LLNL-TR-585933

LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Rare Plant Monitoring and Restoration at the Lawrence Livermore National Laboratory Experimental Test Site, Site 300, Project Progress Report 2007 through 2011

T. M. Carlsen, L. E. Paterson, T. M. Alfaro, S. D. Gregory

September 28, 2012

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Environmental Functional Area

LLNL-TR-585933

Rare Plant Monitoring and Restoration at the Lawrence Livermore National Laboratory Experimental Test Site, Site 300, Project Progress Report 2007 through 2011

Authors:
Tina Carlsen
Lisa Paterson
Teneile Alfaro
Steve Gregory

September 2012

Lawrence Livermore National Laboratory

This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

Acknowledgement

We greatly appreciate the generous long-term support that the Site 300 management has committed toward the restoration, management, and monitoring of rare plants. This commitment has been an essential part of the continued survival and recovery of these unique elements of California's natural heritage. In particular, we would like to thank John Scott, Karen Folks, Jim Lane, and Keith Graham for their support of this work. We would also like to thank the LLNL Fire Department for annually conducting precision controlled burns at the Amsinckia grandiflora experimental population site. The completion of the long-term experiment at this site would have been impossible without their commitment to the work. There is a culture among Site 300 employees that fosters an appreciation for the abundant and diverse natural resources found at the site. Many Site 300 employees and offsite botanists and neighbors have shown a great enthusiasm for the diversity of plant species found at Site 300. It has been a pleasure and privilege to be part of sharing the natural diversity of Site 300's flora with many individuals over the years. In addition, we are extremely grateful to the many LLNL employees who have assisted with field work as part of this project.

Table of Contents

Section A
Amsinckia grandiflora Monitoring and Research

List of Figures

List of Tables

Section B
Blepharizonia plumosa Monitoring

List of Figures

List of Tables

Section C
Eschscholzia rhombipetala Monitoring

List of Figures

List of Tables

Section D
California macrophylla Monitoring

List of Figures

List of Tables

Section A
Amsinckia grandiflora
Monitoring and Research

Section A
Amsinckia grandiflora
Monitoring and Research

A-1. Introduction

The large-flowered fiddleneck, *Amsinckia grandiflora* (A. GRAY) 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) (Figure A1). 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. 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 native populations containing individuals historically numbering from fewer than 30 to several thousand (Figure A2; CNDDB, 2012). All native 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 native populations occur at Lawrence Livermore National Laboratory (LLNL) Site 300, a high-explosive testing facility operated by Lawrence Livermore National Security (LLNS) for the U.S. Department of Energy (DOE) (Figure A3). The two native populations at Site 300 are known as the Drop Tower native population and the Draney Canyon native population. Located in the north/southwest trending Drop Tower canyon, the Drop Tower native population was historically 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 native population was discovered in a north/southwest trending canyon to the west of the Drop Tower canyon. *Amsinckia grandiflora* has not been observed at this site since 1997 when heavy winter rains resulted in a landslide at the site. The Drop Tower native population consists of the primary Drop Tower native population, and a subpopulation located to the south and around the hill from the primary Drop Tower native population, called the Carlsen-Gregory subpopulation.

In 1991, a large natural *A. grandiflora* population, known as the Carnegie Canyon native population, was discovered on private rangelands near the southeast border of Site 300 (Figure A2; CNDBB, 2012). Between 1991 and 1996, this population numbered from approximately 1,500 to 4,000 individuals, covering a large area of hillside. No individuals were seen during limited observations made between 2000 and 2008. Land on which this population occurs was purchased by Contra Costa Water District in 2011 as part of their mitigation package for expanding the Los Vaqueros Reservoir. Their monitoring showed the population to have 134 individuals in 2010 and 688 in 2011 (Wilde Legard, East Bay Regional Park Botanist, April 24, 2011).

Amsinckia grandiflora was federally listed as endangered in 1985. On May 8, 1985, one hundred and sixty acres of Site 300 surrounding the Drop Tower native 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). Three experimental populations were established in *A. grandiflora's* historic northern range (Pavlik, 1991). Two of the experimental populations were established at Black Diamond Mines Regional Preserve in Contra Costa County in 1991 near the historic Judsonville location. These experimental populations are known as Black Diamond II and Lougher Ridge (Figure A2; CNDBB, 2012; Pavlik, 1991 and 1994). Plants have not been observed at the Black Diamond II site since 1993. Restoration efforts have continued at the Lougher Ridge site. This experimental population has also declined in recent years. Results of a population enhancement effort conducted by LLNL, and funded by the U.S. Bureau of Reclamation, were reported on in the FY05-06 rare plant monitoring report (Paterson et al., 2010). A third experimental population was attempted on land owned by the Contra Costa Water District near Los Vaqueros reservoir. Known as the Los Vaqueros I population (Figure A2; CNDDB, 2012), plants failed to establish at this site.

Attempts at establishing experimental populations have also occurred near Site 300 in the southern portion of *A. grandiflora's* historic range. An experimental population was attempted near the southeast border of Site 300 at the privately owned Connolly Ranch. This experimental population, known as the Connolly population (Figure A2; CNDBB, 2012), failed possibly due to extremely high rodent activity (Pavlik, 1994). Adjacent to the southeast border of Site 300 is an ecological reserve owned by the California Department of Fish and Game. 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 not listed in the California Natural Diversity Database), but no reproductive plants have been observed at this site in recent years, suggesting the establishment was not successful.

Between 1993 and 1995, using funds obtained through a grant from LLNL's Laboratory Directed Research and Development Program (LDRD), LLNL researchers teamed with the researchers from Mills College to further investigate the causes of *A. grandiflora* rarity and to establish an additional experimental population at Site 300. The Site 300 experimental population (known as the Drop Tower experimental population in the CNDDB, Figure A2) 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). The Site 300 experimental population is divided into two portions. The original experimental population is referred to as the Flashing (FL) experimental subpopulation because it was surrounded by metal flashing to exclude rodents from the population during the original experiments (Figures A4 and A5). This experimental population was originally established to conduct competition experiments (Carlsen et al., 2000). The plot identifiers shown in Figure A5 originated from this experiment and have been retained to ensure consistent plot identification over time. The Site 300 experimental population was expanded in 1999 to include 20 additional plots to be used in an experiment on the effects of prescribed burns on *A. grandiflora* and *Poa secunda.* This portion of the experimental population is referred to as the Fire Frequency experimental subpopulation (Figure A4).

Earlier research conducted in the 1990's on the Site 300 experimental population and the Lougher Ridge experimental population, and data from management of the Drop Tower native population, indicated 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). Early efforts focused on using grass-selective herbicide to control exotic annual grasses. While between 1991 and 1996 this proved to be a successful strategy, beginning in 1997 the Site 300 experimental population and the Drop Tower native population began to dramatically decline even with the use of the grass-selective herbicide. Concurrent with this period, at the Lougher Ridge experimental site and at the Drop Tower native site, bush lupines began to aggressively invade these populations (Carlsen et al., 2003). Because there was concern that the grass-selective herbicide may be facilitating this invasion the use of the herbicide was discontinued. The bush lupines have subsequently died back (Paterson et al., 2010), however, the *A. grandiflora* populations have not recovered. In addition to support received from LLNL's Site 300, the USFWS and the U.S. Bureau of Reclamation provided funding for this earlier research.

More recent research conducted at Site 300 shows that predation pressure on *A. grandiflora* nutlets can interact negatively with the use of fire in establishing bunch grass communities (Espeland et al., 2005), and that fire can have short-term negative effects on *A. grandiflora* establishment (Paterson et al., 2010).

The goal of the ongoing management of the Site 300 *A. grandiflora* populations is to monitor the existing native and experimental populations, and to investigate techniques to restore native perennial grasslands. The use of controlled burning continues to be investigated as a potential long-term tool for developing and maintaining perennial grasslands.

A-2. Methods and Materials

Monitoring and field activities conducted at the Site 300 native and experimental *A. grandiflora* populations are summarized in Table A1. The Site 300 experimental population includes the Flashing experimental subpopulation (designated FL), and the Fire Frequency experimental subpopulation (designated FF). The native populations include the Drop Tower native population and Draney Canyon native population. The Drop Tower native population also includes the Carlsen-Gregory subpopulation. Monitoring and field activities conducted at the native and experimental populations include: 1) periodic seed bank enhancement in the FF and FL experimental subpopulations, 2) spring census of FF and FL experimental subpopulations and the Drop Tower native population, and periodic surveys of the Draney Canyon native population site for the presence of *A. grandiflora*, 3) collection of community cover estimates from the FF and FL experimental populations and the Drop TowerR= native population, 4) collection of *P. secunda* persistence data from the FF and FL experimental subpopulations, 5) collection of biomass data from the FL experimental subpopulation (2007 only), 6) nutlet predation monitoring (2007 only), and 8) annual prescribed burning in the FF experimental subpopulation.

A-2.1. Seed Bank Enhancement

Due to the continued decline in the numbers of *A. grandiflora* in the experimental population, seed bank enhancement was conducted in December of 2006, 2009 and 2010 (fiscal years 2007, 2009 and 2010, respectively, Table A1).

In 2006, 64 seeds (also known as nutlets) were planted in all plots within the first three rows of the FL experimental subpopulation (Figure A5) and within all the plots in the FF experimental subpopulation (Figure A4). Nutlets were planted in an 8 x 8 visually estimated grid, with each nutlet approximately 10 cm apart. The grid was centered within the FF plots, whereas the grid encompassed the entire FL plots. All FF plots were covered with bird netting to prevent bird predation of the nutlets. The FL plots were not netted.

In 2009, all FF plots were planted with 100 nutlets in a visually estimated 10 x 10 grid centered within the plot, with each nutlet approximately 10 cm apart. All plots were netted in 2009. In 2010, nine locations within the first row and one location within the second row of the FL population (Figure A5) were planted with 100 nutlets in a visually-estimated 10 x 10 grid with each nutlet approximately 10 cm apart. Locations did not precisely correlate with plot locations, as the planting grids did not fit well into each plot. All plots were netted in 2010.

Planting was conducted by excavating a hole to a depth of about 0.5 cm into the mineral soil. A single nutlet was placed into each hole. Each nutlet was then lightly covered with mineral soil and lightly tapped down.

A-2.2. Spring Census

Table A1 summarizes the dates in which the spring census of the Site 300 experimental and native populations occurred for 2007 through 2011. Subpopulation, flower 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 2007 through 2011. Draney Canyon was surveyed for the presence of *A. grandiflora* on April 4, 2011.

A-2.2.1. 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-2.2.2. Analysis of Nearest Neighbor Data

The frequency of nearest neighbor species and Shannon's Diverstiy Index (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 the 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 *i*th 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-2.3. Community Cover Estimates

Table A1 summarizes the dates and locations in which community cover estimates were collected from the Site 300 experimental and native populations for 2007 through 2011. Specific cover estimates were recorded by placing a 60 cm × 60 cm quadrat centered in existing plots (FF and FL experimental subpopulations) or random locations (Drop Tower native population including the Carlsen-Gregory subpopulation) 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 Site 300 experimental population, specific plant cover estimates were taken on all 20 FF subpopoulation plots for each year from 2007 through 2011. In the FL subpopulation, cover estimates were collected from the 55 original 60 cm × 60 cm plots for each year from 2007 through 2011, with the exception that cover was collected from only 47 plots in 2009, and one additional location was sampled in 2008 for a total of 56 plots.

In the Drop Tower native population, specific plant cover estimates were taken from five to six randomly placed quadrats within the primary Drop Tower native population in years 2007 through 2009 and 2011. Cover estimates were not collected from this population in 2010.

Cover estimates were recorded from two quadrats centered on the location where *A. grandiflora* was found in 2007 in the Carlsen-Gregory subpopulation of the Drop Tower native population in years 2007 and 2008. Cover estimates were not collected from this subpopulation in the years 2009 through 2011.

A-2.3.1. Analysis of the Cover Estimates

Cover data were analyzed by calculating mean cover, constancy and importance value (IV) for each species. 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. Mean cover was also calculated for thatch and bare ground.

Shannon's Index (H') was also calculated using the cover data from the Drop Tower native population and the FL and FF experimental subpopulations using the equation shown in Section A-2.2.2. In this case, the sum of all the individual cover measurements collected in the population was used as n (the total number of individuals), and the sum of the cover measurements for species *i* was used as n_i (the number of individuals of the *i*th species).

A-2.4. *Poa secunda* Persistence

The number of the perennial bunch grass *P. secunda* was counted in both the FF and FL experimental subpopulations to monitor long-term establishment of *P. secunda* (Table A1). The number of *P. secunda* was counted in all 20 plots of the FF subpopulation each year from 2007 through 2011. *Poa secunda* were counted in each of the 55 plots within the FL subpopulation in 2007 and 2009 through 2011. Counts were not obtained from this subpopulation in 2008.

A-2.5. Flashing Subpopulation Biomass Collection

Biomass samples have been from the FL experimental subpopulation each year since 1998 from plots originally established in 1993. Two types of plots were established in 1993: plots containing *P. secunda*, either planted with *P. secunda* or with existing *P. secunda* (both of these plots types are referred to as *Poa* plots) and plots cleared of all perennial grasses. Plots cleared of all perennial grasses were established with three densities of annual grass or kept clear of all plant biomass except *A. grandiflora* (control plots). These plot types are referred to as annual grass plots. The planted *Poa* and existing *Poa* plots were also established at three different densities.

Baseline biomass data were 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 subpopulation plots on May 17, 2007. One plot was selected randomly from each of the five rows for biomass sampling. The selection was further constrained in that plots could not have been used in biomass sampling in the previous two years. Biomass samples were separated into *Poa,* other grass, forbs, and thatch. Biomass collection was not conducted in 2008 through 2011 due to personnel limitations.

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 *P. 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 shifted 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 experimental subpopulation and round two was conducted after the FF subpopulation burn. A single round of predation monitoring was conducted in 2005 through 2007. Predation monitoring was not conducted in 2008 through 2011 due to personnel limitations.

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 subpopulation plot. Each nail was pressed into the soil so the nail head was flush with the soil surface.

In 2007, a total of ten grids of nutlet/nails were placed: five in the FF subpopulation plots and five in the FL subpopulation plots (Table A1). Plots were chosen haphazardly from plots that would not be burned in 2007 and that were not used to study predation in 2006. Nutlet/nails were placed in the plots on May 31, 2007. Nails were checked on June 12, June 14, and June 22 of 2007.

A-2.7. Fire Frequency Experiment

The FF experimental subpopulation consists of twenty plots:

- five control plots 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, and
- five high frequency plots that are burned each year.

Figure A4 shows the layout of these plots. Plots are 2 m x 2 m with a 0.5 m buffer between each plot. The population was established by initially burning the entire area of the FF subpopulation in 1998. Plugs of the perennial bunch grasses *P. secunda* were planted in the 1 m x 1 m center portion of each FF subpopulation 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 (33 plugs in the center 1 m^2). 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 4.5 m × 2 m blocks (including the 0.5 m space between plots), rather than the intended 2 m × 2 m areas. Burn treatments began in the summer of 2001. Table A2 summarizes the burn treatments conducted in the fire frequency experiment. All FF subpopulation plots, except the control plots, were burned on July 18, 2001, and on June 20, 2002, the high frequency FF subpopulation 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 twenty FF subpopulation 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, seventeen of the twenty FF subpopulation plots were burned in 2005.

During the 2006 prescribed burn, to control for the impacts of the 2005 wildfire the three low frequency, medium frequency, and control plots (plots A, C, and D) that had not burned during the 2005 wildfire were burned (Table A2).

From 2001 through 2011, the burn treatments as shown in Table A2 were conducted. Upon completion of the 2011 prescribed burn, all low frequency plots had been burned three times between 2001 and 2011, and all medium frequency plots had been burned five times between 2001 and 2011 (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 2011 for a total of 11 burns.

A-3. Results

A-3.1. Spring Census

Population sizes continued to be very small in the Drop Tower native population in 2007 through 2011. During this period, only a single plant, located in the Carlsen-Gregory subpopulation, was observed (Table A3, Figure A6).

Both the FL and FF experimental subpopulations have been maintained through periodic seeding to enhance the seed bank. The FL subpopulation appears to be particularly dependent on seed bank enhancement, often falling to zero plants within two years of seed bank enhancement (Figure A7). The FF subpopulation has never fallen to zero plants, even three years post seed bank enhancement (Figure A8).

A-3.1.1. Nutlet Production

There has been no estimated nutlet production in the Drop Tower native population since 2006 (Table A3). It is possible that the seed bank is no longer sufficient to maintain this native population.

Even with seed bank enhancement in December of 2006, the FL experimental subpopulation failed to produce nutlets in 2007. Although the seed bank enhancement resulted in 103 plants in 2007, these plants were small (averaging just 10 cm in height) and single branched. The seven plants observed in this subpopulation in 2008 were slightly larger, resulting in an estimated 47 nutlets produced during that year. No plants were observed in this subpopulation between 2009 and 2010. The seed bank enhancement conducted in December of 2010 resulted in 111 *A. grandiflora* plants in this subpopulation in 2011. These plants were estimated to have produced around 112 nutlets (Table A3).

Estimated nutlet production has been greater in the FF experimental subpopulation, with nutlets produced every year between 2007 and 2011. Nutlet production ranged from a low of 13 in 2009 up to 2,133 in 2011 (Table A3).

A-3.1.2. 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 may be useful in making comparisons among populations and years. Tables A4 through A7 shows the percent species composition of *A. grandiflora* nearest neighbors for the Drop Tower native and Site 300 experimental populations. Shannon's Index (H') of diversity is also shown. Table A8 summarizes the nearest neighbor data for the years 1997 through 2010.

The exotic grasses *Avena* sp., *Bromus diandrus,* and *Bromus hordeaceus* have consistently been among the most common nearest neighbors in the FF and FL experimental subpopulations and the Drop Tower native population. Another exotic grass, *Vulpia myuros,* did not occur as a nearest neighbor in the Drop Tower native population in 1997–1998 but has periodically been a common nearest neighbor in the Drop Tower native and the Site 300 experimental populations since 1999. In 2007, the native *Vupia* species, *V. microstachys*, appeared in the Drop Tower native population.

Since 2007, this species has also commonly been observed in the cover data in the experimental population (Tables A9 through A13). It is likely many of the individuals identified as *V. myuros* prior to 2007 were actually *V. microstachys*. 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 *P. secunda,* as nearest neighbors in the Site 300 experimental and Drop Tower native populations has been much more variable. However, it does appear that these native species were more common in the Drop Tower native population location compared to the Site 300 experimental population. Other native plants that often occur as nearest neighbors are *Claytonia parviflora* and *Lupinus bicolor*, particularly in the experimental sites.

The Shannon's Index (H') suggests that diversity has decreased over time, particularly in the native population. However, the use of this index in this context is very sensitive to the number of *A. grandiflora* within each population, since this determines the number of sampling sites. With large numbers of *A. grandiflora* individuals, there is a greater likelihood of sampling uncommon nearest neighbor species. With smaller numbers of *A. grandiflora* individuals, the more common nearest neighbor species are more likely to be sampled. Because of the limitations of this type of data, collection of nearest neighbor data was discontinued in 2011.

A-3.2. Community Cover

Cover estimates have been taken in the Drop Tower native population (which included the Carlsen-Gregory subpopulation in 2007 and 2008) and the two subpopulations of the Site 300 experimental population (FF and FL experimental subpopulations) since 2001. Cover estimates for 2007 through 2011 are shown in Tables A9 through A13. Table A14 summarizes the cover data for years 2007 through 2011.

Bromus hordeaceous, *Erodium cicutarium* and *Avena* sp. tend have high importance values in both the Drop Tower native population and the Site 300 experimental population. *Erodium cicutarium* is more common in the Site 300 experimental population as compared to the Drop Tower native population. This is likely due to the more frequent presence of fire in the experimental population. *Erodium cicutarium* did have a high IV in 2007 and 2008 in the Drop Tower native population, up to three years after the 2005 wildfire that went through the area. However, IVs of this species dropped in 2009 and 2011. This may also have been an artifact of including the Carlsen-Gregory subpopulation during these years, as this subpopulation occurs on a dryer, more southerly portion of the slope, which may favor *E. cicutarium*. Other differences can be seen in the cover data between the populations. In the FL experimental subpopulation, *Lupinus bicolor* and an unknown Poaceae periodically have high IVs, while in the FF experimental subpopulation, the native grass *P. secunda* was frequently observed with a high IV, as was *Vulpia microstachys* (also a native grass). In the Drop Tower native population, *Bromus diandrus*, *Bromus madritensis*, *Vulpia myuros* and *Gallium aparine* all periodically had high IVs. As discussed above with the nearest neighbor data, it is likely the *V. myuros* observed in 2007 in the Drop Tower native population may have also contained *V. microstachys* individuals.

Shannon's Index (H') is significantly higher for the Drop Tower native and Site 300 experimental populations when cover data is used to calculate the index as opposed to nearest neighbor data. This is because the number of sampling locations is not dependent upon the number of *A. grandiflora* present. However, the data still suffer from the fact that between 5 and 7 plots are sampled in the Drop Tower native population, 20 plots in the FF experimental subpopulation, and around 55 plots in the FL experimental subpopulation. Thus, the FL experimental subpopulation consistently has the highest diversity index, primarily due to the large number of plots sampled. This increases the likelihood of detecting infrequently occurring species. The exception to this trend is 2007, in which the Drop Tower native population had a very high H'. This was due to the very even distribution of the species observed in terms of cover.

The amount of thatch cover is relatively low in the FF experimental subpopulation when compared to the FL experimental subpopulation, with the amount of bare ground typically higher. This is likely due to the presence of fire in portions of the FF experimental subpopulation. Thatch cover, as well as bare ground, is quite variable in the primary Drop Tower native population.

A-3.3. *Poa secunda* Persistence

Table A16 and Figure A10 shows the density of *P. secunda* in the FL experimental subpopulation by plot type. As can be seen, even though the *P. secunda* plots were established back in 1993, these plots still have significantly more *P. secunda* than the annual grass plots, although density in both plot types have declined over time. Although *P. secunda* was removed from all of the annual grass plots in 1992, *P. secunda* has been able to reestablish in these plots, which was likely facilitated by the periodic presence of fire in this subpopulation.

A-3.4. Biomass Production

Figure A11 shows biomass production by plot type from 1998 through 2007 (see Paterson et al., 2007 for a discussion of biomass production by burn treatment). Biomass production generally follows rainfall distribution, with greater biomass being produced in rainier years. From 1998 through 2001, annual grass plot types typically had higher biomass production than *Poa* plots. Interpretation of this observation is complicated by the fact that plots that were burned in 1998 and 1999 are not evenly distributed between plot types (*Poa* and annual grass plot types). After 2001, there is very little difference between plot types. Biomass results by plot type are also shown in Table A9.

Figure A12 shows biomass production by biomass type between 2003 and 2007. Annual grass dominates biomass production in all years, with forbs and thatch being the next most numerous. *Poa secunda* makes up a very small percentage of the biomass in all years.

A-3.5. Nutlet Predation

Figure A13 shows the cumulative percent granivory observed in 2005 through 2007 in the experimental subpopulations. Granivory was highest in 2005 in the FL experimental subpopulation, where it reached over 90%. Interestingly, it was lowest the same year in the unburned plots of the FF experimental subpopulation, where granivory reached around 55%. For 2006 and 2007, granivory was just over 65% in both FF and FL subpopulations.

A-3.6. Effects of Fire Frequency

Table A17 and Figure A14 shows the density of *P. secunda* in the FF experimental subpopulation by fire frequency. The high frequency treatment, in which plots have been burned every year for the past 11 years, have significantly more *P. secunda* compared to all of the other treatments. Although the medium frequency treatment appears to have an intermediate *P. secunda* density when compared to the low and high frequency treatments, this density is not significantly different from the low frequency treatment of the control.

The number of *A. grandiflora* present in plots of each burn frequency is shown in Table A18 and Figure A15. The high amount of variability in the data is a result of the need to reseed the plots to maintain the population. In addition, the effect of the burn itself also complicates the interpretation of the data. Although not significant, in 2011 more *A. grandiflora* plants were found in the control plots as compared to the high and medium frequency plots.

A-4. Discussion and Recommendations for Future Work

The number of *A. grandiflora* in the Drop Tower native population continues to be very small. There appeared to be a stimulating effect of the 2005 wildfire that burned the entire Drop Tower native population site. Four plants were observed in 2006, and one plant observed in 2007. No plants were observed in 2008 through 2011. It is unknown if a seedbank is still present in this area. This highlights the importance of maintaining the experimental populations and *ex situ* seedbanks for this species. In addition, seeding of this site using stored seeds that trace back to the Site 300 experimental population should be considered. As this action could have significant consequences (such as potentially turning a native population into an experimental population), it should only be conducted after extensive discussion with and agreement by all involved stakeholders.

The 2005 wildfire also burned the entire FL experimental subpopulation. As with the Drop Tower native population, there appeared to be a slight stimulatory effect from the wildfire. However, periodic seeding has been required to maintain this population, with the number of individuals typically dropping to zero two to three years post-seeding.

The FF experimental subpopulation has been the only population not to have dropped to zero at some time between 2007 and 2011. However, periodic seeding has still been required to maintain adequate numbers of individuals in this subpopulation. Periodic seeding of both subpopulations should continue to maintain the Site 300 experimental population.

While rainfall has a clear impact on the amount of biomass produced in the grassland community in which *A. grandiflora* occurs (Figure A10), a clear connection between rainfall and the number of *A. grandiflora* individuals has not been established (Figure A9). Trying to determine a relationship between *A. grandiflora* and rainfall in the Site

300 populations is confounded by the periodic seeding that has occurred in the experimental populations, and the previous use of grass selective herbicide at the Drop Tower native population. Thus, any future investigations into the potential impact of the amount and timing of rainfall on *A. grandiflora* numbers will have to account for these effects. For example, it may be possible to investigate the effect of rainfall on the percent establishment of the seeded plots.

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.

It is clear that *A. 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 Site 300 experimental population 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 the burns. 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.

However, as evidenced by the slight stimulatory effect of the 2005 wildfire, controlled burns may have a long-term positive effect on *A. grandiflora*. This will be further investigated in the fire frequency experiment. Controlled burns in this subpopulation were completed in the spring of 2011. No seeding in this subpopulation will occur in the winter of 2011/2012, and the subpopulation will be censused in the spring of 2012. The subpopulation will be seeded in the winter of 2012/2013, and again censused in 2013. This should allow an evaluation of the communities established by the differing fire frequencies on the success of *A. grandiflora* establishment without the cofounding direct effects of the burn itself.

A-5. References

Carlsen, T.M., J.W. Menke, and B.M. Pavlik. 2000. “Reducing competitive suppression of a rare annual forb by restoring native perennial grasslands.” *Restoration Ecology* **8**:18–29.

Carlsen, T.M., E.K. Espeland, and A.H. Smith. 2001. *Rare plant restoration and monitoring at Lawrence Livermore National Laboratory Site 300*. Lawrence Livermore National Laboratory, Livermore, CA. UCRL-AR-142408-01.

Carlsen, T.M., E.K. Espeland, and A.H. Smith. 2002. *Rare plant restoration and monitoring at Lawrence Livermore National Laboratory Site 300*. Project Progress Report, Fiscal year 2001. Lawrence Livermore National Laboratory, Livermore, CA. UCRL-AR-142408-01.

Carlsen, T.M., L.E. Paterson, and E.K. Espeland. 2003. *Rare plant restoration and monitoring at Lawrence Livermore National Laboratory Site 300, Project Progress Report, Fiscal Year 2002*. Lawrence Livermore National Laboratory, Livermore, CA. UCRL-AR-142408-02.

CNDDB (California Natural Diversity Data Base). 2012. California Natural Diversity Database, Biogeographic Data Branch, California Department of Fish and Game, Sacramento, CA. Accessed on Thur., Jan. 12, 2012 from http://www.dfg.ca.gov/biogeodata/cnddb/mapsanddata.asp

Espeland, E.K. T.M. Carlsen, and D. Macqueen. 2005. "Fire and Dynamics of Granivory on a California grasslands forb." *Journal of Biodiversity and Conservation* **14**:267–280.

Heady, H.F. 1990. "Valley grassland." *in* Terrestrial Vegetation of California. M.G. Barbour and J. Majors, Eds. California Native Plant Society, Sacramento, CA. pp 491–514.

Ludwig, J.A., and J.F. Reynolds. 1988. *Statistical Ecology*. John Wiley & Sons, NY. 337 pp.

Ornduff, R. 1976. "The reproductive system of *Amsinckia grandiflora*, a distylous species." *Systematic Botany* **1**:57–66.

Paterson, L.E., T.M. Carlsen, T.M. Alfaro and E. Espeland. 2010. *Rare plant restoration and monitoring at Lawrence Livermore Laboratory, Site 300, Project Progress Report, Fiscal Year 2005 and 2006.* Lawrence Livermore National Laboratory, Livermore, CA. LLNL-TR-457357.

Pavlik, B.M. 1988a. "Nutlet production and germination of *Amsinckia grandiflora*." I. Measurements from cultivated populations. California Department of Fish and Game, Endangered Plant Program, Sacramento, CA.

Pavlik, B.M. 1988b. "Habitat characterization and selection of potential sites for establishment of new populations of *Amsinckia grandiflora*." California Department of Fish and Game, Endangered Plant Program, Sacramento, CA.

Pavlik, B.M. 1991. "Management of reintroduced and natural populations of *Amsinckia grandiflora*." California Department of Fish and Game, Endangered Plant Program, Sacramento, CA.

Pavlik, B.M., D.L. Nickrent, and A.M. Howald. 1993. "The recovery of an endangered plant. I. Creating a new population of *Amsinckia grandiflora*." *Conservation Biology* **7(3)**510–526.

Pavlik, B.M. 1994. "Tales of success and failure: trends in natural and reintroduced populations of *Amsinckia grandiflora* under different management regimes." Prepared for the Endangered Plant Program, California Department of Fish and Game, Sacramento, CA.

Ray, P.M., and H.F. Chisaki. 1957a. Studies of *Amsinckia*. I. A synopsis of the genus, with a study of heterostyly in it. *American Journal of Botany* **44**:524–536.

Ray, P.M., and H.F. Chisaki. 1957b. Studies of *Amsinckia*. II. Relationships among primitive species. *American Journal of Botany* **44**:537–544.

Shannon, C.E., and W. Weaver. 1949. *The Mathematical Theory of Communication*. (University of Illinois Press, Urbana IL).

Shoen, D.J., M.O. Johnston, A-M L'Hereux, and J.V. Marsolais. 1997. "Evolutionary history of the mating system in *Amsinckia* (Boraginaceae)." *Evolution* **51**:1090–1099.

USFWS. 1997. "Large-flowered Fiddleneck (*Amsinckia grandiflora*) Recovery Plan." U.S. Fish and Wildlife Service, Portland, OR. 44 pp.

U.S. DOE. 2000. Memorandum of Agreement between the US Department of the Interior and the US Department of Energy for the *Amsinckia grandiflora* Reserve at Lawrence Livermore National Laboratory Site 300 Experimental Test Facility San Joaquin and Alameda Counties, California.

Section A
Figures

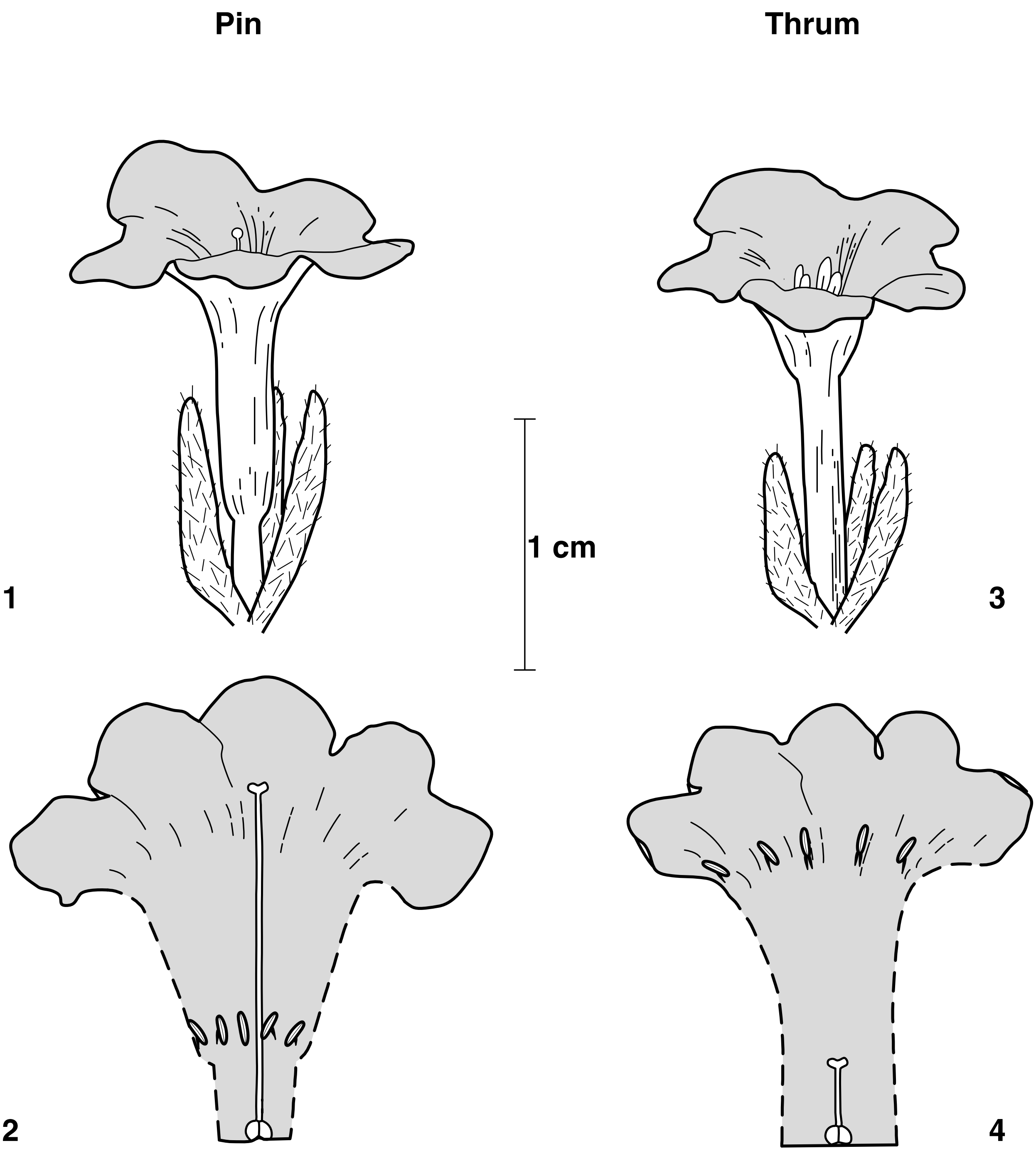


Figure A1. Flowers of *Amsinckia grandiflora*. 1. Intact pin flower. 2. Dissected pin flower. 3. Intact thrum flower. 4. Dissected thrum flower (from Ornduff, 1976).

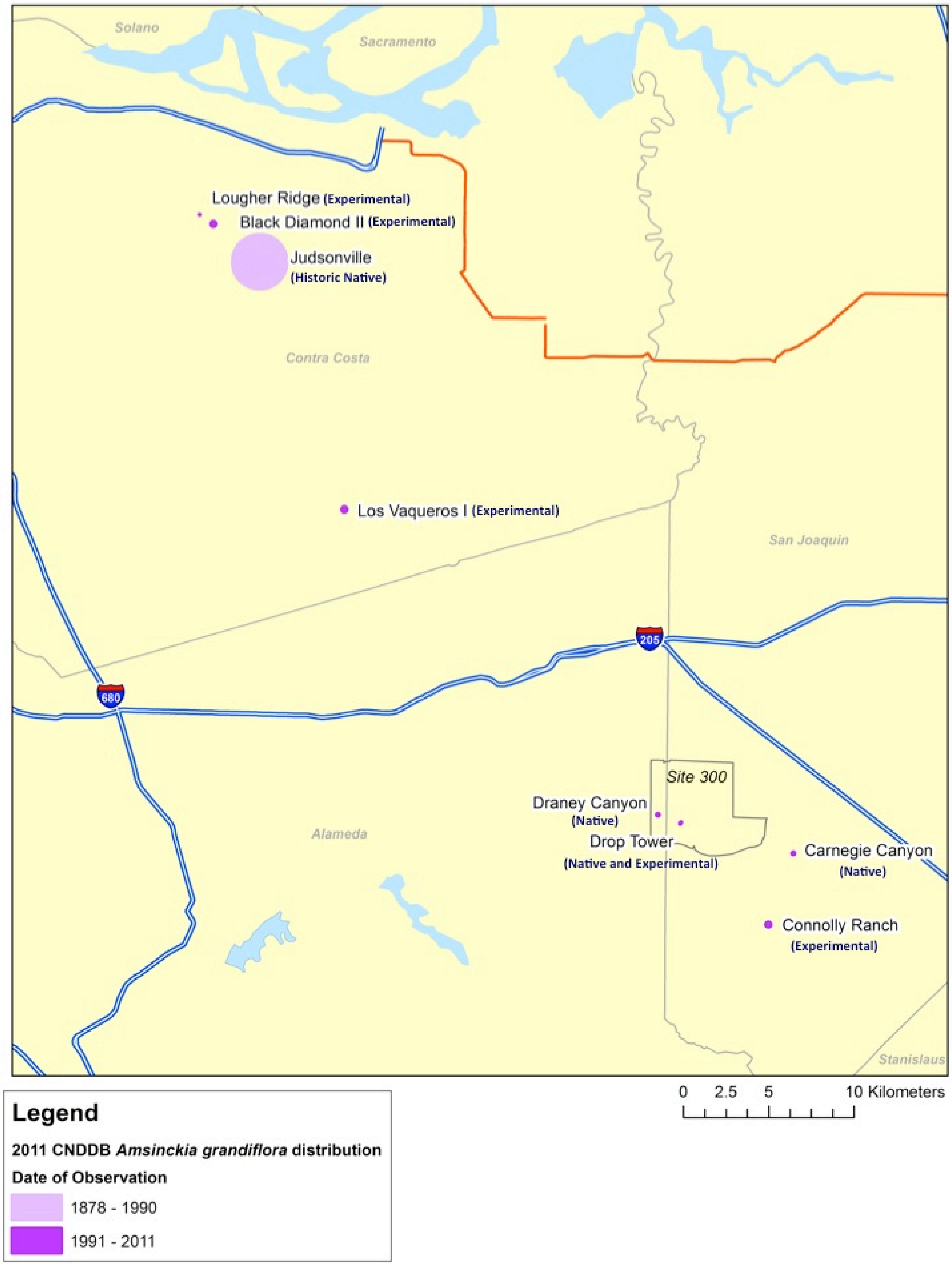


Figure A2. Current and historic occurrences of *Amsinckia grandiflora* as described by the California Natural Diversity Data Base (CNDDB, 2012).

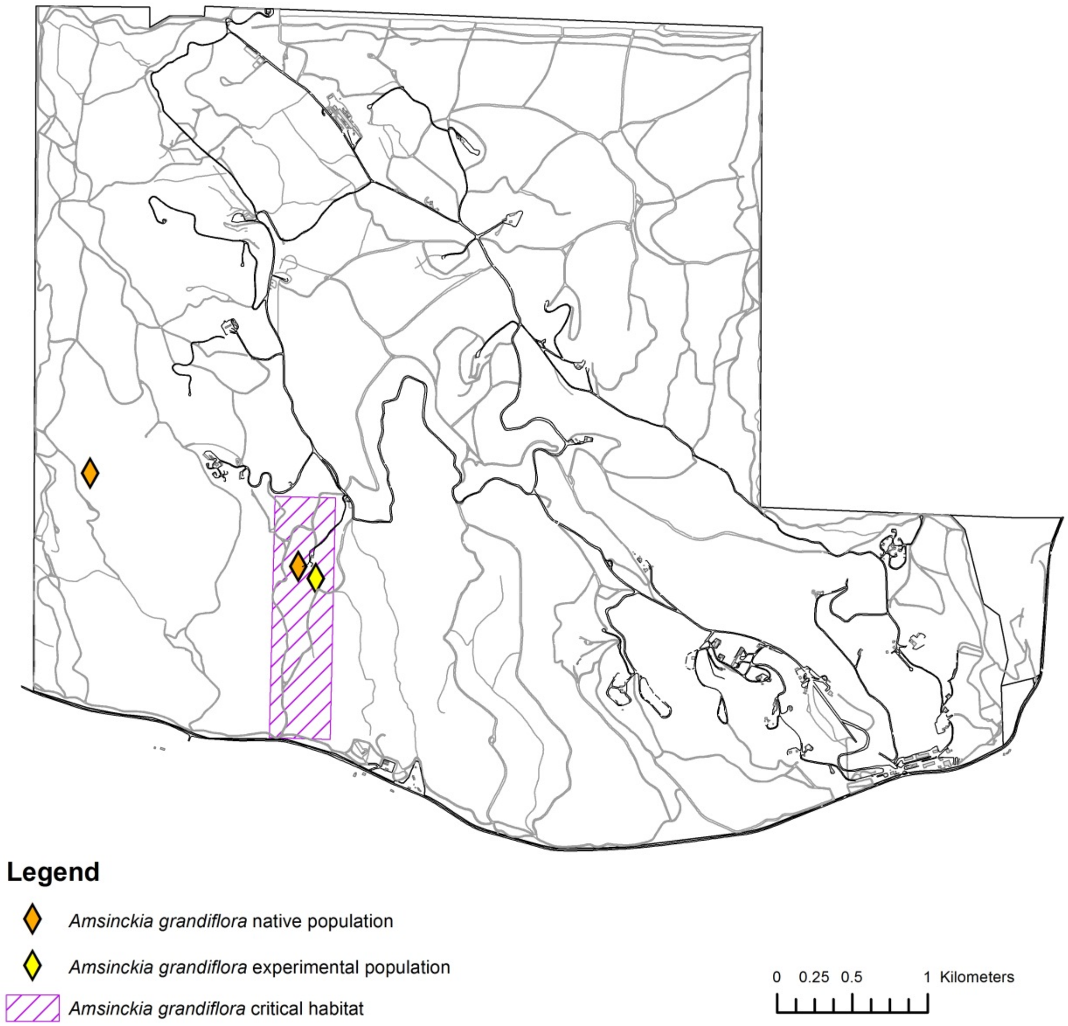


Figure A3. Distribution of *Amsinckia grandiflora* at Site 300, and *Amsinckia grandiflora* critical habitat.

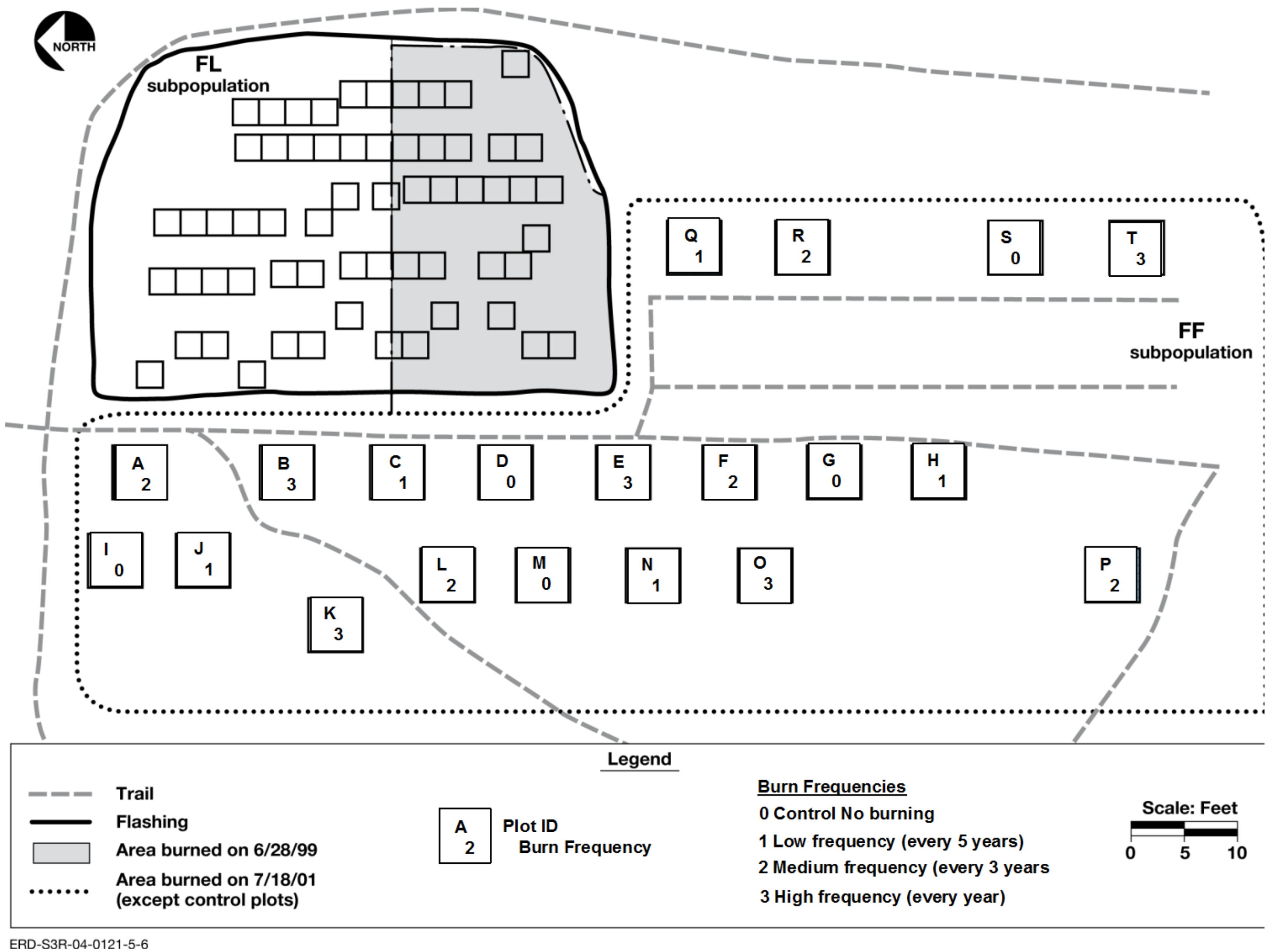


Figure A4. Plot layout in the Fire Frequency (FF) experimental subpopulation. The Flashing (FL) experimental subpopulation location is also shown without experimental treatments.

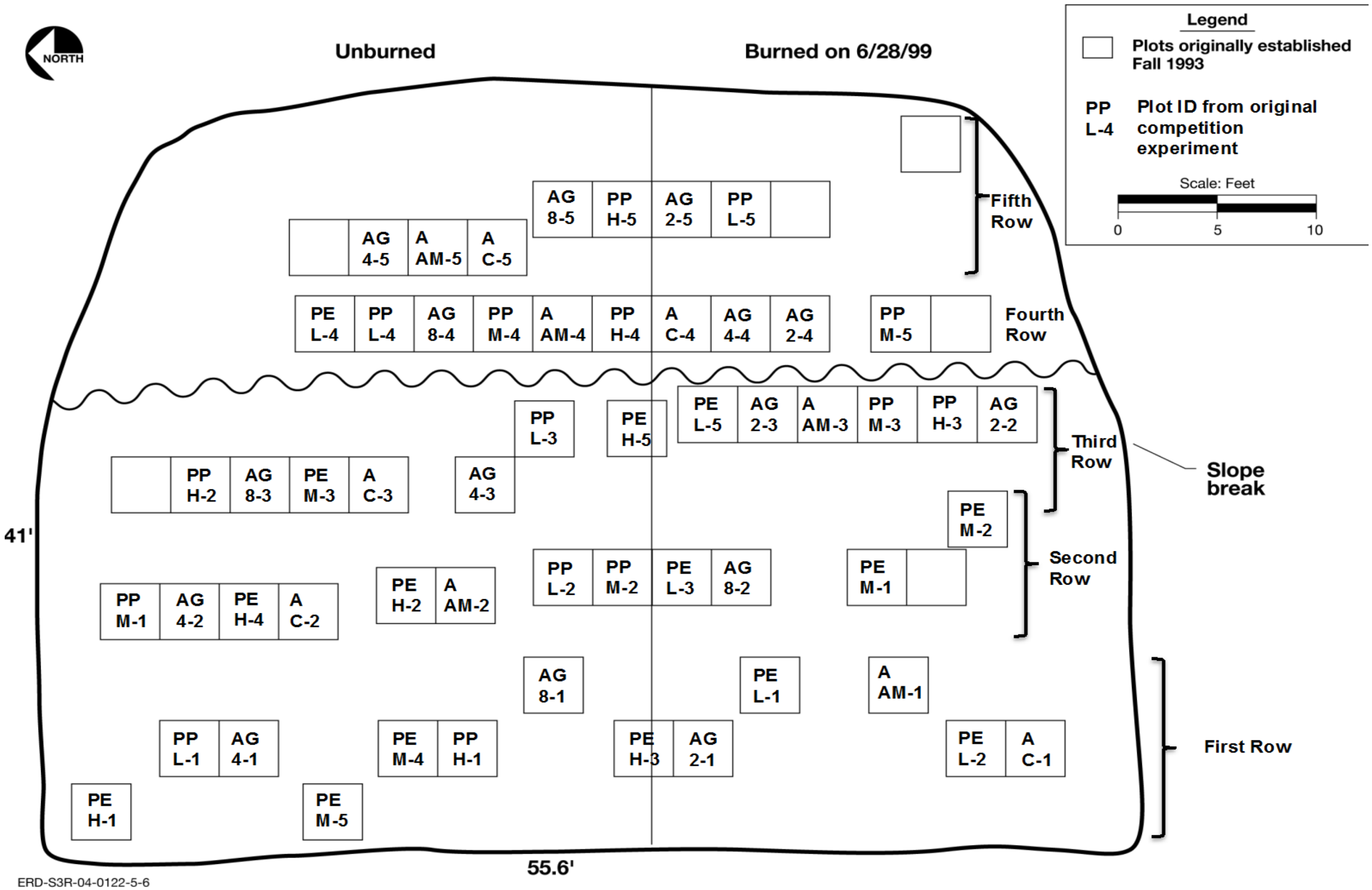


Figure A5. Plot layout in the Flashing (FL) experimental subpopulation.

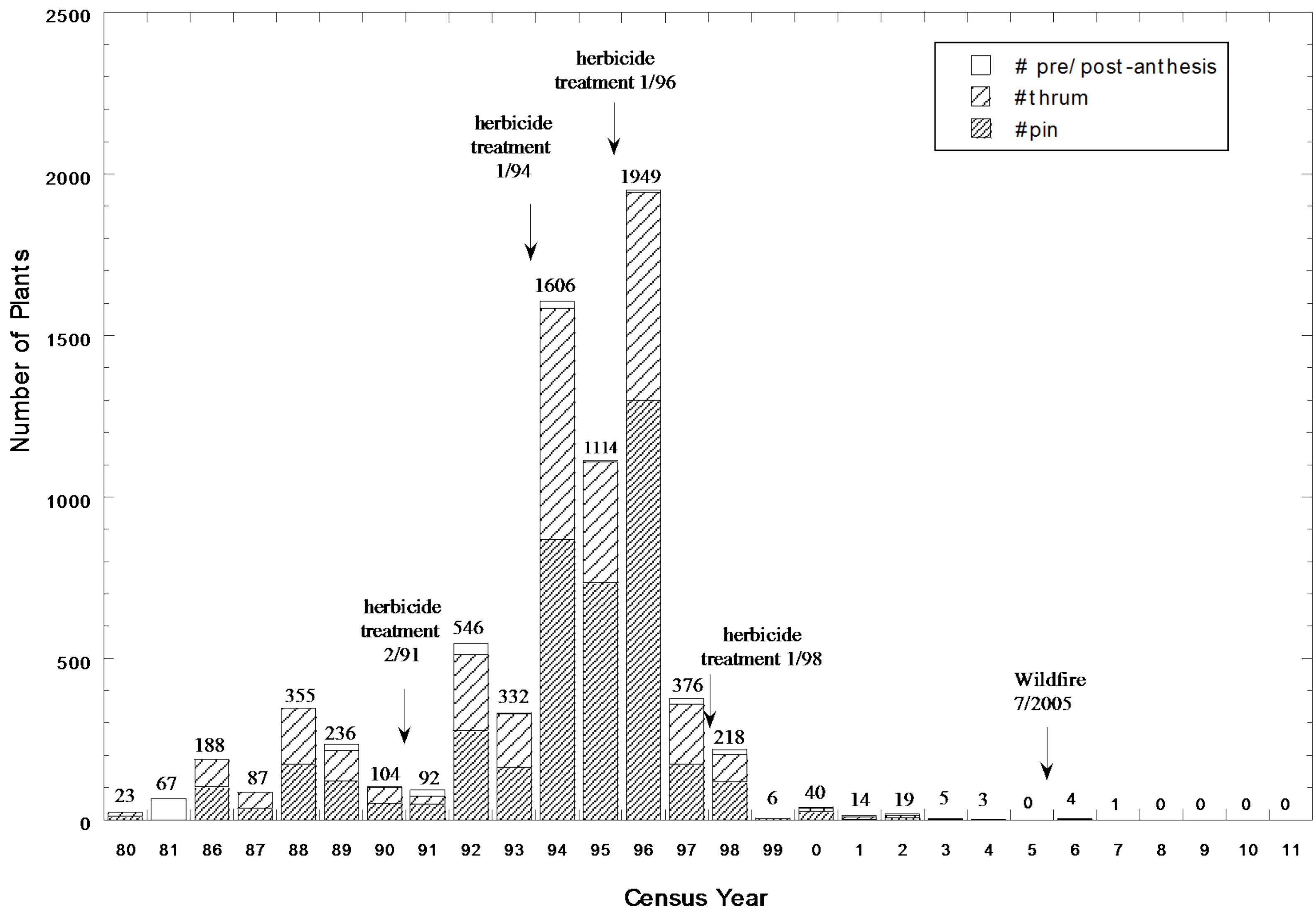


Figure A6. Spring census data of the Site 300 Drop Tower native population (including the Carlsen-Gregory subpopulation). Total population size is given above each bar. Approximate timing of herbicide treatments is shown.

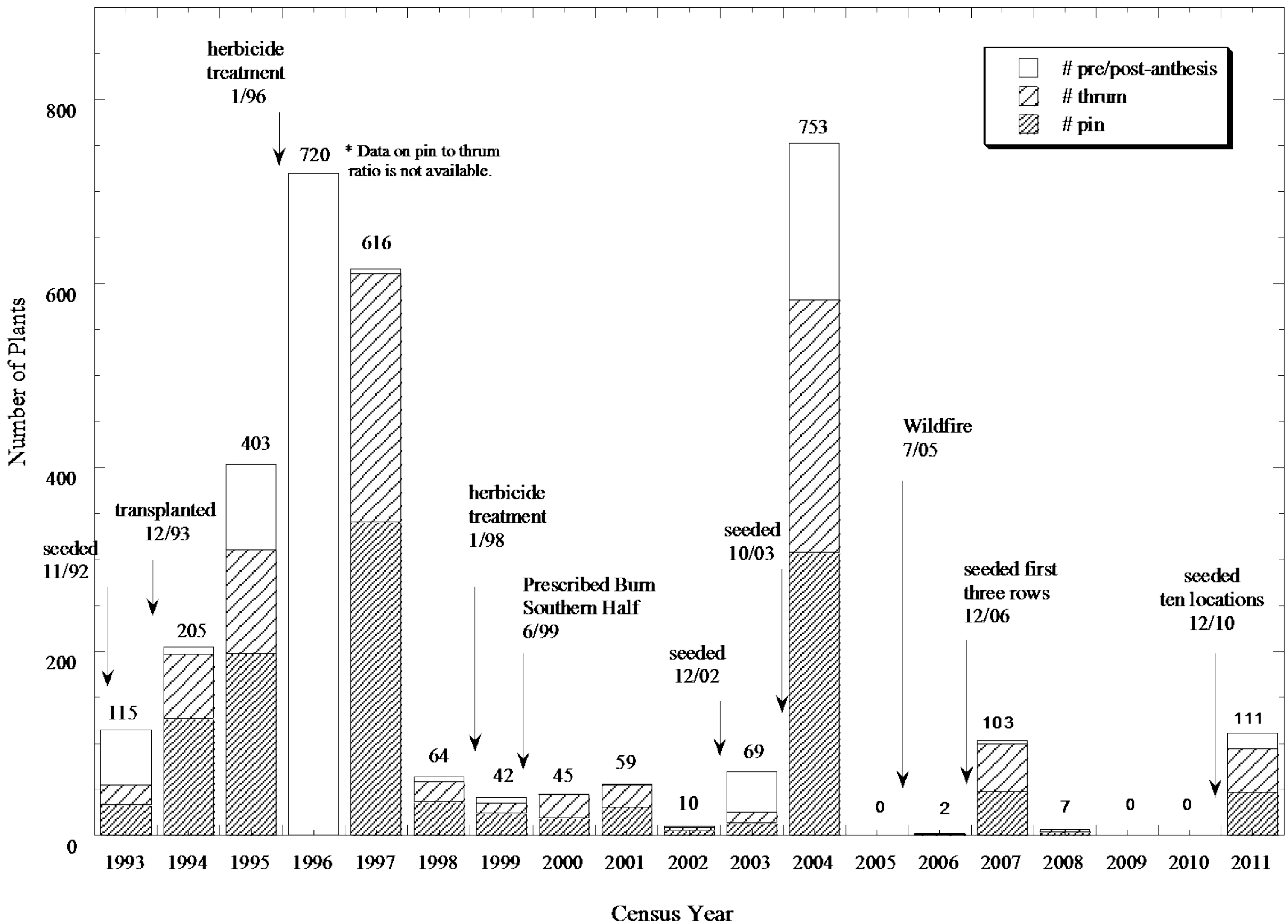


Figure A7. Spring census data of the Site 300 Flashing (FL) experimental subpopulation. Total population size is given above each bar. Approximate timing of all treatments are shown.

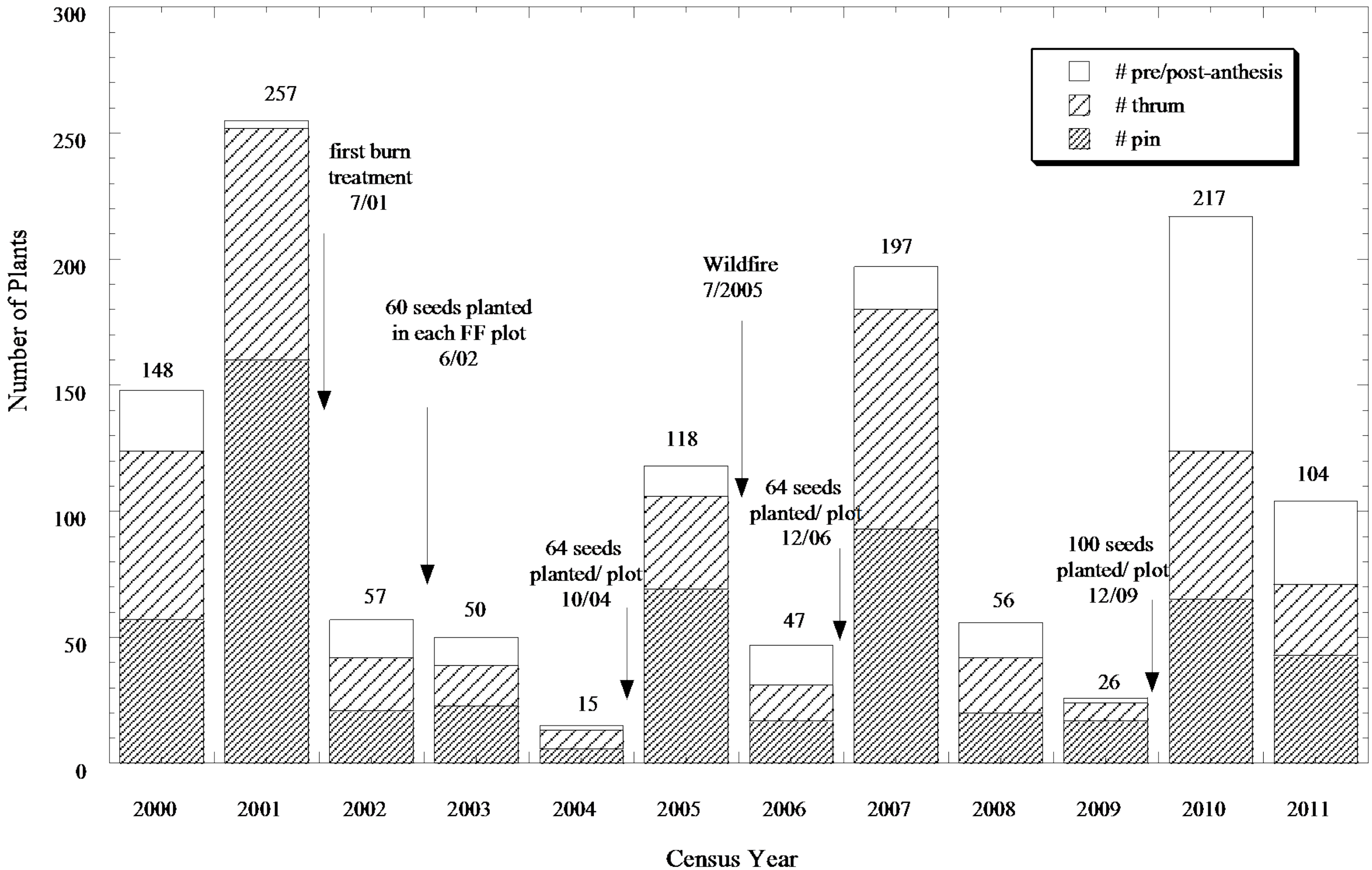


Figure A8. Spring census data of the Site 300 Fire Frequency (FF) experimental subpopulation. Total population size is given above each bar.

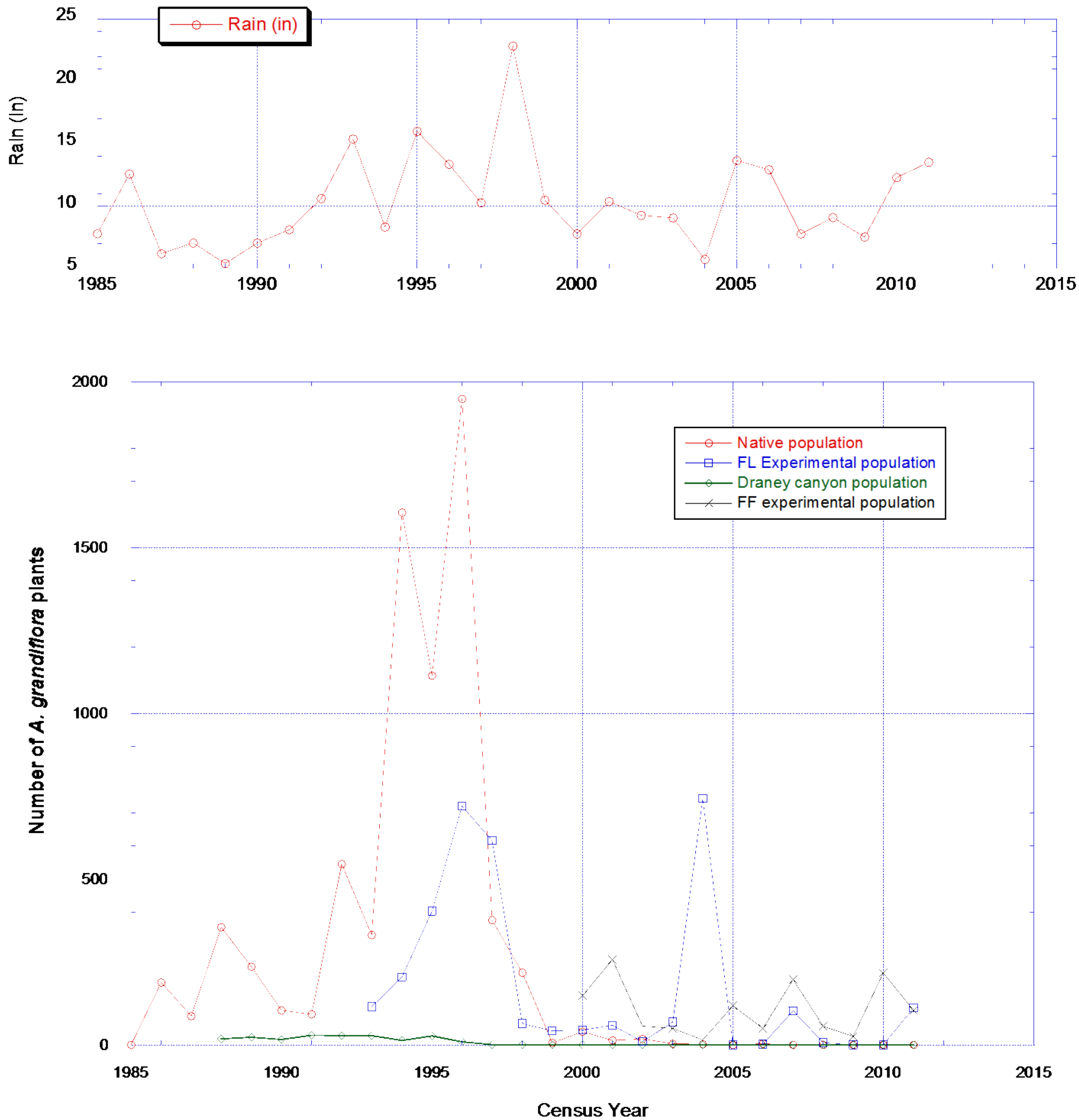


Figure A9. Plot of population size at time of census in the Drop Tower native population (Native population, includes the Carlsen-Gregory subpopulation), the Flashing (FL) experimental subpopulation, the Draney Canyon native population, and the Fire Frequency (FF) experimental subpopulation, shown with rainfall totals over growing season.

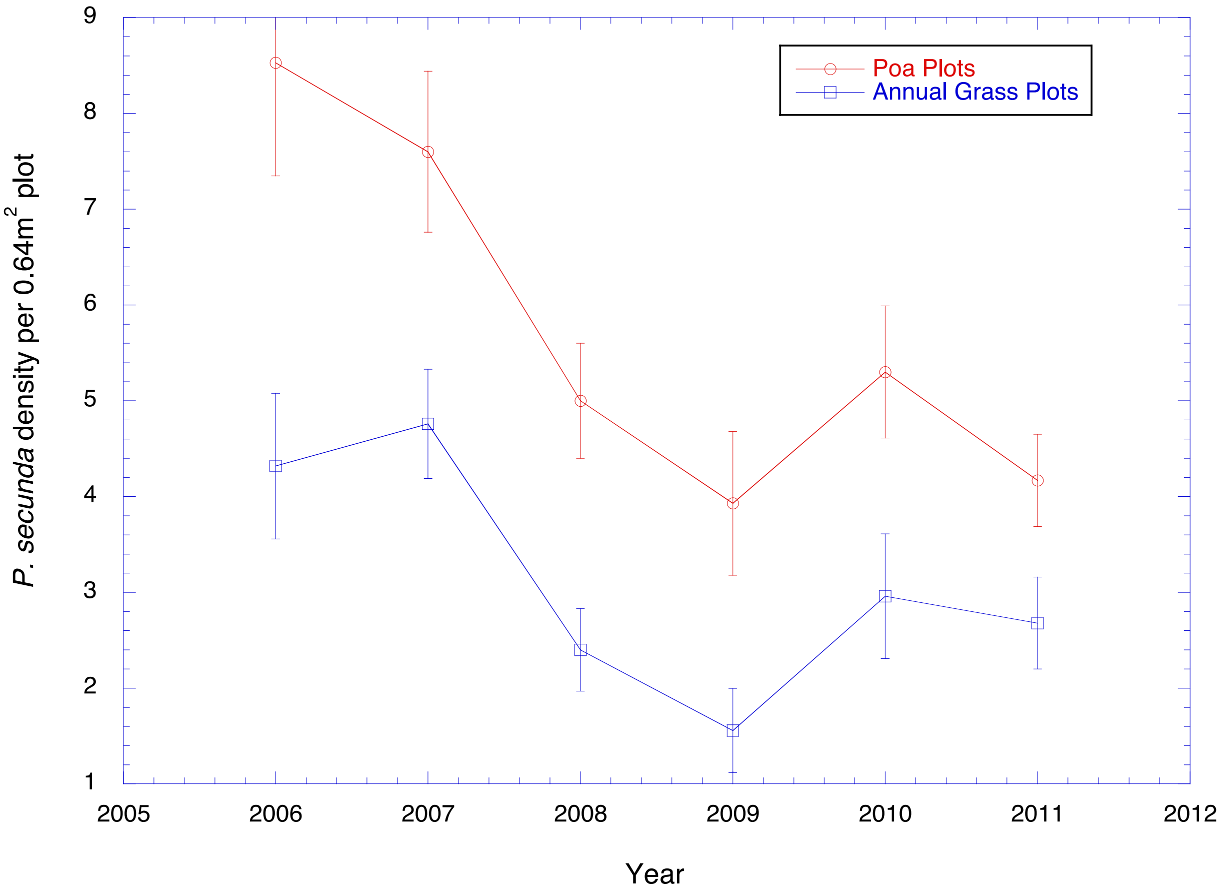


Figure A10. ***Poa secunda*** **density in the Flashing (FL) experimental subpopulation by plot type between 2006 and 2011.**

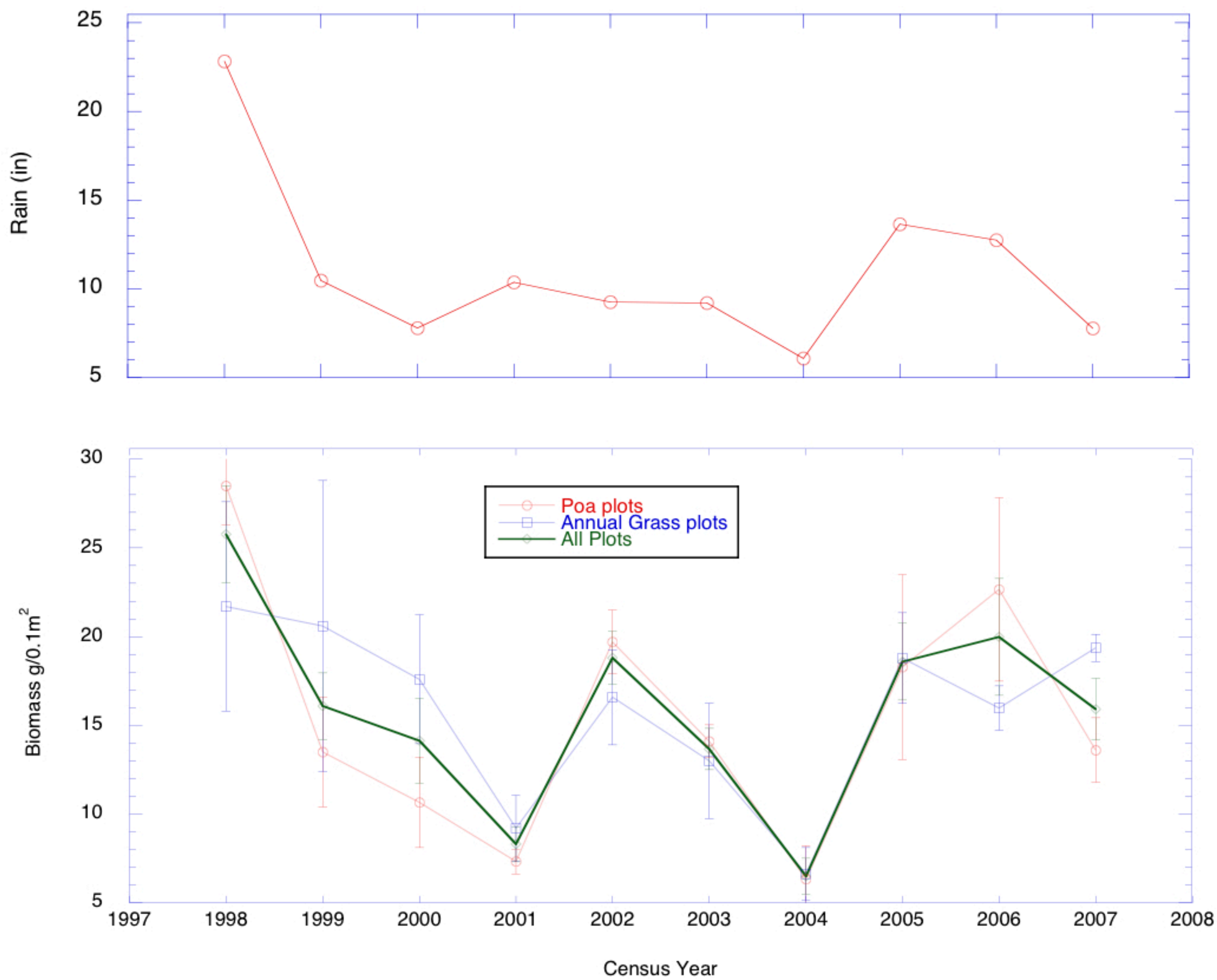


Figure A11. Total average biomass in Flashing (FL) experimental population plots from 1998 through 2011. Plot type refers to the type of plot originally established in 1993, which consisted of *Poa secunda* (Poa plots) or exotic annual grasses (Annual Grass plots). Rain is total rainfall for the water year ending in the year shown (i.e. 1998 refers to the water year October 1, 1997 through September 31, 1998).

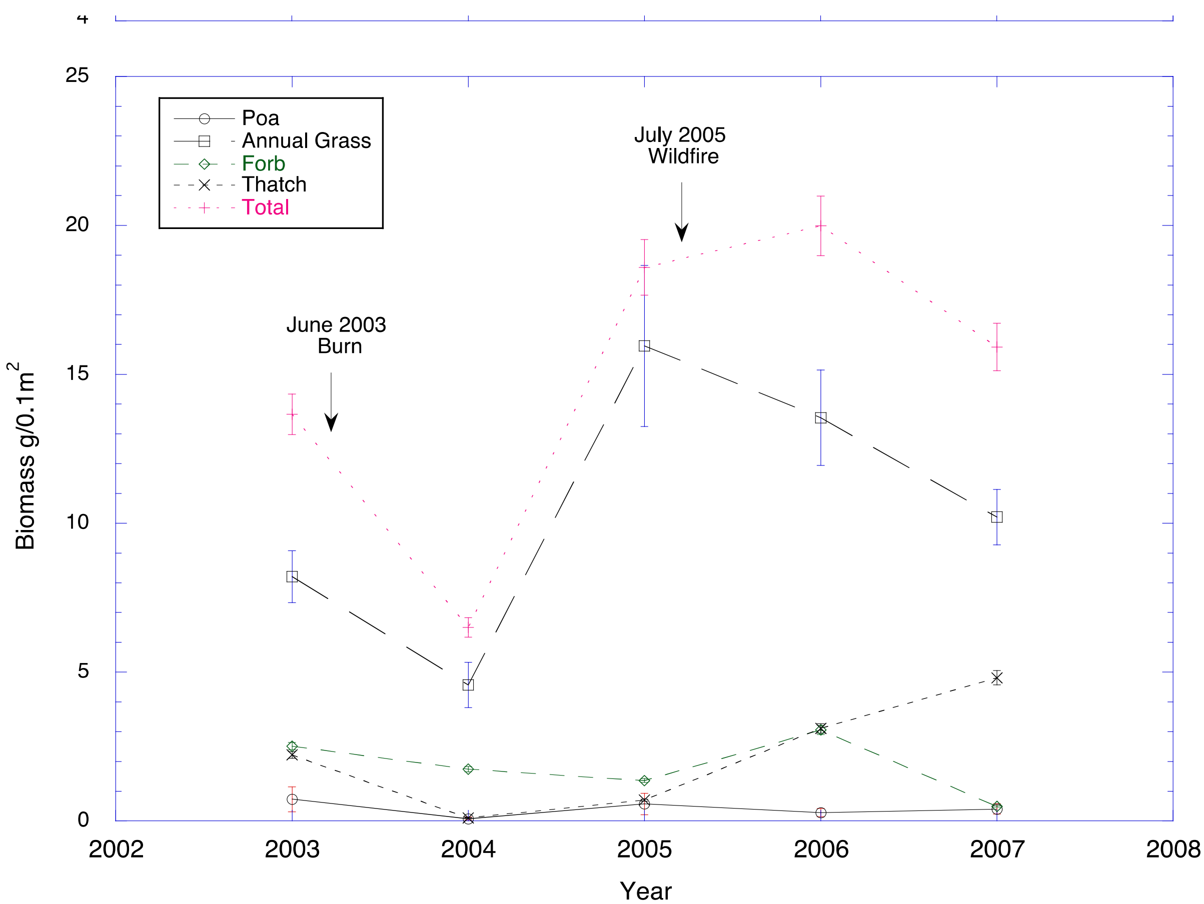


Figure A12. Total average biomass in Flashing (FL) experimental population plots from 2003 through 2011 by biomass type. Bars are one standard error.

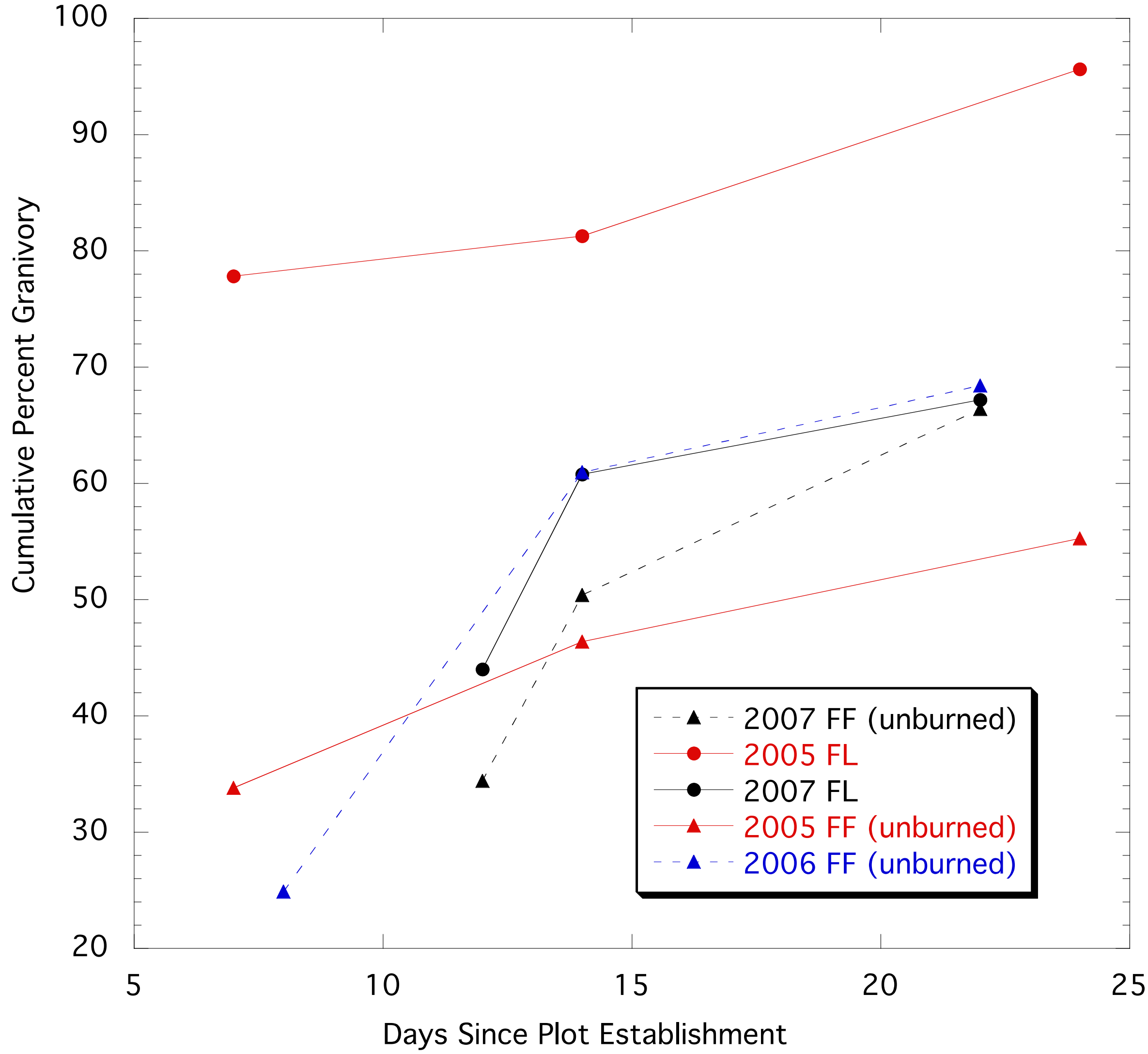


Figure A13. Cumulative percent granivory in the first three weeks after plot establishment in the Flashing (FL) and Fire Frequency (FF) experimental subpopulations, 2005 through 2007.

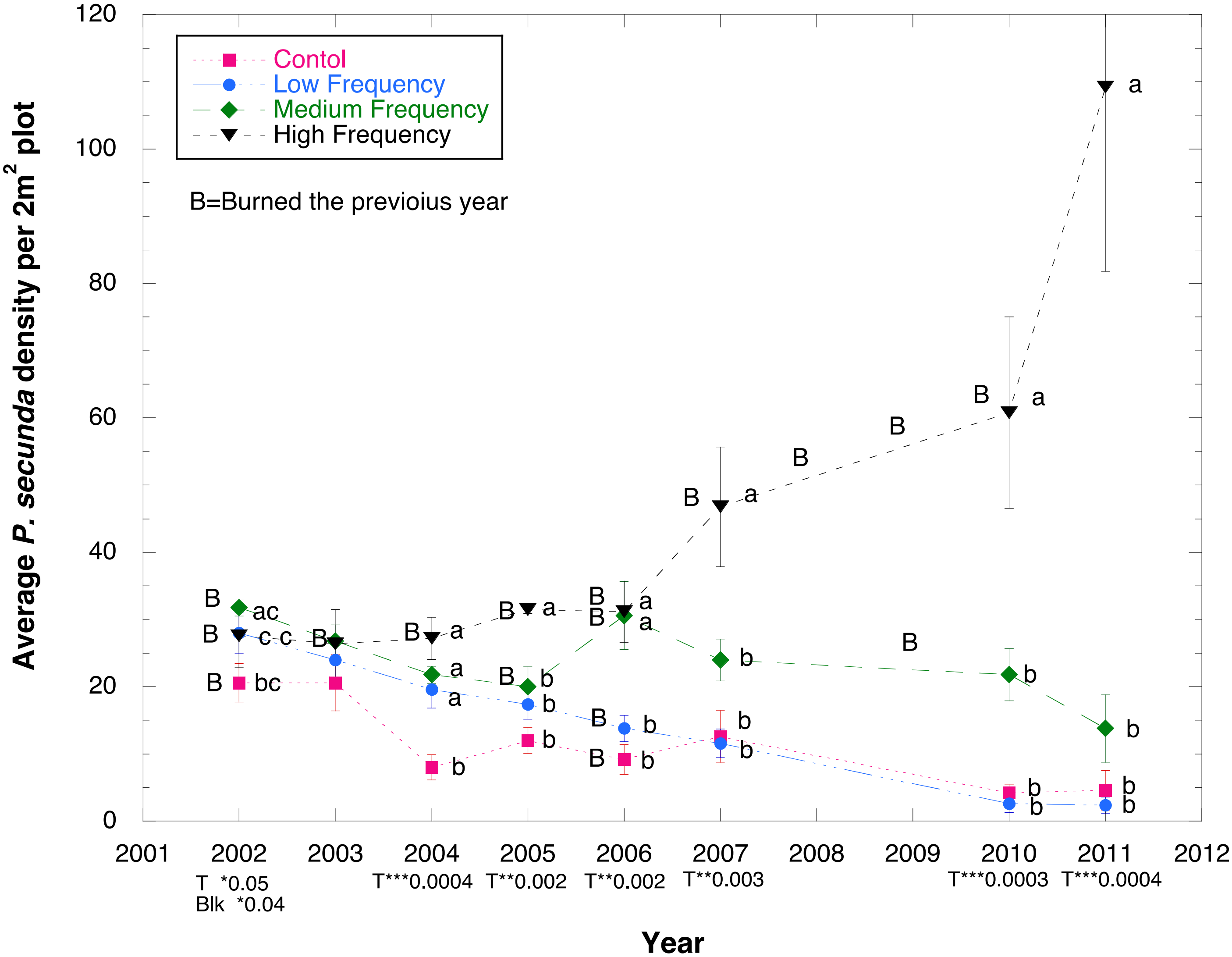


Figure A14. Average number of *Poa secunda* plants per plot for each of the four burn frequencies: 1) Control (no burns except for 2005 wildfire), 2) Low Frequency (every 5 years), 3) Medium Frequency (every 3 years), 4) High Frequency (every year). Treatments with different lower case letters are significantly different at the significance level T for any given year. A significant block effect (Blk) was observed in 2002. Error bars are one standard error.

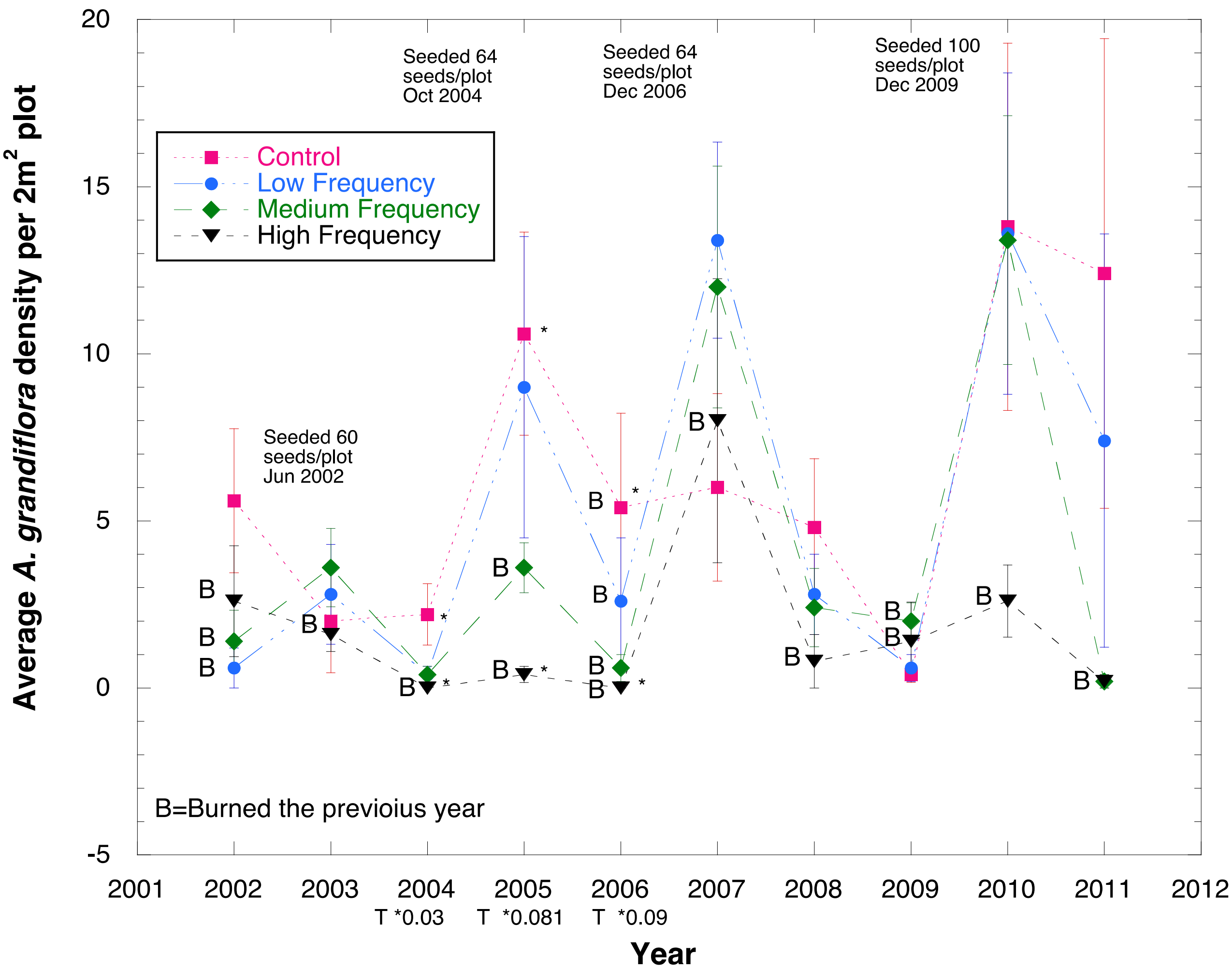


Figure A15. Average number of *Amsinckia grandiflora* plants per plot for each of the four burn frequencies: 1) Control (no burns except for 2005 wildfire), 2) Low Frequency (every 5 years), 3) Medium Frequency (every 3 years), 4) High Frequency (every year). Treatments with asterisks are significantly different at the significance level T for any given year. Error bars are one standard error.

Section A
Tables

Table A1. Summary of *Amsinckia grandiflora* field work conducted between November 2006 and July 2011.

	Site 300 experimental population				Site 300 native populations	
Fiscal Year	**Flashing subpopulation**		**Fire Frequency subpopulation**		**DT (including CG) and DC**	
Activity	**Dates**	**Plots/Area/Notes**	**Dates**	**Plots/Area/Notes**	**Dates**	**Plots/Area/Notes**
2007						
Seed enhancement	12/08/06	First three rows, 64 seeds/plot, 8 x 8 visually estimated grid, not netted	12/08/06	All plots, 64 seeds/plot, 8 x 8 visually estimated grid, netted, netting removed 03/15/07	NA	NA
Census (ht, br#, morph, nn)	03/22/07 03/30/07	All plots	03/22/07 03/30/07	All plots	03/15/07	DT (including CG) site
Cover measurements	04/03/07	All plots (60 cm x 60 cm quadrats centered on plot)	04/03/07	All plots (60 cm x 60 cm quadrats centered on plot)	04/03/07	Five 60 cm x 60 cm quadrats in primary DT, two quadrats in CG
Poa counts	04/03/07	All 0.64m^2 plots	04/03/07	All 2 m^2 plots	NA	NA
Biomass sampling	06/06/07	Plots PPL-5, AC-3, PEL-4, AG4-2, PPH-1 (0.1 m^2)	NA	NA	NA	NA
Predation Study established	05/31/07	AG8-5, AG8-4, PEH-5, AAM-2, AG8-1	05/31/07	C, G, I, N, R	NA	NA
Predation Study 1st read	06/12/07	AG8-4, PEH-5, AAM-2, AG8-1	06/12/07	C, G, I, N, R	NA	NA
Predation Study 2nd read	06/14/07	AG8-5, AG8-4, PEH-5, AAM-2, AG8-1	06/14/07	C, G, I, N	NA	NA
Predation Study 3rd read	06/22/07	AG8-5, AG8-4, PEH-5, AAM-2, AG8-1	06/22/07	C, G, I, N	NA	NA
Prescribed Burn	NA	NA	06/04/07	High frequency plots	NA	NA
2008						
Census (ht, br#, morph, nn)	03/28/08	All plots	03/28/08	All plots	03/28/08	DT (including CG) site
Cover measurements	03/28/08 03/31/08	All plots (60 cm x 60 cm quadrats centered on plot)	03/28/08	All plots (60 cm x 60 cm quadrats centered on plot)	03/28/08	Five 60 cm x 60 cm quadrats in primary DT, two quadrats in CG
Poa counts	NA	NA	05/12/08	All plots (center 1 m^2)	NA	NA
Prescribed Burn	NA	NA	06/24/08	High and medium frequency plots	NA	NA

Table A1 (continued). Summary of *Amsinckia grandiflora* field work conducted between November 2006 and July 2011.

	Site 300 experimental population				Site 300 native populations	
Fiscal Year	**Flashing subpopulation**		**Fire Frequency subpopulation**		**DT (including CG) and DC**	
Activity	**Dates**	**Plots/Area/Notes**	**Dates**	**Plots/Area/Notes**	**Dates**	**Plots/Area/Notes**
2009						
Census (ht, br#, morph, nn)	04/03/09	All plots	04/03/09	All plots	03/27/09	DT (including CG) site
Cover measurements	04/03/09 04/14/09	All plots except AAM-2 through PEM-2 in 2nd row, and AG2-2 in 3rd row (60 cm x 60 cm quadrats centered on plot)	04/03/09	All plots (60 cm x 60 cm quadrats centered on plot)	04/14/09	Five 60 cm x 60 cm quadrats in primary DT site
Poa counts	04/03/09 04/14/09	All 0.64 m^2 plots	05/21/09	All plots (center 1 m^2)	NA	NA
Prescribed Burn	NA	NA	06/09/09	High frequency plots	NA	NA
2010						
Seed enhancement	NA	NA	12/04/09 12/11/09	All plots, 100 seeds/plot, 10 x 10 visually estimated grid, netted, removed 2/2011	NA	NA
Census (ht, br#, morph, nn)	04/02/10	All plots	04/01/10 04/02/10	All plots	04/01/10	DT (including CG) site
Cover measurements	04/02/10	All plots (60 cm x 60 cm quadrats centered on plot)	04/01/10 04/02/10	All plots (60 cm x 60 cm quadrats centered on plot)	NA	NA
Poa counts	04/02/10 04/09/10	All 0.64 m^2 plots	04/02/10	All 2 m^2 plots	NA	NA
Prescribed Burn	NA	NA	06/22/10	High frequency plots	NA	NA

Table A1 (continued). Summary of *Amsinckia grandiflora* field work conducted between November 2006 and July 2011.

	Site 300 experimental population				Site 300 native populations	
Fiscal Year	**Flashing subpopulation**		**Fire Frequency subpopulation**		**DT (including CG) and DC**	
Activity	**Dates**	**Plots/Area/Notes**	**Dates**	**Plots/Area/Notes**	**Dates**	**Plots/Area/Notes**
2011						
Seed enhancement	12/03/10	9 locations first row, 1 location second row, 100 seeds 10 x 10 visually estimated grid	NA	NA	NA	NA
Census (ht, br#, morph)	04/07/11 04/08/11	All plots	04/07/11 04/08/11	All plots	04/04/11 04/05/11	DT (including CG) site, visited DC site
Cover measurements	04/08/11 04/11/11 04/12/11	All plots (60 cm x 60 cm quadrats centered on plot)	04/08/11	All plots (60 cm x 60 cm quadrats centered on plot)	04/04/11	Five 60 cm x 60 cm quadrats in primary DT site
Poa counts	04/08/11 04/11/11	All 0.64 m^2 plots	04/08/11	All 2 m^2 plots	NA	NA
Prescribed Burn	NA	NA	June 17, 2011	High, medium, and low frequency plots	NA	NA

Notes:

br# = **Branch number**
CG = **Carlsen-Gregory subpopulation of the Drop Tower native population**
cm = **Centimeter**
DC = **Draney Canyon native population**
DT = **Drop Tower native population**
ht = **Height**
m^2= **Meter squared**
morph = **Flower morphology**
NA = **Not applicable**
nn = **Identify of nearest plant neighbor**

Table A2. Summary of burns occurring in the Fire Frequency (FF) experiment.

		Year											
		2001	**2002**	**2003**	**2004**	**2005**	**2005 wildfire**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Number of Burns Planned By Treatment													
Control	0												
Low	2	burn											burn
Med	4	burn			burn					burn			burn
High	11	burn	burn	burn	burn	burn		burn	burn	burn	burn	burn	burn
Number of Burns Actually Occurring by Plot													
D (Control)	1							burn					
G (Control)	1						burn						
I (Control)	1						burn						
M (Control)	1						burn						
S (Control)	1						burn						
C (Low)	3	burn						burn					burn
H (Low)	3	burn					burn						burn
J (Low)	3	burn					burn						burn
N (Low)	3	burn					burn						burn
Q (Low)	3	burn					burn						burn
A (Medium)	5	burn			burn			burn		burn			burn
F (Medium)	5	burn			burn		burn			burn			burn
L (Medium)	5	burn			burn		burn			burn			burn
P (Medium)	5	burn			burn		burn			burn			burn
R (Medium)	5	burn			burn		burn			burn			burn
B (High)	11	burn	burn	burn	burn	burn		burn	burn	burn	burn	burn	burn
E (High)	11	burn	burn	burn	burn	burn		burn	burn	burn	burn	burn	burn
K (High)	11	burn	burn	burn	burn	burn		burn	burn	burn	burn	burn	burn
O (High)	12	burn	burn	burn	burn	burn	burn	burn	burn	burn	burn	burn	burn
T (High)	11	burn	burn	burn	burn	burn		burn	burn	burn	burn	burn	burn

Table A3. Summary of demographic data collected from the Site 300 experimental and native populations, the Lougher Ridge experimental population, and the Carnegie Canyon native population. (Values are means ± 1 SD)

Population[a]	Total plant N	P/T ratio[b]	Average height (cm)	Average branch N per plant[c]	Estimated average seed production per plant[d]	Estimated total seed production per population
Spring 1999						
DT (native)	6	all P	15.30 ± 7.30	1.0 ± 0	0	0
FL (experimental)	42	2.18	13.30 ± 5.41	1.02 ± 0.15	0	0
Spring 2000						
DT (native)	40	2.16	20.13 ± 6.51	1.70 ± 1.16	10.92 ± 14.44	436.98
FL (experimental)	45	0.76	16.78 ± 5.52	1.32 ± 0.97	2.70 ± 10.74	121.92
FF (experimental)	148	0.85	16.67 ± 5.98	2.33 ± 1.55	10.54 ± 20.58	1560.85
Spring 2001						
DT (native)	14	0.43	17.21 ± 4.09	1.0 ± 0	1.42 ± 2.35	36.40
FL (experimental)	59	1.29	13.67 ± 5.09	1.0 ± 0	0	0
FF (experimental)	257	1.74	15.74 ± 4.51	1.02 ± 0.20	0.11 ± 1.22	28.27
Spring 2002						
DT (native)	19	1.14	24.69 ± 4.83	1.50 ± 0.56	9.93 ± 11.13	188.7
FL (experimental)	10	1.67	15.78 ± 6.39	1.0 ± 0	0	0
FF (experimental)	57	1.00	15.15 ± 6.25	1.05 ± 0.26	0	0
Spring 2003						
DT (native)	5	4	18 ± 3.65	1.0 ± 0	3.18 ± 4.61	12.72
FL (experimental)	69	1.27	7.30 ± 4.04	1.0 ± 0	0	0
FF (experimental)	50	1.43	14.02 ± 4.23	1.0 ± 0	0	0
Lougher Ridge (experimental)	205	N/A	23.5 ± 9.7	N/A	N/A	1592
Spring 2004						
DT (native)	3	0P, 2T, 1B	20.67 ± 11.11	1.33 ± 0.58	16.37 ± 28.35	49.11
FL (experimental)	753	1.12	13.69 ± 5.34	1.08 ± 0.31	0.02 ± 0.50	13.67
FF (experimental)	15	0.86	17.53 ± 4.71	1.2 ± 0.56	0.91 ± 3.53	13.67
Lougher Ridge (experimental)	868	1.59	20.74 ± 8.21	1.93 ± 2.45	50.81 ± 67.93	8739.04
Spring 2005						
DT (native)	0	0	0	0	0	0
FL (experimental)	0	0	0	0	0	0
FF (experimental)	118	1.86	23.70 ± 1.30	1.30 ± 0.59	0.72 ± 3.72	85.16
Lougher Ridge (experimental)	173	0.97, 4B	35.43 ± 10.01	1.57 ± 1.29	3.9 ± 15.92	669.5
Spring 2006						
DT (native)	4	3P, 1B	28.50 ± 6.19	2.00 ± 1.63	31.28 ± 22.53	128.04
FL (experimental)	2	1T, 1B	15.75 ± 6.01	1.0 ± 0	0	0
FF (experimental)	49	1.13, 15B	17.69 ± 5.17	1.12 ± 0.56	0.84 ± 0	41.01
Spring 2007						
DT (native)	1	1Unk	18.0	1	0	0
FL (experimental)	103	0.94, 4Unk	10.12 ± 3.29	1.01 ± 0.10	0 ± 0	0
FF (experimental)	197	1.07, 17Unk	16.86 ± 6.45	1.15 ± 0.44	0.43 ± 2.89	85.16
Spring 2008						
DT (native)	0	0	0	0	0	0
FL (experimental)	7	1.3	16.64 ± 5.57	1.58 ± 1.51	7.88	47.29
FF (experimental)	56	0.91, 14Unk	19.07 ± 7.21	1.57 ± 0.99	3.64 ± 9.75	203.94
Lougher Ridge (experimental)[e]	5					

Table A3 (continued). Summary of demographic data collected from the Site 300 experimental and native populations, the Lougher Ridge experimental population, and the Carnegie Canyon native population. (Values are means ± 1 SD)

Population[a]	Total plant N	P/T ratio[b]	Average height (cm)	Average branch N per plant[d]	Estimated average seed production per plant[d]	Estimated total seed production per population
Spring 2009						
DT (native)	0	0	0	0	0	0
FL (experimental)	0	0	0	0	0	0
FF (experimental)	26	2.42, 9 Unk	16.62 ± 6.69	1.12 ± 0.43	0.53 ± 2.68	13.67
Lougher Ridge (experimental)[e]	5					
Spring 2010						
DT (native)	0	0	0	0	0	0
FL (experimental)	0	0	0	0	0	0
FF (experimental)	217	1.10, 93 Unk	15.06 ± 5.71	1.23 ± 1.11	2.12 ± 15.42	460.34
Lougher Ridge (experimental)[e]	2					
Carnegie Canyon (native)[e]	134					
Spring 2011						
DT (native)	0	0	0	0	0	0
FL (experimental)	111	1.0, 17 Unk	18.47 ± 7.54	1.21 ± 0.57	1.01 ± 4.19	112.5
FF (experimental)	104	1.54, 33 Unk	31.43 ± 9.71	2.24 ± 2.80	14.23 ± 41.83	1480.6
Lougher Ridge (experimental)[e]	0					
Carnegie Canyon (native)[e]	688					

Notes:

B = Plants that are still in bud
DT = Drop Tower native population (includes the Carlsen-Gregory subpopulation)
FL = Flashing experimental subpopulation
FF = Fire Frequency experimental subpopulation
N = Number
NA = Not available
P = Pin-flowered plants
T = Thrum-flowerd plants
SD = Standard deviation
Unk = Plants with unknown flower morph. Includes both plants in bud and senesced plants

[a] Populations are only listed under years in which population size data is available for that location. If a population is not listed under a specific year, this indicates that survey data is not available for that location during that year not that there were no plants observed.

[b] 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.

[c] 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.

[d] 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.

[e] Survey conducted by Wilde Legarde, East Bay Regional Parks Botanist.

Table A4. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower native and Site 300 experimental population: 1997–2001.

Species	DT 1997 (%)	DT 1998 (%)	DT 1999 (%)	FL 1999 (%)	DT 2000 (%)	FL 2000 (%)	FF 2000 (%)	DT 2001 (%)	FL 2001 (%)	FF 2001 (%)
Achillea millefolium	5	5	–	–	5	–	–	–	–	–
Allium serra	–	1	–	–	–	–	–	–	–	–
Amsinckia grandiflora	–	–	–	–	–	7	–	–	4	5
Amsinckia tessellata	–	–	–	–	3	5	–	–	4	1
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
B. hordeaceus	31	21	50	33	3	5	1	14	7	7
B. 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	–	–	–	–
Erodium cicutarium	4	5	–	24	18	16	4	21	41	21
Galium aparine	11	23	17	2	5	–	4	7	2	1
Lithophragma affinis	–	–	–	–	–	2	–	–	–	–
Lupinus albifrons	–	1	–	–	–	–	–	–	–	–
L. bicolor	–	–	–	–	–	–	1	–	–	4
Phacelia tanacetifolia	–	–	–	–	3	–	–	–	–	–
Poa secunda	–	1	–	–	–	–	11	–	5	9
Sonchus sp.	1	–	–	–	–	–	–	–	–	–
Vulpia myuros	–	–	–	10	20	30	11	7	9	5
Unknown dicot	3	3	–	7	8	2	2	7	–	2
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:

DT = Drop Tower native population (includes the Carlsen-Gregory subpopulation)
FL = Flashing experimental subpopulation
FF = Fire Frequency experimental 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 Site 300 experimental population: 2002–2004.

Species	DT 2002 (%)	FL 2002 (%)	FF 2002 (%)	DT 2003 (%)	FL 2003 (%)	FF 2003 (%)	DT 2004 (%)	FL 2004 (%)	FF 2004 (%)
Achillea millefolium	–	–	–	–	–	–	–	0.27	–
Amsinckia grandiflora	–	22.2	–	–	–	–	–	3.47	–
Amsinckia sp.	12.5	–	–	–	–	–	–	0.40	–
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
B. hordeaceus	12.5	–	–	–	1.54	2	–	6.8	–
B. madritensis ssp. *rubens*	–	–	–	–	–	–	–	0.13	–
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 bicolor	–	–	4.3	–	1.54	–	–	1.07	–
Minuartia californica	–	–	–	–	–	–	–	0.27	–
Phacelia tanacetifolia	–	–	–	–	–	–	–	0.13	–
Poa secunda	–	–	–	–	–	2	–	1.33	2
Thysanocarpus curvipes	–	–	–	–	1.54	–	–	–	–
Vulpia microstachys	–	–	–	–	–	–	–	5.2	–
V. 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:

DT = Drop Tower native population (includes the Carlsen-Gregory subpopulation)

FL = Flashing experimental subpopulation

FF = Fire Frequency experimental subpopulation

n = Total number of plants

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.

Table A6. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower native and Site 300 experimental population: 2005–2007.

Species	FL 2005 (%)	FF 2005 (%)	DT 2006 (%)	FL 2006 (%)	FF 2006 (%)	FL 2007 (%)	FF 2007 (%)
Amsinckia grandiflora	–	1.7	–	–	4.1	–	–
Avena sp.	22.2	22.0	–	–	18.4	–	2.0
Bromus diandrus	–	10.2	–	–	2	3.9	1.0
B. hordeaceus	–	14.4	–	–	6.1	26.5	8.1
B. madritensis ssp. *rubens*	–	2.5	–	–	–	–	2.0
Castilleja exserta	–	0.8	–	–	–	–	2.0
Clarkia sp.	–	4.2	–	–	2	1.0	2.5
Claytonia sp.	–	0.8	–	–	–	1.0	0.5
Delphinium sp.	–	–	–	–	–	1.0	1.5
Erodium cicutarium	11.1	33.1	25	50	36.7	25.5	45.7
Filagro sp.			–	–	–	–	0.5
Galium aparine	–	0.8	–	–	–	–	–
Lithophragma sp.	11.1	–	–	–	–	–	2.0
Lotus wrangelliannus	–	–	50	–	–	–	–
Lupinus bicolor	–	2.5	–	–	–	–	1.5
Minuartia sp.	–	–	–	–	–	1.0	2.0
Poa secunda	11.1	–	–	50	8.2	2.0	0.5
Vulpia microstachys	–	–	–	–	–	21.6	1
V. myuros	44.4	3.4	25	–	–	2.0	–
Unidentified dicot	–	1.7	–	–	–	2.0	2.0
Unknown Poaceae	–	1.7	–	–	24.5	12.8	24.9
No. of species (S)	5	14	3	2	7	12	17
n	9	118	4	2	49	102	197
Shannon's Index (H')[a]	1.43	1.97	1.04	0.69	1.61	1.83	1.78

Notes:

DT = Drop Tower native population (includes the Carlsen-Gregory subpopulation)

FL = Flashing experimental subpopulation

FF = Fire Frequency experimental subpopulation

n = Total number of plants

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 Drop Tower native population site.

Table A7. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower native and Site 300 experimental population: 2008–2010.

Species	FL 2008 (%)	FF 2008 (%)	FF 2009 (%)	FF 2010 (%)
Amsinckia grandiflora	–	3.6	–	0.9
Avena sp.	–	25	19.2	8.3
Bromus diandrus	–	7.1	–	1.4
B. hordeaceus	28.6	3.6	3.8	1.4
B. madritensis ssp. *rubens*	14.3	3.6	3.8	1.8
Clarkia sp.	–	–	3.8	–
Claytonia sp.	–	–	3.8	0.9
Delphinium sp.	–	–	–	0.5
Erodium cicutarium	28.6	42.9	53.9	31.9
Lithophragma sp.	14.3	–	–	3.7
Lupinus bicolor	–	–	–	0.9
Poa secunda	–	–	–	1.8
Vulpia microstachys	–	–	3.8	1.4
Unidentified dicot	–	–	–	2.3
Unknown Poaceae	14.3	14.3	7.7	42.6
No. of species (S)	5	7	8	14
n	7	56	26	216
Shannon's Index (H')[a]	1.55	1.53	1.47	1.63

Notes:

DT = Drop Tower native population (includes the Carlsen-Gregory subpopulation)

FL = Flashing experimental subpopulation

FF = Fire Frequency experimental subpopulation

n = Total number of plants

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 Drop Tower native population site.

Table A8. Summary of *Amsinckia grandiflora* nearest neighbor data, 1997 through 2010.

Year	Drop Tower native population (includes Carlsen-Gregory subpopulation)				Flashing experimental subpopulation				Fire Frequency experimental subpopulation			
	S	n	H'	Top Species (%)	S	n	H'	Top Species (%)	S	n	H'	Top Species (%)
1997	12	100	1.92	*B. hord* (31), *B. dian* (22), *Avena* (18)	–	–	–	–	–	–	–	–
1998	14	129	2.16	*Gallium* (23), *B. hord* (21), *Avena* (13)	–	–	–	–	–	–	–	–
1999	4	6	1.31	*B. hord* (50), *B. dain/ Collinsial Galium* (17)	8	42	1.59	*B. hord* (33), *E. cic* (24), *Clay* (12)	–	–	–	–
2000	14	39	2.40	*V. my* (20), *E. cic* (18), *Avena* (15)	12	45	2.14	*V. my* (30), *E. cic/ Clay* (16)	12	151	1.93	*Bromus* (28), *Avena* (24), *V. my/ P. sec* (11)
2001	8	14	1.97	*E. cic/ Avena* (21), *B. dian/ B. hord* (11)	10	56	1.80	*E. cic* (41), *Avena* (21), *V. my* (9)	15	244	2.35	*E. cic/ Avena* (21), *B. dian* (16), *P. sec* (9)
2002	5	8	1.39	*Avena* (50), *Amsin/ B. dian/ B. hord/ Galium* (12.5)	5	9	1.43	*E. cic* (44), *A. grand* (22)	7	23	1.68	*V. my* (30), *E. cic/ Avena* (22)
2003	3	4	1.04	*E. cic* (50), *UnkP/ B. dian* (25)	10	65	1.75	*E. cic* (37), *V. my* (25), *Avena* (12)	8	50	1.53	*E. cic* (48), *UnkP* (20), *V. my* (12)
2004	3	3	1.10	*V. my/ B. dian/ Avena* (33)	26	750	2.06	*E. cic* (38), *UnkP* (10), *Avena* (8)	4	15	1.08	*E. cic* (47), *Avena* (40), *V. my /B. dian* (7)
2005	–	–	–	–	5	9	1.43	*V. my* (44), Avena (22), three remaining (11)	14	118	1.97	*E. cic* (30), *Avena* (22), *B. hord* (14),
2006	3	4	1.04	*Lotus* (50), *E. cic* (25) *V. my* (25)	2	2	0.16	*P. sec/ E. cic* (50)	7	49	1.61	*E. cic* (37), *UnkP* (25), *Avena* (18)
2007	–	–	–	–	12	102	1.83	*B. hord* (27), *E. cic* (26), *V. mi* (22)	17	197	1.78	*E. cic* (46), *UnkP* (25), *B. hord* (8)
2008	–	–	–	–	5	7	1.55	*B. hord/ E. cic* (29), *Lith/ UnkP/ B. mad* (14)	7	56	1.53	*E. cic* (43), *Avena* (25), *UnkP* (14)
2009	–	–	–	–	–	–	–	–	8	26	1.47	*E. cic* (54), *Avena* (19), *UnkP* (8)
2010	–	–	–	–	–	–	–	–	14	216	1.63	*UnkP* (43), *E. cic* (32), *Avena* (8)

Notes:

Amsin = *Amsinckia* species
A. grand = *Amsinckia grandiflora*
Avena = *Avena* species
Bromus = *Bromus* species
B. dian = *Bromus diandrus*
B. hord = *Bromus hordeaceaus*
B. mad = *Bromus madritensis*
Clay = *Claytonia* species
Collinsia = *Collinsia heterophylla*
E. cic = *Erodium cicutarium*
Gallium = *Gallium aparine*
H' = Shannon's Diversity Index
Lith = *Lithophragma* species
Lotus = *Lotus wrangelliannus*
S = Number of species
n = Number of *Amsinckia grandiflora* sampled
P. sec = *Poa secunda*
UnkP = Unknown Poaceae
V. my = *Vulpia myuros*
V. mi = *Vulpia microstachys*

Table A9. Mean percent cover and standard deviation, Constancy and Importance Values (IV) for plots collected from the Site 300 experimental population and the Drop Tower native population in 2007.

Species	Flashing experimental subpopulation, N=55				Fire Frequency experimental subpopulation, N=20				Drop Tower native population[a] N=7			
	Mean % Cover	Stdev % Cover	Con-stancy	I.V.	Mean % Cover	Stdev % Cover	Con-stancy	I.V.	Mean % Cover	Stdev % Cover	Con-stancy	I.V.
Bare	**24.32**	**16.10**	**–**	**–**	**23.75**	**18.04**	**–**	**–**	**20.71**	**18.58**	**–**	**–**
Thatch	**29.80**	**20.95**	**–**	**–**	**32.75**	**23.48**	**–**	**–**	**60.00**	**22.36**	**–**	**–**
Achillea millifolium	**0.36**	**1.55**	**7.27**	**7.64**	**18.50**	**20.57**	**5.00**	**5.50**	**2.14**	**3.93**	**28.57**	**30.71**
Amsinckia grandiflora	**1.09**	**1.34**	**41.82**	**42.91**	**0.50**	**2.24**	**80.00**	**86.38**	**–**	**–**	**–**	**–**
***Amsinckia* sp.**	**0.45**	**0.97**	**18.18**	**18.64**	**6.38**	**6.04**	**25.00**	**25.63**	**0.71**	**1.22**	**28.57**	**29.29**
***Avena* sp.**	**7.59**	**7.48**	**78.18**	**85.77**	**0.63**	**1.11**	**70.00**	**81.00**	**9.29**	**8.38**	**71.43**	**80.71**
Bromus diandrus	**3.05**	**3.81**	**52.73**	**55.77**	**11.00**	**12.63**	**50.00**	**55.38**	**0.71**	**1.89**	**14.29**	**15.00**
B. hordeaceus	**24.00**	**18.56**	**92.73**	**116.73**	**5.38**	**13.26**	**100.00**	**107.00**	**8.21**	**10.87**	**71.43**	**79.64**
B. madritensis* ssp. *rubens	**3.64**	**6.01**	**61.82**	**65.45**	**7.00**	**5.77**	**40.00**	**41.75**	**3.21**	**5.54**	**42.86**	**46.07**
B. tectorum	**0.36**	**1.89**	**3.64**	**4.00**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Castilleja exerta	**1.58**	**2.90**	**38.18**	**39.76**	**2.25**	**3.13**	**50.00**	**52.25**	**–**	**–**	**–**	**–**
***Cirsium* sp.**	**0.05**	**0.34**	**1.82**	**1.87**	**0.75**	**1.64**	**20.00**	**20.75**	**–**	**–**	**–**	**–**
***Clarkia* sp.**	**2.86**	**5.34**	**58.18**	**61.05**	**3.50**	**6.15**	**55.00**	**58.50**	**–**	**–**	**–**	**–**
***Claytonia* sp.**	**0.14**	**0.57**	**5.45**	**5.59**	**2.50**	**4.33**	**30.00**	**32.50**	**–**	**–**	**–**	**–**
Collinsia heterophylla	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**2.86**	**5.67**	**28.57**	**31.43**
***Delphinium* sp.**	**2.27**	**3.00**	**52.73**	**55.00**	**0.75**	**1.64**	**20.00**	**20.75**	**–**	**–**	**–**	**–**
Dichelostemma capitatum	**0.59**	**2.80**	**9.09**	**9.68**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Erodium botrys	**–**	**–**	**–**	**–**	**0.13**	**0.56**	**5.00**	**5.13**	**–**	**–**	**–**	**–**
E. cicutarium	**14.32**	**11.71**	**90.91**	**105.23**	**20.25**	**7.34**	**100.00**	**120.25**	**9.29**	**6.07**	**85.71**	**95.00**
Filago sp.	**0.64**	**1.20**	**23.64**	**24.27**	**0.25**	**0.77**	**10.00**	**10.25**	**–**	**–**	**–**	**–**
Galium aparine	**–**	**–**	**–**	**–**	**0.25**	**0.77**	**10.00**	**10.25**	**5.36**	**8.47**	**42.86**	**48.21**
Grindelia camporum	**0.27**	**2.02**	**1.82**	**2.09**	**0.38**	**0.92**	**15.00**	**15.38**	**–**	**–**	**–**	**–**
Gutierrizia sp.	**0.05**	**0.34**	**1.82**	**1.86**	**0.25**	**1.12**	**5.00**	**5.25**	**–**	**–**	**–**	**–**
Lepidium nitidum	**0.05**	**0.34**	**1.82**	**1.86**	**–**	**–**	**–**	**–**	**–**	**–**	**–**	**–**
Lithophragma sp.	**0.32**	**0.84**	**12.73**	**13.05**	**0.13**	**0.56**	**5.00**	**5.13**	**–**	**–**	**–**	**–**
Lotus wrangelliannus	**0.05**	**0.34**	**1.82**	**1.86**	**0.13**	**0.56**	**5.00**	**5.13**	**2.86**	**5.48**	**42.86**	**45.71**

Table A9 (continued). Mean percent cover and standard deviation, Constancy and Importance Values (IV) for plots collected from the Site 300 experimental population and the Drop Tower native population in in 2007.

	Flashing experimental subpopulation, N=55				Fire Frequency experimental subpopulation, N=20				Drop Tower native population[a] N=7			
Species	Mean % Cover	Stdev % Cover	Con-stancy	I.V.	Mean % Cover	Stdev % Cover	Con-stancy	I.V.	Mean % Cover	Stdev % Cover	Con-stancy	I.V.
Lupinus albifrons	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
L. bicolor	2.86	2.17	74.55	77.41	7.88	9.94	65.00	72.88	1.07	1.97	28.57	29.64
Minuartia sp.	0.36	1.01	12.73	13.09	0.88	1.47	30.00	30.88	–	–	–	–
Phacelia distans	0.14	0.57	5.45	5.59	–	–	–	–	–	–	–	–
Poa secunda	11.91	10.34	70.91	82.82	13.75	11.20	85.00	98.75	1.07	1.97	28.57	29.64
Schisnus sp.	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
Solidago sp.	0.14	0.75	3.64	3.77	0.38	0.92	15.00	15.38	–	–	–	–
Stylomecon heterophylla	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
Thysanocarpus curvipes	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
Tropidocarpum gracile	–	–	–	–	0.13	0.56	5.00	5.13	–	–	–	–
Unknown Apiaceae	–	–	–	–	–	–	–	–	1.43	1.34	57.14	58.57
Unknown Asteraceae	0.50	1.62	12.73	13.23	–	–	–	–	0.36	0.94	14.29	14.64
Unknown Caryophyllaceae	–	–	–	–	–	–	–	–	1.43	1.97	42.86	44.29
Unknown dicot	0.05	0.34	1.82	1.86	0.25	0.77	10.00	10.25	–	–	–	–
Unknown Poaceae	8.09	7.42	65.45	73.55	8.25	8.63	65.00	73.25	18.57	23.40	57.14	75.71
Vulpia microstachys	9.68	15.70	61.82	71.50	7.75	11.61	60.00	67.75	–	–	–	–
V. myuros	4.68	13.07	23.64	28.32	0.63	1.38	20.00	20.63	27.14	22.70	71.43	98.57
Unknown moss	0.09	0.67	1.82	1.91	–	–	–	–	–	–	–	–
No. of species (S)	36				29				17			
Shannon's Index (H')[b]	2.51				2.60				2.65			

Notes:
Constancy = Number of times a species occurs/total number of plots) × 100
I.V. = Importance values. Constancy + Mean Cover
N = Number of plots
SD = Standard deviation
[a] The Drop Tower native population includes plots sampled from the Carlsen-Gregory subpopulation.
[b] 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 sum of the cover of all species observed; and n_i is the sum of the cover of the *i*th species.

Table A10. Mean percent cover and standard deviation, Constancy and Importance Values (IV) for plots collected from the Site 300 experimental population and the Drop Tower native population in 2008.

	Flashing experimental subpopulation, N=56				Fire Frequency experimental subpopulation, N=20				Drop Tower native population[a] N=7			
Species	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV
Bare	22.05	16.15	–	–	25.25	19.70	–	–	24.43	25.34	–	–
Thatch	27.95	12.68	–	–	20.38	16.51	–	–	35.00	17.08	–	–
Achillea millifolium	0.54	2.27	7.14	7.68	1.38	1.72	45.00	46.38	0.36	0.94	14.29	14.64
Amsinckia grandiflora	0.18	0.65	7.14	7.32	0.63	2.28	10.00	10.63	–	–	–	–
Amsinckia sp.	0.85	3.61	12.50	13.35	10.25	14.60	70.00	80.25	0.71	1.22	28.57	29.29
Apiastrum angustifolium	–	–	–	–	–	–	–	–	1.07	1.97	28.57	29.64
Avena sp.	3.13	4.77	55.36	58.48	1.50	1.88	45.00	46.50	5.00	5.59	71.43	76.43
Bromus diandrus	3.08	4.18	51.79	54.87	5.38	8.78	75.00	80.38	0.71	1.89	14.29	15.00
B. hordeaceus	15.31	14.43	94.64	109.96	1.75	2.00	50.00	51.75	4.64	2.67	100.00	104.64
B. madritensis ssp. rubens	4.33	4.99	69.64	73.97	1.38	1.72	45.00	46.38	3.93	3.49	71.43	75.36
Capsella bursa-pastoris	–	–	–	–	1.25	5.59	5.00	6.25	–	–	–	–
Castilleja exerta	0.45	0.97	17.86	18.30	–	–	–	–	–	–	–	–
Cirsium sp.	0.04	0.33	1.79	1.83	0.13	0.56	5.00	5.13	0.36	0.94	14.29	14.64
Clarkia sp.	2.10	2.64	58.93	61.03	0.66	1.13	25.00	25.66	1.07	1.34	42.86	43.93
Claytonia sp.	0.31	0.83	12.50	12.81	–	–	–	–	0.36	0.94	14.29	14.64
Collinsia heterophylla	–	–	–	–	–	–	–	–	0.36	0.94	14.29	14.64
Delphinium sp.	3.08	2.74	78.57	81.65	0.63	1.38	20.00	20.63	0.71	1.22	28.57	29.29
Dichelostemma capitatum	0.45	1.52	12.50	12.95	–	–	–	–	–	–	–	–
Elymus elymoides	–	–	–	–	1.75	7.83	5.00	6.75	–	–	–	–
Erodium cicutarium	11.21	10.64	98.21	109.42	17.63	9.98	100.00	117.63	4.29	3.13	85.71	90.00
Galium aparine	–	–	–	–	–	–	–	–	2.14	1.73	71.43	73.57
Grindelia camporum	0.45	3.34	1.79	2.23	0.38	1.22	10.00	10.38	–	–	–	–
Hirschfeldia	–	–	–	–	0.13	0.56	5.00	5.13	–	–	–	–
Lepidium nitidum	0.13	0.57	5.36	5.49	–	–	–	–	–	–	–	–
Lithophragma sp.	0.80	1.27	30.36	31.16	0.63	1.11	25.00	25.63	0.36	0.94	14.29	14.64
Lotus wrangelliannus	–	–	–	–	–	–	–	–	0.71	1.22	28.57	29.29
Lupinus albifrons	0.13	0.74	3.57	3.71	0.75	1.64	20.00	20.75	–	–	–	–
L. bicolor	1.88	2.15	53.57	55.45	–	–	–	–	–	–	–	–

Table A10 (continued). Mean percent cover and standard deviation, Constancy and Importance Values (IV) for plots collected from the Site 300 experimental population and the Drop Tower native population in 2008.

	Flashing experimental subpopulation, N=56				Fire Frequency experimental subpopulation, N=20				Drop Tower native population[a] N=7			
Species	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV
Monolopia major	–	–	–	–	–	–	–	–	–	–	–	–
Phacelia distans	–	–	–	–	–	–	–	–	1.43	3.78	14.29	15.71
Poa secunda	9.02	6.48	83.93	92.95	11.00	7.00	85.00	96.00	–	–	–	–
Pterostegia drymarioides	0.09	0.47	3.57	3.66	–	–	–	–	0.36	0.94	14.29	14.64
Senecio vulgaria	–	–	–	–	–	–	–	–	0.36	0.94	14.29	14.64
Thysanocarpus curvipes	0.18	0.65	7.14	7.32	–	–	–	–	–	–	–	–
Trifolium gracilentum	–	–	–	–	–	–	–	–	–	–	–	–
Trifolium willdenovii	–	–	–	–	0.13	0.56	5.00	5.13	–	–	–	–
Tropidocarpum sp.	0.04	0.33	1.79	1.83	–	–	–	–	–	–	–	–
Unknown Asteraceae	0.85	1.45	28.57	29.42	0.38	1.22	10.00	10.38	0.36	0.94	14.29	14.64
Unknown Brassicaceae	–	–	–	–	–	–	–	–	0.71	1.22	28.57	29.29
Unknown dicot	0.09	0.47	3.57	3.66	–	–	–	–	0.71	1.22	28.57	29.29
Unknown Liliaceae	0.18	1.34	1.79	1.96	–	–	–	–	–	–	–	–
Unknown moss	5.89	5.03	69.64	75.54	1.13	3.49	15.00	16.13	–	–	–	–
Unknown Poaceae	12.23	8.89	92.86	105.09	21.75	22.26	85.00	106.75	36.43	27.65	71.43	107.86
Vulpia microstachys	4.11	6.26	64.29	68.39	1.38	1.90	40.00	41.38	–	–	–	–
V. myuros	0.63	2.71	5.36	5.98	1.50	5.58	15.00	16.50	3.57	4.53	57.14	60.71
No. of species (S)	30				23				24			
Shannon's Index (H')[b]	2.56				2.23				1.99			

Notes:

CG = Carlsen-Gregory subpopulation
Constancy = Number of times a species occurs/total number of plots) × 100
I.V. = Importance values. Constancy + Mean Cover
N = Number of plots
SD = Standard deviation

[a] The Drop Tower native population includes plots sampled from the Carlsen-Gregory subpopulation.

[b] 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 sum of the cover of all species observed; and n_i is the sum of the cover of the *i*th species.

Table A11. Mean percent cover and standard deviation, Constancy and Importance Values (IV) for plots collected from the Site 300 experimental population and the Drop Tower native population in 2009.

Species	Flashing experimental subpopulation, N=47				Fire Frequency experimental subpopulation, N=20				Drop Tower native population[a] N=6			
	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV
Bare	3.33	3.63	–	–	22.00	14.88	–	–	10.00	5.48	–	–
Thatch	15.11	8.31	–	–	21.50	18.20	–	–	43.33	5.16	–	–
Achillea millifolium	1.33	4.72	10.64	11.97	0.13	0.56	5.00	5.13	0.42	1.02	14.29	14.70
Amsinckia grandiflora	–	–	–	–	1.25	1.28	50.00	51.25	–	–	–	–
Amsinckia sp.	0.27	0.94	8.51	8.78	0.50	1.03	20.00	20.50	–	–	–	–
Avena sp.	10.64	7.84	76.60	87.23	23.50	18.07	80.00	103.50	15.00	12.65	71.43	86.43
Bromus diandrus	0.59	1.19	21.28	21.86	4.25	9.77	30.00	34.25	16.67	15.06	85.71	102.38
B. hordeaceus	8.72	9.69	65.96	74.68	6.00	8.21	45.00	51.00	2.50	2.24	57.14	59.64
B. madritensis ssp. rubens	11.81	8.50	85.11	96.91	4.50	7.93	40.00	44.50	15.83	12.42	71.43	87.26
B. tectorum	8.62	7.05	78.72	87.34	–	–	–	–	–	–	–	–
Carduus sp.	–	–	–	–	0.13	0.56	5.00	5.13	–	–	–	–
Castilleja exerta	1.22	2.60	21.28	22.50	0.50	1.03	20.00	20.50	–	–	–	–
Centaurea melitensis	1.12	1.63	36.17	37.29	–	–	–	–	–	–	–	–
Clarkia sp.	0.96	1.23	38.30	39.26	0.88	1.22	35.00	35.88	0.42	1.02	14.29	14.70
Claytonia perfoliata	0.11	0.51	4.26	4.36	0.25	1.12	5.00	5.25	0.42	1.02	14.29	14.70
Collinsia heterophylla	–	–	–	–	–	–	–	–	0.42	1.02	14.29	14.70
Delphinium sp.	1.65	1.41	61.70	63.35	1.13	1.28	45.00	46.13	0.83	1.29	28.57	29.40
Dichelostemma capitatum	0.11	0.73	2.13	2.23	0.13	0.56	5.00	5.13	–	–	–	–
Elymus elymoides	–	–	–	–	1.50	6.71	5.00	6.50	–	–	–	–
Eriogonum sp.	0.43	1.20	12.77	13.19	–	–	–	–	–	–	–	–
Erodium cicutarium	13.46	6.07	100.00	113.46	22.75	18.32	80.00	102.75	2.50	3.87	42.86	45.36
Galium aparine	–	–	–	–	–	–	–	–	2.08	1.02	71.43	73.51
Galium sp.	–	–	–	–	–	–	–	–	0.83	1.29	28.57	29.40
Grindelia camporum	0.59	2.28	12.77	13.35	–	–	–	–	–	–	–	–
Lithophragma sp.	0.21	0.71	8.51	8.72	0.38	0.92	15.00	15.38	0.42	1.02	14.29	14.70
L. bicolor	8.35	4.98	97.87	106.22	2.00	3.20	40.00	42.00	0.42	1.02	14.29	14.70

Table A11 (continued). Mean percent cover and standard deviation, Constancy and Importance Values (IV) for plots collected from the Site 300 experimental population and the Drop Tower native population in 2009.

	Flashing experimental subpopulation, N=47				Fire Frequency experimental subpopulation, N=20				Drop Tower native population[a] N=6			
Species	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV
Minuartia sp.	0.05	0.36	2.13	2.18	–	–	–	–	0.42	1.02	14.29	14.70
Monolopia major	–	–	–	–	–	–	–	–	–	–	–	–
Phacelia distans	–	–	–	–	–	–	–	–	–	–	–	–
Poa secunda	8.46	6.95	78.72	87.18	9.50	9.85	60.00	69.50	–	–	–	–
Pterostegia drymarioides	0.05	0.36	2.13	2.18	–	–	–	–	–	–	–	–
Senecio vulgaria	–	–	–	–	–	–	–	–	–	–	–	–
Thysanocarpus curvipes	0.48	1.12	17.02	17.50	0.75	3.35	5.00	5.75	–	–	–	–
Trifolium gracilentum	–	–	–	–	–	–	–	–	–	–	–	–
Tropidocarpum gracile	–	–	–	–	0.13	0.56	5.00	5.13	–	–	–	–
Unknown Asteraceae	0.43	2.04	4.26	4.68	0.38	1.22	10.00	10.38	0.42	1.02	14.29	14.70
Unknown dicot	0.59	1.82	12.77	13.35	0.38	0.92	15.00	15.38	1.67	1.29	57.14	58.81
Unknown Liliaceae	0.11	0.73	2.13	2.23	–	–	–	–	–	–	–	–
Unknown moss	8.09	4.84	85.11	93.19	–	–	–	–	4.17	3.76	57.14	61.31
Unknown Poaceae	5.74	10.48	27.66	33.40	10.75	16.80	40.00	50.75	–	–	–	–
Vulpia microstachys	2.98	3.96	42.55	45.53	3.00	4.10	40.00	43.00	–	–	–	–
V. myuros	0.05	0.36	2.13	2.18	–	–	–	–	1.67	4.08	14.29	15.95
No. of species (S)	31				24				20			
Shannon's Index (H')[b]	2.63				2.25				2.12			

Notes:

Constancy = Number of times a species occurs/total number of plots) × 100
I.V. = Importance values. Constancy + Mean Cover
N = Number of plots
SD = Standard deviation

[a] No plots were sampled from the Carlsen-Gregory subpopulation of the Drop Tower native population in 2009.

[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 sum of the cover of all species observed; and n_i is the sum of the cover of the *i*th species.

Table A12. Mean percent cover and standard deviation, Constancy and Importance Values (IV) for plots collected from the Site 300 experimental population and the Drop Tower native population in 2010.

	Flashing experimental subpopulation, N=55				Fire Frequency experimental subpopulation, N=20				Drop Tower native population[a] N=0			
Species	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV
Bare	11.18	7.44	–	–	22.75	21.49	–	–	–	–	–	–
Thatch	45.45	18.01	–	–	33.25	28.51	–	–	–	–	–	–
Achillea millifolium	1.09	4.46	9.09	10.18	4.13	4.61	85.00	89.13	–	–	–	–
Amsinckia grandiflora	0.23	0.73	9.09	9.32	0.38	0.92	15.00	15.38	–	–	–	–
Amsinckia sp.	6.59	5.43	94.55	101.14	9.13	8.56	90.00	99.13	–	–	–	–
Avena sp.	0.18	0.66	7.27	7.45	0.25	0.77	10.00	10.25	–	–	–	–
Blepharizonia sp.	4.59	4.81	74.55	79.14	1.00	3.48	10.00	11.00	–	–	–	–
Bromus diandrus	7.73	6.19	96.36	104.09	2.50	3.44	60.00	62.50	–	–	–	–
B. hordeaceus	5.91	5.86	81.82	87.73	4.20	5.53	65.00	69.20	–	–	–	–
B. madritensis ssp. rubens	0.55	1.33	16.36	16.91	4.13	4.61	85.00	89.13	–	–	–	–
B. tectorum	0.18	1.35	1.82	2.00	–	–	–	–	–	–	–	–
Camissonia sp.	0.27	0.79	10.91	11.18	–	–	–	–	–	–	–	–
Castilleja exerta	0.23	0.73	9.09	9.32	1.75	3.54	35.00	36.75	–	–	–	–
Clarkia sp.	1.64	1.20	65.45	67.09	0.75	1.43	25.00	25.75	–	–	–	–
Claytonia perfoliata	0.23	0.87	7.27	7.50	–	–	–	–	–	–	–	–
Delphinium sp.	2.77	2.24	81.82	84.59	0.88	1.22	35.00	35.88	–	–	–	–
Descarania sp.	0.14	0.58	5.45	5.59	–	–	–	–	–	–	–	–
Dichelostemma capitatum	0.14	0.57	5.45	5.59	0.13	0.56	5.00	5.13	–	–	–	–
Elymus elymoides	–	–	–	–	0.25	0.77	10.00	10.25	–	–	–	–
Erodium botrys	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
E. cicutarium	7.77	4.92	96.36	104.14	11.50	10.95	85.00	96.50	–	–	–	–
Filago sp.	0.59	3.40	7.27	7.86	0.13	0.56	5.00	5.13	–	–	–	–
Grindelia camporum	0.09	0.67	1.82	1.91	0.25	1.12	5.00	5.25	–	–	–	–
Hypocaris glabra	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
Lepidium nitidum	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
Lithophragma sp.	0.45	0.97	18.18	18.64	1.25	2.36	35.00	36.25	–	–	–	–
L. bicolor	6.64	5.14	92.73	99.36	3.13	5.06	50.00	53.13	–	–	–	–
Medicago polymorpha	0.09	0.67	1.82	1.91	–	–	–	–	–	–	–	–

Table A12 (continued). Mean percent cover and standard deviation, Constancy and Importance Values (IV) for plots collected from the Site 300 experimental population and the Drop Tower native population in 2010.

	Flashing experimental subpopulation, N=55				Fire Frequency experimental subpopulation, N=20				Drop Tower native population[a] N=0			
Species	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV
Phacelia distans	0.18	1.35	1.82	2.00	0.13	0.56	5.00	5.13	–	–	–	–
Poa secunda	6.41	6.52	72.73	79.14	11.00	13.04	60.00	71.00	–	–	–	–
Stylomecon heterophylla	0.09	0.67	1.82	1.91	–	–	–	–	–	–	–	–
Thercium oxidentalli	–	–	–	–	0.25	1.12	5.00	5.25	–	–	–	–
Thysanocarpus curvipes	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
Trifolium gracilentum	–	–	–	–	–	–	–	–	–	–	–	–
Unknown Asteraceae 1	0.14	0.57	5.45	5.59	0.88	1.68	25.00	25.88	–	–	–	–
Unknown Asteraceae 2	0.36	2.70	1.82	2.18	–	–	–	–	–	–	–	–
Unknown Asteraceae 3	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
Unknown dicot	0.55	1.04	21.82	22.36	1.00	1.88	30.00	31.00	–	–	–	–
Unknown Liliaceae	–	–	–	–	0.13	0.56	5.00	5.13	–	–	–	–
Unknown moss	5.64	6.86	54.55	60.18	2.13	3.65	40.00	42.13	–	–	–	–
Unknown Poaceae	10.64	10.46	70.91	81.55	12.75	12.62	75.00	87.75	–	–	–	–
Vulpia microstachys	3.27	3.22	69.09	72.36	1.63	2.19	40.00	41.63	–	–	–	–
V. myuros	–	–	–	–	–	–	–	–	–	–	–	–
No. of species (S)	35				26							
Shannon's Index (H')[a]	2.69				2.52							

Notes:

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

I.V. = Importance values. Constancy + Mean Cover

N = Number of plots

SD = Standard deviation

[a] No plots were sampled from the primary Drop Tower native population or the Carlsen-Gregory subpopulation in 2010.

[b] 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 sum of the cover of all species observed; and n_i is the sum of the cover of the *i*th species.

Table A13. Mean percent cover and standard deviation, Constancy and Importance Values (IV) for plots collected from the Site 300 experimental population and the Drop Tower native population in 2011.

Species	Flashing experimental subpopulation, N=55				Fire Frequency experimental Subpopulation, N=20				Drop Tower native population[a] N=5			
	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV
Bare	25.55	16.35	–	–	27.38	11.40	–	–	34.00	21.62	–	–
Thatch	43.82	18.78	–	–	16.75	13.82	–	–	54.00	8.94	–	–
Achillea millifolium	0.95	3.17	12.73	13.68	0.50	1.54	10.00	10.50	1.50	2.24	28.57	30.07
Amsinckia grandiflora	0.64	1.29	21.82	22.45	2.13	4.31	30.00	32.13	–	–	–	–
Avena sp.	9.27	4.71	100.00	109.27	18.63	11.60	95.00	113.63	–	–	–	–
Blepharizoniza sp.	–	–	–	–	–	–	–	–	0.50	1.12	14.29	14.79
Bromus diandrus	0.68	1.12	27.27	27.95	0.63	2.28	10.00	10.63	1.00	2.24	14.29	15.29
B. hordeaceus	7.77	5.52	94.55	102.32	7.25	6.12	100.00	107.25	1.00	2.24	14.29	15.29
B. madritensis ssp. rubens	1.23	1.43	45.45	46.68	4.25	7.44	65.00	69.25	2.00	2.74	28.57	30.57
B. tectorum	1.90	1.75	23.64	25.54	–	–	–	–	–	–	–	–
Carduus pyc	0.12	0.55	1.82	1.94	–	–	–	–	–	–	–	–
Castilleja exerta	0.50	1.01	20.00	20.50	1.25	2.36	35.00	36.25	–	–	–	–
Cirsium sp.	–	–	–	–	0.75	2.31	15.00	15.75	–	–	–	–
Clarkia sp.	2.55	2.18	76.36	78.91	0.75	1.18	30.00	30.75	–	–	–	–
Claytonia perfoliata	0.05	0.34	1.82	1.86	0.38	0.92	15.00	15.38	1.00	1.37	28.57	29.57
Collinsia heterophylla	–	–	–	–	–	–	–	–	0.50	1.12	14.29	14.79
Delphinium sp.	2.41	1.59	83.64	86.05	1.13	2.36	30.00	31.13	–	–	–	–
Dichelostemma capitatum	0.09	0.47	3.64	3.73	1.25	2.36	35.00	36.25	–	–	–	–
Elymus elymoides	–	–	–	–	1.13	4.48	10.00	11.13	–	–	–	–
***Eriogonum* sp.**	0.09	0.47	3.64	3.73	–	–	–	–	–	–	–	–
Erodium cicutarium	3.23	1.96	96.36	99.59	5.25	5.31	70.00	75.25	0.50	1.12	14.29	14.79
***Filago* sp.**	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
Galium aparine	–	–	–	–	0.13	0.56	5.00	5.13	3.00	1.12	71.43	74.43
Grindelia camporum	0.18	0.81	5.45	5.64	0.88	1.68	25.00	25.88	0.50	1.12	14.29	14.79
Hypocharis glabrata	0.32	0.97	10.91	11.23	–	–	–	–	–	–	–	–
Lithophragma affine	0.82	1.18	32.73	33.55	–	–	–	–	–	–	–	–
Lomatium sp.	–	–	–	–	–	–	–	–	0.50	1.12	14.29	14.79
Lupinus albifrons	–	–	–	–	0.13	0.56	5.00	5.13	–	–	–	–
L. bicolor	4.45	4.07	85.45	89.91	2.25	2.91	60.00	62.25	–	–	–	–

Table A13 (continued). Mean percent cover and standard deviation, Constancy and Importance Values (IV) for plots collected from the Site 300 experimental population and the Drop Tower native population in 2011.

	Flashing experimental subpopulation, N=55				Fire Frequency experimental Subpopulation, N=20				Drop Tower native population[a] N=5			
Species	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV	Mean % Cover	Stdev % Cover	Con-stancy	IV
Marah fabaceous	–	–	–	–	–	–	–	–	0.50	1.12	14.29	14.79
Melica sp.	0.09	0.67	1.82	1.91	–	–	–	–	–	–	–	–
Minuartia californica	0.05	0.34	1.82	1.86	–	–	–	–	–	–	–	–
Phacelia distans	2.64	3.31	56.36	59.00	–	–	–	–	–	–	–	–
Poa secunda	0.05	0.34	1.82	1.86	9.75	13.88	50.00	59.75	–	–	–	–
Pteregia sp.	0.09	0.47	3.64	3.73	–	–	–	–	–	–	–	–
Senecio vulgaria	0.18	0.66	7.27	7.45	–	–	–	–	–	–	–	–
Thysanocarpus curvipes	2.64	3.31	56.36	59.00	–	–	–	–	–	–	–	–
Unknown Asteraceae	0.09	0.47	3.64	3.73	1.75	5.45	10.00	11.75	–	–	–	–
Unknown Borage	–	–	–	–	0.13	0.57	5.00	5.13	–	–	–	–
Unknown dicot 1	0.95	1.32	36.36	37.32	0.88	2.33	20.00	20.88	–	–	–	–
Unknown dicot 2	0.26	0.76	10.91	11.17	–	–	–	–	–	–	–	–
Unknown moss	6.23	6.45	65.45	71.68	0.79	1.19	30.00	30.79	–	–	–	–
Unknown Poaceae	–	–	–	–	0.13	0.56	5.00	5.13	16.00	15.57	57.14	73.14
Vulpia microstachys	2.59	3.12	65.45	68.05	3.88	6.71	45.00	48.88	–	–	–	–
V. myuros	0.27	1.42	5.45	5.73	–	–	–	–	–	–	–	–
No. of species (S)	32				24				13			
Shannon's Index (H')[b]	2.62				2.41				1.68			

Notes:

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

I.V. = Importance values. Constancy + Mean Cover

N = Number of plots

SD = Standard deviation

[a] No plots were sampled from the Carlsen-Gregory subpopulation of the Drop Tower native population in 2011.

[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 sum of the cover of all species observed; and n_i is the sum of the cover of the *i*th species.

Table A14. Summary of the cover data collected from the Site 300 experimental population and the Drop Tower native population from 2007 through 2011.

Year	Flashing experimental Subpopulation					Fire Frequency experimental subpopulation					Drop Tower native population[a]				
	Thatch Cover (%)	Bare Cover (%)	S	H'	Top IV	Thatch Cover (%)	Bare Cover (%)	S	H'	Top IV	Thatch Cover (%)	Bare Cover (%)	S	H'	Top IV
2007	29.80 ± 20.95	24.32 ± 16.10	36	2.51	*B. hord* (117) *E. cic* (105) *Avena* (86)	32.75 ± 23.48	23.75 ± 18.04	29	2.60	*E. cic* (120) *B. hord* (107) *P. sec* (99)	60.00 ± 22.36	20.71 ± 18.58	17	2.65	*V. my* (99) *E. cic* (95) *Avena* (81)
2008	27.95 ± 12.68	22.05 ± 16.15	30	2.56	*B. hord* (110) *E. cic* (109) *UnkP* (105)	20.38 ± 16.51	25.25 ± 19.70	23	2.23	*E. cic* (118) *UnkP* (107) *P. sec* (96)	35.00 ± 17.08	24.43 ± 25.34	24	1.99	*UnkP* (108) *B. hord* (105) *E. cic* (90)
2009	15.11 ± 8.31	3.33 ± 3.63	31	2.63	*E. cic* (113) *L. bi* (106) *B. hord* (97)	21.50 ± 18.20	22.00 ± 14.88	24	2.25	*Avena* (104) *E. cic* (103) *P. sec* (70)	43.33 ± 5.16	10.00 ± 5.48	20	2.12	*B. dian* (102) *B. mad* (87) *Avena* (86)
2010	45.45 ± 18.01	11.18 ± 7.44	35	2.69	*E. cic* (104) *B. hord* (104) *Avena* (101)	33.25 ± 28.51	22.75 ± 21.49	26	2.52	*E. cic* (97) *P. sec* (71) *V. mi* (42)	–	–	–	–	–
2011	43.82 ± 18.78	25.55 ± 16.35	32	2.62	*Avena* (109) *B. hord* (102) *E. cic* (100)	16.75 ± 13.82	27.38 ± 11.40	24	2.41	*Avena* (114) *B. hord* (107) *E. cic* (75)	54.00 ± 8.94	34.00 ± 21.62	13	1.68	*Gallium* (74) *UnkP* (73) *B. mad* (31)

Notes:

Avena = *Avena* species
B. dian = *Bromus diandrus*
B. hord = *Bromus hordeaceaus*
B. mad = *Bromus madritensis*
E. cic = *Erodium cicutarium*
Gallium = *Gallium aparine*
H' = Shannon's Diversity Index
IV = Importance Value
L. bi = *Lupinus bicolor*
S = Number of species
P. sec = *Poa secunda*
UnkP = Unknown Poaceae
V. mi = *Vulpia microstachys*
V. my = *Vulpia myuros*

Thatch and Cover data are ± one standard deviation.

[a] The Drop Tower native population includes plots sampled from the Carlsen-Gregory subpopulation.

Table A15. Dry biomass by dominant grass type in the Flashing experimental subpopulation. Values are means ± 1 SE.

Year	*Poa secunda* plots[a] Final dry biomass (g/0.1 m^2)[c]	N	Annual grass plots[b] Final dry biomass (g/0.1 m^2)[c]	N	All plots Final dry biomass (g/0.1 m^2)[c]	N
2007	13.60 ± 1.82	3	19.36 ± 0.76	2	15.91 ± 1.74	5
2006	22.66 ± 5.17	3	15.97 ± 1.25	2	19.98 ± 3.29	5
2005	18.28 ± 5.21	2	18.79 ± 2.56	3	18.59 ± 2.17	5
2004	6.32 ± 1.88	2	6.63 ± 1.48	3	6.50 ± 1.01	5
2003	14.1 ± 0.92	3	13.0 ± 3.24	2	13.66 ± 1.17	5
2002	19.70 ± 1.80	7	16.58 ± 2.69	3	18.80 ± 1.49	10
2001	7.32 ± 0.70	5	9.2 ± 1.85	5	8.30 ± 0.99	10
2000	10.66 ± 2.55	5	17.59 ± 3.63	5	14.13 ± 2.39	10
1999	13.5 ± 3.1	5	20.6 ± 8.2	5	16.08 ± 1.87	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:

NA = Not applicable
N = Number of plots
SE = Standard error

[a] Plots established with fixed densities of *P. secunda* in 1993 and 1994. Includes plots planted with low, medium and high densities of *P. secunda*.

[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, June 2007.

Table A16. *Poa secunda* density by dominant grass type in the Flashing experimental subpopulation. Values are means ± 1 SE.

Year	*Poa secunda* plots[a] *P. secunda* density per 0.64 m^2	N	Annual grass plots[b] *P. secunda* density per 0.64 m^2	N
2006	8.53 ± 1.18	30	4.32 ± 0.76	25
2007	7.60 ± 0.84	30	4.76 ± 0.57	25
2008	5.00 ± 0.60	30	2.40 ± 0.43	25
2009	3.93 ± 0.75	30	1.56 ± 0.44	25
2010	5.30 ± 0.69	30	2.96 ± 0.65	25
2011	4.17 ± 0.48	30	2.68 ± 0.48	25

Notes:

N = Number of plots
SE = Standard error

[a] Plots established with fixed densities of *P. secunda* in 1993 and 1994. Includes plots planted with low, medium and high densities of *P. secunda*.

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

Table A17. Number of *Poa secunda* per 2 m² plot in the Fire Frequency experimental subpopulation. Values are means ± 1 SD. Italics indicate plots burned the previous year.

		Fire Frequency			
	All frequencies N = 20	Control N = 5	Low N = 5	Medium N = 5	High N = 5
2011	32.5 ± 54.0	4.9 ± 6.6	2.4 ± 2.5	13.8 ± 11.3	*109.2 ± 61.3*
2010	22.3 ± 28.5	4.2 ± 2.8	2.6 ± 2.9	21.8 ± 8.7	*60.8 ± 31.8*
2009[b]	–	–	–	–	–
2008[b]	–	–	–	–	–
2007	23.8 ± 18.0	12.6 + 8.6	11.6 + 4.7	24.0 + 7.0	*46.8 + 19.9*
2006[a]	*21.2 ± 12.6*	*9.2 ± 4.9*	*13.8 ± 4.3*	*30.6 ± 11.3*	*31.2 ± 10.2*
2005	19.6 ± 8.3	12.0 ± 4.4	17.4 ± 4.9	20.0 ± 6.6	*31.5 ± 1.3*
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	24.0 ± 7.0	26.8 ± 5.4	*26.4 ± 11.4*
2002	27.0 ± 7.8	20.6 ± 6.4	28.0 ± 6.7	31.8 ± 2.9	*27.6 ± 10.5*
2001	21.7 ± 5.3	22.0 ± 5.8	22.0 ± 5.2	23.2 ± 3.3	21.6 ± 7.2
2000	29.3 ± 6.0	31.6 ± 4.4	29.2 ± 1.1	30.0 ± 2.1	26.2 ± 11.4
1999	33	33	33	33	33

Notes:

Plots planted in 1999. 2 m² plots were established and cleared of all *P. secunda*. Thirty-three *P. secunda* plugs were then planted in the center 1 m². Beginning in 2000, *P. secunda* were counted in the entire 2 m² plot.

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] In July 2005, a wildfire burned both the experimental and native *Amsinkia* populations.
[b] *P. secunda* were inadvertently counted from only the center 1 m² during these years.

Table A18. Number of *Amsinckia grandiflora* per 2 m^2 plot in the Fire Frequency experimental subpopulation. Values are means ± 1 SD.

		Fire Frequency		
	All frequencies N = 20	Control N = 5	Low & Medium N = 10	High N = 5
2011	5.3 ± 11.2	12.4 ± 15.7	3.8 ± 10.0	0
2010	10.9 ± 9.8	13.8 ± 12.3	13.5 ± 9.1	2.6 ± 2.4
2009	1.0 ± 1.3	0.4 ± 0.4	1.1 ± 1.1	1.2 ± 2.2
2008	2.7 ± 3.2	4.8 ± 4.6	2.6 ± 2.5	0.8 ± 1.8
2007	3.1 ± 4.0	2.6 ± 3.4	3.6 ± 4.7	2.6 ± 3.8
2006[a]	2.3 ± 4.2	6.8 ± 6.4	1.6 ± 3.1	0
2005	5.9 ± 7.0	10.6 ± 6.8	6.3 ± 7.4	0.4 ± 0.5
2004	0.8 ± 1.3	2.2 ± 2.0	0.4 ± 0.5	0
2003	2.5 ± 2.7	2.0 ± 3.5	3.2 ± 2.9	1.6 ± 1.1
2002	2.6 ± 3.6	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

Section B
Blepharizonia plumosa
Monitoring

B-1. Introduction

Site 300 populations of *Blepharizonia plumosa* (KELLOGG) GREENE (the big tarplant, previously known as *Blepharizonia plumosa* subsp. *plumosa*) were first identified during a 1996 habitat survey 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, 2012). As shown in Figure B1, the historic distribution of *B. plumosa* ranged from as far west as Benicia and Walnut Creek in Alameda County and as far east as Stockton in San Joaquin County and Salida in Stanislaus County (1994; CNDDB, 2012). The current distribution is restricted to an area of the Coastal Range that ranges from the Clayton and Antioch areas in the northwest, to the Del Puerto Canyon area in the southeast. In the northern extent of its range, populations of *B. plumosa* are currently known to occur on a private ranch in Deer Valley about 1.5 miles south of Antioch, at Black Diamond Mines Regional Park, and on private property southwest of Brentwood (CNDDB, 2012). Another small population was found at Chaparral Springs, near Mount Diablo (Preston, 1996). In the center of its range, populations have been observed at Site 300 and in areas adjacent to Site 300, including at the Carnegie State Vehicular Recreation Area in 1998, and on property used for wind-power generation in the Midway area in 2003 (CNDDB, 2012). In the southern portions of its range, small populations (<20 plants) were observed in lower Del Puerto Canyon near the town of Patterson in 2000 and 2003. In addition, a photo observation of the species was made in 2005 at Copper Mountain. The current status of these populations is unknown. During the 1996 and 2002 habitat surveys of Site 300, a few populations of the more common big tarweed *Blepharizonia laxa* GREENE (previously known as *Blepharizonia plumosa* subsp. *viscida* D.D. KECK) were found.

The genus *Blepharizonia* was taxonomically revised in 2001. 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*. Nomenclature for these species based on Baldwin et al. (2001) is 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, Figure B2).

Blepharizonia plumosa can generally be distinguished from *B. laxa* by fruit morphology and leaf color (Baldwin, 2012; 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 from the eastern San Francisco Bay area, to the western San Joaquin Valley, and south to the southern coast range (Baldwin, 2012). 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 (Baldwin, 2012).

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. 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 effective conservation and management, 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 demographic and population biology data on *B. plumosa* and *B. laxa* were collected. 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 (Paterson et al., 2005). These results suggested that 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. This work also suggested *B. plumosa* may be acting as a metapopulation, in which smaller subpopulations may be established or extinguished, depending on the fire uniformity and intensity.

Although some ecological differences between *B. plumosa* and *B. laxa* have been identified (Gregory et al., 2001; Paterson et al., 2005), the relative differences in abundance between the two species at Site 300 cannot yet be explained. Therefore, current and future work focus on understanding the population dynamics of *B. plumosa* across the entire site.

B-2. Methods and Materials

B-2.1. Site-wide Mapping

Surveys for *B. plumosa* and *B. laxa* were conducted by driving the Site 300 fire trail system at slow speeds while surveying for both *Blepharizonia* species from the vehicle. All accessible fire trails are driven to ensure that a comparable effort is committed to surveying for *Blepharizonia* each year. In addition, the survey team 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 time of the survey, so it is easily identified using binoculars.

In 2003 through 2011, tarplant mapping was conducted using handheld Trimble XH and XT Global Positioning System (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). Populations that were physically difficult to get to were manually mapped and the number of individuals estimated. The populations were then drawn by hand in ArcGIS using topography, roads, and buildings as reference.

All data recorded using the Trimble units were differentially corrected using base stations at Site 300, Mt. Hamilton, or Livermore. The corrected GPS data were 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 2011 because data from these years were 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 conducted on the following dates between 1996 through 2011.

- 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 Trimble GPS unit).

- 2001: On three dates between October 25 and November 8, 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.
- 2003: Site-wide *Blepharizonia* mapping was conducted on October 14–17 and 20.
- 2004: Site-wide *Blepharizonia* mapping was conducted on September 29 and 30, 2004, and October 8 and 15.
- 2005: Site-wide *Blepharizonia* mapping was conducted on ten days between September 22 and October 11.
- 2006: Site-wide *Blepharizonia* mapping was conducted on six days between September 26 and October 6.
- 2007: Site-wide *Blepharizonia* mapping was conducted on twelve days between September 18 and October 26.
- 2008: Site-wide *Blepharizonia* mapping was conducted on eight days between September 19 and October 17.
- 2009: Site-wide *Blepharizonia* mapping was conducted on eleven days between August 21 and October 21.
- 2010: Site-wide *Blepharizonia* mapping was conducted on eleven days between September 24 and November 5.
- 2011: Site-wide *Blepharizonia* mapping was conducted on seven days between September 9 and October 27.

B-2.1.1. Data Analysis

Using the ArcGIS geodatabase created from field data described above the area of the *B. plumosa* and *B. laxa* populations at Site 300 from 2001 through 2011 were 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 2011. 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 nine plants were used as the maximum population size for this polygon. The minimum and maximum population sizes of *B. plumosa* at Site 300 were calculated by summing these minimum or maximum population sizes for all *B. plumosa* polygons at Site 300 during a particular year. The frequency of occurrence map was constructed as described in Section C-2.1.

The population area was compared to the total annual rainfall at Site 300 for 2002 through 2011. Data from 2001 were 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. Building 801 Burn Study

In 2005, a study was conducted to attempt to determine if seedling recruitment increased in the years following a prescribed burn (Figure B10). Prior to 2002, the area surrounding Building 801 had routinely been included 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. Transects were established and monitored to evaluate seedling recruitment. Results of the seedling recruitment study are reported in Paterson et al. (2010). Although results of the recruitment study were inconclusive, the area surrounding Building 801 that underwent the prescribed burn is monitored to evaluate long-term trends.

B-3. Results

B-3.1. Site-wide Mapping

Figures B3 through B5 summarize the results of *Blepharizonia* mapping and/or burning conducted between 2001 and 2011. 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 B6 through B16).

Tables B1 and B2 shows that the number of *B. plumosa* and *B. laxa* varies greatly between years. By comparing the maximum estimated population sizes for each year fluctuations in population size can be observed. Between 2002 and 2011, 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 2011, and showed a similar pattern of variation. 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 2011 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 B17 shows the area of Site 300 occupied by *B. plumosa* (in acres), as well as the occupied density (plants/acres) for years 2003 through 2011. The occupied area follows a similar pattern as the estimated maximum population size, being at a maximum in 2005, with lows in 2004 and 2006. While there appeared to be a slight correlation between area and rainfall, this was not statistically significant. The density of *B. plumosa* at Site 300 was inversely related to the size of the occupied area, as can be seen in Figures B17 and B18a. This relationship was statistically significant (r2=0.74, *p*<0.005). However, it should be noted that the number of individuals in larger populations are visually estimated (while smaller populations are manually counted), and this may underestimate the number of individuals in the larger populations. At the same time, larger areas may include smaller subareas with few or no plants, and this would reduce the effect of the population number underestimation.

Figure B19 shows the frequency of occurrence of *B. plumosa* in occupied areas between 2003 and 2011. Populations appear to have a central core, which are typically always occupied, with the occupied area increasing from that core when conditions are favorable. Since it appears that density increases with smaller occupied area, it is likely these core areas have a fairly stable density, with density decreasing in years that favor expansion from the core population.

B-3.2. Building 801 Burn Study

Unlike the overall Site 300 B. *plumosa* population, the maximum estimated population size at Building 801 was significantly higher after 2005, reaching a maximum in 2010 (Table B1). While the pattern was not as strong for *B. laxa* (Table B2), the number of *B. laxa* decreased between 2003 through 2006, and began to increase in 2007. Figure B20 shows that the occupied area and occupied density of *B. plumosa* at Building 801 followed a different pattern when compared to the rest of the site. Figure B20a shows the fraction of total Site 300 occupied area that consisted of the occupied area at Building 801. The Building 801 area fraction decreased from 2003 through 2006, and began increasing from 2007 to a maximum in 2009, when it again began decreasing. Density of the Building 801 occupied area was decreased when compared to the overall Site 300 population through 2006, at which time it began increasing, reaching a high of more than twice as dense as the overall Site 300 population. Figure B18b shows that unlike the overall Site 300 population, the Building 801 occupied area is statistically correlated with density.

B-4. Discussion and Recommendations for Future Work

A better understanding of the mechanisms at work controlling the distribution of this species is gained by mapping *B. plumosa* populations on a yearly basis. *Blepharizonia plumosa* is so widespread at Site 300 that mapping over multiple years is required to provide information on the relationship between population presence, burn frequency, and climatic variables such as rainfall amount and timing. Intensity and timing of burning may have profound effects on *B. plumosa* population dynamics. 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 Site 300.

The information gained from monitoring the burn survivorship at Building 850, Elk Ravine, and Building 812 in 2001 and 2002 (Paterson et al. 2005) was useful in interpreting the site-wide data. It was shown conclusively that *B. plumosa* does not survive direct contact with the flames, but rather survives in patches of unburned habitat. However, it was 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 from 2001 through 2004, near Building 801, suggested this to be the case.

Therefore, 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 in 2006, likely due to some combination of climatic variables. 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. In addition, mapping since that time suggest the prescribed burn did have a positive effect at Building 801. The fraction of the Site 300 occupied area composed of Building 801 occupied area increased from 2007 through 2009, at which time it began to decline again, suggesting this area would once again benefit from a prescribed burn.

Developing a method of measuring burn patchiness would allow the fluctuations in population size near Buildings 801 and 851 to be understood more clearly. By mapping unburned patches immediately following controlled burns at Buildings 801 and 851 annually, the distribution of *B. plumosa* in relationship to the patchiness of the burns could be compared and possibly explain why the *B. plumosa* population surrounding Building 851 continues to persist despite annual burns. It is likely that since the Building 851 population consistently occurs directly adjacent to the facility, the prescribed burn is less intense or more patchy in this area. Mapping burn patchiness may also help to explain population size fluctuations throughout the site. However, there also appears to be a complex relationship between burning and rainfall on the distribution of *B. plumosa*, which warrants further study.

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 core 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. Data suggesting that density decreases with occupied area, and the frequency of occurrence data showing several “core” populations with a fairly consistent density strongly suggest that the Site 300 *B. plumosa* population is operating as described scenario 1, with gene flow between the core subpopulations occurring during years of favorable conditions. Such conditions may be driven by the fire frequency, rainfall patterns, or both. This preliminary conclusion suggests that protecting these core subpopulations is critical to the management and conservation of *B. plumosa* at Site 300. It also suggests that the loss of smaller, less important subpopulations may not significantly impact the larger Site 300 population, depending on its size and location. The best method to validate this population structure is through molecular and/or genetic analysis of plants from subpopulations across Site 300. Should funding opportunities arise, this work should be considered.

B-5. References

Baldwin, B.G., R.E. Preston, B.L. Wessa, and M. Wetherwax. 2001. "A biosystematic and phylogenetic assessment of sympatric taxa in *Blepharizonia* (Compositae-Madiinae)." *Systematic Botany* **26**:184–194.

Baldwin, B. G. 2012. *Blelpharizonia* (Big tarweed). In Baldwin, B. G., D. H. Goldman, D. J. Keil, R. Patterson, T. J. Rosatti, and D. H. Wilken, (Ed.) 2012. *The Jepson manual: vascular plants of California*, second edition (pg. 262). (University of California Press, Berkeley, CA.)

Bevill, R.L., and S.M. Louda. 1999. Comparisons of related rare and common species in the study of plant rarity. *Conservation Biology* **13**:493–498.

Bremer, K. 1994. "Fruits of Asteraceae." In *Asteraceae Cladistics and Classification.* K. Bremer, Ed. (Timber Press, Inc. Portland, OR) pp. 34–35.

Byers, D.L. 1998. "Effect of cross proximity on progeny fitness in a rare and a common species of *Eupatorium* (Asteraceae)." *American Journal of Botany* **85**(5):644–653.

CNDDB (California Natural Diversity Data Base). 2012. California Natural Diversity Database, Biogeographic Data Branch, California Department of Fish and Game, Sacramento, CA. Accessed on Thur., Jan. 12, 2011 from http://www.dfg.ca.gov/biogeodata/cnddb/mapsanddata.asp

CNPS (California Native Plant Society). 2012. Inventory of Rare and Endangered Plants (online edition, v8-01a). California Native Plant Society. Sacramento, CA. Accessed on Fri, Jan. 13, 2012 from http://www.cnps.org/inventory.

Gregory, S.D., E.K. Espeland, T.M. Carlsen, and E.K. Bissell. 2001. "Demography and population biology of a rare tarplant, *Blepharizonia plumosa* (Asteraceae), a California summer annual forb." *Madroño* **48**(4):272–285.

Karis, P.O., and O. Ryding. 1994. "Tribe Helenieae." In *Asteraceae Cladistics and Classification*. K. Bremer, Ed. (Timber Press, Inc. Portland, OR) pp. 521–556.

Pantone, D.J., B.M. Pavlik, and R.B. Kelley. 1995. "The reproductive attributes of an endangered plant as compared to a weedy congener." *Biological Conservation* **71**:305–311.

Paterson, L.E, E.K. Espeland and T.M. Carlsen. 2005. *Rare plant restoration and monitoring at Lawrence Livermore National Laboratory Site 300, project progress report, fiscal years 2003 and 2004, October 2002-October 2004*. Lawrence Livermore National Laboratory, Livermore, CA. UCRL-AR-142408-03/04.

Paterson, L.E, T.M. Carlsen, T.M. Alfaro and E.K. Espeland. 2010. *Rare plant restoration and monitoring at Lawrence Livermore National Laboratory Site 300, project progress report, fiscal years 2005 and 2006*. Lawrence Livermore National Laboratory, Livermore, CA. LLNL-TR-457357.

Preston, R.E. 1996. "Status of *Blepharizonia plumosa* (Big Tarplant), its occurrence on LLNL Site 300, and potential project impacts of the species." Report to LLNL Environmental Impact Report (EIR) Update Project File.

Preston, R.E. 2002. "Special-status plant species surveys and vegetation mapping at Lawrence Livermore National Laboratory." (Jones and Stokes, Sacramento, CA).

Section B
Figures

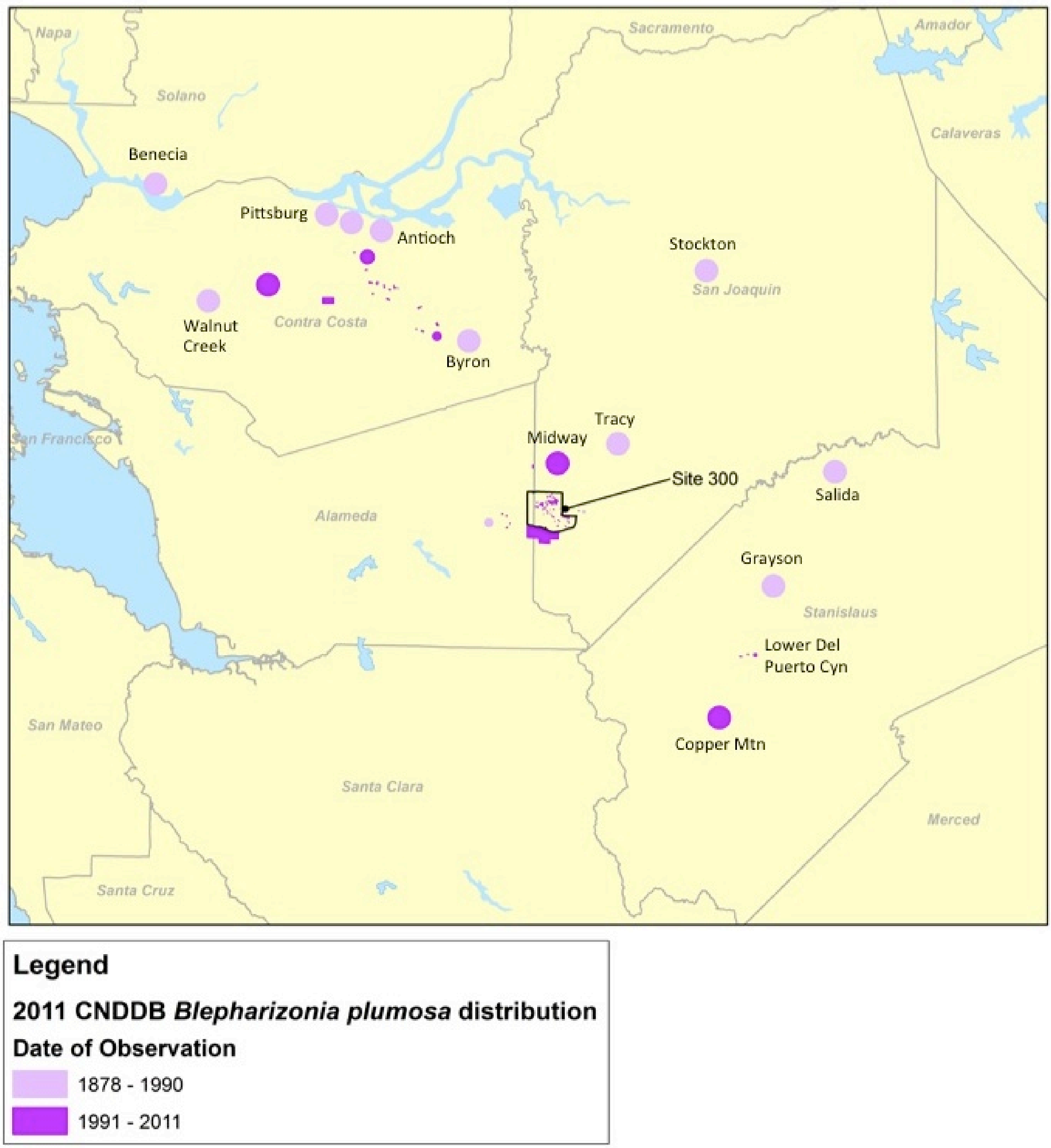


Figure B1. Current and historic occurrences of *Blepharizonia plumosa* as described by the California Natural Diversity Data Base (CNDDB, 2012).

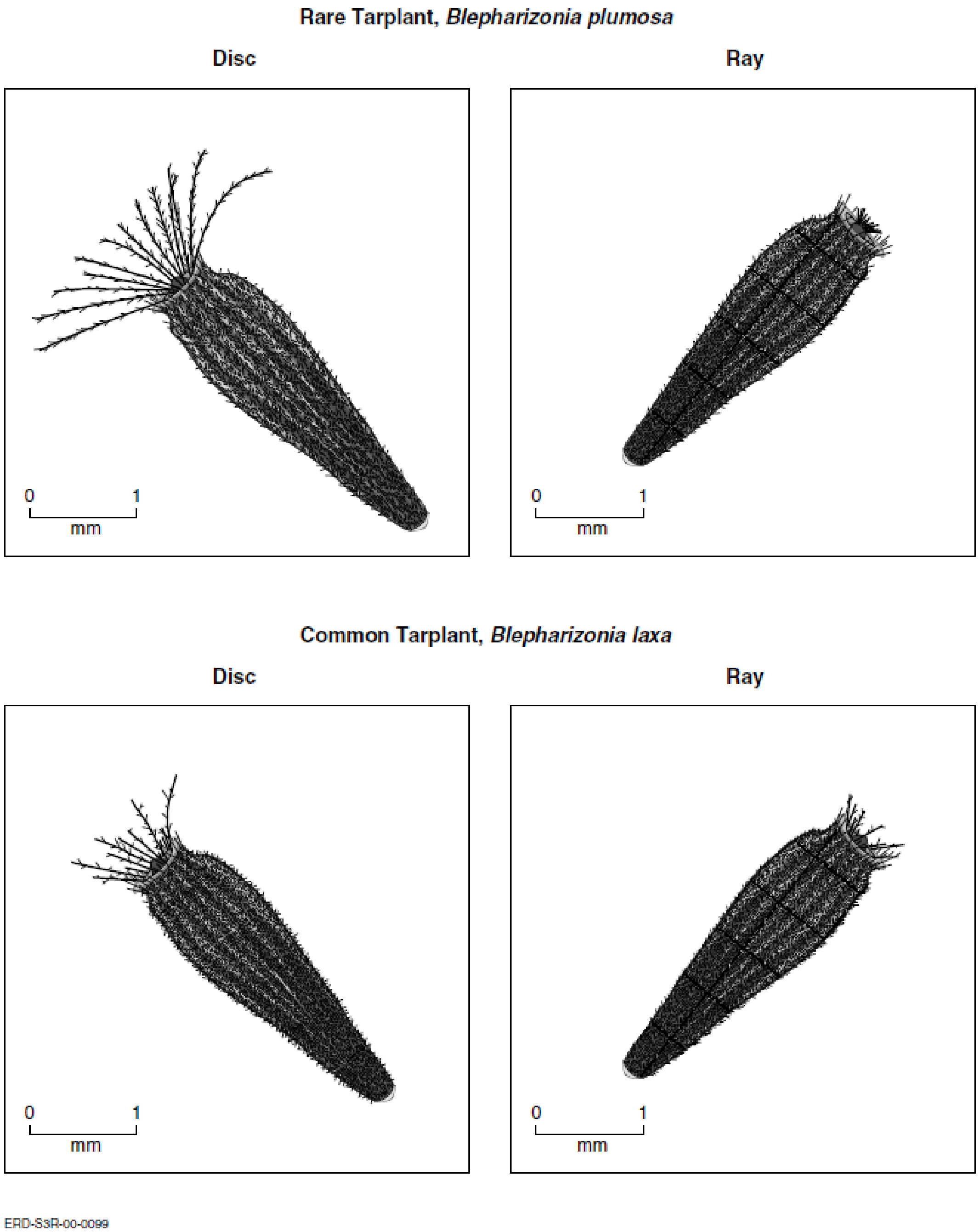


Figure B2. *Blepharizonia plumosa* fruit and *Blepharizonia laxa* fruit.

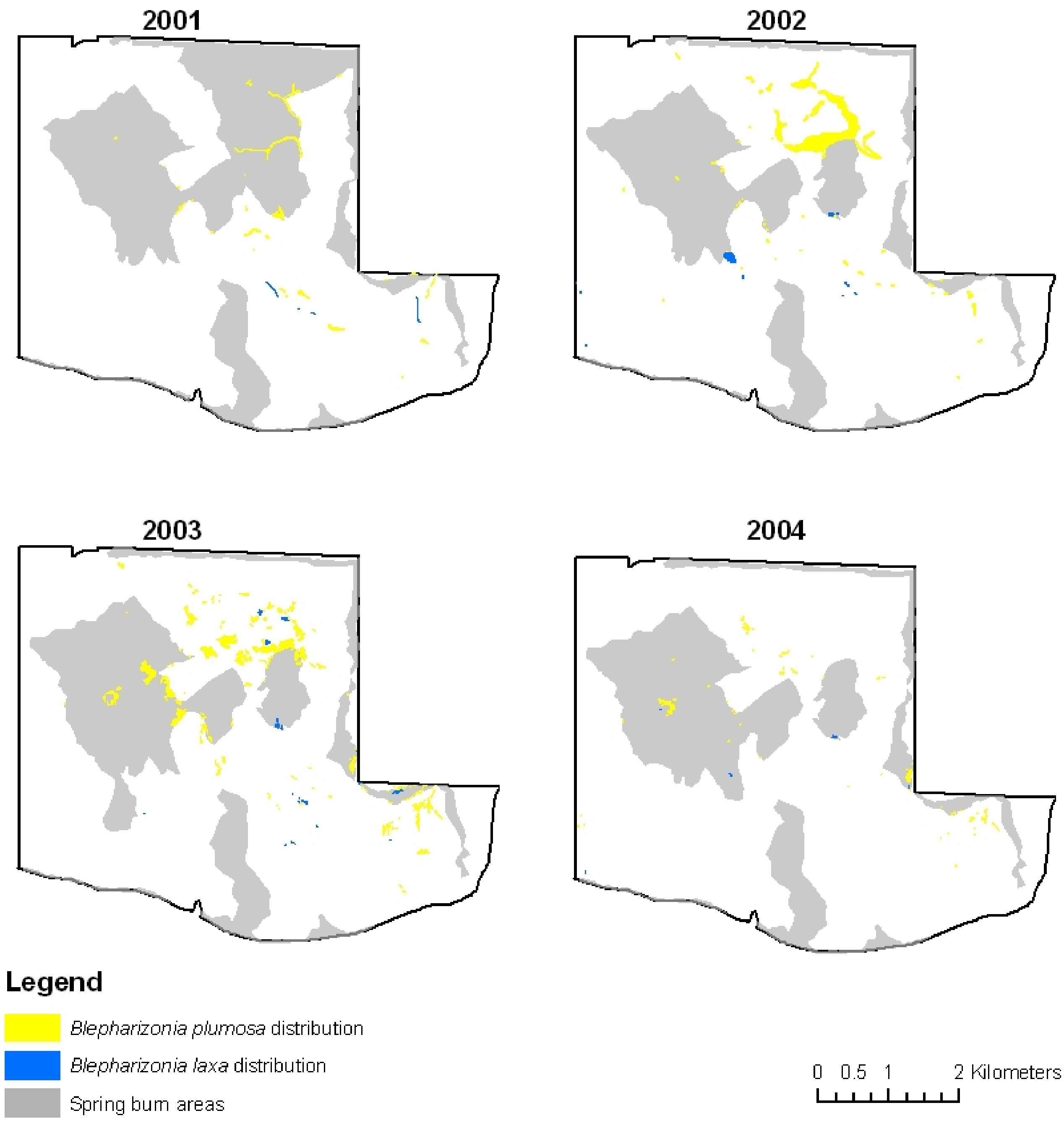


Figure B3. *Blepharizonia* populations mapped in the fall of 2001 through 2004. Spring prescribed burns are also shown. For map enlargements, refer to Figures B6 through B9.

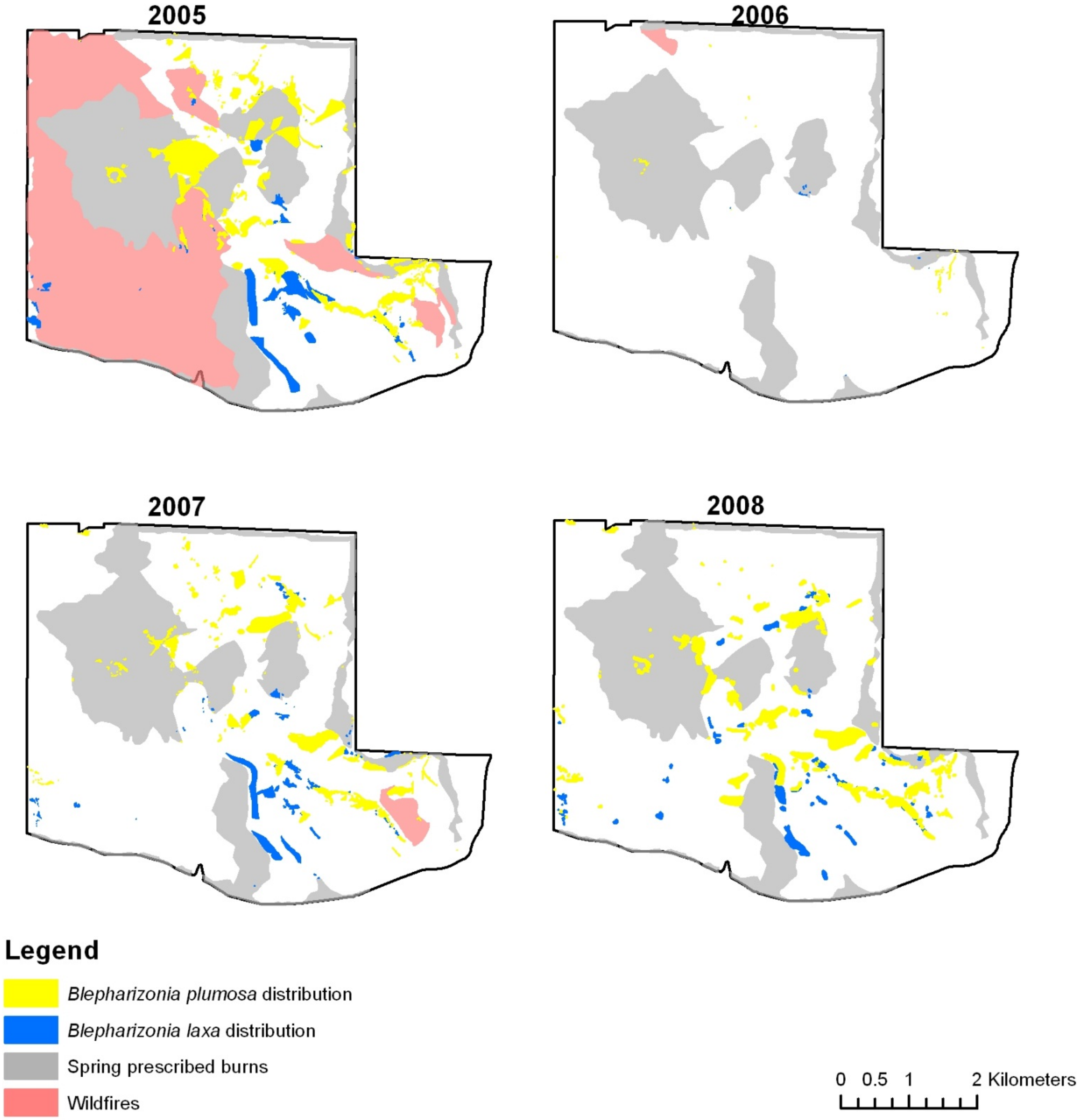


Figure B4. *Blepharizonia* populations mapped in the fall of 2005 through 2008. Spring prescribed burns and wildfires are also shown. For map enlargements, refer to Figures B10 through B13.

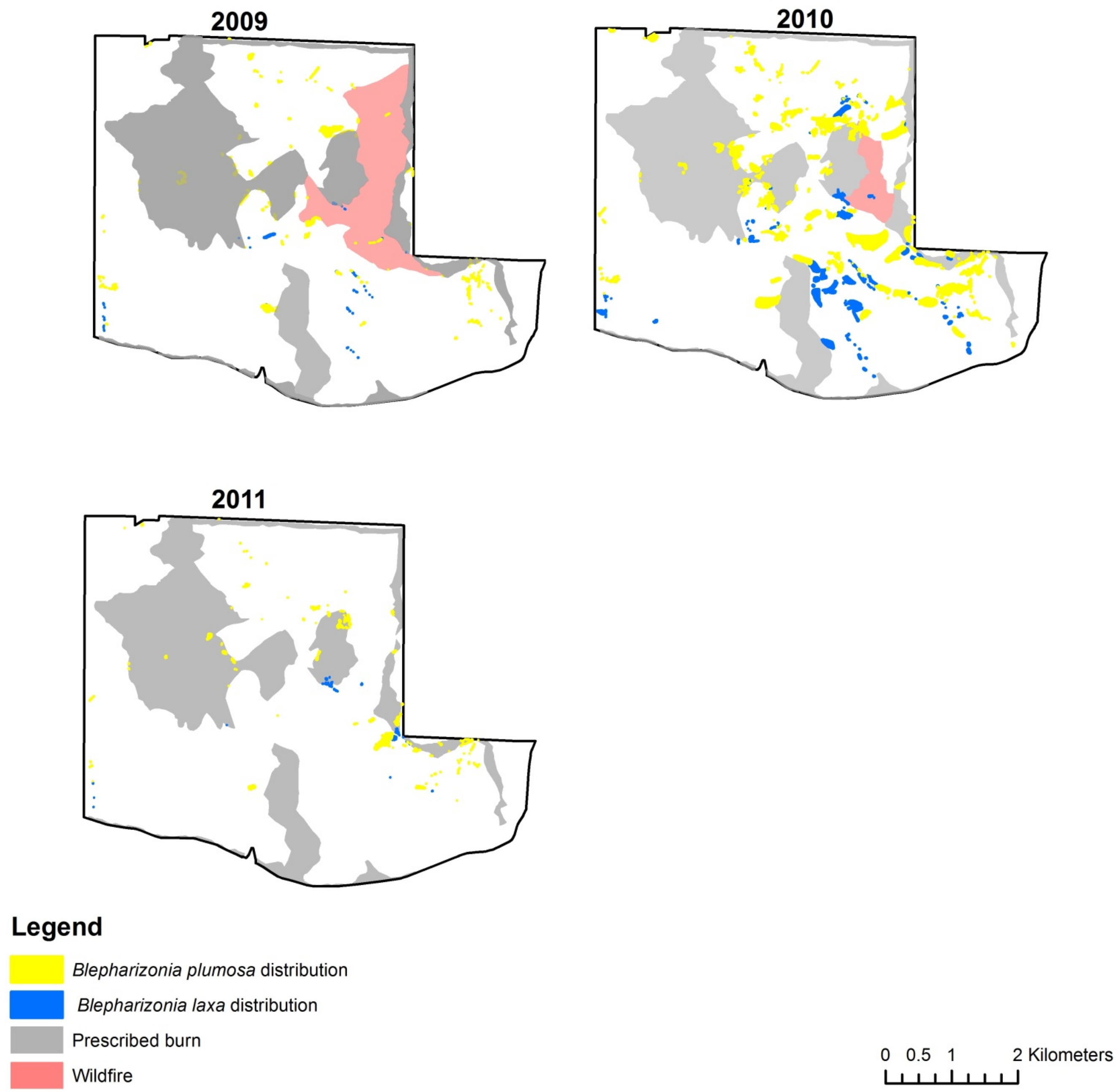


Figure B5. *Blepharizonia* populations mapped in the fall of 2009 through 2011. Spring prescribed burns and wildfires are also shown. For map enlargements, refer to Figures B14 through B16.

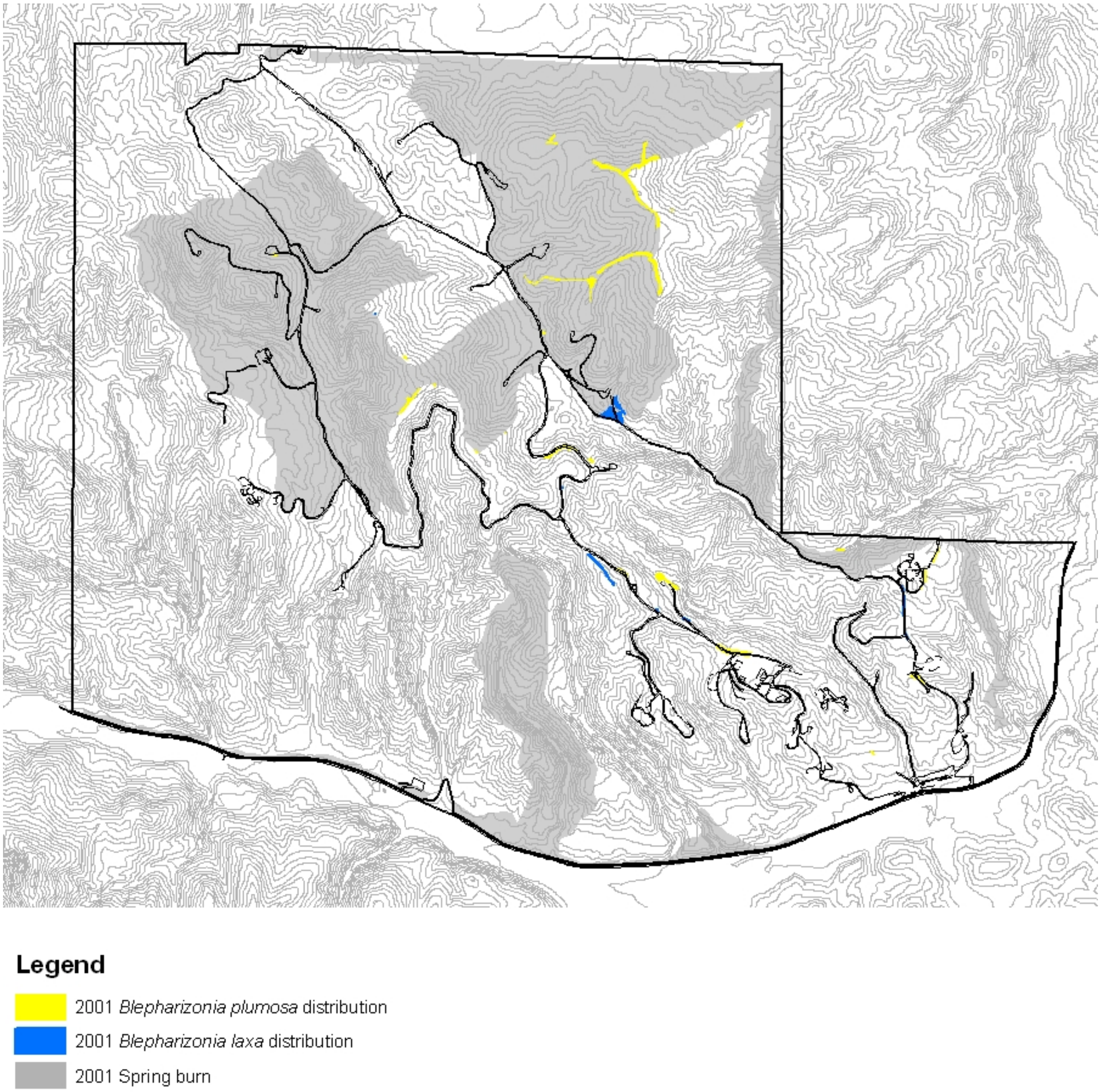


Figure B6. Enlargement of Figure B3 (2001). *Blepharizonia* populations mapped in the fall of 2001. The 2001 prescribed burn is also mapped.

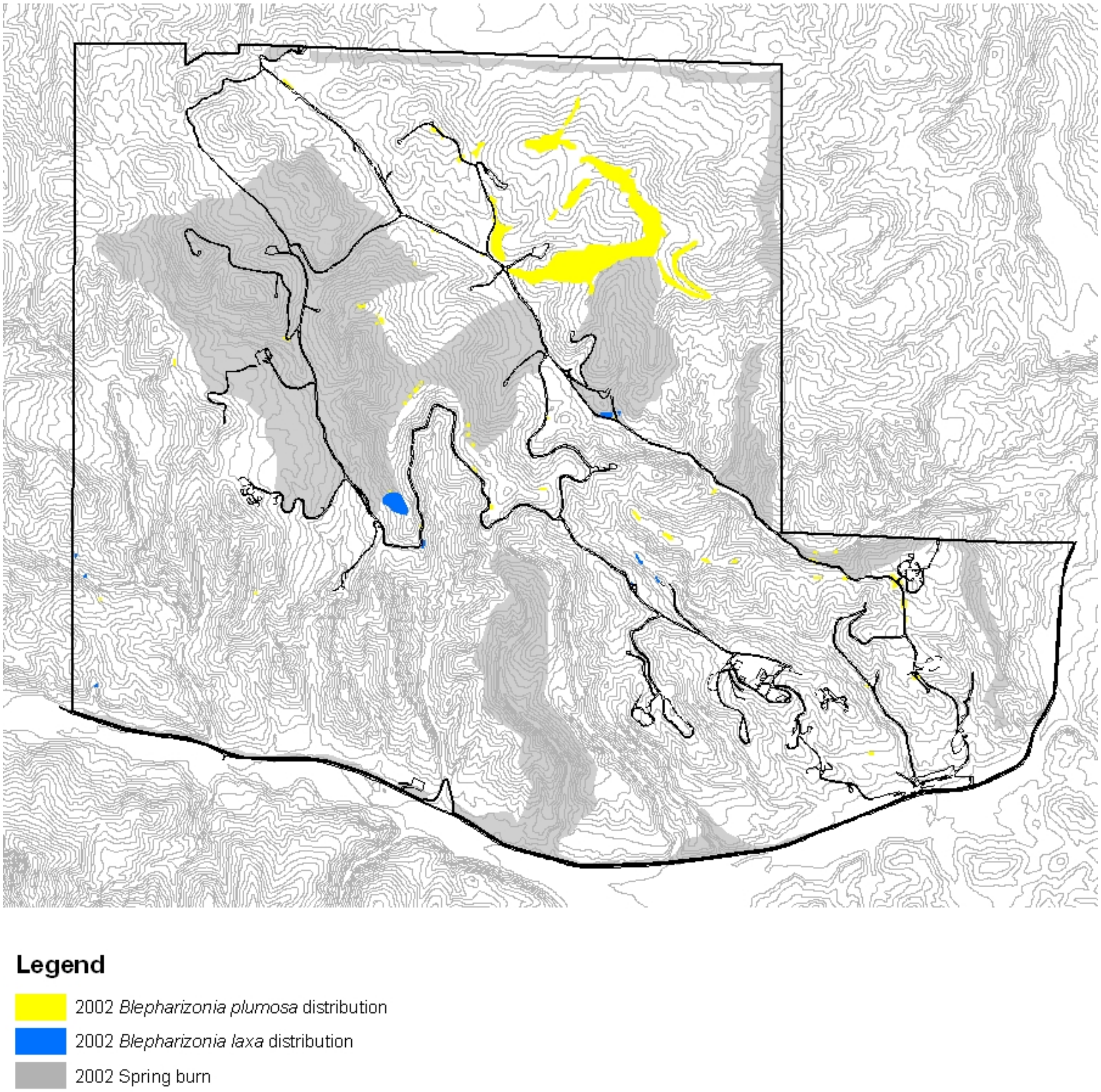


Figure B7. Enlargement of Figure B3 (2002). *Blepharizonia* populations mapped in the fall of 2002. The 2002 prescribed burn is also mapped.

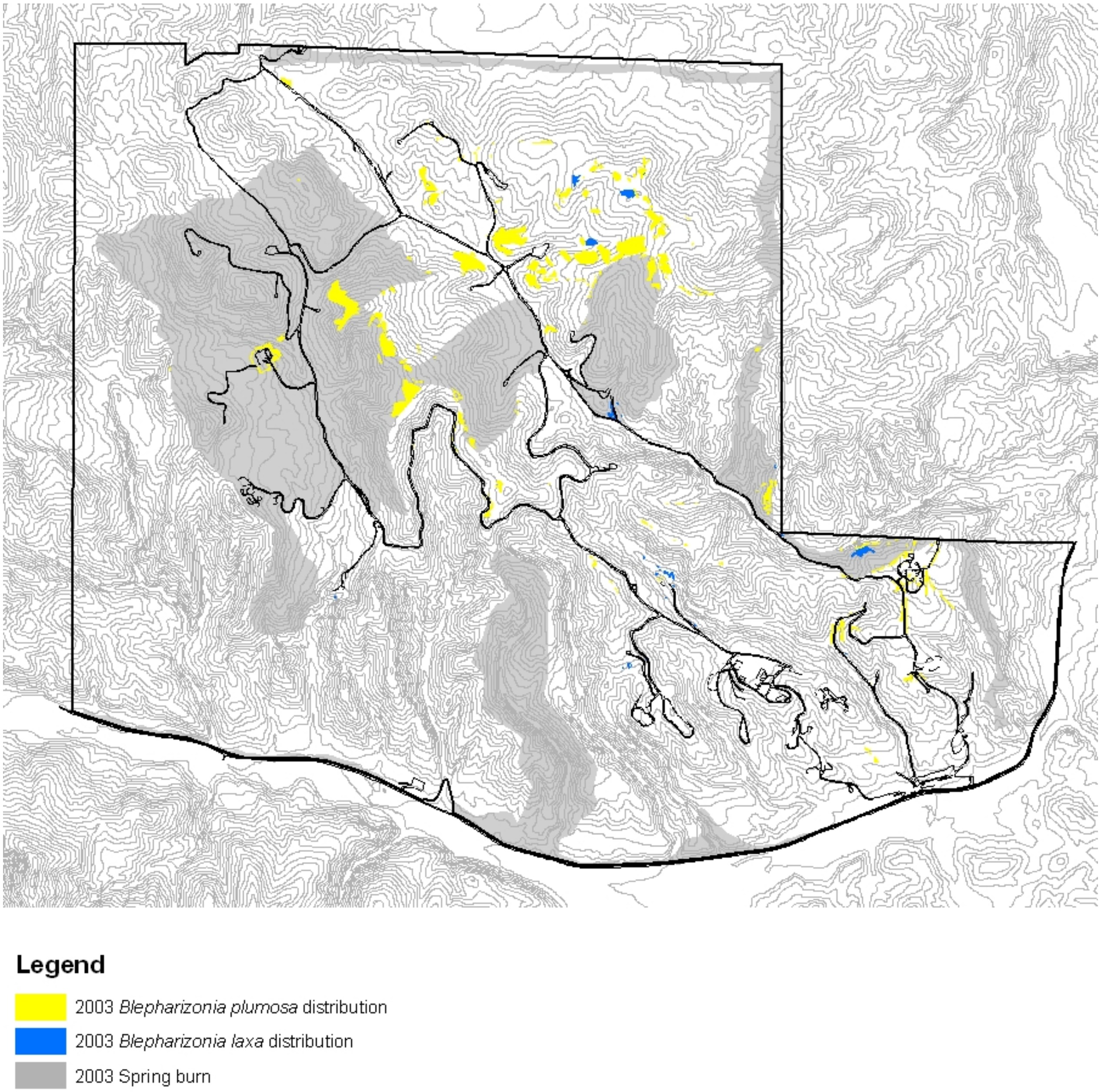
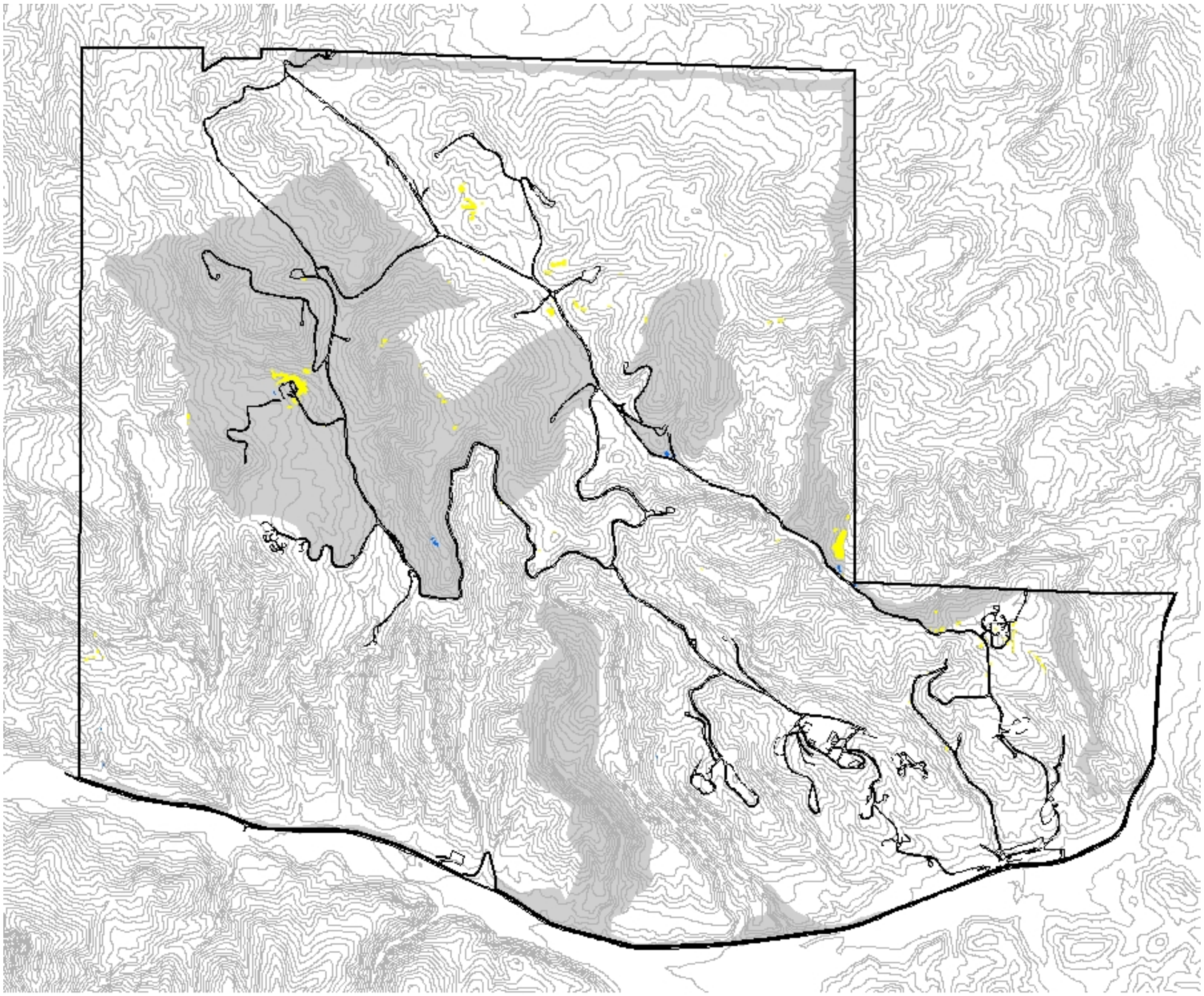


Figure B8. Enlargement of Figure B3 (2003). *Blepharizonia* populations mapped in the fall of 2003. The 2003 prescribed burn is also mapped.



Legend

2004 *Blepharizonia plumosa* distribution

2004 *Blepharizonia laxa* distribution

2004 Burn areas

Figure B9. Enlargement of Figure B3 (2004). *Blepharizonia* populations mapped in the fall of 2004. The 2004 prescribed burn is also mapped.

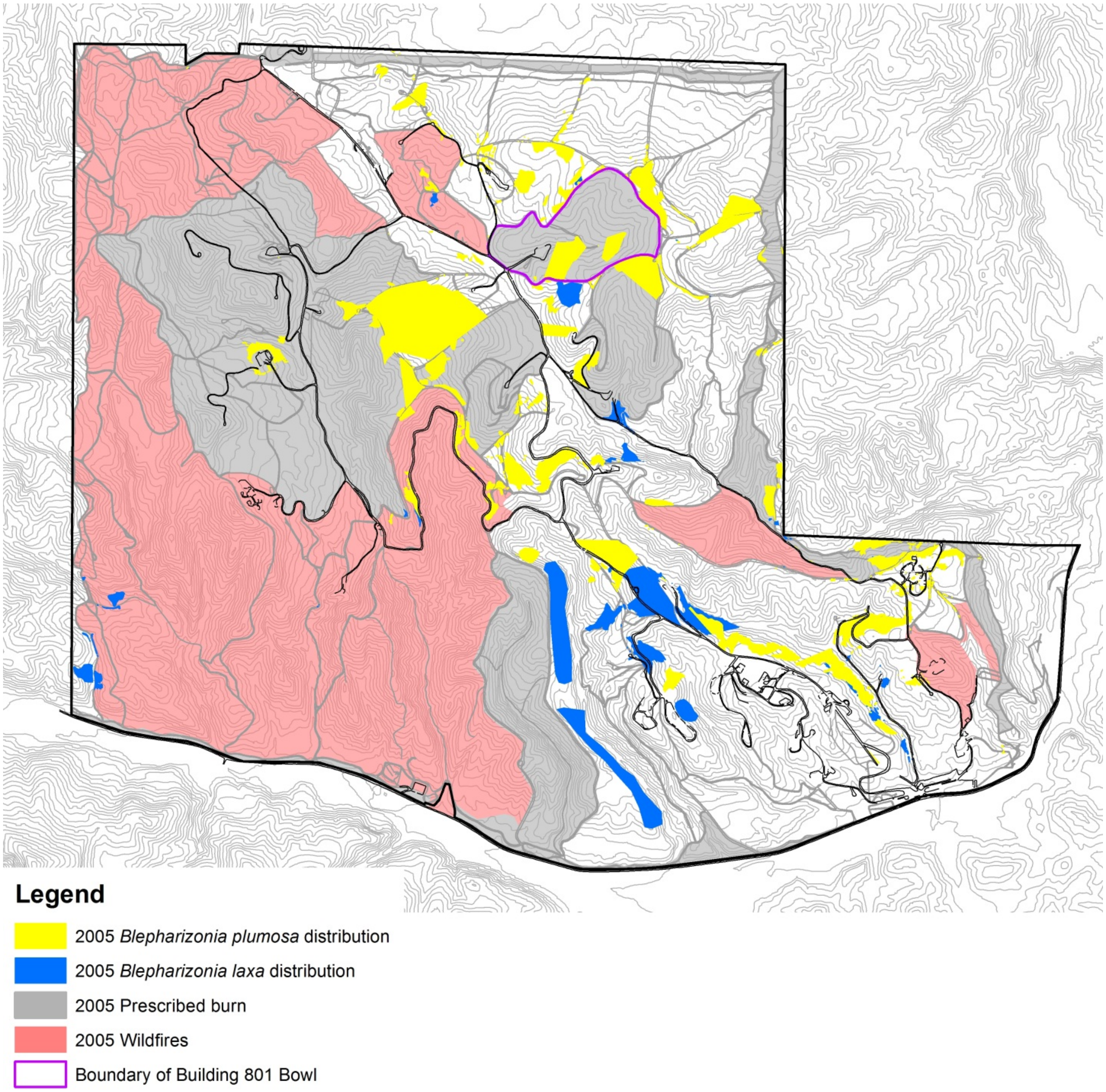


Figure B10. Enlargement of Figure B4 (2005). *Blepharizonia* populations mapped in the fall of 2005. The 2005 prescribed burn and wildfire areas are also mapped.

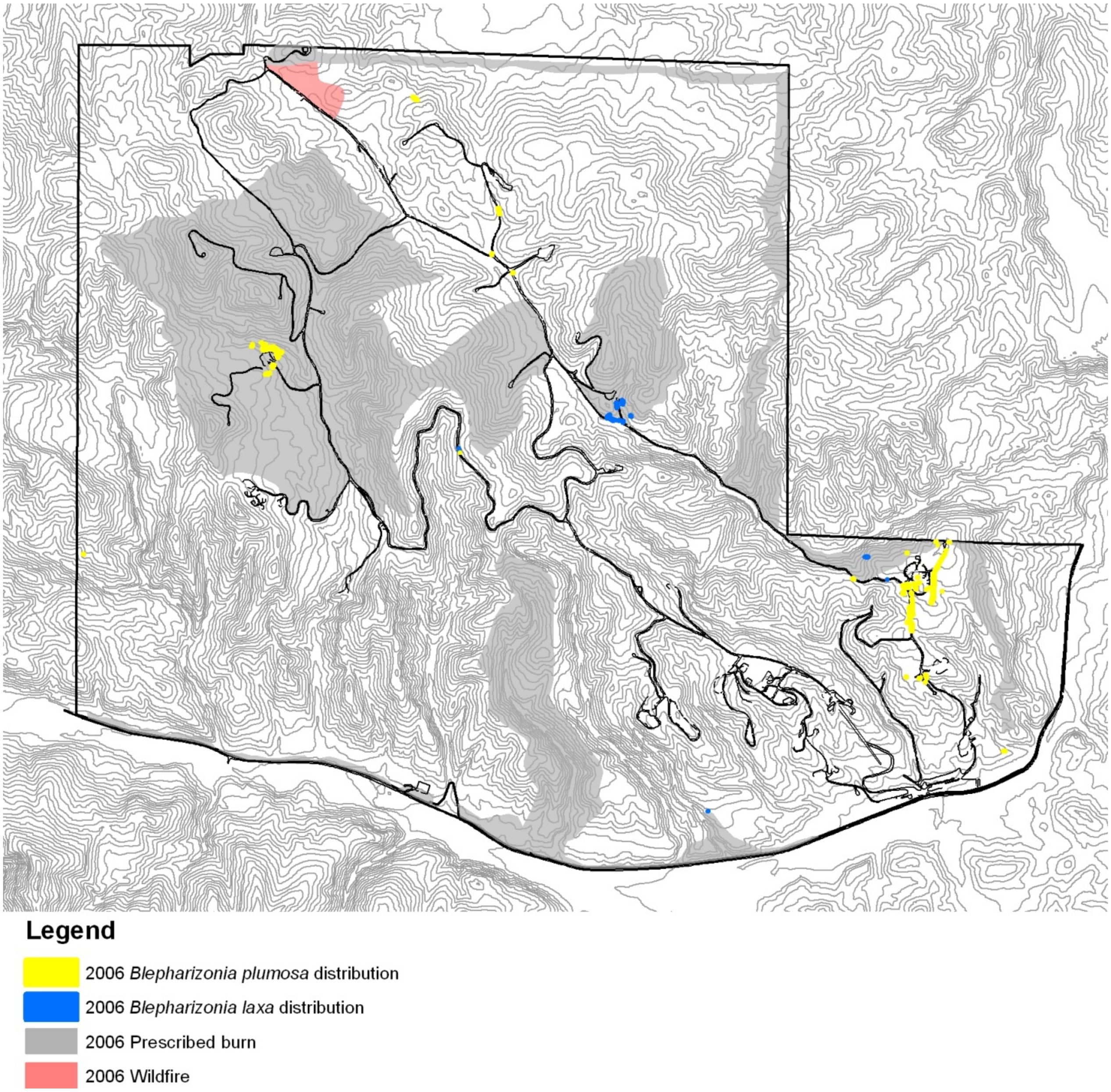


Figure B11. Enlargement of Figure B4 (2006). ***Blepharizonia*** **populations mapped in the fall of 2006. The 2006 prescribed burn and wildfire areas are also mapped.**

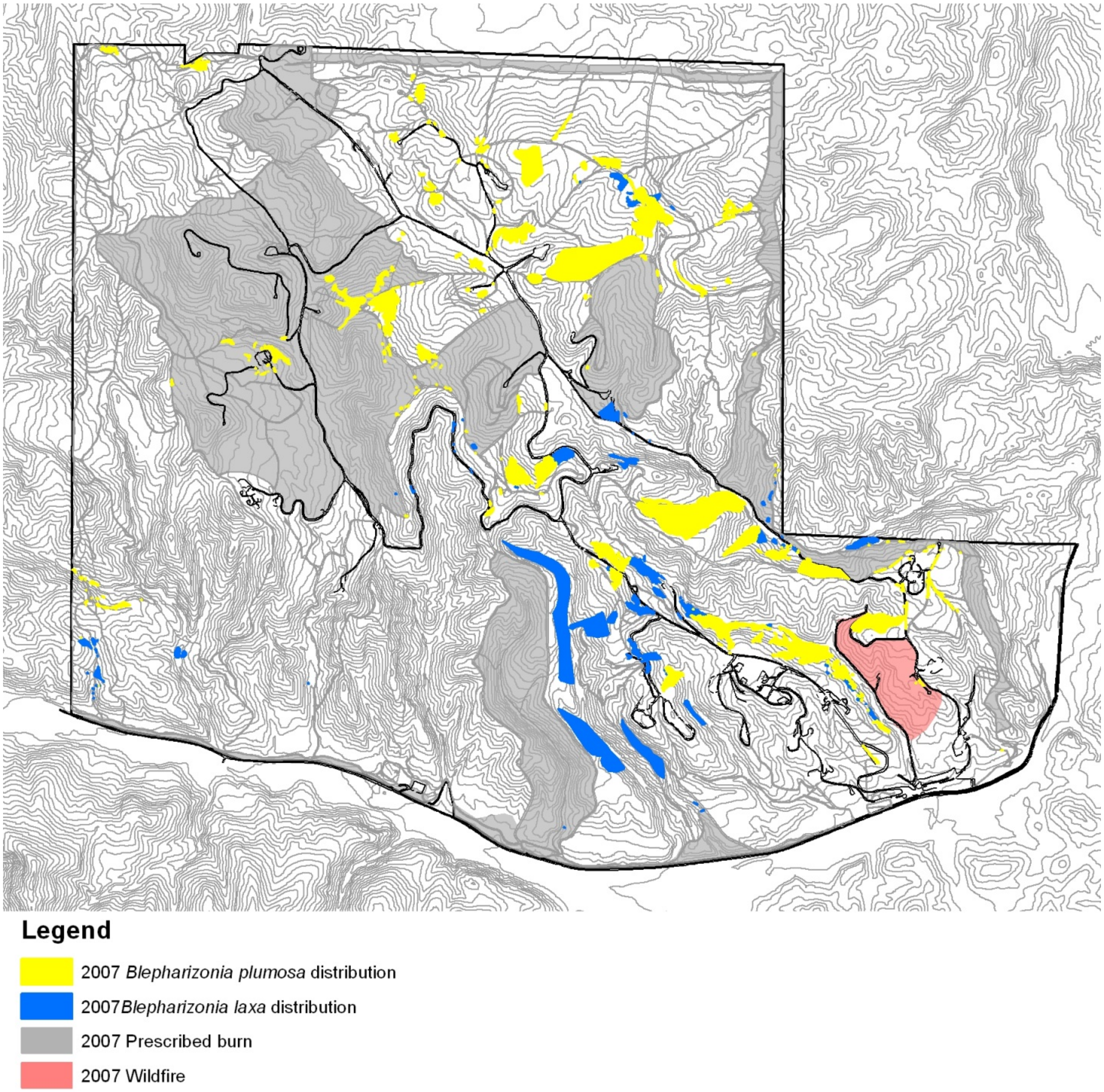


Figure B12. Enlargement of Figure B4 (2007). *Blepharizonia* populations mapped in the fall of 2007. The 2007 prescribed burn and wildfire areas are also mapped.

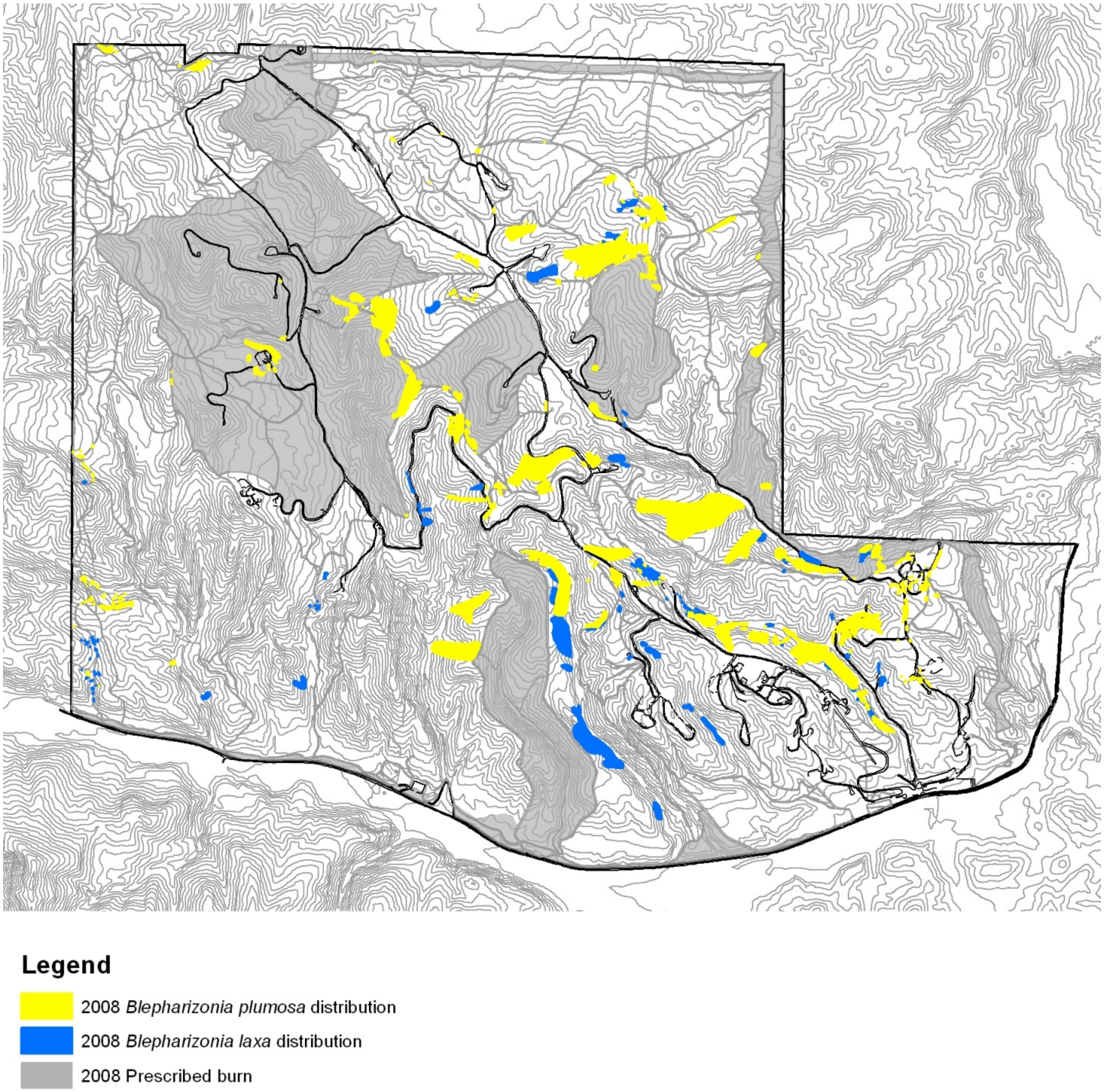


Figure B13. Enlargement of Figure B4 (2008). ***Blepharizonia*** **populations mapped in the fall of 2008. The 2008 prescribed burn is also mapped.**

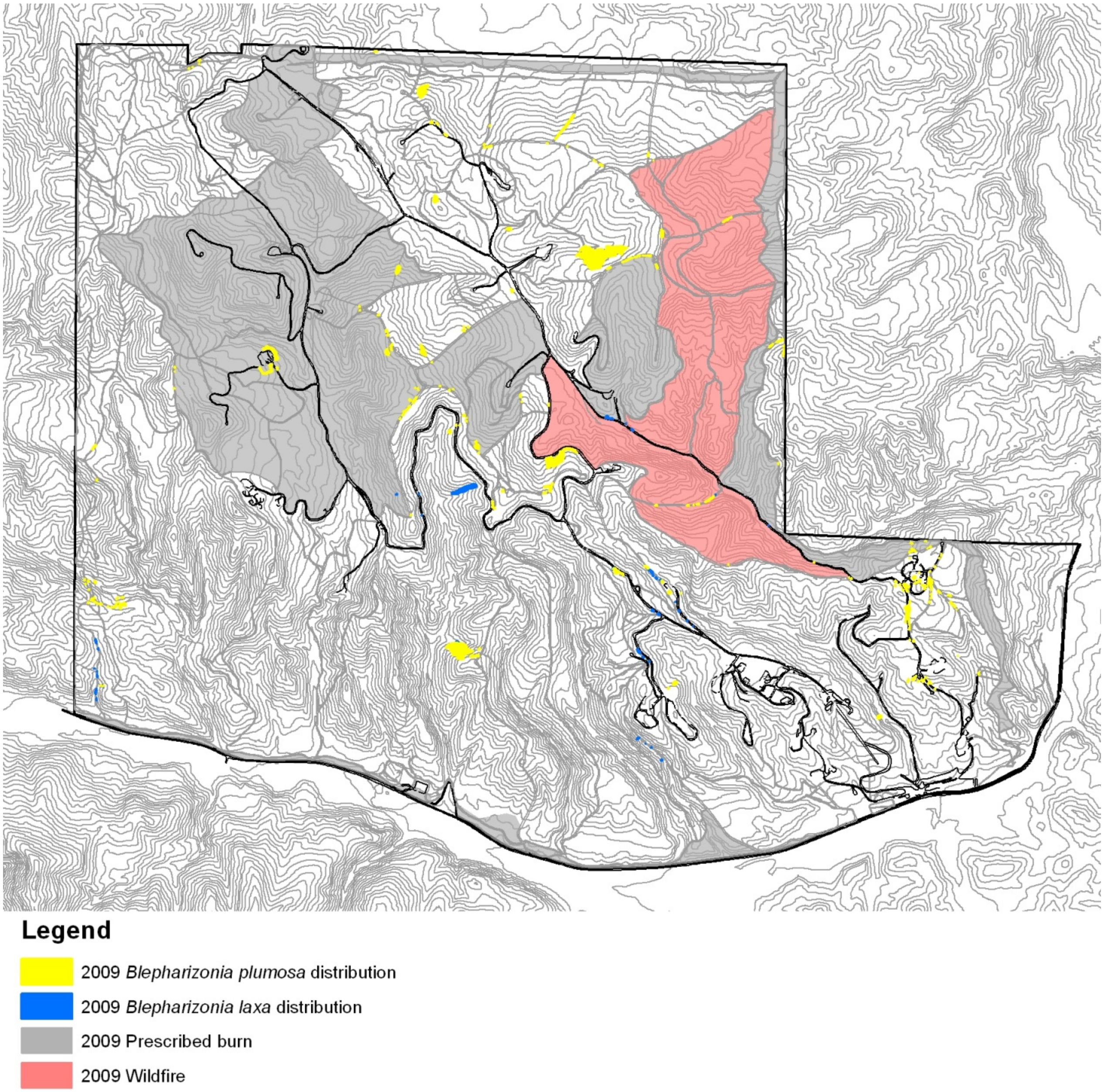


Figure B14. Enlargement of Figure B5 (2009). *Blepharizonia* populations mapped in the fall of 2009. The 2009 prescribed burn and wildfire areas are also mapped.

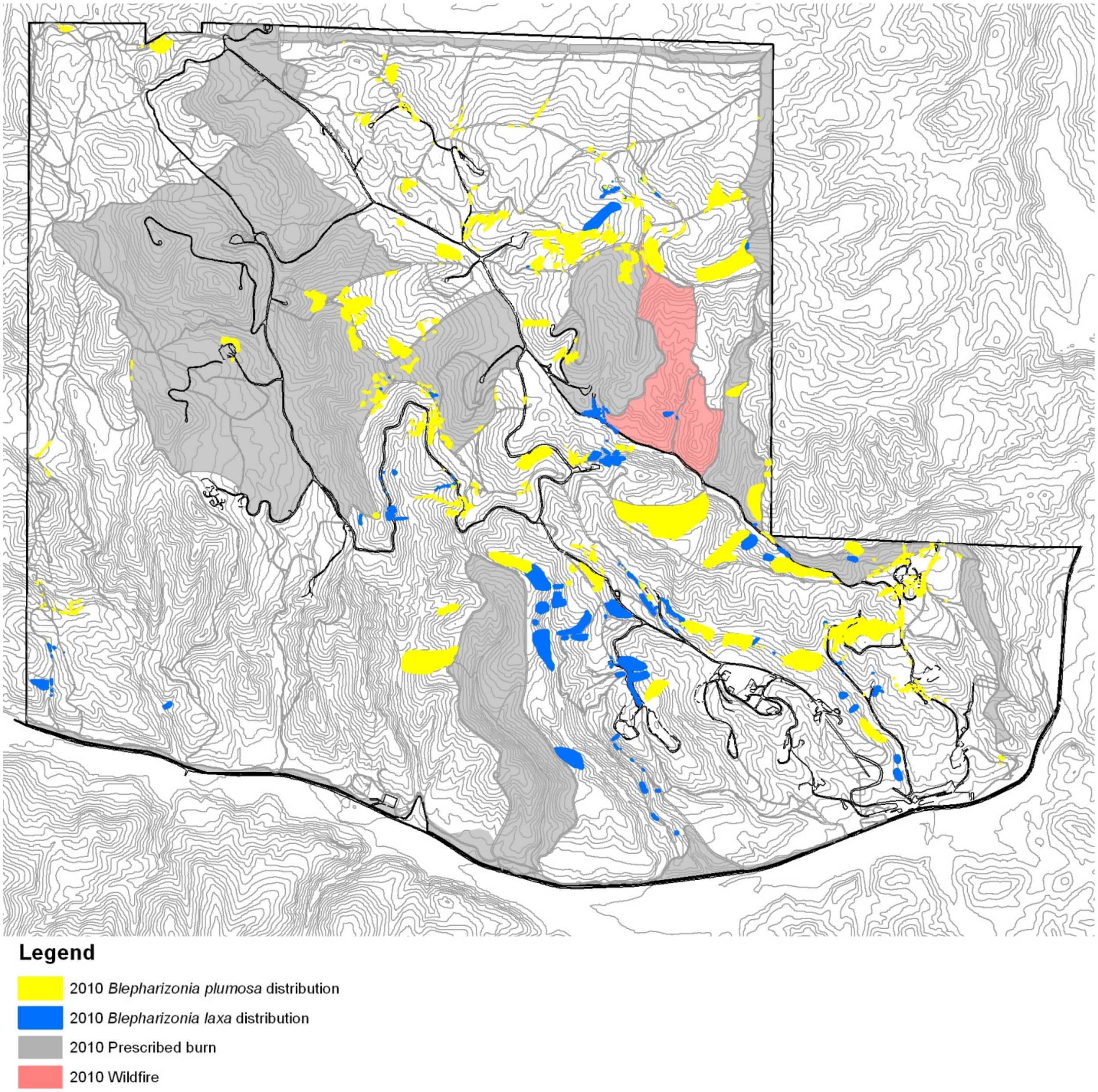


Figure B15. Enlargement of Figure B5 (2010). *Blepharizonia* populations mapped in the fall of 2010. The 2010 prescribed burn and wildfire areas are also mapped.

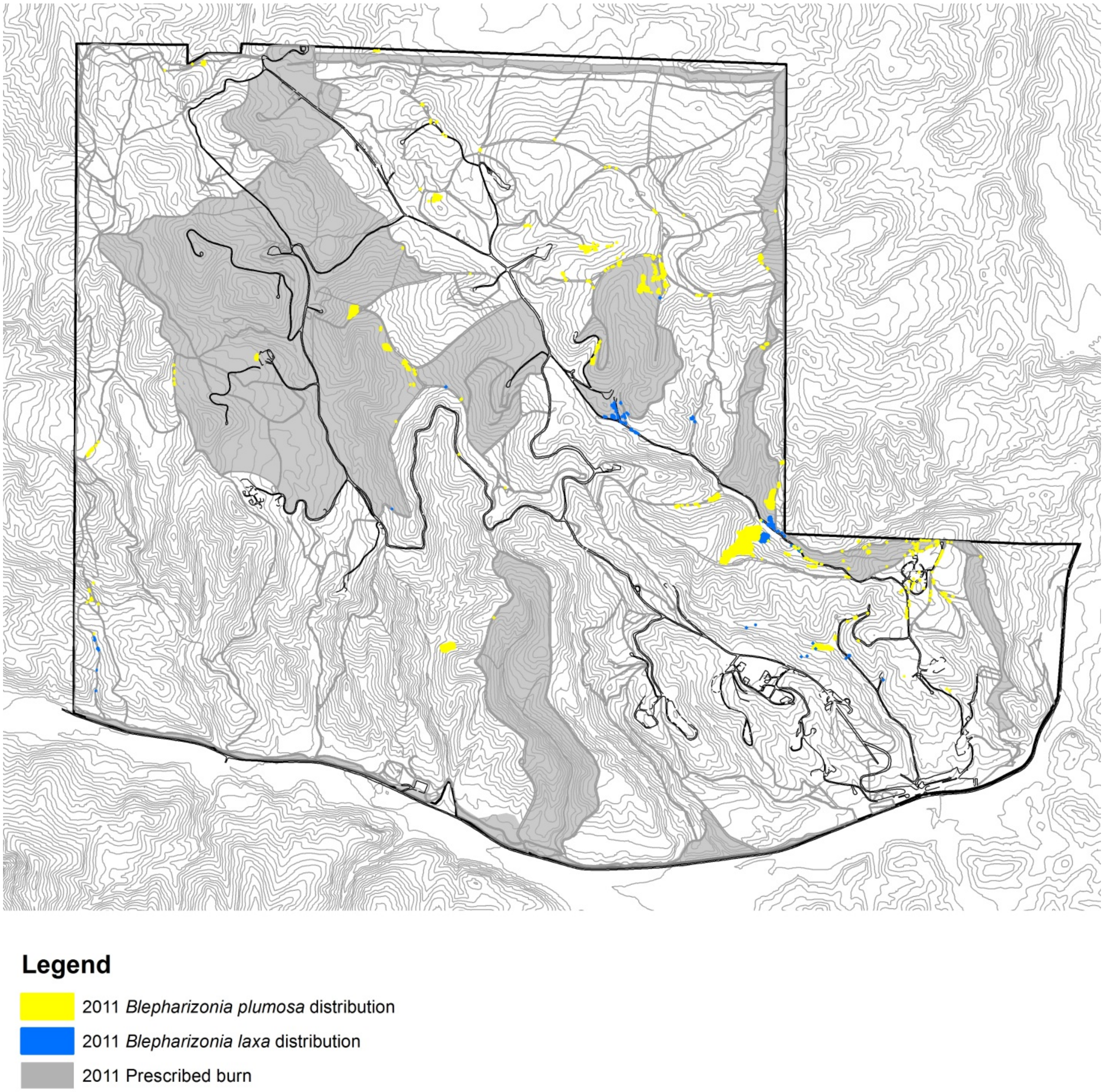


Figure B16. Enlargement of Figure B5 (2011). *Blepharizonia* populations mapped in the fall of 2011. The 2011 prescribed burn and wild fire areas are also mapped.

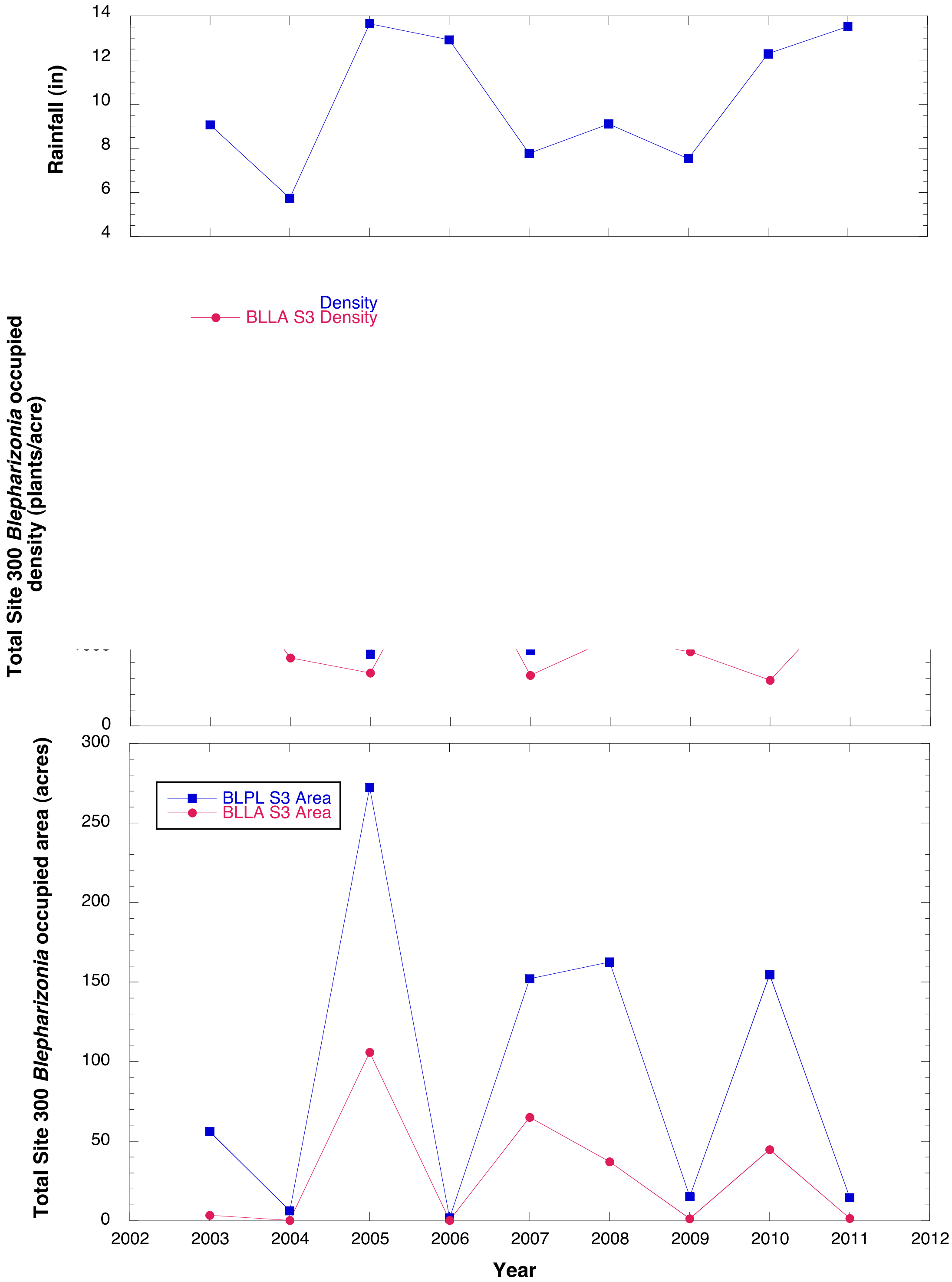
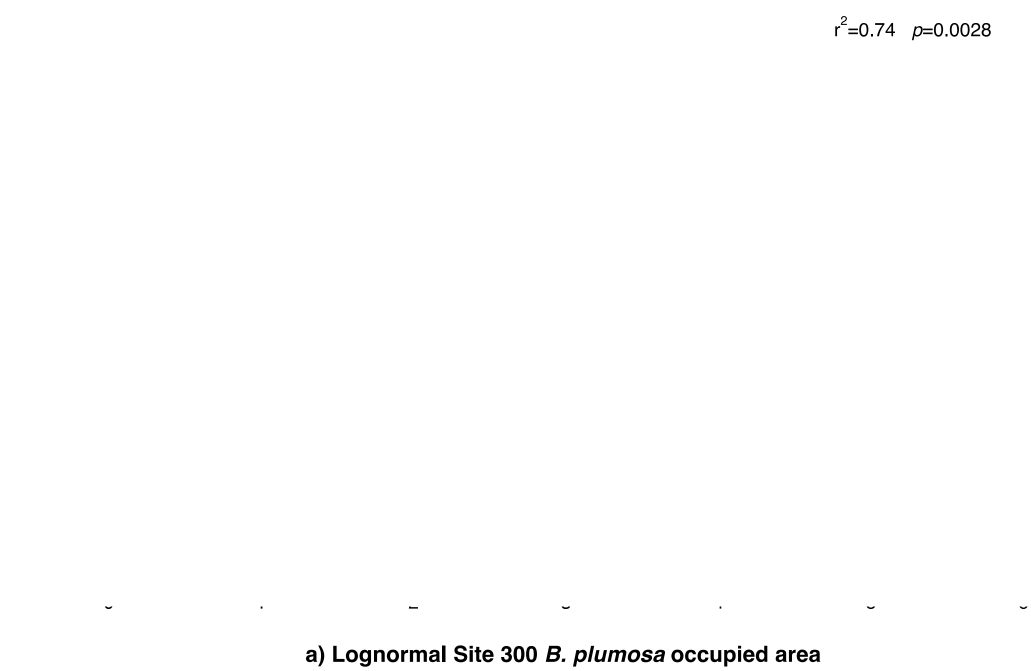


Figure B17. The total area of *Blepharizonia* populations at Site 300 each year compared to rainfall for the previous winter. For example, for 2001 the rainfall includes all rain recorded at Site 300 from September 1, 2000, to August 31, 2001.



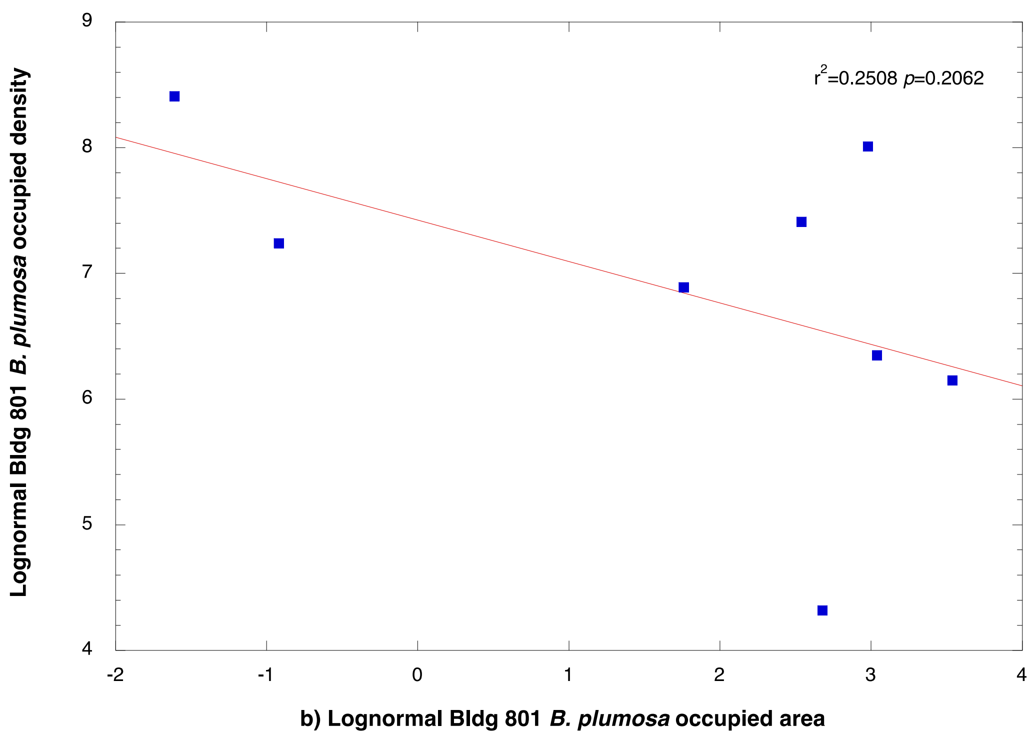


Figure B18. Relationship between *Blepharizonia plumosa* occupied area and *B. plumosa* occupied density for a) all Site 300 occupied area, and b) Building 801 occupied area only. Data lognormally transformed.

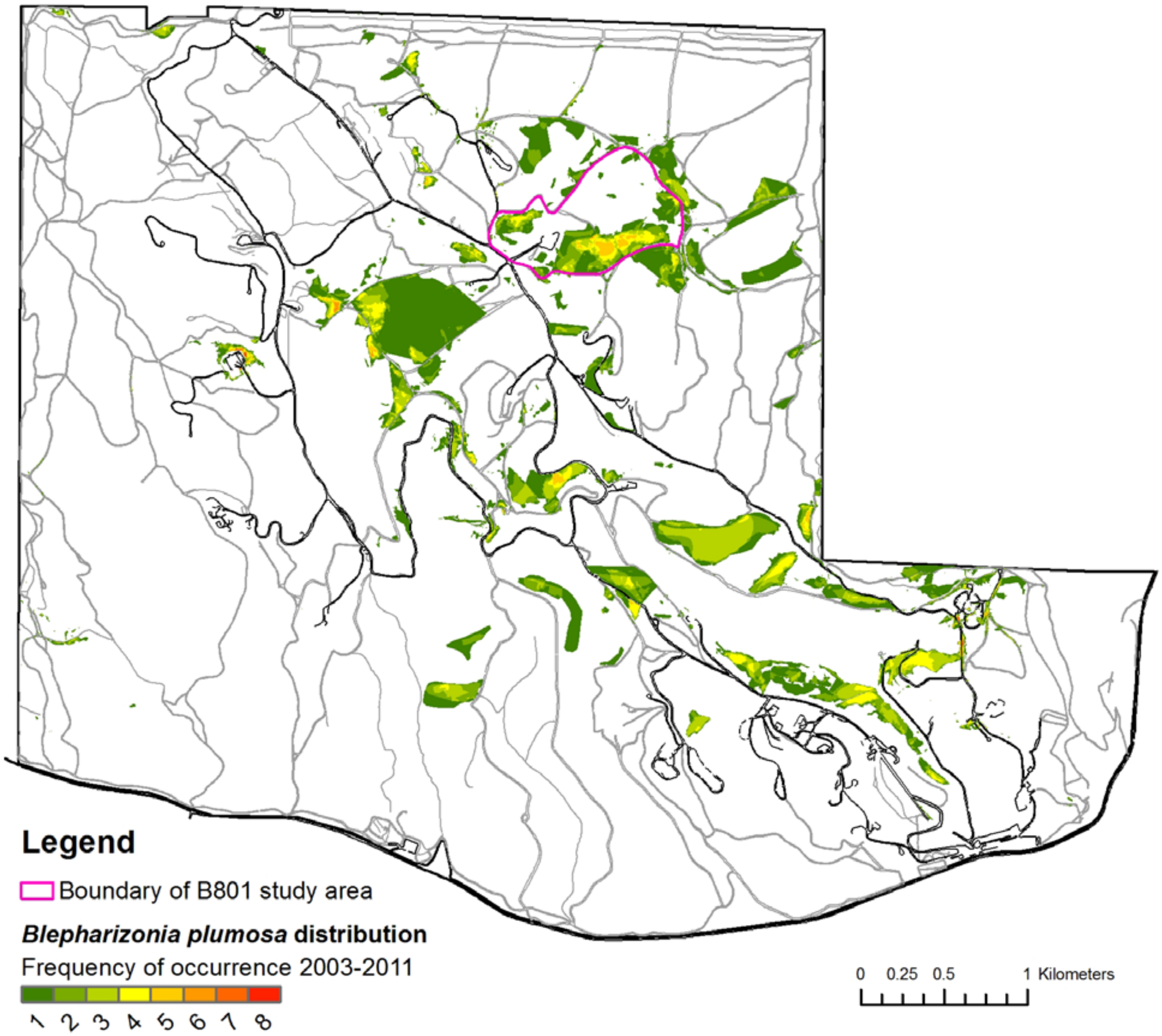
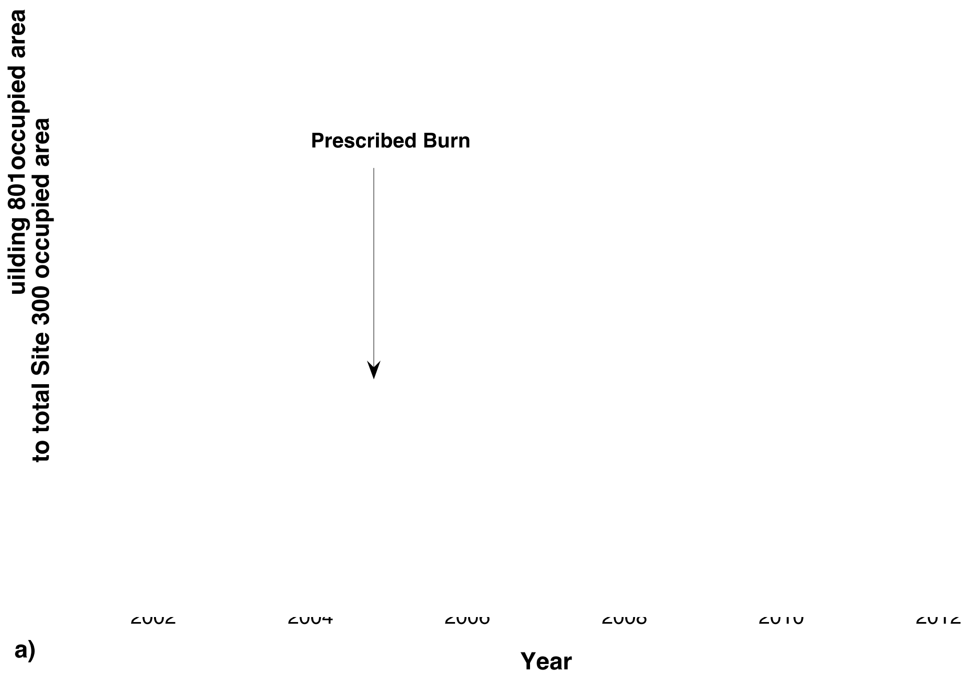
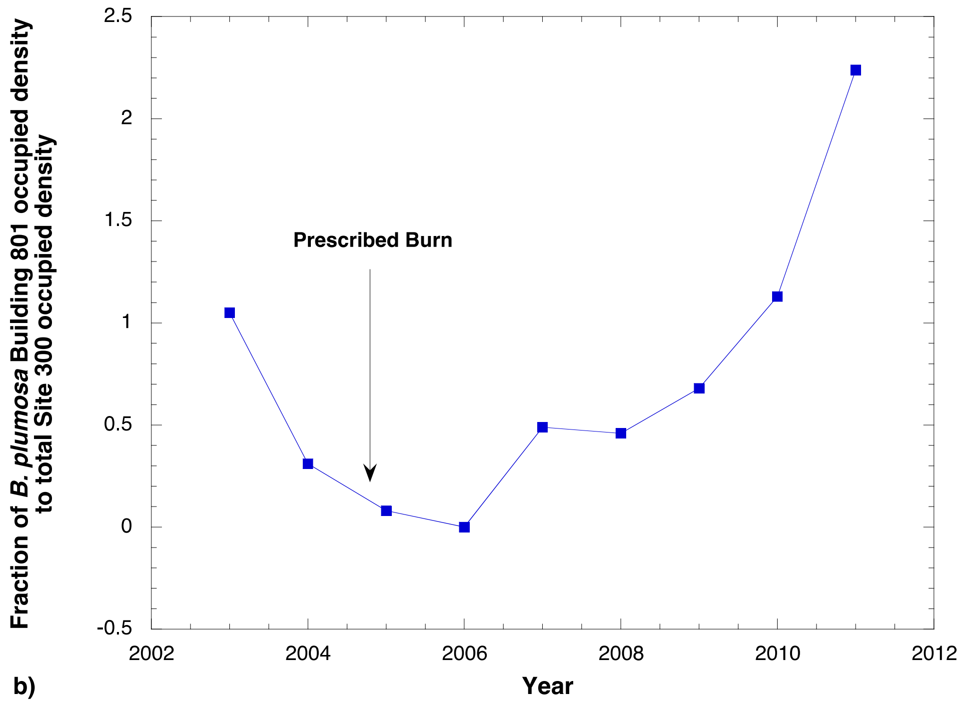


Figure B19. Frequency of occurrence of *Blepharizonia plumosa* individuals in populations mapped in 2003 through 2011.



a)



b)

Figure B20. Relationship of *Blepharizonia plumosa* populations at Building 801 to Site 300 populations, a) fraction Building 801 occupied area to total Site 300 occupied area, b) fraction of Building 801 occupied density to total Site 300 occupied density.

Section B
Tables

Table B1. Estimated population size, area and density of *Blepharizonia plumosa* at Site 300: 2001-2011.

Year	Estimated Site 300 Population Size	Total Occupied Area at Site 300 (acres)	Maximum Estimated Density at Site 300 (plants/acre)	Maximum Estimated Population Size at Bldg 801	Total Occupied Area at Bldg 801 (acres)	Maximum Estimated Density at Bldg 801 (plants/acre)
2001[a]		15.5			0	
2002[a,b]		76.3			46.7	
2003	57,851–160,209	56.1	2856	59,048	19.6	3013
2004	9,806–28,304	6.3	4493	556	0.4	1390
2005	95,653–247,047	272.3	907	1098	14.6	75
2006	2,686–10,144	1.8	5636	0	0	0
2007	55,409–145,395	152.1	956	16,261	34.6	470
2008	78,023–201,993	162.6	1242	11,954	20.9	572
2009	6,376–21,846	15.2	1437	5,700	5.8	983
2010	76,048–225,582	154.6	1459	20,927	12.7	1648
2011	6,702–28,974	14.5	1998	895	0.2	4475

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

Table B2. Estimated population size, area and density of *Blepharizonia laxa* at Site 300: 2001-2011.

Year	Estimated Site 300 Population Size	Total Occupied Area at Site 300 (acres)	Maximum Estimated Density at Site 300 (plants/acre)	Maximum Estimated Population Size at Bldg 801	Total Occupied Area at Bldg 801 (acres)	Maximum Estimated Density at Bldg 801 (plants/acre)
2001[a]		2.7				
2002[a,b]		4.9				
2003	1759–7721	3.5	2206	5500	1.4	3929
2004	42–258	0.3	860	0	0	0
2005	23,349–71,011	105.9	671	0	0	0
2006	176–754	0.3	2513	0	0	0
2007	16,311–41,707	65.0	642	368	1.8	204
2008	11,791–40,895	37.1	1102	868	4.0	217
2009	266–1224	1.3	942	0	0	0
2010	8,302–25,928	44.8	579	809	4.2	193
2011	639–2,327	1.4	1662	0	0	0

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

Section C
Eschscholzia rhombipetala
Monitoring

Section C
Eschscholzia rhombipetala
Monitoring

C-1. Introduction

Eschscholzia rhombipetala Greene (the diamond-petaled poppy) is an extremely rare spring-flowering annual plant currently included on the California Native Plant Society (CNPS) List 1B (CNPS, 2012). 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 Range (Figure C1; CNDDB, 2012). The last herbarium collections of *E. rhombipetala* were made in 1950 in San Luis Obispo County, and the species had 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, *E. rhombipetala* grows 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 in Corral Hollow in 1937 (collection number UC765993, cited in Espeland and Carlsen, 2003), 1940 (CNDDB, 2012) and 1949 (P. Raven, personal communication cited in 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 C2). 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 *Monolopia* and *Lupinus* 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 C2). 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 near the western perimeter 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 populations at 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).

During the 2008 spring census of *California macrophylla*, two *E. rhombipetala* plants were observed at *C. macrophylla* site 2 (Figure C2, Figure D10) on the southern berm of the fire trail at that location. Because *E. rhombipetala* is so small and easily overlooked, it is likely that it is found at other Site 300 locations that have not yet been identified.

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 (Hannan and Clark, 2012).

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, census data is collected annually 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. Spring Census

Table C1 summarizes the fieldwork conducted at the *E. rhombipetala* populations between March 2007 and April 2011. Table C1 shows the dates in which the census (plant count) of each population was conducted. Table C1 also shows the dates in which plant measurements were obtained. Measurements were taken either at the time of the population census, or during the vegetation sampling. Height, flower number and capsule length were recorded for populations at 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 recorded 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).

The distribution of *E. rhombipetala* was recorded at the time of the spring census using a handheld Trimble Geo XT Global Positioning System (GPS). Data were post processed to improve accuracy. Average estimated accuracy is less than 0.5 m. For groups of one or two plants, the location of these plants was recorded as points. Larger groups of plants were recorded as polygons.

The GPS data were important to ESRI ArcGIS 10.0 for analysis. Polygon and point data were converted to raster data with 3 ft^2 cells. The ArcGIS tool "feature to raster" was used to complete this conversion. A separate raster layer was constructed for each year (2005-2011), and cells containing *E. rhombipetala* were assigned the value of "1" using the following map algebra equation:

((Abs(IsNull("ESRH20XXpnt")-1)) + (Abs(IsNull("ESRH20XXply")-1))

The frequency maps where constructed by summing the raster layers for all years 2005 through 2011 and assigning a green to red color ramp to the values. Red cells contained *E. rhombipetala* seven and of seven years (a raster value of 7) and dark green cells only contained *E. rhombipetala* once in the seven year period (a raster value of 1).

C-2.2. Community Cover Estimates

Community cover estimates were collected from 60 cm $\times$ 60 cm quadrats on the dates shown in Table C1. 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 community sampling: slump, scarp and grassland. The goal was to measure five quadrats with *E. rhombipetala* and five quadrats without *E. rhombipetala* in each of the three areas. In some cases, there were less than five locations with *E. rhombipetala.* In these cases, quadrats were sampled in all locations where *E. rhombipetala* was found (Table C1). The locations of quadrats that did not contain *E. rhombipetala* were selected haphazardly within the general boundary of the area where *E. rhombipetala* was found during the census.

For sites 2 and 3, the goal was to measure at least five quadrats containing *E. rhombipetala* and five that did not contain *E. rhombipetala.* At site 2, five quadrats with *E. rhombipetala* and five quadrats without *E. rhombipetala* were measured in all years except for in 2011, when no *E. rhombipetala* was present. The locations of quadrats that did not contain *E. rhombipetala* were selected haphazardly within the general boundary of the area where *E. rhombipetala* was found during the census except in 2008. In this year, the quadrats that did not contain *E. rhombipetala* were placed adjacent to the quadrats that contained *E. rhombipetala* (i.e. the quadrats were paired).

Because of the large number of plants typically present at site 3, community 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*. Five quadrats with *E. rhombipetala* and five without *E. rhombipetala* were sampled for all years (Table C1).

C-2.2.1. Analysis of Cover Estimates

Cover data were analyzed by calculating mean cover, constancy and importance value (IV) for each species. 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. Mean cover was also calculated for thatch, bare ground, total native grass cover, total native forb cover, total exotic grass cover and total exotic forb cover.

Shannon's Diversity Index (Shannon's Index, H') was also calculated using the cover data from each site using the equation shown in Section A-2.2.2. In this case, the sum of all the individual cover measurements collected in the population was used as n (the total number of individuals), and the sum of the cover measurements for species *i* was used as n_i (the number of individuals of the *i*th species).

C-3. Results

C-3.1. Spring Census

Results of the spring census are shown in Figures C3 and C4 and Tables C2 and C3. Populations at all three sites were relatively large in 2008 and 2010, with fewer plants observed in 2007 and 2011. Moderate numbers of plants were observed in 2009. As can be seen in Figure C3, the number of *E. rhombipetala* appears to be negatively associated with rainfall, with fewer numbers of individuals observed when rainfall exceeds around 10 inches per year. As shown in Figure C4, at site 1, when rainfall is low, more individuals are observed in the grassland area, whereas in high rainfall years, most individuals are observed in the scarp area.

As shown in Table C3, plants at site 3 tend to be larger, with more floral units per plant and longer capsules. However, this may be an artifact of the time when measurements are taken, as the population at site 3 is typically measured later in the growing season.

The average estimated seed production per plant for the measured plants at each site is also shown in Table C3. This estimate used a regression equation developed in 2005 from measurements obtained from site 3 plants (Paterson et al., 2010). The relationship of seed number to capsule length was significant (r^2 of 0.91 at p<0.001). The regression equation explaining the number of seeds produced by capsule length was number of seeds = 5.64 • (capsule length in cm) – 9.59. This regression is probably most accurate for plants at site 3 and for plants measured later in the growing season. Plants at site 3 tended to have a higher average seed production per plant than those found at sites 1 or 2. As mentioned above, this may be an artifact of the time when measurements are take at site 3.

Figures C5 through C10 shows the distribution and the frequency of occurrence of *E. rhombipetala* plants in the populations at sites 1 through 3, as determined by available GPS data. As can be seen in Figure C6, *E. rhombipetala* has a core location at site 1 on the scarp where plants have been observed in all years. No core location is observed in the slump and grassland areas, indicating locations containing *E.*

rhombipetala vary from year to year in these areas. There is also no core area observed at site 2 (Figure C8). Site 3 contains two core areas, a large and persistent area within the grassland bowl area, and a smaller, slightly less persistent area along the road (Figure C10).

C-3.2. Community Cover Estimates

Table C4 summarizes the community cover estimates for site 1 for quadrats measured in the slump, scarp and grassland areas, both with and without *E. rhombipetala*. Table C5 summarizes the community cover estimates for quadrats measured in sites 2 and 3, both with and without *E. rhombipetala*. Table C6 lists the species observed in the three sites.

In site 1, quadrats containing *E. rhombipetala* tend to have more bare ground and less thatch (Table C4). The scarp area, which often contains the most *E. rhombipetala* individuals, has the highest amount of bare ground, and the least amount of thatch of the three areas. Exotic grass cover also tends to be lower in quadrats containing *E. rhombipetala* when compared to quadrats without *E. rhombipetala*. In addition, the number of species observed and Shannon's Index (H') also tend to be higher in quadrats containing *E. rhombipetala.* In sites 2 and 3 (Table C5), the relationship of *E. rhombipetala* to bare ground, thatch and exotic grass cover is more variable as compared to site 1. This is also the case for the number of species and Shannon's Index (H'). However, in general, the same relationships observed in site 1 also hold in sites 2 and 3.

Using the combined data from all sites from the years 1999-2006, a logistic regression analysis found that *E. rhombipetala* absence is negatively correlated with the percent cover of bare ground and native grass, and positively correlated to the percent cover of thatch, exotic grass, and exotic forbs (Paterson et al., 2010). *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. The data presented in Tables C4 and C5 continue to support this conclusion.

C-4. Discussion and Recommendations for Future Work

The population at site 1 has now been censused for fourteen consecutive years, site 2 has been censused for ten years, and site 3 has been censused for eight years. These populations continue to follow similar abundance patterns, with all three populations increasing and decreasing in abundance over time generally in synch with each other. Since its discovery in 2004, site 3 consistently has been the largest of the three Site 300 *E. rhombipetala* populations, containing more than 7000 plants in 2008, 400 plants in 2009 and 1000 plants in 2010, although just over 100 plants were observed in 2007 and only 31 plants in 2011. During 2007, site 1 had 7 plants and site 2 had six plants, where as in 2011 no plants were observed in site 2 and only 16 plants in site 1.

Site 3 differs from 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 2 is 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, although some of this may be an artifact of measurement timing.

Using data collected between 1999 and 2006 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 (Paterson et al., 2010). In other words, *E. rhombipetala* is less likely to occur in areas with dense cover of thatch, exotic grasses and exotic forbs that lack native grasses. This pattern continued through 2011. Although sites 1, 2, and 3 are very different from one another in terms of vegetation and slope, 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 addition, the data collected through 2011 show that *E. rhombipetala* population size appears to be inversely related to rainfall. This would be consistent with the interpretation that increased rainfall favors large amount of exotic grass cover, thus reducing bare ground and increasing thatch. Additional statistical analysis should be conducted to further explore this relationship.

The regression equation developed in 2005 (Paterson et al., 2010) relating capsule length to seed production was used on the plants measured from the three sites between 2007 and 2011. While this did not represent the entire seed production for each site, the results demonstrated the high seed production occurring in site 3 compared to sites 1 and 2. However, caution should be used in interpreting these data, as the average capsule length measured during the census is seldom done at maturity, as was done in developing the regression equation. The annual census is typically conducted over one or two days during the early spring when plants are still in flower and many capsules are not yet mature. This equation could be made more accurate by determining the relationship between the capsule length at the time of the spring census compared to the capsule length when fruits are mature.

Frequency of occurrence analysis using GPS data from years 2005 through 2011 revealed that sites 1 and 3 have core populations that occur in most years, from which the population likely expands during favorable years. The site 2 location, on the other hand, has no core area, suggesting a widely dispersed seed bank from which seedlings establish each year on a somewhat random basis. The gene flow between these populations is not known, and investigating this would be an important area of future research.

Size, fecundity and cover data, have been collected to explore the environmental factors that positively influence *E. rhombipetala* fitness and create self-sustaining populations. *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. Data on germination and survivorship for this species have not been collected at Site 300 because of the extreme rarity of *E. rhombipetala*.

C-5. References

Clark, C. 2000. (http://www.csupomona.edu/~jcclark/poppy/rho.html); Personal communication between Dr. Tina M. Carlsen, environmental scientist, Lawrence Livermore National Laboratory, Livermore, Calif. and Dr. Curtis Clark, professor, Biological Science Department, California State Polytechnic University, April 10, 11, and July 4, 2000.

CNPS (California Native Plant Society). 2012. Inventory of Rare and Endangered Plants (online edition, v8-01a). California Native Plant Society. Sacramento, CA. Accessed on Fri, Jan. 13, 2012 from http://www.cnps.org/inventory.

CNDDB (California Natural Diversity Data Base). 2012. California Natural Diversity Database, Biogeographic Data Branch, California Department of Fish and Game, Sacramento, CA. Accessed on Thur., Jan. 12, 2012 from http://www.dfg.ca.gov/biogeodata/cnddb/mapsanddata.asp

Espeland, E.K., and T.M. Carlsen. 2003. "Population characteristics of *Eschscholzia rhombipetala* E. Greene (Papaveraceae)." *Madroño* **50**(1):1–7.

Espeland, E.K., and R.G. Myatt. 2001. "Evidence for a sand hills ecotype of *Eschscholzia californica* (Papaveraceae)." *Madroño* **48**:25–32.

Fox, G.A., A.S. Evans, and C.J. Keefer. 1995. Phenotypic consequences of forcing germination: a general problem of intervention in experimental design. *American Journal of Botany* **82**(10):1264–1270.

Hannan, G. L., and C. Clark. 2012. *Eschscholzia*. In Baldwin, B. G., D. H. Goldman, D. J. Keil, R. Patterson, T. J. Rosatti, and D. H. Wilken, (Ed.) 2012. *The Jepson manual: vascular plants of California*, second edition (pg. 982). (University of California Press, Berkeley, CA.)

Hayes, G. 2002. *Cattle grazing effects on California coastal prairie and associated annual forbs*. PhD dissertation, University of California, Santa Cruz.

Heady, H.F. 1956. Changes in a California annual plant community induced by manipulation of natural mulch. *Ecology*. **37**:798–812.

Keil, D. 2001. personal communication between Dr. Tina M. Carlsen, environmental scientist, Lawrence Livermore National Laboratory, Livermore, Calif. and Dr. David Keil, professor, Biological Science Department, California State Polytechnic University, February 3, 2001.

Meyer, M.D., and P.M. Schiffman. 1999. "Fire season and mulch reduction in a California grassland: a comparison of restoration strategies." *Madroño* **46**:25–37.

Paterson, L.E., T.M. Carlsen, T.M. Alfaro and E. Espeland. 2010. *Rare plant restoration and monitoring at Lawrence Livermore Laboratory, Site 300, Project*

Progress Report, Fiscal Year 2005 and 2006. Lawrence Livermore National Laboratory, Livermore, CA. LLNL-TR-457357.

Preston, R.E. 2000. "Noteworthy Collection: *Eschscholzia rhombipetala*." *Madroño* **47**:138.

Skinner, M.W., and B.M. Pavlik, Eds. 1994. *Inventory of rare and endangered vascular plants of California*. California Native Plant Society Special Publication 9.

Section C
Figures

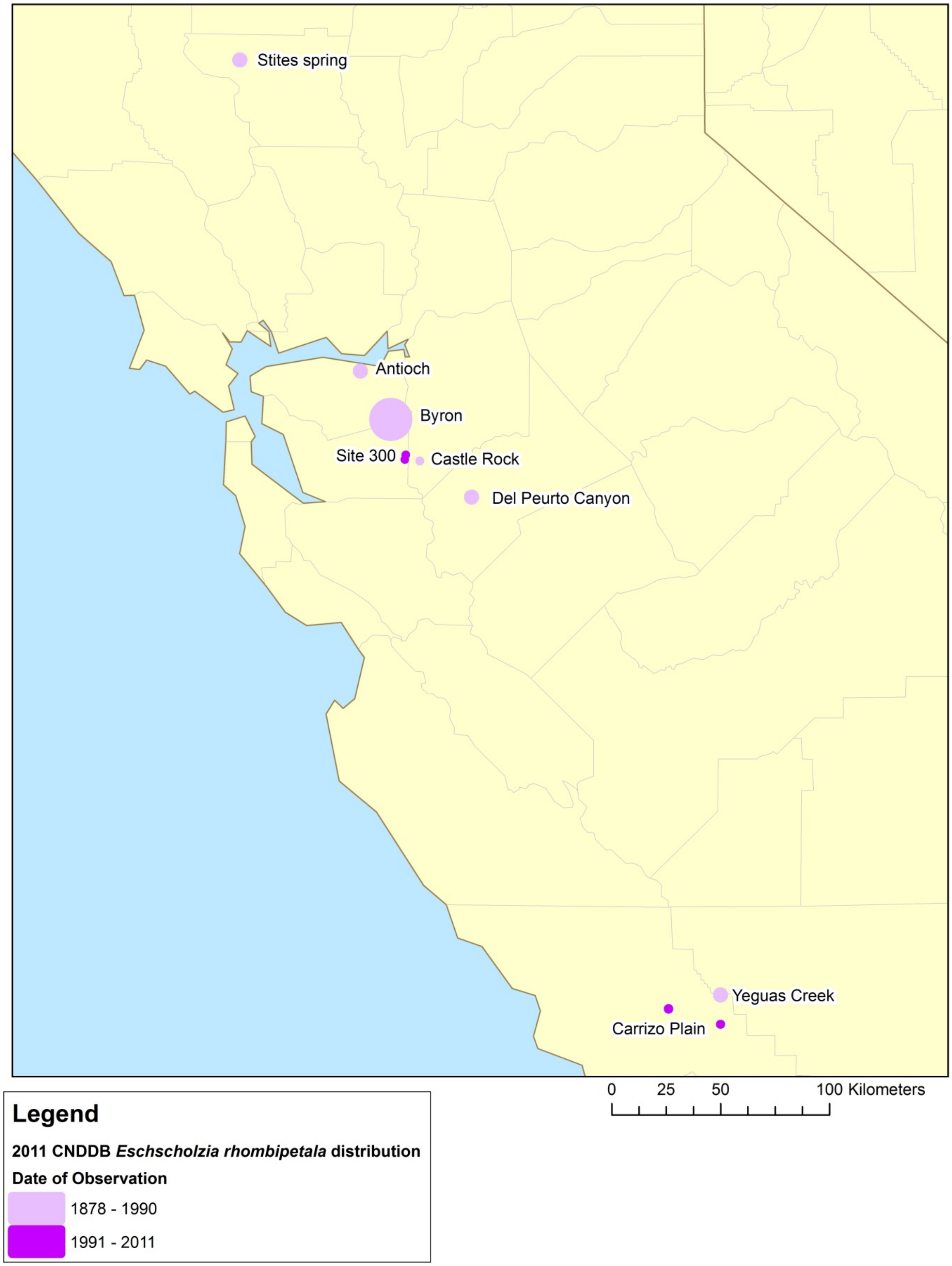


Figure C1. Current and historic occurrences of *Eschscholzia rhombipetala* as described by the California Natural Diversity Data Base (CNDDB, 2012).

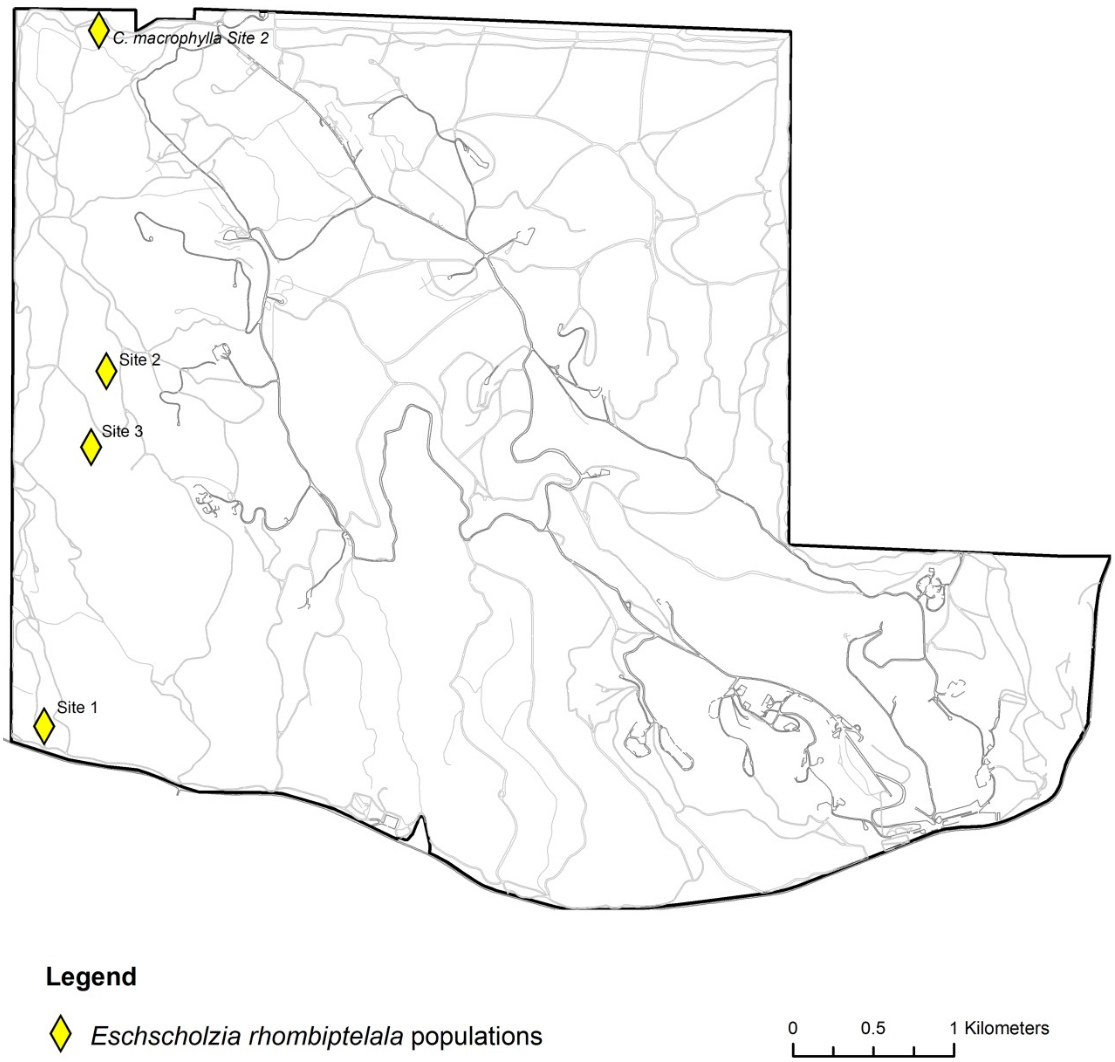


Figure C2. Distribution of *Eschscholzia rhombipetala* at Site 300.

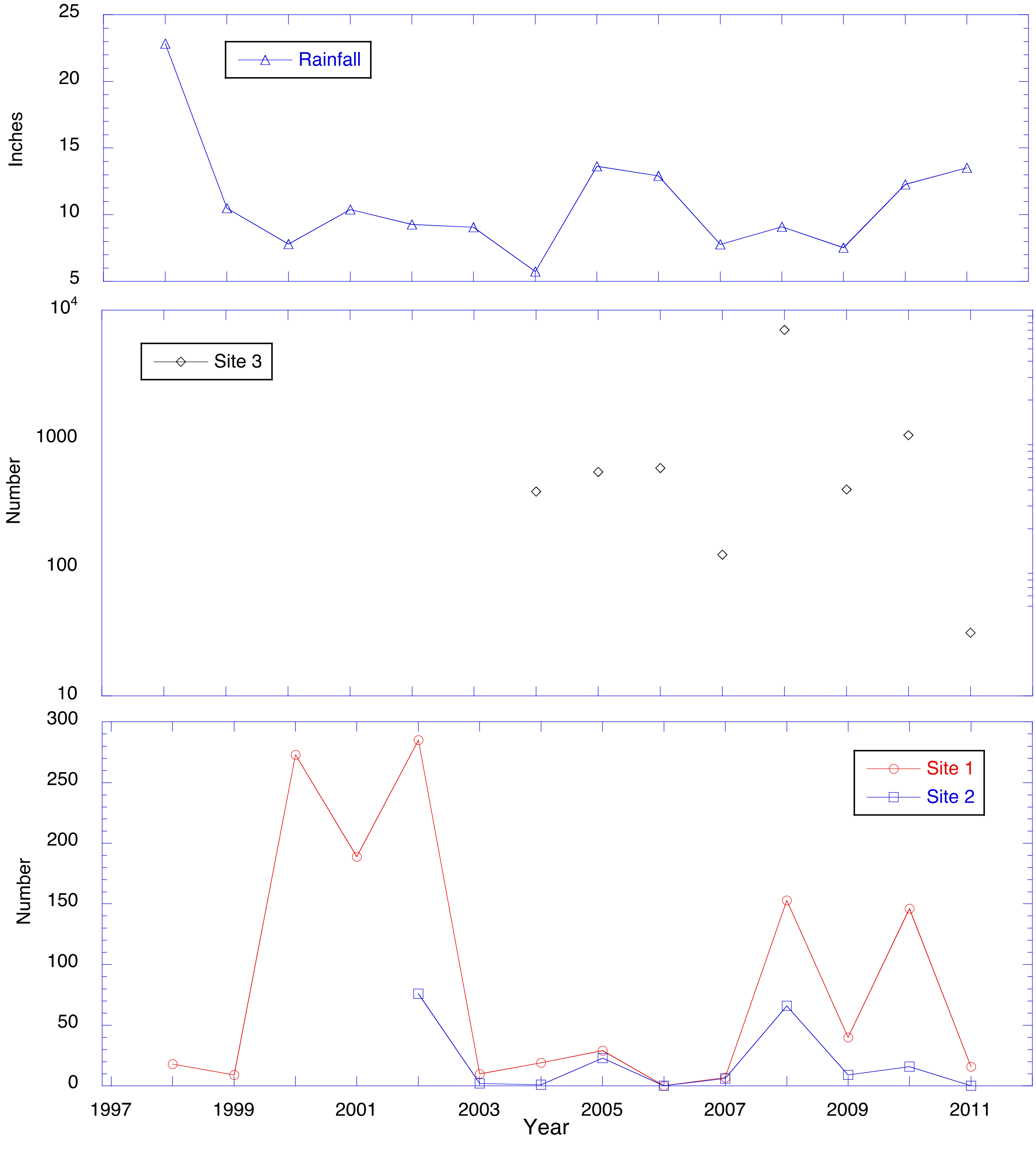


Figure C3. Spring census data of *Eschscholzia rhombipetala* at Site 300.

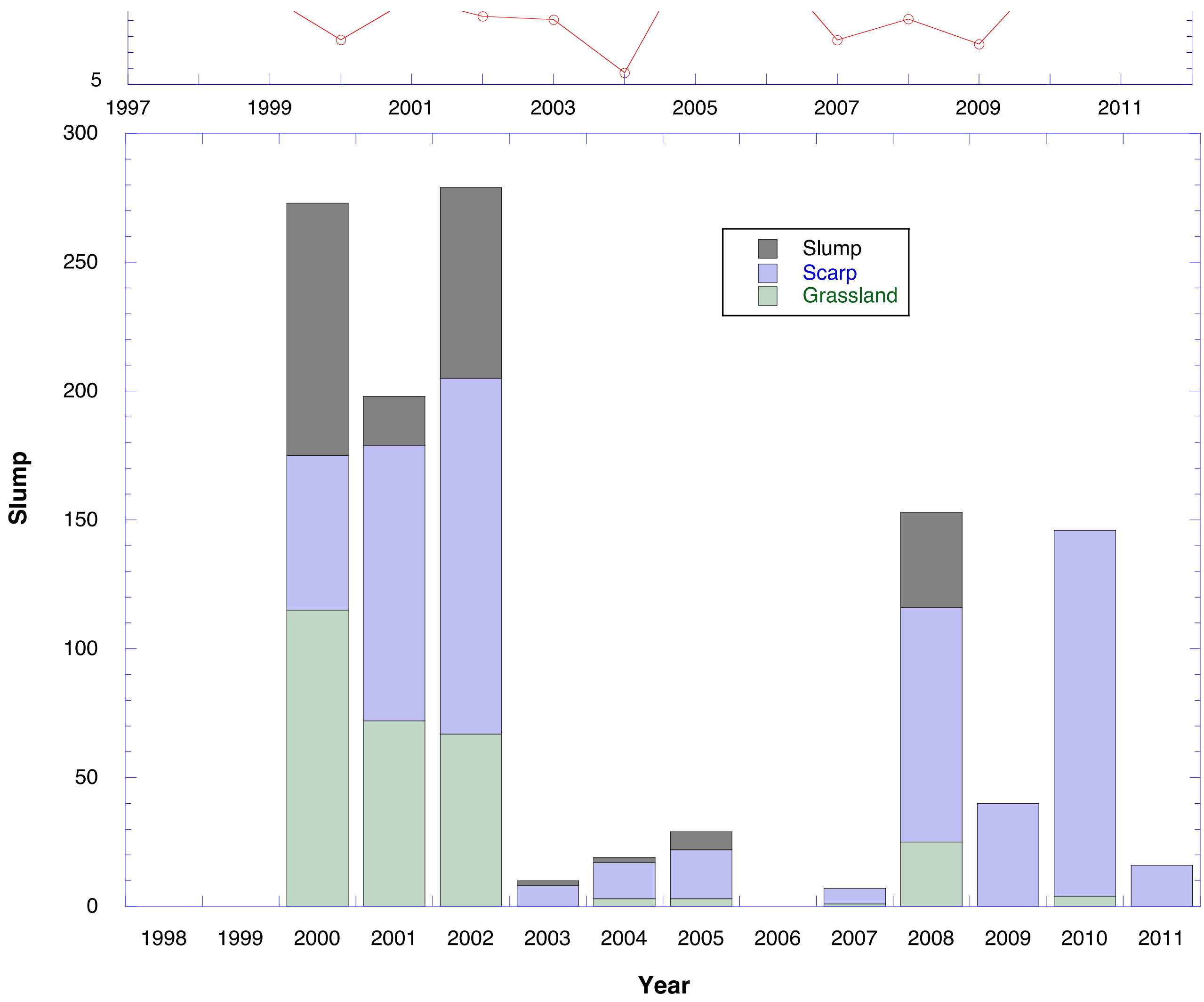


Figure C4. Spring census data for *Eschscholzia rhombipetala* at site 1 at Site 300.

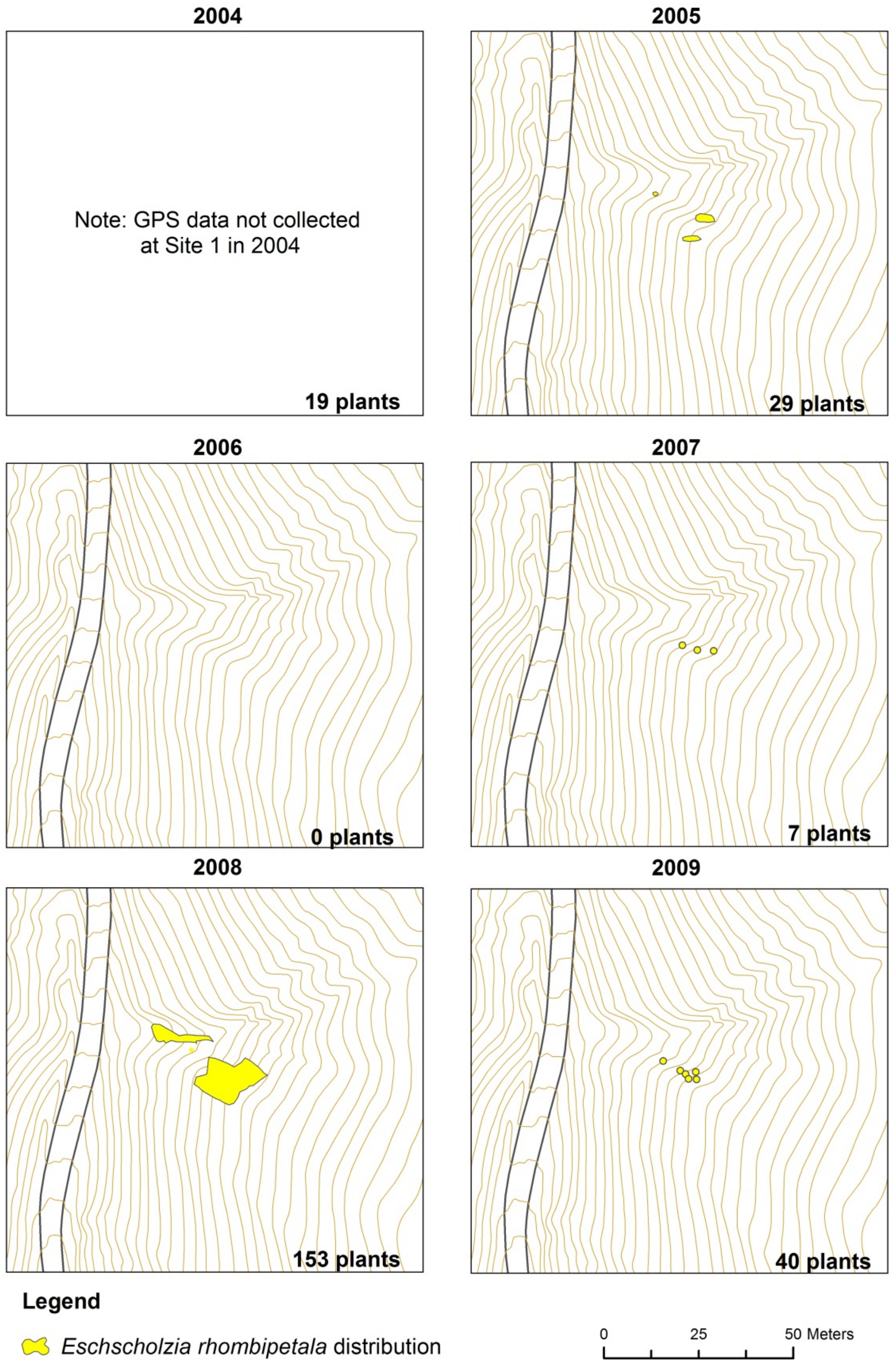


Figure C5. ***Eschscholzia rhombipetala*** **distribution at site 1 from 2005 through 2009.**

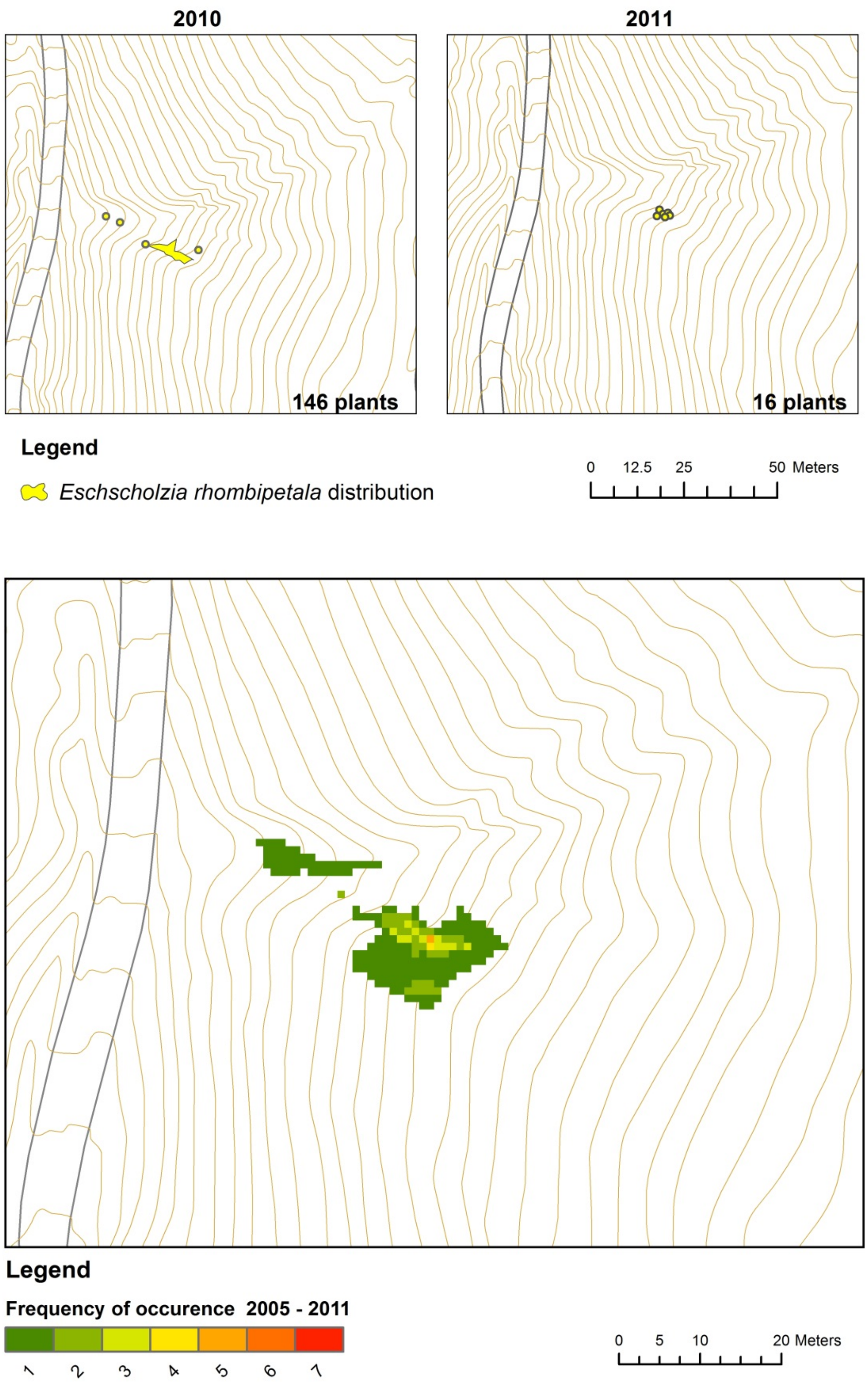


Figure C6. ***Eschscholzia rhombipetala*** **distribution at site 1 in 2010 and 2011, and frequency of occurrence of** ***Eschscholzia rhombipetala*** **at site 1 from 2005 through 2011.**

Figure C7. Boundary of the *Eschscholzia rhombipetala* distribution from 1998 through 2004, and the *Eschscholzia rhombipetala* distribution at site 2 from 2006 through 2009.

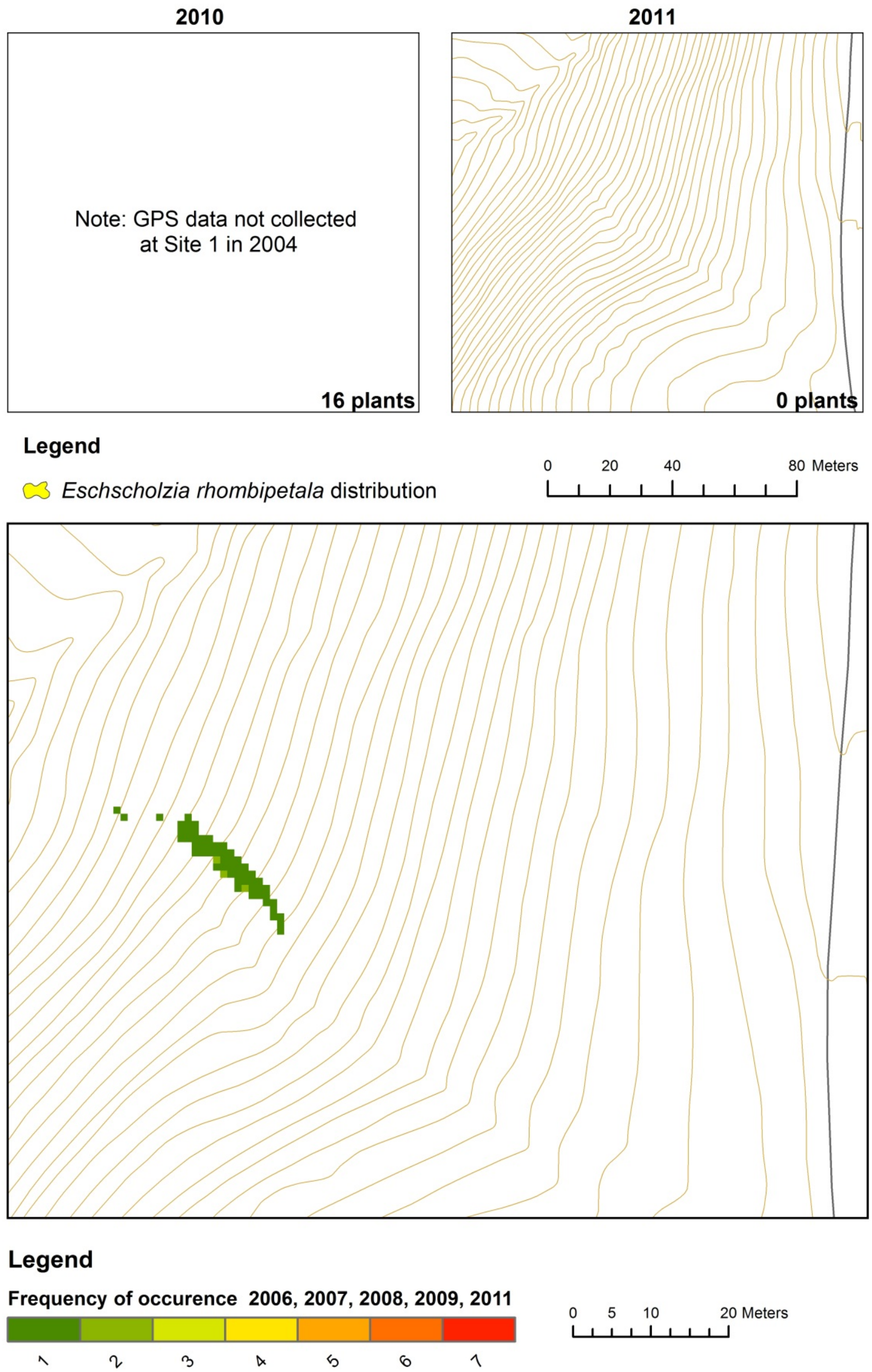


Figure C8. ***Eschscholzia rhombipetala*** **distribution at site 2 in 2011, and frequency of occurrence of** ***Eschscholzia rhombipetala*** **at site 2 for 2004, 2006 through 2009, and 2011.**

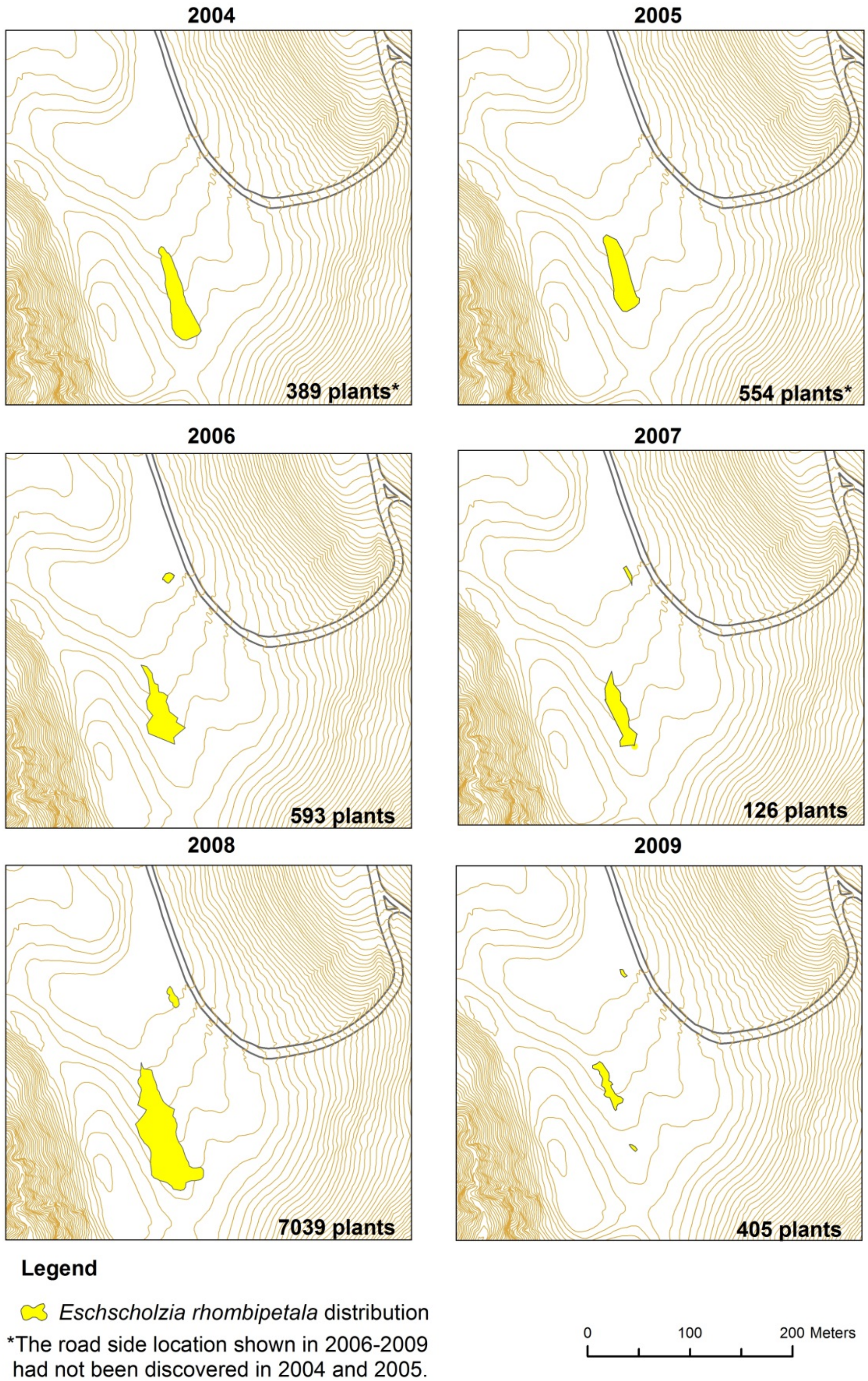


Figure C9. ***Eschscholzia rhombipetala*** **distribution at site 3 from 2004 through 2009.**

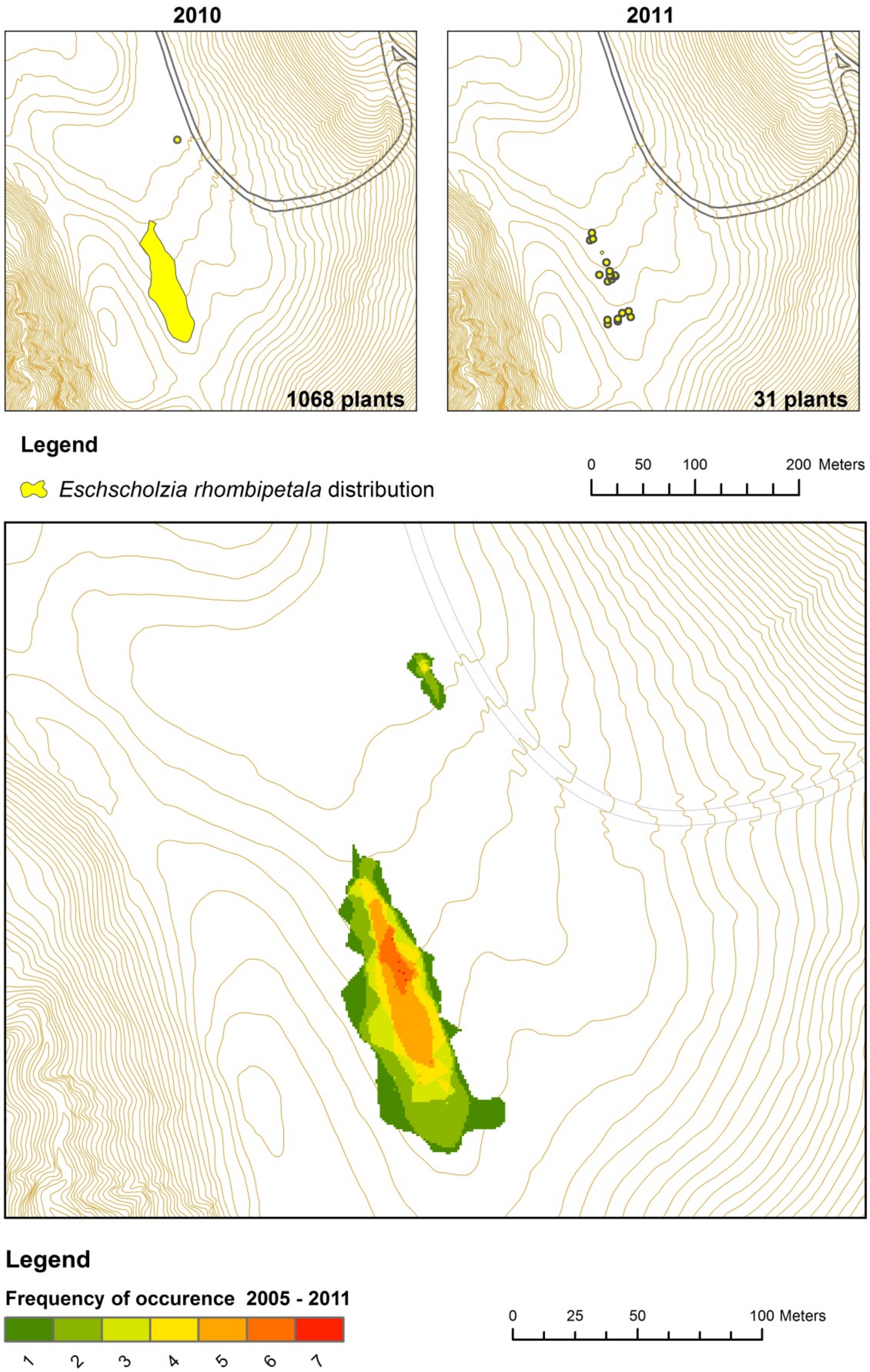


Figure C10. *Eschscholzia rhombipetala* distribution at site 3 in 2010 and 2011, and frequency of occurrence of *Eschscholzia rhombipetala* at site 3 from 2005 through 2011.

Section C
Tables

Table C1. Summary of *Eschscholzia rhombipetala* field work conducted between March 2007 and April 2011.

Year Activity	Site 1	Site 2	Site 3
2007			
Plant count	03/30/07	04/02/07	04/05/07 & 04/06/07
Plant measurements	03/30/07	04/02/07	04/05/07 & 04/06/07
GPS locations	04/02/07	04/02/07	04/13/07
Vegetation mapping	04/02/07	04/02/07	
Quadrat sampling for community data	03/30/07: Scarp – 3 quadrats with and 5 without ESRH; Slump – 1 with and 5 without ESRH; Grassland – 5 without ESRH; without selected haphazardly	04/02/07: 5 quadrats with and 5 without ESRH; without selected haphazardly	04/05/07: 5 quadrats with and 5 without ESRH; all quadrats randomly selected
2008			
Plant count	03/27/08	04/03/08	04/04/08
Plant measurements	03/27/08	04/03/08	04/11/08: only plants within quadrats sampled for community data
GPS locations	03/27/08	04/03/08	04/11/08
Vegetation mapping	03/27/08	04/03/08	
Quadrat sampling for community data	03/27/08: Slump, scarp and grassland – 5 quadrats with and 5 without ESRH; without selected haphazardly	04/03/08: 5 quadrats with and 5 without ESRH; paired next to each other	04/11/08: 5 quadrats with and 5 without ESRH; all quadrats randomly selected
2009			
Plant count	04/15/09	03/27/09	04/21/09
Plant measurements	04/15/09	03/27/09	
GPS locations		03/27/09	
Quadrat sampling for community data	04/15/09: Scarp – 5 quadrats with and 5 without ESRH; Slump – 5 without ESRH; Grassland – 5 without ESRH; without selected haphazardly	03/27/09: 5 quadrats with and 5 without ESRH; without selected haphazardly	04/21/09: 5 quadrats with and 5 without ESRH; all quadrats randomly selected

Table C1 (continued). Summary of *Eschscholzia rhombipetala* field work conducted between March 2007 and April 2011.

Year Activity	Site 1	Site 2	Site 3
2010			
Plant count	04/08/10	03/29/10	04/09/10
Plant measurements	04/08/10	03/29/10	04/14/10: only plants within quadrats sampled for community data
GPS locations	04/08/10	GPS data not recorded at Site 2 in 2010	04/09/10
Quadrat sampling for community data	04/08/10: Scarp – 5 quadrats with and 5 without ESRH; Slump – 5 with and 5 without ESRH; Grassland – 5 without ESRH; without selected haphazardly	03/29/10: 5 quadrats with and 5 without ESRH; without selected haphazardly	04/14/10: 5 quadrats with and 5 without ESRH; all quadrats randomly selected
2011			
Plant count	04/12/11	04/05/11	04/05/11
Plant measurements	04/12/11	No plants	04/15/11
GPS locations	04/12/11	No plants	04/05/11
Quadrat sampling for community data	04/12/11: Scarp – 5 quadrats with and 5 without ESRH; Slump – 5 without ESRH; Grassland – 5 without ESRH; without selected haphazardly	04/15/11: 6 quadrats without ESRH; all quadrats haphazardly selected	04/15/11: 5 quadrats with and 5 without ESRH; all quadrats randomly selected

Notes:

ESRH = *Eschscholzia rhombipetala*

Table C2. Summary of *Eschscholzia rhombipetala* census data collected from sites 1, 2, and 3: 1998–2011.

	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	0	29	23	554
2006	0	0	0	0	0	0	593
2007	0	6	1	0	7	6	126
2008	37	91	25	0	153	66	7039
2009	0	40	0	0	40	9	405
2010	0	142	4	0	146	16	1068
2011	0	16	0	0	16	0	31

Notes:

-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 C3. Height, number of floral units (buds + flowers + capsules) per plant, and capsule length for marked *Eschscholzia rhombipetala* plants: 1998–2011. All averages are ± one standard deviation.

Site	Date measured	Height (cm)	Number of floral units/plant	N[a]	Capsule length (cm)	N[b]	Average seed production per plant[c]
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	
1	30 Mar 07	4.8 ± 2.3	1.6 ± 0.5	5	1.3 ± 1.3	3	2.9 ± 6.5
2	02 Apr 07	5.7 ± 2.6	1.2 ± 1.0	6	2.8 ± 1.8	3	2.2 ± 5.3
3	04 & 05 Apr 07	6.3 ± 3.4	2.2 ± 2.5	39	3.5 ± 1.4	24	14.4 ± 27.9
1	27 Mar 08	6.8 ± 2.6	1.4 ± 1.1	65	3.2 ± 1.8	26	5.1 ± 11.0
2	03 Apr 08	6.8 ± 2.6	2.8 ± 2.5	48	3.4 ± 1.8	37	14.5 ± 22.1
3	11 Apr 08	9.3 ± 2.9	3.9 ± 3.8	55	3.9 ± 1.7	50	45.8 ± 61.2
1	15 Apr 09	6.1 ± 2.0	0.1 ± 0.1	32	2.5 ± 1.5	25	5.0 ± 6.7
2	27 Mar 09	3.7 ± 1.5	0.7 ± 0.5	7	0.6	1	0
1	08 Apr 10	7.9 ± 2.9	2.6 ± 2.1	79	3.4 ± 1.9	52	10.1 ± 17.0
2	29 Mar 10	7.3 ± 3.3	1.8 ± 1.7	16	2.0 ± 2.1	8	2.9 ± 7.7
3	14 Apr 10	10.7 ± 3.7	2.8 ± 2.4	40	3.6 ± 1.5	29	12.8 ± 15.0
1	12 Apr 11	6.0 ± 2.3	1.5 ± 0.5	16	2.2 ± 1.1	11	3.7 ± 4.9
3	15 Apr 11	9.9 ± 3.6	2.7 ± 1.9	29	3.3 ± 1.5	21	15.4 ± 15.4

Notes on next page.

Table C3 (continued). Height, number of floral units (buds + flowers + capsules) per plant, and capsule length for marked *Eschscholzia rhombipetala* plants: 1998–2011. All averages are ± one standard deviation.

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.
[c] Seed production was estimated using the equation: # seeds produced = 5.64 • (capsule length in cm) – 9.59 (Paterson et al. 2010).

Table C4. Summary of *Eschscholzia rhombipetala* community data between March 2007 and April 2011 for site 1. All averages are ± one standard deviation.

	Slump		Scarp		Grassland	
	No E. rhom	With E. rhom	No E. rhom	With E. rhom	No E. rhom	With E. rhom
2007	N=5	N=1	N=5	No E. rhom	N=5	No E. rhom
Bare Cvr (%)	30.5 ± 16.6	60	17.0 ± 10.4	–	20.0 ± 26.0	–
Thatch Cvr (%)	13.0 ± 6.71	10	33.0 ± 14.4	–	33.0 ± 13.5	–
Native Grass Cvr (%)	22.0 ± 14.4	0	7.0 ± 11.0	–	5.0 ± 8.7	–
Native Forb Cvr (%)	6.0 ± 4.5	10	5.0 ± 5.9	–	4.5 ± 4.1	–
Exotic Grass Cvr (%)	40.5 ± 29.3	37.5	54.0 ± 9.6	–	52.5 ± 9.0	–
Exotic Forb Cvr (%)	8.5 ± 5.5	5	11.5 ± 12.1	–	3.5 ± 2.2	–
No. of Species (S)	16	8	12	–	11	–
Shannon's Index (H')	1.97	NA	1.77	–	1.51	–
Top IV Species	V. mi (97); E. cic (88); B. dian (83.5)	V. my (20); Avena sp (15); E. rhom (2.5)	Avena sp (125); V. my (121); E. cic (83)	–	Avena sp (132); B. mad (110); E. cic (84)	–
2008	N=5	N=5	N=5	N=5	N=5	N=5
Bare Cvr (%)	18.0 ± 10.4	33.0 ± 13.0	40.0 ± 21.0	70.0 ± 11.7	9.0 ± 8.0	8.5 ± 7.0
Thatch Cvr (%)	43.0 ± 16.81	29.0 ± 18.5	15.0 ± 11.7	8.0 ± 4.5	46.0 ± 12.9	36.0 ± 21.9
Native Grass Cvr (%)	1.0 ± 1.4	2.0 ± 2.7	4.0 ± 9.0	4.0 ± 6.5	0	0
Native Forb Cvr (%)	9.5 ± 4.8	13.5 ± 8.8	11.5 ± 13.5	11.5 ± 6.3	6.0 ± 4.2	11.0 ± 5.2
Exotic Grass Cvr (%)	32.5 ± 11.2	22.5 ± 13.9	32.5 ± 20.9	14.0 ± 4.18	57.0 ± 7.58	61.0 ± 26.0
Exotic Forb Cvr (%)	3.0 ± 2.1	4.5 ± 3.7	7.5 ± 5.3	2.5 ± 1.77	2.5 ± 3.1	2.5 ± 1.8
No. of Species (S)	14	15	16	14	12	17
Shannon's Index (H')	1.32	1.81	1.91	2.02	1.63	1.96
Top IV Species	Avena sp (132); L. wrang (104); E. cic (61.5)	Avena sp (122); E. rhom (103.5); L wrang (84)	Avena sp (125); E. cic (107); G. aparine (62)	Avena sp (113); E. rhom (103); L. wrang (84.5)	Unk Poa (112); B. dian (111); B. mad (90)	E. rhom (102.5); Avena sp (99); Unk Poa (88)

Table C4 (continued). Summary of *Eschscholzia rhombipetala* community data between March 2007 and April 2011 for site 1. All averages are ± one standard deviation.

	Slump		Scarp		Grassland	
	No E. rhom	With E. rhom	No E. rhom	With E. rhom	No E. rhom	With E. rhom
2009	N=5	No E. rhom	N=4	N=5	N=5	No E. rhom
Bare Cvr (%)	28.0 ± 13.0	–	52.5 ± 15.6	50.0 ± 13.3	19.0 ± 10.8	–
Thatch Cvr (%)	40.0 ± 22.4	–	13.8 ± 7.5	12.0 ± 2.7	45.0 ± 9.4	–
Native Grass Cvr (%)	2.0 ± 4.5	–	1.3 ± 2.5	1.0 ± 2.2	0	–
Native Forb Cvr (%)	2.5 ± 3.1	–	3.8 ± 4.8	20.5 ± 11.5	2.5 ± 1.8	–
Exotic Grass Cvr (%)	37.0 ± 5.7	–	38.8 ± 11.8	32.0 ± 15.2	51.0 ± 8.4	–
Exotic Forb Cvr (%)	0	–	3.1 ± 3.1	3.5 ± 4.2	2.0 ± 1.1	–
No. of Species (S)	8	–	11	17	8	–
Shannon's Index (H')	0.63	–	1.75	2.13	0.95	–
Top IV Species	Avena sp (136); P. sec (22); B. mad (21)	–	Avena sp (119); B. mad (88); E. cic (78)	Avena sp (116); B. mad (113); E. rhom (103)	Avena sp (141); B. mad (108); E. cic (82)	–
2010	N=5	N=3	N=4	N=5	N=5	No E. rhom
Bare Cvr (%)	27.0 ± 18.9	46.7 ± 12.6	37.5 ± 15.6	60.0 ± 11.7	17.0 ± 10.4	–
Thatch Cvr (%)	27.0 ± 10.4	15.0 ± 5	22.5 ± 11.9	8.0 ± 2.7	49.0 ± 14.3	–
Native Grass Cvr (%)	1.0 ± 2.2	1.7 ± 2.9	1.3 ± 1.4	2.0 ± 2.7	0	–
Native Forb Cvr (%)	8.0 ± 3.3	10.8 ± 1.4	10.6 ± 4.3	16.0 ± 5.2	4.0 ± 1.4	–
Exotic Grass Cvr (%)	55.5 ± 25.3	24.2 ± 8.0	43.8 ± 18.0	23.5 ± 11.4	47.5 ± 12.5	–
Exotic Forb Cvr (%)	0	0.8 ± 1.4	3.8 ± 1.4	4.5 ± 2.1	6.5 + 6.3	–
No. of Species (S)	13	9	12	17	8	–
Shannon's Index (H')	1.25	1.35	1.53	2.23	1.49	–
Top IV Species	Avena sp (141); B. mad (93); L. wrang (63)	Avena sp (123); L. wrang (104); E rhom (104)	B. mad (132); Avena sp (111); E. cic/L. wrang (103)	Avena sp (112); E. rhom (106); E. cic (83)	B. mad (123); L. wrang (103); Avena sp (101)	–

Table C4 (continued). Summary of *Eschscholzia rhombipetala* community data between March 2007 and April 2011 for site 1. All averages are ± one standard deviation.

	Slump		Scarp		Grassland	
	No E. rhom	With E. rhom	No E. rhom	With E. rhom	No E. rhom	With E. rhom
2011		No E. rhom				No E. rhom
Bare Cvr (%)	28.0 + 17.5	–	40.0 + 25.7	59.0 + 14.3	15.0 + 7.9	–
Thatch Cvr (%)	46.0 + 22.2	–	20.0 + 13.7	9.0 + 4.2	61.0 + 9.6	–
Native Grass Cvr (%)	0.5 + 1.1	–	2.0 + 2.7	0.5 + 1.1	0	–
Native Forb Cvr (%)	5.5 + 9.6	–	11.0 + 10.7	15.0 + 6.4	3.5 + 1.4	–
Exotic Grass Cvr (%)	24.5 + 5.4	–	35.0 + 17.7	26.0 + 8.2	35.5 + 9.1	–
Exotic Forb Cvr (%)	5.5 + 4.1	–	3.5 + 2.2	3.5 + 2.2	3.5 + 3.8	–
No. of Species (S)	12	–	15	15	12	–
Shannon's Index (H')	1.95	–	2.20	2.24	1.61	–
Top IV Species	B. mad (114); Avena sp (105); B. hor (104)	–	B. mad (110); Avena sp (107); M. doug (87)	Avena sp (113); E. rhom (103); B. mad (88)	Avena sp (118); B. mad (114); L. wrang (82)	–

Notes:

Avena sp= *Avena* species
B. dian = *Bromus diandrus*
B. hord = *Bromus hordeaceaus*
B. mad = *Bromus madritensis*
C. heter = *Collinsia heterophylla*
Cvr = Cover
E. cic = *Erodium cicutarium*
E. rhom = *Eschscholzia rhombipetala*
G. aparine = *Gallium aparine*
H' = Shannon's Diversity Index
IV = Importance Value
L. wrang = *Lotus wrangelliannus*
S = Number of species
M. doug = *Microseris douglasii*
N = Number of plots sampled
No. = Number
P. sec = *Poa secunda*
UnkPoa = Unknown Poaceae
V. my = *Vulpia myuros*
V. mi = *Vulpia microstachys*

Table C5. Summary of *Eschscholzia rhombipetala* community data between March 2007 and April 2011 for sites 2 and 3. All averages are ± one standard deviation.

	Site 2		Site 3	
	No E. rhom	With E. rhom	No E. rhom	With E. rhom
2007	N=5	N=5	N=5	N=5
Bare Cvr (%)	23.0 + 18.9	27.0 + 11.5	13.8 + 4.8	27.0 + 7.6
Thatch Cvr (%)	76.3 + 32.0	49.0 + 28.6	93.0 + 7.6	77.0 + 8.4
Native Grass Cvr (%)	5.0 + 5.0	4.0 + 5.5	0	10.0 + 14.14\
Native Forb Cvr (%)	5.0 + 4.7	7.0 + 2.3	11.0 + 5.8	9.5 + 6.0
Exotic Grass Cvr (%)	50.0 + 11.59	56.2 + 27.8	95.0 + 22.6	63.0 + 13.0
Exotic Forb Cvr (%)	7.0 + 3.26	6.0 + 3.4	6.0 + 2.8	6.0 + 8.0
No. of Species (S)	17	14	16	16
Shannon's Index (H')	2.00	1.87	1.34	1.73
Top IV Species	Avena sp (54); V. my (52); B. mad (42)	E. cic (106); E. rhom (103); Avena sp (95)	Unk Poa (157); V. my (137); E. cic (105)	V. my (138); Unk Poa (103); E. rhom (102)
2008	N=5	N=5	N=5	N=5
Bare Cvr (%)	13.0 ± 5.7	25.0 ± 10.0	8.0 ± 6.7	13.0 ± 5.7
Thatch Cvr (%)	40.0 ± 6.12	28.0 ± 8.4	63.0 ± 18.9	47.0 ± 7.6
Native Grass Cvr (%)	4.0 ± 6.5	3.0 ± 3.3	0	0
Native Forb Cvr (%)	6.0 ± 7.0	12.0 ± 10.0	5.0 ± 2.5	14.0 ± 5.8
Exotic Grass Cvr (%)	47.0 ± 9.1	40.0 ± 10.0	24.5 ± 9.1	30.5 ± 10.1
Exotic Forb Cvr (%)	2.5 ± 1.8	2.0 ± 2.1	11.0 ± 11.8	4.5 ± 3.3
No. of Species (S)	10	16	12	10
Shannon's Index (H')	1.71	2.00	2.09	1.72
Top IV Species	Unk Poa (122); Avena sp (115); E. cic (82)	Avena sp (119); E. rhom (104); Unk Poa (74)	V. my (105); B. mad (103); Vicia sp (82)	Unk Poa (120); V. my (110); E. rhom (108)
2009	N=5	N=5	N=5	N=5
Bare Cvr (%)	19.0 + 10.3	16.0 + 4.2	4.0 + 3.8	9.0 + 4.2
Thatch Cvr (%)	34.0 + 9.6	37.0 + 6.7	75.0 + 9.4	69.0 + 15.6
Native Grass Cvr (%)	3.0 + 4.5	2.5 + 4.3	0	0
Native Forb Cvr (%)	4.0 + 3.4	7.0 + 4.1	7.5 + 4.0	8.0 + 4.5
Exotic Grass Cvr (%)	49.0 + 15.2	44.0 + 4.2	56.5 + 9.6	45.0 + 8.1
Exotic Forb Cvr (%)	2.0 + 2.1	0.5 + 1.1	3.0 + 1.1	5.0 + 5.9
No. of Species (S)	9	10	15	13
Shannon's Index (H')	0.85	0.85	1.57	1.64
Top IV Species	Unk Poa (147); E. cic (62); P. sec (43);	Unk Poa (144); E. rhom (103); A. lycop (62)	Avena sp (119); B. mad (88); C. spar (62)	Avena sp (131); B. mad (111); E. rhom (103)

Table C5 (continued). Summary of *Eschscholzia rhombipetala* community data between March 2007 and April 2011 for sites 2 and 3. All averages are ± one standard deviation.

	Site 2		Site 3	
	No E. rhom	With E. rhom	No E. rhom	With E. rhom
2010	N=5	N=5	N=5	N=5
Bare Cvr (%)	18.0 + 9.1	20.0 + 7.1	9.0 + 4.2	12.0 + 4.5
Thatch Cvr (%)	35.0 + 6.2	38.0 + 6.7	42.0 + 28.0	42.0 + 20.8
Native Grass Cvr (%)	2.5 + 5.6	2.0 + 2.7	5.0 + 6.1	5.0 + 3.1
Native Forb Cvr (%)	8.5 + 2.9	6.5 + 2.9	11.0 + 9.5	21.5 + 18.4
Exotic Grass Cvr (%)	46.0 + 12.5	44.5 + 9.8	41.0 + 6.5	43.0 + 18.3
Exotic Forb Cvr (%)	2.0 + 2.1	0.5 + 1.1	3.0 + 4.1	6.5 + 2.2
No. of Species (S)	14	12	13	15
Shannon's Index (H')	1.84	1.69	1.77	2.21
Top IV Species	B. mad (112); Avena sp (110); Unk Poa (84)	Avena sp (115); E. rhom 103); Unk Poa (77)	Avena sp (128); B. mad (112); C. heter (41)	Avena sp (118); V. mi/ E. rhom/ E. cic (105)
2011	N=6	No E. rhom	N=5	N=5
Bare Cvr (%)	29.2 + 16.9	–	20.0 + 13.7	35.0 + 21.2
Thatch Cvr (%)	46.7 + 20.2	–	62.0 + 13.5	39.0 + 18.2
Native Grass Cvr (%)	1.7 + 2.6	–	1.0 + 1.4	2.5 + 4.3
Native Forb Cvr (%)	0.8 + 2.0	–	4.5 + 1.1	6.5 + 4.2
Exotic Grass Cvr (%)	30.4 + 4.3	–	23.0 + 6.9	21.5 + 12.3
Exotic Forb Cvr (%)	1.3 + 2.1	–	1.5 + 2.2	4.5 + 2.1
No. of Species (S)	9	–	10	16
Shannon's Index (H')	1.58	–	1.66	2.34
Top IV Species	Avena sp (114); B. mad (91); V. my (70)	–	B. mad (111); Unk Poa (71); Vicia sp/ Unk Di (42)	B. mad (107); E. rhom (103); Unk Poa (86)

Notes:

A. lycop = *Amsinckia lycopsoides*
Avena sp= *Avena* species
B. dian = *Bromus diandrus*
B. hord = *Bromus hordeaceaus*
B. mad = *Bromus madritensis*
C. heter = *Collinsia heterophylla*
Cvr = Cover
E. cic = *Erodium cicutarium*
E. rhom = *Eschscholzia rhombipetala*
G. aparine = *Gallium aparine*
H' = Shannon's Diversity Index
IV = Importance Value
L. wrang = *Lotus wrangelliannus*
S = Number of species
N = Number of plots sampled
No. = Number
P. sec = *Poa secunda*
Unk Di = Unknown DIcot
Unk Poa = Unknown Poaceae
Vicia sp = *Vicia species*
V. my = *Vulpia myuros*
V. mi = *Vulpia microstachys*

Table C6. Plant species found in and around *Eschscholzia rhombipetala* populations: 1999–2011. Sites where species found in parentheses.

Native	Exotic
Grasses	
Elymus sp. (1) *Poa secunda* (1, 2) *Vulpia microstachys* (1, 2, 3)	*Avena* sp. (1, 2, 3) *Bromus diandrus* (1, 2) *Bromus hordeaceous* (1, 2, 3) *Bromus madritensis* subsp. *rubens* (1, 2, 3) *Hordeum murinum* (1) *Vulpia myuros* (1, 2, 3)
Forbs	
Achillea millifolium (1) *Amsinckia eastwoodaei* (2) *Amsinckia intermedia* (1) *Amsinckia lycopsoides* (2) *Amsinckia mensezii* (1, 2) *Amsinckia tessellata* (2) *Astragolus* sp. (1, 3) *Blepharizonia laxa* (1) *Blepharizonia plumosa* (1) *Brodiaea* sp. (1) *Chamaesyce ocellata* (3) *Clarkia* sp**.** (1, 2, 3) *Claytonia* sp. (1, 2) *Collinsia* sp. (2, 3) *Crassula* sp. *(2)* *Dichelostema capitatum* (1, 3) *California macrophylla* (1, 3) *Eschscholzia rhombipetala* (1, 2, 3) *Euphorbia spathulata* (1, 3) *Galium aparine* (1, 3) *Grindelia camporum* (2) *Gutierrezia californica* (1) *Lathryus* sp. (1) *Lepidium nitidum* (1, 2) *Lithophragma* sp. (2) *Lotus wrangellianus* (1, 3) *Lupinus albifrons** (1) *Lupinus bicolor* (3) *Lupinus microcarpus* (1, 2) *Lupinus succulentus* (1) *Microseris douglasii* (1) *Minuarta* sp. (1, 2) *Monolopia major* (1) *Plantago erecta* (1) *Stylomecon heterophylla* (1, 2) *Triteleia laxa* (1, 3) *Trifolium* sp. (1, 2, 3) *Yabea microcarpa* (3)	*Brassica* sp. (1) *Carduus pynocephalus* (1) *Centaurea melitensis* (1) *Centaurea solstitialis* (1) *Erodium botrys* (1) *Erodium cicutarium* (1, 2, 3) *Hirschfeldia* sp. (1) *Medicago polymorpha* (1, 2) *Salsola tragus* (1) *Sanicula bipinnata* (1) *Scandex* sp. (3) *Senecio vulgare* (1) *Sonchus asper* (1, 2, 3) *Vicia* sp. (1, 3)

Notes:

For plants identified only to genus, native versus exotic identifications were made using species lists generated by Preston (2002).

***Lupinus albifrons* is a shrub but is included with forbs for simplicity.**

Section D
California macrophylla
Monitoring

Section D
California macrophylla
Monitoring

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 petals that are occasionally red tinted and 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 (Alarcon et al., 2012; Taylor, 1993).

Based on morphological data *C. macrophylla* was segregated from the genus *Erodium* into the new monotypic genus *California* (Aldasoro et al., 2002). Aldasoro et al. (2002) described three characteristics that separate *C. macrophylla* from species of *Erodium* (and the genus *Monsonia*): 1) arrangement of stamens, 2) mericarp bristle morphology, and 3) 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. Recent phylogenetic and biogeographic analysis supported the conclusion that the monospecific genus *California* is a sister genus to the genera *Erodium* and *Geranium* within the Geraniacea family (Fiz et al., 2006; Fiz et al., 2008).

Of the six species of *Erodium* that are described in the first edition of 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 Central Valley, San Francisco Bay area, the northern to southern coastal range, the south coast, and the Channel Islands of California (CNDDB, 2012; Figure D1). 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, 2012). 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. All six populations occur at sites on the western side of Site 300 at elevations between 360 m and 450 m (Figure D2).

Of the six Site 300 populations, those at sites 1 through 4 occur within annually graded dirt fire trails. Populations at these sites are largely 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 late May or June. Fire trail grading typically occurs in May at the end of the rainy season and after *C. macrophylla* has set seed. Of these four fire trail sites, only site 1 occurs adjacent to an area that is routinely burned as part of the Site 300 annual prescribed burn. Although site 1 is adjacent to an area that is routinely included in the annual prescribed burn, most of site 1 where the *C. macrophylla* population most typically occurs does not burn because it occurs on the fire trails that are graded prior to the annual prescribed burns. Although the majority of site 1 does burn during the annual prescribed burn, individual *C. macropylla* plants are frequently found in the burned grassland adjacent to the fire trail.

Populations at the remaining two sites (site 5 and 6) occur in grasslands 100 to 500 feet from the fire trails. Populations at these two off-road sites occur in areas that are not typically included in the annual prescribed burns at Site 300. The population at site 5 occurs in a small, relatively level bowl surrounded by small hills known as Round Valley. This population occurs with another extremely rare annual forb, *Eschscholzia rhombipetala* (*E. rhombipetala* site 3 occurs in the same location as *C. macrophylla* site 5). *Eschscholzia rhombipetala* and *C. macrophylla* have also historically been reported to occur together in San Luis Obispo County (Hoover, 1970). The population at site 6 is found on a west-facing hillside.

In 2007 through 2011, the abundance and distribution of *C. macrophylla* was recorded for populations at all six Site 300 sites with the exception of site 2 in 2009. In addition, for the years 2007 and 2008, the composition of the vegetation community in each population was recorded, and the community composition of plots containing *C. macrophylla* was compared to those without *C. macrophylla.*

D-2. Methods and Materials

D-2.1. Spring Census

California macrophylla populations at sites 1 through 6 were censused in 2007 through 2011 with the one exception, it was not possible to access site 2 in 2009. Table D1 summarizes the census activities for each site for each year. The boundaries of the population at each of the six sites were recorded using a Trimble handheld GPS and an estimate of the total population size was made.

For the years 2007 and 2008, specific plant cover was also measured in each of the six sites. Cover estimates were made using 60 cm $\times$ 60 cm quadrats. For sites 2 through 5, approximately ten random locations within each *C. macrophylla* population were chosen for cover estimates. The population at site 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 fire trails). Populations at sites 1 through 4 occur along fire trails and, therefore, have a basically linear distribution. At these four sites, 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. The population at 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. The population at site 6 includes three separate patches. Four to six cover quadrats were sampled from the two larger patches (Areas 2 and 3), and two cover quadrats were sampled from the smaller patch (Area 1). 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 (flowers and seed pods), the height, and the width of each *C. macrophylla* within the quadrat. The area of each plant was calculated by multiplying height by width. GPS data collection and GIS analysis were conducted as described in Section C-2.1.

D-2.1.1. Data Analysis

Specific cover data were combined into six categories: bare ground, thatch, exotic grasses, native grasses, exotic forbs, and native forbs. In addition, importance value (IV) and Shannon's Diversity Index (Shannon's Index, H') was also calculated using the cover data, as described in Section A-2.3.1.

D-3. Results

D-3.1. Spring Census

The overall distribution of *C. macrophylla* at Site 300 in 2007 through 2011 is shown in Figures D2 through D6, with each site shown in more detail in figures D7 through D16 along with the frequency of occurence. Estimates of the total number of plants and the area of each Site 300 *C. macrophylla* population are given in Table D2. Figure D17 shows the area occupied by *C. macrophylla* plants for each site (m^2), the estimated density (plants/m^2), as well as the rainfall for each year. As shown in Table D3, for the years 2004 through 2011, the estimated number of *C. macrophylla* in the four fire trail sites (sites 1 through 4) tended to be smaller than the two grassland sites (sites 5 and 6), with the exception of years 2004 and 2005. Beginning in 2006, the grassland sites tended to have larger numbers. However, the occupied area for the fire trail sites could be quite large, especially for sites 1 and 4 (Figure D17). The number of plants at the fire trail sites was quite small in 2008, and appeared to increase in number occupied through 2011. These sites also appeared to respond positively to increased rainfall.

The number of plants and the occupied area at the two grassland sites during this period were quite variable, and had very large swings. However, after the 2005 wildfire that burned the two off-road sites and the grasslands adjacent to the fire trail sites, the populations at the grassland sites had very large numbers of individuals compared to the populations at the fire trail sites.

The population at site 5 appeared to respond negatively to increased rainfall, whereas the population at site 6 appeared to respond positively. The average height, width and area of plants sampled in each population in 2007 and 2008 are shown in Table D2. Plants in all populations tended to be quite small in 2007 and were significantly larger in 2008.

Although there is a large amount of variation between sites with respect to the number of plants, occupied area and density of *C. macrophylla*, when all sites and all years are combined, a general pattern emerges. Figure D18a shows that generally, as the size of the occupied area increases, the number of plants increases. In addition, the density of *C. macrophylla* appears to remain relatively constant (Figure 18b), although with a high degree of variability.

Figures D7 through D16 also show the frequency of occurrence of *C. macrophylla* at each site for the years 2004 through 2011. A core area is apparent for each site, where plants have been observed every year. The occupied area apparently increases from these core areas during years with favorable conditions. Populations at sites 2, 4, 5 and 6 have small, somewhat disjunct areas that have occurred very infrequently.

The vegetation community composition for 2007 and 2008 is shown in Table D4 and Figures D19 and D20. Table D5 lists the species that were observed in the six sites in 2007 and 2008. There is not a significant difference in the vegetation community composition between quadrats that contained *C. macrophylla* and those that did not. In 2007, in the fire trail sites (sites 1 through 4), the amount of bare ground in quadrats containing *C. macrophylla* tended to be a bit higher, although this pattern was not observed in 2008. In contrast, the two grassland sites (sites 5 and 6) had a very low amount of bare ground and very high thatch cover. These two sites also had very high amounts of exotic annual grass cover. Species diversity, as measured by Shannon's Index (H'), tended to be lower in the grassland sites as compared to the fire trail sites (Table D4), although species diversity was quite high in site 5 in 2008.

D-4. Discussion and Recommendations for Future Work

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 populations. 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.

Ongoing monitoring continues to show 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 areas that are annually graded. There was also significantly less exotic grass cover in the fire trail population compared to the grassland populations.

In a study by Gillespie and Allen (2004), weeding (manually removing an exotic species) was found to have a positive effect on *C. macrophylla* emergence survival and fecundity, and that exotic grasses competitively suppress *C. macrophylla.* More recent work has shown that competitive hierarchies exist between exotic and native forbs, and exotic grasses with respect to their impact on C. macrophylla (Cox and Allen, 2011; Gillespie and Allen, (2008). All exhibit a negative effect on *C. macrophylla*, with *Amsinckia menziesii* (a native forb) and *Erodium brachycarpum* (an exotic forb) exhibiting a stronger effect than *Bromus* species (exotic grasses). However, when one of these competitors is removed, the remaining competitors increase in cover and biomass at the expense of *C. macrophylla*. These hierarchies do have an interaction with climate (not as strong during low precipitation years) and soil nutrient status (*Bromus* exhibits a stronger effect in more nutrient rich soils). A greenhouse study by Gillespie and Allen (2006) found that although *C. macrophylla* most typically occurs naturally in clay soils, it performs better in loamy soils with a mycorrhizae community found in soils invaded by exotic grasses. This suggests that the more open clay soils provide a refuge from competition from the higher density of exotic species more typically found in loamy soils.

Monitoring of the Site 300 fire trail populations shows that these populations do have a decreased exotic grass cover compared to areas outside of the fire trails. These sites also have a high percentage of bare soil. This decreased annual grass cover could, at least partially, contribute to the success on *C. macrophylla* in the fire trails. However, recent monitoring data show that the two grassland sites, with high levels exotic annual grass and thatch cover, have the capacity to sustain very high numbers of *C. macrophylla*. The specific soil types found at these sites is not known, although *E. rhombipetela* sites 1 and 2 in the western portion of Site 300 where shown to have clay or clay loam soil (Espeland and Carlsen, 2003). At least one of the *C. macrophylla* grassland sites (site 5) appeared to benefit from reduced rainfall, which can reduce the amount of competition from annual grasses (Cox and Allen, 2011). The overall cover of annual exotic grasses in site 5 was reduced from around 80% to around 60% between 2007 and 2008. Clearly, however, other factors are contributing to the presence of *C. macrophylla* in these grassland areas.

Although *C. macrophylla* 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. Site 1 is the only one of the six populations that occurs within the area where annual prescribed burns are conducted. Even though site 1 is within an annual burn area, the fire trails are graded annually in May (after *C. macrophylla* has gone to seed) to provide a firebreak, with the controlled burn typically occuring in June. The actual fire trails where most of the *C. macrophylla* plants at this site grow and go to seed do not have enough fuel to burn, although the areas adjacent to the fire trails are burned. It is interesting to note that the population at site 1 is the only fire trail population where *C. macrophylla* plants are periodically observed in the adjacent grasslands. It would appear that *C. macrophylla* during some years take advantage of the reduced cover resulting from the prior years burn.

In July of 2005, a large wildfire occurred across the western portion of Site 300 that impacted all six sites. *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 the grassland site 6 (Paterson et al., 2010). It would appear that the two grassland sites benefited from this burn, although additional analysis should be conducted. This observation is consistent with the observation that plants at site 1 periodically occur in the adjacent grassland that had been burned the prior year. More detailed statistical analysis between soil types, cover, fire and precipitation could shed additional light on the factors controlling *C. macrophylla* distribution and abundance. Determining soil type and nutrient status of each site would facilitate this analysis.

Each site appears to have a core area from which plants expand from during years with favorable (although as yet undetermined) conditions. The density of plants within the occupied area remains relatively constant. The amount of gene flow, and thus the metapopulation dynamics, between sites is not known. Sites 1, 4 and 5 are in reasonable proximity to one another, and insect pollination may provide some gene flow. Similarly, sites 2, 3 and 6 may experience some gene flow. *California macrophylla* has been described as a facultative autogamous (self-fertilizing) species (Fiz et al., 2008). Some insect pollination may occur, but the pollinator biology is not known. Low efficiency pollinators such as flies, wasps and bees are known to pollinate closely related *Erodium* species (FIz et. al, 2008). Therefore, the ability for pollinators found at Site 300 to facilitate gene flow between *C. macrophylla* sites is speculative at best. As discussed for *B. plumosa*, should funds become available, genetic analysis of *C. macrophylla* populations should be considered to more fully investigate gene flow between these populations.

It would appear that *C. macrophylla* takes advantage of the reduced cover afforded by the fire trails, and at least under certain conditions, the reduced cover from a prior years burn. However, if this is the case, it is not clear why *C. macrophylla* does not occur to a greater extent in burned grassland areas. Frequency of the burn may be a factor, as may be a combination of climate and burn frequency. Annual monitoring and mapping of the populations, along statistical investigations into of the interaction between fire frequency and climate on the expansion of *C. macrophylla* from site 1 into the adjacent grasslands and the dynamics of the two grassland populations should continue. Collecting biomass over multiple years from the adjacent grassland from all sites should be considered as a means to further investigate the mechanisms controlling *C. macrophylla* expansion into grassland areas.

D-5. References

Alarcon, M., C. Aedo and C. Navarro. 2012. *California* (California Filaree). In Baldwin, B. G., D. H. Goldman, D. J. Keil, R. Patterson, T. J. Rosatti, and D. H. Wilken, (Ed.) 2012. *The Jepson manual: vascular plants of California*, second edition (pg. 818). (University of California Press, Berkeley, CA.)

Aldasoro, J.J., P. Vargas, L.L. Saez. 2002. *California*, a new genus of Geraniaceae endemic to the southwest of North American. *Anales Jardin Botanico de Madrid* **59**(2):209–216.

Biosystems. 1986. A Rare Plant Survey of Site 300 Lawrence Livermore National Laboratory San Joaquin County, California. BioSystems Analysis Inc., Santa Cruz, CA.

California Natural Diversity Data Base (CNDDB). 2012. California Natural Diversity Database, Biogeographic Data Branch, California Department of Fish and Game, Sacramento, CA. Accessed on Wed., Jan. 18, 2011 from http://www.dfg.ca.gov/biogeodata/cnddb/mapsanddata.asp

California Native Plant Society (CNPS). 2012. Inventory of Rare and Endangered Plants (online edition, v8-01a). California Native Plant Society. Sacramento, CA. Accessed on Wed, Jan. 18, 2012 from http://www.cnps.org/inventory.

Cox, R.D. and E.B. Allen. 2011. The role of exotic grasses and forbs when restoring native species to highly invaded southern California annual grassland. Plant Ecology 212:1699-1707.

Espeland, E.K. and T.M. Carlsen. 2003. Population characteristics of *Eschscholzia rhombipetala* (Papaveraceae). Madrono 50(1):1-7.

Fiz, O., P. Vargas, M.L. Alarcon and J.J. Aldasoro. 2006. Phylogenetic relationships and evolution in *Erodium* (Geraniaceae) based on trnL-trnF sequences. Systematic Botany 31(4):739-763.

Fiz, O., P. Vargas, M. Alarcon, C. Aedo, J.L. Garcia and J.J. Aldasoro. 2008. Phylogeny and historical biogeography of Geraniaceae in relation to climate changes and pollination ecology. Systematic Botany 33(2):326-342.

Gillespie, I.G. 2003. Ecology and restoration of *Erodium macrophyllum* [dissertation]. University of California, Riverside. 174 pp.

Gillespie, I.G. and E.A. Allen. 2004. Fire and competition in a southern California grassland: impacts on the rare form *Erodium macrophyllum. Journal of Applied Ecology* 41:643-652.

Gillespie, I.G. and E. B. Allen. 2006. Effects of soil and mycorrhizae from native and invaded vegetation on a rare California forb. *Applied Soil Ecology* 32:6-12.

Gillespie, I.G. and E. B. Allen. 2008. Restoring the rare forb *Erodium macrophyllum* to exotic grassland in southern California. Endangered Species Research 5:65-72.

Hoover, R.F. 1970. *The vascular plants of San Luis Obispo County, California* University of California Press, Berkeley, 350 pp.

Paterson, L.E., T.M. Carlsen, T.M. Alfaro and E. Espeland. 2010. *Rare plant restoration and monitoring at Lawrence Livermore Laboratory, Site 300, Project Progress Report, Fiscal Year 2005 and 2006.* Lawrence Livermore National Laboratory, Livermore, CA. LLNL-TR-457357.

Preston, R.E. 2002. *Special-status plant species surveys and vegetation mapping at Lawrence Livermore National Laboratory* (Jones and Stokes, Sacramento, Calif.).

Taylor, M.S. 1993. Erodium. In Hickman, J.C. (ed.), *The Jepson Manual: Higher Plants of California*, (University of California Press, Berkeley, CA) pp. 672-673.

Section D
Figures

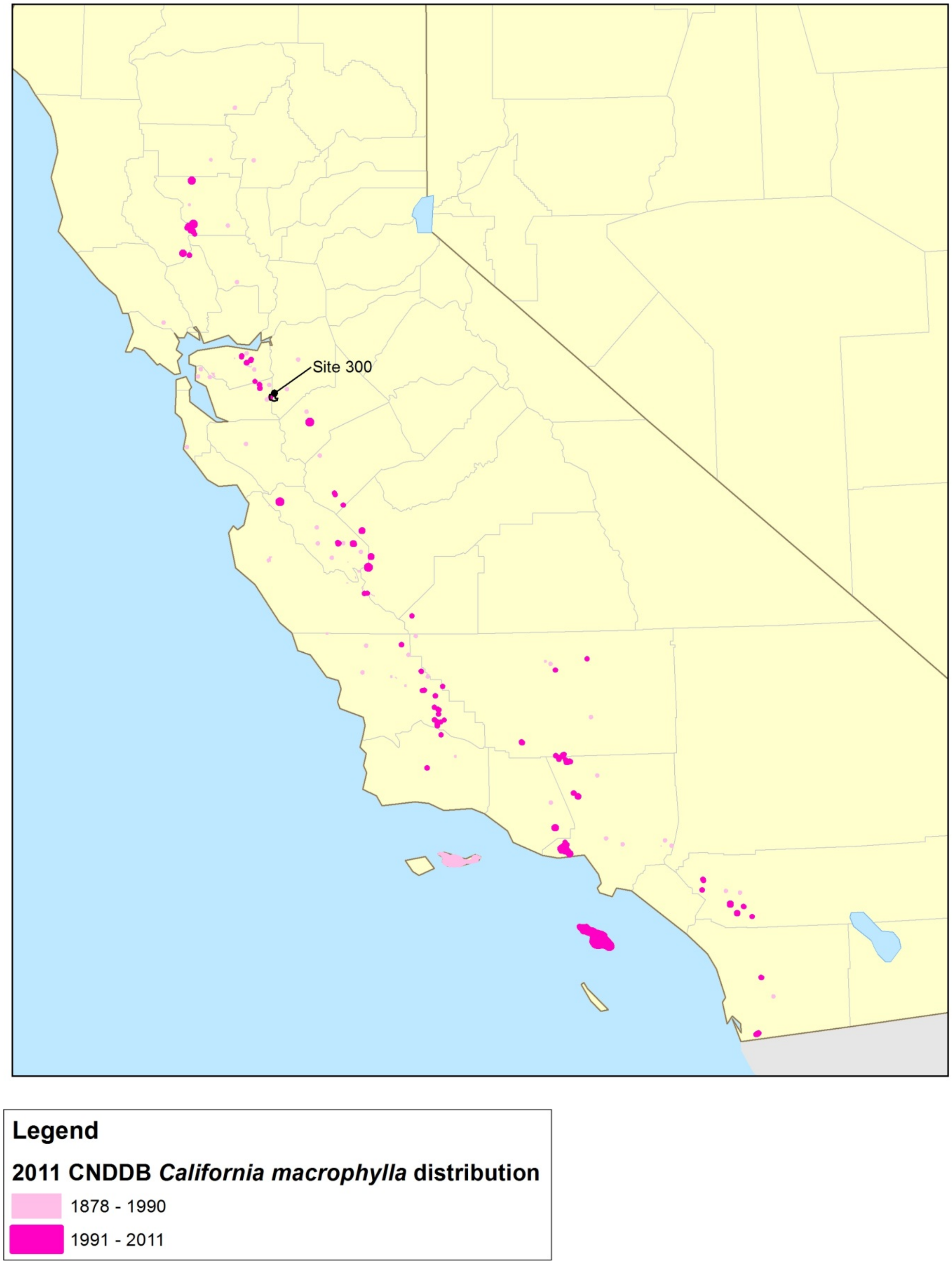


Figure D1. Current and historic occurrences of *California macrophylla* as described by the California Natural Diversity Data Base (CNDDB, 2012).

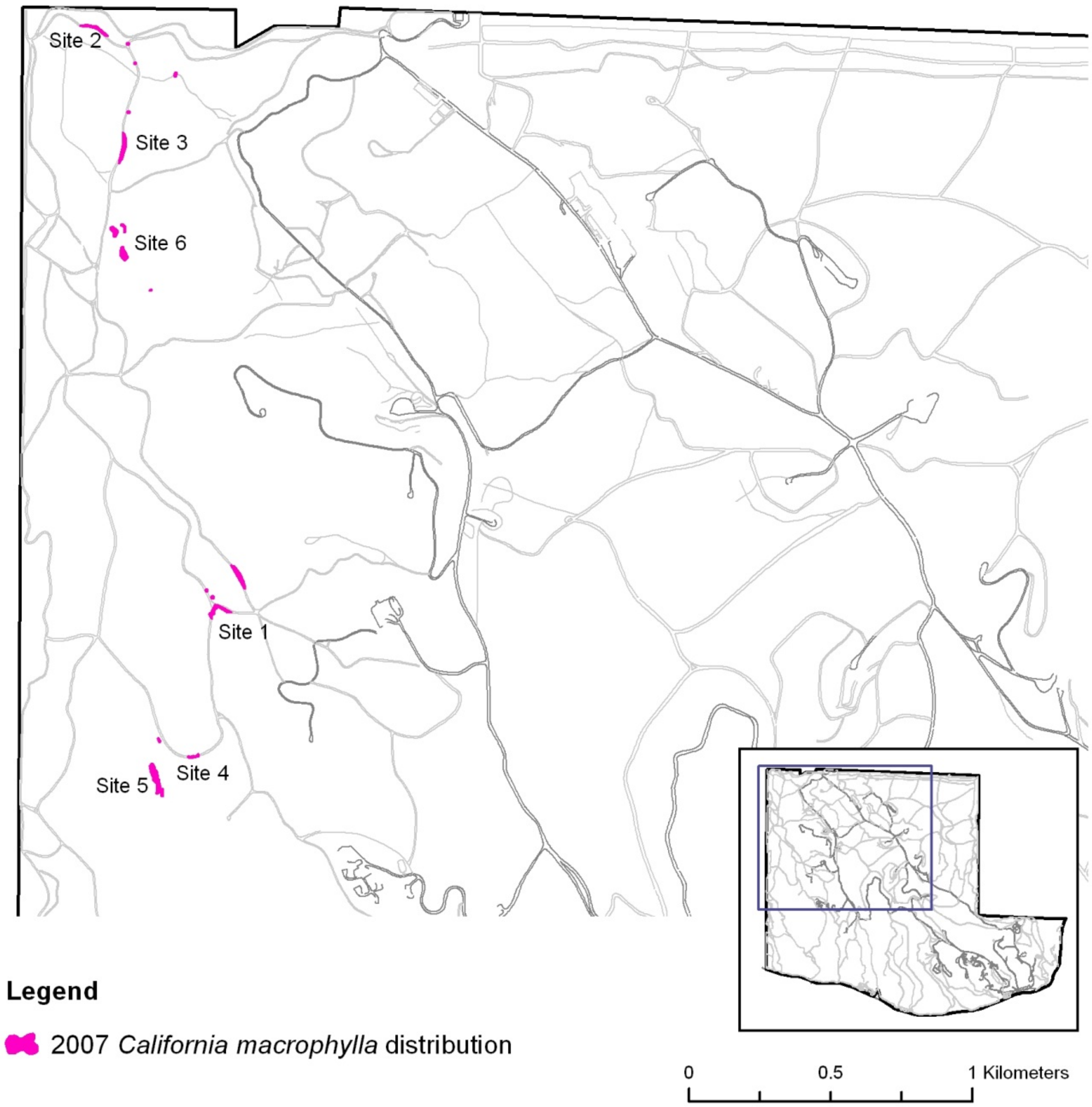


Figure D2. 2007 distribution of *C. macrophylla* (all sites) at Site 300.

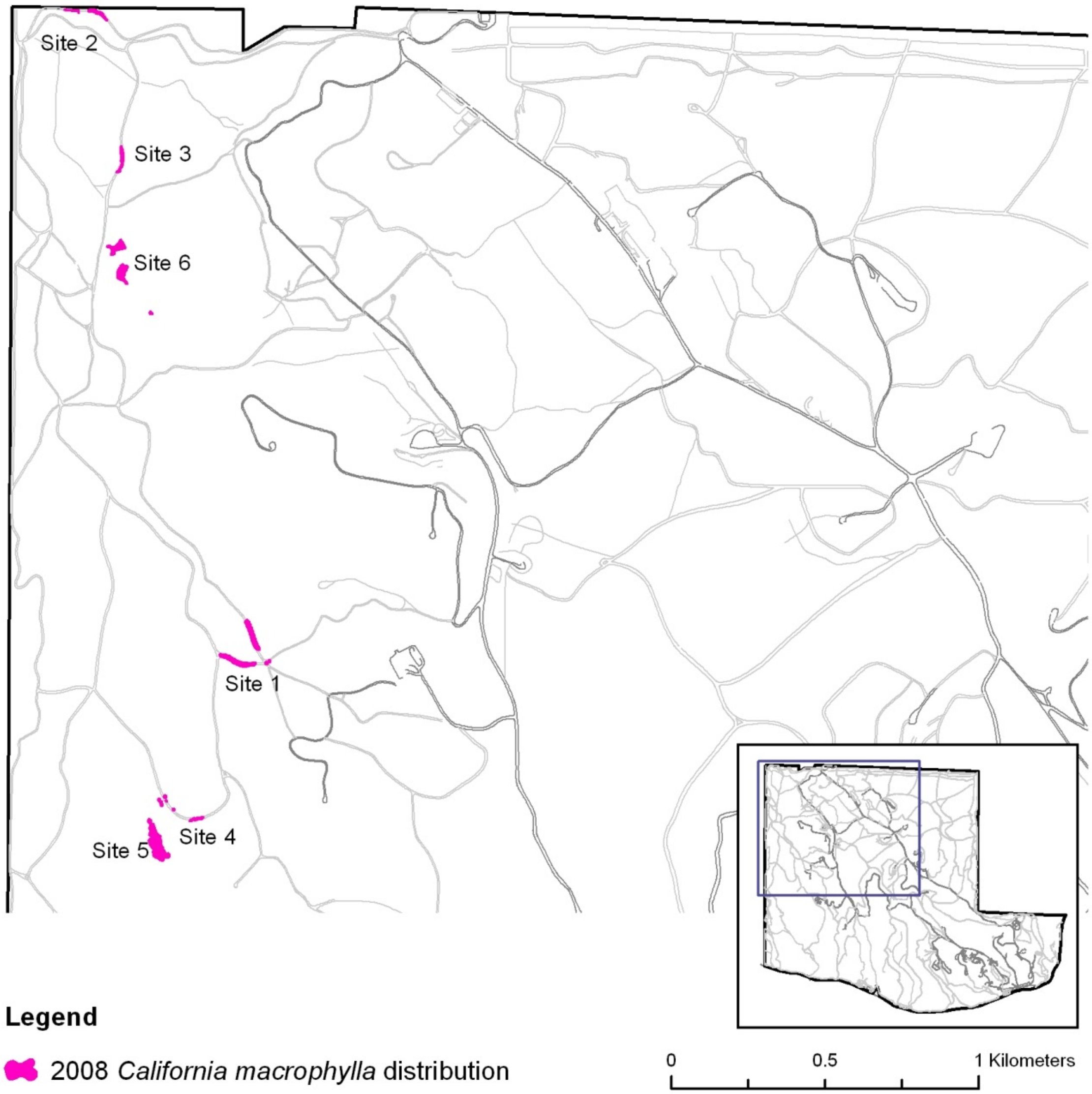


Figure D3. 2008 distribution of *C. macrophylla* (all sites) at Site 300.

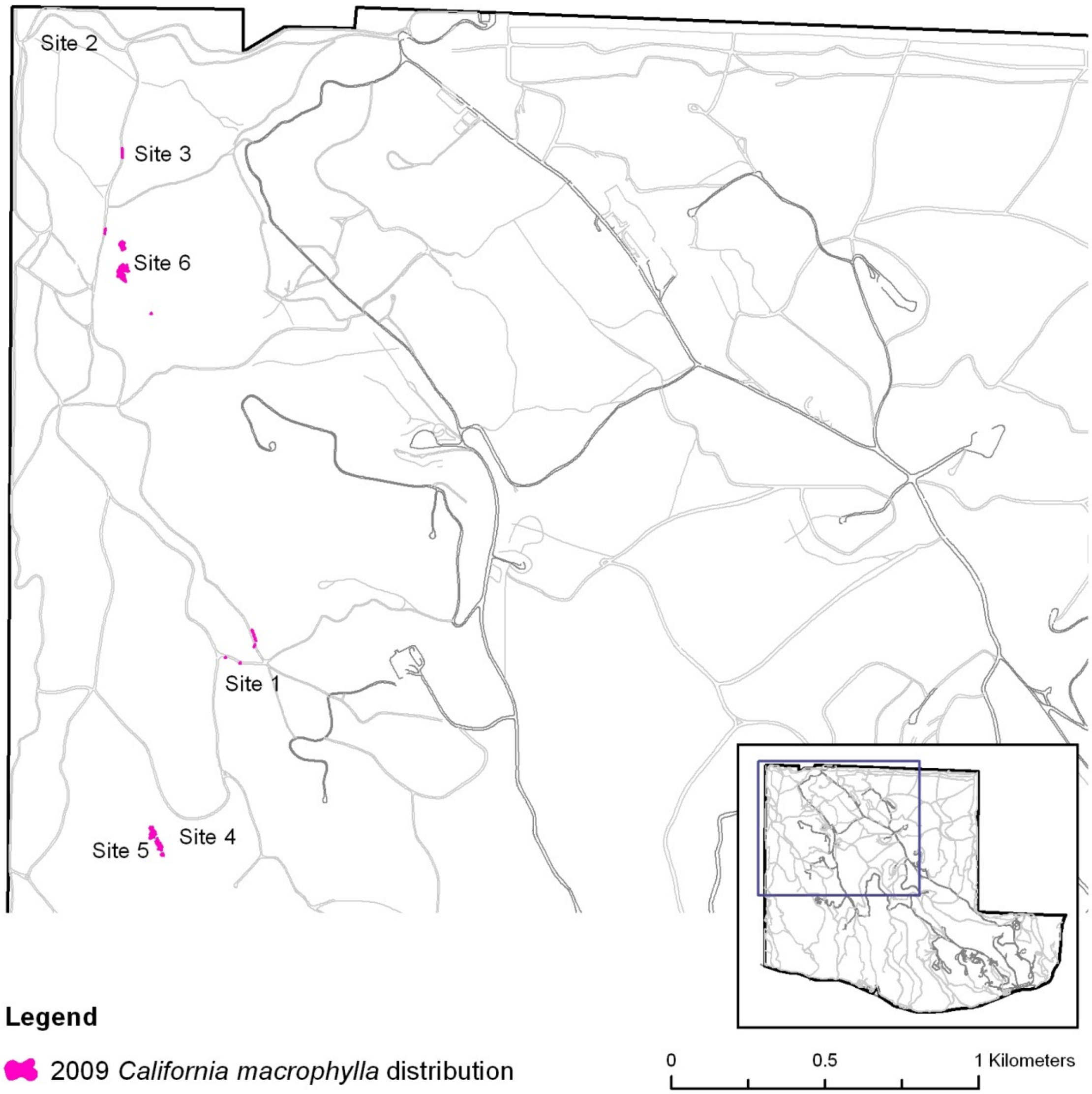


Figure D4. 2009 distribution of *C. macrophylla* (all sites) at Site 300.

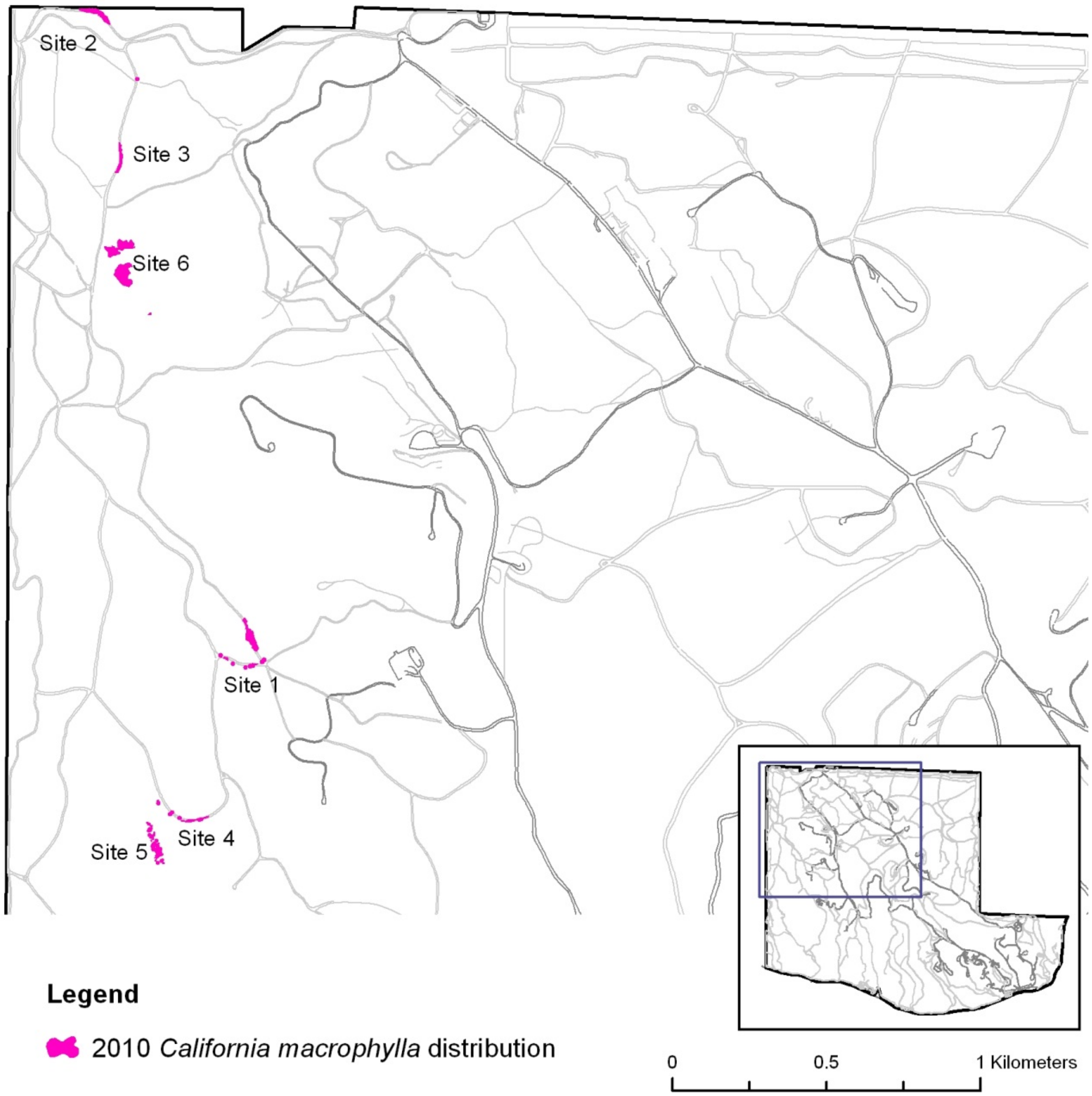


Figure D5. 2010 distribution of *C. macrophylla* (all sites) at Site 300.

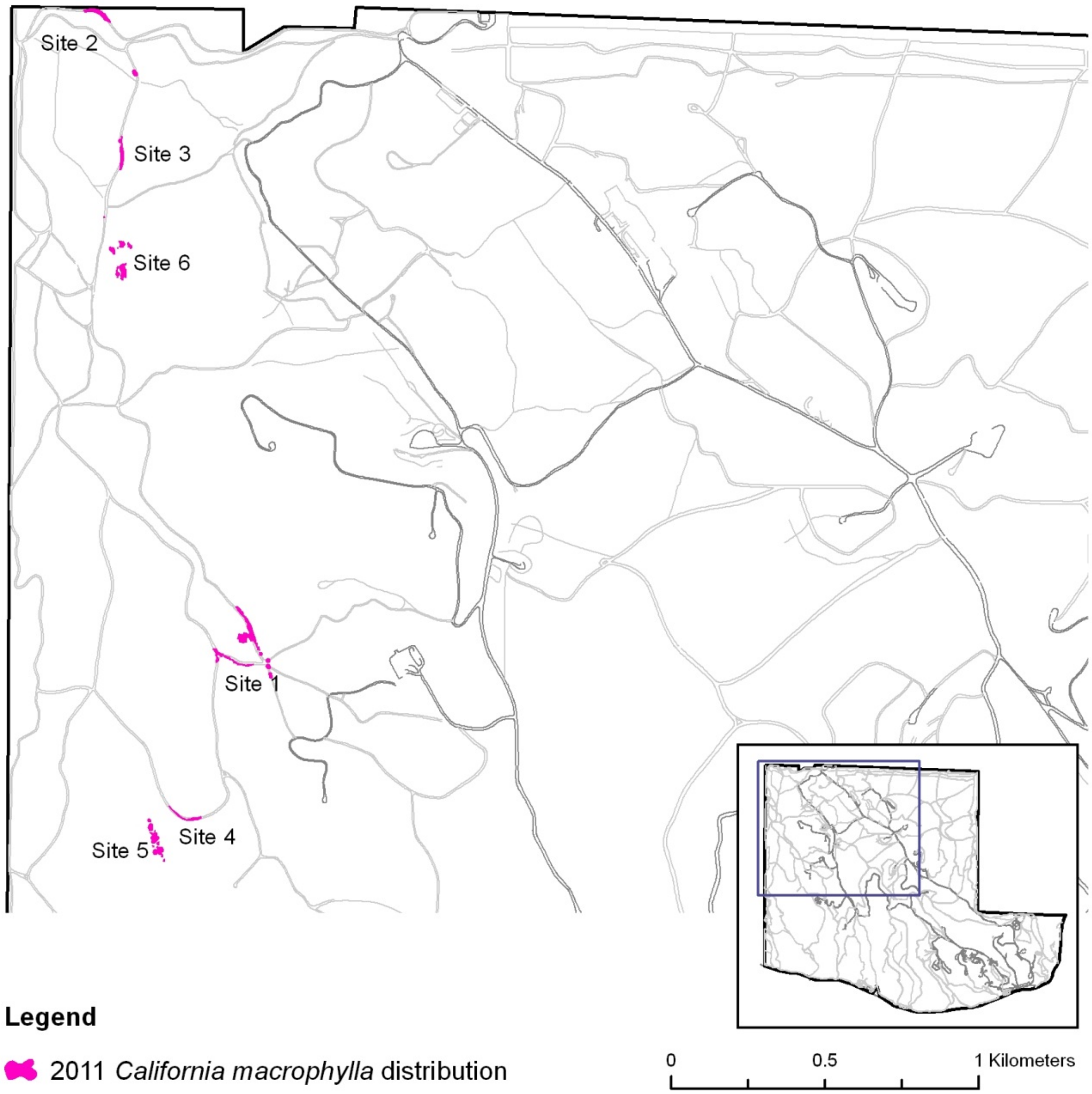


Figure D6. 2011 distribution of *C. macrophylla* (all sites) at Site 300.

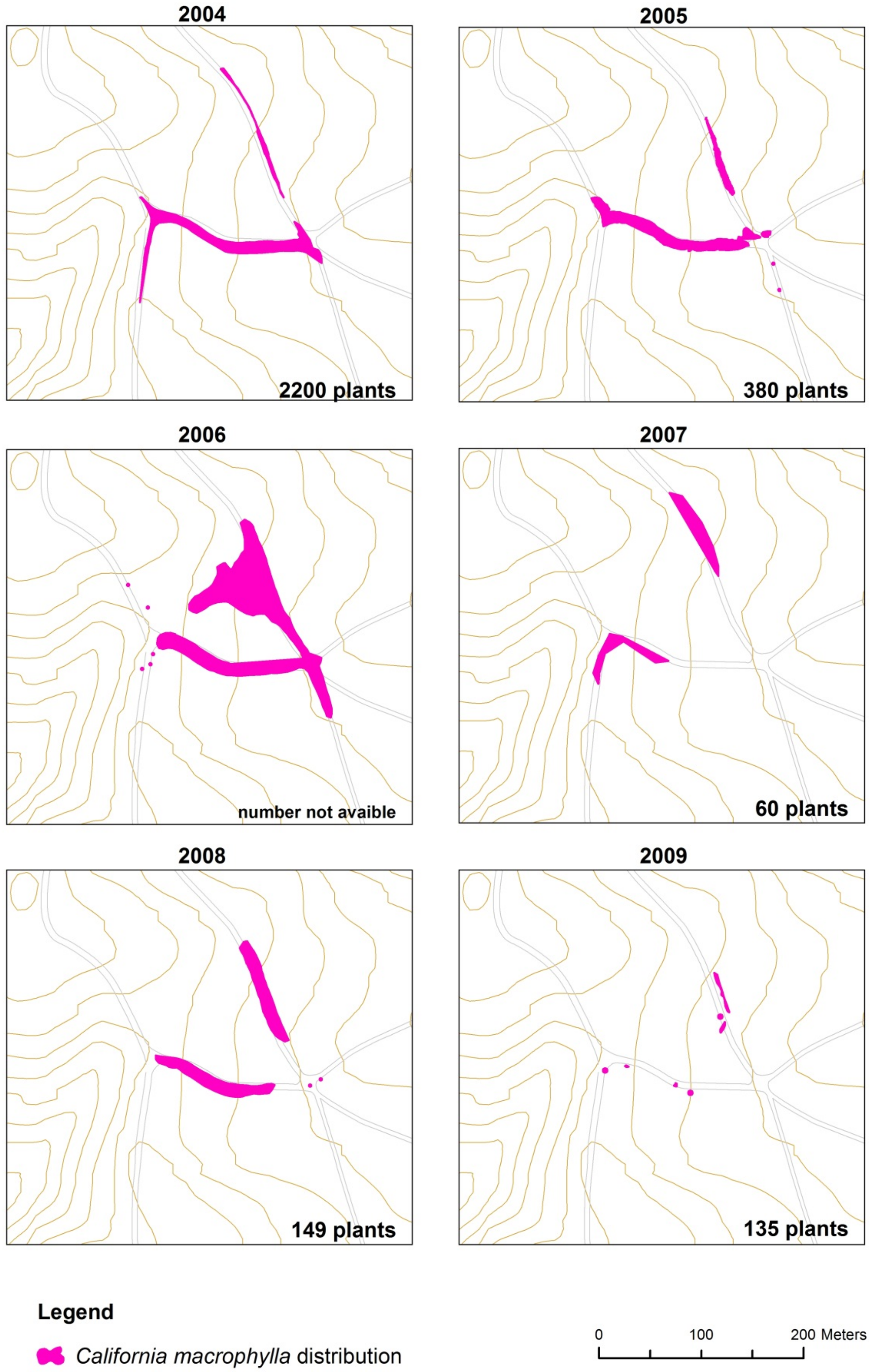
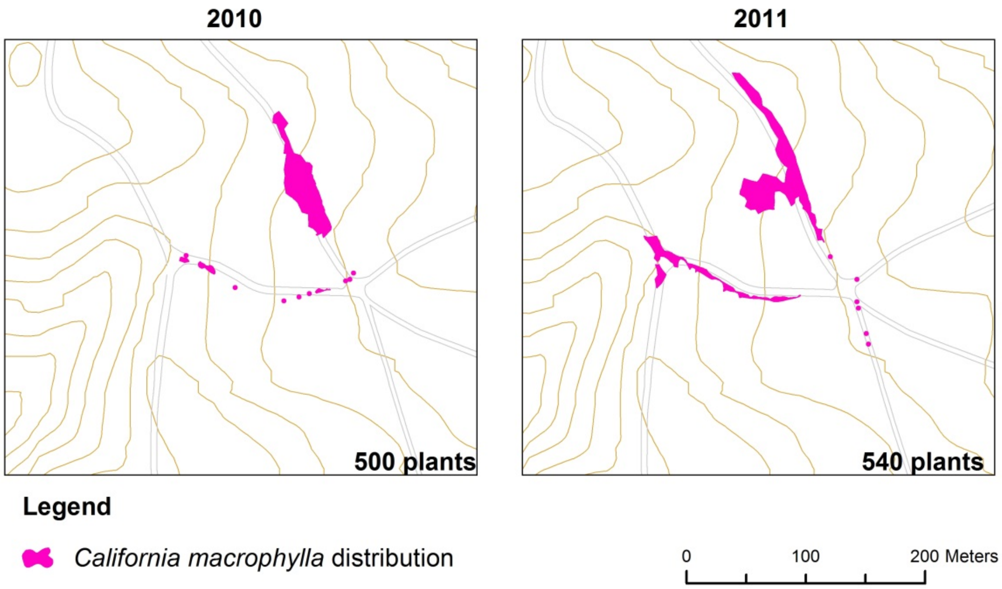


Figure D7. Site 1 distribution for the years 2004 through 2009.



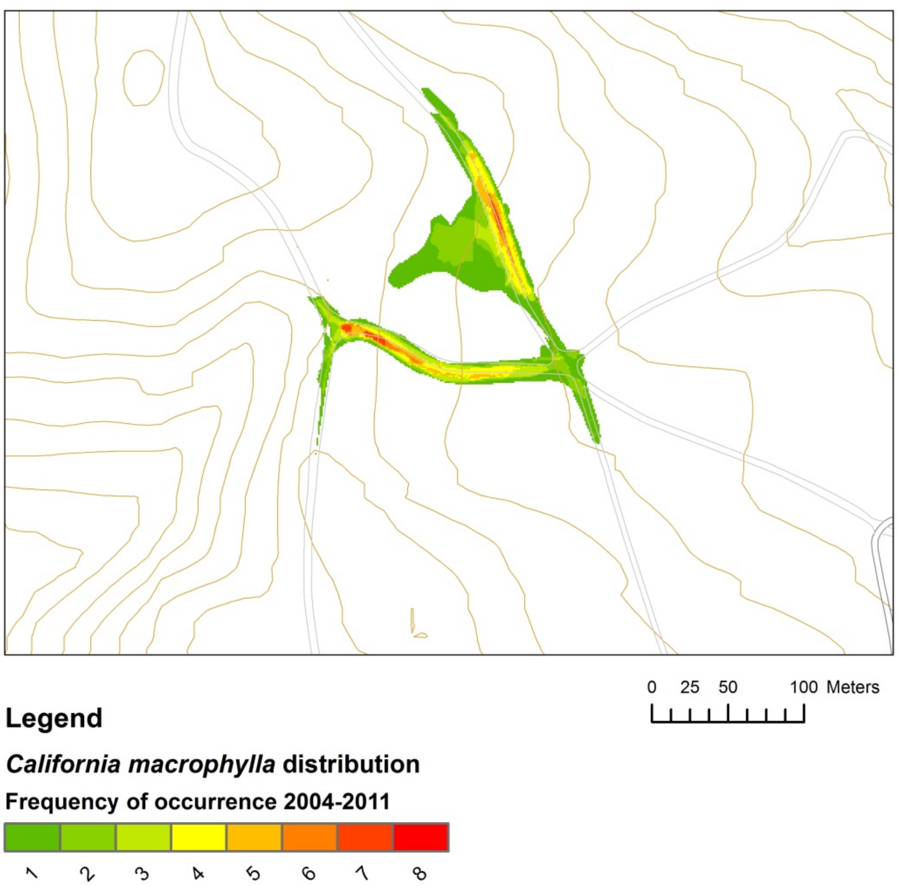


Figure D8. Site 1 distribution for the years 2010 and 2011 and frequency of occurrence for the years 2004 through 2011.

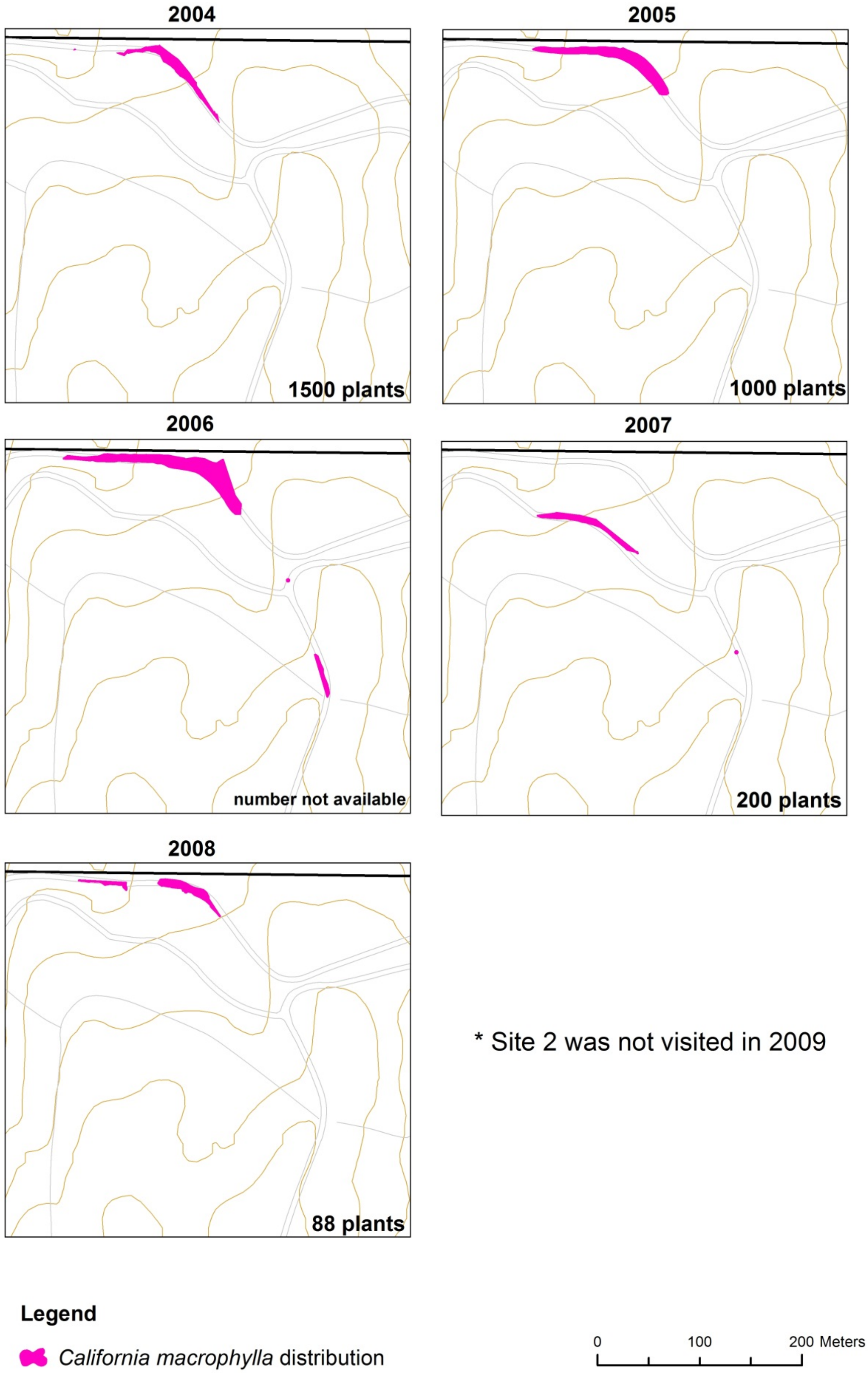


Figure D9. Site 2 distribution for the years 2004 through 2009.

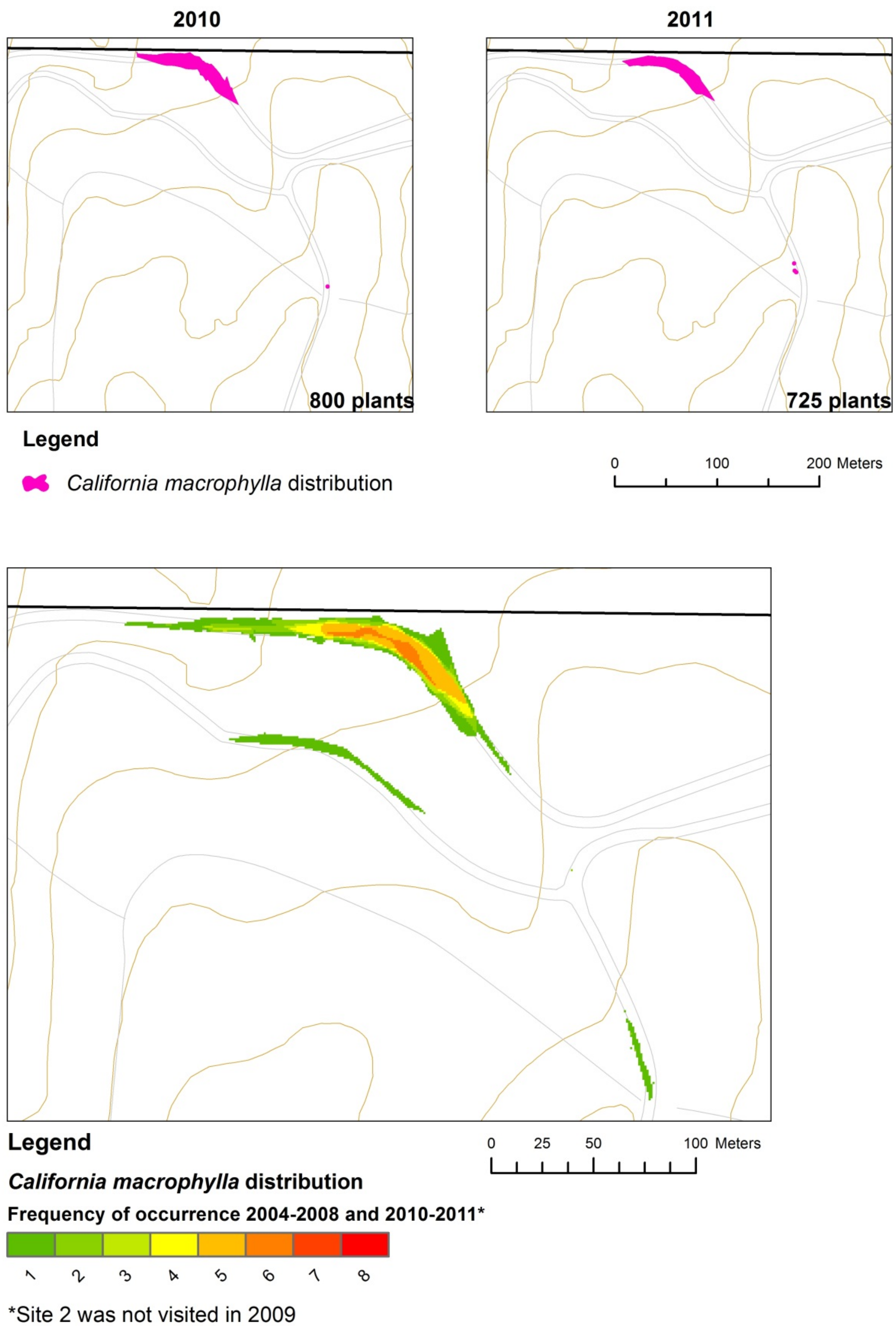


Figure D10. Site 2 distribution for the years 2010 and 2011 and frequency of occurrence for the years 2004 through 2011.

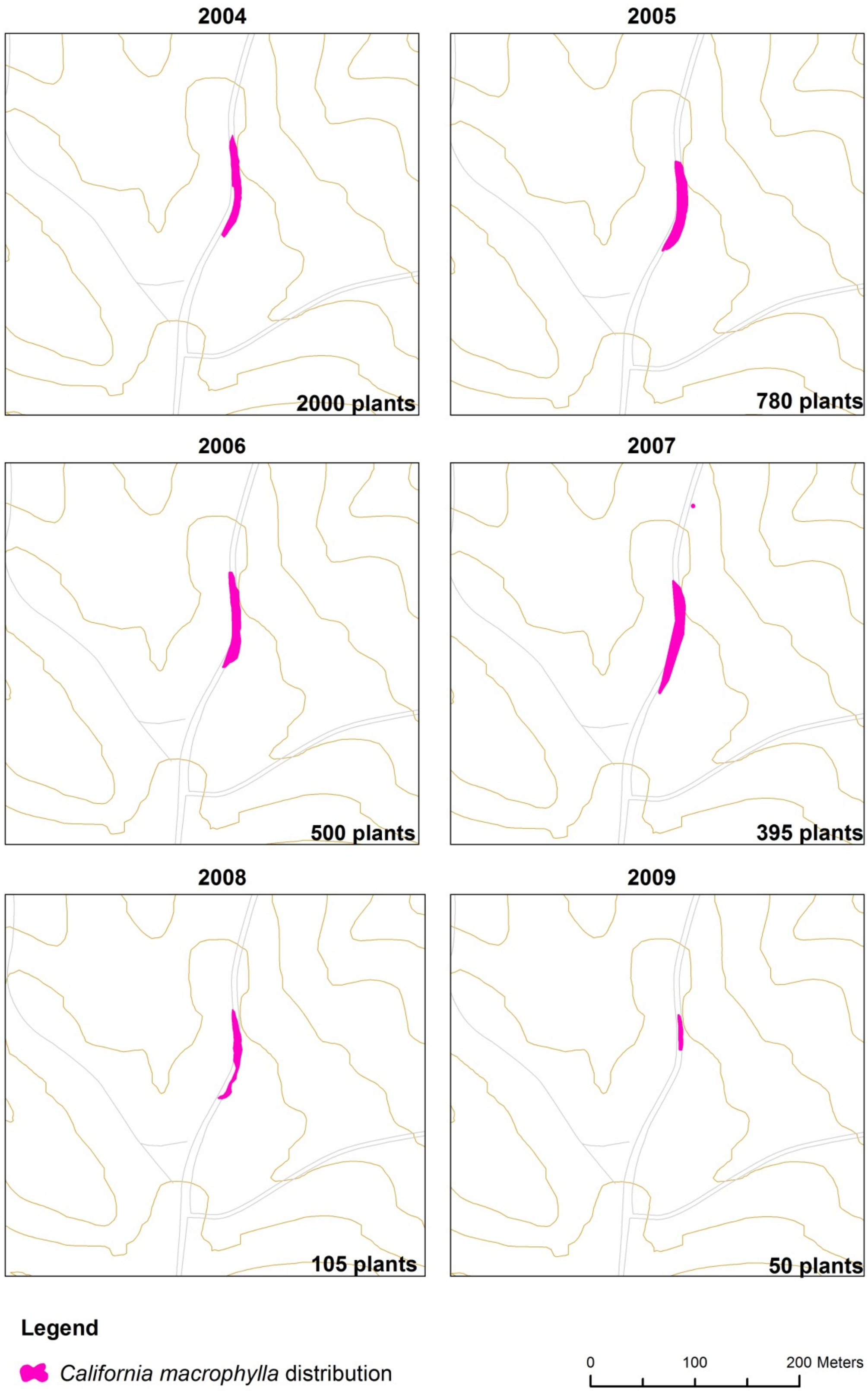
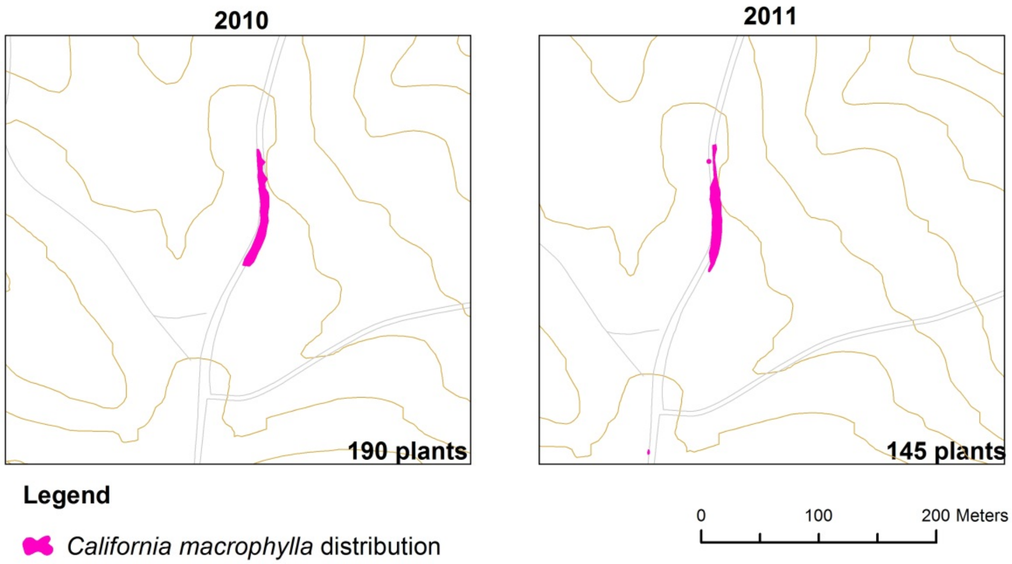


Figure D11. Site 3 distribution for the years 2004 through 2009.



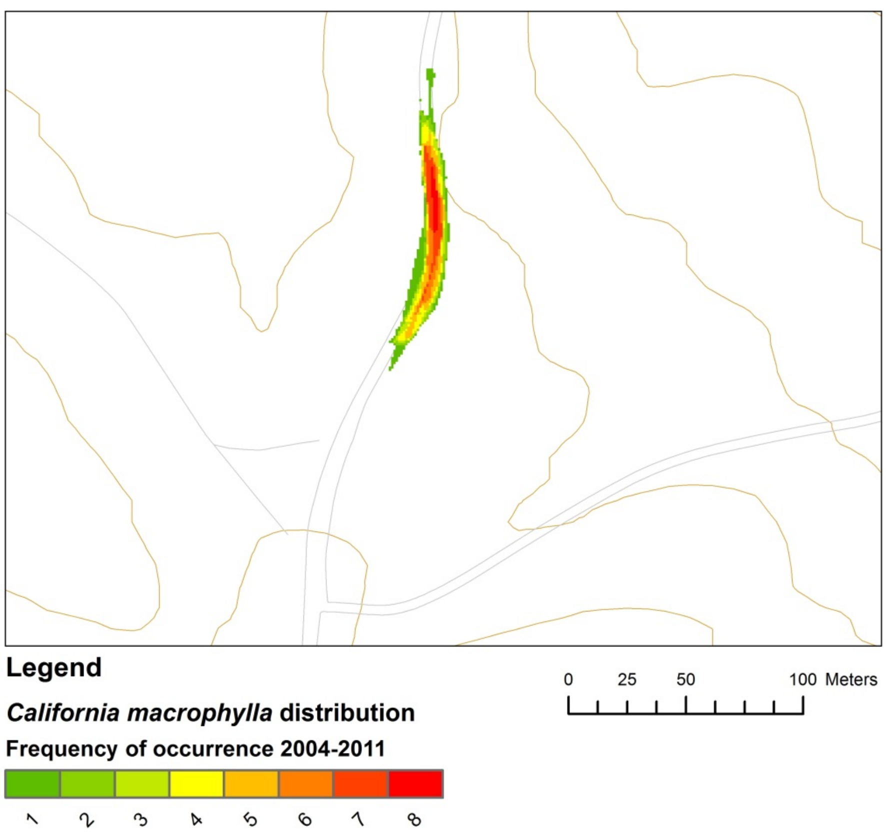


Figure D12. Site 3 distribution for the years 2010 and 2011 and frequency of occurrence for the years 2004 through 2011.

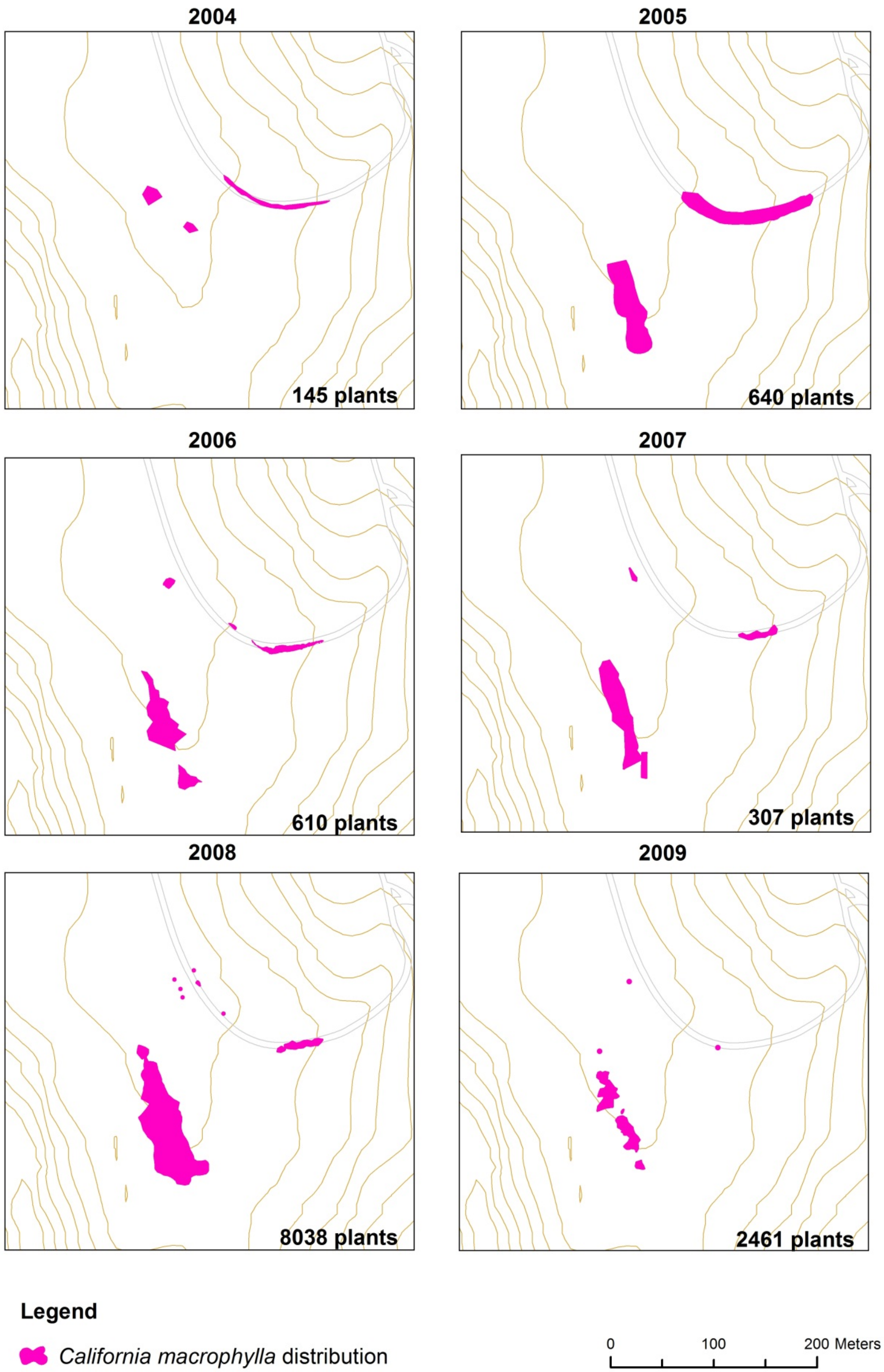


Figure D13. Sites 4 and 5 distribution for the years 2004 through 2009.

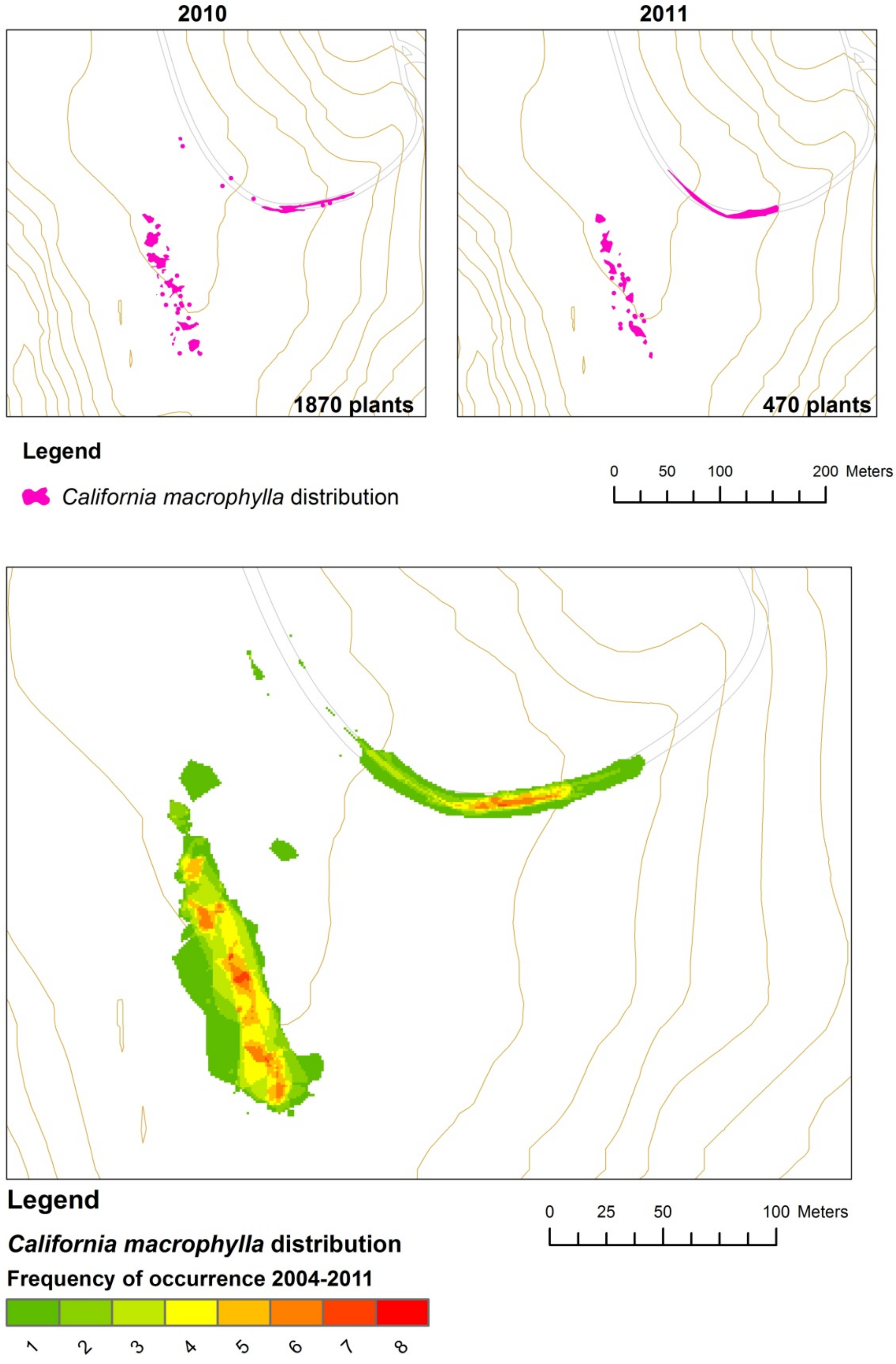


Figure D14. Sites 4 and 5 distribution for the years 2010 and 2011 and frequency of occurrence for the years 2004 through 2011.

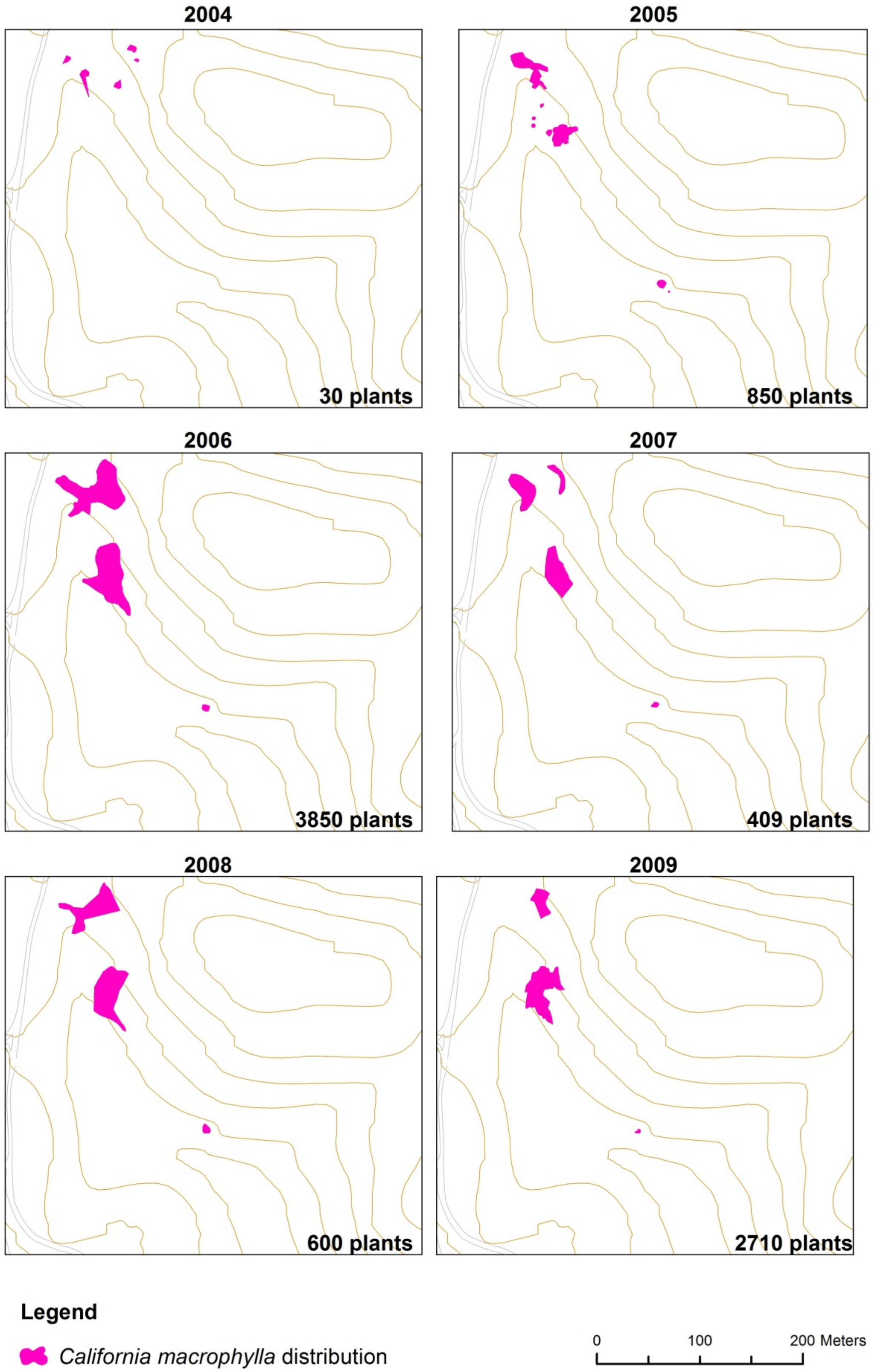


Figure D15. Site 6 distribution for the years 2004 through 2009.

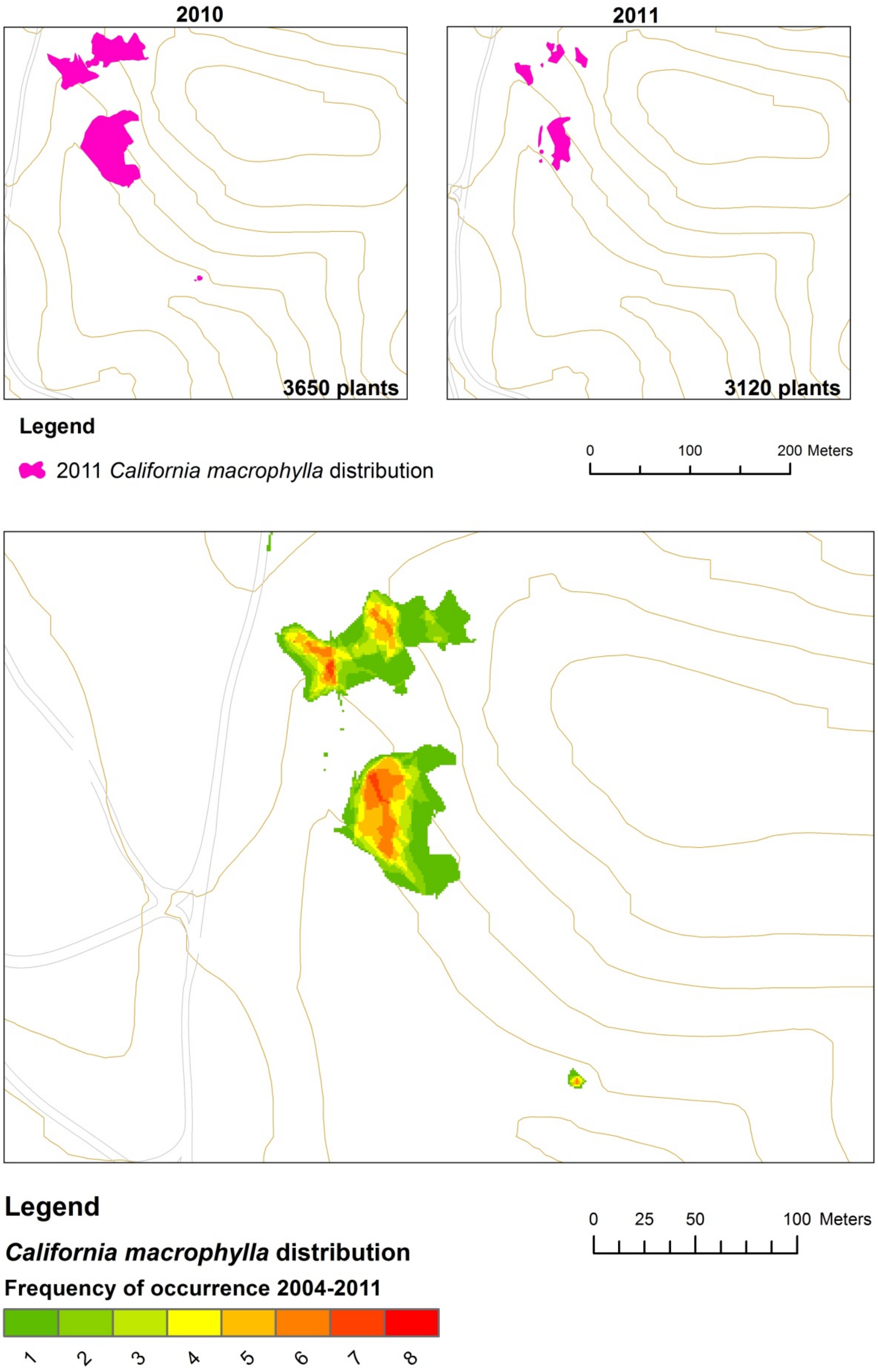


Figure D16. Site 6 distribution for the years 2010 and 2011 and frequency of occurrence for the years 2004 through 2011.

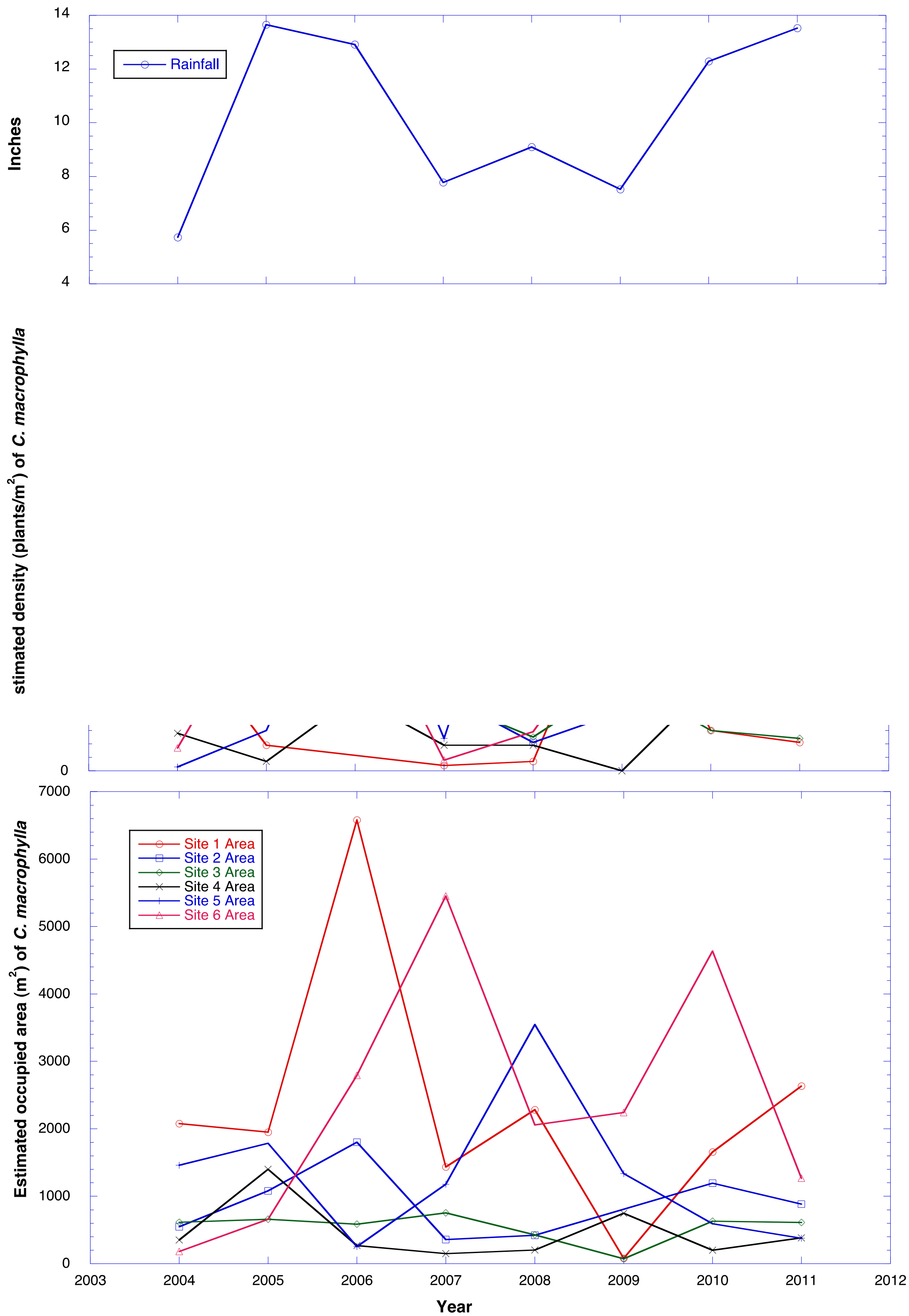


Figure D17. *California macrophylla* estimated area and density for 2004 through 2011.

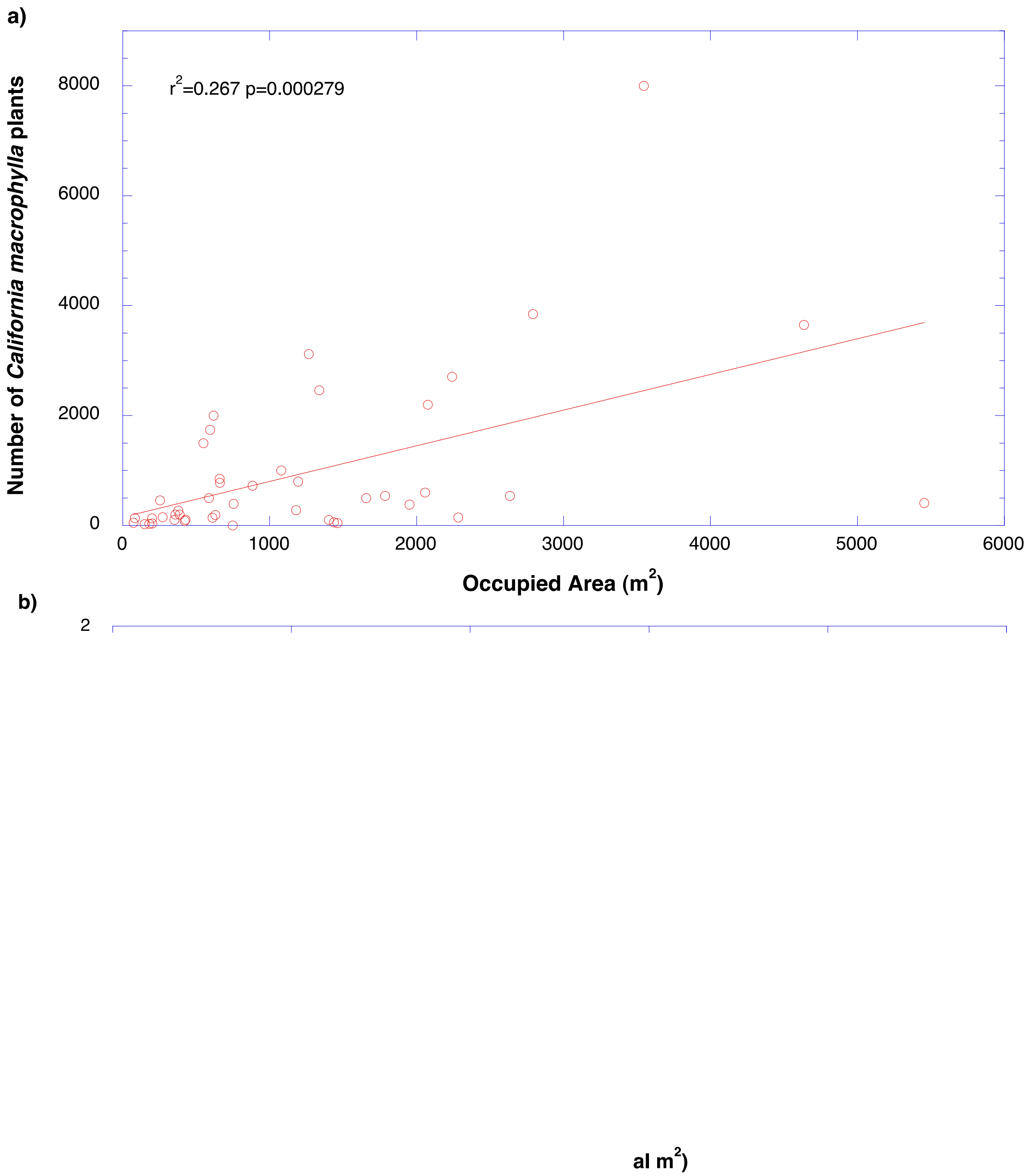


Figure D18. Relationship between number of individuals, density and occupied area of *California macropylla* for all sites and all years combined.

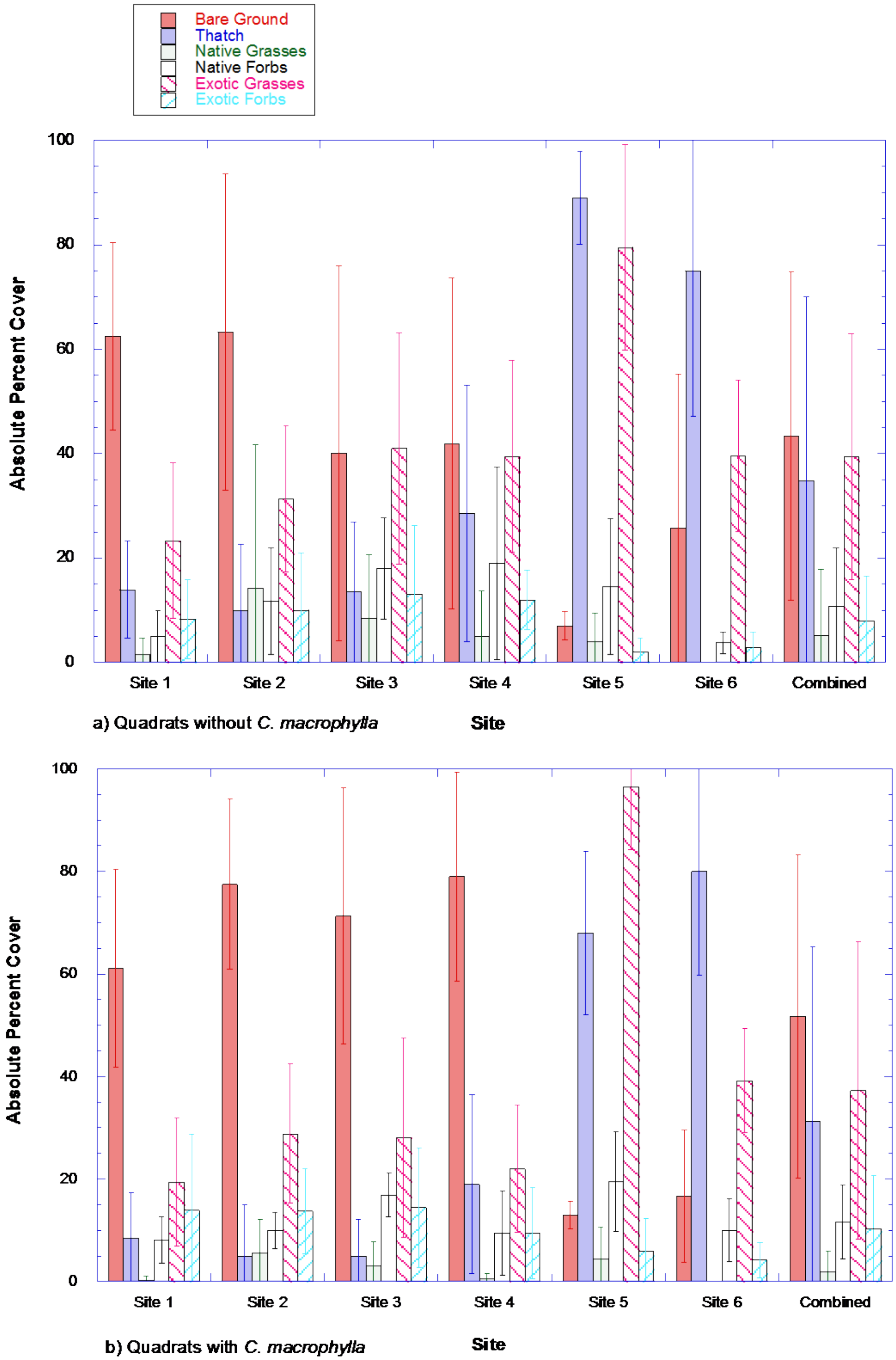


Figure D19. 2007 absolute percent cover of six vegetation categories at sites 1 – 6 and all sites combined. Error bars are ± one standard deviation

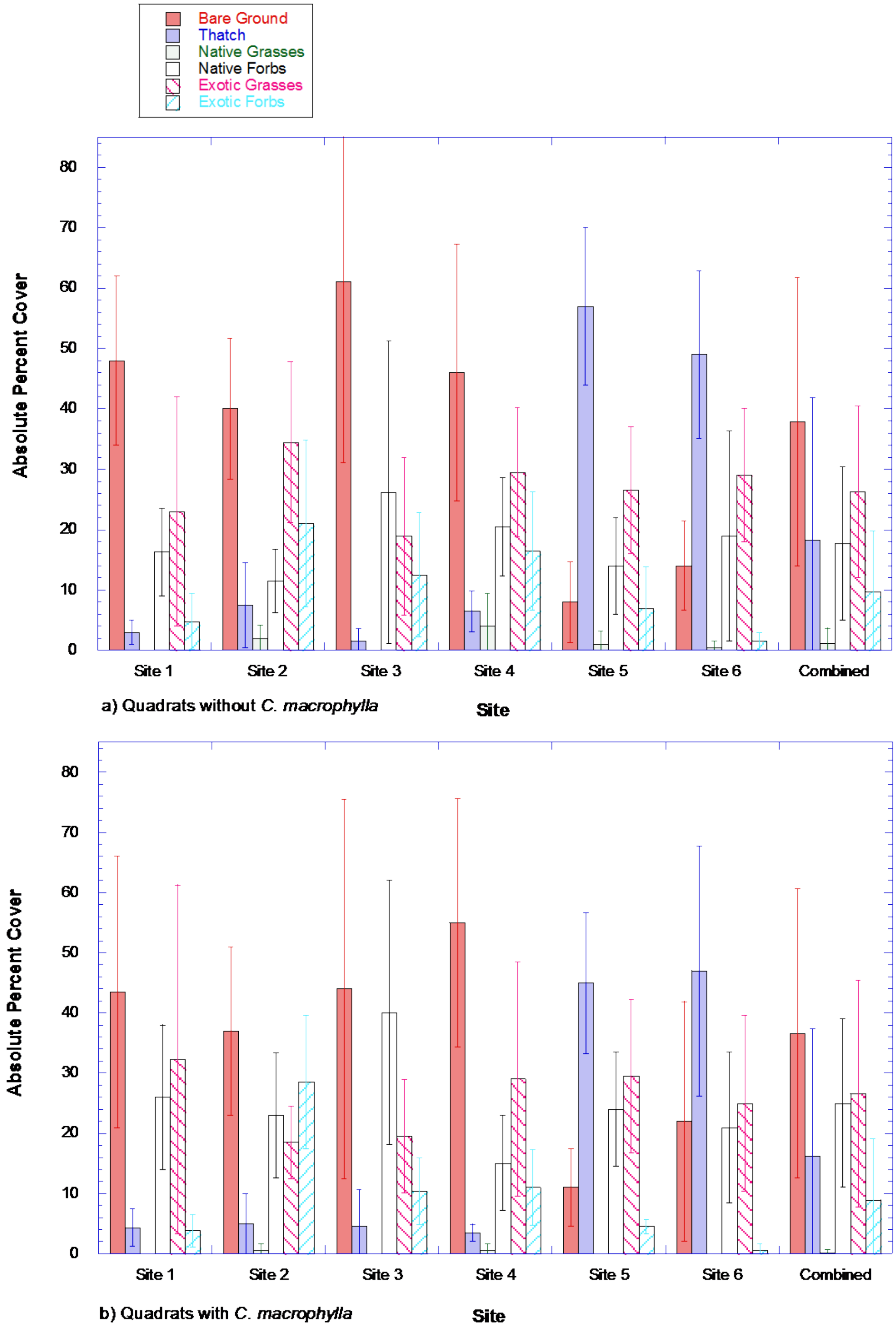


Figure D20. 2008 absolute percent cover of six vegetation categories at sites 1 – 6 and all sites combined. Error bars are ± one standard deviation.

Section D
Tables

Table D1. Summary of *California macrophylla* field work conducted between March 2007 and April 2011.

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
2007						
Plant count	03/29/07	04/13/07	03/30/07	04/02/07	04/05/07 & 04/13/07	04/13/07
GPS locations	03/29/07	04/13/07	04/13/07	04/02/07	04/13/07	04/13/07
Plant msmnt	03/29/07	04/13/07	03/30/07	04/02/07	04/06/11	04/13/07
Quadrat sampling for community data	03/29/07: Two 200 ft transects, 5 with and 5 without C. mac selected randomly	04/13/07: One 300 ft transect, 5 with and 5 without C. mac selected randomly	03/30/07: One 300 ft transect, 4 with and 5 without C. mac selected randomly	04/02/07: One 150 ft transect, 5 with and 5 without C. mac selected randomly	04/06/11: One 350 ft transect, 5 with and 5 without C. mac selected randomly	04/13/07: 1 with and 1 without C. mac in Area 1, 3 with and 3 without C. mac in Area 2 and 2 with and 2 without in Area 3, selected haphazardly
2008						
Plant count	04/10/08	04/17/08	04/17/08	04/11/08	04/04/11	04/18/08
GPS locations				04/11/08		04/18/08
Plant msmnt	04/10/08	04/17/08	04/17/08	04/11/08	04/11/08	04/18/08
Quadrat sampling for community data	04/10/08: Two 300 ft transects, 5 with and 5 without C. mac selected randomly	04/17/08: One 260 ft transect, 5 with and 5 without C. mac selected randomly	04/17/08: One 200 ft transect, 4 with and 5 without C. mac selected randomly	04/11/08: One 200 ft transect, 5 with and 5 without C. mac selected randomly	04/11/08: One 300 ft transect, 5 with and 5 without C. mac selected randomly	04/18/08: 1 with and 1 without C. mac in Area 1, 3 with and 3 without C. mac in Area 2 and 2 with and 2 without in Area 3, selected haphazardly
2009						
Plant count	04/21/09	Did not census	04/24/09	04/21/09	04/17/09	04/24/09
GPS locations	04/21/09	Did not census	04/24/09	04/21/09	04/17/09	04/24/09
2010						
Plant count	04/22/10	04/16/10	04/16/10	04/15/10	04/15/10	04/16/10
GPS locations	04/22/10	04/16/10	04/16/10	04/15/10	04/15/10	04/16/10
2011						
Plant count	04/15/11	04/12/11	04/12/11	04/15/11	04/15/11	04/15/11
GPS locations	04/15/11	04/12/11	04/12/11	04/15/11	04/15/11	04/15/11

Table D2. Area and estimated population size and density of all Site 300 *California macrophylla* populations: 2004-2011.

Year	Location	Site	Area (m^2)	Population size estimate	Density (plants/m^2)	Date of Census
2004	Fire trail	1	2077.1	2200	1.06	29 Mar 04
		2	549.5	1500	2.73	30 Mar 04
		3	617.9	2000	3.24	30 Mar 04
		4	352.6	100	0.28	01 Apr 04
	Grassland	5	1461.9	45	0.03	01 Apr 04
		6	181.7	30	0.17	08 Apr 04
2005	Fire trail	1	1952.1	380	0.19	11 Apr 05
		2	1078.7	1000	0.93	18 Apr 05
		3	660.1	780	1.18	18 Apr 05
		4	1401.8	100	0.07	06 Apr 05
	Grassland	5	1786.6	540	0.30	06 Apr 05
		6	658.6	850	1.29	18 Apr 05
2006	Fire trail	1	6582.7	*	*	07 Apr 06
		2	1803.9	*	*	06 Apr 06
		3	586.3	500	0.85	06 Apr 06
		4	271.3	150	0.55	19 Apr 06
	Grassland	5	254.2	460	1.81	19 Apr 06
		6	2792.1	3850	1.38	13 Apr 06
2007	Fire trail	1	1437.1	60	0.04	29 Mar 07
		2	357.9	200	0.56	13 Apr 07
		3	754.0	395	0.52	30 Mar 07
		4	149.6	28	0.19	02 Apr 07
	Grassland	5	1179.4	279	0.24	05 Apr 07
		6	5453.1	409	0.08	13 Apr 07
2008	Fire trail	1	2283.7	149	0.07	10 Apr 08
		2	420.9	88	0.21	17 Apr 08
		3	427.6	105	0.25	17 Apr 08
		4	201.3	38	0.19	11 Apr 08
	Grassland	5	3546.3	8000	2.26	04 Apr 08
		6	2058.8	600	0.29	18 Apr 08
2009	Fire trail	1	82.7	135	1.63	21 Apr 09
		2	*	*	*	*
		3	73.5	50	0.68	24 Apr 09
		4	748.1	1	0.0013	21 Apr 09
	Grassland	5	1337.1	2460	1.84	17 Apr 09
		6	2241.3	2710	1.21	24 Apr 09
2010	Fire trail	1	1657.1	500	0.30	22 Apr 10
		2	1193.8	800	0.67	16 Apr 10
		3	631.4	190	0.30	16 Apr 10
		4	199.2	130	0.65	15 Apr 10
	Grassland	5	594.2	1740	2.93	15 Apr 10
		6	4636.5	3650	0.79	16 Apr 10

Table D2 (continued). Area, elevation, and estimated population size and density of all Site 300 *California macrophylla* populations: 2004-2011.

Year	Location	Site	Area (m^2)	Population size estimate	Density (plants/m^2)	Date of Census
2011	Fire trail	1	2634.1	540	0.21	15 Apr 11
		2	883.0	725	0.82	12 Apr 11
		3	611.0	145	0.24	12 Apr 11
		4	386.6	200	0.52	15 Apr 11
	Grassland	5	377.6	270	0.72	15 Apr 11
		6	1267.0	3120	2.46	15 Apr 11

***Population estimate are not available for Sites 1 and 2 in 2006. Site 2 was not visited in 2009. Site 1 not visited in 2010.**

Table D3. Number of floral units per plant for the six *California macrophylla* populations, 2004-2008. Values are means ± one standard deviation, N = Number of plants.

Year	Location	Site	Floral units per plant	Width (cm)	Height (cm)	Area (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
2007	Fire trail	1	3.9 ± 2.9	6.6 ± 3.0	3.4 ± 1.1	22.7 ± 14.1	14
		2	0.9 ± 0.8	3.6 ± 1.2	4.3 ± 1.2	15.9 ± 7.2	7
		3	2.8 ± 2.8	5.2 ± 4.0	3.7 ± 1.5	17.7 ± 13.2	6
		4	0.9 ± 0.4	3.1 ± 0.8	3.2 ± 1.0	10.3 ± 5.0	14
	Grassland	5	1.3 ± 1.3	4.5 ± 2.0	7.9 ± 2.9	39.0 ± 28.3	44
		6	0.9 ± 0.5	2.6 ± 0.9	3.5 ± 2.5	10.5 ± 8.9	19
2008	Fire trail	1	15.0 ± 15.1	19.3 ± 10.1	14.5 ± 5.2	292.2 ± 221.5	13
		2	10.3 ± 6.6	18.6 ± 9.4	7.1 ± 2.1	136.8 ± 87.7	8
		3	7.2 ± 5.9	14.4 ± 9.8	8.5 ± 6.2	134.6 ± 162.6	12
		4	6.2 ± 5.3	10.2 ± 5.2	14.6 ± 5.7	155.5 ± 83.1	5
	Grassland	5	10.4 ± 7.0	13.0 ± 6.1	12.8 ± 3.9	175.9 ± 100.0	13
		6	6.8 ± 4.6	12.5 ± 6.2	13.9 ± 2.7	176.9 ± 96.5	27

*** Width measurements were not recorded in 2004.**

Table D4. Average absolute cover recorded in 0.6 m^2 quadrats with *California macrophylla* and without *C. macrophylla* in 2007 and 2008. Values are means ± one standard deviation, N = Number of quadrats sampled.

Cover Class	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	All Sites Combined
2007 Without C. mac	N=10	N=6	N=5	N=5	N=5	N=6	N=37
Bare Ground	62.5 ± 18.0	63.3 ± 30.3	40.0 ± 35.9	42.0 ± 31.7	7.0 ± 2.7	25.8 ± 29.4	43.4 ± 31.4
Thatch	13.9 ± 9.3	10.0 ± 12.6	13.5 ± 13.4	28.5 ± 24.5	89.0 ± 8.9	75.0 ± 27.9	34.9 ± 35.1
Native Grasses	1.5 ± 3.2	14.2 ± 27.6	8.5 ± 12.2	5.0 ± 8.7	4.0 ± 5.5	0	5.1 ± 12.7
Native Forbs	5.0 ± 4.9	11.7 ± 10.2	18.0 ± 9.7	19.0 ± 18.5	14.5 ± 13.0	3.8 ± 2.1	10.8 ± 11.2
Exotic Grasses	23.3 ± 14.9	31.3 ± 14.0	41.0 ± 22.2	39.5 ± 18.4	79.5 ± 19.7	39.6 ± 14.5	39.4 ± 23.6
Exotic Forbs	8.3 ± 7.6	10.0 ± 11.0	13.0 ± 13.2	12.0 ± 5.7	2.0 ± 2.7	2.9 ± 2.9	8.0 ± 8.5
No. Species (S)	17	15	25	18	11	13	38
Shannon's (H')	2.03	2.10	2.58	2.49	1.33	1.69	2.65
Top IV	E. cic (108); Avena sp (105); B. mad (73)	Avena sp (111); Lolium sp (101); E. cic (91)	Avena sp (126); L. wrang (103); E. bot (86)	Avena sp (121); E. cic (107); Unk Poa (69)	Unk Poa (161); V. my (118); L. wrang (65)	Avena sp (123); B. mad (91); V. my (56)	Avena sp (100); E. cic (78); Unk Poa (46)
With C. mac	N=9	N=4	N=4	N=5	N=5	N=6	N=33
Bare Ground	61.1 ± 19.3	77.5 ± 16.6	71.3 ± 25.0	79.0 ± 20.4	13.0 ± 2.7	16.7 ± 12.9	51.7 ± 31.5
Thatch	8.4 ± 8.9	5.0 ± 10.0	5.0 ± 7.1	19.0 ± 17.5	68.0 ± 16.0	80.0 ± 20.2	31.2 ± 34.2
Native Grasses	0.3 ± 0.8	5.6 ± 6.6	3.1 ± 4.7	0.5 ± 1.1	4.5 ± 6.2	0	1.9 ± 4.0
Native Forbs	8.1 ± 4.5	10.0 ± 3.5	16.9 ± 4.3	9.5 ± 8.2	19.5 ± 9.7	10.0 ± 6.1	11.7 ± 7.2
Exotic Grasses	19.4 ± 12.5	28.8 ± 13.6	28.1 ± 19.5	22.0 ± 12.4	96.5 ± 12.2	39.2 ± 10.1	37.3 ± 29.0
Exotic Forbs	13.9 ± 14.9	13.8 ± 8.3	14.4 ± 11.6	9.5 ± 8.9	6.0 ± 6.3	4.2 ± 3.4	10.3 ± 10.4
No. Species (S)	18	17	24	18	15	11	38
Shannon's (H')	1.82	2.22	2.76	2.36	1.71	1.71	2.60
Top IV	Avena sp (115); E. cic (114); C. mac (103)	Avena sp (118); Lolium sp (109); E. cic (107)	E. cic (109); C. mac (104); Avena sp (81)	Avena sp (114); B. dian/ C. mac (103);	Unk Poa (163); V. my (126); C. mac (106)	Avena sp (126); C. mac (107); V. my (73)	Avena sp (106); C. mac (104); E. cic (80)

Table D4 (continued). Average absolute cover recorded in 0.6 m^2 quadrats with *California macrophylla* and without *C. macrophylla* in 2007 and 2008. Values are means ± one standard deviation, N = Number of quadrats sampled.

Cover Class	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6	All Sites Combined
2008							
Without C. mac	N=10	N=5	N=5	N=5	N=5	N=5	N=35
Bare Ground	48.0 ± 14.0	40.0 ± 11.7	61.0 ± 29.9	46.0 ± 21.3	8.0 ± 6.7	14.0 ± 7.4	37.9 ± 23.9
Thatch	3.0 ± 2.0	7.5 ± 7.1	1.5 ± 2.2	6.5 ± 3.4	57.0 ± 13.0	49.0 ± 13.9	18.2 ± 23.6
Native Grasses	0	2.0 ± 2.1	0	4.0 ± 5.5	1.0 ± 2.2	0.5 ± 1.1	1.1 ± 2.6
Native Forbs	16.3 ± 7.3	11.5 ± 5.2	26.2 ± 25.0	20.5 ± 8.2	14.0 ± 8.0	19.0 ± 17.4	17.7 ± 12.7
Exotic Grasses	23.0 ± 19.0	34.5 ± 13.3	18.9 ± 13.0	29.5 ± 10.7	26.5 ± 10.5	29.0 ± 11.0	26.3 ± 14.2
Exotic Forbs	4.8 ± 4.6	21.0 ± 13.8	12.5 ± 10.3	16.5 ± 9.8	7.0 ± 6.9	1.5 ± 1.4	9.7 ± 10.1
No. Species (S)	14	21	16	20	15	11	42
Shannon's (H')	1.83	2.24	2.21	2.32	2.45	1.51	2.77
Top IV	T. wild (107); Avena sp (90); E. cic (85)	Avena sp (121); Lolium sp (109); E. cic (106)	Avena sp (117); E. cic (109); L. succ (87)	Avena sp (125); E. cic (108); L. succ (107)	V. my (107); B. mad (88); Unk Poa (68)	Avena sp (124); Tritelia sp (114); Unk mono (64)	Avena sp (98); E. cic (82); L. succ (40)
With C. mac	N=10	N=5	N=5	N=5	N=5	N=5	N=35
Bare Ground	43.5 ± 22.6	37.0 ± 14.0	44.0 ± 31.5	55.0 ± 20.6	11.0 ± 6.5	22.0 ± 19.9	36.6 ± 24.0
Thatch	4.3 ± 3.1	5.0 ± 5.0	4.5 ± 6.2	3.5 ± 1.4	45.0 ± 11.7	47.0 ± 20.8	16.2 ± 21.1
Native Grasses	0	0.5 ± 1.1	0	0.5 ± 1.1	0	0	0.1 ± 0.6
Native Forbs	26.0 ± 12.0	23.0 ± 10.4	40.1 ± 22.0	15.0 ± 7.9	24.0 ± 9.5	21.0 ± 12.6	25.0 ± 14.0
Exotic Grasses	32.3 ± 29.0	18.5 ± 6.0	19.5 ± 9.4	29.0 ± 19.5	29.5 ± 12.8	25.0 ± 14.6	26.6 ± 18.9
Exotic Forbs	3.8 ± 2.7	28.5 ± 11.1	10.4 ± 5.5	11.0 ± 6.3	4.5 ± 1.1	0.5 ± 1.1	8.9 ± 10.2
No. Species (S)	13	21	19	17	17	10	41
Shannon's (H')	1.84	2.34	2.39	1.87	2.38	1.65	2.64
Top IV	Avena sp (120); C. mac (108); T. wild (104)	M. poly (122); Avena sp (114); C. mac (105)	Avena sp (119); L. succ (109); C. mac/E. cic (105)	Avena sp (128); E. cic/L. succ (106); C. mac (103)	C. mac (110); Unk Poa (94); V. my (88)	Avena sp (120); C. mac (109); Unk mono (63)	Avena sp/C mac (107); E. cic (84); P. cil/T. wild (42)

Notes on following page.

Table D4 (continued). Average absolute cover recorded in 0.6 m^2 quadrats with California macrophylla and without C. macrophylla in 2007 and 2008. Values are means ± one standard deviation, N = Number of quadrats sampled.

Notes:

Avena sp=	***Avena* species**	**L. succ =**	***Lupinus succulentus***
B. dian =	***Bromus diandrus***	**M. poly =**	***Medicago polymorpha***
B. mad =	***Bromus madritensis***	**N =**	**Number of plots sampled**
C. mac =	***California macrophylla***	**No. =**	**Number**
Cvr =	**Cover**	**P. cil =**	***Phacelia ciliata***
E. bot =	***Erodium botrys***	**S =**	**Number of species**
E. cic =	***Erodium cicutarium***	**T. wild =**	***Trifolium wildenovii***
H' =	**Shannon's Diversity Index**	**Tritelia sp =**	***Tritelia* species**
IV =	**Importance Value**	**UnkPoa =**	**Unknown Poaceae**
Lolium sp =	***Lolium* species**	**Unk mono =**	**Unknown monocot**
L. wrang =	***Lotus wrangelliannus***	**V. my =**	***Vulpia myuros***

Table D5. Plant species found in and around *California macrophylla* populations in 2007 and 2008. Sites where species found in parentheses.

Native	Exotic
Grasses	
Poa secunda (3) *Vulpia microstachys* (1,2,3,4,5,6)	*Avena barbata* (1,2,3,4,5,6) *Avena fatua* (1,2,4,6) *Avena* sp. (3,5) *Bromus diandrus* (1,2,3,4,5,6) *Bromus hordeaceous* (1,2,3,4,5,6) *Bromus madritensis* subsp. *rubens* (1,2,3,4,6) *Hordeum murinum* (1) *Lolium* sp. (1,2,3) *Vulpia myuros* (1,2,3,4,5,6)
Forbs	
Achyrachaena mollis (3,6) *Amsinckia lycopsoides* (1,3,4) *Amsinckia mensezii* (2,3,4) *Amsinckia tessellata* (1,2,3,4,6) *Amsnckia* sp. (2,3,4,6) *Astragolus* sp. (1) *Calandrinia ciliata* (1,2,3) *Castillejia* sp. (2,3) *Clarkia* sp**.** (5) *Claytonia perfoliata* (2,3) *Collinsia sparsiflora* (5) *California macrophylla* (1,2,3,4,5,6) *Eschscholzia rhombipetala* (5) *Euphorbia spathulata* (2,5) *Galium aparine* (5) *Guillenia lasiophylla* (4) *Gutierrezia californica* (3,4) *Lepidium nitidum* (1,2,3,4,6) *Lotus wrangellianus* (1,2,3,4,5,6) *Lupinus bicolor* (1,2) *Lupinus microcarpus* (1) *Lupinus succulentus* (1,3,4) *Marah fabaceus* (2) *Microseris douglasii* (3,4) *Minuarta* sp. (5) *Monolopia major* (1,2,3,4,6) *Phacelia ciliata* (1,2,3,4) *Phacelia distans* (3) *Stylomecon heterophylla* (3) *Triteleia laxa* (6) *Trifolium albopurpureum* (4) *Trifolium gracilentum* (1,3,4,6) *Trifolium wildenovii* (1,2,3,4) *Trifolium* sp. (2,4,5)	*Brassica* sp. (1) *Capsella bursa-pastoris* (4) *Carduus pynocephalus* (4) *Erodium botrys* (2,3) *Erodium cicutarium* (1,2,3,4,5,6) *Hirschfeldia incana* (4) *Hypochaeris* sp. (3) *Medicago polymorpha* (2,3,4,5) *Silybum* sp. (4,6) *Sonchus asper* (2,5) *Vicia* sp. (1,2,5,6)

Notes: For plants identified only to genus, native versus exotic identifications were made using species lists generated by Preston (2002).