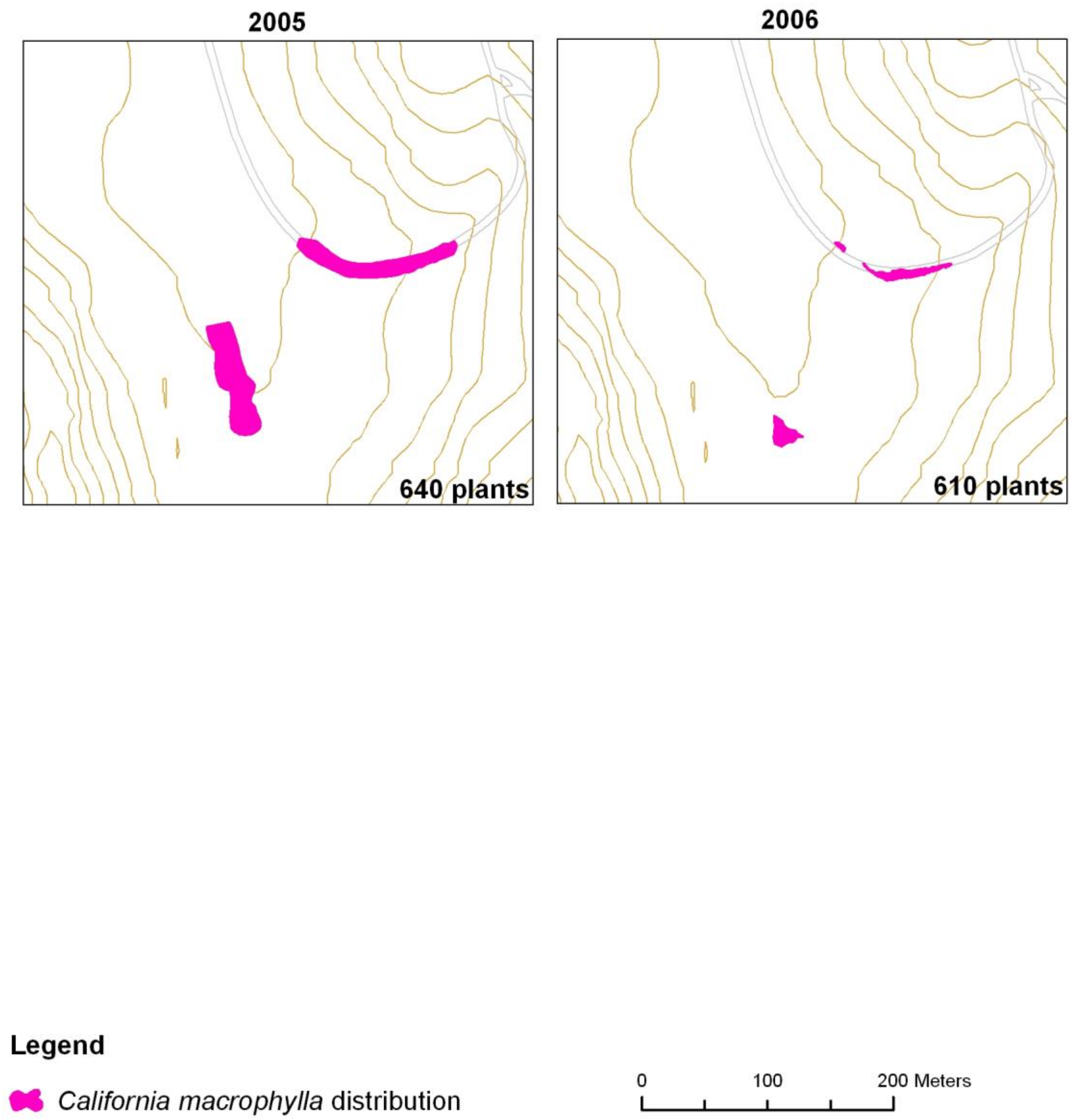

Figure D6. 2005 and 2006 site 4 and 5 distributions.

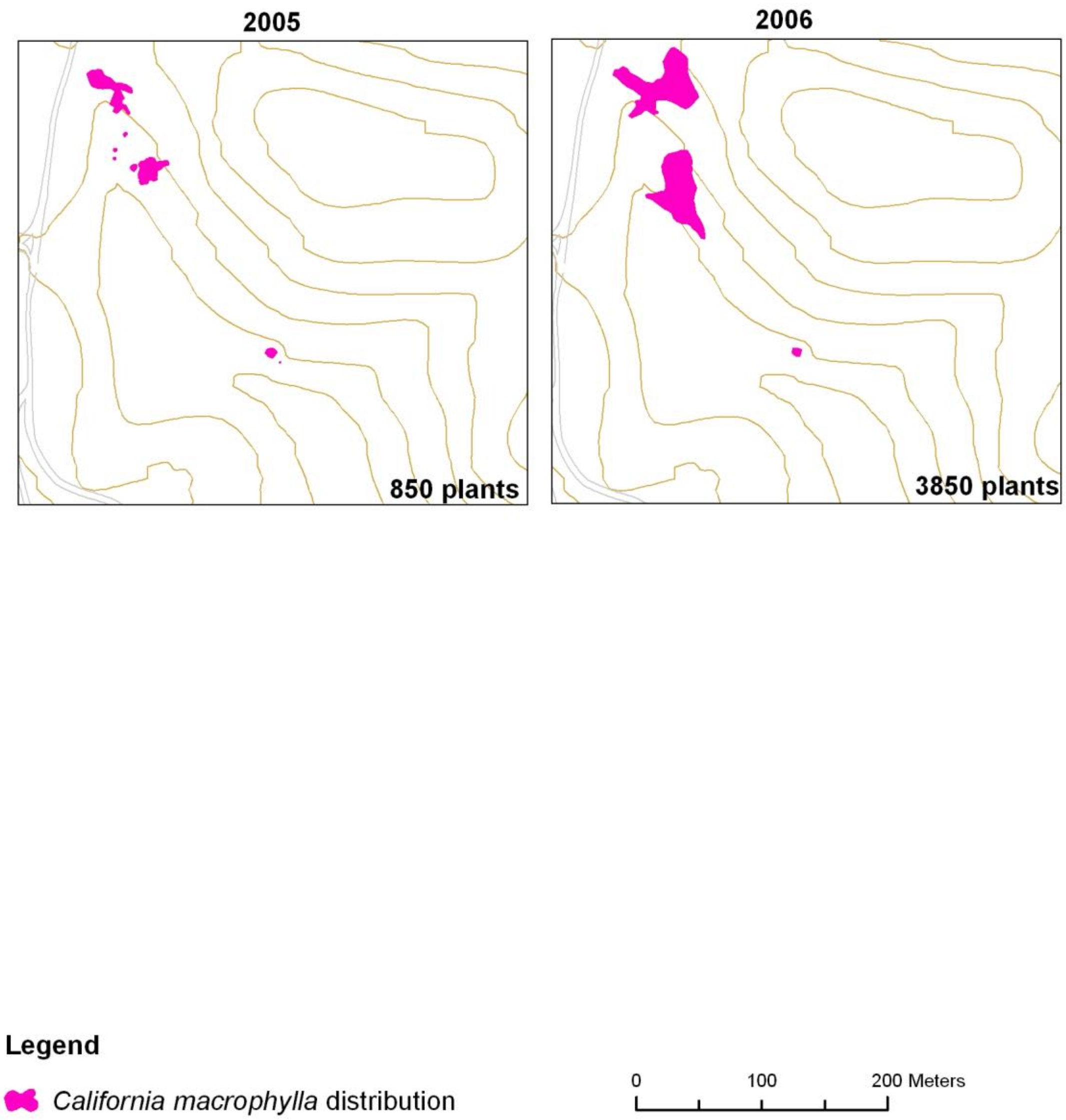

Figure D7. 2005 and 2006 site 6 distribution.

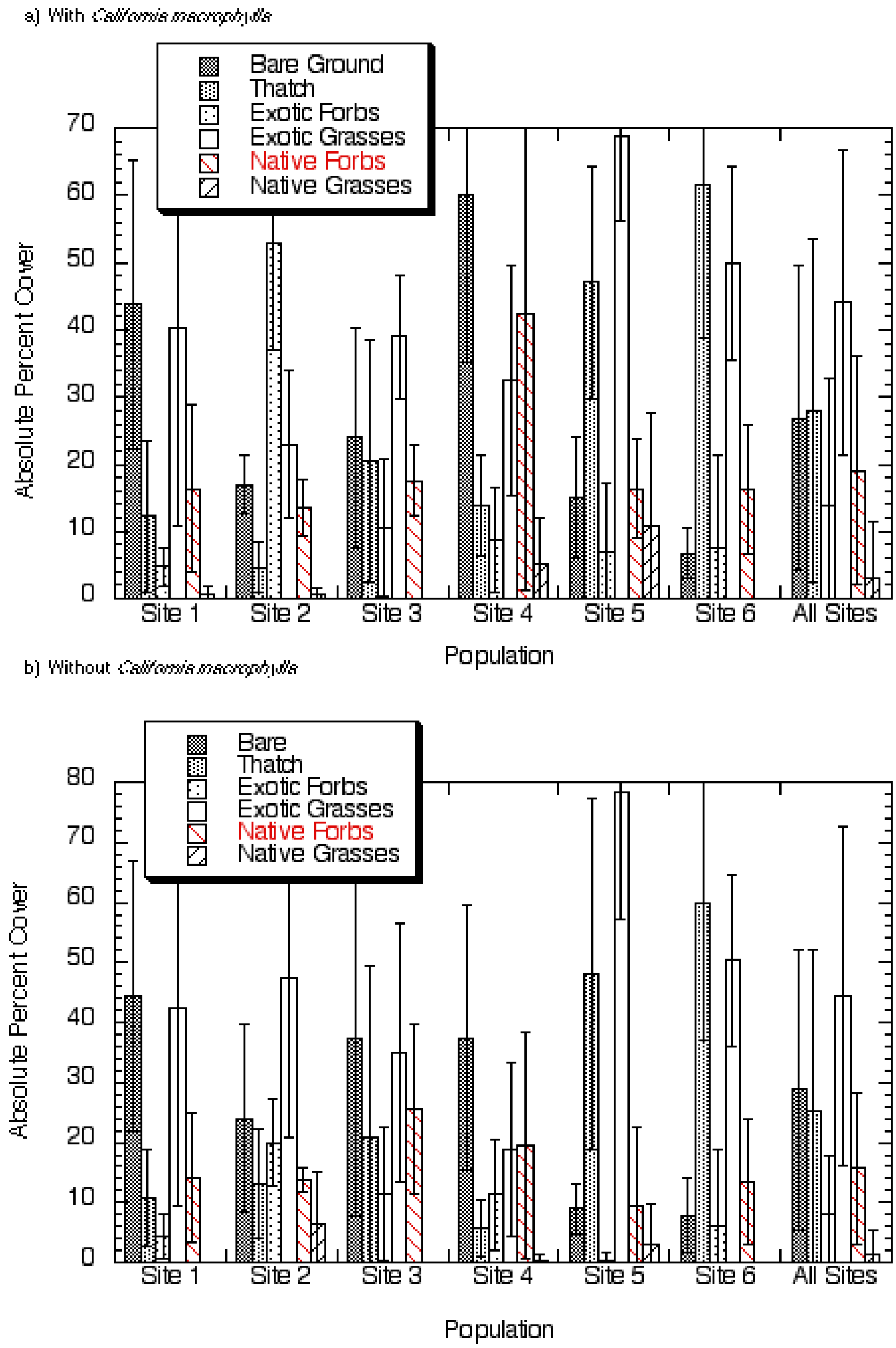

Figure D8. 2005 absolute percent cover of six vegetation categories at sites 1 – 6 and all sites combined. Error bars are ± one standard deviation.

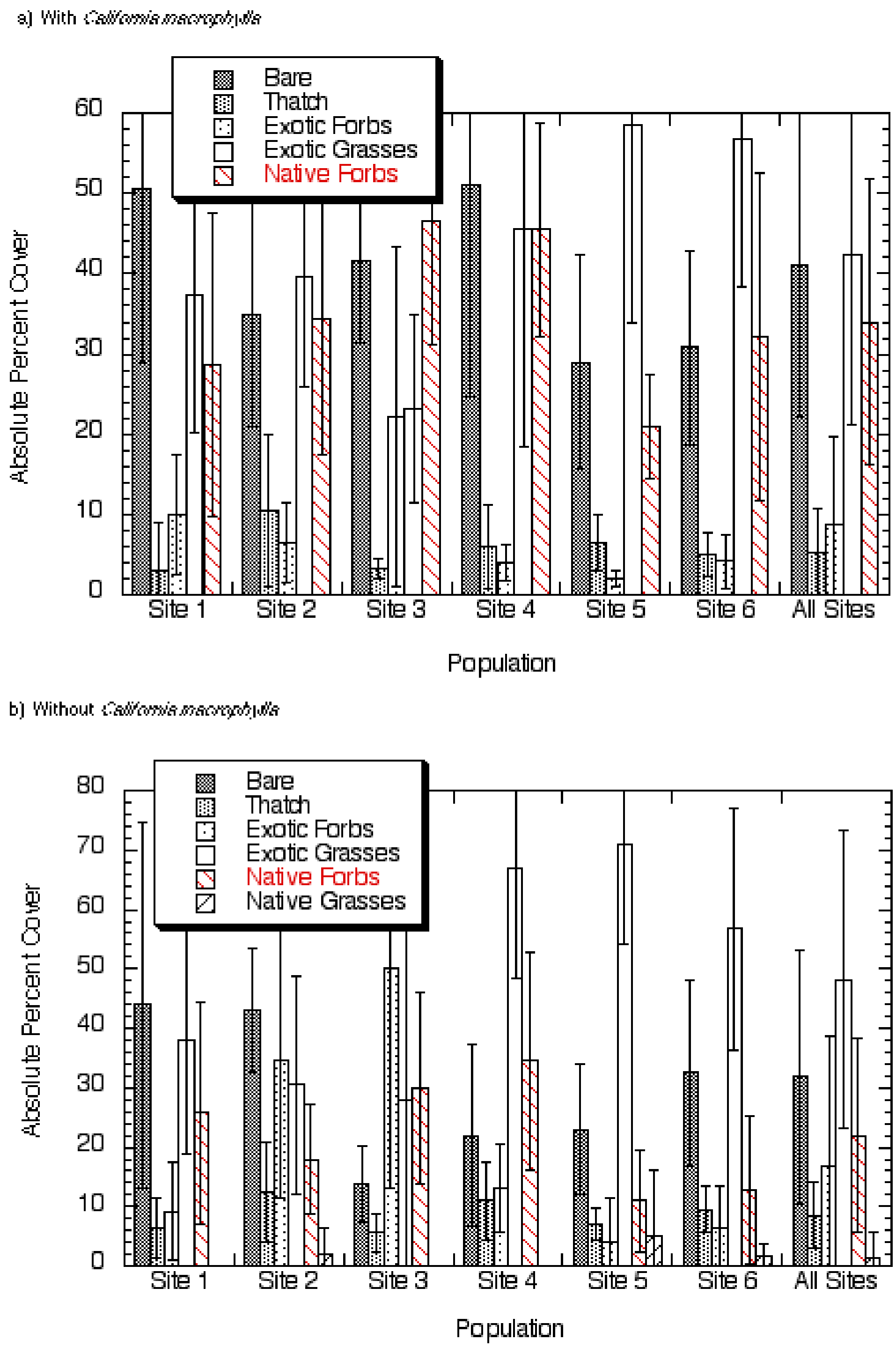

Figure D9. 2006 absolute percent cover of six vegetation categories at sites 1 – 6 and all sites combined. Error bars are ± one standard deviation.

Site 2 – September 2005

Site 3 – September 2005

Figure D10 (Page 1 of 3). ***California macrophylla*** **populations at site 2 through 6 following the July 2005 wildfire (no site 1 photograph available).**

Site 4 – September 2005

Site 5 – September 2005

Figure D10 (Page 2 of 3). ***California macrophylla*** **populations at site 2 through 6 following the July 2005 wildfire (no site 1 photograph available).**

Site 6 – September 2005

Figure D10 (Page 3 of 3). ***California macrophylla*** **populations at site 2 through 6 following the July 2005 wildfire (no site 1 photograph available).**

Section D
Tables

Table D1. Area, elevation, and estimated population size and density of all Site 300 *California macrophylla* populations: 2004-2006.

	Location	Population	Area (m^2)	Population size estimate	Date of Census
2004	Fire trail	1	2077.1	2200	29 Mar 04
		2	549.5	1500	30 Mar 04
		3	617.9	2000	30 Mar 04
		4	352.6	100	01 Apr 04
	Grassland	5	1461.9	45	01 Apr 04
		6	181.7	30	08 Apr 04
2005	Fire trail	1	1952.1	380	11 Apr 05
		2	1078.7	1000	18 Apr 05
		3	660.1	780	18 Apr 05
		4	1401.8	100	06 Apr 05
	Grassland	5	1786.6	540	06 Apr 05
		6	658.6	850	18 Apr 05
2006	Fire trail	1	6582.7	*	07 Apr 06
		2	1803.9	*	06 Apr 06
		3	586.3	500	06 Apr 06
		4	271.3	150	19 Apr 06
	Grassland	5	254.2	460	19 Apr 06
		6	2792.1	3850	13 Apr 06

*Population estimate are not available for Sites 1 and 2 in 2006

Table D2. Number of floral units per plant for the six *California macrophylla* populations 2004-2006. Values are means ± one standard deviation, *n* = Number of plants.

Year	Location	Population	No. of floral units/plant	Width (cm)	Height (cm)	Volume (cm^2)	N
2004*	Fire trail	1	1.3 ± 1.6				58
		2	1.7 ± 1.8				48
		3	3.0 ± 3.2				36
		4	1.1 ± 0.8				13
	Grassland	5	2.9 ± 2.4				45
		6	1.2 ± 1.1				17
2005	Fire trail	1	4.3 ± 3.3	9.3 ± 4.6	12.8 ± 5.4	140.0 ± 242.7	16
		2	5.4 ± 3.2	14.4 ± 3.8	21.3 ± 3.6	413.5 ± 276.1	8
		3	2.5 ± 2.1	6.6 ± 3.0	11.7 ± 3.5	57.7 ± 64.7	20
		4	5.0 ± 7.4	9.1 ± 4.2	12.3 ± 2.7	104.4 ± 97.5	27
	Grassland	5	3.5 ± 2.8	10.3 ± 4.7	16.4 ± 4.9	207.4 ± 256.2	537
		6	4.1 ± 3.2	9.7 ± 4.7	19.2 ± 4.7	210.2 ± 216.0	80
2006	Fire trail	1	4.0 ± 3.7	8.6 ± 4.5	9.8 ± 4.6	104.7 ± 200.9	24
		2	3.1 ± 2.3	7.6 ± 3.8	10.0 ± 3.9	74.3 ± 118.4	13
		3	1.6 ± 2.0	7.2 ± 3.2	5.4 ± 2.9	36.0 ± 68.0	11
		4	3.2 ± 2.2	9.6 ± 4.9	11.0 ± 6.8	127.2 ± 134.0	9
	Grassland	5	6.6 ± 3.2	2.7 ± 1.2	3.2 ± 2.5	3.4 ± 3.0	14
		6	2.0 ± 0.9	4.1 ± 1.4	9.5 ± 2.2	15.9 ± 14.1	88

* Width measurements were not recorded in 2004.

Table D3. 2005 absolute cover recorded in 0.6 m^2 quadrats containing *California macrophylla.*

Population	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	All Sites Combined
N	**8**	**5**	**5**	**4**	**7**	**6**	**35**
Bare Ground	43.8 ± 21.5	17.0 ± 4.5	24.0 ± 16.4	60.0 ± 24.8	15.0 ± 9.1	6.7 ± 3.8	26.9 ± 22.6
Thatch	12.2 ± 11.3	4.6 ± 3.7	20.5 ± 18.1	13.8 ± 7.5	47.1 ± 17.3	61.7 ± 22.9	27.9 ± 25.5
Exotic Forbs	4.7 ± 2.8	53.0 ± 16.1	10.5 ± 10.2	8.8 ± 7.8	6.8 ± 10.5	7.5 ± 13.8	13.8 ± 19.1
Exotic Grasses	40.3 ± 29.6	23.0 ± 11.1	39.0 ± 9.1	32.5 ± 17.0	68.9 ± 12.8	50.0 ± 14.4	44.1 ± 22.6
Native Forbs	16.3 ± 12.5	13.5 ± 4.2	17.5 ± 5.3	42.5 ± 41.3	16.4 ± 7.3	16.3 ± 9.6	19.1 ± 16.9
Native Grasses	0.6 ± 1.2	0.5 ± 1.1	0.0 ± 0.0	5.0 ± 7.1	10.7 ± 16.9	0.0 ± 0.0	2.9 ± 8.6

Table D4. 2005 absolute cover recorded in 0.6 m^2 quadrats without *California macrophylla.*

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	All Sites Combined
N	11	5	5	6	5	7	39
Bare	44.5 ± 22.5	24.0 ± 15.6	37.5 ± 29.6	37.5 ± 21.9	9.0 ± 4.2	7.9 ± 6.2	28.8 ± 23.5
Thatch	10.7 ± 8.1	13.0 ± 9.1	21.0 ± 28.4	5.8 ± 4.7	48.0 ± 29.3	60.0 ± 23.1	25.2 ± 26.9
Exotic Forbs	4.5 ± 3.7	20.0 ± 7.3	11.5 ± 11.0	11.3 ± 9.3	0.5 ± 1.1	6.1 ± 12.9	8.2 ± 9.7
Exotic Grasses	42.3 ± 32.9	47.5 ± 26.5	35.0 ± 21.4	18.8 ± 14.5	78.5 ± 21.3	50.4 ± 14.3	44.5 ± 28.2
Native Forbs	14.1 ± 10.8	13.8 ± 1.9	25.7 ± 14.1	19.6 ± 18.9	9.5 ± 13.0	13.4 ± 10.4	15.7 ± 12.5
Native Grasses	0.0 ± 0.0	6.5 ± 8.6	0.0 ± 0.0	0.4 ± 1.0	3.0 ± 6.7	0.0 ± 0.0	1.3 ± 4.2

Table D5. 2006 absolute cover recorded in 0.6 m^2 quadrats containing *California macrophylla.*

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	All Sites Combined
N	11	5	6	5	5	5	37
Bare	50.5 ± 21.7	35.0 ± 14.1	41.7 ± 10.3	51.0 ± 26.3	29.0 ± 13.4	30.8 ± 12.0	41.2 ± 18.9
Thatch	3.0 ± 6.0	10.5 ± 9.4	3.3 ± 1.3	6.0 ± 5.2	6.5 ± 3.4	5.0 ± 2.7	5.2 ± 5.6
Exotic Forbs	110.0 ± 7.4	6.5 ± 4.9	22.1 ± 21.2	4.0 ± 2.2	2.0 ± 1.1	4.2 ± 3.4	8.7 ± 11.1
Exotic Grasses	37.3 ± 17.0	39.5 ± 13.5	23.3 ± 11.7	45.5 ± 27.0	58.5 ± 24.5	56.7 ± 18.3	42.3 ± 21.0
Native Forbs	28.6 ± 18.9	34.5 ± 17.0	46.7 ± 15.5	45.5 ± 13.3	21.0 ± 6.5	32.1 ± 20.4	34.0 ± 17.8
Native Grasses	0	0.5 ± 1.1	0	1.0 ± 1.4	0	0.4 ± 1.0	0.8 ± 4.1

Table D6. 2006 absolute cover recorded in 0.6 m^2 quadrats without *California macrophylla.*

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	All Sites Combined
N	11	5	6	5	5	6	
Bare	43.9 ± 30.9	43.0 ± 10.4	13.8 ± 6.3	22.0 ± 15.2	23.0 ± 11.0	32.5 ± 15.7	31.9 ± 21.3
Thatch	6.4 ± 5.0	12.5 ± 8.3	5.6 ± 3.1	11.0 ± 6.5	7.0 ± 2.7	9.6 ± 4.0	8.5 ± 5.5
Exotic Forbs	9.2 ± 8.2	34.5 ± 23.1	50.0 ± 37.0	13.0 ± 7.4	4.0 ± 7.6	6.3 7.2	17.0 ± 21.7
Exotic Grasses	38.1 ± 19.4	30.5 ± 18.2	28.1 ± 31.4	67.0 ± 18.7	71.0 ± 17.0	56.7 ± 20.2	48.2 ± 25.1
Native Forbs	25.8 ± 18.6	18.0 ± 9.1	30.0 ± 16.2	34.5 ± 18.3	11.0 ± 8.6	12.9 ± 12.5	22.0 ± 16.2
Native Grasses	0	2.0 ± 4.5	0	0	5.0 ± 11.2	1.7 ± 2.0	1.3 ± 4.6