Lawrence Livermore National Laboratory
University of California
Livermore, California 94551

UCRL-AR-142408

Rare Plant Restoration and Monitoring at Lawrence Livermore National Laboratory Site 300

Project Progress Report
Fiscal Year 2000
October 1999–September 2000

Authors

Tina Carlsen
Erin Espeland
Abigail Smith

February 2001

Environmental Protection Department
Environmental Restoration Division

This work was performed under the auspices of the U. S. Department of Energy by the University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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Executive Summary

Four rare native plant species occur at Site 300: (1) *Amsinckia grandiflora*, a federally-listed endangered borage, (2) *Blepharizonia plumosa* ssp. *plumosa*, a late-flowering tarplant that is extremely rare throughout its range, (3) *Eschscholzia rhombipetala,* the diamond-petaled poppy which was not seen from 1950 to 1993 and presumed extinct, and (4) *Delphinium gypsophilum* ssp. *gypsophilum*, the gypsum-loving larkspur which is on the California Native Plant Society watch list indicating it is rare, but with a wide enough distribution so as not to be threatened at this time. This report summarizes the work performed on these four species for the fiscal year 1999–2000.

Each of these species has varying levels of statewide rarity and abundance at Site 300 and research and management of each species is different as a result. *A. grandiflora* currently occurs in two populations at Site 300: one native population (an additional native population has been extirpated for three years) and one experimental population. The goal of research and management of *A. grandiflora* populations is to control the cover of exotic annual grasses while developing techniques to restore native perennial grasslands and preserve *A. grandiflora* numbers. *B. plumosa plumosa* occurs in large numbers throughout Site 300, and thus occurs in areas of active Site 300 operations. However, its close relative, *B. plumosa viscida* is not common at Site 300. Efforts are focused on determining the effects of fire on the distribution of both species and identifying possible metapopulation dynamics controlling the Site 300 *B. plumosa plumosa* populations. *E. rhombipetala* is found in one small population at in the southwestern corner of Site 300 on a small landslide. Because the population is small and occurs at a geologically unstable location, low-impact population demographic and community association data are all that are being collected at this time. Population locations and plant numbers are being collected for *D. gypsophilum gypsophilum* so that basic information about the species is available should its non-threatened status change.

Amsinckia grandiflora Work

Activity Summary

Densities of the native perennial bunch grass *Poa secunda* in the expansion area of the experimental population (the subpopulation of the experimental population for use in testing effect of fire frequency - designated FF) were restored and *A. grandiflora* seedlings were transplanted into the plots. The existing experimental subpopulation (designated FL) was monitored for survivorship throughout the year. Both the experimental population and the native population were censused in the spring. Biomass was collected from FL plots. Seed predation in FL, FF, and control plots was monitored. A two-week trapping period was conducted between monitoring rounds to determine if rodent removal would reduce seed predation. An experiment to determine the effectiveness of cutting bush lupine (*Lupinus albifrons*) in an effort to reduce *A. grandiflora* competitor biomass near the native population was conducted. A test was performed to determine if heating the seeds of *A. grandiflora* (as would occur during exposure to fire) would affect germination.

Results Summary

- Population numbers were up in the native population (40 plants, up from 6 in 1999) and remained about the same in the experimental FL subpopulation (45 plants, compared to 42 in 1999).
- The experimental FF subpopulation was successfully established after some initial herbivory on early transplants. In the spring this expansion area contained 143 flowering plants.
- The survivorship in the experimental FL subpopulation was higher this year (36%) than previous years (18% in 1998, 1% in 1999).
- Biomass in the FL plots in 2000 was similar to 1999 (close to $20g/0.1m^2$ in unburned and about $10g/0.1m^2$ in burned plots). Differences in biomass composition were observed between burned and unburned plots.
- Seed predation was quite low, with percent seeds lost at less than 50%, compared to over 90% the previous year. Trapping yielded one rodent. The pattern of predation was cyclic as opposed to the density dependence observed in prior years. This may indicate bird, and not rodent, seed predation predominated in the year 2000.
- Large amounts of biomass were collected next to cut lupines and underneath living lupines (around $22g/0.1m^2$ for both). Control biomass (collected not near a lupine) was lower ($13g/0.1m^2$).
- Heat treatment of seeds resulted in no germination.

Blepharizonia plumosa ssp. *plumosa* Work

Activity Summary

Selected populations of *B. plumosa plumosa* were sampled prior to spring burns, after spring burns and at fall flowering. Survivorship, height and microtopological data were collected. All populations at Site 300 were mapped using a GPS unit when plants were flowering. A field experiment using buried pots sown with *B. plumosa plumosa* seeds was initiated to determine if exposure to fire increases germination in the species.

Results Summary

- Survivorship following the burn differed between years and populations. In 1998, 1999 and 2000, survivorship at Elk Ravine was 0%, 5% and 81% respectively. At B850, survivorship was 85%, 68% and 77% for those three years.
- In 1999, plants found in sheltered locations were more likely to survive, but this was not the case in 2000.
- In 1999, plant height was greater pre-burn than immediately post-burn. In 2000, plants were larger immediately after the burn.
- The burn in 2000 occurred six weeks later in the year than the burn in 1999, and likely had an effect on differences in survivorship and height between the two years.

- *B. plumosa plumosa* was common along fire trails throughout Site 300.
- The burn at B850, where the germination experiment pots were located, was patchy and large amounts of ash were not deposited on the pots. Germination in the pots will be monitored throughout the growing season of 2000–2001.

Eschscholzia rhombipetala Work

Activity Summary

The single *Eschscholzia rhombipetala* population was censused at flowering. Plant height, number of flowers, location (slump, scarp or grassland), and surrounding cover type (open, clipped or grassland) was recorded. A clipping experiment was performed to determine if the reduction of standing biomass from the previous year would affect *E. rhombipetala* height or flower number. Community composition data were collected from releve samples located within the population and in the area surrounding it.

Results Summary

- In 1998, 1999, and 2000 the *E. rhombipetala* population consisted of 18, 6, and 273 plants respectively.
- Plants are small. Average heights range from 4.7 cm to 7.5 cm. Plants as small as 2.5 cm were found flowering.
- In 2000, plants were tallest in the slump and grassland and in areas where there was surrounding cover.
- Plants in the slump had the greatest number of flowers in 2000. Plants on the scarp and in clipped areas had the fewest flowers.
- The clipping treatment in fall of 1999 resulted in areas with higher grass and higher total cover than control areas in summer of 2000.
- Releve sampling showed a more diverse community in 2000 than in 1999, with native forb diversity increasing from three species in 1999 to six species in 2000.
- The importance of native species in describing the community increased in 2000. Importance Values for *E. rhombipetala*, *Blepharizonia plumosa* and *Poa secunda* all were greater in 2000 compared to 1999.
- Native species were also important in describing the variability among releves for both years. *E. rhombipetala* was important in both 1999 and 2000.

Delphinium gypsophilum ssp. *gypsophilum* Work

Activity Summary

Areas where *Delphinium gypsophilum gypsophilum* had been found previously were resurveyed. Specimens were collected from all locations and taken to the Jepson Herbarium for positive identification.

Results Summary

- Survey results and herbarium identification indicate that *D. hesperium var. pallescens* was previously misidentified as *D. gypsophilum gypsophilum* in many locations.
- Populations of *D. gypsophilum gypsophilum* near the microwave towers and near the *E. rhombipetala* population were identified for future monitoring.

Section A
Amsinckia grandiflora Restoration

Section A

Amsinckia grandiflora Restoration

A-1. Introduction

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

A. grandiflora has been recently known from only three natural populations containing individuals numbering from fewer than 30 to several thousand. All natural populations occur on steep, well-drained north facing slopes in the Altamont Hills of the Diablo range, about 30 km southeast of San Francisco, California. The populations occur at low elevations (approx. 300 m) and border on blue oak woodland and coastal sage scrub communities. Two of the natural populations occur on LLNL Site 300, a high-explosive testing facility operated by the University of California for the United States Department of Energy (DOE). The two natural populations at Site 300 are known as the Drop Tower population and the Draney Canyon population. Located in the north/southwest trending Drop Tower canyon, the Drop Tower population is the larger of the two populations at Site 300 and was the only known population of *A. grandiflora* up through 1987. In 1987, the Draney Canyon population was discovered in a north/southwest trending canyon to the west of the Drop Tower canyon. This population is now believed to have been extirpated. In 1993, a large *A. grandiflora* population, known as the Carnegie Canyon population, was discovered on private rangelands near the southeast border of Site 300. Attempts at establishing two experimental populations have also occurred near Site 300. Located adjacent to the southeast border of Site 300 is an ecological reserve owned by the California Department of Fish and Game (CDFG). An attempt was made to establish an experimental population of *A. grandiflora* at this site (known in Pavlik, 1994 as the Corral Hollow population), but no reproductive plants have been observed at this site in recent years, suggesting the establishment was not successful. Also near the southeast border of Site 300 is the Connolly Ranch, a privately owned ranch. An experimental population at this site was attempted, but failed, possibly as a result of extremely high rodent activity (Pavlik, 1994). Figure A2 shows the approximate locations of the *A. grandiflora* populations at or near Site 300.

Amsinckia grandiflora was federally listed as endangered in 1985. On May 8, 1985, one hundred and sixty acres of LLNL surrounding the native Drop Tower *A. grandiflora* population was designated critical habitat by the U.S. Fish and Wildlife Service (USFWS). In 1997, the USFWS published the final recovery plan for the species (USFWS, 1997). On April 28, 2000, the Secretary of the U.S. Department of Energy established the *Amsinckia 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 (USDOE, 2000).

Restoration efforts began in 1988 by researchers from Mills College. These efforts focused on determining the factors necessary for the successful establishment of additional populations of *A. grandiflora* (Pavlik, 1988a and 1988b), and have resulted in the establishment of at least one apparently successful experimental population at Lougher Ridge (Pavlik, 1994). Between 1993 and 1995 using funds obtained through a grant from LLNL's Laboratory Directed Research and Development Program, LLNL researchers teamed with researchers from Mills College to further investigate the causes of *A. grandiflora* rarity and to establish an additional population at Site 300. The experimental population was established near the Drop Tower native population on a north-facing slope on the eastern fork of the Drop Tower canyon where it bifurcates around the Drop Tower facility parking lot (Figure A3). This population is known as the Drop Tower experimental population.

Research on the Drop Tower experimental population, the Lougher Ridge experimental population, and data from management of the Drop Tower natural population indicated that competition from exotic annual grasses was contributing 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 was necessary to ensure the persistence of this species (Pavlik et al., 1993; Pavlik, 1994; Carlsen et al., 2000). Long-term financial support is being provided through LLNL Site 300 management. Additional funding from the U.S. Bureau of Reclamation was also used in 2000.

The goal of the ongoing management of the Site 300 *A.* grandiflora populations is to control the cover of exotic annual grasses while developing techniques to restore native perennial grasslands. The use of controlled burning is being investigated as a tool for developing and maintaining perennial grasslands. Finally, the impact of seed predation is being investigated to determine its impact on the population dynamics of *A. grandiflora*. This report details progress made during the 2000 federal fiscal year (October 1999 through September 2000).

A-2. Methods and Materials

A-2.1. Demographic Monitoring

Demographic monitoring of the Drop Tower flashing (FL) subpopulation continued in 2000. Due to the large amount of disturbance that frequent trips to the field site impart on the deep soil and plant cover of such steep hillsides, detailed demographic monitoring was limited to the experimental population, which already has well-defined compacted trails around the experimental plots. Germination of *A. grandiflora* in the FL subpopulation occurred in late October and early November. On 10 Dec 1999, a total of 47 seedlings were marked in plots that contained flowering adults the previous spring. One to nine *A. grandiflora* seedlings were marked in each plot. Figure A4 summarizes all of the experimental treatments conducted on the FL subpopulation. The plots labeled "Surv" are the demographic plots containing the marked *A. grandiflora* plants.

Positive field identification between different *Amsinckia* species is difficult at the seedling stage. However, as they flower, *A. grandiflora* can be easily differentiated from congeneric species. When the marked plants were positively identified, some were found to be congeners. Subsequent to correct identification, sample sizes were adjusted to reflect the corrected number of *A. grandiflora* plants. As a result, the number of marked plants in each plot varied from one to five individuals. It is possible that individuals that died prior to flowering (precluding correct identification) may have been from congeneric species, and thus may be included in the pre-flowering demographic data.

The plants were marked on 10 Dec 99 by looping a piece of string loosely around the base of each seedling and placing a wire marker next to the seedling. This ensured that the same plants were monitored during each observation date. Wire makers were shorter than the surrounding plant material and thus unlikely to add significant shading to the seedlings. Height and survivorship of the plants were measured on 10 Jan 00, 11 Feb 00, 18 Feb 00, 10 Mar 00, and 27 Mar 00.

A-2.2. Fire Frequency Subpopulation

On 15 Dec 99, three *A. grandiflora* seedlings were transplanted into each of the 20 plots in the fire frequency (FF) subpopulation. All seedlings were at the cotyledon stage. Seedlings were located in the center of the plot, interspersed with the central *P. secunda* plants. Prior to planting, seedlings were separated into three size classes: small, medium and large. One plant from each size class was planted per plot. To transplant the seedlings, holes were pressed into the soil with a Steuwe tube (a plastic tube resembling a test tube). The sides and bottom of the hole were wetted with deionized water. The Steuwe tube containing the seedling was cut across the bottom and along the sides. The soil within the tube was compressed and then the soil plug containing the seedling was slid out into the hole in the soil. After transplanting, each seedling was watered and covered by a small amount (about half a gram) of thatch. In the ensuing two weeks, most of these seedlings were lost to herbivory. On 10 Jan 00, two additional *A. grandiflora* seedlings were transplanted into each of the twenty plots in the FF subpopulation. These seedlings had reached the true-leaf stage and it was believed they would be less attractive to herbivores.

On 26-28 Jan 00, additional *A. grandiflora* seedlings were transplanted into the plots to bring the total number of *A. grandiflora* in each plot to ten. Most plots had only a single *A. grandiflora* seedling remaining at this time due to plant loss to herbivores. Due to the large number of deer tracks found in the area, we believe deer may have been responsible for some of this herbivory. Plants were located in the center of each plot, with one *P. secunda* plant between each *A. grandiflora.* Most seedlings had true leaves at the time of this latest transplant. Each 1m x 1m plot was netted after the transplant in an attempt to prevent herbivore access. Half-inch diameter doweling was used to lift the netting six inches above the soil surface.

Due to the rodent damage sustained by experimental plots established during 1999, approximately ninety-eight missing *Poa secunda* tussocks were replanted on 26 Jan 00.

Tussocks from the surrounding area were excavated, divided into 3 cm diameter plugs and transplanted into locations within the original checkerboard pattern, bringing the total number of *Poa secunda* per plot back up to thirty-three. The establishment of the bunch grasses within the FF subpopulation was monitored throughout April 2000. All plugs established successfully, and many were flowering by 12 Apr 00, with plants beginning to go dormant by 5 May 99. Survivorship of the newly transplanted *A. grandiflora* was also monitored during 2000 on 4 Feb 00, 11 Feb 00, 28 Feb 00, 10 Mar 00, and 5 Apr 00. Although we attempted to collect survivorship data on 19 Feb 00 and 25 Feb 00, we were unable to locate many of the seedlings, thus data from these dates were discarded.

A-2.3. Spring Census

The experimental and native Drop Tower populations as well as the Draney Canyon population were censused during late March and early April. All three areas were surveyed completely. *A. grandiflora* plants were flagged and demographic data were collected.

The census of the FF and FL subpopulations took place on 3 Apr 00 and 5 Apr 00. The flower morph, plant height, and inflorescence number were recorded for each plant. Any plants missed at this time were measured on 14 Apr 00. The identity of the nearest species (nearest neighbor) was also recorded. In addition, biomass samples (0.1 m^2) were collected from the center of ten FL plots on 17 May 00 and 18 May 00. These plots were selected using a randomized block design. Biomass was collected from five sample plots from the area that was burned in 1999 and five sample plots from the unburned area. These plots are shown on Figure A4 as “Biom”. Plots are further identified as to whether they were annual grass plots (labeled as A) or perennial grass plots (labeled as P) when the population was originally established in 1993. Perennial bunch grasses were counted in both the FF and FL subpopulations on 10 Apr 00 and 12 April 00 to monitor long-term establishment of *Poa secunda*.

The native Drop Tower population census was conducted on 3 Apr 00. Flower morph, plant height and branch number were recorded for each plant. Branch number is defined as the number of major branches off the main stem. Nearest neighbor data were also collected for every plant. No biomass samples were taken from the native population.

Draney Canyon was surveyed along the entire length of the canyon on 31 Mar 00.

A-2.4. Predation Study

The predation study was initiated in 1998 to estimate seed loss to predators such as birds, rodents and insects. Rounds were conducted before and after spring burns to examine the effect of the burn on seed loss. Each round was conducted in the same manner, with different plots chosen for each round to prevent predator training. In 1999, the study was replicated. In 2000, no burns were conducted. To study the effect that trapping rodents within the population might have upon seed loss, a 2-week period of rodent trapping was inserted between the rounds.

Three areas in and around the experimental Drop Tower population were designated for study in 2000 (Figure A5): the previously unburned area within the FL subpopulation, an area within the FF subpopulation, and an area outside the population, northeast of the flashing (Control). Each area contained five plots. Each plot contained twenty-five, 3 1/2-in. galvanized nails spaced 5 cm apart in five rows of five nails. A 10-cm buffer zone was present between the edge of the plot and the outermost nails. Double stick tape was placed on the nail head, and each nail was pressed into the soil so as the nail head was flush with the soil surface. A single nutlet was lightly pressed onto the tape. In round 1, the nails were placed in the field on 1 May 00. The nails were censused on 3 May 00, 5 May 00, 8 May 00, 10 May 00, 12 May 00, 15 May 00, 17 May 00, 19 May 00, and 22 May 00.

The day where nails were taken up from the field after the first round (22 May 00), lethal snap traps were installed in the FF and FL areas. These traps were designed to trap *Diponomys hermanii* (kangaroo rat), members of the *Peromuscus* genus (deer mouse), *Perignathus californicus* (pocket mouse), *Reithrodontomys megalotis* (harvest mouse), *Microtus californicus* (vole), and *Mus musculus* (house mouse). All of these species have been found in the area of the experimental population. The Control area remained untrapped. The traps were installed in a grid where traps were spaced 3 m apart. Traps were baited each day (Monday through Thursday) and checked the following morning. The traps were removed on 2 June 00 and the second round of predation tests were installed on 5 June 00.

For round 2, nails were placed in the field on 5 June 00. The nails were censused on 12 June 00, 14 June 00, 16 June 00, 19 June 00, 21 June 00, 23 June 00, and 26 June 00.

A-2.5. Lupine study

The lupine study was initiated in the fall of 1999 to investigate the potential effects of lupine expansion on the biomass accumulation of *A. grandiflora* competitors. Three pairs of lupines were selected and flagged just downslope of the main area of the Native *A. grandiflora* population (Figure A6). Lupines were paired according to size: small, medium, and large. For each lupine pair, one plant was sawed off at the base on 8 Nov 99, while the other was allowed to remain standing. Commercially purchased Round Up was applied directly to the cut stump. On 22 May 00, biomass was collected from a $0.1m^2$ area adjacent to the base of the standing lupine or the stump of the removed lupine. Biomass was also collected from a random location near each pair, but not underneath a lupine, for a negative control.

A-2.6. Germination Test

A germination test was performed to see if *A. grandiflora* seed germination would positively respond to heating, as is found in other fire-adapted species (Keeley, 1987). One hundred seeds from pot-grown plants of 1998 and one hundred seeds collected from the experimental population in 1994 were placed in paper envelopes in the drying oven for five minutes at 105°C on 5 Nov 99. After the heat treatment, seeds were allowed to cool. They were then placed in a plastic container, along with envelopes of 100 untreated 1998 seeds and 100 untreated 1994 seeds, inside a transportainer at Building 833. The seeds were therefore exposed to ambient Site 300 temperatures until the start of the germination experiment on 24 Nov 00.

Seeds were placed on wetted filter paper in petri plates which were stored in a cooler left outside at the LLNL main site. Twenty seeds were arranged in each plate. Five replicates each of 1998 heated, 1998 unheated, 1994 heated, and 1994 unheated were prepared. Also, five replicates of office-stored seed were created each from seed collected from 1995 greenhouse pot-grown plants and seed collected from the experimental population in 1993. The cooler was left outdoors, allowing the seeds to experience buffered ambient temperature. Filter papers were rewet as they dried and plates were checked every few days for germination. Germinules were transplanted into steuwe tubes filled with soil collected near the experimental population and grown in a sheltered location at the LLNL main site until they were transplanted out into the field.

On 29 Dec 00, plates were allowed to begin to dry out. Plates were rewet on 14 Jan 00 in an attempt to stimulate additional germination.

A-3. Results and Discussion

A-3.1. Demographic Monitoring of the Experimental Population

Survivorship in the experimental population varied significantly between the two subpopulations. Newly transplanted *A. grandiflora* was more likely to survive than *A. grandiflora* germinated from the seed bank. In the FL plots approximately 36% survived to flowering in 2000 representing a large increase from survival percentages in 1999 and 1998 (1% and 18% respectively) (Figure A7). Of the forty-seven plants originally marked on 10 Dec 00 , thirty-nine either died or were subsequently identified as *A. tessellata*. Eight plants survived to 27 March 00, and five survived to 5 April 00. In the FF plots, 71% of the transplants survived to flowering. Of the two hundred *A. grandiflora* transplanted into the plots, 193 survived to 4 Feb 00, and 169 to 3 Mar 00. A total of 143 plants survived to 5 Apr 00 and were in flower.

Figure A4 shows that all forty-seven plants tracked for survival in FL plots were located within the unburned section of the subpopulation. Although four *A. grandiflora* plants were found on the burned side (Figure A8), they were not monitored since they were located outside of area in which *A. grandiflora* were found in 1999.

A-3.2. Spring Census

The three *A.* grandiflora populations were censused during the spring of 2000. Figure A8 shows the general locations and flower morph of *A. grandiflora* plants observed in the FL subpopulation. Figure A6 shows the general location of *A. grandiflora* plants observed in the native population from 1998 to 2000. Figure A9 shows the census history for all Site 300 *A. grandiflora* populations (data for the FF subpopulation is not included we only have one year), along with rain totals for each census year.

Figure A10 shows the census history for the Draney Canyon population. A large amount of water flowed through the canyon in 1997, causing a landslide in the area of the *A. grandiflora* population. In that year, only one *A. grandiflora* plant was found. In 1998, further erosion was observed at the site of the population. Flags that once marked *A. grandiflora* plants from previous censuses were located in 1999 and 2000 but no *A. grandiflora* plants were found. A large population of congeneric *Amsinckia* was observed in this area. It seems likely that this population has been extirpated.

Figure A6 shows the general locations of *A. grandiflora* plants observed in the native Drop Tower population in 1998, 1999, and 2000. Figure A11 shows the census history for this population. Like the experimental population, this population declined dramatically to an all time low of six plants in 1999 but has increased to 40 plants in 2000. This year's increase in plant numbers is still well below the high of 1,949 plants observed in 1996. The average number of inflorescenes per plant increased from 1 in 1999 to 1.7 in 2000. This increase in inflorescenes and overall plant numbers should increase the nutlet production for this population from 0 in 1999 to 437 in 2000 (Table A1).

As seen in Figure A12, numbers of individuals observed in the FL subpopulation has also declined dramatically in recent years, with only 45 plants observed this year compared to the high of 720 plants observed in 1996. A majority of the newly transplanted *A. grandiflora* plants in the FF subpopulation survived after the last transplant attempt and were censused. At the time of the census 143 *A. grandiflora* plants were alive and flowering. The self-regenerating (FL) portion of the experimental population has been at an all time low for the past three years. Amounts of biomass have been declining gradually since 1998 (Table A2). If this drop in neighbor biomass continues, we may see a delayed resurgence in *A. grandiflora* numbers in response. Besides the small number of individuals, the *A. grandiflora* plants were very small in size. The number of inflorescences remained constant at approximately 1 for 1999 and 1.3 for 2000 (Table A1). Using a regression equation developed in 1994 (unpublished data), it would appear that this population produced approximately 122 nutlets during 2000 (Table A2). The number of inflorescences (branches) per plant is the greater in the FF subpopulation, averaging over two branches per plant with the potential to produce approximately 1,560 nutlets during 2000.

Seven-year persistence of *Poa secunda* in the FL plots is shown in Table A3. Plots appear to be shifting towards an ideal density of about six plants per plot in existing *Poa* plots. The number of plants per plot is generally higher in the burned plots compared to the unburned plots.

Table A4 shows the percent species composition of *A. grandiflora* nearest neighbors for both native and experimental populations. Shannon's index of diversity is also shown. This diversity index is an expression of the likelihood that two plants picked at random will be of two different species. So, 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. Species diversity was the greatest in spring of 2000. The FL subpopulation and the native population had very high indices of diversity this year. The FF subpopulation was lower for species diversity, due to the predominance of *Avena* and *Bromus* as *A. grandiflora* nearest neighbors. Neighbor species were more evenly distributed in the native population and in the FL subpopulation. The extremely low diversity index for the native population in 1999 is inextricable from the very small population size. Even if every *A. grandiflora* plant had a different species as its nearest neighbor, the diversity index would still be the lowest for this year, due to the fact that there were only six plants. However, data from the FL population, which had a much larger size, confirm that species diversity was indeed low for 1999.

Vulpia myuros, *Galium aparine*, *Erodium cicutarium*, *Bromus* species and *Avena* are all significant parts of the species composition of this area. The absence of *Avena* and *E. cicutarium* from the native population in 1999 is notable, although the sample size for that year is very small. The absence of *Vulpia myuros* from the native population in 1997–1999 is also interesting.

From 1999 to 2000, FL plots showed a drop in *Bromus mollis* composition from 33% to 5% and a notable increase in *Vulpia myuros* occurrence from 10% to 30%. Presence of native forbs such as *A. grandiflora*, *Delphinium hesperium* and *Lithophragma affinis* helped to increase the species richness in 2000 compared to 1999.

The FF plots were dominated by *Bromus* and *Avena* species, 31% and 24% respectively in 2000. At planted densities, the native grass *Poa secunda* comprised approximately 11% of all *A. grandiflora* nearest neighbors in these plots.

A-3.3. Spring Burn

As previously mentioned, the half of the experimental population containing no *A. grandiflora* was burned in the spring of 1999 to encourage *A. grandiflora* nutlet dispersal and plant establishment into this area. No *A. grandiflora* plants were observed in this area in 1998 or 1999, but in 2000 four plants were found (Figure A8).

Biomass samples collected from the FL subpopulation in the year 2000 showed a difference between burned and unburned plots in both *P. secunda* biomass accumulation and in the accumulation of thatch (Figure A13). Thatch was much greater in unburned plots while *P. secunda* only occurred in burned plots. The difference in thatch biomass also occurred in 1999. In that year, total biomass was also greater in the unburned plots than the burned plots. While the averages for total biomass were similar between 1999 and 2000 (total biomass close to $20g/0.1m^2$ in unburned plots and around $10g/0.1m^2$ in burned plots), greater variability of the sample in 2000 made the difference between burned and unburned plots not significant for total biomass. No significant differences in total biomass were found in 1998. The lack of perennial grass cover in unburned plots is not confirmed in the counts of *Poa* made in May 2000 at all plots in the FL subpopulation. Table A3 shows the counts for each plot type, and that while the burned area has consistently higher numbers of *P. secunda* plants than the unburned area, *P. secunda* was found in unburned plots. *P. secunda* leaves are small and are not easily identifiable without an attached inflorescence. The plants may simply have not have been seen in the high-cover, unburned plots during biomass collection. Accurately measuring the amount of *P. secunda* biomass was also problematic in 1999. Counts should be considered a more reliable estimate of *P. secunda* presence until this problem is rectified.

A-3.4. Predation Study

Overall predation was much lower this year than in 1998 and 1999 (Table A5). Predation in 2000 was more comparable to predation levels in 1995, but since the methodology was different between the two years this comparison is marginal at best. Similar to 1998 and 1999, in 2000 all, or nearly all, plots were discovered by granivores in each round, but localization was quite low. Only one plot was decimated in each round in 2000, whereas in 1998 and 1999 most plots were decimated.

During the 2-week trapping period, only one rodent was caught. A deer mouse was caught on the very southwestern edge of the trapped area (Figure A5). This contrasts previous years, where rodent trapping has yielded dozens of rodents on this hillside (Woollett, 2000). The fact that only one rodent was caught limits our ability to analyze the effect of trapping on the reduction of seed loss. Figure A14 shows the cumulative predation intensity (number of nutlets lost divided by the number originally placed in the field). In the untrapped area, predation was lower in round 2 (around 25%) compared to round 1 (around 50%). Predation was also lower in round two in the trapped area outside the flashing (58% versus 68% in round 1). In the trapped area within the flashing, seed predation increased from 14% in round 1 to about 30% in round 2.

Figure A15 shows the cumulative predation intensity over time in 1998, 1999, and 2000 for the unburned open plots within the flashing only. Again, predation is much lower in 2000. Differences between rounds are not consistent between years: while predation is higher overall in round 2 in 1999, predation is lower overall in round 2 in 2000.

The shape of the normalized daily predation intensity curve (percent nutlets taken of number of nutlets present at last observation divided by the number of days since last observation) is very different compared to previous years (Figure A16). In 1998 and 1999, daily predation intensity decreases as time passes, indicating a strong density dependence in seed removal. The fewer seeds present at the beginning of each observation interval, the fewer were removed over the interval. In contrast, daily predation intensity appears to be cyclic in 2000. Figure A16 only compares daily predation intensity for unburned open plots within the flashing. Figure A17, showing normalized daily predation intensity for each area and each round in 2000, indicates that daily predation intensity is cyclic in the areas outside the flashing, but not all areas cycle on the same period.

The contrast between strong density dependence versus cyclic predation, combined with the low rodent yield from the trapping and low overall predation rates indicates that in 2000 the main predator of *A grandiflora* seeds may have shifted from rodents to other seed predators. Cyclic predation has been found to occur on prey that contain toxins that build up in the bodies of predators (Brower and Calvert, 1985). *Amsinckia* seeds contain pyrrolizidine alkaloids that cause heart and liver damage in livestock (Kelley and Siber, 1992). Effects of the pyrrolizidine alkaloids found in *Amsinckia* have not been assessed in wild birds or in rodents. The concentration of these toxins can be extremely variable from plant to plant, and effects of the toxin for individual animals can also vary with differences in age, sex, and metabolic rate (Stegelmeier et al., 1999).

The cyclic granivory pattern observed indicates some ecotoxicological interactions may be taking place. In a large population of rodents, while individuals may feed cyclically, the effects of such cyclic predation may not be apparent due to the large number of predators acting in a nonsynchronous manner. However, a very small population of rodents might show a cyclic effect. Bird predation may also be indicated by the cyclic nature of seed disappearance in the year 2000. Birds tend to feed in social groups, so feeding is much more synchronous and cyclic predation may show up even when the number of predators is large (Brower and Calvert, 1985).

In an effort to determine the optimal number of weeks a predation experiment should run, we attempted to find correlations between final predation percentages and the predation intensity after the first week as well as the number of weeks the experiment was run. Cumulative predation levels after a single week did not have a relationship to final predation, nor does the number of weeks an experiment has run have any relationship to final predation intensity. Looking at Table A5, it appears that 3–4 week experiments have a smaller gap between estimated and average weekly predation intensities than longer experiments and may be close to the optimal length of future experiments. Since most of the seeds may disappear within the first week, depending upon the predation pressure, two or three observation dates within the first week of the experiment would be ideal.

In order to gain information on how levels of seed predation may affect population dynamics, a scaled-down predation experiment should be conducted every year. While it appears that the flashing is not a significant barrier to granivores, predation rates were generally lower inside the flashing than outside and future experiments should be blocked accordingly. While differences in predation rates between rounds within years indicate that unidentified factors may affect predation intensity, these factors must remain unexplored at this time. Future predation studies should be timed to coincide with *A. grandiflora* seed set to most accurately assess the levels of granivory this species undergoes.

A-3.5. Lupine Study

Figure A18 shows the results of the biomass collection. No significant differences were observed between any of the treatments (cut lupine, uncut lupine and control). The sample size of this experiment was extremely small. It appears that if the sample size were to be enlarged, differences might only appear between the control and the other two treatments. The amount of biomass collected from areas not adjacent to lupine stumps or trunks appeared to be less than the amount of biomass collected from areas adjacent to lupine stumps or trunks. There seems to be little difference between biomass collected next to lupines, whether the lupine was cut or uncut. At this point in time, there appears to be no benefit to cutting lupines for the purpose of reducing the biomass of *A. grandiflora* competitors. However, biomass will be collected again next spring in order to assess any multi-year effects that may be present.

A-3.6. Germination Test

The results of the germination test are shown in Table A6. Germination was quite low for 1993 seed (33%), 1994 seed (20%), and 1995 seed (36%). These results are quite different from germination tests conducted in 1998 (see Carlsen et al., 1998) where 1993 seed had 92% germination and 1994 seed had 96% germination. Seed germination from 1995-collected seed is not comparable, as field-grown seed was used in the 1998 trial. In the 1998 report (Carlsen et al., 1998), it was hypothesized that seed germination improved with seed age. Under different conditions (ambient temperature, seeds rewet often versus room temperature, seeds rewet only three times in 50 days), the positive relationship between seed age and germination does not appear to hold up. Germination of the 1998 pot-grown seed source was quite high compared to the other seed sources (79%) but not as high as germination observed in the 1998 tests. It appears that room temperature conditions with infrequent wetting may be optimal for inducing *A. grandiflora* germination.

Not one heat-treated seed germinated. It is unknown at this time whether the heat treatment killed the seed or if there is an additional germination requirement for heat-treated seeds. Viability analysis will be performed on leftover seed from this experiment.

A-4. Recommendations and Future Work

Population numbers at both the native and experimental Drop Tower locations remain low. Competition from neighbor biomass and high predation pressure may be contributing to the low number of plants. Last year we predicted that if biomass can be used as an indicator of rodent population size, and therefore as a predictor of seed predation pressure, 1999s reduced biomass compared to 1998 would foreshadow a decrease in seed predation in 2000. This was indeed the case. We hope that the decrease in seed predation found this year foreshadow an increase in *A grandiflora* numbers in 2001.

It appears that lupines at the native site may be beginning to die back, however the results of our study of lupine's effect on biomass accumulation indicates that if lupine expansion was the cause of *A. grandiflora* decline, *A. grandiflora* recovery may not necessarily be generated by lupine die back.

It is important to monitor both predator pressure and standing biomass at the *A. grandiflora* populations. Biomass samples should be collected each spring from the *A. grandiflora* populations, taken in such a way to minimize impact to the *A. grandiflora* plants. A small-scale predation experiment of six plots (3 in FF, 3 in FL) should be set up each year at the time of seed set and run for three weeks. While using a GPS unit would the most accurate way of tracking lupine expansion and decline, the impact would be too great upon the native population. Instead, we recommend that a photograph be taken yearly from the other side of the canyon to monitor lupine population dynamics.

It may be necessary to control grass competition, lupine expansion and predator pressure to ensure persistence of the populations, particularly during the early establishment phase of experimental populations. Ground dwelling predators were controlled during the first two years of the Drop Tower experimental FL subpopulation, which may have allowed the large numbers of plants to establish during these years. In the absence of any such controls, it will be interesting to see if the FF subpopulation will be able to reseed itself and establish a successful flowering subpopulation in Spring 2001. If not, we may have an indication that more aggressive assistance is necessary for population establishment.

Controlled burning is probably the most feasible method for controlling biomass amount and composition. The FF plots will be used to investigate the effects of fire frequency for maintaining intermediate densities of native perennial bunch grasses. These plots will be subjected to controlled burns either annually, every other year, or every 5th year starting in 2001 and monitored for spread of *P. secunda* and *A. grandiflora* from the nucleus into the rest of the plot.

Continued management of the existing native and experimental Drop Tower *A. grandiflora* populations will also continue, and will be modified based on data collected from biomass samples and predation monitoring.

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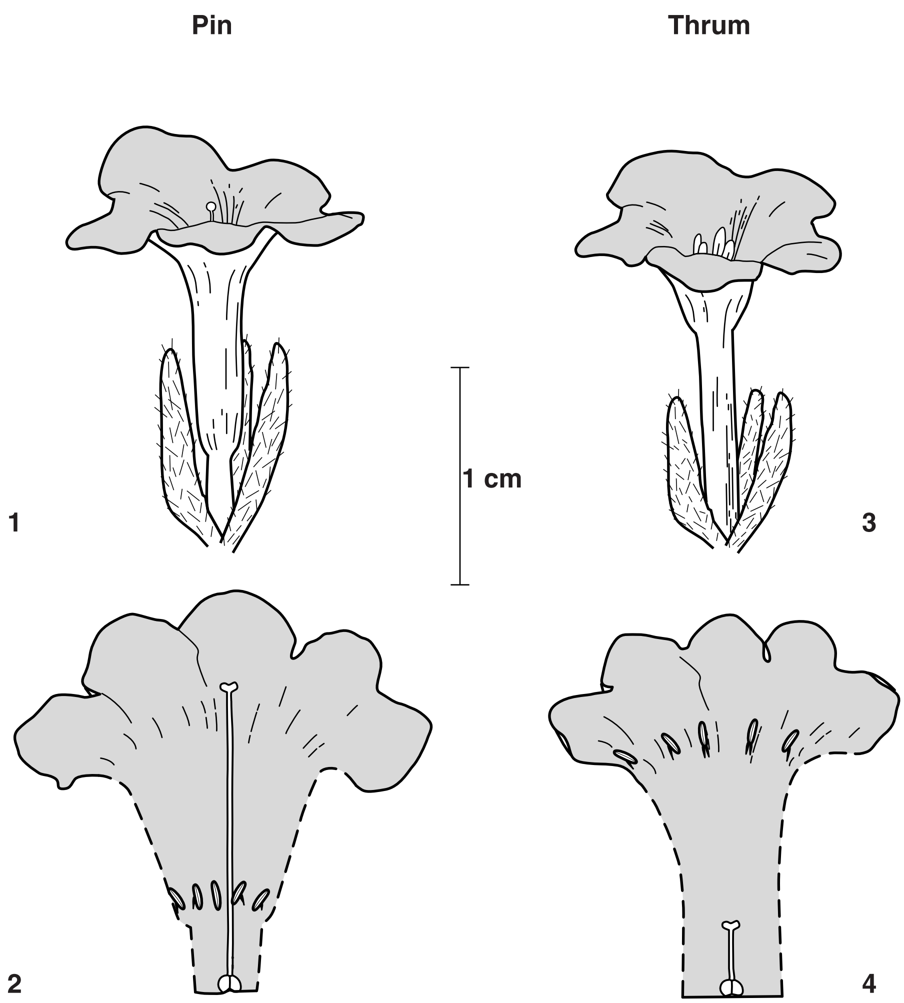
Section A
Figures



ERD-S3R-00-0122

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

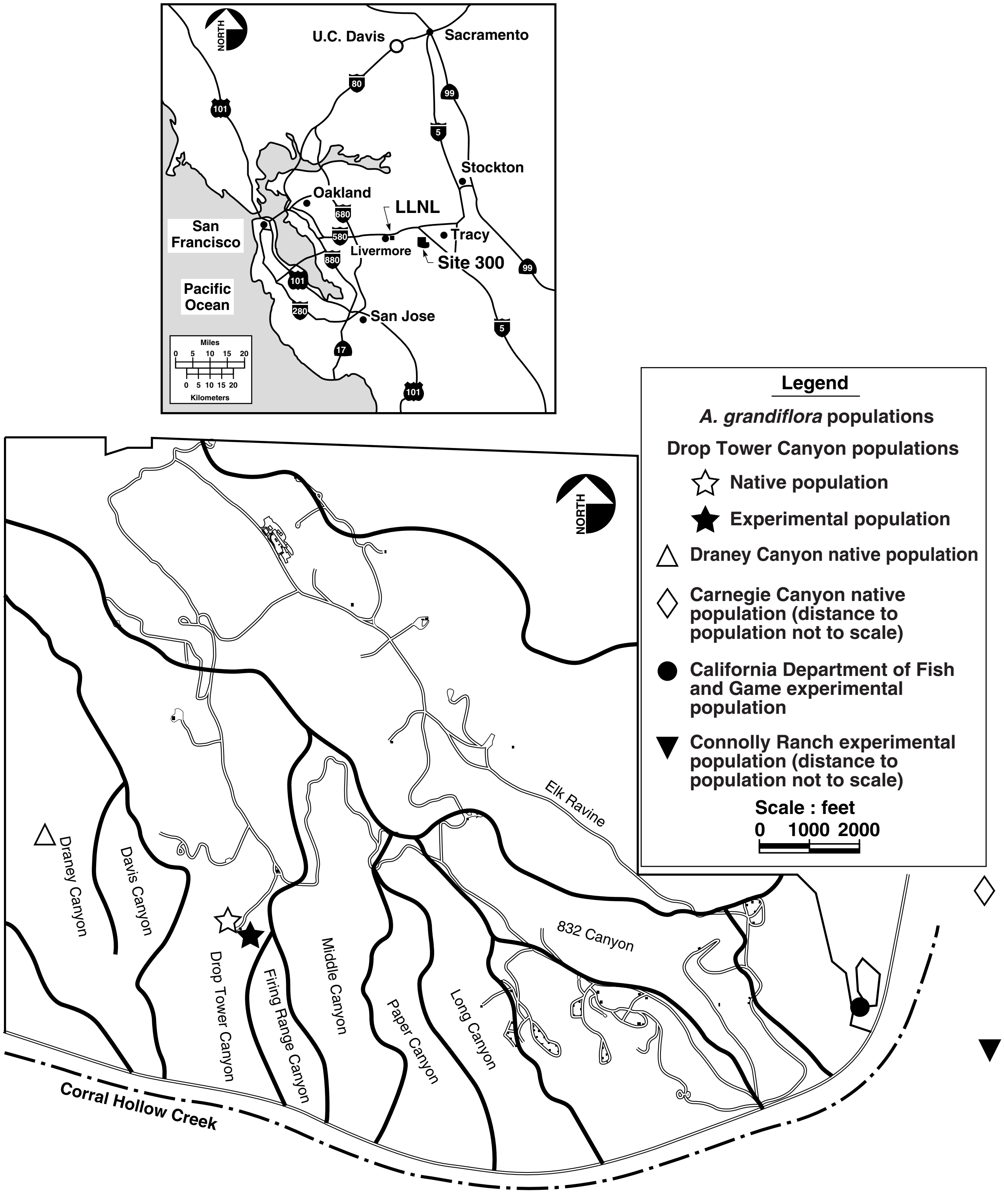


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Figure A2. Locations of *A. grandiflora* populations at or near Lawrence Livermore National Laboratory (LLNL) Site 300.

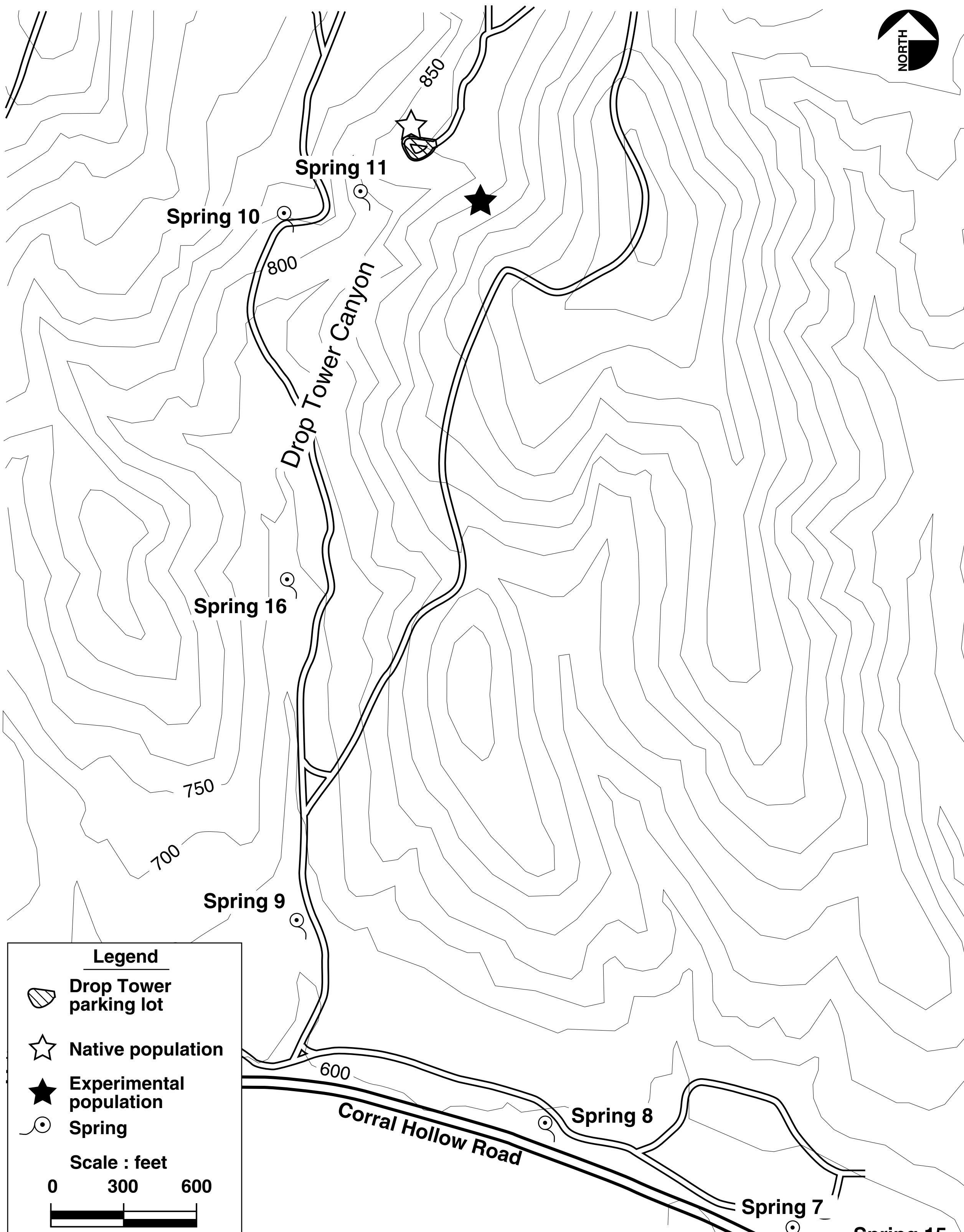

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Figure A3. Location of native and experimental *A. grandiflora* populations in Drop Tower Canyon.

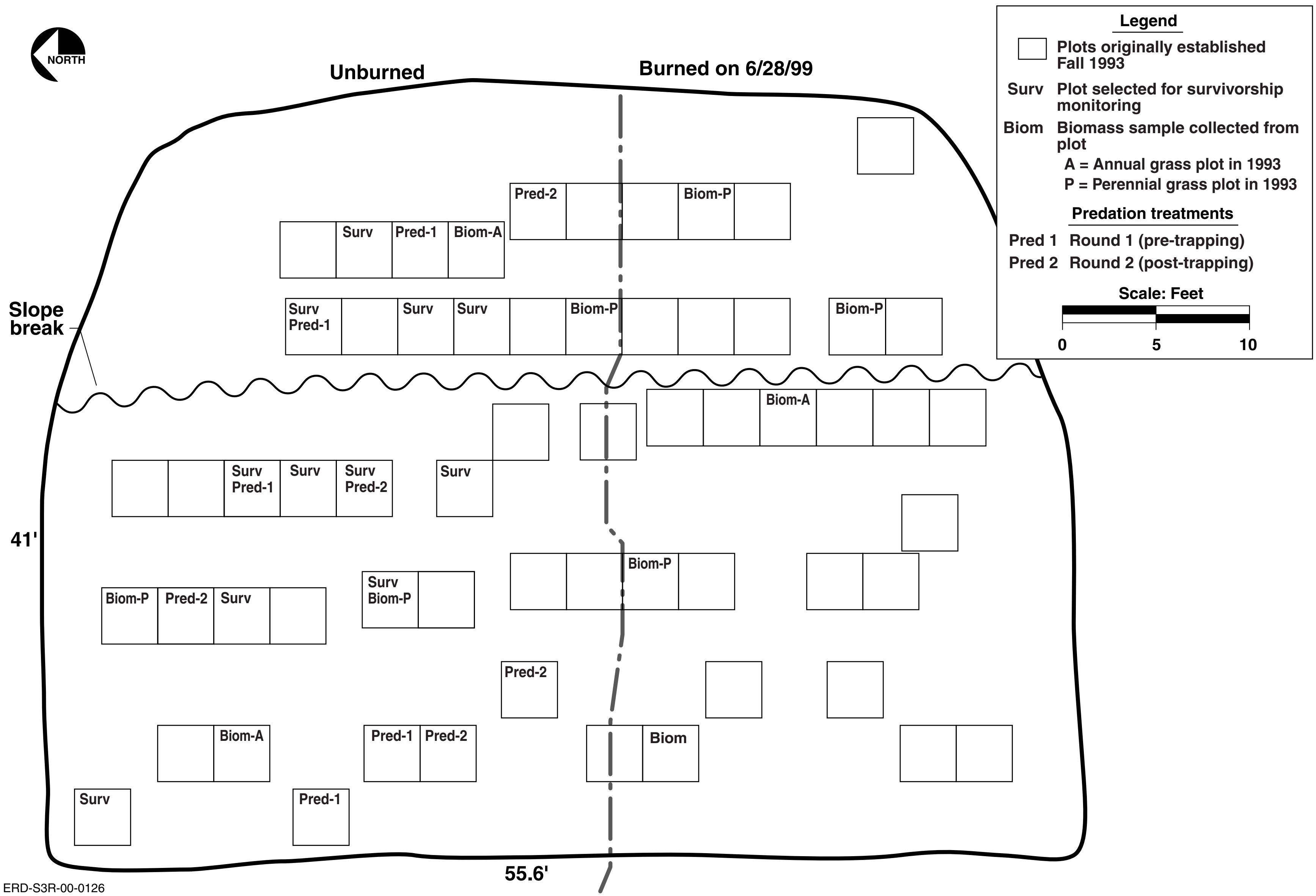

Figure A4. Summary of experimental treatments at the *A. grandiflora* FL subpopulation.

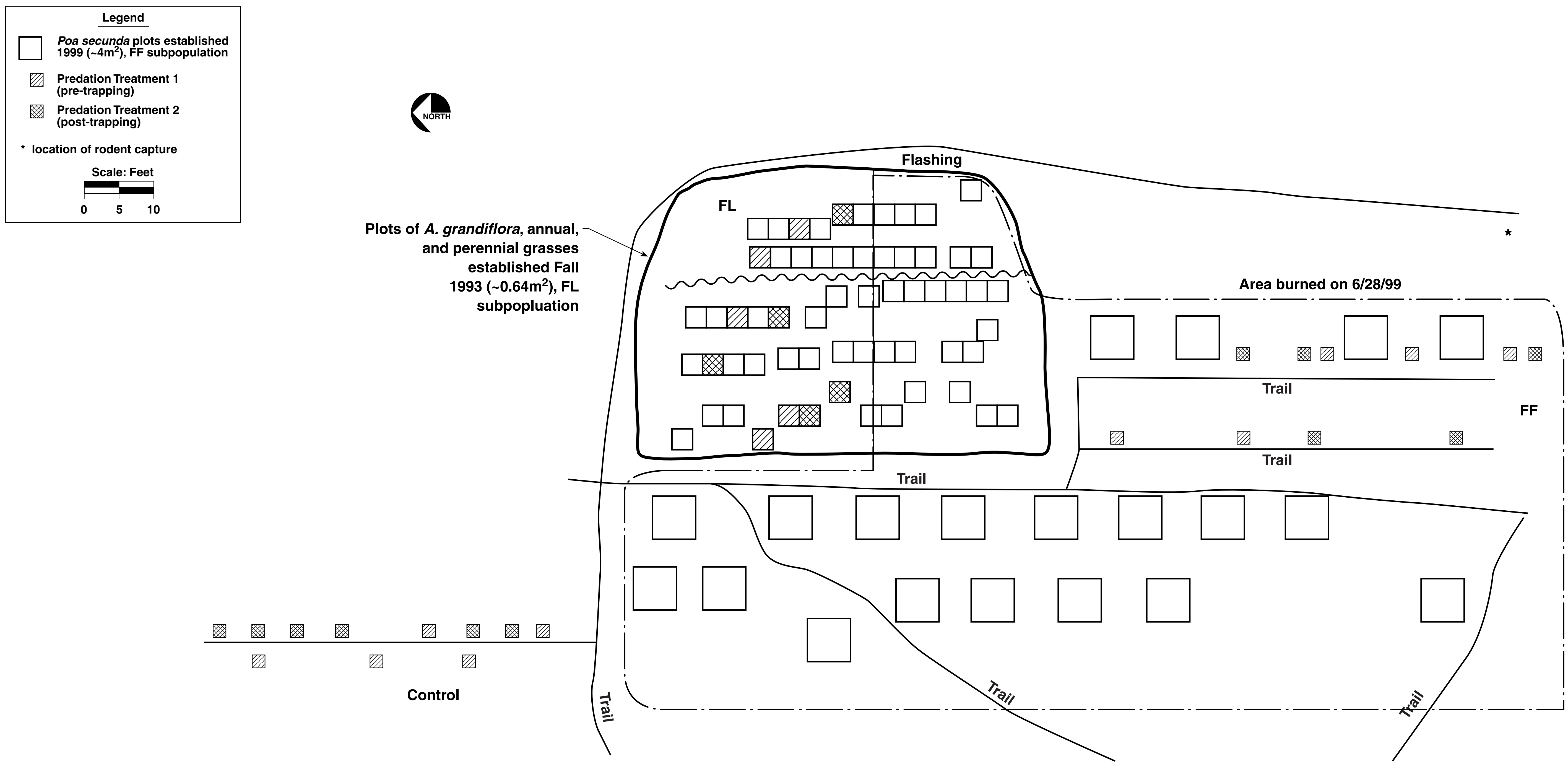

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Figure A5. Map of predation experiment: 2000.

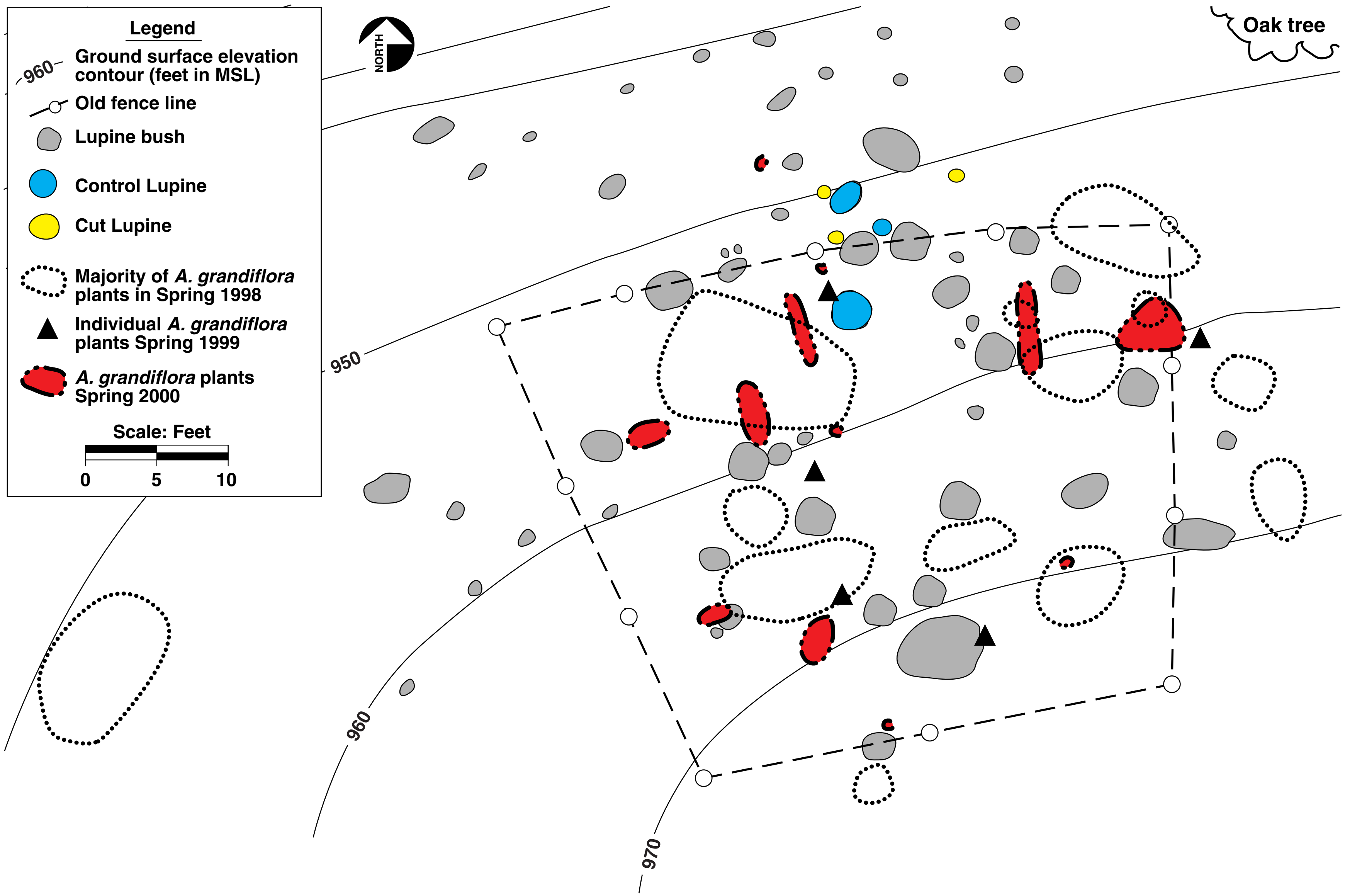

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Figure A6. Spring census of the *A. grandiflora* native Drop Tower population: 1998-2000.

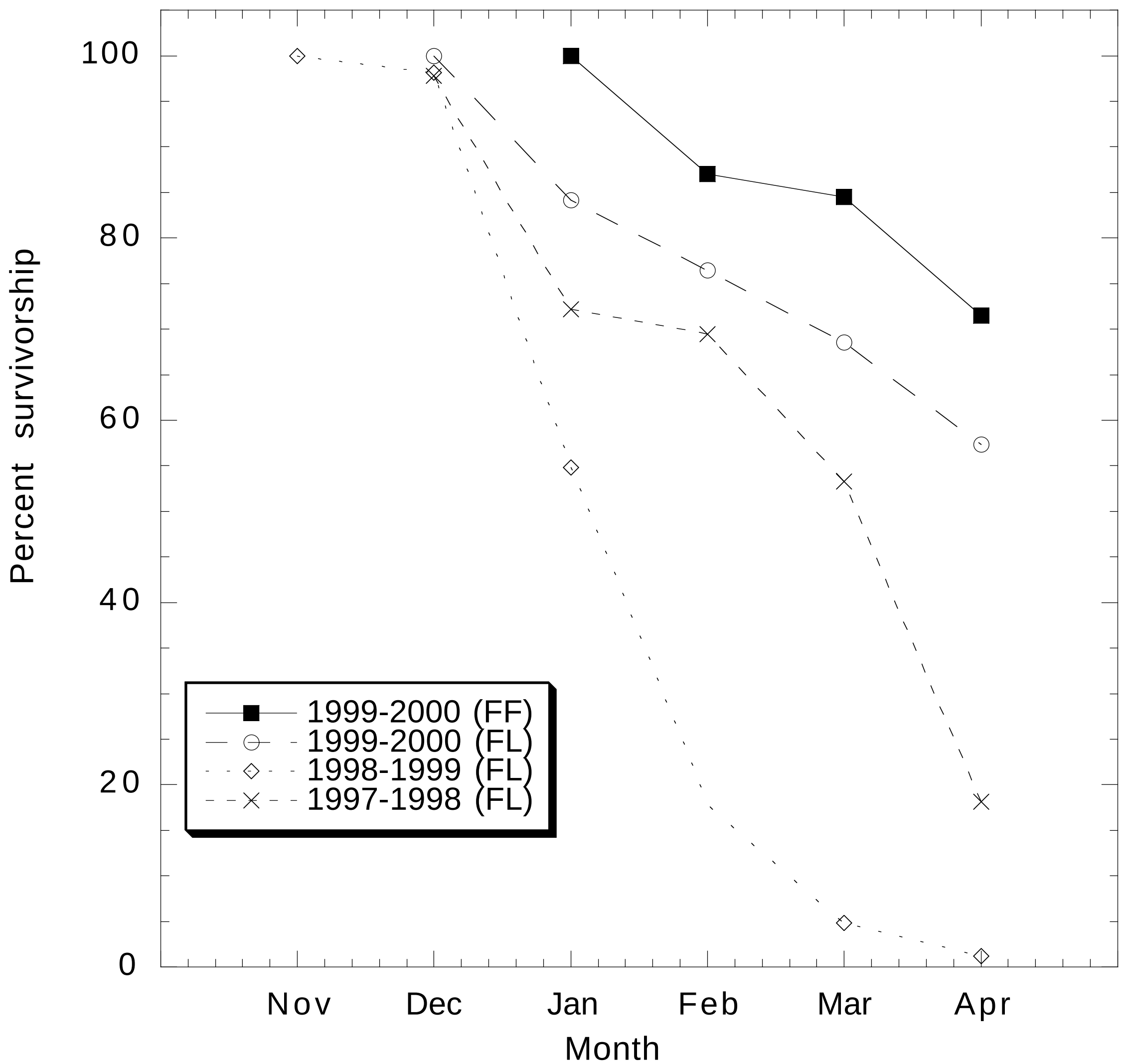

Figure A7. Mean survivorship of *A.grandiflora* in the FF and FL plots followed from winter through spring: for FF plots, n=20; for FL plots,1997-1998 (n=6), 1998-1999 (n=6), 1999-2000 (n=8). (n=8). Survivorship averaged over plots, n = number of plots. Bars represent one standard error.

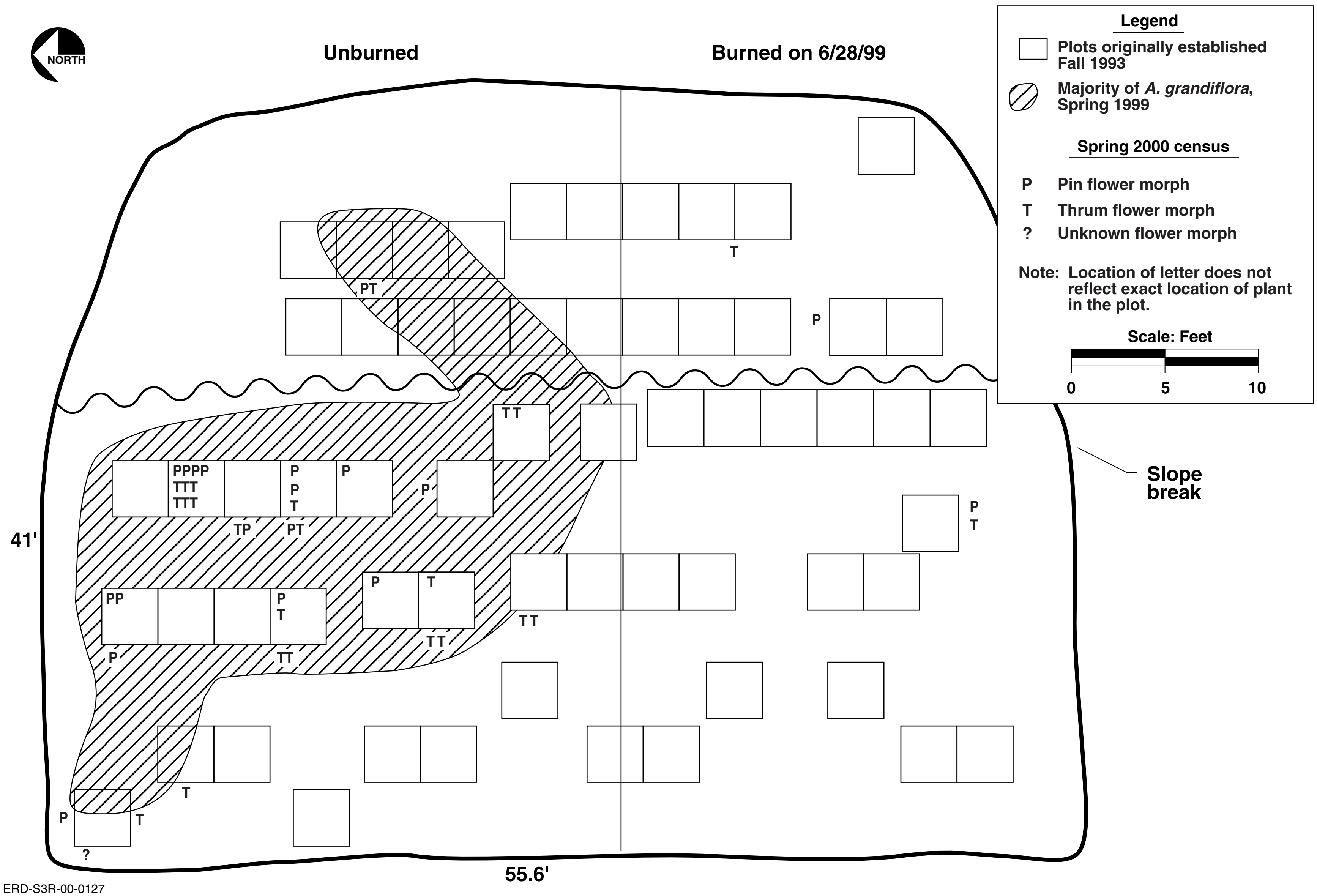

Figure A8. Spring census of the *A. grandiflora* FL subpopulation.

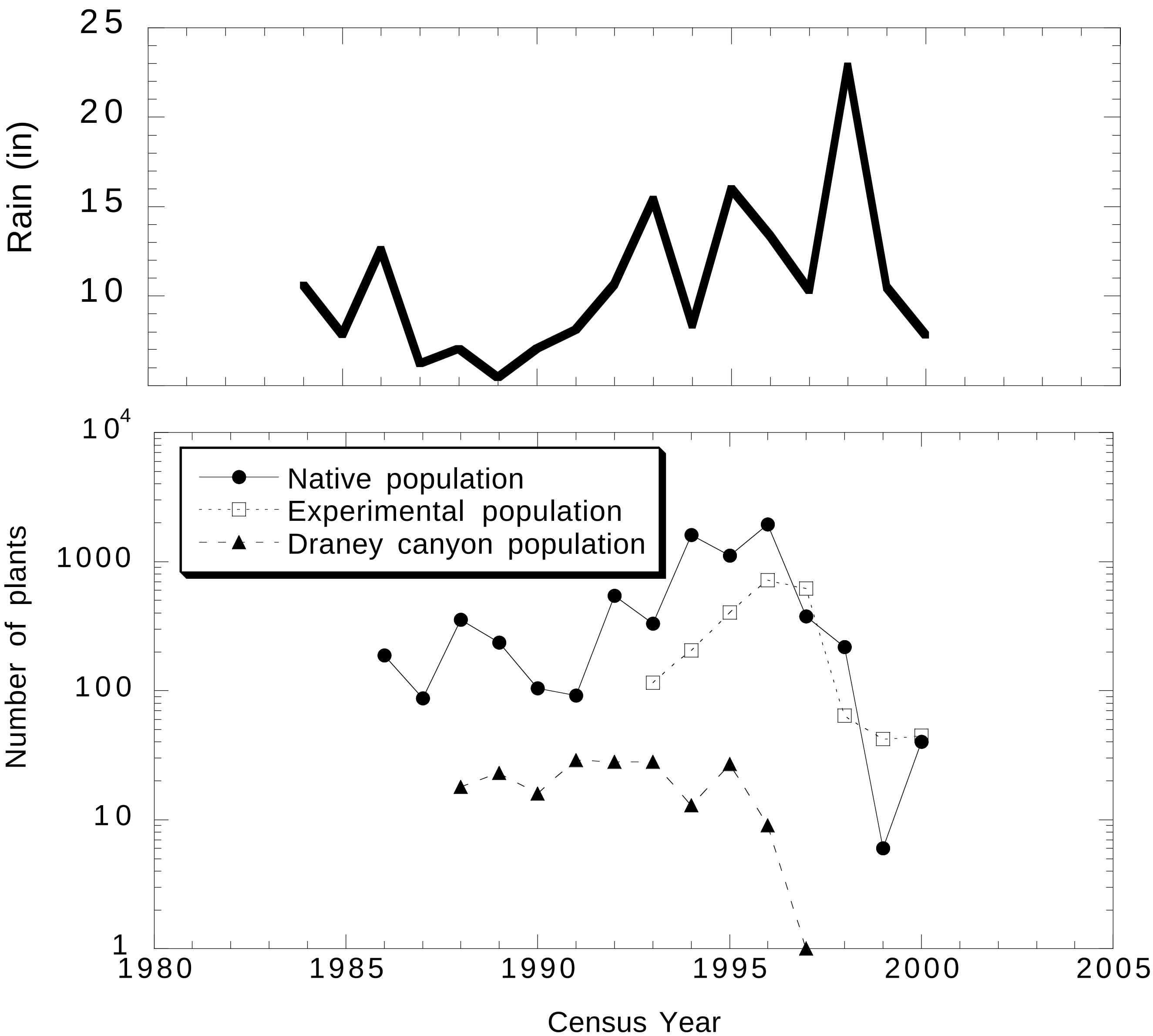

Figure A9. Log plot of population size at time of census, shown with rainfall totals over growing season.

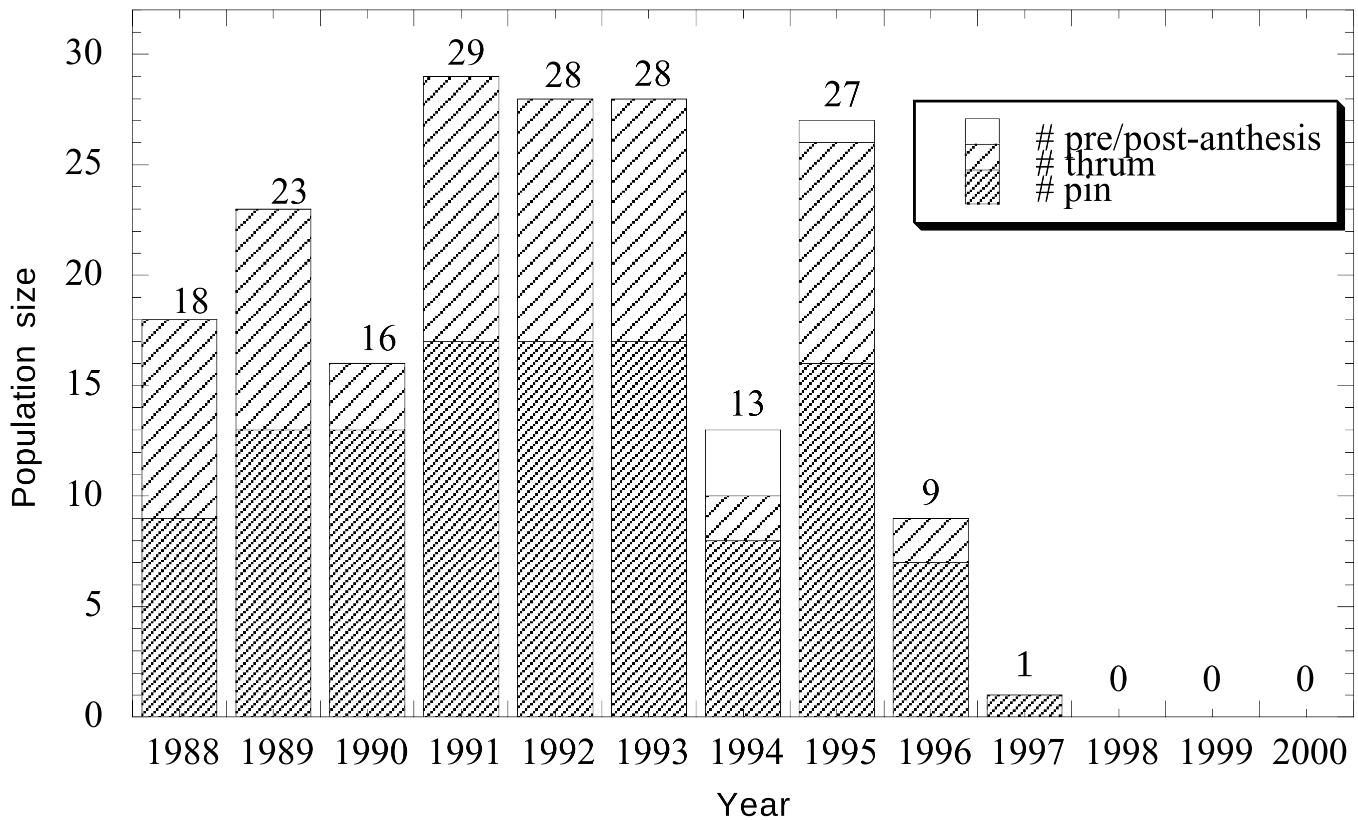

Figure A10. Historical spring census data of the Draney Canyon population at Site 300.
Total population size is given above each bar.

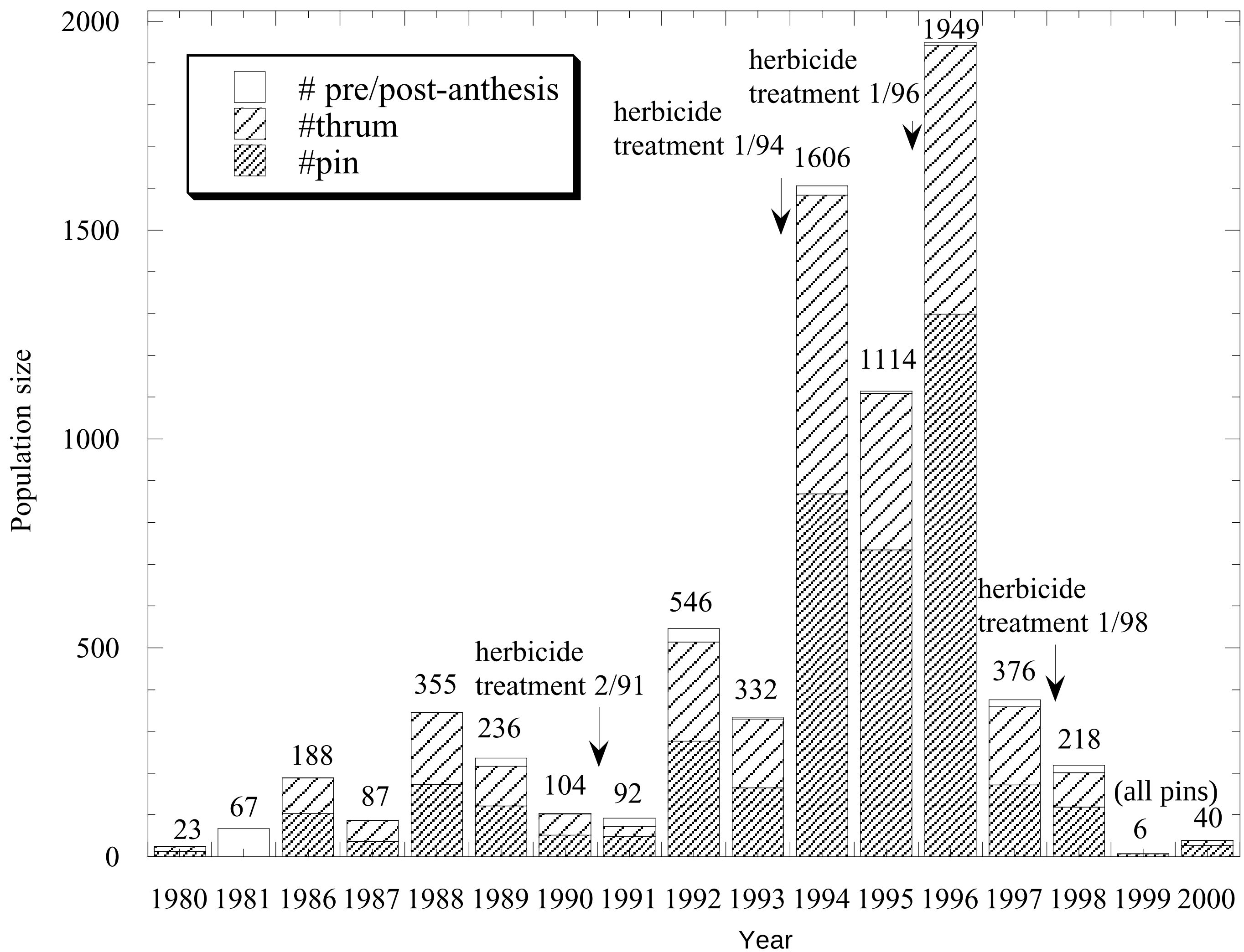

Figure A11. Historical spring census data of the Site 300 Native Drop Tower population. Total population size is given above each bar. Approximate timing of herbicide treatments is shown.

1/98

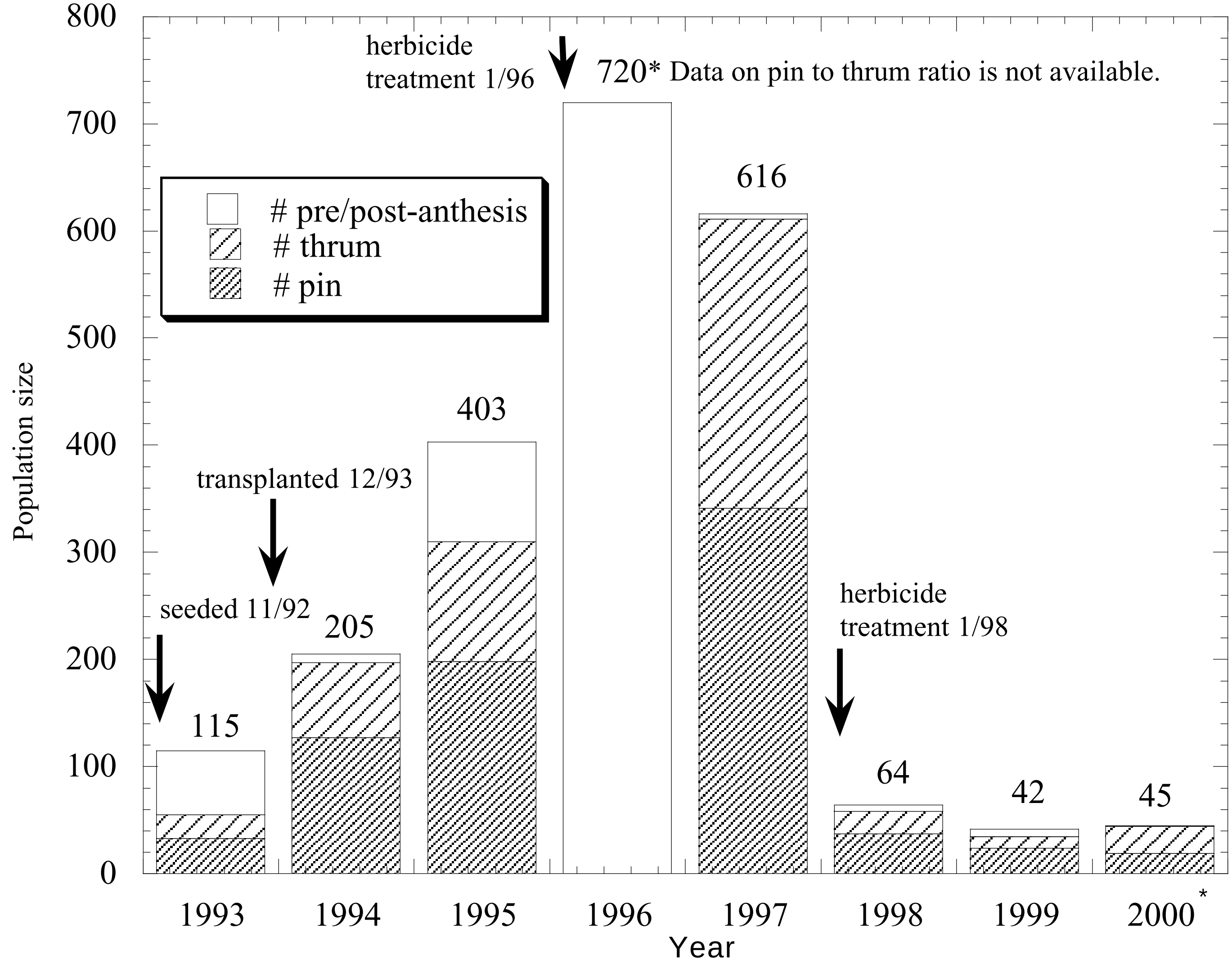

Figure A12. Historical spring census data of the Site 300 experimental FL subpopulation. Total population size is given above each bar. Approximate timing of all treatments are shown. * Population expansion into FF plots excluded.

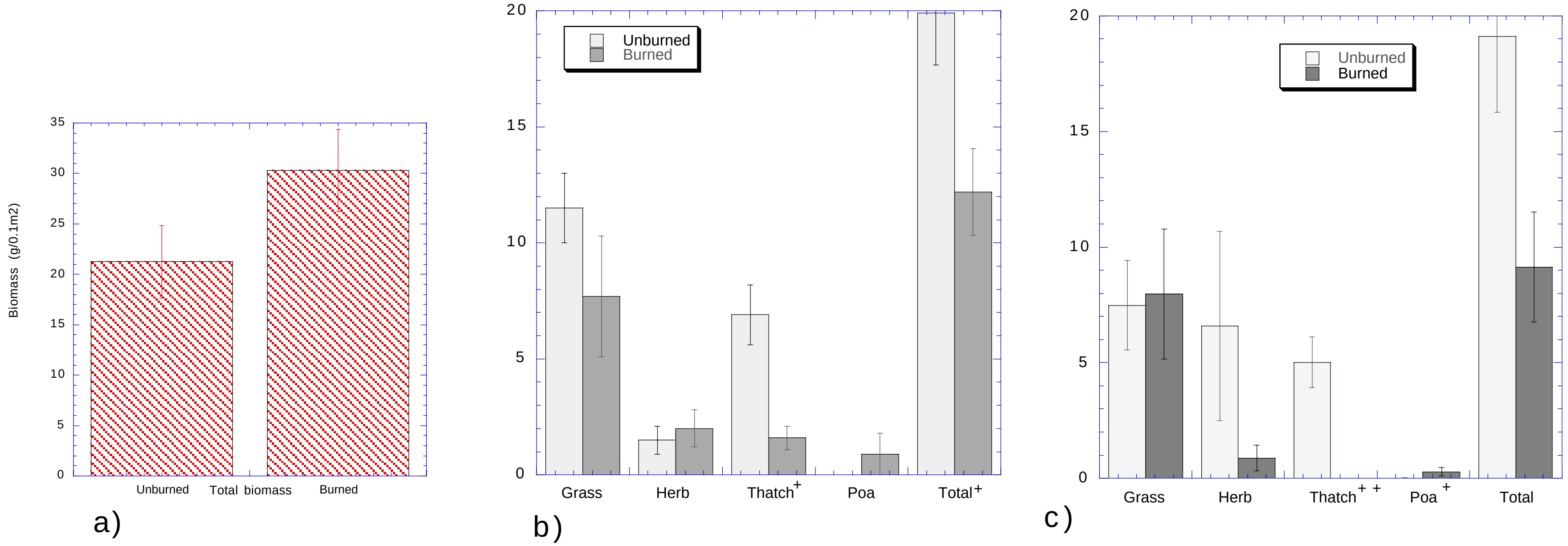

Figure A13. Biomass of burned versus unburned FL plots. Bars are one standard error. ++ indicates treatments differ at p<0.01. + indicates treatments differ at p<0.05. n=5. a) 1998 data, total biomass only, b) 1999 biomass by type, c) 2000 biomass by type.

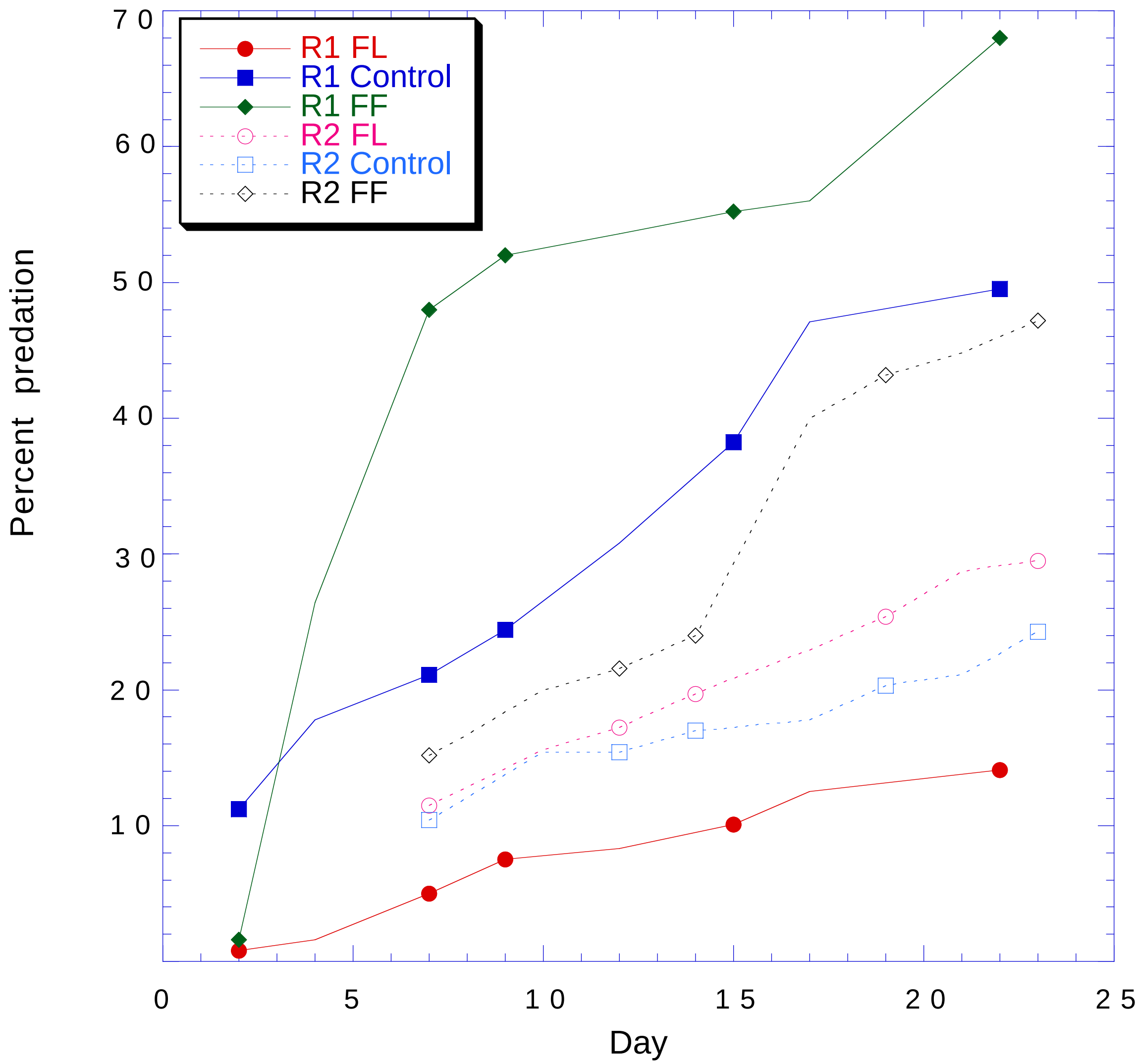

Figure A14. Cumulative percent predation intensity in the Drop Tower experimental population, rounds 1 and 2: 2000.

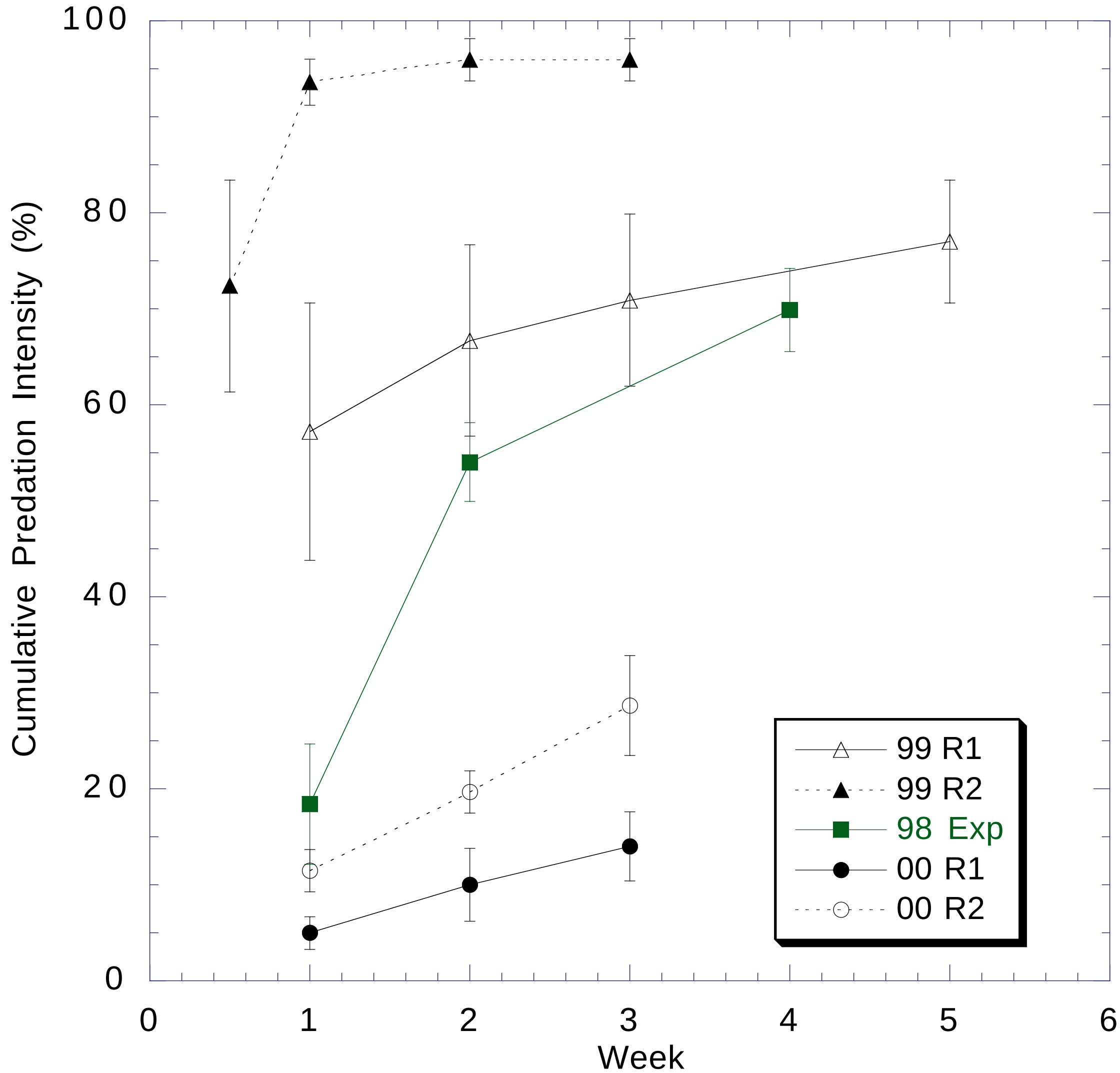

Figure A15. Cumulative predation intensity in the unburned open FL plots: 1998-2000. Bars represent one standard error.

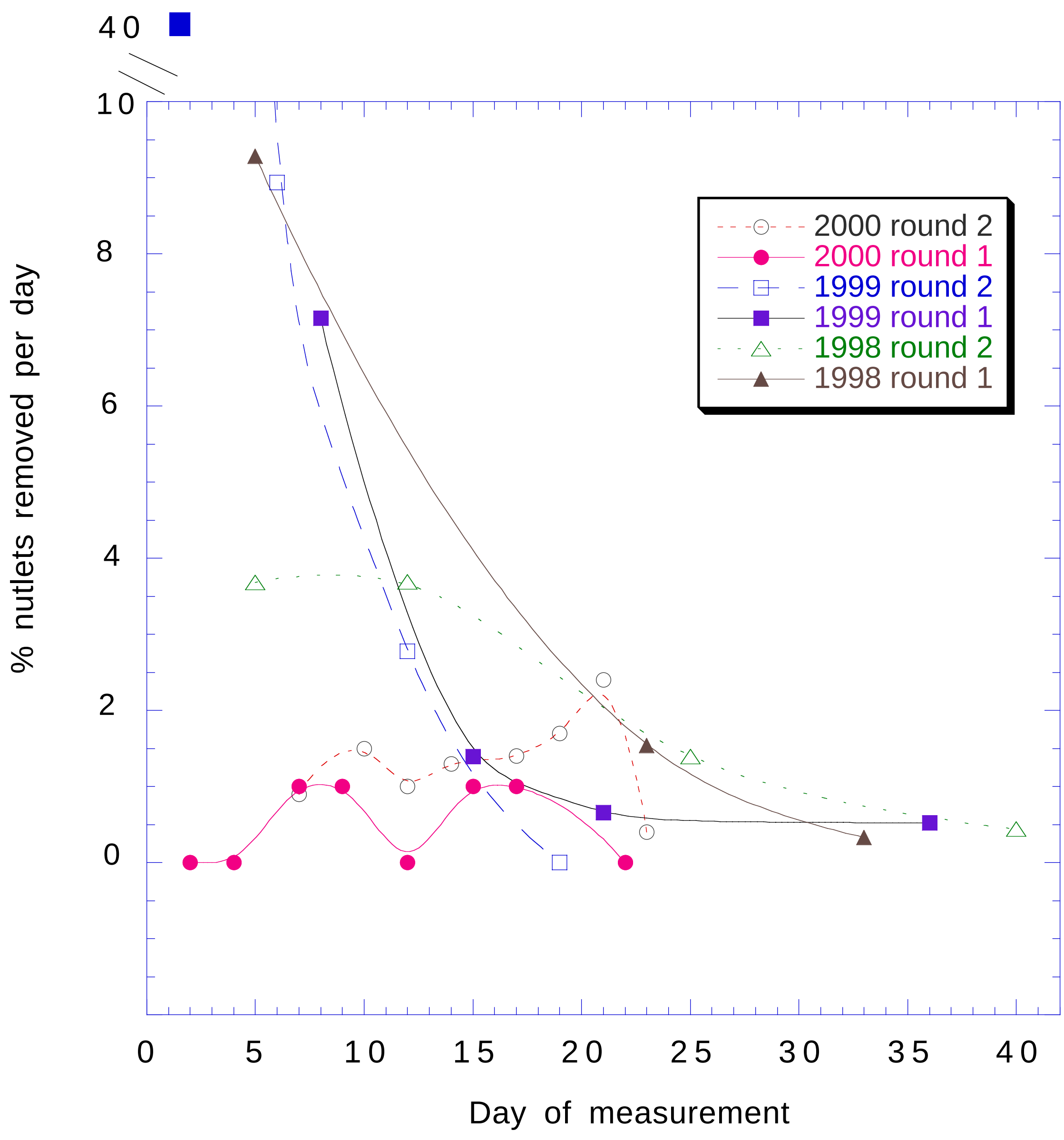

Figure A16. Comparison of normalized daily predation intensity, all years, all rounds, unburned FL plots.

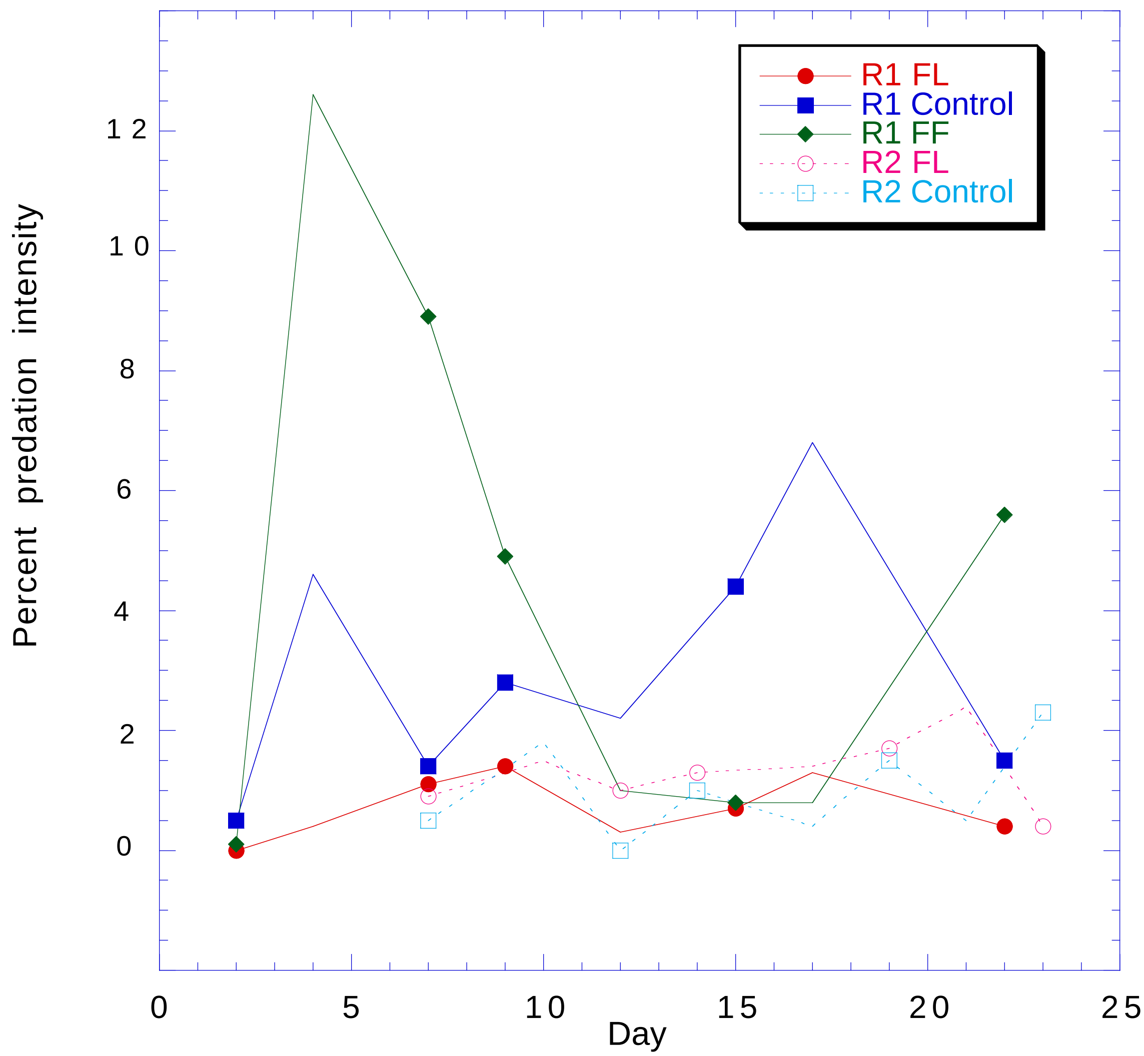

Figure A17. Normalized daily predation intensity in the Drop Tower experimental population, rounds 1 and 2: 2000.

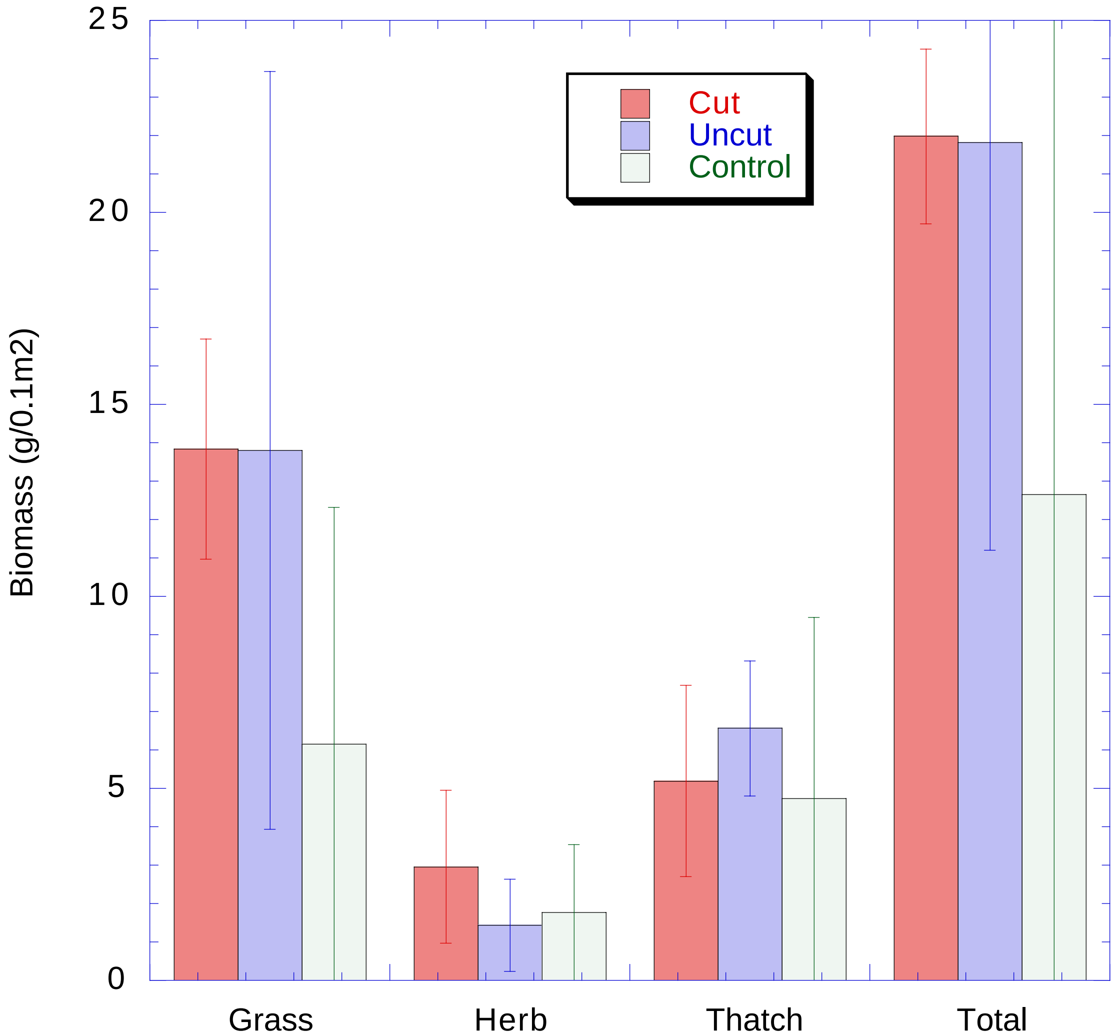

Figure A18. Biomass collected from lupine experiment at Drop Tower Native population. Bars are one standard error.

Section A
Tables

Table A-1. Summary of demographic data collected from the Site 300 Drop Tower experimental and native populations. All averages are ± one standard error.

Population	Total no. of plants	P/T ratio[a]	Average height[b]	Average no. of branches per plant[b]	Estimated average seed production per plant[b]	Estimated total seed production per population[g]
Spring 1999						
Native	6	all P	15.3 ± 2.98	1.0 ± 0[c]	0[e]	0
Experimental flashing	42	2.18	13.3 ± 0.83	1.0 ± 0.02[d]	0[f]	0
Spring 2000						
Native	40	2.16	20.13 ± 0.75	1.7 ± 0[c]	10.92[e]	436.98
Experimental flashing	45	0.76	16.78 ± 0.84	1.32 ± 0[c]	2.7[f]	121.92
Experimental fire frequency	148	0.85	16.67 ± 0.50	2.33 ± 0[c]	10.54	1560.85

[a] Pin to thrum (P/T) ratio: calculated using the number of pin versus thrum plants in the entire population. Does not include plants that were senescent or had not flowered at the time of the census.

[b] Results are presented ± one standard error.

[c] In the native population, branch number was defined as the number of stems branching from the main stem.

[d] In the experimental population, branch number was defined as the number of inflorescences per plant.

[e] 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.

[f] 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.

[g] Total seed production per population was estimated by multiplying the average seed production per plant by the total number of plants in the population.

Table A-2. Summary of dry biomass by dominant grass type in FL plots at the Site 300 Drop Tower experimental population.

	Plots originally with high densities of *Poa secunda*		Plots originally with high densities of annual grasses	
Year	Final dry biomass (g/m^2)[a]	n	Final dry biomass (g/m^2)[a]	n
2000	106 ± 29	5	176 ± 41	5
1999	135 ± 31	5	206 ± 82	5
1998	285 ± 22	6	217 ± 59	4
1994	99 ± 9.1	13	87 ± 8.9	20

[a] 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, and May 2000. Results are presented ± one standard error.

Table A3. Summary of *Poa* counts in FL experimental plots established in 1993. All averages are ± one standard error.

Number of *Poa* in 1993		Number of *Poa* in 1999			Number of *Poa* in 2000		
Planted *Poa* plots[b]	**Total[a]**	**Total[a]**	**Unburned**	**Burned**	**Total[a]**	**Unburned**	**Burned**
Low density	11	2.4 ± 0.93	2.4 ± 0.93 (N=5)	N/A	4.2 ± 0.5	3.75 + 0.5 (N=4)	6.0 (N=1)
Medium density	22	3.2 ± 0.92	2.5 ± 1.5 (N=2)	3.7 ± 0 (N=3)	8.0 ± 2.5	2.0 (N=1)	9.5 ± 2.4 (N=4)
High density	45	9.8 ± 4.4	12.3 ± 7.3 (N=3)	6 ± 3 (N=2)	12.8 ± 4.3	6.5 ± 2.1 (N=2)	19.0 ± 2.8 (N=2)
Existing *Poa* plots[c]							
Low density	4	1.8 ± 0.37	2 (N=1)	1.75± 0.71(N=4)	11.0 ± 3.9	0	11.0 ± 3.9 (N=3)
Medium density	5.6	1.2 ± 0.49	1.3 ± .67 (N=3)	1±1 (N=2)	5.8 ± 2.3	4.6 ± 2.9 (N=3)	9.0 (N=1)
High density	10.6	1.6 ± 1.36	0.3 ± 0.3 (N=3)	3.5±3.5 (N=2)	5.6 ± 1.6	5.0 ± 1.9 (N=4)	8.0 (N=1)
Plots cleared of perennial grass[d]	0	0.68 ± 0.19	0.87 ± 0.21 (N=15)	0.5 ± 0 (N=10)	2.6 ± 1.2	1.8 ± 0.6 (N=10)	3.4 ± 2.5 (N=9)

[a] For all totals, *Poa* counts are averaged across burned and unburned plots.

[b] Plots planted in fixed densities in 1993 and maintained at these densities through 1994.

[c] Plots created around existing *Poa* plants. No new plantings occurred in these plots.

[d] Plots cleared of perennial grass were cleared only through 1994.

Table A-4. Species composition of *Amsinckia grandiflora* nearest neighbors at the Drop Tower Native and Experimental (Exp) populations: 1997–2000.

Species	Native 97 (%)	Native 98 (%)	Native 99 (%)	Exp FL 99 (%)	Native 00 (%)	Exp FL 00 (%)	Exp FF 00 (%)
Achillea millefolium	5	5	–	–	5	–	–
Allium serra	–	1	–	–	–	–	–
Amsinckia grandiflora	–	–	–	–	–	7	–
Amsinckia tessellata	–	–	–	–	3	5	–
Astragalus didymocarpus	–	–	–	–	3	–	–
Avena sp.	18	13	–	7	15	11	24
Bromus diandrus	22	9	17	5	5	2	2
Bromus mollis	31	21	50	33	3	5	1
Bromus rubens	1	–	–	–	–	–	–
Unidentifiable Bromus	–	–	–	–	5	5	28
Clarkia sp.	–	3	–	–	5	–	1
Claytonia parviflora	1	1	–	12	–	16	6
Collinsia heterophylla	3	9	17	–	–	–	–
Delphinium hesperium	1	3	–	–	3	2	–
Erodium cicutarium	4	5	–	24	18	16	4
Galium aparine	11	23	17	2	5	–	4
Lithophragma affinis	–	–	–	–	–	2	–
Lupinus albifrons	–	1	–	–	–	–	–
Lupinus bicolor	–	–	–	–	–	–	1
Phacelia tanacetifolia	–	–	–	–	3	–	–
Poa secunda	–	1	–	–	–	–	11
Sonchus sp.	1	–	–	–	–	–	–
Vulpia myuros	–	–	–	10	20	30	11
Unidentifiable Asteraceae	–	–	–	–	8	2	–
Unidentified dicot	3	3	-	7	–	–	2
# species	12	14	4	8	14	12	12
N	100	129	6	42	39	45	151
Shannon's Index (H')[a]	1.92	2.16	1.31	1.59	2.40	2.14	1.93

Notes:

Exp FL = Experimental flashing subpopulation.

Exp FF = Experimental fire frequency population.

[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 A-5. Weekly predation of *A. grandiflora* nutlets in 1995, 1998, 1999, and 2000. Open, standard spaced, unburned plots only. All rate and intensity data are ± one standard deviation.

Site	Year	Time interval	No. of weeks	Predation rate (end of week 1)	Final predation intensity	Average weekly predation rate[a]	Estimated weekly predation rate[b]	Evenness[c]	Localization[d]	Pre/ post burn	n
Native[e]	1995	Apr 3–Apr 10	1	4. 0 ± 6.5	4. 0 ± 6.5	4. 0 ± 6.5	4. 0 ± 6.5	60	0	N/A	5
EXP[e]	1995	Apr 3–Apr 10	1	20.0 ± 22.1	20.0 ± 22.1	20.0 ± 22.1	20.0 ± 22.1	33.33	0	N/A	5
CDFG[e]	1995	Apr 3–Apr 10	1	39.0 ± 33.0	39.0 ± 33.0	39.0 ± 33.0	39.0 ± 33.0	100	40	N/A	5
Native[e]	1995	Jul 20–Sep 22	9	N/A	68.8 ± 42.7	N/A	7.6 ± 4.7	88.88	33.33	N/A	9
EXP[e]	1995	Jul 20–Sep 22	9	N/A	34.2 ± 33.3	N/A	3.8 ± 3.7	70	20	N/A	10
CDFG[e]	1995	Jul 20–Sep 22	9	N/A	64.8 ± 33.3	N/A	7.2 ± 3.7	100	62.5	N/A	8
EXP[e]	1998	Apr 29–Jun 1	4.5	46.6 ± 16.1	92.6 ± 7.1	15.6 ± 26.9	20.6 ± 1.6	100	100	Pre	10
EXP[e]	1998	Jun 1–Jun 9	1.14	N/A	94.4 ± 9.5	N/A	82.5 ± 7.5	100	100	Pre	10
EXP[f]	1998	Jul 15–Aug 25	5.25	25.8 ± 8.8	75.3 ± 7.5	17.82 ± 7.7	12.9 ± 1.3	95	40	Post	5
Native[f]	1998	Jul 15–Aug 25	5.25	13.3 ± 18.3	52.8 ± 24.9	12.7 ± 10.1	9.0 ± 4.3	100	30	N/A	5
EXP[f]	1999	Apr 26–Jun 1	5	57.2± 29.9	77.0 ± 6.4	28.6 ± 19.5	13.6 ± 8.3	100	100	Pre	5
EXP[f]	1999	Jun 28–Jul 20	3	72.4 ± 24.7	96.0 ± 2.2	30.8 ± 22.4	31.0 ± 4.4	100	90	Post	5
EXP[f]	2000	May 1–May 22	3.14	24.4 ± 27.5	43.9 ± 30.0	20.7 ± 10.6	14.6 ± 1.0	93	6.7	N/A	15
EXP[f]	2000	Jun 5–Jun 28	3.28	12.1 ± 16.6	33.7 ± 22.6	14.5 ± 5.4	10.3 ± 6.9	100	6.7	N/A	15

[a] Average of all normalized predation rates gathered over trial.

[b] Represents the estimated rate (nutlets missing at end of trial divided by original nutlet number divided by number of weeks).

[c] Evenness is the percent of plots (or average number of plates per plot for 1998 round 1, phases 1 and 2) missing at least one nutlet by the end of the time interval.

[d] Localization is the percent of plots (or average number of plates per plot for 1998 round 1, phases 1 and 2) with less than 5 nutlets remaining at the end of the time interval.

[e] Plate methodology (Carlsen et al., 1998).

[f] Nail methodology (Carlsen et al., 1998).

Table A6. Results of germination experiment. All averages are ± one standard error (n=5).

Year collected	Source	Treatment	Round 1[a] % germination	Round 2[b] % germination	Total
1993	Experimental population	none	24 ± 4	9 ± 6	33 ± 8
1994	Experimental population	none	12 ± 3	8 ± 5	20 ± 5
1994	Experimental population	5 min at 105° C	0	0	0
1995	Greenhouse	none	11 ± 2	25 ± 8	36 ± 7
1998	Outdoor pots	none	76 ± 2	3 ± 1	79 ± 11
1998	Outdoor pots	5 min at 105° C	0	0	0

[a] Germination from 24 Nov 00 to 17 Dec 00.

[b] After 12 days of drying, germination from 29 Dec 00 to 14 Jan 00.

Section B
Blepharizonia plumosa plumosa
Monitoring and Research

Section B

Blepharizonia plumosa plumosa Monitoring and Research

B-1. Introduction

Several populations of *Blepharizonia plumosa* ssp. *plumosa* (*B. plumosa plumosa*, the big tar plant) were identified during a habitat survey in 1996 at Site 300 (Preston, 1996). *B. plumosa plumosa* is an extremely rare late-season flowering annual plant included on the California Native Plant Society (CNPS) List 1B (Skinner and Pavlik, 1994). The CNPS List 1B includes plants that are rare, threatened, or endangered. The CNPS R-E-D code (rarity-endangerment-distribution) for *B. plumosa plumosa* is 3-3-3, indicating that this plant is limited to one population or several restricted ones, is endangered throughout its range, and is endemic to California. The CNPS also noted that possibly the only remaining populations exist on private property in the hills near Livermore, California. Populations have been previously identified in Alameda, Contra Costa, San Joaquin, Stanislaus, and Solano Counties (Skinner and Pavlik, 1994). Preston (1996) noted that a population was discovered at Contra Loma Regional Park, south of Antioch in 1979, but that surveys conducted by the East Bay Regional Park District in 1991 were unable to relocate the subspecies. In 1994, several more populations were discovered on private property southwest of Brentwood (CNDDB, 1996). Another small population was found at Chaparral Springs, near Mount Diablo (Preston, 1996). Current status of these populations is unknown. Also during the 1996 habitat survey of Site 300, a few populations of the more common big tarplant, *Blepharizonia plumosa* ssp. *viscida*, were also found. Neither species has been extensively studied, particularly *B. plumosa plumosa*.

Both *B. plumosa plumosa* and *B. plumosa viscida* 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 vein and deeply three lobed (Bremer, 1994).

The *B. plumosa plumosa* can generally be distinguished from *B. plumosa viscida* by fruit morphology and leaf color (Hickman, 1993; personal observation). The most distinctive characteristic of *B. plumosa plumosa* is the pappus of 1.5 to 3mm 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 (Figure B1). The plants also have a pale green color as their foliage is sparsely glandular below the inflorescence. Older plants have many inflorescences lateral on side branches.

B. plumosa viscida, although also endemic to California, exists in large numbers and has a much larger range which extends farther south into the inner South Coast Ranges including San Benito County (Hickman, 1993). The disc and ray seeds of *B. plumosa viscida* appear quite similar and have a short pappus from 0–1 mm in length (Figure B1). *B. plumosa viscida* is much more glandular than *B. plumosa plumosa* (thus the name *viscida)*, giving the plant a more yellow-green color and a much stronger scent. They also tend to be slightly taller than *B. plumosa plumosa* (personal observation). Older plants have inflorescences mostly terminal on slender wand-like, bracted peduncles (Hickman, 1993).

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

And while common throughout its range, *B. plumosa viscida* is very uncommon at Site 300. The two subspecies occur sympatrically (together) at only two locations: one is routinely burned (near Building 812) and the other is in an active slump (the southwest corner of the site at the location of the diamond-petaled poppy, see section C). Other *B. plumosa viscida* populations occur sporadically in both unburned and burned areas. That the two subspecies appear to differ in their habitat requirements may indicate some ecological differentiation between them.

For conservation and management purposes, a thorough understanding of the population dynamics of *B. plumosa plumosa* is necessary. *B. plumosa viscida* is also of interest as comparisons of rare and common congeners can provide important information for rare plant management (Pantone et al., 1995) and can illuminate differences which affect comparative abundance (Byers, 1998). Therefore, in November of 1996, we began collecting basic demographic and population biology data on *B. plumosa plumosa.* Because so little is known about population biology of this subspecies, and because ongoing activities at Site 300 could potentially impact the populations, these data will be useful for both improving management practices and in preparing for any necessary onsite mitigation. Little information also exists in the literature on *B. plumosa viscida,* therefore we began collecting limited information on this subspecies as well. In 1996, three populations of *B. plumosa plumosa* (designated Building 834 [B834] Berm, Elk Ravine, and Building 850 [B850]), and one population of *B. plumosa viscida* (designated Middle Canyon), were delineated for monitoring purposes (Figure B2). Table B1 includes some habitat characteristics of all four populations.

Because *B. plumosa plumosa* populations occur in areas where the Environmental Restoration Division (ERD) has ongoing activities, ERD was interested in determining whether populations could be experimentally established, in the event mitigation measures were necessary. Therefore, a common garden experiment, a field reciprocal transplant experiment, and germination tests were conducted between 1996 and 1998 (Gregory et al., 2001). Little subpopulation differentiation was found in terms of transplant success, with seeds successfully germinating and establishing seedlings in all the field sites. Disc seeds germinated at a much higher rate than ray seeds in both subspecies. Overall seed production was lower for *B. plumosa plumosa* compared to *B. plumosa viscida*, and the majority of seeds produced by *B. plumosa plumosa* were the lower germinating ray, whereas the majority of seeds produced by *B. plumosa viscida* were the higher germinating disc seeds. In addition, *B. plumosa plumosa* plants grown from the ray seeds which did germinate had a lower biomass accumulation and a lower percent survival to flowering compared to *B. plumosa viscida* plants.

It appears that germination and seedling recruitment will not limit the establishment of new *B. plumosa plumosa* populations. We have begun to discern ecological differences between *B. plumosa plumosa* and *B. plumosa viscida*, however we cannot yet explain the relative differences in abundance between the two subspecies at Site 300. Therefore, current and future work will focus on understanding the population dynamics of *B. plumosa plumosa* across the entire site. If indeed *B. plumosa plumosa* is acting as a large metapopulation, smaller subpopulations may be of less importance. But we must verify that *B. plumosa plumosa* is indeed acting as a metapopulation, and understand how it is maintained before we can be certain loss of smaller subpopulations will not threaten the overall metapopulation. And by continued work with *B. plumosa viscida* we will gain a better understanding of the mechanisms controlling the relative abundance of the two subspecies at Site 300.

B-2. Methods and Materials

B-2.1. Monitored Populations

Branches from *B. plumosa* plants were collected on 4 Oct 96 from B834 berm, B850 and Elk Ravine for positive identification. Several sample flower heads were dissected and positively identified as *B. plumosa plumosa*. On 9 Oct 96, 10 Oct 96 and 18 Oct 96 the native populations of *B. plumosa plumosa* at B834, B850, and Elk Ravine were roped off.

In 1996, 1997, and 1998, complete censuses were made of each population. Each plant was counted and nearest neighbor data were collected. In 1997, the population was divided into four quadrants for determination of percent visual cover estimates of other plant species in spring. The percent nearest neighbor composition of each species other than *B. plumosa plumosa* was summed across the four quadrants and then normalized by dividing the sum by the total of all cover averages over all four quadrants. This normalization scaled the 1997 data over 100% total cover to make the data comparable to that collected in years 1999 and 2000. For species diversity index calculations, Shannon's index (Shannon and Weaver, 1949) was used: $-\Sigma$ (of i = 1 to S) $(n_i/n)\bullet\ln(n_i/n)$, 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. In the case of the 1997 data, n_i was the normalized percent cover for each species, and n was 100.

In 1999 and 2000, randomly selected plants in each population were marked. A point-compass method was used to select plants for marking. A two foot square piece of cardboard with a large compass drawn on its face was placed at each of between three and eight locations, the number and placement of which was determined by the size of the population to ensure no large groups of plants were outside the selection range. A survey pin was passed through the end of a meter tape and used to anchor the center of the cardboard compass to the ground. Randomly generated numbers set the degree angle and the number of meters away from the center point of the compass that determined the location of each sample point. The *B. plumosa plumosa* plant closest to the sample point was marked.

Seventy-five to 175 plants were marked in late spring, prior to the annual burn. Plant heights and species of nearest neighbors were collected at this time. After the burn, the plant markers were censused for surviving plants. The height of any plant surviving was recorded and the marker was removed if the plant was missing or dead. The microtopography of all marked plants was noted as either exposed or sheltered. There were so few plants remaining after the burn in 1999 that all plants found, regardless of whether they were marked previously, were measured for height. The marked plants were censused once again at the time of flowering. Again, height data were collected for all plants found. As of the writing of this report, flowering sampling had not been conducted for the year 2000.

B834 berm population was censused on 9 Oct 96 and 22 Sep 97. No plants were found at this population location for 1998 and 1999. The population reappeared in 2000 and was mapped but not censused.

B850 population was censused on 9 Oct 96 (flowering), 28 May 97 (pre-burn), 30 Sep 97 (flowering), 22 Jun 98 (pre-burn), 8 Jul 98 (post burn), and 18 Aug 98 (flowering). In 1999, sampling occurred on 24 May 99 (pre-burn), 25 Jun 99 (post-burn) and 15 Oct 99 (flowering). In 2000, sampling occurred on 18 May 00 (pre-burn) and 24 Jul 00 (post-burn).

The Elk Ravine population was censused on 18 Oct 96 (flowering), 3 Jun 97 (post-burn), 29 Sep 97 (flowering), 3 Jun 98 (pre-burn), 2 Jul 98 (post-burn), and 13 Aug 98 (flowering). The population was sampled on 19 May 99 (pre-burn), 11 Jun 99 (post-burn) and 29 Oct 99 (flowering). In 2000, sampling occurred on 12 May 00 (pre-burn) and 24 Jul 00 (post-burn).

B-2.2. Mapping

On 22 Oct 99, 29 Oct 99, and 3 Nov 99, most areas of Site 300 were surveyed for flowering *B. plumosa plumosa* populations. All *B. plumosa plumosa* and *B. plumosa viscida* populations found were mapped using a Trimble Global Positioning System (GPS) unit. The southwest and northwest corners of the site were not surveyed.

B-2.3. Fire Germination Experiment

To determine the effects of fire on *B. plumosa plumosa* germination, a field experiment was designed to test germination under fire conditions. On 31 May 00, soil filling three 10-in. diameter circular pots was collected from the B850 population area. This soil was then placed in the drying oven at 150°C for 2 days. Most seeds are expected to lose viability after 24 hours at this temperature (Wright, 1928). Ten, 10-in. diameter pots were filled to 1in from the top with potting soil. The top 1 in. of each pot contained B850 soil from the drying oven. After the soil had cooled, ray and disk seeds collected from the B850 population in 1996 and 1998 were sown into the pots. Each pot was divided into quadrants and marked on the outside in permanent pen. In each quarter of the pot, near the center, nine 1996 disk seeds and thirteen seeds of each other type (1996 ray, 1998 ray, 1998 disk) were sown 5mm deep into the soil. Due to a seed shortage, two of the five control pots had five 1996 disk seeds, thirteen 1996 ray seeds, thirteen 1998 ray seeds, and twelve 1998 disk seeds. The five pots receiving the burn treatment were taken to the B850 population on 2 Jun 00 and buried so the pot rim was flush with the soil. Dry grasses from the surrounding area were placed in and around the pots in an upright position in an attempt to duplicate density of surrounding cover and to reduce any impedance to fire flow that could be caused by too much bare soil. The five remaining pots were placed at Building 833.

On 24 July 00, after the burn, the five pots at B850 were collected and returned to Building 833 (B833). Any remaining grass was removed from the pots that were exposed to fire so they that the lack of cover would be similar to control pots at B833. All ten pots will be exposed to winter rains and germination will be monitored.

B-3. Results

B-3.1. Monitored Populations

The *B. plumosa plumosa* population at B850 was the largest of the three in 1996–1998 (Table B2). The sampling technique used in 1999–2000 was focused on survivorship and did not include population size estimates. For the years 1998 and 1999, survivorship was high following the burn at the B850 population (85% and 68%), but low at the Elk Ravine population (0% and 5%). In 2000, survivorship was low in both populations (10% for B850 and 2% for Elk Ravine). Table B3 lists environmental characteristics present at the time of each burn.

Figure B3 shows that in the post-burn sample of 1999, 29% of the plants found dead were in sheltered locations while 35% of alive plants were found in sheltered locations. In 2000, only 16% of plants alive after the burn were sheltered, and 27% of the plants that were dead after the burn were in sheltered locations. Although it appears that there is no relationship between the amount of microtopographical shelter a plant receives and the chances of plant survival, the burns in 1999 and 2000 were very different (Table B3). The fire in 2000 was very late in the year, resulting in larger plants at the time of the burn. In 1999, topological shelter may have had more of an effect for the smaller plants.

Species composition appeared different between populations. In 1997, the B834 berm population was dominated by *Bromus diandrus* (Figure B4), where the B850 (Figure B5) and Elk Ravine (Figure B6) populations were more diverse, with no one species making up more than 25% of the percent cover. This is reflected in the species diversity values (H'), which were 2.06 for Elk Ravine, 2.80 for B850 and 1.13 for B834 Berm. The lack of diversity in the 834 berm population could have been due to the lack of burning at this location, and indeed, *B. plumosa plumosa* was not found at that location in two successive years.

The Elk Ravine population is characterized by *Vulpia myros* and *Poa secunda* (Figure B6), while the B850 population (Figure B5) has a strong *Bromus mollis* presence. Diversity values are high overall, with the highest values occurring in 1997. The difference between 1997 and succeeding year estimates at the B850 location may be due to the difference in measurement technique. Nearest neighbor measurements tend to focus on small, understory plants to the exclusion of overstory plants, and cover estimates allow for more equal treatment between understory and overstory plants.

In 1999, plant height tended to be greater pre-burn compared to post-burn, but in 2000, surviving plants were taller after the burn (Figure B7). While differences are not consistent across years, they are consistent within years. At both B850 at Elk Ravine, plant height dropped after the burn in 1999. In 2000, plants were taller after the burn. This difference between years could be due to the timing of the burn. The burn in 2000 was nearly six weeks later in the year than the burn in 1999 (Table B3), which could have allowed the plants additional time to grow before being stressed by the burn. Elk Ravine plants tend to be shorter than B850 plants, and this height difference may have been a critical determinant of survivorship (Table B2). In both 1999 and 2000, Elk Ravine plants are shorter than B850 plants prior to the burn (Figure B7). Smaller plants may be more susceptible to death during the burn than taller plants.

B-3.2. Mapping

Figure B8 shows the 20-year fire history for Site 300. The annual burns at Site 300 may be strongly influencing the distribution of *B. plumosa* populations across the site. Figure B9 shows the results of our mapping of *B. plumosa* populations in 1999, as well as the mapping conducted by Preston in 1996. *B. plumosa plumosa* and *B. plumosa viscida* populations were common along fire roads on the ridges of Site 300. Populations were generally found within the areas that were burned in 1999 or directly adjacent to the burned areas. GPS mapping of the populations will continue on a yearly basis and will be compared to maps of burn frequency which have been digitized and entered into our geographical information system (GIS) database.

B-3.3. Fire Germination Experiment

Fire appeared to have only burned the edge of two of the pots and the other three were completely untouched. Although the amount of ash deposited on the experimental pots was probably minimal and may not be enough to affect germination, other researchers have found that the change in gas ratios caused by fire can be enough to stimulate germination in fire-adapted species (Keely and Fotheringham, 1999). The population dynamics of *B. plumosa plumosa* probably have a complex relationship with fire, as populations are found where annual burns occur and yet, burns seem to be directly responsible for a large degree of mortality at least in some populations. Germination in the pots will be monitored over the 2000–2001 growing season.

B-4. Recommendations and Future Work

By mapping *B. plumosa plumosa* populations on a yearly basis, we will gain a better understanding of the dispersal, germination and survivorship mechanisms at work in this species. *B. plumosa plumosa* is so widespread at Site 300 that mapping over multiple years should be able to provide information on the relationship between population presence and burn frequency. Intensity and timing of burn may be confounding factors and, in absence of the ability to control these effects, several years of data will be needed to shed light on the relationship between *B. plumosa plumosa* and the annual burns that occur at the site. The monitoring of burn survivorship at B850 and Elk Ravine will assist in the interpretation of the site-wide data. Because subpopulations occur so frequently along the sides of fire trails, it is also possible that the process of road cutting is important to the dispersal of seeds and to metapopulation maintenance.

To understand why *B. plumosa plumosa* is widespread at the site while the *B. plumosa viscida* is not, similar measurements will be taken at populations for each subspecies. Several populations of each subspecies will be demarcated and monitored, ideally in both burned and unburned locations. We will identify additional candidate populations during the spring of 2001.

One outstanding question with respect to the Site 300 *B. plumosa plumosa* population is that of gene flow. The Site 300 *B. plumosa plumosa* population may be acting in one of three ways: (1) a true metapopulation, in that gene flow is semi-restricted, with most of the gene flow occurring within subpopulations, with limited gene flow occurring between subpopulations, (2) one large population, with extensive gene flow occurring between all subpopulations, the locations of the subpopulations being environmentally controlled (i.e., a pseudo-metapopulation), or (3) many small populations, with no gene flow among them. We have been operating under the hypothesis that the Site 300 *B. plumosa plumosa* population is either (1) a true metapopulation, or (2) a single large population with pseudo-metapopulation dynamics. Under either case, the loss of a subpopulation would not particularly impact the larger Site 300 population, assuming it is within some undetermined threshold. However, should 3 (individual populations) be the case, this calls for a much different management scheme. In this case, each population is valuable from an evolutionary perspective and theoretically should be protected. The best method to determine the population structure at this level is through molecular and/or genetic analysis of plants from subpopulations across the site. Should funding opportunities arise, this work should be considered.

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Section B
Figures

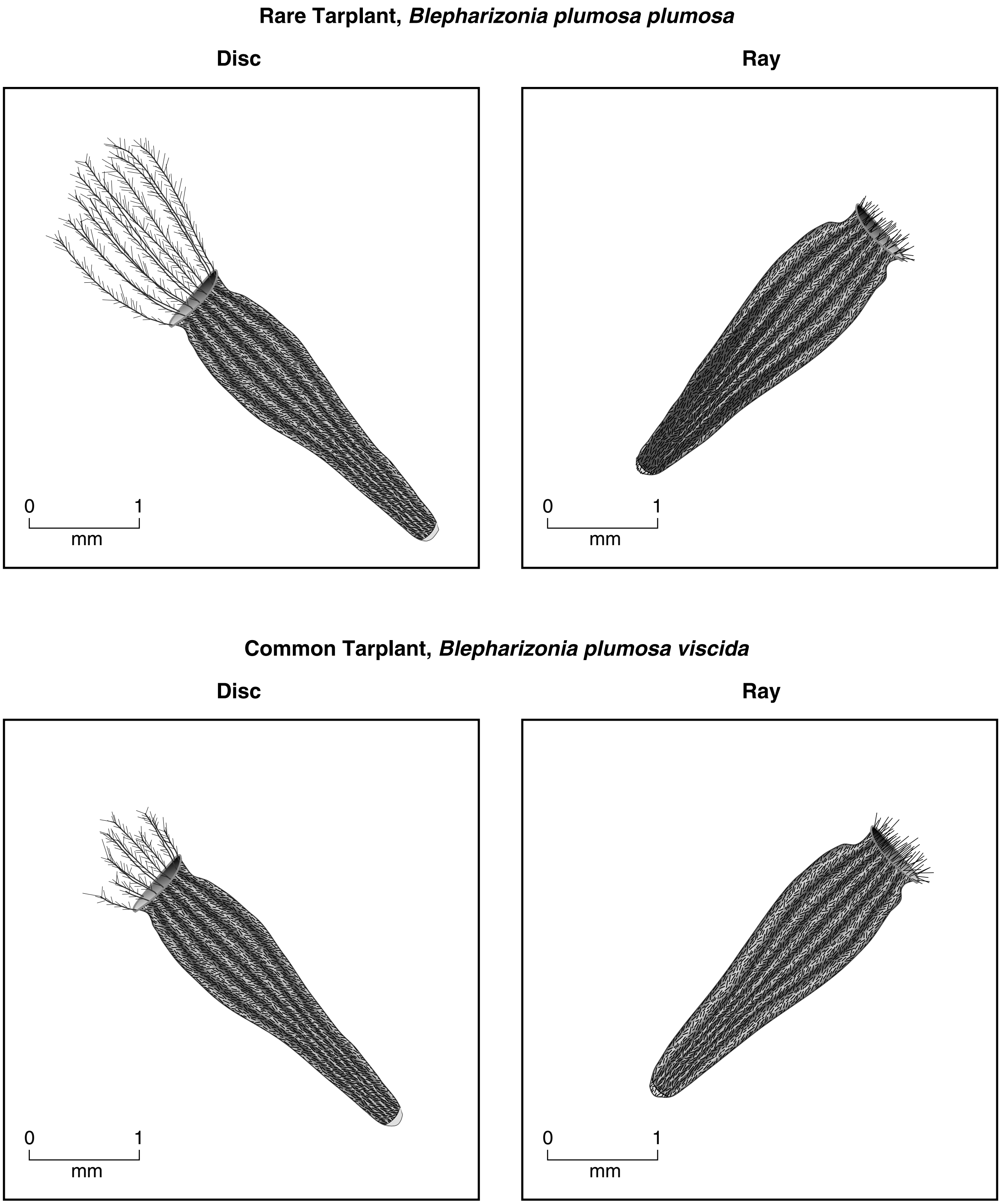

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Figure B1. ***B. plumosa plumosa*** **fruit and** ***B. plumosa viscida*** **fruit.**

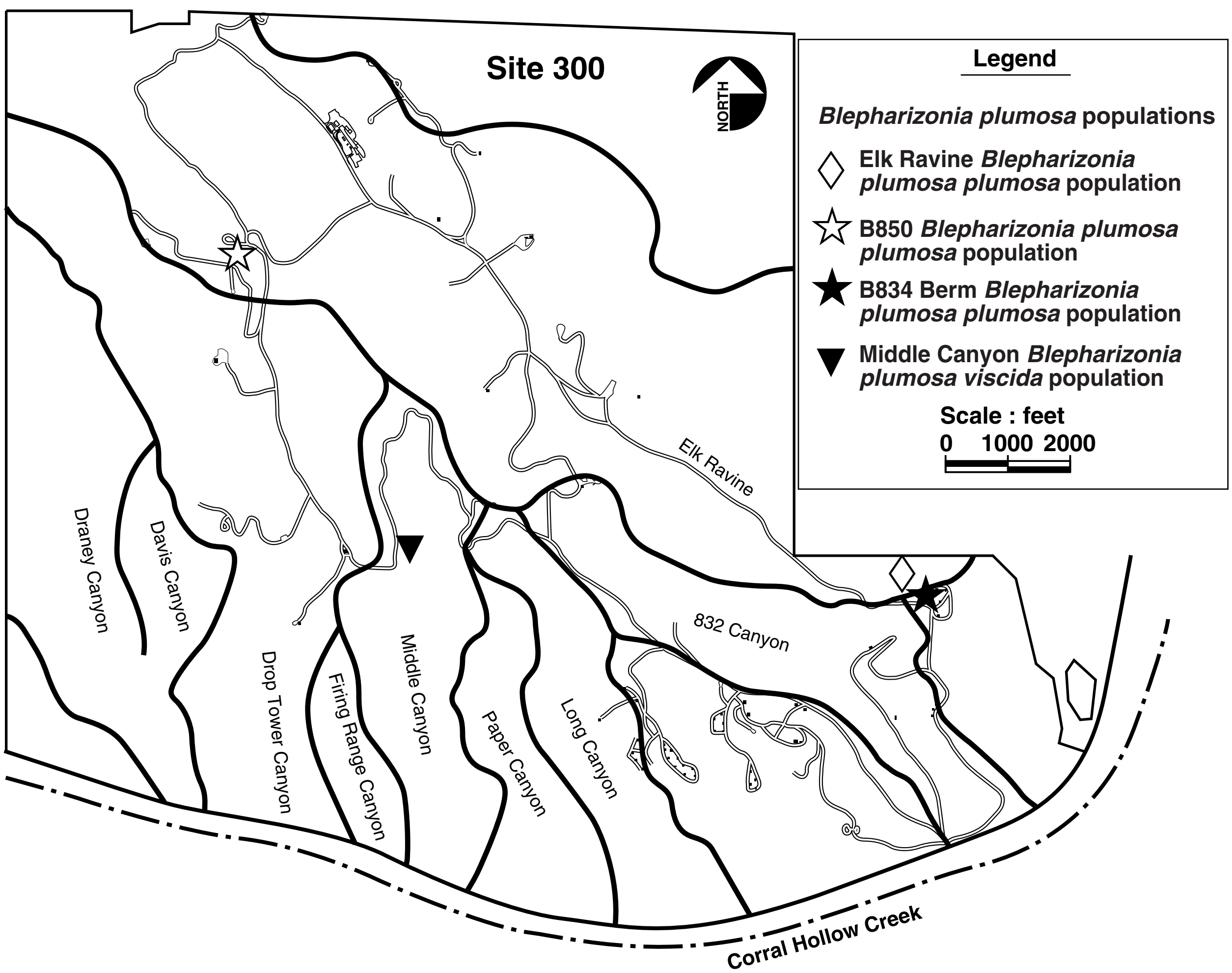

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Figure B2. Location of monitored *Blepharizonia plumosa plumosa* populations at Lawrence Livermore National Laboratory (LLNL) Site 300.

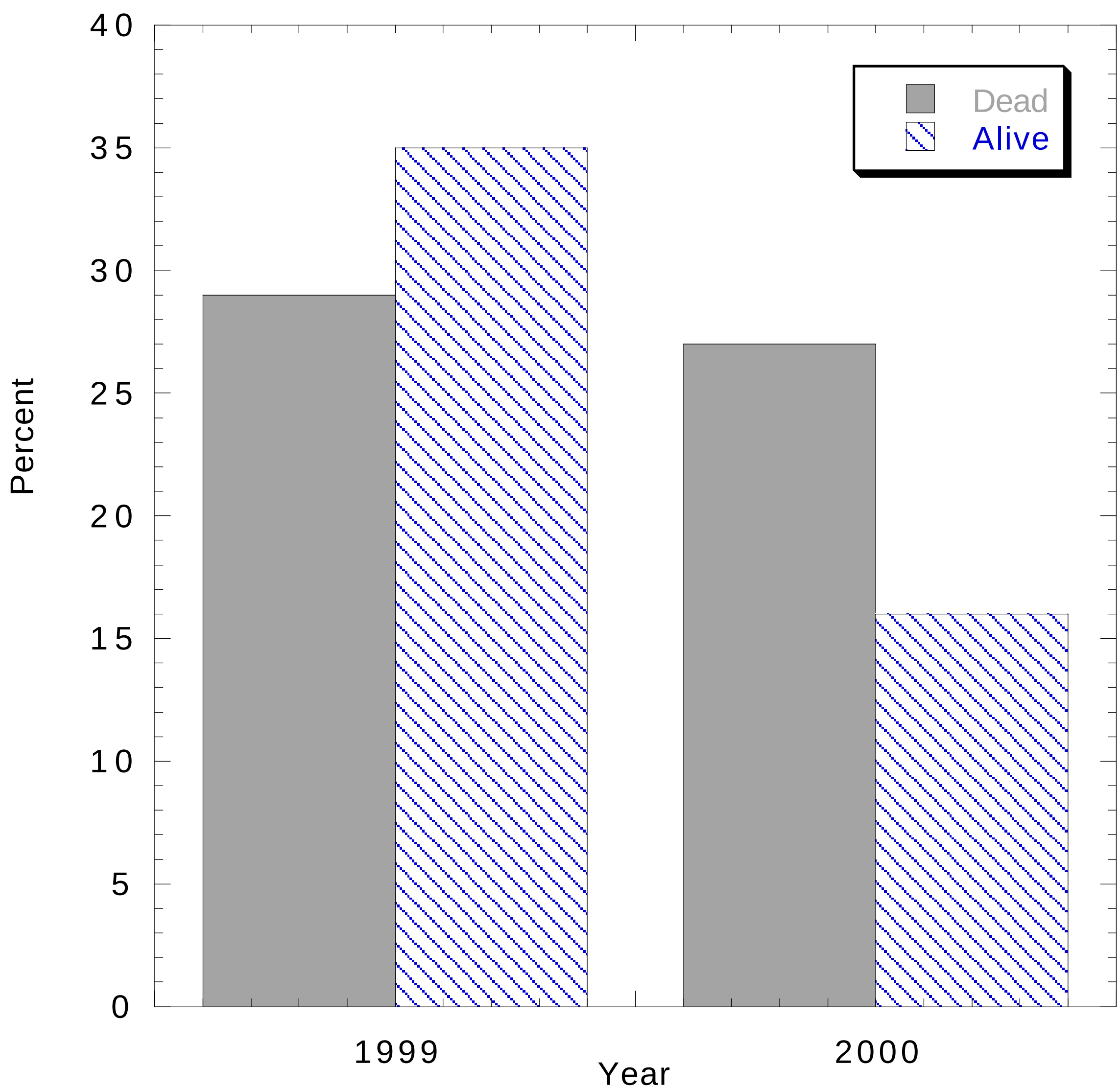

Figure B3. Percent of *Blepharizonia plumosa plumosa* plants in sheltered locations at post-fire census, all populations lumped: 1999 and 2000.

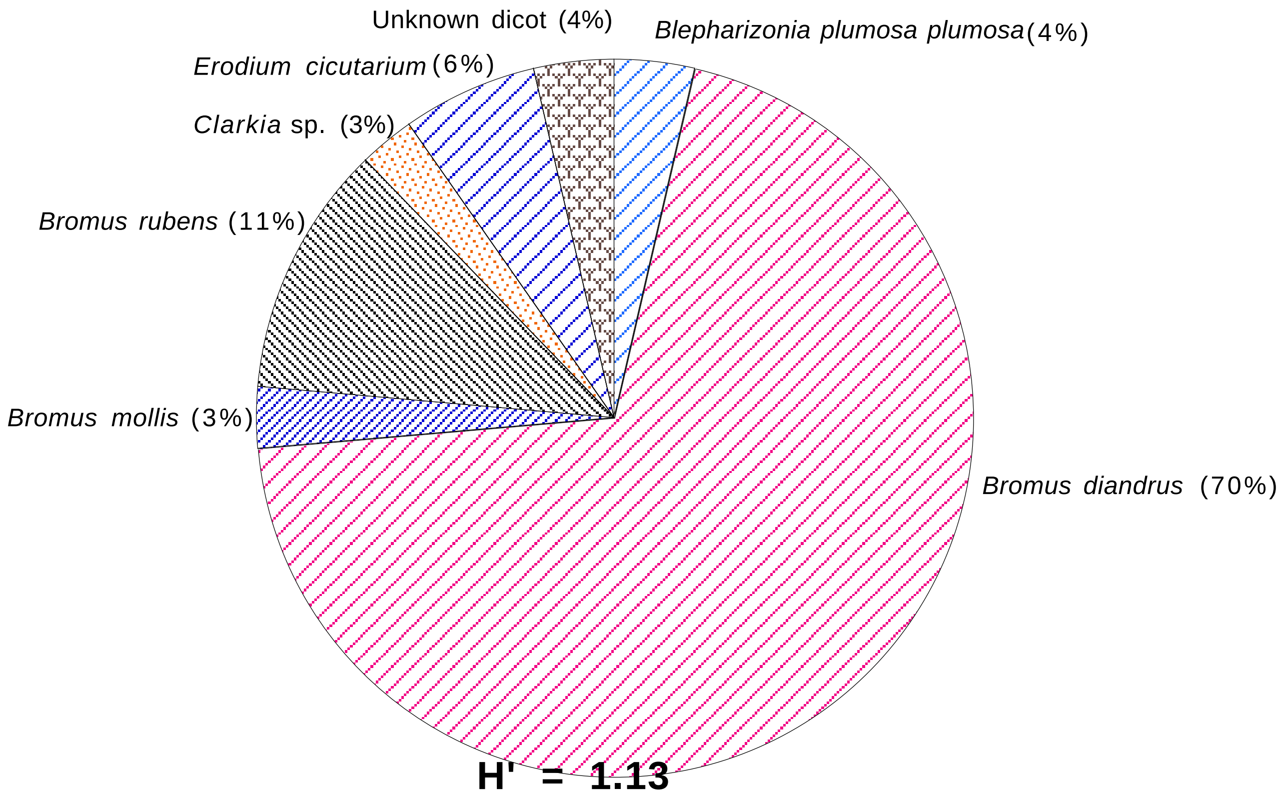

Figure B4. Normalized cover estimates of *Blepharizonia plumosa plumosa* community at Building 834 berm location: 1997. Shannon's diversity index (Shannon and Weaver 1949), H', is also shown.

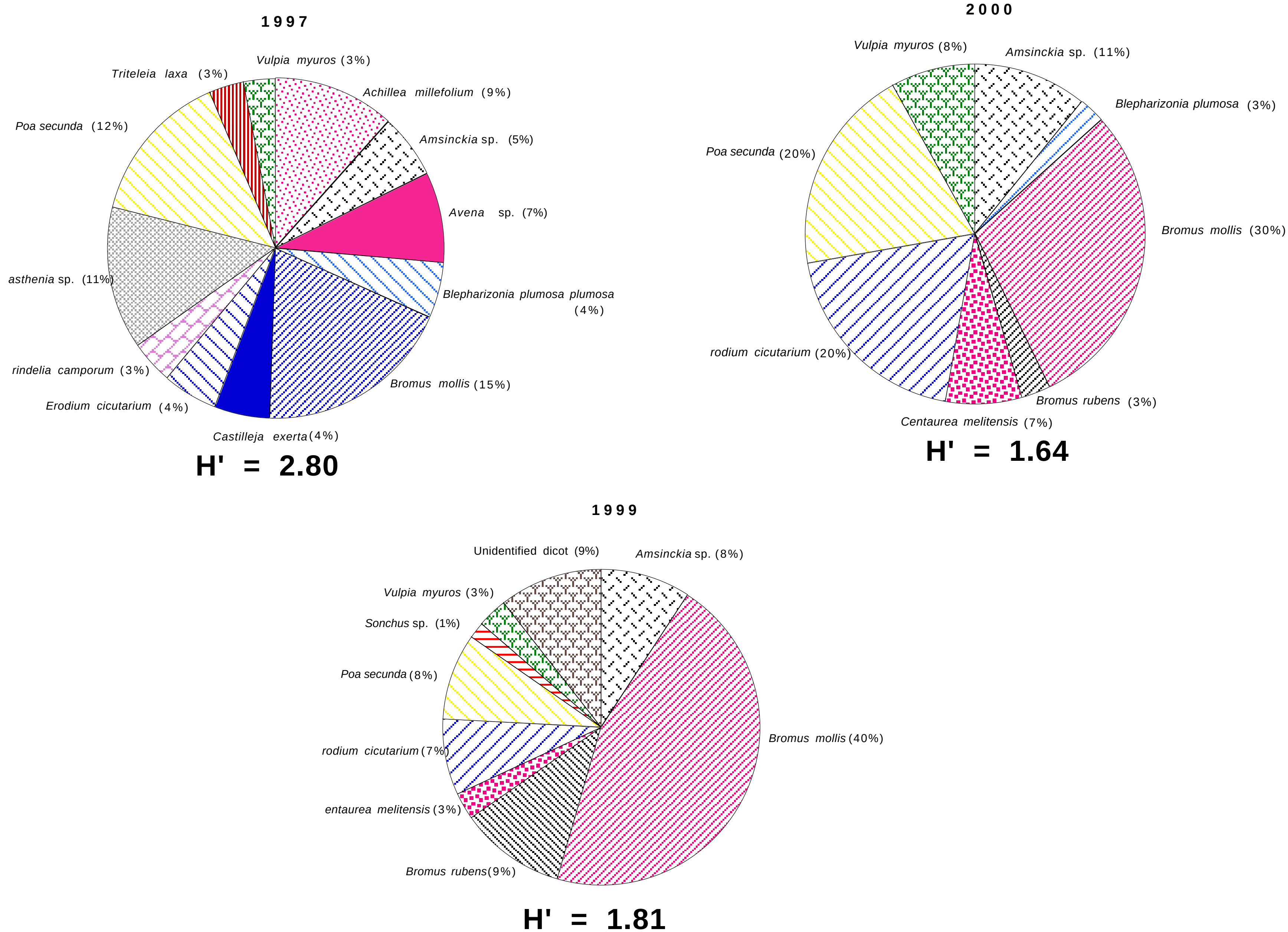

Figure B5. Species composition of *Blepharizonia plumosa plumosa* nearest neighbors at Building 850: 1997*, 1999 and 2000. Shannon's diversity index (Shannon and Weaver 1949), H', for each year is also shown. *1997 data are percent cover estimates

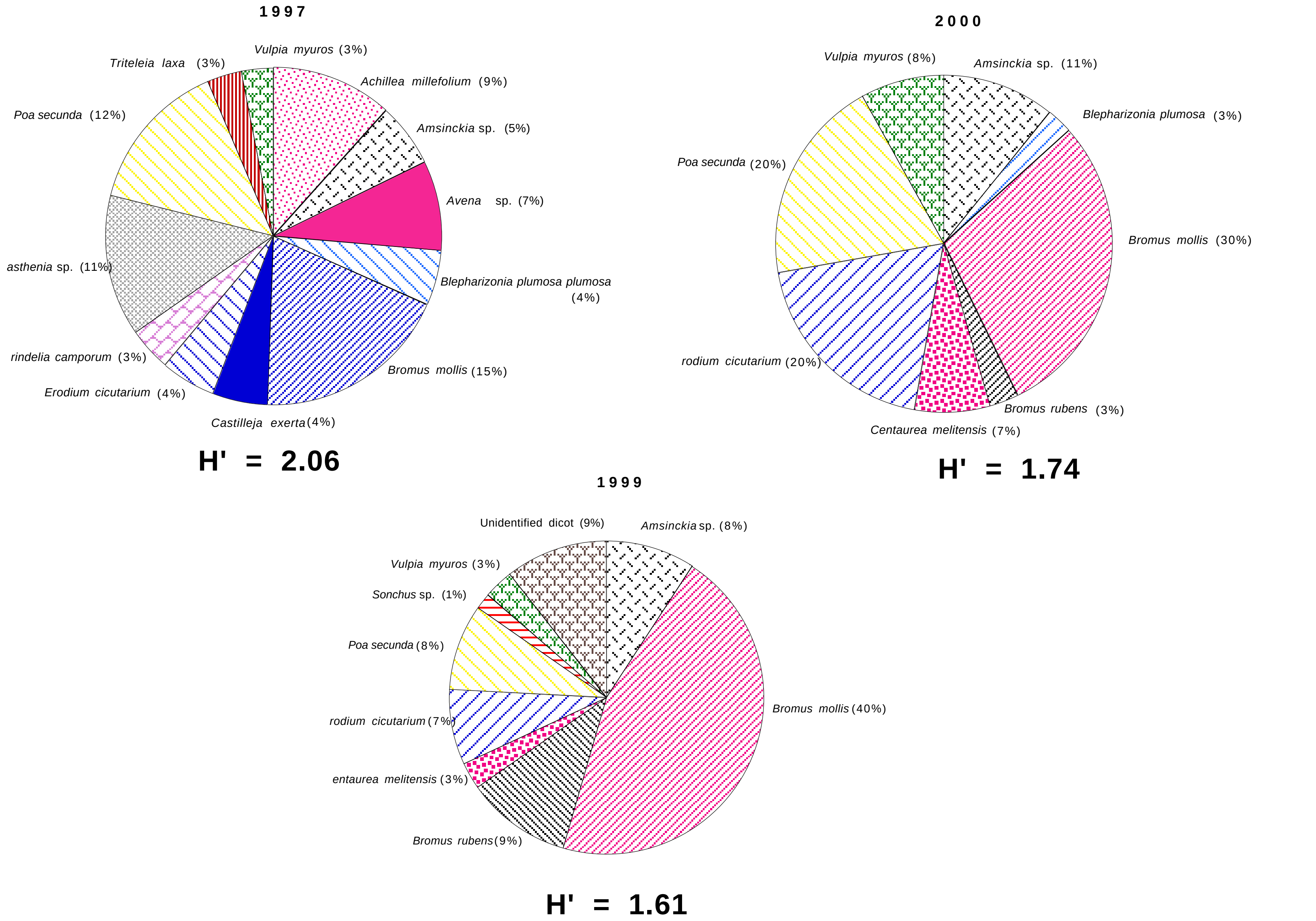

Figure B6. Species composition of *Blepharizonia plumosa plumosa* nearest neighbors at Elk Ravine: 1997*, 1999 and 2000. Shannon's diversity index (Shannon and Weaver 1949), H', for each year is also shown. *1997 data are cover estimates normalized for comparison.

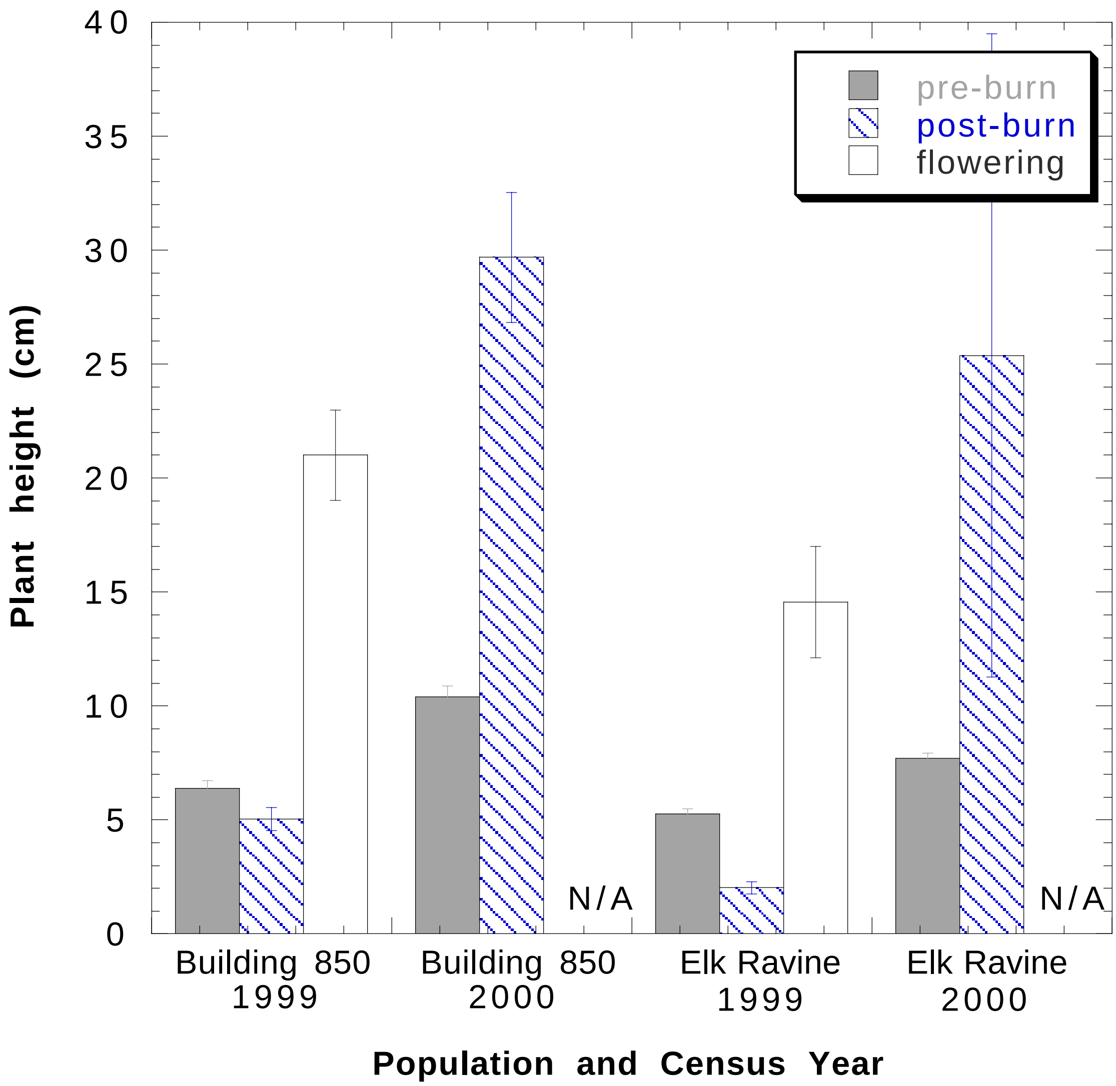

Figure B7. Mean height of *Blepharizonia plumosa plumosa* followed from pre-burn census to flowering census: 1999 and 2000. Bars represent one standard error.

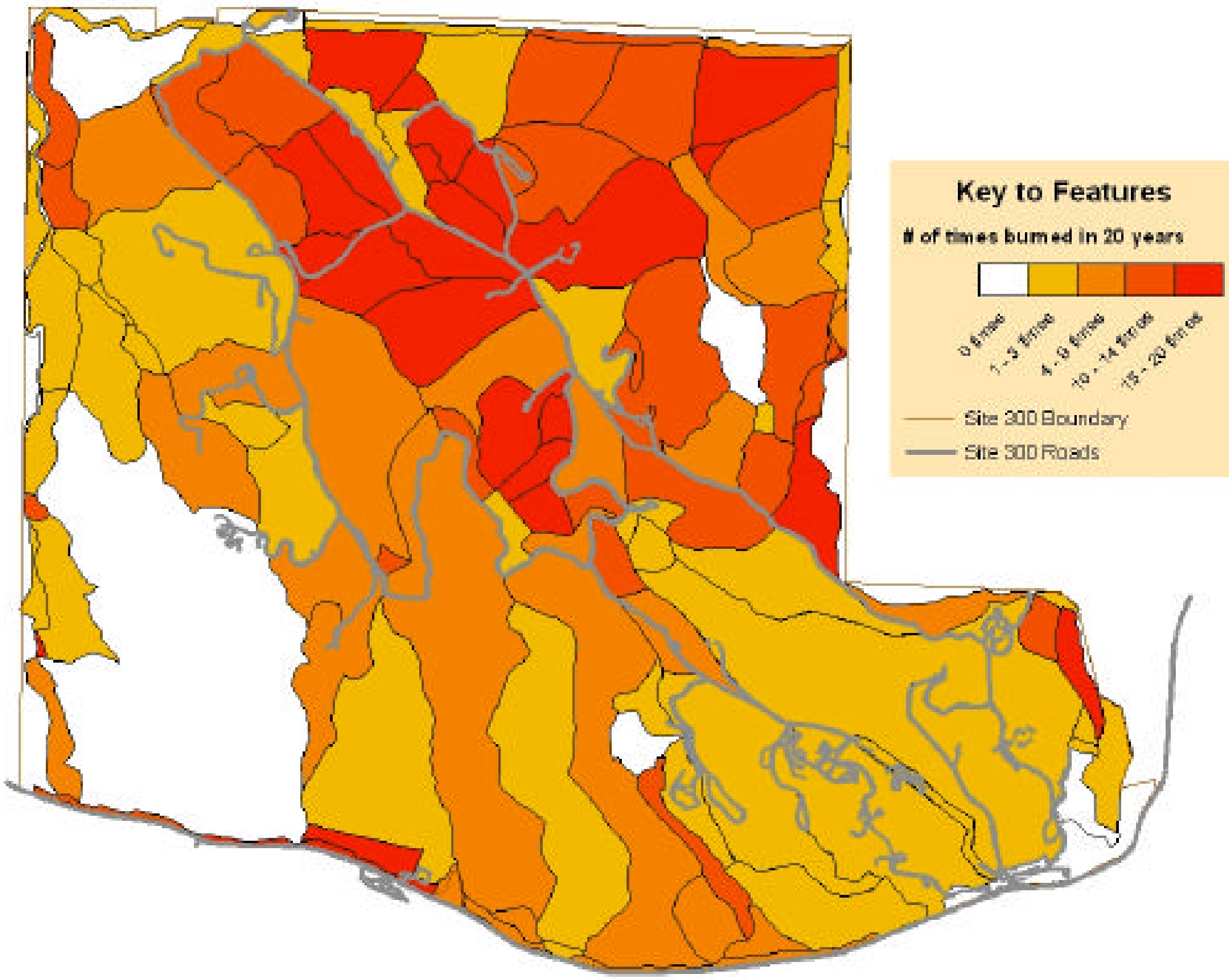

Figure B8. Burned areas at Site 300.

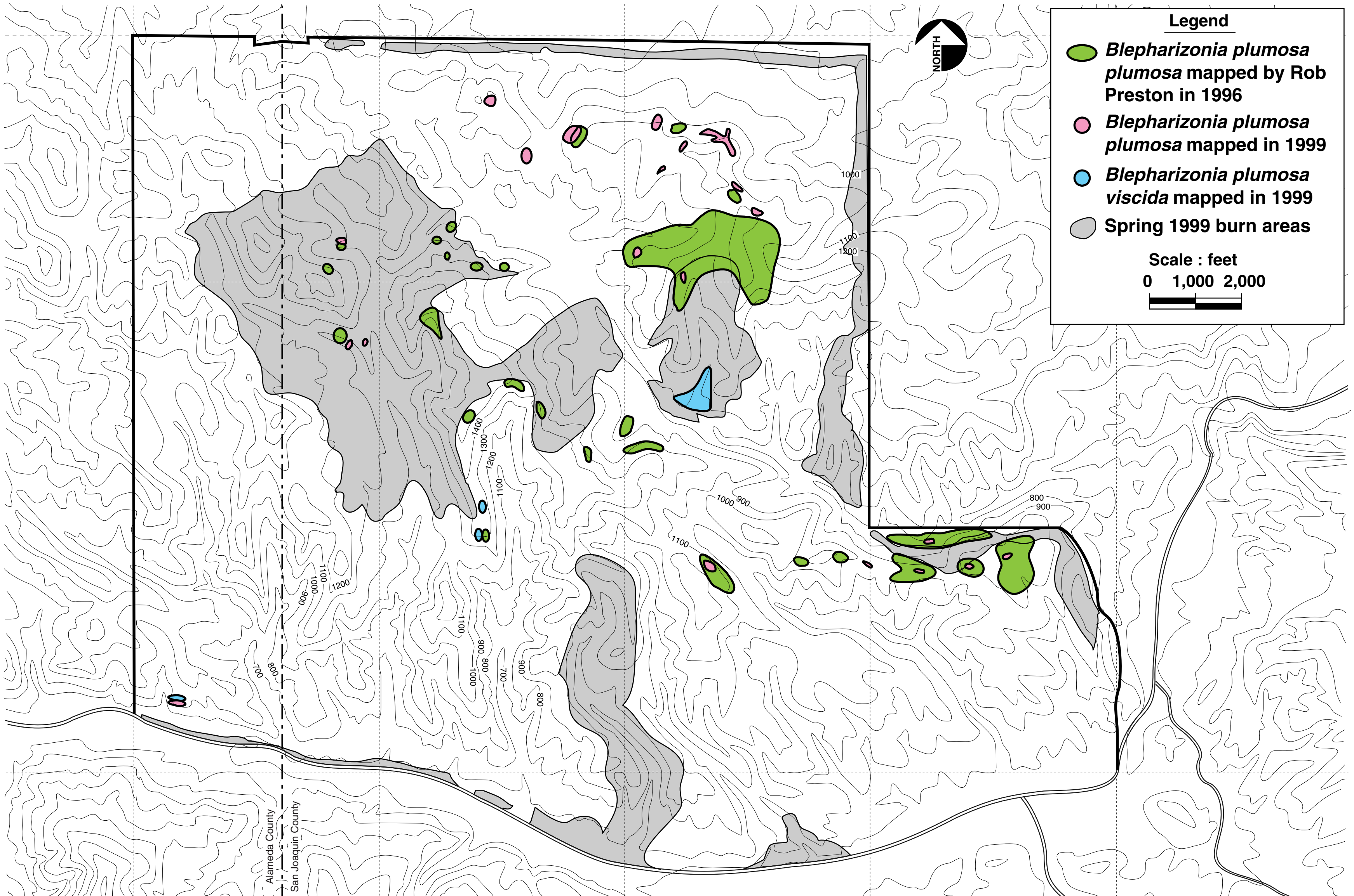

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Figure B9. ***Blepharizonia plumosa*** **populations mapped in 1996 and 1999. Areas burned in Spring of 1999 shown.**

Section B
Tables

Table B-1. Habitat characteristics of three *B. plumosa plumosa* populations and one *B. plumosa viscida* population at Site 300.

Population	Number of plants	Synecology	Elevation (ft)	Aspect	Slope (%)	Soil type	Management practices
B850 (*plumosa*)	≈100	Disturbed annual grassland, *Nassella pulchra* and *Poa secunda* grasses on adjacent slope	≈1,300	North	30–50	Rocky sandy to clay loam, Wisflat-Arburua-San Timoteo complex	Annually burned
B834 Berm (*plumosa*)	≈200	Exotic annual grassland, *Avena* sp., *Gutierrezia californica*, *Eriogonum angulosum*, *Bromus diandrus*, *Holocarpha obconica*	≈1,025	North	8–30	Clay, Alo-Vaquero complex	Not burned, berm with low grass cover
B834 Drainage (*plumosa*)	500–1500	Exotic annual grassland, *Bromus hordeaceus*, *B. diandrus*, *Amsinckia intermedia*, *B. madritensis* ssp. *rubens*, *Grindelia comporum*. Stands of *Leymus triticoides* along drainage route.	≈700	North	50–75	Sandy to clay loam, Wisflat-Arburua-San Timoteo complex	Annually burned
Middle Canyon (*viscida*)	Not determined	Exotic annual grassland, *Avena* sp., *Bromus diandrus*, *B. rubens*, *B. hordeaceus*, *Hordeum marinum*, *Silybum marianum*, *Marah fabaceus*, *Gutierrezia californica*, *Phacelia distans*	≈1,300	East	50–75	Sandy to clay loam, Wisflat-Arburua-San Timoteo complex	Not burned

Note:

Adapted from Preston (1996).

Table B2. Numbers of marked and measured plants and survivorship estimates for Building 850 (B850), Elk Ravine, and Building 834 (B834): 1996–2000.

Year	Population	Pre-burn N	Post-burn N (% survivorship)[a]	Flowering N (% survivorship)[b]
1996	B850	n/a	n/a	700 (n/a)
	Elk Ravine	n/a	n/a	470 (n/a)
	B834	n/a	n/a	146 (n/a)
1997	B850	738	n/a	1385 (n/a)
	Elk Ravine	n/a	62	38 (61%)
	B834	n/a	n/a	189 (n/a)
1998	B850	484	414 (85%)	52 (11%)
	Elk Ravine	284	0 (0%)	0 (0%)
1999	B850	75	51 (68%)	40 (53%)
	Elk Ravine	175	9 (5%)	9 (5%)
2000	B850	113	11 (10%)	pend
	Elk Ravine	175	4 (2%)	pend

Notes:

n/a = Not applicable.

pend = pending Fall 2000 census.

[a] **Percent survivorship was calculated by dividing the number of plants present at the post-burn census by the total number of plants observed in the pre-burn census.**

[b] **Percent survivorship was calculated by dividing the number of plants present at the flowering census by the total number of plants observed in the first census.**

Table B3. Burn data for 850 and Elk Ravine: 1997-2000. Wind speed, temperature, and relative humidity are average values reported for each date.

Population	Date of burn	Temperature (°F)	Wind speed (mph)	Relative humidity (%)
Building 850				
	06/06/97	74	20	32.94
	06/14/98	73	12	50.12
	06/10/99	68	16	30.45
	07/18/00	73	15	36.13
Elk Ravine				
	05/16/97	79	9	35.03
	05/30/98	58	12	66.07
	06/01/99	57	13	64.88
	07/12/00	72	17	43.72

Note:

Mph = Miles per hour.

Section C
Eschscholzia rhombipetala Monitoring

Section C

Eschscholzia rhombipetala Monitoring

C-1. Introduction

A single population of *Eschscholzia rhombipetala* (the diamond-petaled poppy) was identified during a habitat survey in 1997 at Site 300. *E. rhombipetala* is an extremely rare spring-flowering annual plant included on the California Native Plant Society (CNPS) List 1A (Skinner and Pavlik, 1994). The CNPS List 1A includes plants that are presumed extinct. According to the CNPS, the plant had last been seen in 1950, with an historical range that includes the inner north Coast ranges, the eastern San Francisco Bay region, and the inner South Coast Ranges. However, 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 (Clark, 2000). This population was seen again in 1995 but not in 1997. At this location, they grow on heavy clay soils that accumulate water in the spring, forming vernal pools. The poppies grow in an ecotone on the higher areas between an *Amsinckia*-dominated mound and a *Layia*-dominated swale, in open patches. They grow as almost an understory to the taller *Lasthenia*, *Phacelia*, and various grasses (Clark, 2000).

At Site 300, *E. rhombipetala* is found in the extreme southwest corner of the site (Figure C1). Like the Carrizo plain population, it occurs on heavy clay soils. Also like the Carrizo plain population, the Site 300 *E. rhombipetala* population occurs in an ecotone. At Site 300, this ecotone 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. The *E. rhombipetala* population is found on the southern side of the slump (a north-west facing aspect) near the edge of the scarp, some distance into the surrounding grassland, and in the slump itself. The surrounding grasslands are composed primarily of the exotic grasses *Avena* and *Bromus*, with *Sonchus* and *Brassica* species being the primary forbs. The slump contains various grasses, along with *B. plumosa plumosa* and *B. plumosa viscida*.

E. rhombipetala is a small, erect annual, 5–30 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 3–15 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 4–7 cm long, containing numerous round, net-ridged black seeds 1.3–1.8 mm wide (Hickman, 1993).

The Site 300 *E. rhombipetala* population is located in a remote portion of Site 300, far removed from programmatic areas. However, for conservation and management purposes, an understanding of the population dynamics of *E. rhombipetala* is desirable. Therefore, in 1998, we began collecting census data on the *E. rhombipetala* population, and began additional characterization of the surrounding plant community. This data will begin to provide some information concerning the mechanisms controlling the abundance and distribution of *E. rhombipetala*.

C-2. Methods and Materials

C-2.1. Census

The entire *E. rhombipetala* population was censused on 8 Apr 98. Small, numbered flags were used to mark individual plants so they could be tracked. Height, flower number and capsule length data were collected. On 18 Apr 98, the population was revisited and marked plants were found and measured again. The same method of measuring and marking took place on 30 Apr 99, with a follow-up visit on 21 May 99. In 2000, the population was censused on a single date: 24 March 00. On this date, 273 plants were found, but only 171 were marked and measured. In addition to height, flower number and capsule length, the geographic feature of where the plant was found (in the slump, on the scarp next to the slump, in the interior grassland) was recorded and the basic cover type (open, plant cover, or clipped) was also noted. The "open" cover type was recorded when *E. rhombipetala* plants were located in a patch of bare ground, with no significant other plant cover above or below the plant. The "plant cover" type was recorded when the *E. rhombipetala* plant was located in an area where other plants surrounded it. The "clipped" cover type referred to *E. rhombipetala* plants found within the clipped treatment of the clipping experiment (see below). Tukey's separation of means was performed on plant height, flower number and capsule length data for 2000 data only.

C-2.2. Specimen Collection

In 2000, plant voucher specimens and capsules were collected. For the voucher specimens, two medium-sized plants were placed between newspaper and botany blotter paper and pressed in a plant press until dry. Capsules were collected from five different plants in the *E. rhombipetala* population. After drying, seeds were removed from the capsules and placed into paper envelopes. One plant voucher and 24 seeds from two plants were sent to Dr. Curtis Clark of the Biological Sciences Department at California State Polytechnic University for possible use in genetic surveys of the *Eschscholzia* genus. The remaining plant voucher and seeds are stored in ERD's plant laboratory at room temperature.

C-2.3. Clipping Experiment

On 5 Nov 99, two $1m^2$ plots were located on the scarp and the interior grassland areas where the population was found in 1998. Because of the high levels of standing biomass in 1999, these two plots were clipped to see if *E. rhombipetala* presence could be stimulated by this treatment. Biomass was cut close to the ground and placed into bags for weighing. Plots were revisited on 24 May 00 and biomass from a $0.1m^2$ area in the center of each plot was removed for weighing. Biomass was also collected from two control areas less than 2m from each clipped plot.

C-2.4. Releve Sampling

On 21 May 99 and 27 Apr 00, cover and composition of species in the *E. rhombipetala* population area were recorded using the releve sampling technique (Taylor and Davilla, 1986). Areas that appeared to have similar community characteristics were visually identified and one or two $0.64m^2$ plots (releves) were located in each area. For each releve, species were identified and their percent cover was visually estimated and recorded. Data were collected from 53 releves in 1999 and 57 releves in 2000. Of these releves, 52 were mapped in 1999 (Figure C2) and 40 were mapped in 2000 (Figure C3).

C-2.4.1. Data Analysis

Releve data were analyzed by calculating constancy, mean cover and importance value for each species. Constancy was calculated by dividing the number of times any one species was observed in a releve (referred to as the count) by the total number of releves for that year. Mean cover was calculated by averaging the cover over all releves where each species was found. Importance Values (I.V.) for each species was calculated by summing the constancy and mean cover value by species.

Principal Components Analysis (PCA) was run on releve data to describe the effect of each species on the variation among releves. We are using PCA to provide a statistic which indicates the importance of each species in describing the variation among releves. PCA allows cover values of the many species to be collapsed into two or three factors. The amount of variation that the factors described was calculated by taking the sum of the eigenvalues of the factors chosen to report divided by the total number of factors calculated (Tabachnick and Fidell, 1996). Species correlated with each other at a value of $R > 0.58$ (Pearson's correlation) were treated as duplicates and only one was used in the factors, nor were species with absolute loading values < 0.32 used. Loading is an indicator of the effect the variable has on a factor score. Loadings of absolute value less then 0.33 indicate that the variable does not affect the score significantly. Twenty-six species were included in the PCA.

C-3. Results and Discussion

C-3.1. Census

The *E. rhombipetala* population comprised 18 plants in 1998 (Table C1). This number decreased to nine plants in 1999. In 2000, 273 plants were found, but only 171 were marked and measured. Survivorship over the 10-day period in 1998 was 92%. The three-week monitoring period of 1999 resulted in a recorded 67% survivorship. No survivorship data were recorded for 2000. Plants are typically small, with average heights ranging from 4.7 to 7.5 cm. Plants as small as 2.5 cm have been observed flowering and the largest plants recorded in this population are approximately 12 cm tall. Most plants have only one flower open at a time, but plants with dehisced capsules usually have several per plant.

Both cover type and geographic feature had an effect on plant height and the number of flowers per plant. Capsule length was not affected by either variable. Plant heights (Figure C4) were highest in the slump and in the grassland and in areas with plant cover. Plant heights were lowest in clipped areas, on the scarp, and in open areas with no other plant cover. Plants in the slump had the most flowers (Figure C5) and plants on the scarp had the fewest. Clipped areas contained plants with the fewest flowers. The majority of plants found were in areas with plant cover (61%) and more were located in the slump (48%) than in the scarp (24%) or the grassland (28%).

While some cover has a positive effect on the *E. rhombipetala* plants (plants in the open were smaller and had fewer flowers than plants in areas with other plant cover), too much surrounding biomass may be detrimental. Biomass collected in the clipping experiment (below) showed larger amounts on the scarp (21.4 g/0.1m^2) than in the grassland (7.5g/0.1m^2), and scarp *E. rhombipetala* plants were smaller and had significantly fewer flowers than grassland plants. It appears that biomass must be limited for *E. rhombipetala* success.

C-3.2. Clipping Experiment

Biomass collected on 5 Nov 99 was 7.5 grams in the interior grassland area and 21.4 grams on the scarp. For the biomass collected the following spring, Figure C6 shows that grass cover and total cover was higher in the two clipped plots and forb cover was much higher in the two control plots. Thatch biomass was about the same between the two treatments. Seven percent of the total number of plants were found in the area clipped in 1999. Because we did not establish control plots to follow, we cannot make any inferences as to whether the clipping treatment promoted *E. rhombipetala* establishment. However, it appears that the clipping increased grass cover at the expense of forb cover and also increased total biomass. Clipping does not appear to be a strongly effective restoration technique in this location.

C-3.3. Releve Sampling

Figure C3 shows releve locations for 2000 along with visual estimates of sub-community types. Five sub-community types were described in 2000: bare (almost no plant cover), *Avena* dominant, *Bromus diandrus* dominant, *Bromus rubens*/*Avena* dominant, and native perennial grassland (*Poa secunda* dominant). More sub-community types were defined in 1999 (Figure C2): *Avena* dominant grasslands were broken up into those with an understory and those without an understory, *Bromus hordeaceus*, *Hordeum murinum*, and *Elymus* each had their own patches of dominance, and there were large areas of mixed *Bromus* stands not found in 2000. While it appears that the *E. rhombipetala* area was more diverse in 1999, releve data show that the reverse is actually true. The large areas that appeared homogenous in 2000 were in fact collections of more species than the smaller, more well-defined areas of 1999 that contained fewer species. Visual estimates of dominant species on a large scale do not truly reflect the species composition at this location.

While the annual grass composition of the site did not change much from 1999 to 2000 with *Avena*, *Bromus* and *Sonchus* sp. remaining the dominant species, *Poa secunda* almost doubled in importance (0.14 to 0.25) and the diversity of native forbs increased (Tables C2 and C3). Diversity of native forbs increased from six species in 1999 to 11 in 2000.

While importance values describe the importance of each species in describing the overall community type, PCA describes the importance of each species in describing differences between releves, or the variability within the community. A species with a high constancy value would be important in describing the community but would not be very important in describing variability among releves, as a species with a high constancy value would be found in nearly every releve.

PCA showed three factors that described 25% of the variation among releves for years 1999 and 2000 combined. The important species in these factors were *Guterrizia californica*, *Blepharizonia plumosa*, *Erodium cicutarium*, *Salsola tragus*, and *Eschscholzia rhombipetala*.

When broken down by year, *Eschscholzia rhombipetala* was important in the factors for each year (see Table C4 for loadings). In 1999, *E. rhombipetala* and *Galium aparine* densities were positively correlated (R = 0.61) and in 2000, *E. rhombipetala* cover was positively correlated with *Medicago polymorpha* (R= 0.67). When examining only releves where *E. rhombipetala* was present, *Erodium cicutarium*, *Montia parviflora*, *Bromus rubens* and *Avena* were important species in describing the variability among releves. There were differences between years: while in each year, covers of five species explained over 35% of the variability among releves, only one of those species remained the same between years – *Bromus diandrus*.

In the future, PCA will be used relate species composition gradients and vegetation characteristics (e.g. percent bare ground and canopy height) to *E. rhombipetala* presence or absence. By plotting releve locations against PCA factors of species composition and defining vectors of vegetation characteristics, we can begin to describe *E. rhombipetala* presence in a way that reflects the complexity of the local environment.

C-4. Recommendations and Future Work

The yearly census of *E. rhombipetala* showed a wide range in population size, from a low of nine to a high of 273 individuals. This is typical of small, annual plant populations. In addition, we were able to detect strong changes in community species composition between years. However, as yet, we are unable to specifically correlate these changes (i.e., that of *E. rhombipetala* abundance and community composition), but additional data analysis may shed light on underlying mechanisms controlling *E. rhombipetala* abundance and distribution. Therefore, we will continue to collect census and community composition data, as well as environmental data, during our monitoring of the population. We will explore adding additional environmental variables (such as soil type, moisture, etc.) in attempt to further identify mechanisms controlling *E. rhombipetala* abundance and distribution.

We will continue to interact with Dr. Curtis Clark of the California State Polytechnic University as he works to determine chromosome number and additional genetic characteristics of *E. rhombipetala*. In addition, we hope to make contact with Dr. Dave Keil of the California Polytechnic State University in San Luis Obispo and arrange for a visit to the Carrizo plains population. These exchanges of information will enhance our ability to manage the Site 300 *E. rhombipetala* population. A literature review to determine factors affecting *E. californica* (the California poppy) establishment will be performed. *E. californica*, which also occurs at Site 300, to may provide additional insight to the dynamics of the *E. rhombipetala* population. Because *E. californica* is a reasonably well-studied species, the collection of field data on the Site 300 populations is not planned at this time.

C-5. References

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Section C
Figures

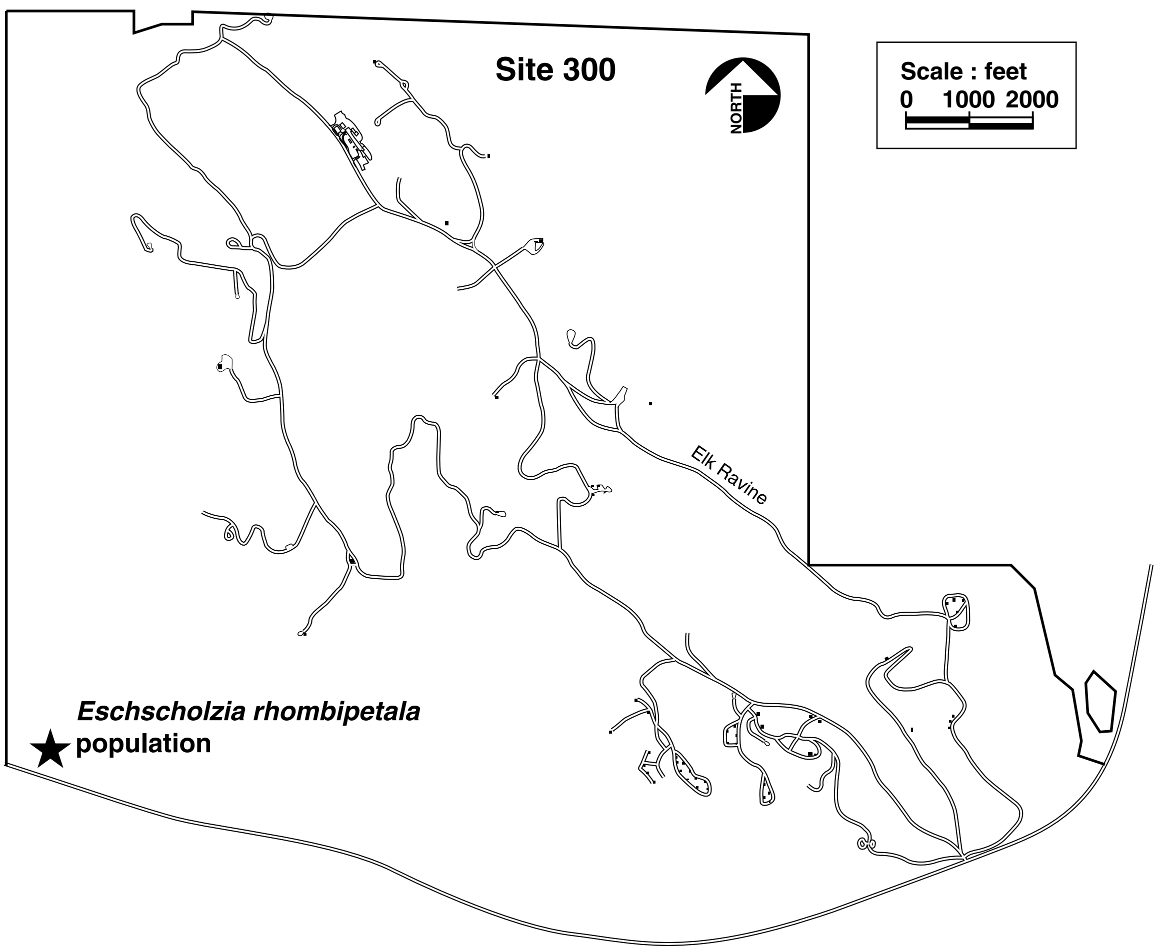

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Figure C1. ***Eschscholzia rhombipetala*** **population location map LLNL Site 300.**

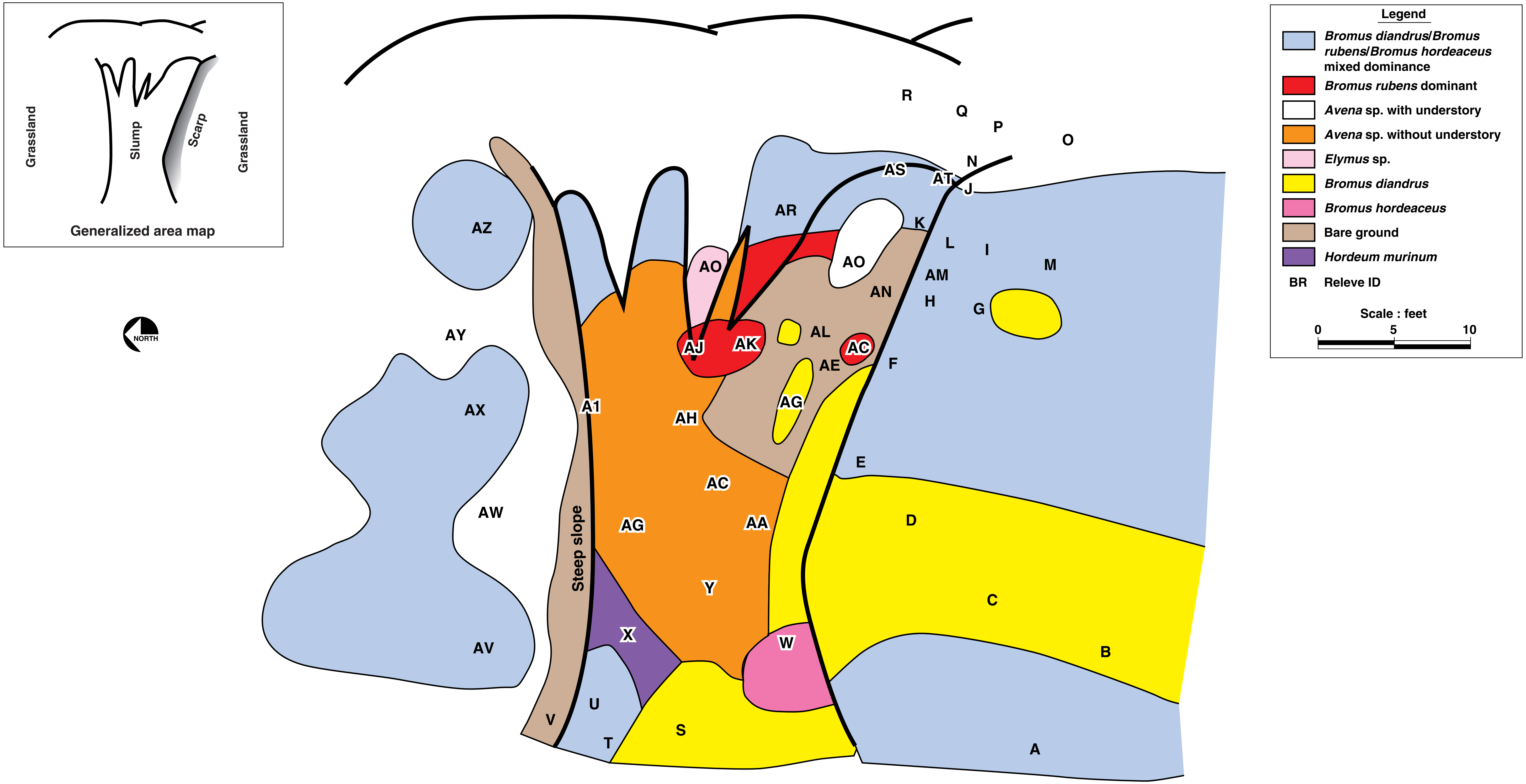

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Figure C2. Releve plot locations and dominant vegetation type: 1999.

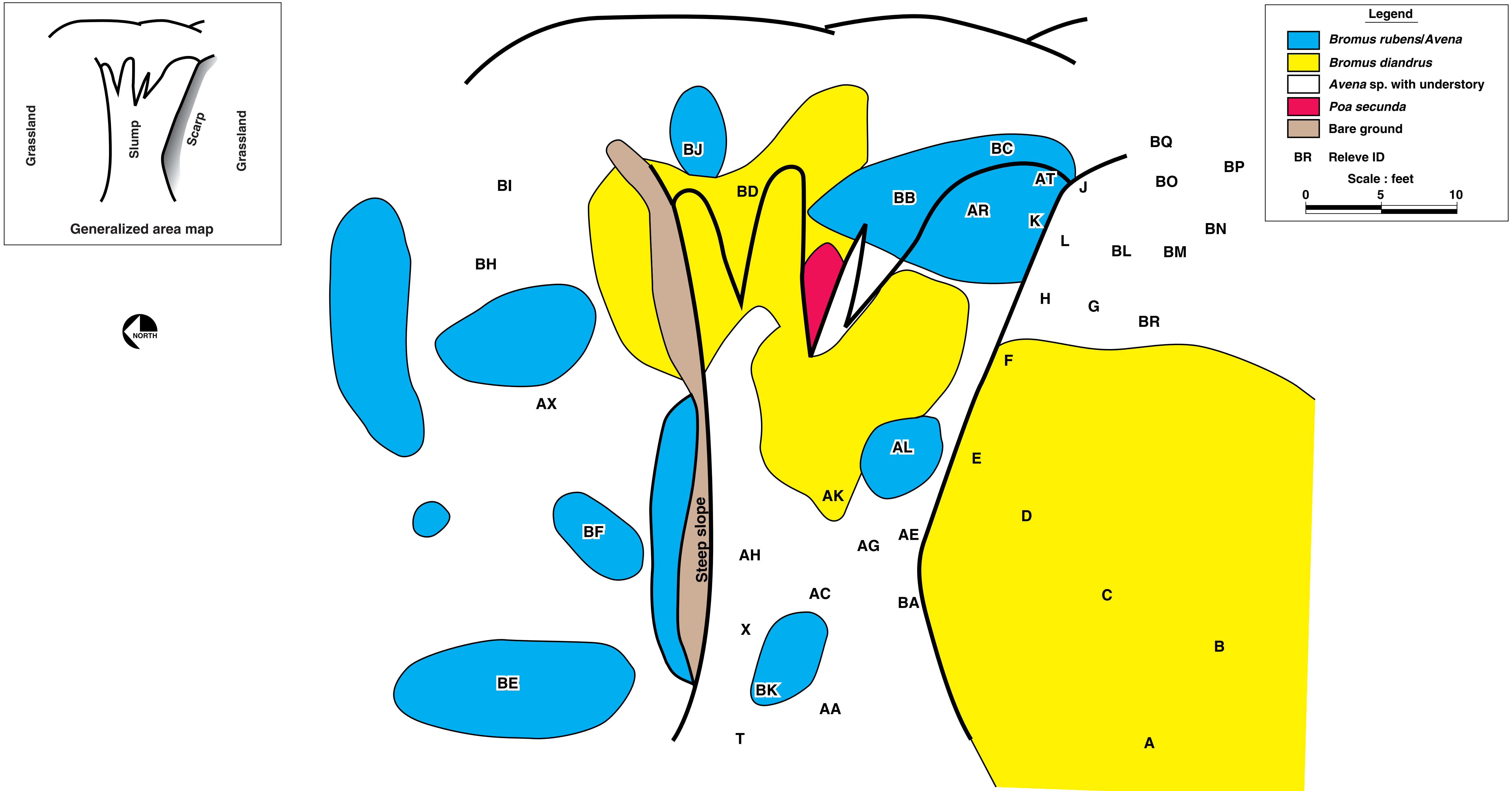

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Figure C3. Releve plot locations and dominant vegetation type: 2000.

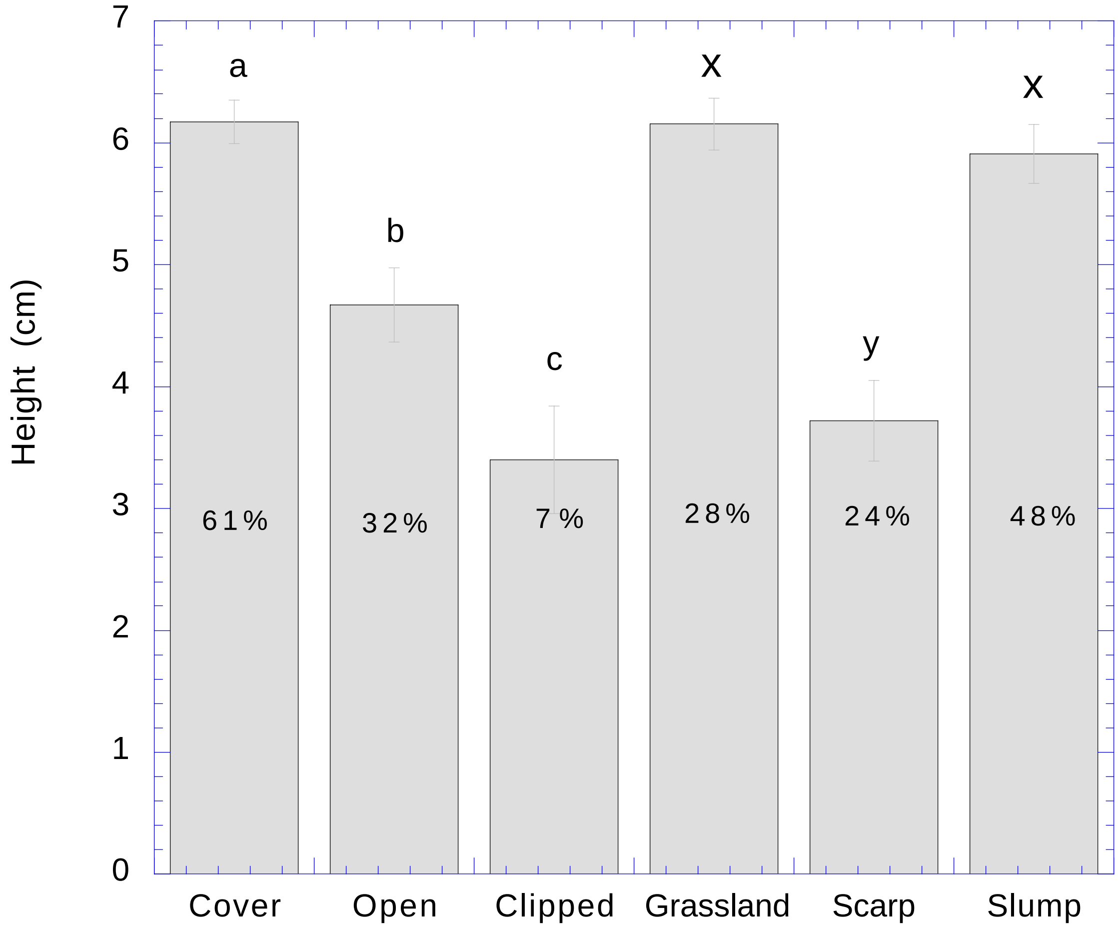

Figure C4. Height of *E. rhombipetala* plants in different cover types and in different geographic areas on 24 Mar 00. Percent of plants found in each are shown. Different letters indicate differences between cover types or geographic areas ($p<0.05$). Bars are one standard error.

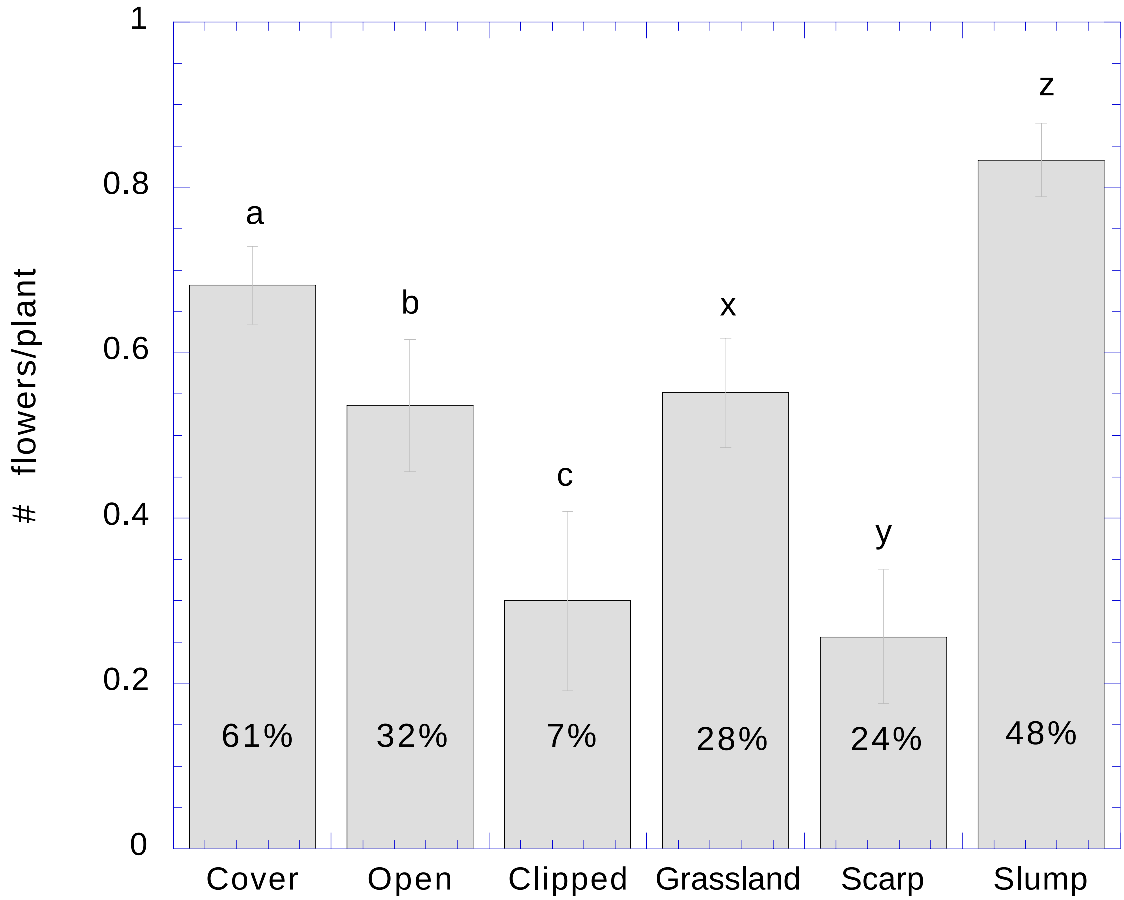

Figure C5. Number of flowers per *E. rhombipetala* plant in different cover types and geographic areas on 24 Mar 00. Percent of plants found in each are shown. Different letters indicate significant differences among cover types or geographic areas ($p<0.05$). Bars are one standard error.

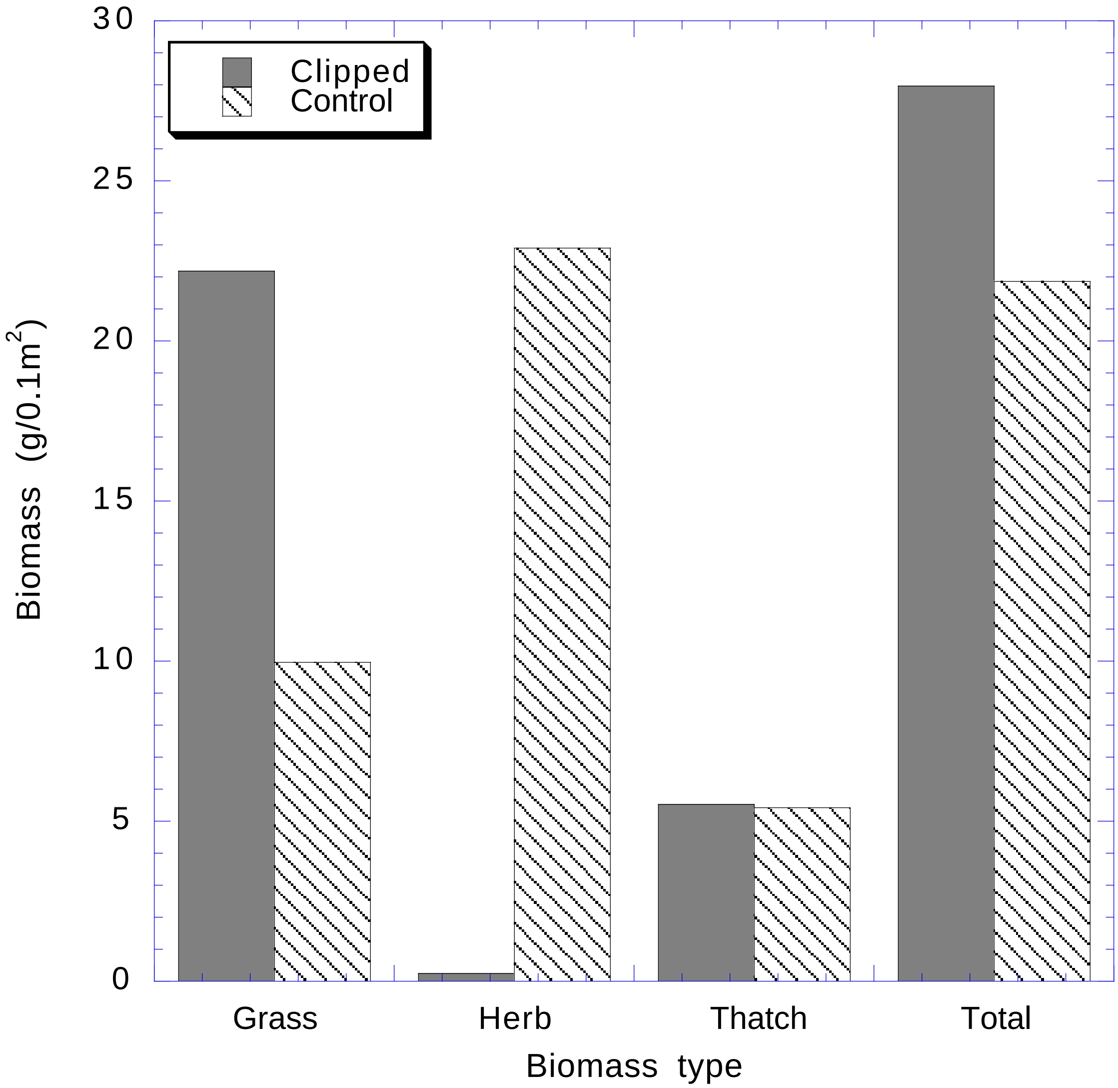

Figure C6. Effect of clipping treatment on biomass distribution at *E. rhombipetala* location. Average biomass by type (n=2).

Section C
Tables

Table C1. Height, number of flowers per plant, capsule length, and survivorship for marked *E. rhombipetala* plants: 1998–2000. All averages are ± one standard error.

Date measured	Height (cm)	No. of flowers/plant	N[a]	Capsule length (cm)	N[b]	% Survivorship[c]
8 Apr 98	7.5 ± 2.8	0.4 ± 0.5	24	2.8 ±1.4	16	
18 Apr 98	6.9 ± 2.7	–	26	2.1 ± 1.1	18	92
30 Apr 99	6.0 ± 1.8	0.7 ± 0.7	9	2.1 ± 0.6	6	
21 May 99	4.7 ± 2.7	–	6	4.0 ± 0.6	6	67
24 Mar 00	5.5 ± 2.1	0.6 ± 0.5	171	2.3 ± 1.4	44	–

[a] Number of plants measured is the same for the height and number of flowers measurement. Plants with no flowers were included in the average.

[b] Number of plants measured for capsule length includes only those plants with capsules.

[c] Percent survivorship is the number of marked plants at the first census of the year to survive until the second census of that year.

Table C2. Ranked constancy, mean cover, standard error (SE), and Importance Value (I.V.) for releves: 1999.

Species (bold = native)	Constancy (%)	Mean cover (%)	SE	I.V.
Avena sp.[a]	92.45	8.53	.02	1.01
Bromus rubens[a]	77.36	18.15	.02	.96
Sonchus sp.[b]	84.91	10.89	.01	.96
Bromus diandrus[a]	64.15	24.21	.04	.88
Bromus hordeaceus[a]	52.83	12.21	.03	.65
Hordeum marinum[a]	35.85	13.42	.05	.49
Centaurea melitensis[b]	3.77	26.50	.33	.30
Brassica sp.[b]	16.98	12.33	.07	.29
Vulpia myuros[a]	24.53	3.38	.01	.28
Unknown Grass[a]	3.77	22.5	.11	.26
Gutierrezia californica[b]	**3.77**	**17.50**	**.18**	**.21**
Unknown Dicots [b]	11.32	7.5	0.05	.19
Blepharizonia plumosa[b]	**15.09**	**2.5**	**.01**	**.18**
Carduus pynocephalus[b]	5.66	11.67	.04	.17
Poa secunda[a]	**3.77**	**10.00**	**.07**	**.14**
Eschscholzia rhombipetala[b]	**7.55**	**4.25**	**.02**	**.12**
***Elymus* sp.**[a]	**9.43**	**2.60**	**.01**	**.12**
Erodium cicutarium[b]	7.55	2.5	.01	.10
Hordeum murinum[a]	3.77	5.50	.06	.09
Galium aparine[b]	3.77	5.00	.00	.09
***Trifolium* sp.** [b]	**3.77**	**3.00**	**.03**	**.07**
Monolopia major [b]	**5.66**	**1.00**	**.00**	**.07**
Brome sp.[a]	1.89	3.00	NA	.05
Montia parvifolia[b]	**1.89**	**1.00**	**NA**	**.03**

Note:

For plants identified only to genus, native versus non-native species were determined using species lists generated by Taylor and Davilla in 1986.

[a] **Grass.**

[b] **Forb.**

Table C3. Ranked constancy, mean cover, standard error (SE), and Importance Value (I.V.) for releves: 2000.

Species (bold = native)	Constancy (%)	Mean cover (%)	SE	I.V.
Avena sp.[a]	84.21	17.94	.02	1.02
Bromus diandrus[a]	70.18	23.68	.03	.94
Bromus rubens[a]	64.91	13.62	.02	.79
Sonchus sp.[b]	73.68	3.57	.00	.77
Bromus hordeaceus[a]	56.14	8.19	.02	.64
Erodium cicutarium[b]	45.61	1.62	.00	.47
Brassica sp.[b]	29.82	17.24	.05	.47
Galium aparine[b]	29.82	7.82	.02	.38
Blepharizonia plumosa[b]	**31.58**	**5.06**	**.01**	**.37**
Monolopia major [b]	**31.58**	**3.89**	**.01**	**.35**
Gutierrezia californica[b]	**3.51**	**27.50**	**.32**	**.31**
Eschscholzia rhombipetala[b]	**22.81**	**5.96**	**.02**	**.28**
Hordeum murinum[a]	17.54	9.4	.03	.27
Poa secunda[a]	**7.02**	**17.50**	**.08**	**.25**
Centaurea melitensis[b]	15.79	7.56	.05	.23
Vicia sp.[b]	15.79	2.22	.01	.18
Lupinus densiflorus[b]	**10.53**	**5.33**	**.02**	**.16**
***Trifolium* sp.**[b]	**7.02**	**5.00**	**.04**	**.12**
Medicago polymorpha[b]	1.75	10.00	NA	.12
Vulpia myuros[a]	8.77	1.80	.01	.11
Stylomecon heterophylla[b]	**3.51**	**5.5**	**.06**	**.09**
***Amsinckia* sp.**[b]	**7.02**	**2.00**	**.01**	**.09**
Carduus pynocephalus[b]	3.51	2.00	.01	.06
Sanicula bipinnata[b]	1.75	3.00	NA	.05
Montia parvifolia[b]	**1.75**	**3.00**	**NA**	**.05**
***Brodiaea* sp.**[b]	**1.75**	**3.00**	**NA**	**.05**
Unknown Dicots[b]	1.75	1.00	NA	.03
Lupinus bicolor[b]	**1.75**	**1.00**	**NA**	**.03**

Note:

For plants identified only to genus, native versus non-native species were determined using species lists generated by Taylor and Davilla in 1986.

[a] **Grass.**

[b] **Forb.**

Table C4. Results of PCA on the twenty-six species found in releves at the *E. rhombipetala* population location: (a) all releves, (b) releves where *E. rhombipetala* was found only.

Factor	Species	Loading	Variance described
(a) All releves			
1999			
1:	***Bromus diandrus***	**-0.42**	
	***Trifolium* sp.**	**-0.52**	
2:	***Carduus pynocephalus***	**-0.50**	
	Eschscholzia rhombipetala	**0.40**	**20%**
2000			
1:	***Centurea melitensis***	**0.33**	
	Salsola tragus	**0.51**	
2:	***Bromus hordeaceus***	**0.38**	
	Guterrizia californica	**0.57**	
3:	***Erodium cicutarium***	**0.33**	
	Eschscholzia rhombipetala	**0.45**	**25%**
Both years			
1:	***Blepharizonia plumosa***	**0.36**	
	Erodium cicutarium	**0.34**	
2:	***Eschscholzia rhombipetala***	**-0.34**	
	Salsola tragus	**0.47**	
3:	***Guterrizia californica***	**0.65**	**25%**
(b) E. rhombipetala releves only			
1999			
1:	***Brassica* sp.**	**0.40**	
2:	***Bromus diandrus***	**-0.43**	
	Bromus hordeaceus	**0.477**	
	Galium aparine	**0.48**	
	Poa secunda	**-0.33**	
3:	***Bromus diandrus***	**0.37**	
	Poa secunda	**-0.58**	
	***Trifolium* sp.**	**0.54**	**50%**
2000			
1:	***Avena* sp.**	**-0.38**	
2:	***Bromus diandrus***	**-0.46**	
3:	***Trifolium* sp.**	**-0.45**	
	Medicago polymorpha	**0.43**	
	Vulpia myros	**-0.32**	**35%**

Table C4. Results of PCA on the twenty-six species found in releves at the *E. rhombipetala* population location: (a) all releves, (b) releves where *E. rhombipetala* was found only (cont.).

Factor	Species	Loading	Variance described
(b) E. rhombipetala releves only (cont.)			
Both years			
1:	***Erodium cicutarium***	**0.40**	
	Eschscholzia rhombipetala	**0.41**	
2:	***Montia parvifolia***	**0.42**	
	Bromus rubens	**-0.36**	
	***Avena* sp.**	**0.47**	**40%**

Section D
Delphinium gypsophilum Monitoring

Section D

Delphinium gypsophilum Monitoring

D-1. Introduction

Populations of *Delphinium gypsophilum* ssp. *gypsophilum* (the gypsum-loving larkspur) have been known to occur at Site 300 since the field surveys of Taylor and Davilla in 1986 (Taylor and Davilla, 1986). *D. gypsophilum gypsophilum* is a spring-season flowering perennial herb included on the California Native Plant Society (CNPS) List 4 (Skinner and Pavlik, 1994). The CNPS List 4 includes plants of limited distribution, essentially a watch list. The CNPS R-E-D code (rarity-endangerment-distribution) for *D. gypsophilum gypsophilum* is 1-1-3, indicating that this plant is rare, but found in sufficient numbers and distributed widely enough that the potential for extinction is low at this time, is not endangered, and is endemic to California. Populations are found in Fresno, King, Kern, Madera, Merced, Monterey, San Joaquin, Stanislaus, and Solano Counties (Skinner and Pavlik, 1994).

D. gypsophilum gypsophilum is an herbaceous perennial within the Ranunculaceae (buttercup) family. It is found on slopes in the grasslands and open oak woodland of the Sierra Nevada foothills, Tehachapi mountain area, San Joaquin valley and south Coast range (Hickman, 1993). The fibrous perennial root, which can be greater than 15 cm long, produces basal leaves upon the onset of winter rains. The plant grows vegetatively throughout the winter. In late spring, a generally single central erect stem of 50 to 150 cm, firmly attached to the root, grows from the basal leaves. The stem is mostly smooth. The most visible part of the inflorescence is the showy white sepals (the lateral sepals being 10 to 19 mm) and the 10- to 15-mm long spur. The petals of the interior flower are white, with lower petal blades of 5 to 8 mm.

Because *D. gypsophilum gypsophilum* is reasonably abundant and not currently threatened at this time, intensive demographic monitoring of the species is not warranted. However, monitoring for the presence of *D. gypsophilum gypsophilum* in locations where it has been previously identified will allow us to track the Site 300 population, and provide some information on abundance and distribution should the conservation status of the species change. Therefore, in the spring of 2000 we conducted a focused field survey of locations at Site 300 where *D. gypsophilum gypsophilum* has been previously identified.

D-2. Methods and Materials

Releve sampling had been performed by in 1986 (Taylor and Devilla, 1986) and population surveys were conducted by Preston in 1997. All locations where *D. gypsophilum* had been previously observed were identified (Figure D1). Nine of the seventeen Taylor and Devilla releves (53%) and five of the six Preston populations (83%) were resurveyed by LLNL in the spring of 2000 (Figure D1).

Locations were surveyed by LLNL on 31 Mar 00, 1 May 00, 3 May 00, 5 May 00, 12 May 00, 18 May 00, 26 May 00, and 7 Jun 00. Field samples were collected and pressed from all surveyed locations. Specimens were taken to the Jepson Herbarium at the University of California on 18 Oct 00 to compare field samples to known *D. gypsophilum* and *D. hesperium* herbarium specimens

D-3. Results and Discussion

D. gypsophilum was positively identified upon comparing herbarium specimens and identifying one key character (stem hairiness) that distinguished *D. gypsophilum gypsophilum* from *D. hesperium.* Based on our observations and conversations with Barbara Ertter of the Jepson Herbarium we found that *D. hesperium* has fine hairs consistently covering and extending up the stem while *D. gypsophilum* is mostly smooth with only isolated patches of finer hair along the stem. Based on this observation field samples were identified as either *D. gypsophilum* or *D. hesperium*

Table D1 shows the results of this year's focused surveys. Of the 17 locations resurveyed, only two locations (population #1 and releve #161) were positively identified as containing *D. gypsophilum* . Our survey originally focused on *D. gypsophilum* locations identified by Taylor and Devilla **(**1986**)**. Our field identification indicated that another white delphinium (*D. hesperium* var. *pallescens)* had been misidentified as *D. gypsophilum* by Taylor and Davilla **(**1986**)**. This was confirmed by conversation with R. Preston (Preston, 2000). Therefore, only a portion of the Taylor and Devilla *D. gypsophilum* releves were surveyed due to time constraints. Of the nine Taylor and Davilla releve locations we visited, only one releve was positively identified as a *D. gypsophilum* site (releve 161). Due to site access restrictions we did not survey the R. Preston population located in the High Explosives Process area. Of the five we surveyed, one location contained *D. gypsophilum*. Two of the five R. Preston locations were surveyed when most of the *Delphinium* had already senesced, rendering field identification impossible.

Both *Delphinium* species were found to occur in more open locations with vegetation cover consisting of only small amounts of thatch. Both species also appeared to co-occur with a number of other native species including *Nasella pulchra*, *Poa secunda* and *Blepharizonia plumosa*.

D-4. Recommendations and Future Work

Annual surveys of locations where *D. gypsophilum gypsophilum* has been previously identified will continue. In 2001, our priority will be to survey the Preston populations early enough in the season to positively identify *D. gypsophilum gypsophilum*. In addition, we will attempt to survey all of the Taylor and Davilla locations, particularly those we were unable to survey this year. In 2001, we will use a GPS unit to obtain coordinates of all locations containing *D. gypsophilum gypsophilum*. General vegetation characteristics of surveyed locations will be recorded. Locations containing *D. gypsophilum gypsophilum* will be mapped and evaluated with respect to land use, especially the presence of fire. Our initial observations suggest locations that are currently not burned and thus building up significant thatch no longer support reproductive populations of *D. gypsophilum gypsophilum,* although the perennial root system may still be present and viable in these locations.

The list of special status plant, animal and natural communities maintained by the California Department of Fish and Game Natural Diversity Database does not list *D. gypsophilum gypsophilum* as being present in Alameda or San Joaquin Counties (CDFG, 1999a,b). However, this subspecies was located in both counties at Site 300. In addition, the California Natural Diversity Database (CNDDB) currently contains no records on *D. gypsophilum gypsophilum*. Therefore, during the field surveys in 2001, we will complete a CNDDB survey form for each location identified at Site 300.

D-5. References

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Section D
Figures

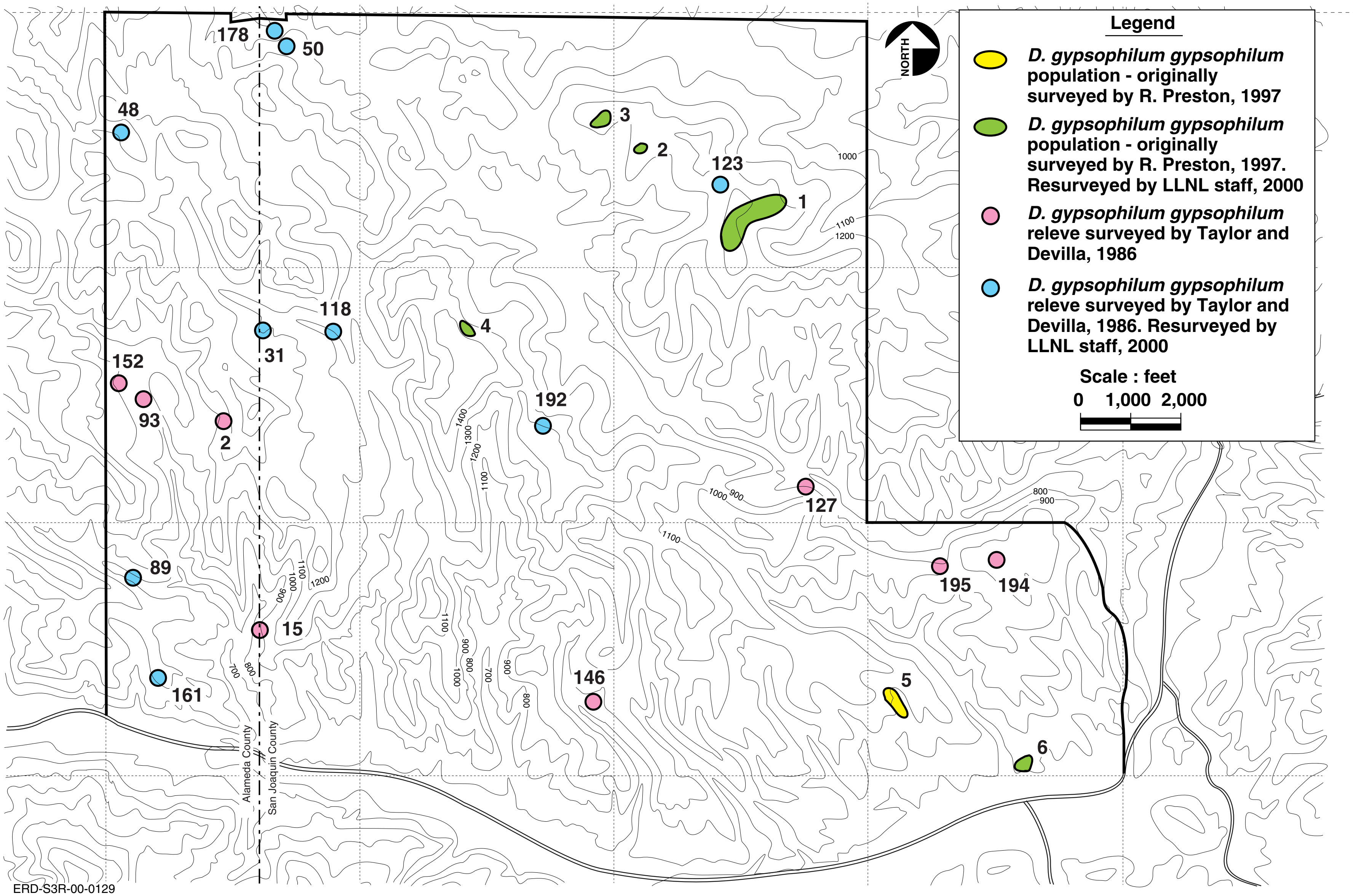

Figure D1. Locations of *Delphinium gypsophilum gypsophilum* identified from previous surveys and locations resurveyed by LLNL.

Section D
Tables

Table D1. Survey data of potential *Delphinium gypsophilum* locations surveyed by LLNL staff during spring 2000.

Map no.	Date surveyed 2000	Location and vegetation community	Delphinium species found	Estimated population size
R. Preston, 1997				
1	June 7	Near the microwave towers in the vicinity of Taylor and Devilla's releve #123. Majority of plants had scenesced, one plant still in bloom.	DEGY[a]	200
2	June 7	Open area with a patch of *Nassella pulchra* southwest of large population of *Delphinium* (Map #1).	DE sp.[b]	200–300
3	June 7	Northwest of Map #2 in *Avena* dominated grasslands with patches of *Nassella pulchra* and *Poa secunda.*	None[b]	–
4	June 7	Area between Route 3 and fence for HE process area was dominated by thistle and non-native grasses	None[b]	–
6	June 7	Area north of Building 871. Dominated by *Avena* and *Bromus*.	None[b]	–
Taylor and Davilla, 1986				
161	May 5	Plants downslope from road and upslope from old telephone pole. All were suffering from a white powdery fungus disease.	DEGY[a]	3
48	May 26	Two meters upslope from west side of road. Majority of plants had senesced and gone to seed.	DEHE	–
89	May 5	In area of Rifle Range, upslope from road and along stream bank.	DEHE[c]	–
192	May 1	Past the 849 gate on the south side of the road.	DEHE[c]	–
195	May 12	On a steep hillside on the south side of the fire trail above Elk Ravine.	DEHE	–
31	May 3	*Avena* dominated grassland with patches of *Nassella pulchra* and *Poa secunda.*	None[d]	–
50	May 3	Surveyed areas both north and south of road. An *Avena* and *Bromus diandrus* dominated grassland with *Brassica*.	None[d]	–
118	May 3	Releve area within grassland of *Avena*, *Bromus rubrens,* and *Vulpia*.	None[d]	–
123	June 7	Area dense with understory vegetation and thatch.	None[d]	–
178	May 26	Dry area covered with thatch.	None[d]	–

[a] Field identified as *Delphinium gypsophilum gypsophilum*, sample collected and identification confirmed against herbarium voucher specimens.

[b] All plants senesced making field sighting difficult and species identification impossible.

[c] Field identified as potentially *Delphinium gypsophilum*, sample collected and identification checked against herbarium voucher specimens and later identified as *Delphinium hesperium pallescens.*

[d] Area surveyed while plants were in bloom but no *Delphinium* plants were found.