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

Project Progress Report

Fiscal Year 2001

October 2000–September 2001

Authors

Tina Carlsen
Erin Espeland
Abigail Smith

January 2002

Environmental Protection Department
Environmental Restoration Division

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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*, 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 2001 (October 2000–September 2001).

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. *Blepharizonia plumosa* occurs in large numbers throughout Site 300, and thus occurs in areas of active Site 300 operations. However, its close relative, *B. laxa* 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* populations. *Eschscholzia 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. Populations of *D. gypsophilum gypsophilum* identified for monitoring had no flowering plants this year, so no data were collected.

Amsinckia grandiflora Work

Activity Summary

The experimental population was monitored for survivorship throughout the year. The Fire Frequency (FF) subpopulation of the experimental population was supplemented with additional *A. grandiflora* seeds to enhance population establishment. Both the experimental population and the native population were censused in the spring. Biomass was collected from plots in the flashing (FL) subpopulation (the original portion of the experimental population circumscribed with metal flashing) and from the ongoing lupine experiment near the native population. A burn was conducted in the FF subpopulation where all plots except the controls were burned. Seed predation in the experimental population was monitored both before and after the burn.

Results Summary

- Population numbers were down in the native population (14 plants, down from 40 in 2000) and increased slightly in the experimental FL subpopulation (59 plants, compared to 45 in 2000).
- The experimental FF subpopulation contained 257 flowering plants, but most were too small to set seed.
- Survivorship in the experimental population was lower this year (~ 25%) than last year (36%). The difference may have been entirely due to early germination and high mortality in the November–December period of 2000.
- Biomass in the FL plots is beginning to drop to levels observed in the early 1990s: less than $10g/0.1m^2$. No differences in biomass composition were observed between unburned and burned (last burned in 1999) plots.
- Biomass adjacent to both cut and uncut lupine was similar in 2000 (around $22g/0.1m^2$), while control biomass was lower ($13g/0.1m^2$). In 2001, uncut and control biomass were similar (around $11g/0.1m^2$), while cut lupine biomass was higher (about $14g/0.1m^2$).
- Seed predation was quite low in the round conducted before the burn, with percent seeds lost at less than 50%. This is similar to levels observed the previous year. Burned, open plots experienced predation close to 90%, but burned, netted plots lost less than 40% of their seeds. Results of this year indicate that birds may have been responsible for the high levels of granivory in burned, open plots.

Blepharizonia plumosa Work

Activity Summary

All populations at Site 300 were mapped using a GPS unit when plants were flowering in fall 2000. Selected populations of *B. plumosa* and its more common relative *B. laxa* were sampled prior to spring burns, after spring burns and at fall flowering. Survivorship, height, nearest neighbor and microtopological data were collected. A field experiment using buried pots sown with *B. plumosa* seeds begun in FY 2000 was monitored to determine if exposure to fire increases germination in the species.

Results Summary

- No plants survived the burn. Populations with some survivorship had plants located in unburned areas.
- Species diversity is high at B850 (H'=1.99), Elk Ravine (1.64) and B812 (1.78). Diversity is low at the Middle Canyon *B. laxa* population (1.07).
- Populations of *B. plumosa* were found throughout Site 300 in fall of 2000. Large populations generally occurred at edges of areas burned in the previous and current year. Smaller populations occurred in the heart of burned areas as well as in unburned areas. Populations of *B. plumosa* in 1999 were small and occurred in all areas.

- The fire germination experiment experienced minimal germination. However, a small number of seeds of each type germinated in pots exposed to fire, where control pots only germinated 1998 disc seeds. Fire may stimulate germination of ray seeds and older seeds and may inhibit the germination of recent-year disc seeds.

Eschscholzia rhombipetala Work

Activity Summary

The single *Eschscholzia rhombipetala* population was censused at flowering. Plant height, number of flowers, location (slump, scarp or grassland) was recorded. Community composition data were collected from releve samples located within the population and in the area surrounding it.

Results Summary

- The *E. rhombipetala* population was somewhat smaller in 2001, with 189 plants compared to 273 plants in the previous year.
- In 2001, few plants were found in the grassland, but these plants were tallest and had the most flowers. Grassland plants were also tallest in 2000, and scarp plants had the fewest flowers in both years.
- Releves located in areas where *E. rhombipetala* were not present had higher importance values for *Brassica* sp. and *Bromus hordeaceous* than releves containing *E. rhombipetala*. *Vulpia myuros* was more important in *E. rhombipetala* releves than in non-*E. rhombipetala* releves.
- *Avena* was the dominant grass in almost all areas surrounding the *E. rhombipetala* population, where *Bromus diandrus* was dominant in at least a few areas in previous years.
- Native forb species in the *E. rhombipetala* area in 2001 were similar in number to 2000 (ten and eleven, respectively).

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. 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 reserved 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.

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 2001 federal fiscal year (October 2000 through September 2001).

A-2. Methods and Materials

A-2.1. Demographic Monitoring

Demographic monitoring of the Drop Tower experimental population continued over the 2000–2001 growing season. 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* occurred in late October and early November. On 15 Nov 2000, a total of 49 seedlings were marked in FL (flashing subpopulation) plots that contained flowering adults the previous spring. One to five

A. grandiflora seedlings were marked in each plot. One to three seedlings were marked in each FF (fire frequency subpopulation) plot, except the four plots that contained no *A. grandiflora* seedlings. Forty four seedlings were marked in the FF plots. Figure A4 summarizes all of the experimental treatments conducted on the subpopulations. The plots labeled “S” are the demographic plots containing the marked *A. grandiflora* plants.

Plants were marked 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 6 Dec 00, 20 Dec 00, 12 Jan 01, 14 Mar 01, and 12 Apr 01.

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, many 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 was only one to three individuals. Individuals that died prior to flowering (precluding correct identification) may have been either *A. grandiflora* or *A. tessellata*, and thus may be included in the pre-flowering demographic data.

A-2.2. Fire Frequency Subpopulation Enhancement

The *A. grandiflora* seed bank in the FF plots was enhanced by planting five seeds per plot on 6 Dec 00. A small area on the center of each plot was cleared, seeds were planted, and the area was marked with string so germination and survivorship of these seeds could be followed. (Observation dates were the same as for marked seedlings, see above.) On 22 Jan 01, five to ten additional seeds were planted in each plot, dispersed in uncleared areas among the grasses. This second enhancement was not monitored for germination or survivorship.

A-2.3. Burn of the Fire Frequency Subpopulation

The Fire Frequency subpopulation was designed so that plots would experience a yearly, once every three years, or once every five years burn (except for unburned control plots). The entire area of the FF subpopulation was burned in 1998. Perennial bunch grasses were planted in 1999 at a single density within the center of the plots (Carlsen et al., 2001). Perennial bunch grasses were allowed to establish in 1999–2000, as were *A. grandiflora* transplanted into the plots. In 2001, plot burn treatments were selected using a randomized block design. Because of the nature of the burns, it was important that no two plots of the same treatment be adjacent to each other. This extra stipulation for plot selection prevented areas from acting ecologically as larger 2.5m × 1m blocks, rather than the intended 1 m × 1 m areas. All FF plots except the control plots were burned on 18 Jul 01.

A-2.4. Spring Census

The experimental and native Drop Tower populations were censused during early April. Both 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 12 Apr 01. The flower morph, plant height, and inflorescence number were recorded for each plant. The identity of the nearest species (nearest neighbor) was also recorded. Specific plant cover estimates were taken from a 60 cm × 60 cm area in the center of each FF plot. Twenty random 60 cm × 60 cm locations within the FL population were selected for cover estimates as well. Cover estimates in this subpopulation were taken from areas within the plots and also next to the plots. Perennial bunch grasses were counted in both the FF and FL subpopulations on 23 Mar 01 at time of bunchgrass flowering to monitor long-term establishment of *Poa secunda*.

Biomass samples ($0.1m^2$) were collected from the center of ten FL plots on 10 May 01 and 17 May 01. 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 “B”.

The native Drop Tower population census was conducted on 12 Apr 01. 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. Four 60 cm × 60 cm quadrats were placed around areas containing *A. grandiflora* and specific plant cover estimates were taken. Ten 60 cm × 60 cm areas were randomly selected within the historic *A. grandiflora* population area for additional cover estimates in areas not containing *A. grandiflora* plants this year. No biomass samples were taken from the native population.

A-2.4.1. Data Analysis of the Cover Estimates

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

A-2.5. Predation Monitoring

Each year, *A. grandiflora* nutlets are set out to monitor levels of seed predation within the experimental population. A single nutlet is adhered with double-stick tape to each of twenty-five 3.5 in-long galvanized nails spaced 10 cm apart in five rows of five nails. Each nail is pressed into the soil so the nail head is flush with the soil surface. Ten 100 cm^2 grids of nutlet/nails were placed using a randomized block design. Five grids were located in the FL plots and five were located in the FF plots (Figure A4). For round 1, nutlet/nails were placed into the plots on 27 April 01. Nails were checked on 30 April, 4 May, 11 May, and 18 May at which time the nutlet/nails were removed.

After the burn of the FF plots, ten nutlet/nail grids were placed into the FF subpopulation on 20 Jul 01. Five grids were located in unburned plots, and five grids were located in burned plots (Figure A4). Nails were checked on 23 Jul, 25 Jul, 30 Jul, and 3 Aug. On 3 August, all burned plots were restocked with nutlets, an additional plot was added, and three out of the six burned plots were netted (Figure A4). Unburned plots had not experienced much granivory over the two weeks and were allowed to remain. Plots were checked on 6 Aug, 8 Aug (burned plots only), 13 Aug and 17 Aug, at which time all nutlets, nails and netting were removed.

A-2.6. Lupine Study

The lupine study was initiated in the fall of 1999 to investigate the potential effects of *Lupinus albifrons* expansion on the biomass accumulation of *A. grandiflora* competitors. Three pairs of *L. albifrons* plants were selected and flagged just downslope of the main area of the native *A. grandiflora* population (Figure A5). Plants were paired according to size: small, medium, and large. For each 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 17 May 01, biomass was collected from a $0.1m^2$ area adjacent to the base of the standing plant or the stump of the removed plant. We were unable to locate the stump of the cut small plant this year. However, we are reasonably confident that we placed our quadrat close to where the stump had been, as our map of lupine locations is fairly accurate. Biomass was also collected from a random location near each pair, but not underneath a lupine, for a negative control.

Lupinus albifrons plants were last mapped on 6 Jul 99. On 12 Apr 01, locations of new plants were recorded, and plants mapped in 1999 that were dead or dying were identified.

A-3. Results and Discussion

A-3.1. Demographic Monitoring of the Experimental Population

Survivorship was higher in the FF than in FL plots over the 2000–2001 winter (Figure A6). Plants in FF plots had lower survivorship rates compared to the previous winter, which could be expected, as survivorship rates for FF plots in 1999–2000 track transplants rather than seed germinated from the seed bank. Survivorship of marked plants in FF plots over the 2000–2001 winter are very similar to survivorship over time of marked plants in the FL plots of the previous year (1999–2000). Survivorship of plants in the FL plots in the 2000–2001 winter was quite low. Each year, plants are marked close to when germination occurs. In previous years, germination was not observed until early December. In 2000, plants were marked in November. Perhaps as a consequence of this early germination, there was over 20% mortality from November to December. Had we waited until December to mark plants, our survivorship curve may have looked more similar to that of the previous year.

A-3.2. Spring Census

Amsinckia grandiflora population sizes remain small. Fourteen plants were found in the historic native population, with no plants occurring in the Carlsen-Gregory subpopulation. The native population has contained less than fifty plants each year for the last three years (Figure A7). Numbers in the FL area of the experimental population increased slightly, from 45 plants in 2000 to 59 plants found this year (Figure A8). Two hundred and fifty-seven plants were observed in the FF subpopulation (Figure A9). Figure A5 shows the general locations of *A. grandiflora* plants observed in the native Drop Tower population in 1998–2001. The average number of inflorescences per plant returned to one this year, the same level it was in 1999 when the population consisted of only six plants (Table A1). It is likely that the native population again produced only a negligible number of nutlets this year.

As can be seen in Figure A8, numbers of individuals observed in the FL subpopulation has also remained low in recent years, with only 59 plants observed this year compared to the high of 720 plants observed in 1996. Figure A10 shows the distribution of plants in the FL subpopulation. Amounts of biomass have been declining gradually since 1998 (Table A2). We expected that the continual drop in biomass prior to this year would signal a resurgence in *A. grandiflora* numbers in response, but this has not been the case so far. We also expected that reduced amounts of granivory in the experimental population (Carlsen et al., 2001) would have forecast an increase in the number of plants for this year.

When examining population sizes from Draney Canyon, the Drop Tower native population, and the Drop Tower experimental population (Figure A11), it appears that numbers remained stable and even increased in the years 1986 to 1996. After 1996, the numbers of all three populations dropped. Draney Canyon had no plants in 1998–2000 and was not surveyed in 2001. While it appears that high rainfall years are detrimental to *A. grandiflora* populations, the effect is either delayed or dependent on multiple years of high rainfall in close proximity.

Plants in both parts of the experimental population were very small in size. Using a regression equation developed in 1994 (unpublished data), it would appear that the FL subpopulation produced no nutlets in 2001 (Table A1). The number of inflorescences (branches) per plant is slightly greater in the FF subpopulation, probably resulting in negligible nutlet production.

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.

Composition of nearest neighbors probably overemphasizes the importance of small, understory plants, but since data collection methods have remained the same over the years, these data are useful in making comparisons among subpopulations and years. The presence of *Erodium cicutarium*, *Vulpia myuros*, and *Galium aparine* appear to be quite variable among years and locations (Table A4). *Vulpia myuros* was absent from the native population in 1997–1999 but has been present in the experimental population since 1999 and appeared in the native population in 2000. Presence of *E. cicutarium* is similar to *V. myuros* population in 1999 and became more dominant in the native population in 2000. *Galium aparine* has followed an opposite pattern: more common in the native population in 1997–1999 and less common in other locations and in later years. *Collinsia heterophylla* appears similar to *G. aparine*, with the exception of a high frequency in 2001 FL plots. *Avena* and *Bromus* species have been consistently well represented over years and locations.

The diversity index was high (1.8 or above) for all locations in 2001. Except for in 1999, when the native population contained six *Amsinckia grandiflora* plants (six data points) and the FL plots contained 42, the diversity index for the native population has always been higher than the diversity index for the FL plots, even though the native population has fewer plants (thus fewer data points). FF plots had a lower diversity index in 2000 than the other two locations but a higher index in 2001. The lower index in 2000 may have been due to the extreme disturbance the plots suffered over the previous winter during plot establishment.

Due to the overemphasis on understory plants in nearest neighbor data, cover estimates were also taken for the three locations in 2001. *Avena* sp., *Bromus hordeaceous* and *Erodium cicutarium* were all in the top five I.V.s for all three locations (Table A5). Other important species were *Bromus diandrus* (ranked fourth for the native population and third for the FF plots) and *Lupinus bicolor* (ranked third in FL plots and fourth in FF plots). That *P. secunda* was ranked first for FF plots is no surprise, given their design. *Castilleja exserta* was ranked fourth in FL plots in terms of importance value. Bare ground had the greatest mean cover in the FL plots (31%) and the least in the native plots (12%). Thatch ranged from 17% in the FL plots to 27% in the native plots. Twenty-six different species were recorded from all three locations in the cover estimates for 2001, and only half as many were recorded in nearest neighbor data from that same year. While this is partially due to the constraint that there can only be as many data points as there are *A. grandiflora* plants for nearest neighbor data, it may also be due to the fact that the closest plant to any given *A. grandiflora* is most often an understory plant such as *E. cicutarium* rather than a larger plant like *Lupinus albifrons*.

A-3.3. Biomass Collection and *Poa secunda* Persistence

Biomass samples collected from the FL subpopulation in the year 2001 did not show much difference between burned and unburned plots (Figure A12). Biomass was low—only about 11 g/0.1m^2. Biomass in 1999 and 2000 was close to 20 g/0.1m^2 in unburned plots and around 10 g/0.1m^2 in burned plots. Biomass was much higher in 1998 at around 30 g/0.1m^2 for burned plots and 20 g/0.1m^2 in unburned plots. "Burned" plots have not been burned since 1999, so it is possible that this lack of difference between the two plot types, particularly for thatch (a variable for which the two areas have traditionally been different in the past), is due to that factor.

Accurately measuring the amount of *P. secunda* biomass has historically been problematic. The lack of perennial grass biomass in unburned plots is never confirmed in the counts of *P. secunda* made earlier in the season (Table A3). For analysis of *P. secunda* persistence and density, early spring counts are more reliable than mid-spring collections of biomass.

Eight-year persistence of *Poa secunda* in the FL plots is shown in Table A3. In 1993, differences between existing and planted *P. secunda* plots were highly significant ($p < 0.0001$), corresponding to experimental design. There was no difference between plots that would end up being burned in the future and those that would remain unburned ($p = 0.32$). Burning in the FL plots began in 1998. In 1999, there was no significant difference in *P. secunda* density between burned and unburned plots ($p = 0.15$) and no difference between the different starting densities ($p = 0.28$). The difference between existing and planted *P. secunda* plots was beginning to wane ($p = 0.07$), although the difference between these and *P. secunda*-removed plots was still highly significant ($p = 0.006$). In 2000, after two consecutive years of burning, there appeared to be a difference in *P. secunda* concentrations between burned and unburned plots ($p = 0.017$). Effects of starting *P. secunda* density and differences among planted, existing, and *P. secunda*-removed plots disappeared ($p = 0.5$ for both). In 2001, when two years had passed since the last burn, the effects of the burn were less significant for *P. secunda* density ($p = 0.09$). Effects of starting densities and plot type (existing, planted, and *P. secunda*-removed) remained nonsignificant (p = 0.56 and 0.22, respectively).

Because data on *P. secunda* persistence were not collected in the years 1995–1998 (1994 data not shown, statistically identical to 1993 data), it is difficult to pinpoint the amount of time needed for differences between the three starting density levels of *P. secunda*, to break down. It is possible that factors affecting perennial bunchgrass persistence operate over the long term: two years of burning may be necessary to induce a difference between burned and unburned plots; seven intervening years occurred before planted plots, pre-existing plots, and *P. secunda*-removed plots began to appear similar.

A-3.4. Predation Study

Predation rates in 2001 were very low in round 1 with granivory at 8% (Table A6). Data were not distributed normally and a nonparametric ANOVA, Kruskal-Wallis, was used to compare medians. There was no difference between plots within the flashing and FF plots for granivory in the first round ($p > 0.6$). After the burn, granivory in the burned area was high (84%), while granivory in the unburned plots remained low. There was no difference between final granivory rates of the burned/open plots in the first two weeks of round 2 and the restocked burned/open plots in the second two weeks of round 2 ($p > 0.2$), so these data were combined for analysis. Netted/burned plots experienced significantly less granivory than did open burned plots ($p < 0.002$). Open/unburned plots experienced similar granivory to netted/burned plots ($p > 0.2$). Cumulative predation increased gradually over the time period in unburned/open plots (Figure A13). Most granivory occurred in burned/open plots just after plot establishment, whereas the majority of granivory did not occur in burned/netted plots until a week after plot establishment (Figure A13).

These results indicate that burning did affect granivory and that birds may be responsible for the difference in granivory between burned and unburned areas. This contrasts findings from 1998 and 1999 which indicated that rodents were the primary granivore of *A. grandiflora* nutlets (Carlsen et al., 1999). In 2001, rodents were not inhibited from granivorizing nutlets in burned areas, which was also the case in 1998 and 1999.

It appears that granivory can be extremely variable among years. Table A7 shows that granivory rates can range from 32% to 96%. Significant differences in granivory can occur among years even when the within-year variance of the data is maximized by combining spring and summer rounds, different sites, and all treatment/cover types. It appears that by conducting a spring round of granivory monitoring, we may be able to predict the relative amount of granivory that will occur in FF plots that are burned that summer. When seed predation rates are high in the spring (above 75% as they were in 1998 and 1999, data not shown, see Carlsen et al., 2001), netting may not be effective in reducing granivory in the burned areas. However, when granivory rates are 50% or below in the spring, netting may reduce granivory in burned plots of the FF subpopulation and may help protect the seed bank of *A. grandiflora* in these areas.

A-3.5. Lupine Study

Figure A14 shows the results of the biomass collection in the lupine area. 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. Biomass was less overall in 2001 compared to 2000, and apparent patterns of similarity among treatments in 2000 were not repeated in 2001. While grass biomass seemed higher in the cut and uncut treatments compared to the control in 2000, the three treatments appeared more similar in 2001. Thatch and total biomass appeared similar between cut and uncut treatments and higher than the control in 2000, while in 2001, uncut and control treatments seemed more similar to each other than to the cut treatment.

Of the 42 *L. albifrons* that were mapped in 1999, 19 were dead or dying. Fourteen new *L. albifrons* plants were recorded. Included among those lupine that are dying is the large shrub that was the only *L. albifrons* apparent within the *A. grandiflora* population in the late 1980s and early 1990s.

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 had hoped that the decrease in seed predation would foreshadow an increase in *A. grandiflora* numbers in 2001. This was not the case, but as competitor biomass accumulation continues to decline and seed predation remains low, *A. grandiflora* recovery may occur in 2002. We will continue to monitor above-ground competition by collecting biomass samples yearly and will continue to monitor seed predation pressure. Long-term data on these variables, combined with *A. grandiflora* fecundity estimates and meteorological data will be combined to establish an algorithm to predict population vigor and to inform management practices.

While it appears that lupines at the native site may be beginning to die back, they are also regenerating at a fast rate. Anecdotal evidence has indicated that *L. albifrons* goes through establishment pulses and catastrophic diebacks, but it is possible that the large-scale *L. albifrons* retreat from the *A. grandiflora* population area that we had hoped for has not begun as yet. We have begun to take a photograph every year from the other side of the canyon to monitor lupine population dynamics and will continue to do so.

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. In the absence of any controls of predators and competitors, it appears that the FF subpopulation was able to reseed itself. The population size in 2001 was larger than it was in 2000, although we cannot be certain how much of a role this years' subpopulation enhancement played in the expansion. *Amsinckia grandiflora* small plant size and resultant reduced fecundity remains a concern in this subpopulation. While the FF plots will be burned relatively often and this will probably control competitor biomass, if poor *A. grandiflora* years continue, we may be forced to continually supplement this subpopulation's seed bank or explore other strategies to maximize *A. grandiflora* success. We expect that burn frequency will affect the spread of *P. secunda* and also the establishment and vigor of *A. grandiflora*.

A-5. References

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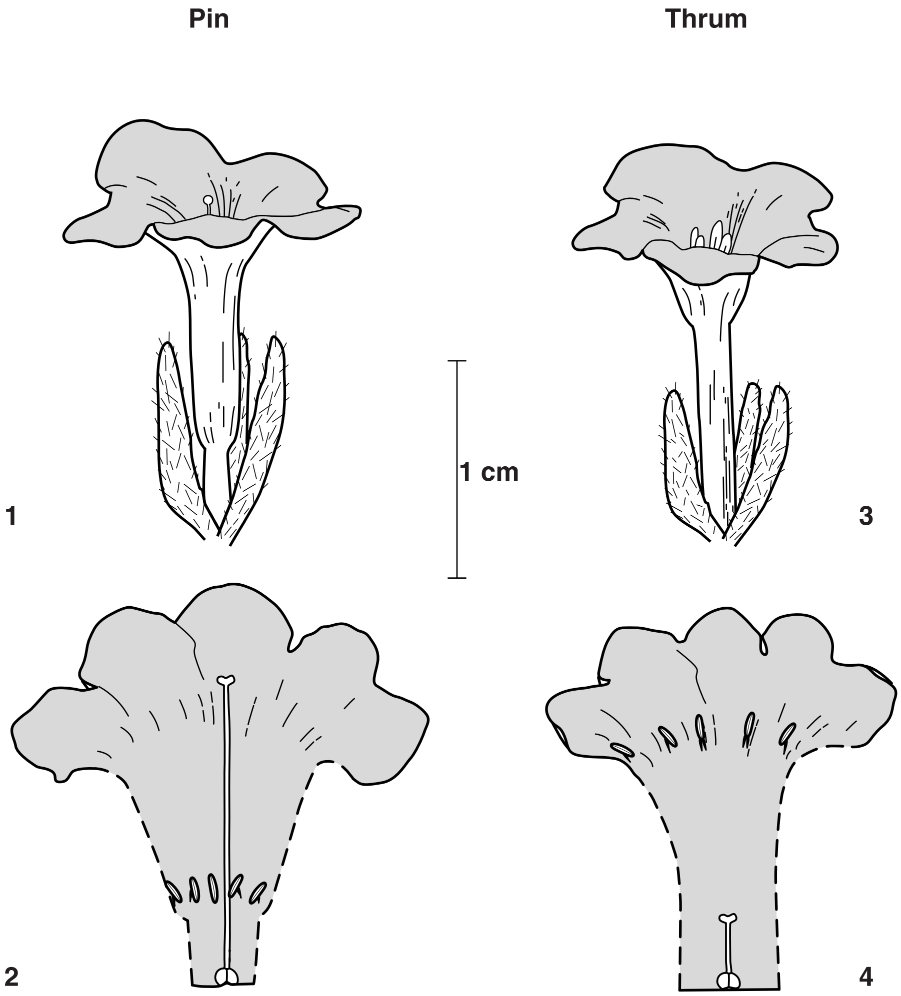
Section A
Figures



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)

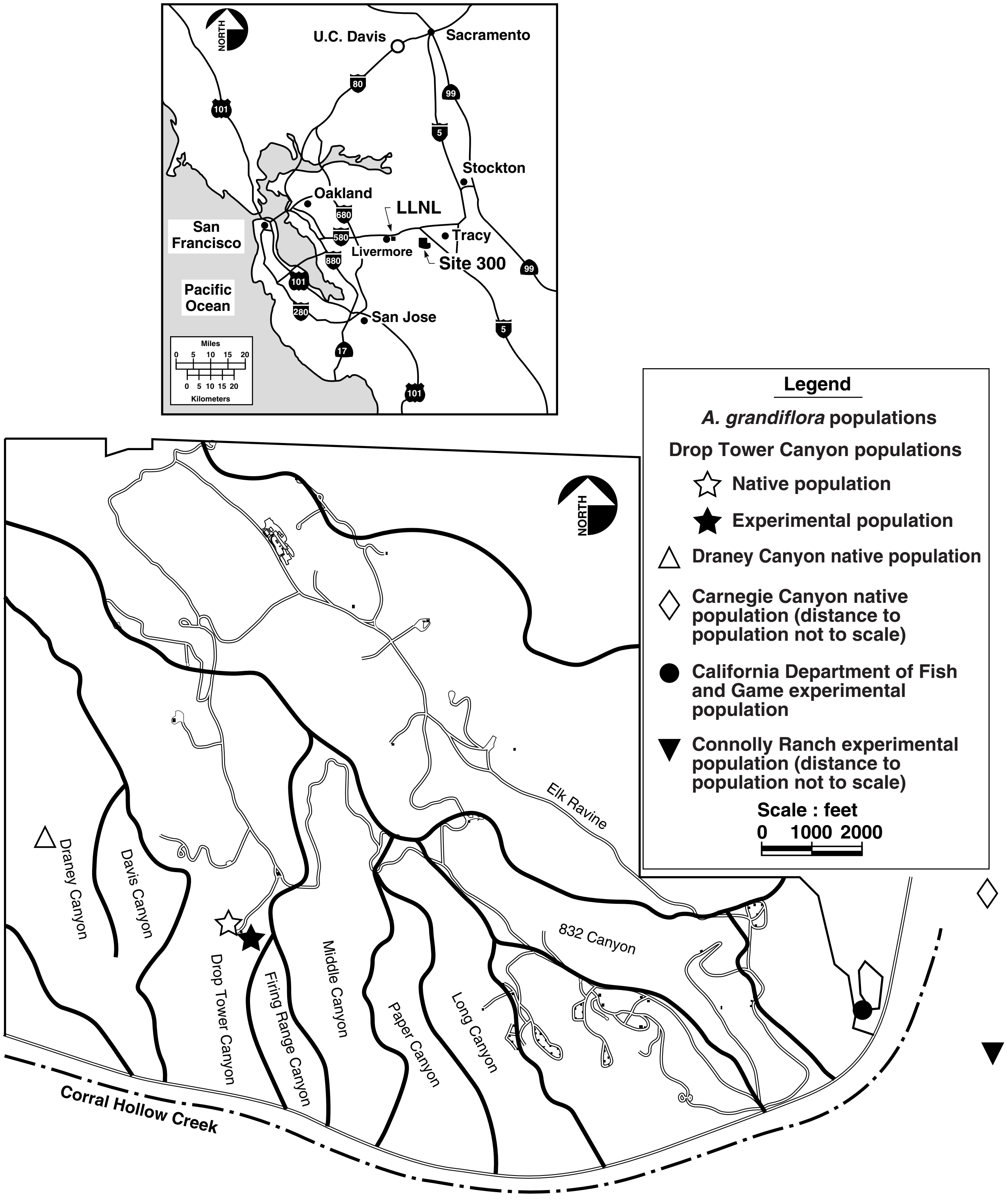


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Figure A2. Locations of *A. grandiflora* populations at or near Lawrence Livermore National Laboratory (LLNL) Site 300.

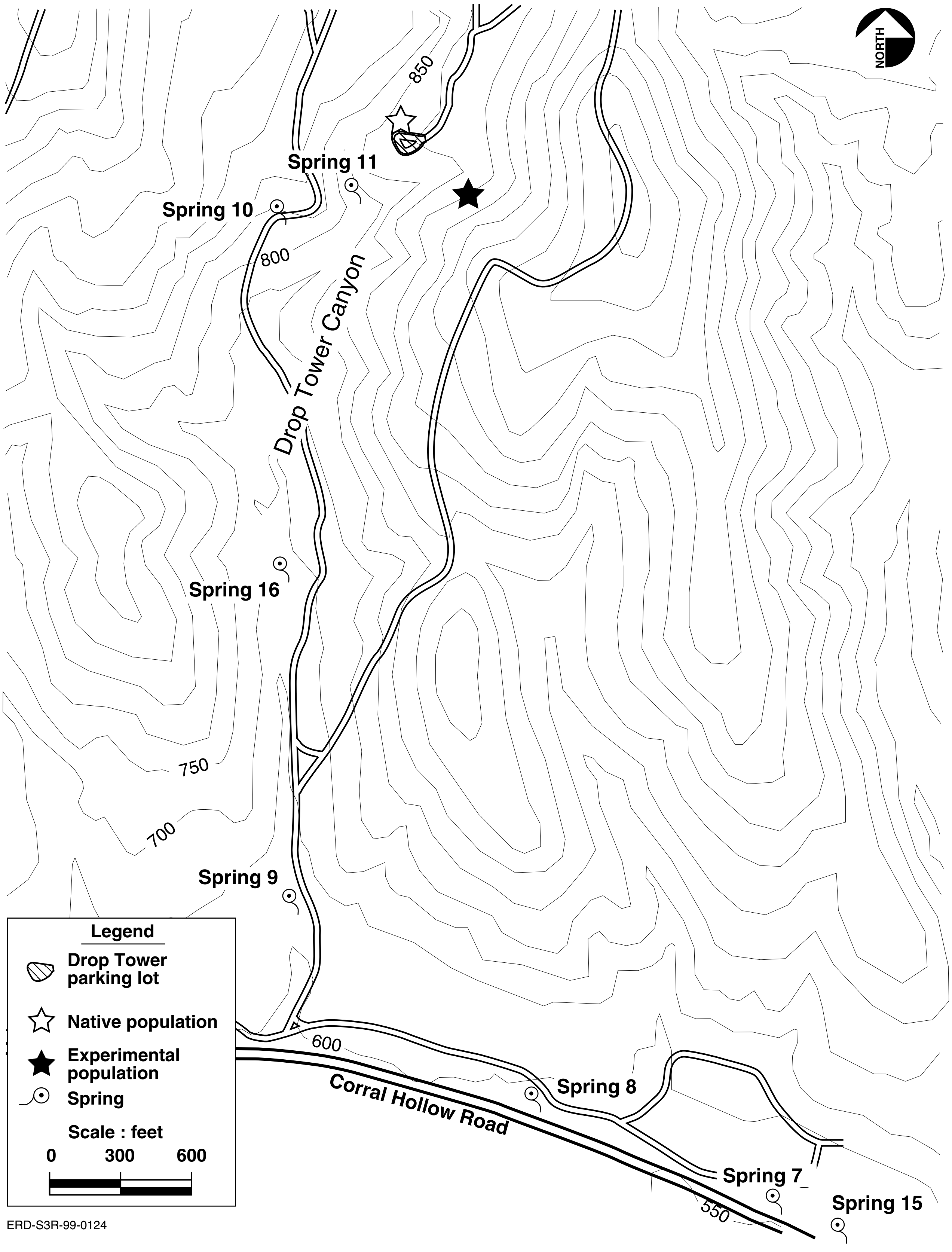

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Figure A3. Location of native and experimental *A. grandiflora* populations in Drop Tower Canyon.

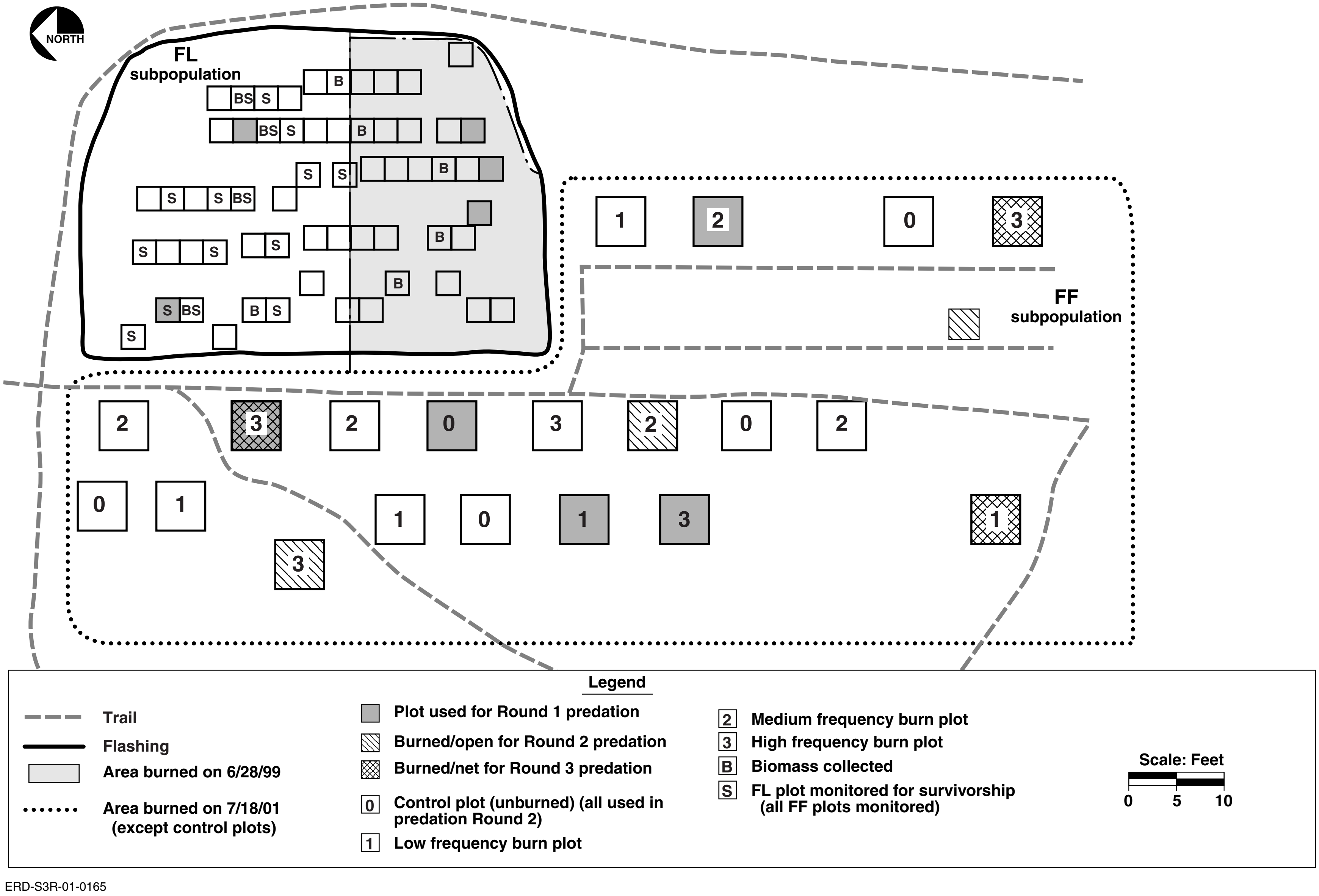

Figure A4. Summary of experimental treatments at the experimental *A. grandiflora* population.

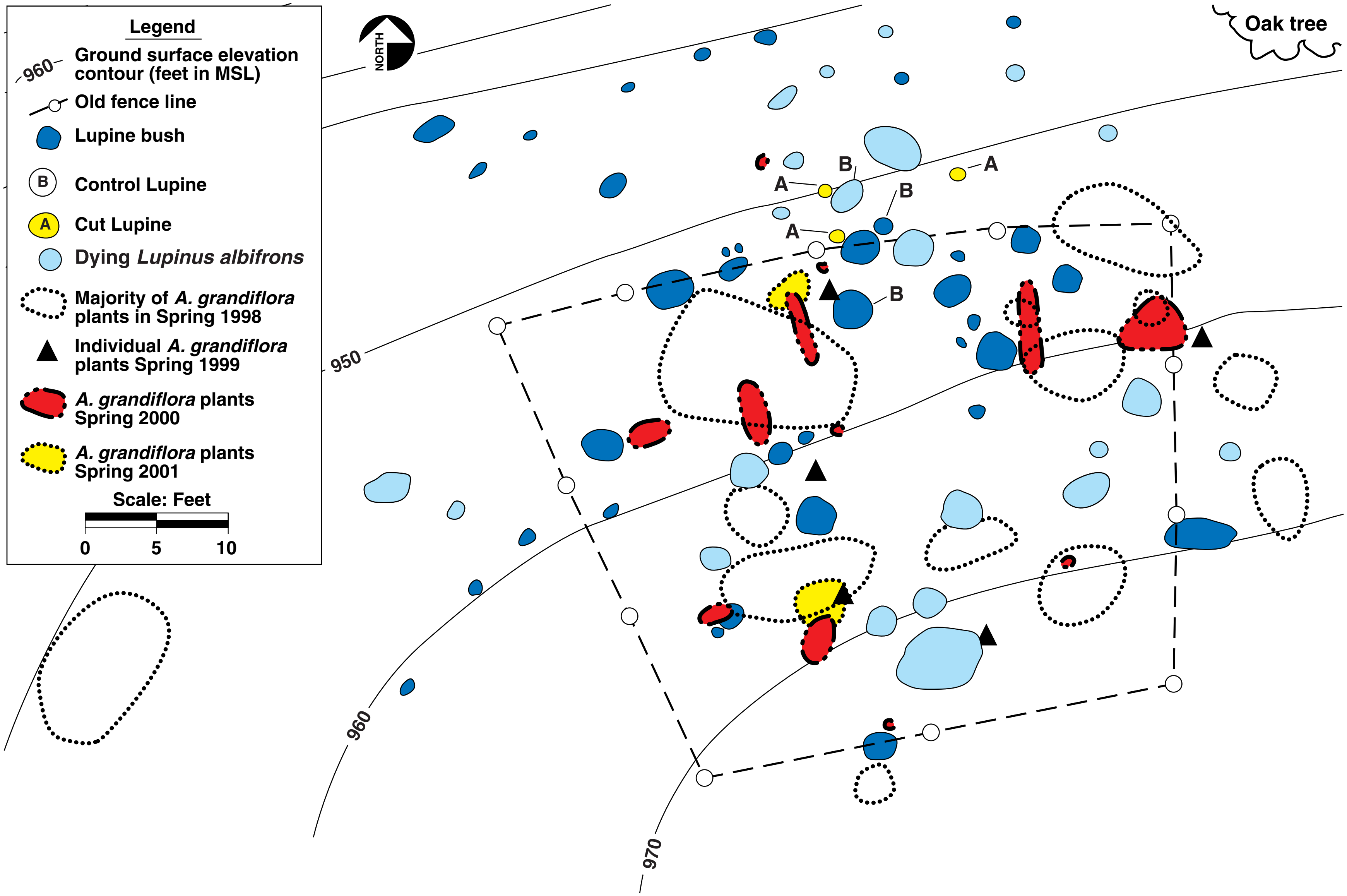

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Figure A5. Spring census of the *A. grandiflora* native Drop Tower population: 1998-2001.

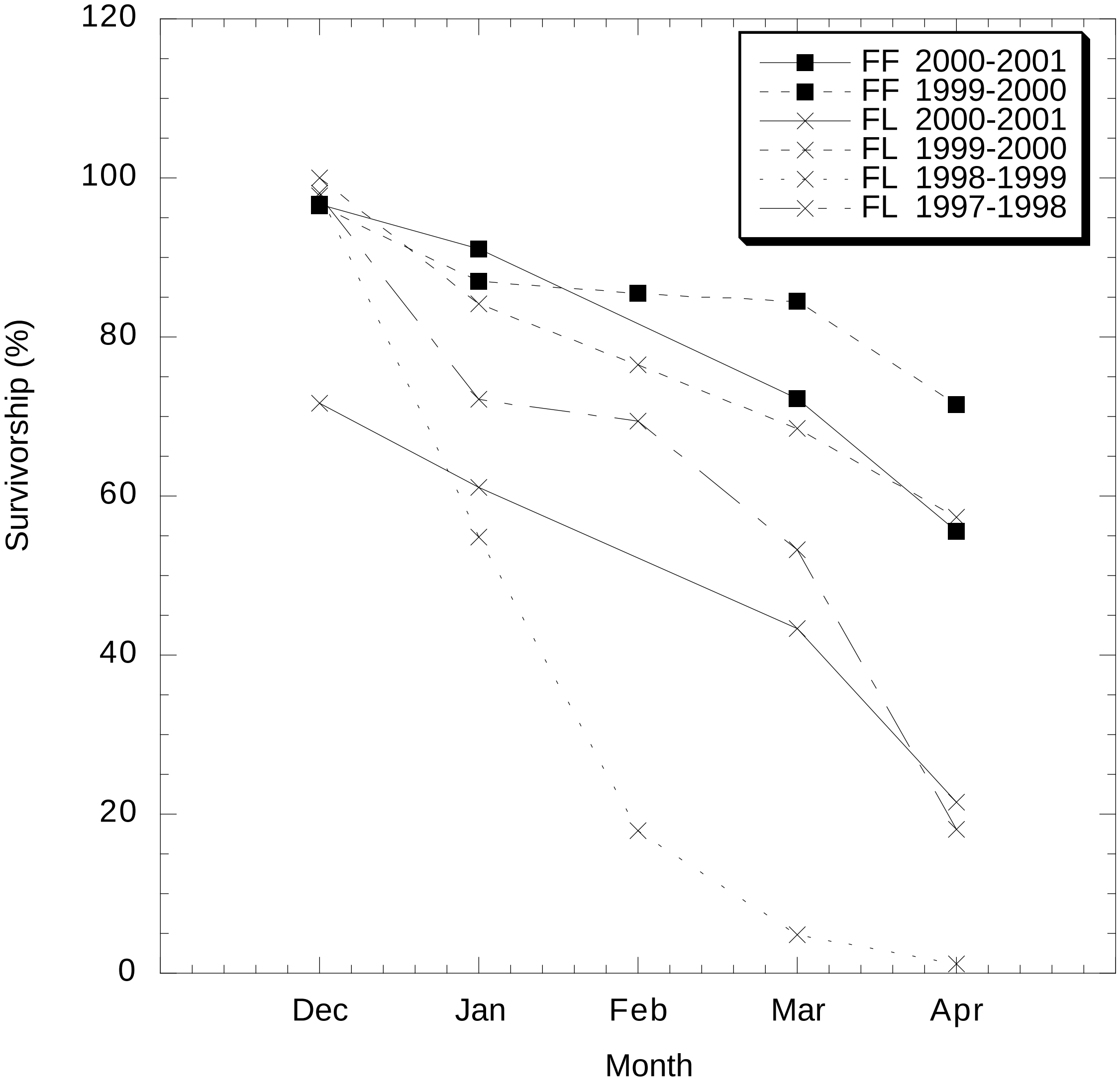

Figure A6. Survivorship of *A. grandiflora* in Experimental population. In 2001, FF plots n=15, FL plots n=10. In 2000, FF plots n=20, FL plots n=6. For FL plots in 1998 and 1999, n=6.

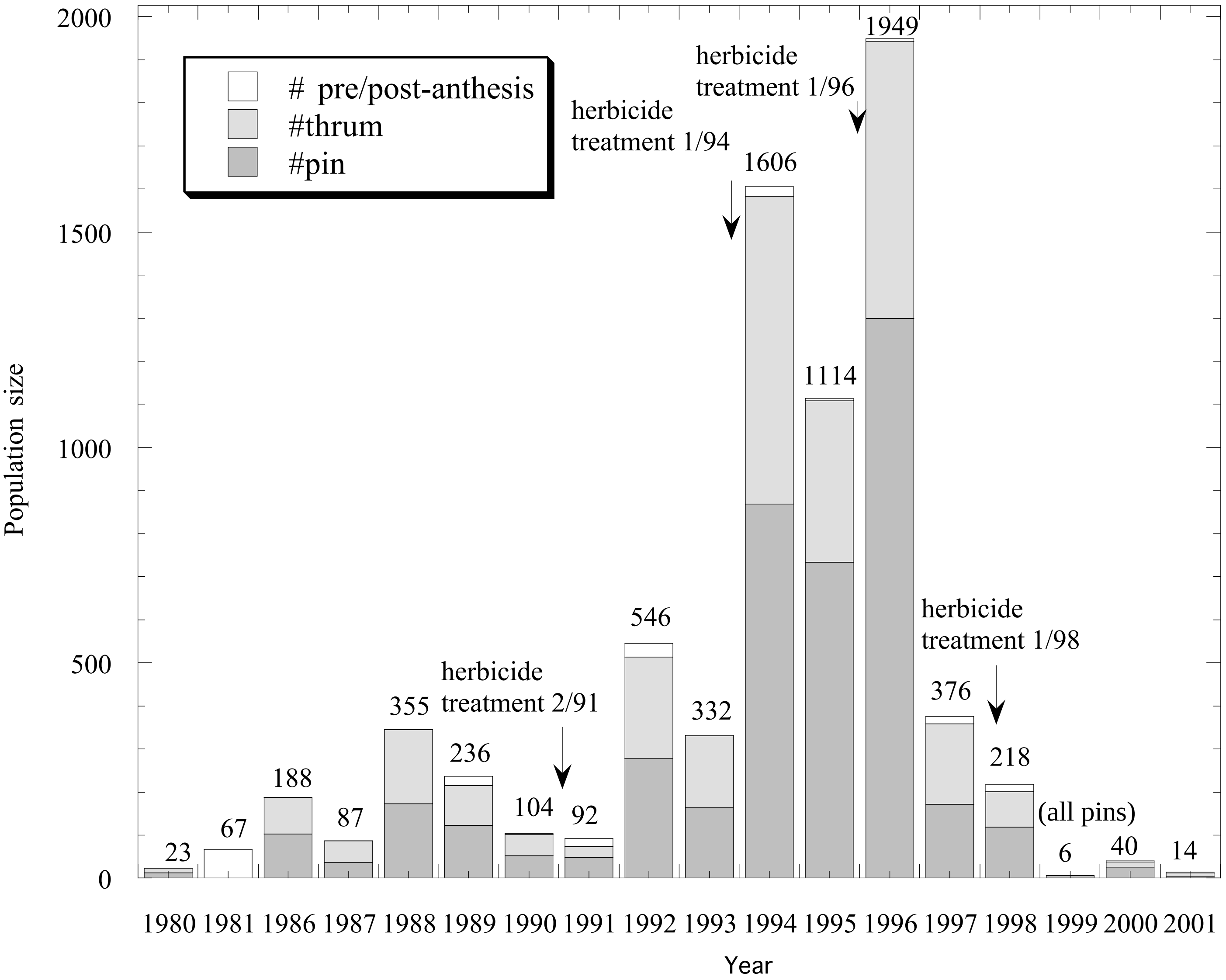

Figure A7. Historical spring census data of the Site 300 native Drop Tower population. Total population size is given above each bar. Approximate timing of herbicide treatments is shown.

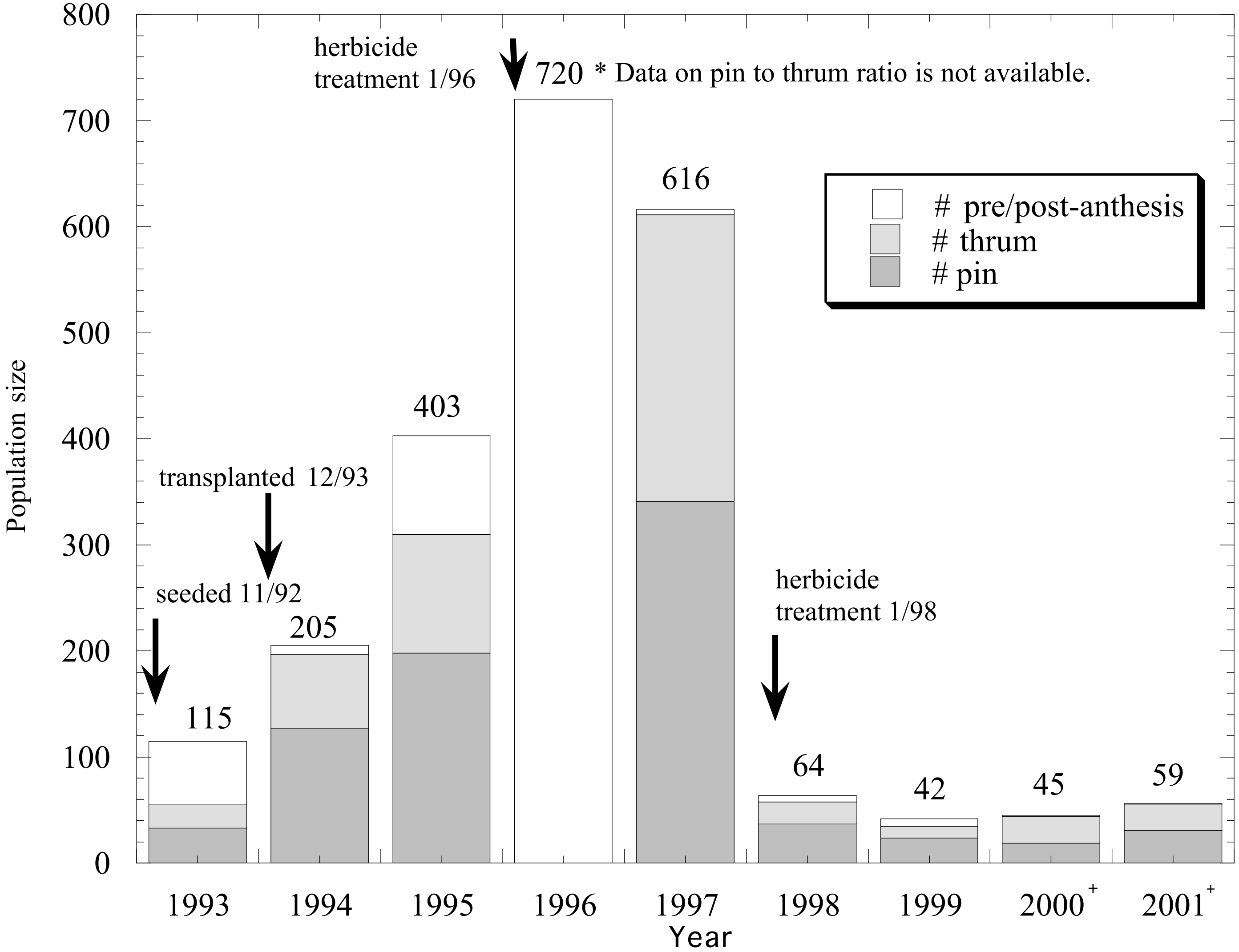

Figure A8. Historical spring census data of the Site 300 experimental FL subpopulation. Total population size is given above each bar. Approximate timing of all treatments are shown.
+ Population expansion into FF plots excluded.

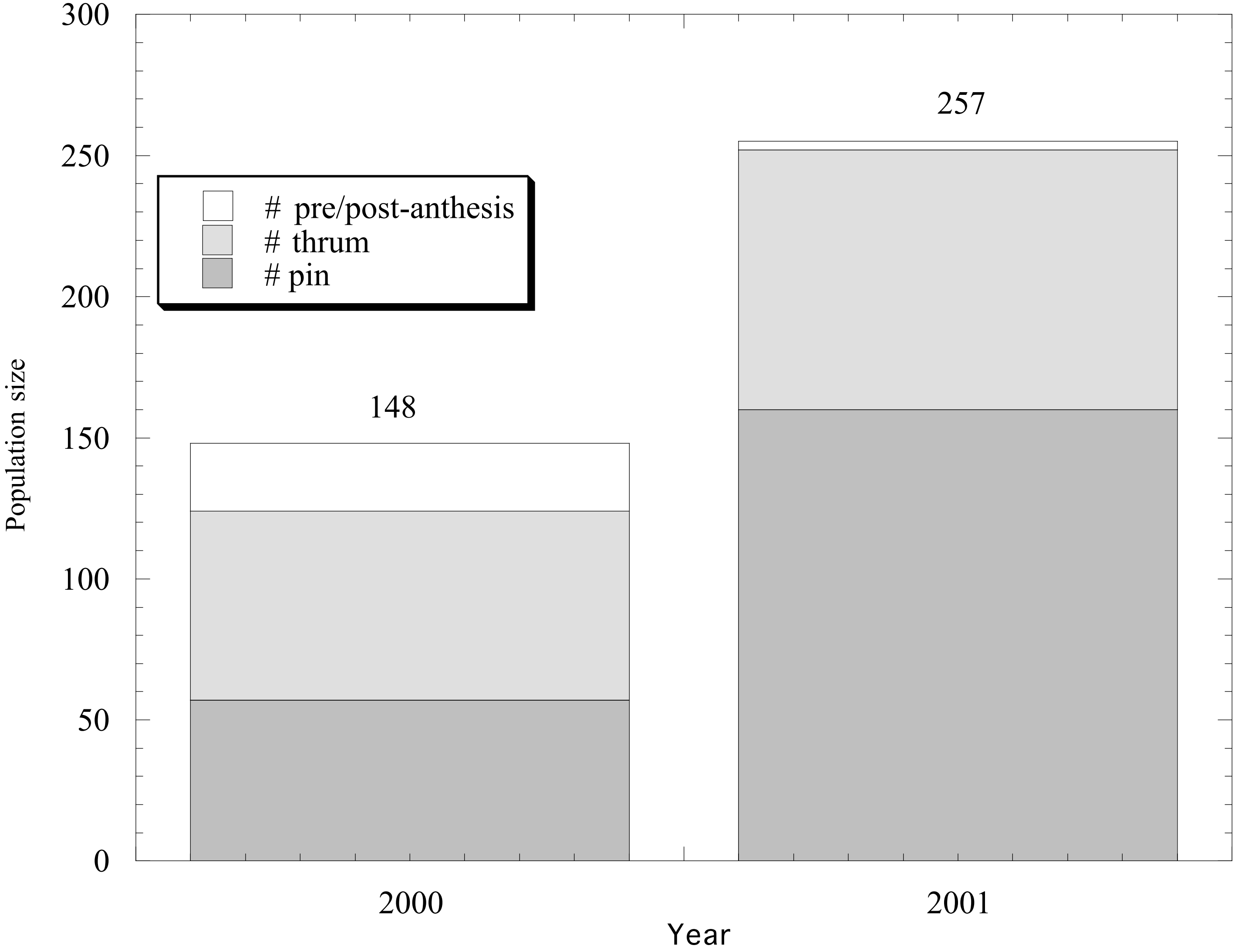

Figure A9. Spring census data of the Site 300 experimental FF subpopulation. Total population size is given above each bar.

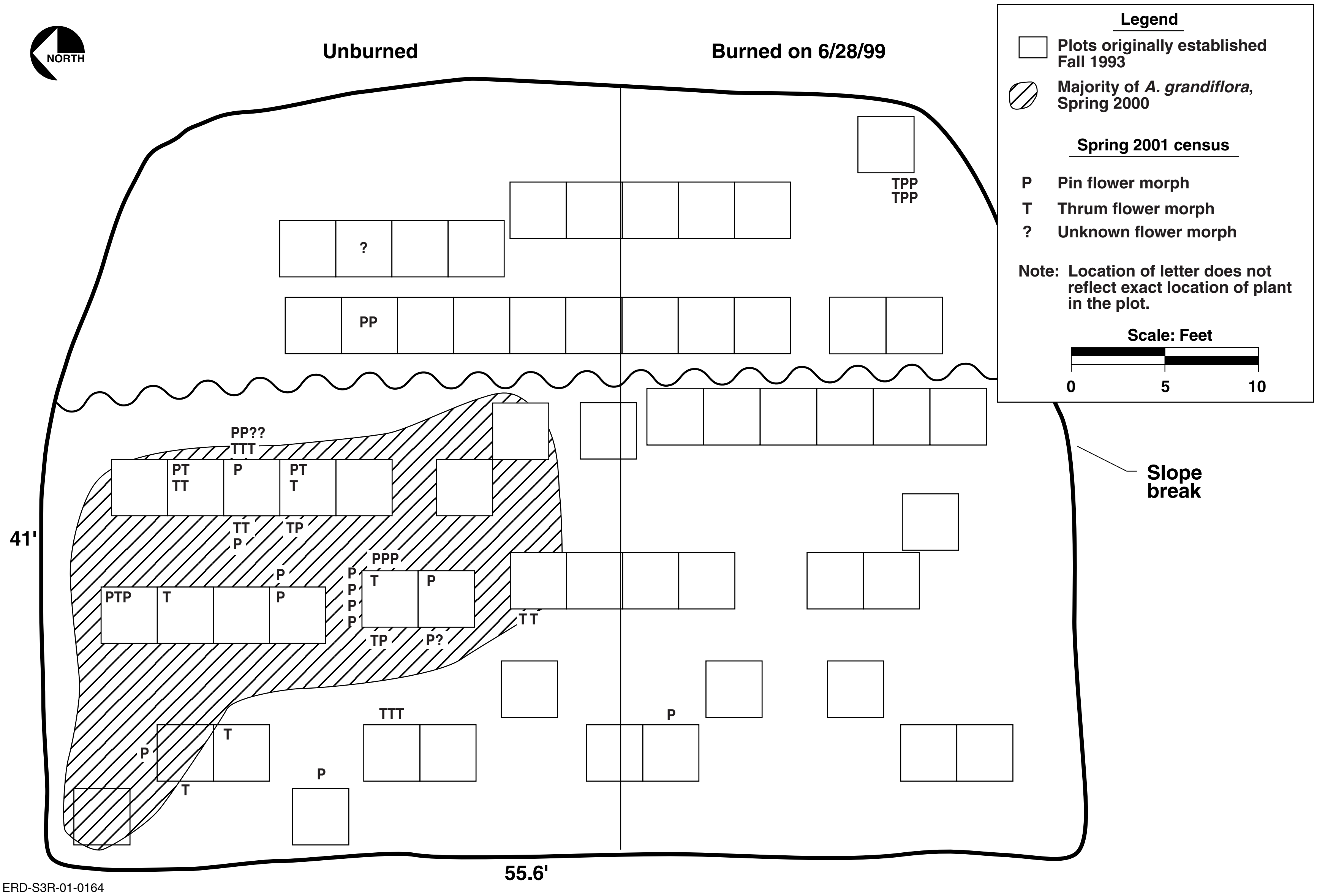

Figure A10. Spring census of the *A. grandiflora* FL subpopulation.

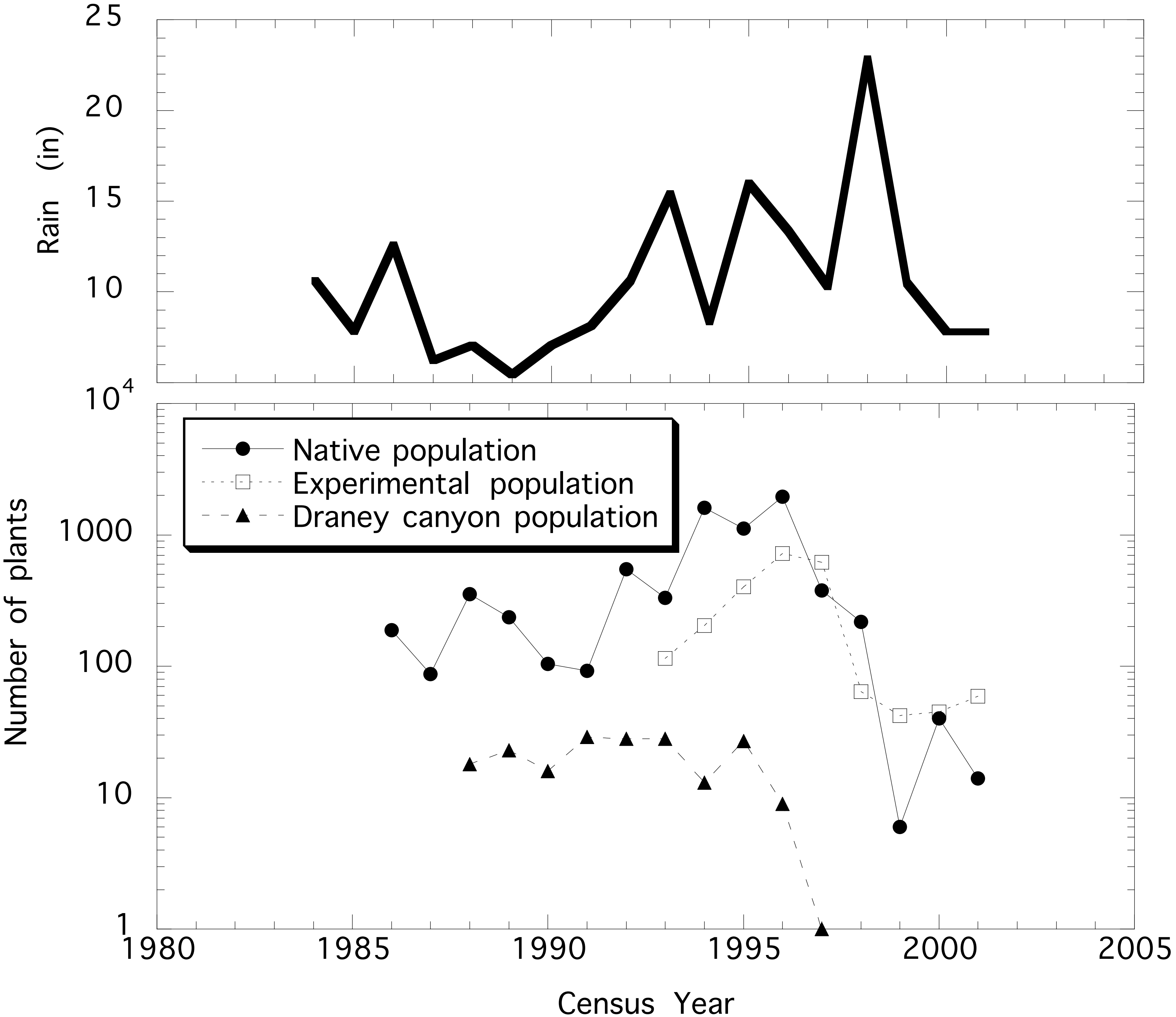

Figure A11. Log plot of population size at time of census, shown with rainfall totals over growing season.

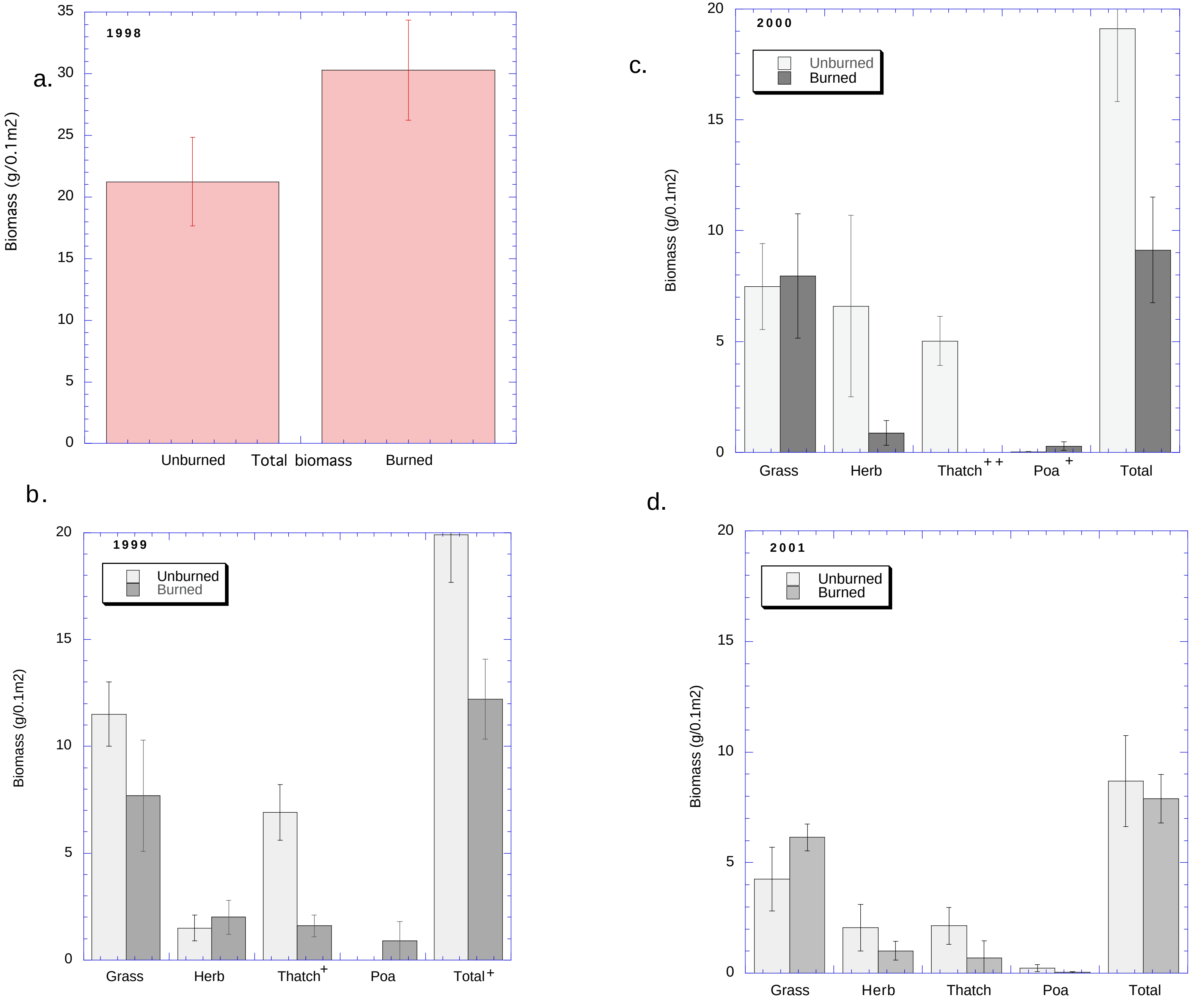

Figure A12. Biomass of burned vs. unburned FL plots. Bars are one standard error. ++ indicates treatments differ at $p < 0.01$. + indicates treatments differ at $p < 0.05$, n=5. a) 1998 data, b) 1999 data, c) 2000 data, d) 2001 data.

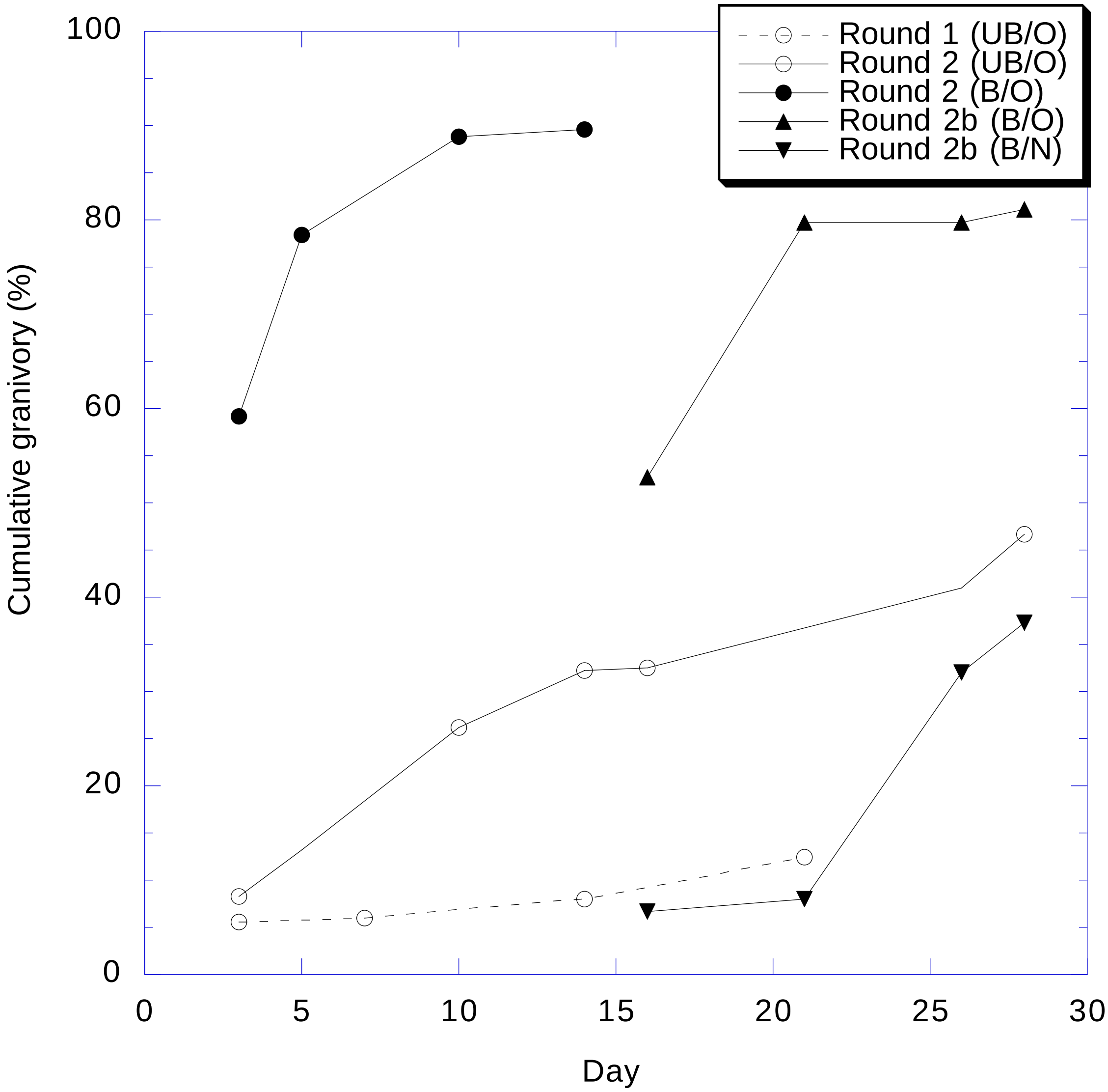

Figure A13. Cumulative percent granivory in 2001 by treatment and burn.

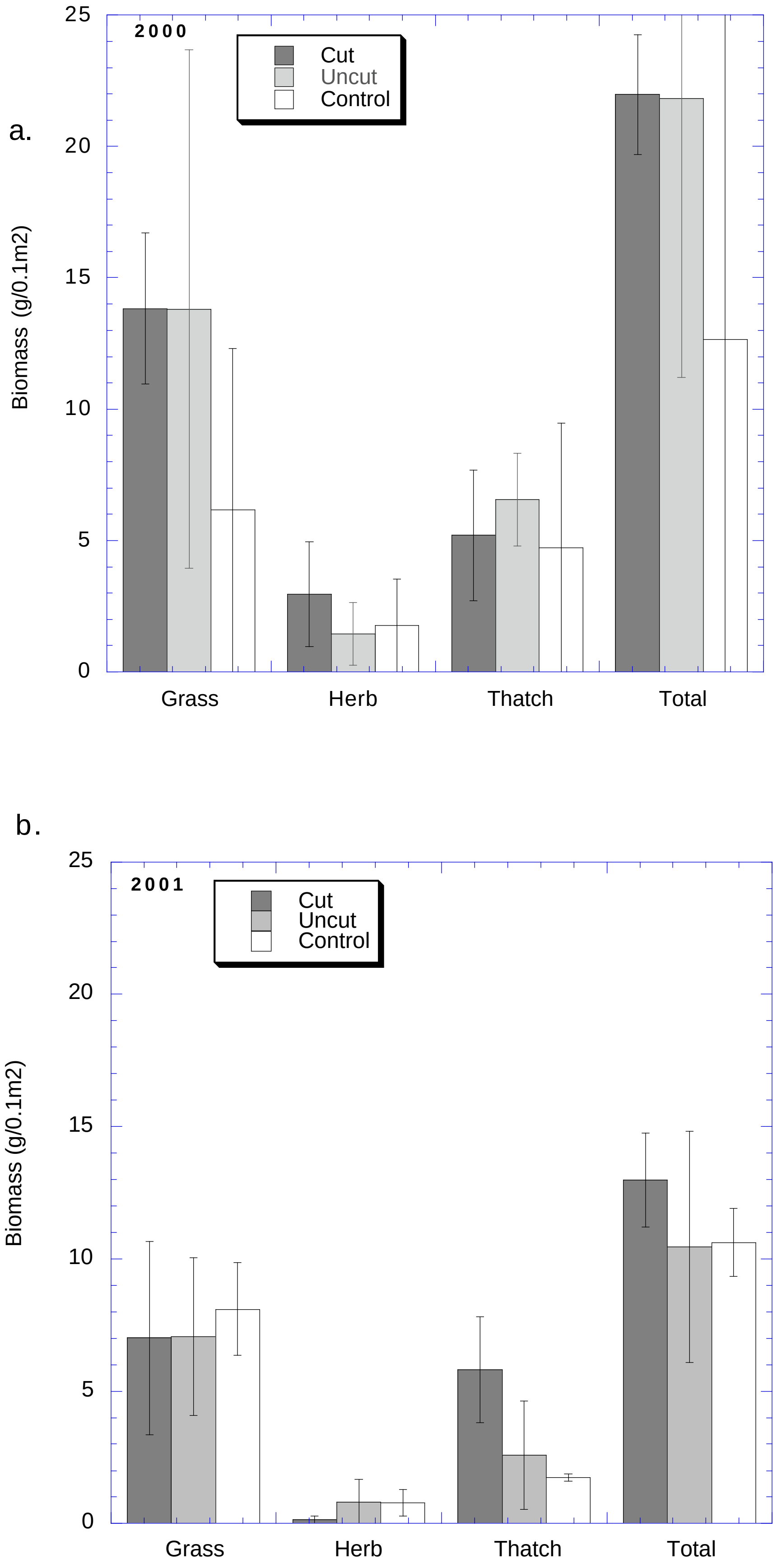

Figure A14. Biomass collected as part of the lupine experiment near the native population. a) Biomass collected 2000 b) biomass collected 2001. n =3.

Section A
Tables

Table A1. 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	Average no. of branches per plant[b]	Estimated average seed production per plant[c]	Estimated total seed production per population[d]
Spring 1999						
Native	**6**	**all P**	**15.3 ± 2.98**	**1.0 ± 0**	**0**	**0**
FL plots (experimental)	**42**	**2.18**	**13.3 ± 0.83**	**1.0 ± 0.02**	**0**	**0**
Spring 2000						
Native	**40**	**2.16**	**20.13 ± 0.75**	**1.7 ± 0**	**10.92**	**436.98**
FL plots (experimental)	**45**	**0.76**	**16.78 ± 0.84**	**1.32 ± 0**	**2.7**	**121.92**
FF plots (experimental)	**148**	**0.85**	**16.67 ± 0.50**	**2.33 ± 0**	**10.54**	**1,560.85**
Spring 2001						
Native	**14**	**0.43**	**17.21 ± 1.14**	**1.0 ± 0**	**2.6**	**36.4**
FL plots (experimental)	**59**	**1.29**	**13.67 ± 0.69**	**1.0 ± 0**	**0**	**0**
FF plots (experimental)	**257**	**1.74**	**15.74 ± 0.29**	**1.02 ± 0.01**	**0.11**	**28.27**

Notes:

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

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

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

[d] **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 A2. 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/0.1 m^2)[a]	n	Final dry biomass (g/0.1 m^2)[a]	n
2001	7.3 ± 0.8	5	9.3 ± 2.1	5
2000	10.6 ± 2.9	5	17.6 ± 4.1	5
1999	13.5 ± 3.1	5	20.6 ± 8.2	5
1998	28.5 ± 2.2	6	21.7 ± 5.9	4
1994	9.9 ± 0.9	13	8.7 ± 0.9	20

Notes:

FL = Flashing subpopulation.

n = Number of replicates.

[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, May 2000, and May 2001. Results are presented ± one standard error.

Table A-3. Summary of *Poa* counts in experimental. All averages are ± one standard error. Numbers in parentheses.

<table>
<tr><th colspan="2">*Poa* density in 1993</th><th colspan="5">*Poa* density in 1999</th><th colspan="5">*Poa* density in 2000</th><th colspan="5">*Poa* density in 2001</th></tr>
<tr><td>Planted *Poa* FL plots[c]</td><td>Total[a]</td><td>Total[a]</td><td colspan="2">Unburned</td><td colspan="2">Burned[b]</td><td>Total[a]</td><td colspan="2">Unburned</td><td colspan="2">Burned[b]</td><td>Total[a]</td><td colspan="2">Unburned</td><td colspan="2">Burned[b]</td></tr>
<tr><td>Low density</td><td>11</td><td>2.4 ± 0.93</td><td colspan="2">2.4 + 0.93 (5)</td><td colspan="2">N/A</td><td>4.2 ± 0.6</td><td colspan="2">3.8 + 0.3 (4)</td><td colspan="2">6.0 (1)</td><td>4.0 ± 0.7</td><td colspan="2">3.5 ± 0.8 (4)</td><td colspan="2">6.0 (1)</td></tr>
<tr><td>Medium density</td><td>22</td><td>3.2 ± 0.92</td><td colspan="2">2.5 + 1.5 (2)</td><td colspan="2">3.7 ± 0 (3)</td><td>8 ± 2.5</td><td colspan="2">3.5 ± 2.1 (2)</td><td colspan="2">11.0 ± 2.6 (3)</td><td>5.8 ± 0.9</td><td colspan="2">4.5 ± 0.7 (2)</td><td colspan="2">5.5 ± 0.7 (2)</td></tr>
<tr><td>High density</td><td>45</td><td>9.8 ± 4.4</td><td colspan="2">12.3 + 7.3 (3)</td><td colspan="2">6 ± 3 (2)</td><td>10.6 ± 4.1</td><td colspan="2">8.0 = (1)</td><td colspan="2">14.3 ± 5.9 (3)*</td><td>8.2 ± 1.9</td><td colspan="2">7.0 ± 2.8 (4)</td><td colspan="2">11.5 ± 5.0 (2)*</td></tr>
<tr><td>Existing *Poa* FL plots[d]</td><td></td><td></td><td colspan="2"></td><td colspan="2"></td><td></td><td colspan="2"></td><td colspan="2"></td><td></td><td colspan="2"></td><td colspan="2"></td></tr>
<tr><td>Low density</td><td>4</td><td>1.8 ± 0.37</td><td colspan="2">2 (1)</td><td colspan="2">1.75 ± 0.71 (4)</td><td>8.6 ± 2.7</td><td colspan="2">3.0 (1)</td><td colspan="2">10.0 ± 2.9 (4)</td><td>5.4 ± 0.8</td><td colspan="2">3.0 (1)</td><td colspan="2">6.0 ± 0.8 (4)</td></tr>
<tr><td>Medium density</td><td>5.6</td><td>1.2 ± 0.49</td><td colspan="2">1.3 ± .67 (3)</td><td colspan="2">1 ±1 (2)</td><td>5.1 ± 1.8</td><td colspan="2">4.7 ± 2.9 (3)</td><td colspan="2">9.0 (1)</td><td>3.8 ± 1.3</td><td colspan="2">3.3 ± 2.0 (4)</td><td colspan="2">5.0 (1)</td></tr>
<tr><td>High density</td><td>10.6</td><td>1.6 ± 1.36</td><td colspan="2">0.3 ± 0.3 (3)</td><td colspan="2">3.5 ±3.5 (2)</td><td>5.6 ± 1.6</td><td colspan="2">4.3 ± 2.7 (3)</td><td colspan="2">7.5 ± 0.7 (2)</td><td>4.0 ± 1.8</td><td colspan="2">2.7 ± 0.8 (3)</td><td colspan="2">6.0 ± 7.1 (2)</td></tr>
<tr><td>Plots cleared of perennial grass[e]</td><td>0</td><td>0.7 ± 0.2</td><td colspan="2">0.9 ± 0.2 (15)</td><td colspan="2">0.5 ± 0 (10)</td><td>2.4 ± 0.9</td><td colspan="2">1.5 ± 0.5 (13)</td><td colspan="2">3.5 ± 2.0 (11)</td><td>2.4 ± 0.7</td><td colspan="2">2.2 ± 0.6 (15)</td><td colspan="2">2.7 ± 1.4 (10)</td></tr>
<tr><td>Planted *Poa* FF plots[f]</td><td>N/A</td><td></td><td>Control</td><td>Low</td><td>Med</td><td>High</td><td></td><td>Control</td><td>Low</td><td>Med</td><td>High</td><td></td><td>Control</td><td>Low</td><td>Med</td><td>High</td></tr>
<tr><td></td><td></td><td>33</td><td>33</td><td>33</td><td>33</td><td>33</td><td>29 ± 6</td><td>32 ± 4</td><td>30 ± 2</td><td>29 ± 1</td><td>26 ± 10</td><td>22 ± 5</td><td>2.2 ± 5</td><td>2.2 ± 5</td><td>2.1 ± 4</td><td>2.2 ± 6</td></tr>
</table>

Notes:

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

N/A = Not applicable.

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

[b] **FL plots were last burned in summer of 1999.**

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

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

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

[f] **Plots planted in 1999. Averages broken down by burn frequency (control = unburned, low = every fifth year, med = every third year, high = every other year). N = 5. Burning begun summer 2001.**

* **These plots were burned in 1998, but, in 1999, a shift in the burn line caused these plots to remain unburned.**

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

Species	Native 97 (%)	Native 98 (%)	Native 99 (%)	Exp FL 99 (%)	Native 00 (%)	Exp FL 00 (%)	Exp FF 00 (%)	Native 01 (%)	Exp FL 01 (%)	Exp FF 01 (%)
Achillea millefolium	5	5	–	–	5	–	–	–	–	–
Allium serra	–	1	–	–	–	–	–	–	–	–
Amsinckia grandiflora	–	–	–	–	–	7	–	–	4	5
Amsinckia tessellata	–	–	–	–	3	5	–	–	4	1
Astragalus didymocarpus	–	–	–	–	3	–	–	–	–	–
Avena sp.	18	13	–	7	15	11	24	21	21	21
Bromus diandrus	22	9	17	5	5	2	2	14	2	16
Bromus hordeaceus	31	21	50	33	3	5	1	14	7	7
Bromus madritensis ssp. *rubens*	1	–	–	–	–	–	–	–	–	1
Unidentifiable *Bromus*	–	–	–	–	5	5	28	–	–	–
Castilleja exserta	–	–	–	–	–	–	–	–	–	1
Clarkia sp.	–	3	–	–	5	–	1	7	5	5
Claytonia parviflora	1	1	–	12	–	16	6	–	–	–
Collinsia heterophylla	3	9	17	–	–	–	–	–	–	21
Delphinium hesperium	1	3	–	–	3	2	–	–	–	–
Erodium cicutarium	4	5	–	24	18	16	4	21	41	21
Galium aparine	11	23	17	2	5	–	4	7	2	–
Lithophragma affinis	–	–	–	–	–	2	–	–	–	–
Lupinus albifrons	–	1	–	–	–	–	–	–	–	–
Lupinus bicolor	–	–	–	–	–	–	1	–	–	4
Phacelia sp.	–	–	–	–	3	–	–	–	–	–
Poa secunda	–	1	–	–	–	–	11	–	5	9
Sonchus sp.	1	–	–	–	–	–	–	–	–	–
Vulpia myuros	–	–	–	10	20	30	11	7	9	5
Unidentified dicot	3	3	–	7	8	2	2	7	–	5
# species (S)	12	14	4	8	14	12	12	8	10	17
n	100	129	6	42	39	45	151	14	56	243
Shannon's Index (H′)[a]	1.92	2.16	1.31	1.59	2.40	2.14	1.93	1.97	1.80	2.22

Notes:

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

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.

[a] **Shannon and Weaver (1949)** $H' = -\Sigma$ (of $i = 1$ to S) $(n_i/n) * \ln(n_i/n)$

Table A5. Constancy, mean cover and Importance Values (I.V.) for cover data collected from the native and experimental populations in 2001.

	Native (n = 14)				FL (n = 20)				FF (n = 20)			
Species	Constancy	Mean Cover	SE	IV	Constancy	Mean Cover	SE	IV	Constancy	Mean Cover	SE	IV
Achillia millefolia	0.5	8.1	0	0.6	–	–	–	–	–	–	–	–
Avena sp.	1.0	56.2	0.1	1.6	1.0	37.0	0	1.3	1.0	28.5	0	1.2
Amsinckia intermedia	–	–	–	–	0.3	2.2	0	0.3	0.1	0.1	–	0.1
Amsinckia grandiflora	0.2	1.2	0	0.2	0.2	0.4	0	0.2	0.8	4.8	0	0.8
Bromus diandrus	0.7	10.4	0	0.8	0.2	0.6	0	0.2	1.0	23.1	0	1.2
Bromus hordeaceous	0.9	13.8	0	1.1	0.6	2.1	0	0.6	0.9	11.3	0	1.0
Bromus madritensis ssp. *rubens*	0.2	2.3	0	0.3	0.2	0.4	0	0.2	0.2	0.5	0	0.2
Achyrachaena mollis	0.1	0.2	–	0.1	–	–	–	–	–	–	–	–
Castilleja exserta	0.2	1.4	0	0.2	0.7	5.0	0	0.7	0.5	3.8	0	0.5
Cirsium sp.	–	–	–	–	–	–	–	–	0.1	1.0	0	0.1
Clarkia sp.	0.4	3.5	0	0.4	0.4	2.5	0	0.4	0.6	2.4	0	0.6
Collinsia heterophylla	0.1	0.3	–	0.1	–	–	–	–	–	–	–	–
Delphinium hesperium	0.1	0.2	–	0.1	–	–	–	–	0.1	0.2	–	0.1
Erodium cicutarium	0.8	15.4	0	0.9	1.0	54.5	0.1	1.5	1.0	23.5	0	1.2
Galium aparine	0.7	7.2	0	0.8	0.2	0.6	0	0.2	–	–	–	–
Grindelia camporum	0.1	1.2	–	0.1	0.1	0.2	–	0.1	–	–	–	–
Guterrizia californica	0.1	0.8	–	0.1	–	–	–	–	–	–	–	–
Thysanocarpus sp.	–	–	–	–	–	–	–	–	0.1	0.2	–	0.1
Lupinus albifrons	0.2	1.9	0	0.3	–	–	–	0.0	–	–	–	–
Lupinus bicolor	0.3	1.7	0	0.3	0.8	6.9	0	0.9	0.9	15.1	0	1.1
Poa secunda	0.2	1.9	0	0.2	0.6	2.6	0	0.6	1.0	30.5	0	1.3
Sonchus sp.	–	–	–	–	–	–	–	–	0.1	1.0	0	0.1
Unknown dicot	–	–	–	–	0.1	0.3	–	0.1	–	–	–	–
Vulpia myuros	0.4	5.0	0	0.4	0.5	8.2	0	0.5	0.6	2.7	0	0.6
Unknown dicot	0.3	3.2	0	0.3	–	–	–	–	0.1	0.2	–	0.1
Thatch	0.9	27.3	0.1	1.2	1.0	16.8	0	1.2	1.0	19.7	0	1.2
Bare ground	1.0	12.3	0	1.1	1.0	30.8	0.1	1.3	1.0	21.8	0	1.2

Notes:

FL = Flashing subpopulation.

FF = Fire frequency subpopulation.

SE = Standard error.

n = Number of plots.

Table A6. Final predation by treatment and cover type: 2001.

	Cumulative percent granivory					
Site or treatment, cover type	**Median (%)**	**Mean (%)**	**Variance (%)**	**Evenness (%)**	**Localization (%)**	**n**
2001, round 1						
Open, unburned (FL)	**8**	**11**	**0.6**	**40**	**0**	**5**
Open, unburned (FF)	**8**	**11**	**1.2**	**40**	**0**	**5**
2001, round 2						
Net, burned	**50**	**37**	**10.3**	**67**	**0**	**3**
Open, burned[**]	**84**	**87**	**1.2**	**100**	**75**	**8**
Open, unburned	**61**	**47**	**7.6**	**100**	**0**	**5**

Note:

n = Replicate number.

[**] **Treatment significantly different ($p < 0.05$) from other treatments within trial.**

Table A7. Final predation: all rounds, sites, treatment and cover types combined: 1995–2001.

	Cumulative percent granivory					
Year[a]	**Median (%)**	**Mean (%)**	**Variance (%)**	**Evenness (%)**	**Localization (%)**	**n**
1995[+]	**37.5**	**42.6**	**14.5**	**69**	**24**	**42**
1998[*,b]	**79.6**	**70.7**	**5.4**	**100**	**56**	**50**
1999[#]	**96**	**93**	**1.0**	**100**	**93**	**40**
2000[+]	**32.7**	**38.8**	**7.1**	**93**	**13**	**30**
2001[+]	**37.0**	**44.1**	**12.9**	**73**	**23**	**26**

Note:

n = Replicate number.

[a] **Years with different symbols indicate that the medians are significantly different ($p < 0.0015$).**

[b] **Ant-only treatment excluded.**

Section B
Blepharizonia plumosa
Monitoring and Research

Section B

Blepharizonia plumosa Monitoring and Research

B-1. Introduction

Several populations of *Blepharizonia plumosa* (the big tar plant, known also as *Blepharizonia plumosa* ssp. *plumosa*) were identified during a habitat survey in 1996 at Site 300 (Preston, 1996). Listed as *Blepharizonia plumosa plumosa* by the California Native Plant Society (CNPS), it is an extremely rare late-season flowering annual plant included on the CNPS List 1B (Tibor, 2001). The CNPS List 1B includes plants that are rare, threatened, or endangered. The CNPS R-E-D code (rarity-endangerment-distribution) for *B. 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 (Tibor, 2001). 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 laxa* (also known as *Blepharizonia plumosa* ssp. *viscida*), were also found. Neither species has been extensively studied, particularly *B. plumosa*.

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

Blepharizonia plumosa can generally be distinguished from *B. laxa* by fruit morphology and leaf color (Hickman, 1993, personal observation). The most distinctive characteristic of *B. plumosa* is the pappus of 1.5 to 3 mm in length on the disc fruits. This pappus, sometimes described as plumose (thus the name *plumosa),* contrasts with the very minute pappus of the ray fruits (Figure B1). The plants also have a pale green color as their foliage is sparsely glandular below the inflorescence. Older plants have many inflorescences on lateral side branches.

Blepharizonia laxa, although also endemic to California, exists in large numbers and has a much larger range which extends farther south into the inner South Coast Ranges including San Benito County (Hickman, 1993). The disc and ray seeds of *B. laxa* appear quite similar and have a short pappus from 0-1 mm in length (Figure B1). *Blepharizonia laxa* is much more glandular than *B. plumosa*, giving the plant a more yellow-green color and a much stronger scent. They also tend to be slightly taller than *B. 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* is quite common at Site 300, occurring in large numbers in areas that are routinely burned. This is interesting, for at the time of the annual spring burns at Site 300, the plant is in a green vegetative stage, and thus very susceptible to fire damage. It is possible that the larger Site 300 *B. plumosa* population may be acting as a metapopulation. Smaller subpopulations may be established or extinguished, depending on fire uniformity and intensity. And although fire is potentially fatal to individual *B. plumosa* plants directly in its path, it may provide the amount of disturbance necessary to reduce competition and allow for subpopulation establishment, thus maintaining the metapopulation.

And while common throughout its range, *B. laxa* is very uncommon at Site 300. The two species have occurred 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). Both locations consisted entirely of *B. laxa* in 2000. Other *B. laxa* populations occur sporadically in both unburned and burned areas. That the two species 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* is necessary. *Blepharioniz laxa* is also of interest as comparisons of rare and common congeners can provide important information for rare plant management (Bevill and Louda, 1999; Pantone et al., 1995) and can illuminate differences which affect comparative abundance (Byers 1998). Therefore, in November of 1996, we began collecting basic demographic and population biology data on *B. plumosa.* Because so little is known about population biology of this species, 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. laxa*, therefore we began collecting limited information on this species as well. In 1996, three populations of *B. plumosa* (designated B834 Berm, Elk Ravine (or B834 Drainage), and B850), and one population of *B. laxa* (designated Middle Canyon), were delineated for monitoring purposes (Figure B2). B834 Berm has not been monitored since 2000, but B812, where *B. plumosa* and *B. laxa* have co-occurred, was selected as an additional monitoring location in 2001. Table B1 includes some habitat characteristics of all five populations.

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

B-2. Methods and Materials

B-2.1. Sitewide Mapping

On seven dates between 20 Oct 00 and 8 Nov 00, all areas of Site 300 were surveyed for flowering *B. plumosa* populations. All *B. plumosa* and *B. laxa* populations found were mapped using a Trimble GPS unit.

B-2.2. Monitored Populations

In the late spring of 2001, 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* or *B. laxa* plant closest to the sample point was marked. The Middle Canyon population of *B. laxa* occurred only next to the road in 2001. All 20 plants found were marked and measured. This population does not experience an annual burn.

At locations other than Middle Canyon, 100 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. Middle Canyon was also censused at this time. 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. The area around the plant was characterized as burned or unburned. 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 2001.

For the flowering census in fall of 2000, all plants, marked or unmarked, were measured at flowering in the B850 and Elk Ravine populations on 16 Oct 00. Flowering plants were sampled at the Middle Canyon location on that date. In late spring of 2001, the pre-burn sample of Elk Ravine, B812, B850, and Middle Canyon was conducted on 14 May, 14 May, 21 and 25 May, and 21 May, respectively. Markers were censused post-burn on 14 Jun, 16 Jul, 10 Jul, and 14 Jun, respectively.

B-2.2.1. Data Analysis

For species diversity index calculations, Shannon’s index (Shannon and Weaver, 1949) was used: $-\Sigma$ (of $i = 1$ to S) $(n_i/\mathrm{n}) * \ln(n_i/\mathrm{n})$, 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, which were collected as percent cover rather than as nearest neighbor (Carlsen et al., 2001), n_i was the normalized percent cover for each species, and n was 100.

B-2.3. Fire Germination Experiment

To determine the effects of fire on *B. plumosa* germination, a field experiment was designed to test germination under fire conditions. On 31 May 00, soil filling three, 10-inch 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-inch diameter pots were filled to 1 inch from the top with potting soil. The top 1 inch 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 5 mm 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 B833.

On 24 July 00, after the burn, the five pots at B850 were collected and returned to 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 833. Pots were monitored every two weeks for germination Nov 00 through Jan 01 and then once in Mar 01.

B-3. Results

B-3.1. Sitewide Mapping

Figure B3 shows *B. plumosa* populations mapped in 2000. Many of the largest populations occurred on the edges of areas that were burned in 1999. The exact same areas were burned in summer of 2000. Only small population patches occurred in the heart of the burned areas. In 1999, *B. plumosa* population areas were much smaller (Figure B4). Small patches of *B. plumosa* occurred in areas that were burned in 1998 and 1999 as well as in areas that remained unburned.

B-3.2. Monitored Populations

Survivorship following the burn is generally low. Survivorship at Elk Ravine was very low in 1998–2000, with values ranging from zero to three percent (Table B2). Survivorship at B850 was higher: from nine to 25%. Overall survivorship at Elk Ravine improved in 2001. This improvement is entirely due to the addition of a quadrat in this population, located in an area which is rarely burned. When comparing survivorship in burned areas to unburned areas, the effect is unmistakable. Nearly all the plants that survive the burn are in areas that escape the flames. Although each population is "burned", burns can be patchy and some areas within the population remain untouched. Burned areas generally have no *B. plumosa* survivorship. The exception is in 2000, when 8% of *B. plumosa* plants in burned areas survived the burn at B850.

However, this is still much lower than the 76% of plants that survived the burn in unburned areas at that location. Table B3 lists environmental characteristics present at the time of each burn. Thus far, we have not been able to make a connection between environmental characteristics and burn patchiness.

At B850 in 2001, it was difficult to tell if plants remained living after the burn. Our post-burn survey was conducted only three days after the burn this year. This may not be enough time for plants that have died as a result of the burn to turn completely brown. Censusing between one and two weeks after the burn generally yields more clear-cut results.

Once *B. plumosa* plants survive the burn, reproduction is not assured. Survivorship to the flowering stage has been measured at 59% at its highest (Table B2). The cause of plant death in the time between the burn and flowering is unknown at this time. The main cause of variability within our results may be due to sample size and to methodology. (The low of zero survivorship was measured from an n of four, while the next lowest survivorship of 13% was found with a counting, versus marking and following, methodology.)

Species composition appeared different between populations. *Erodium cicutarium* appears to be increasing at B850 (Figure B5) and Elk Ravine (Figure B6) and is a large component of the understory vegetation at B812 (Figure B7). *Vulpia myuros* is less frequent at B850 and more frequent at Elk Ravine. B850 also has a strong *Bromus hordeaceous* component that is not evident at Elk Ravine. *Poa secunda* is declining at Elk Ravine but appears to remain around 8–20% at B850. Middle Canyon was dominated by *Avena* in 1997, but less so in 2001 (Figure B7). The change in species composition at this location is probably due to roadside-only sampling in 2001.

Species diversity values appear relatively consistent within populations from 1999 through 2001. Values at Elk Ravine range from 1.61 to 1.74 and values at B850 range from 1.64 to 1.99. Estimates from 1997 may be higher than successive ones 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.

When the average plant height is shorter post-burn, this indicates a larger death rate among taller plants. This occurred at Elk Ravine in both 1999 and 2000 and at B850 in 1999 (Figure B8). When average plant height is taller after the burn than before it, the results are more difficult to interpret. When the pre-burn census occurs close to the burn, we can accurately assess if burning differentially affects short plant versus tall plant survivorship. In 2000, burns were conducted 12 and 17 days after the pre-burn census. However, in 2001, burns were conducted 55 and 61 days after the first census. Burn times are becoming more difficult to predict, due to the increasing number of constraints upon the fire department in conducting the burns. Hence, burns in 2001 occurred over a longer time span and were anywhere from 24 to 53 days after the first (pre-burn) census. The longer a period of time occurs between the pre-burn census and the burns, the less accurately the height data collected represent the heights of the plants undergoing the burn. In addition, it appears that the plants available to measure after the burn have survived the burn more due to burn patchiness than due to their size.

In general, plants are taller at flowering than at the post-burn census (Figure B6). While this result is to be expected, it is not universal. Plants at B850 in 2000 were tallest at the post-burn census, indicating that taller plants died at disproportionate rates prior to flowering

Now that two *B. laxa* populations have been added to this intensive demographic monitoring, we expect that the plant height data will be useful in making interspecies comparisons as well as assessing the effects of burning on any population differentiation among burned and unburned areas. Figure B8 shows that *B. laxa* plants at B812 are shorter than Middle Canyon plants. But the amount of growth that each population experienced appears to be similar, even though B812 underwent a burn and the Middle Canyon population did not.

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. In the burned pots, one 1996 disc seed germinated, one 1996 ray seed germinated, seven 1998 disc seeds germinated, and one 1998 ray seed germinated (Table B4). Twenty-nine 1998 disc seeds, and no others, germinated in the control pots. Although the numbers are to small to run any statistical analyses, it appears that exposure to fire may have a weak stimulation of germination in ray seeds and in seeds from older sources. It is also possible that burning is inhibitory to disc seeds from recent sources. The amount of ash deposited on the experimental pots was probably minimal and may not be enough to have affected germination, but 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). Gregory et al. (2001) found that *B. plumosa* produces a predominance of ray seeds, but seeds of this type have very poor germination rates under laboratory conditions. If germination of ray seeds is stimulated by exposure to burn conditions, this may explain how *B. plumosa* can be so prevalent at Site 300.

B-4. Recommendations and Future Work

By mapping *B. 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* 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* and the annual burns that occur at the site. The monitoring of burn survivorship at B850, Elk Ravine and B812 will assist in the interpretation of the site-wide data. Middle Canyon will continue to be tracked in order to compare ecological requirements between *B. plumosa* and *B. laxa*.

A larger seed germination experiment could be undertaken to determine the effect of fire exposure on ray seed germination. Including *B. laxa* seeds would further elucidate some of the mechanisms of co-occurrence between the two species.

Another outstanding question with respect to the Site 300 *B. plumosa* population is that of gene flow. The Site 300 *B. plumosa* population may be acting in one of three ways: (1) a true metapopulation, in that gene flow is semi-restricted, with most of the gene flow occurring within subpopulations, 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* 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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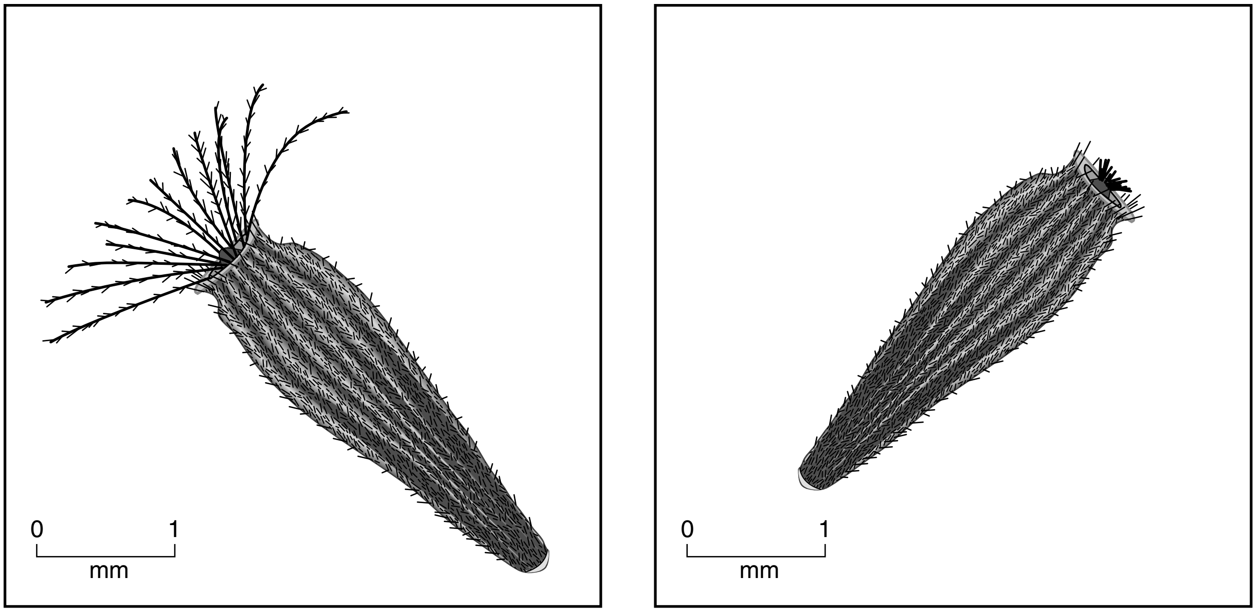
Section B
Figures

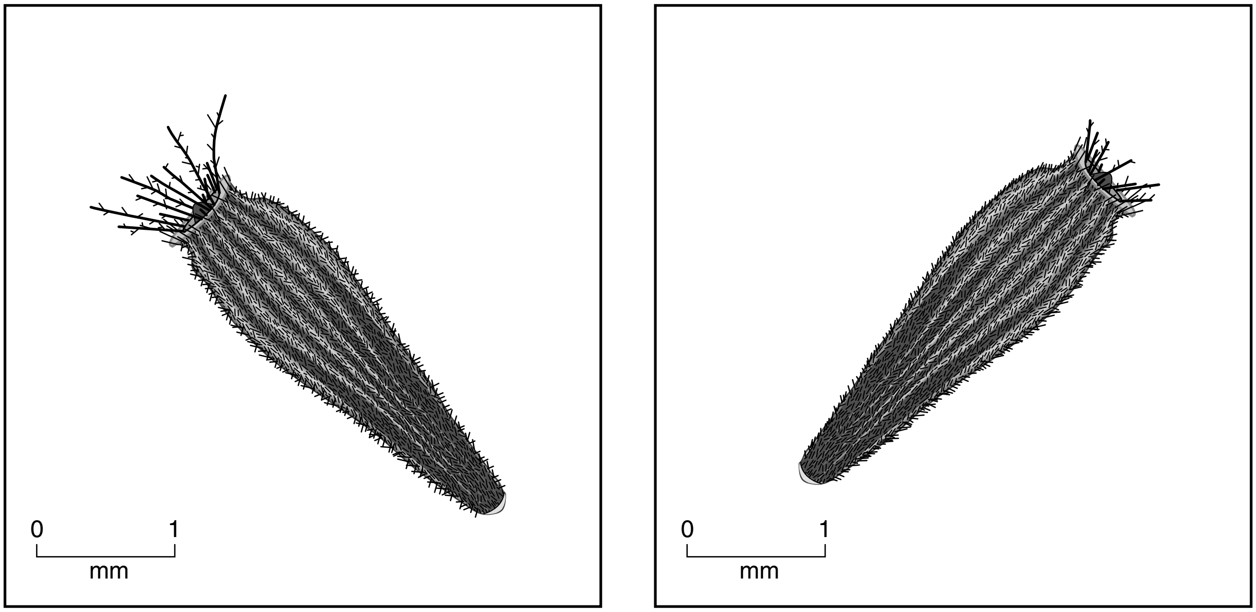
Rare Tarplant, *Blepharizonia plumosa*



Disc

Ray

Common Tarplant, *Blepharizonia laxa*



Disc

Ray

ERD-S3R-01-0162

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

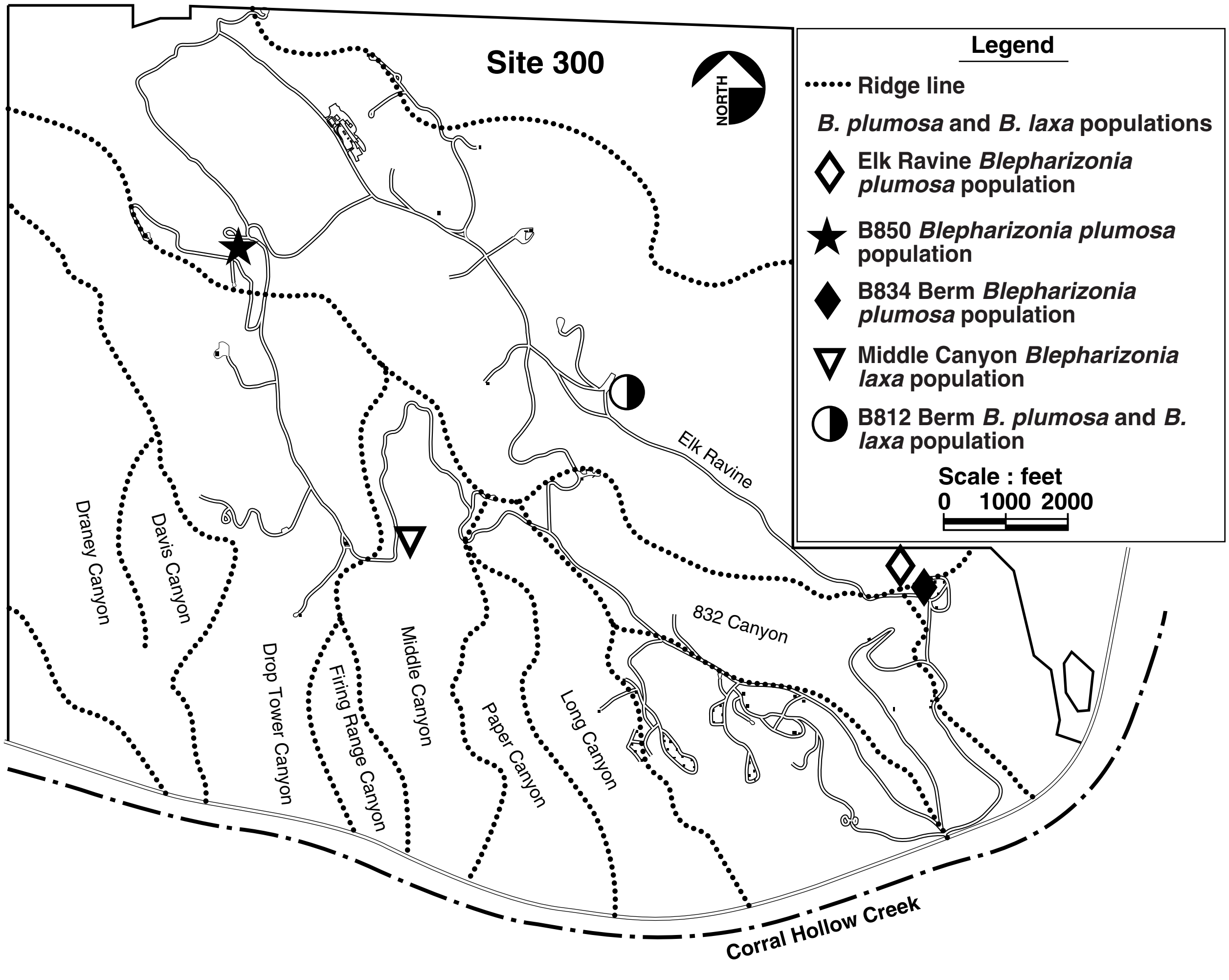


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Figure B2. Location of monitored *B. plumosa* and *B. laxa* populations at Lawrence Livermore National Laboratory (LLNL) Site 300.

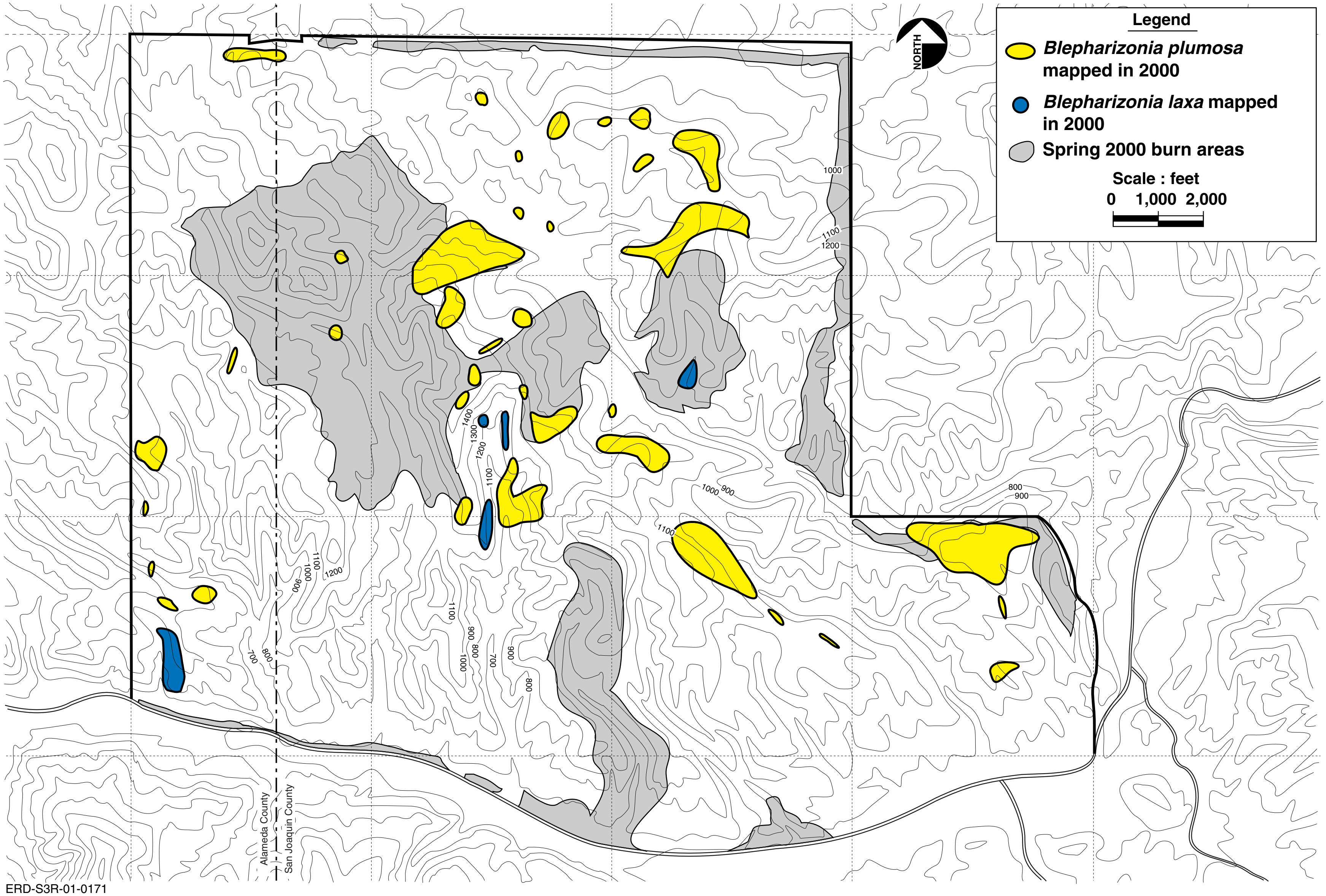

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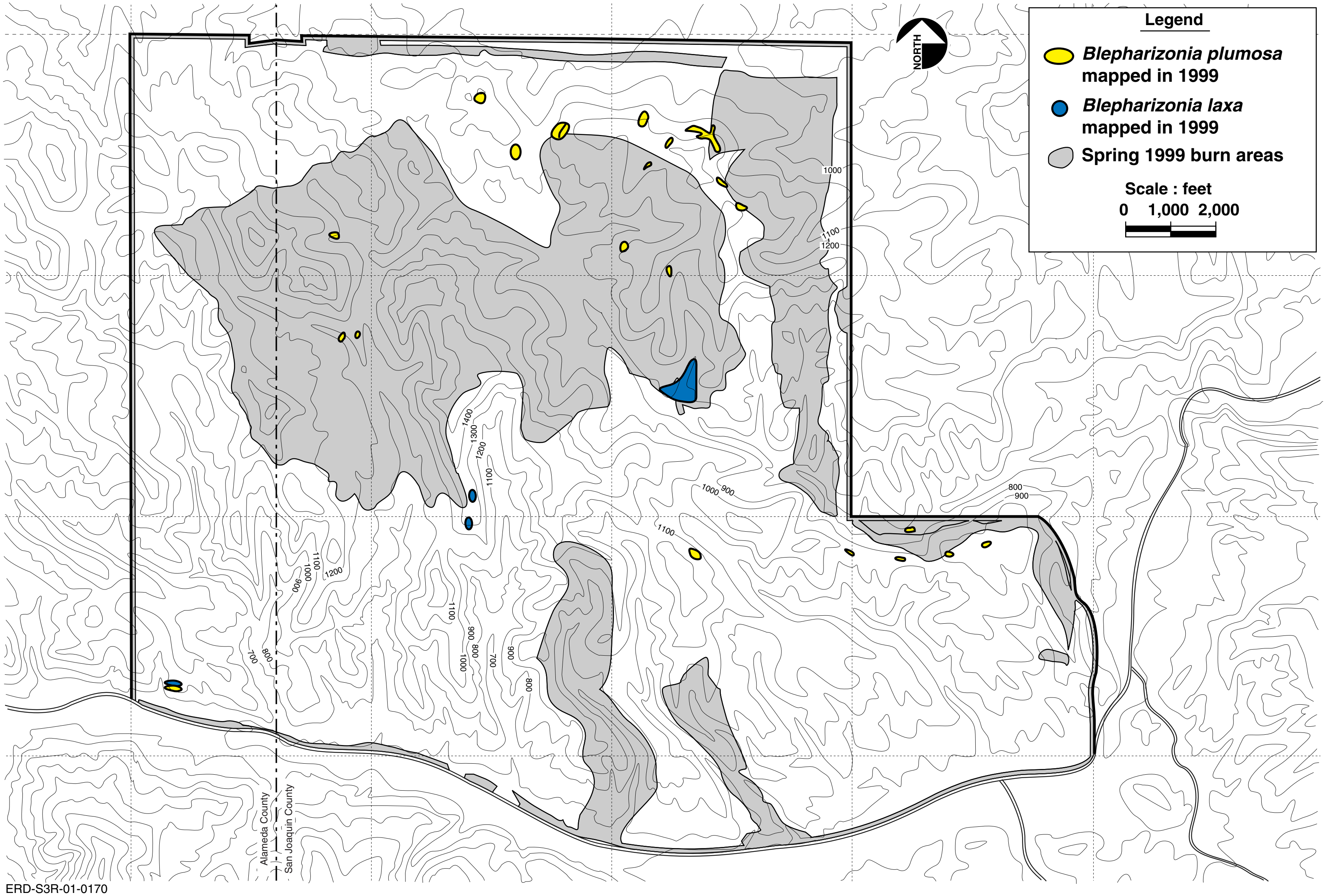
Figure B3. *Blepharizonia* mapped in 2000. Areas burned in Spring of 1999 and Summer of 2000 shown.



ERD-S3R-01-0170

Figure B4. *Blepharizonia* populations mapped in 1999. Areas burned in Spring of 1998 shown.

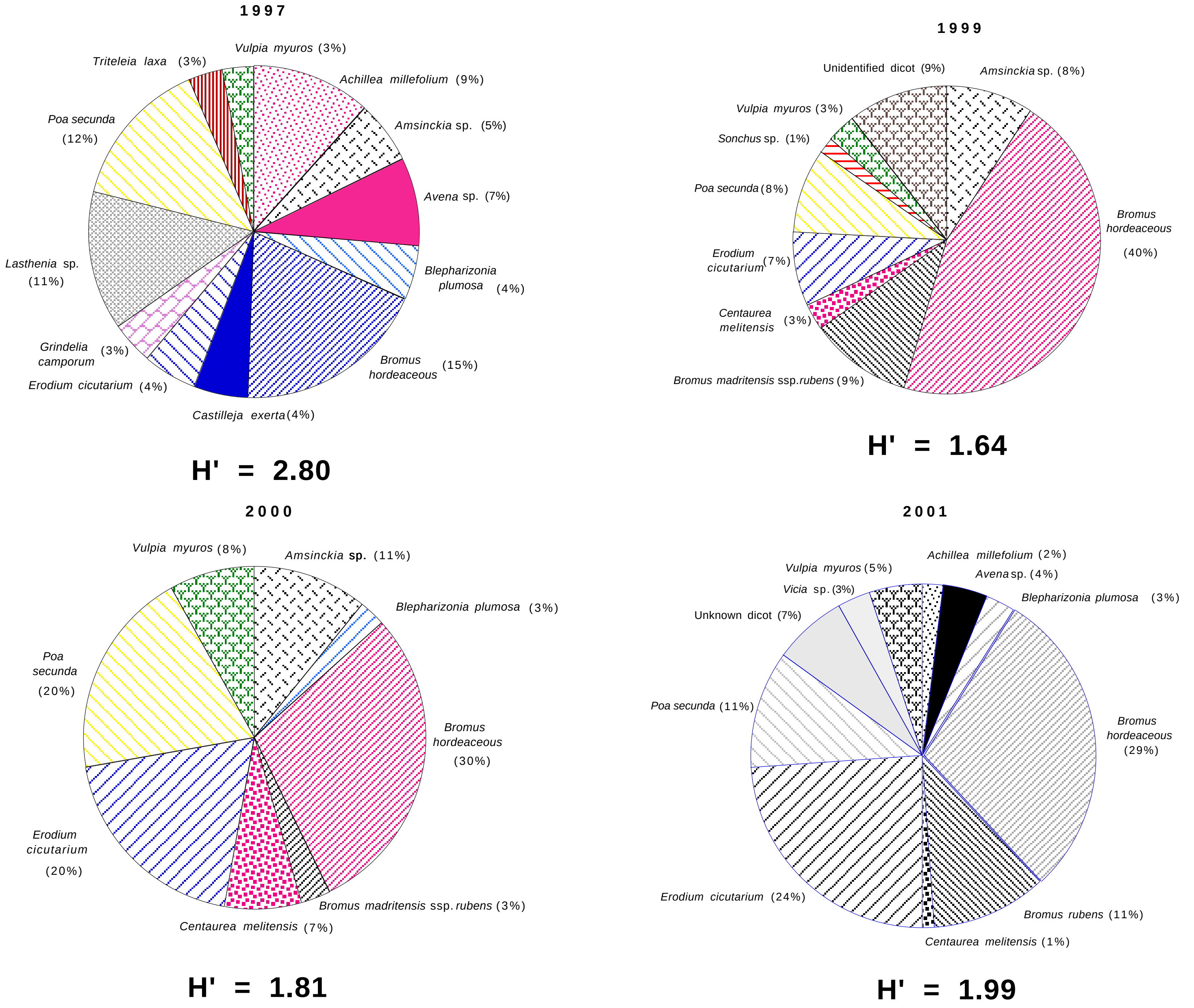


Figure B5. Species composition of *Blepharizonia plumosa* nearest neighbors at Building 850: 1997*and 1999–2001. Shannon's diversity index (Shannon and Weaver 1949), H', for each year is also shown. *1997 data are percent cover estimates normalized for comparison.

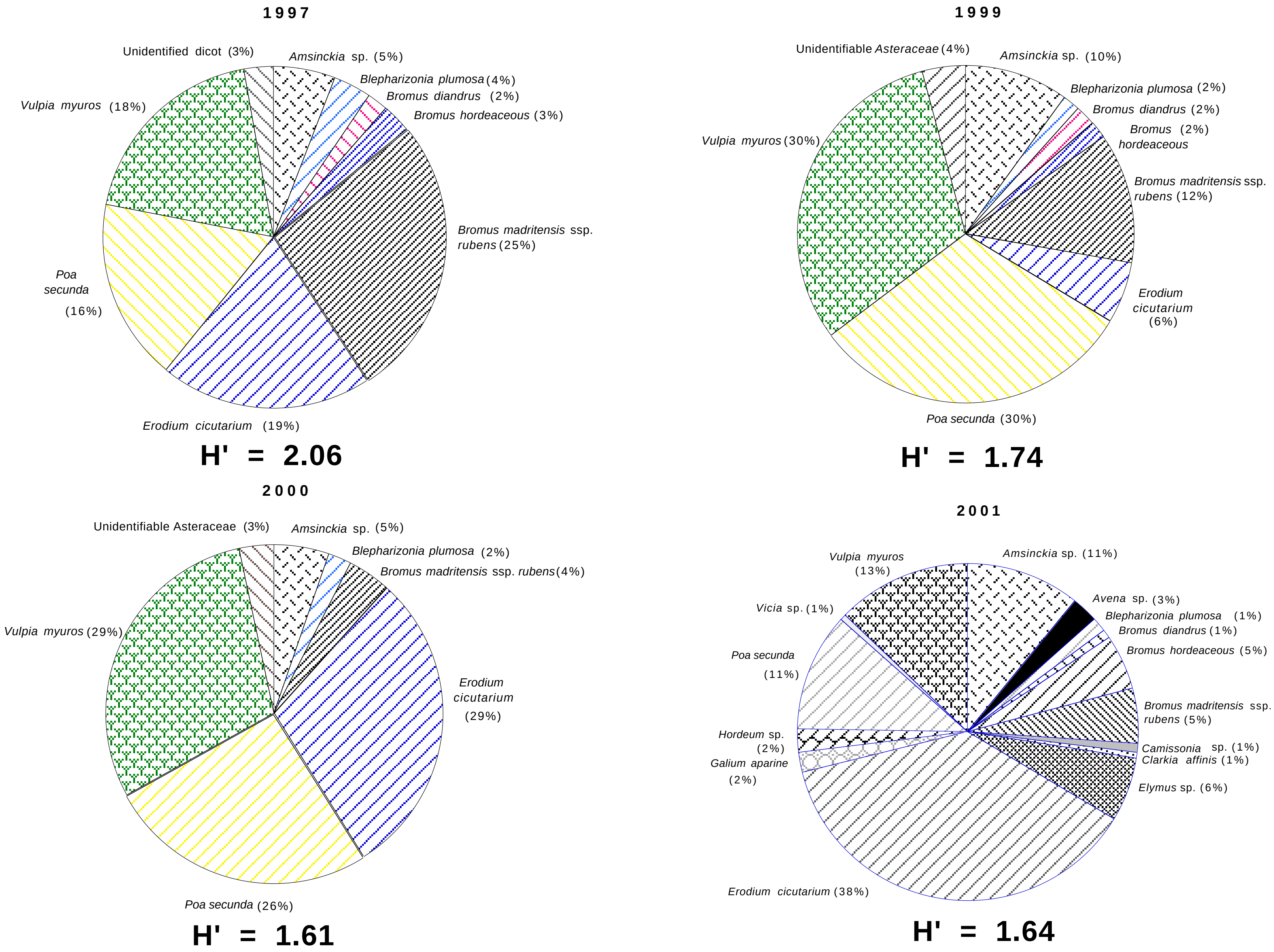


Figure B6. Species composition of *Blepharizonia plumosa* nearest neighbors at Elk Ravine: 1997* and 1999–2001. Shannon's diversity index (Shannon and Weaver 1949), H', for each year is also shown. *1997 data are cover estimates normalized for comparison.

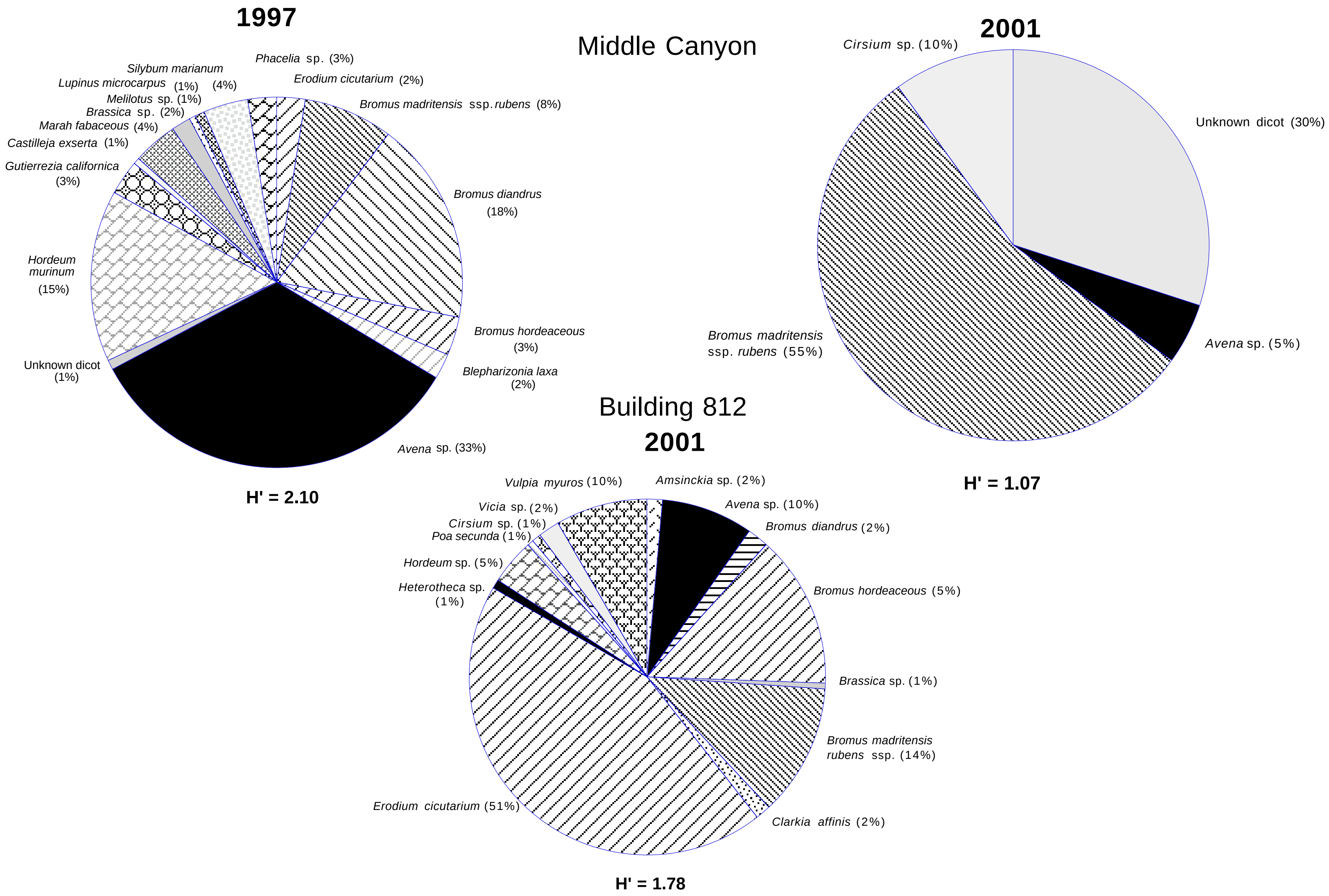


Figure B7. Nearest neighbor composition of *B. laxa* populations at Middle Canyon and B812.

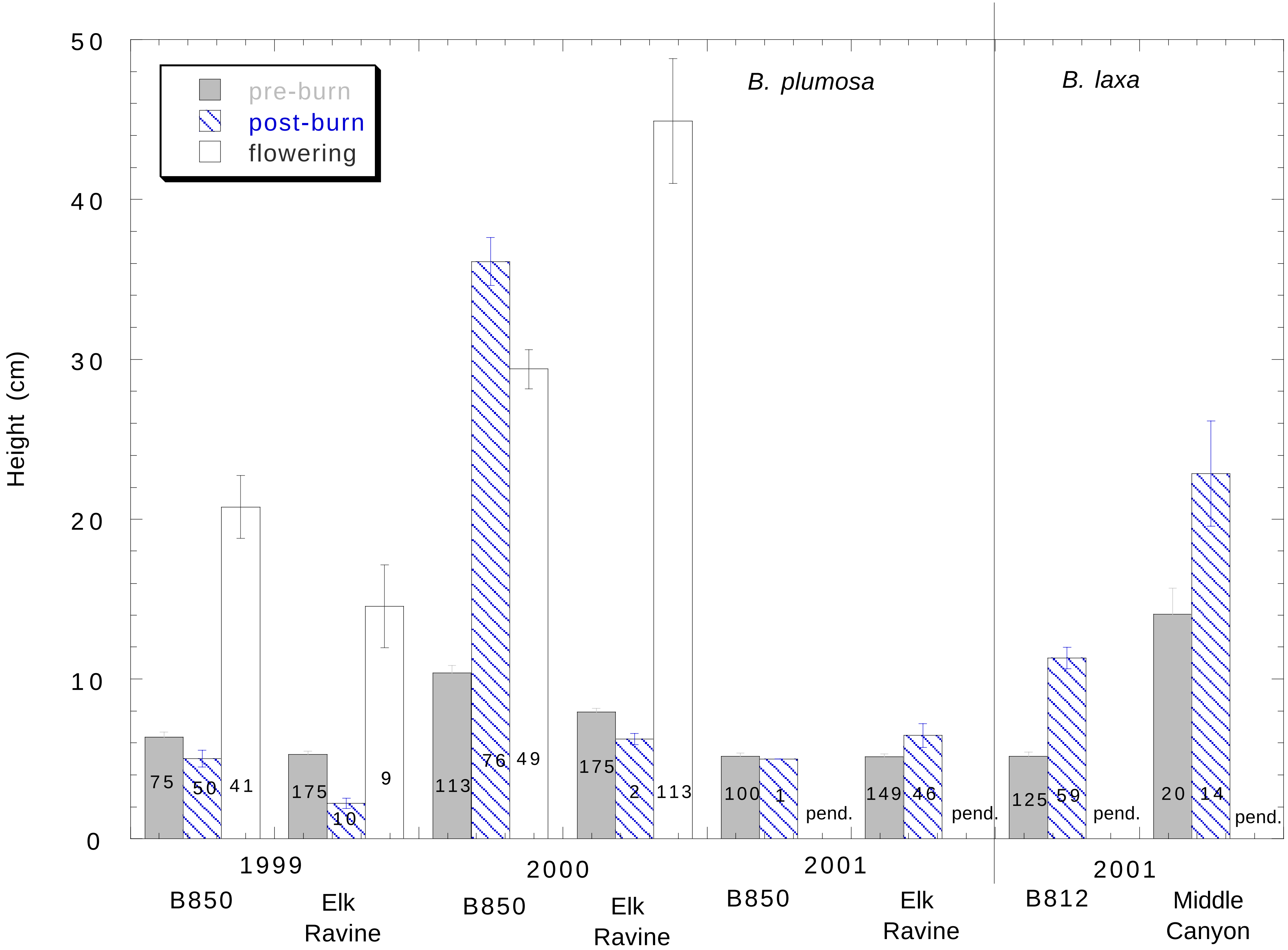


Figure B8. Mean height of *B. plumosa* and *B. laxa* pre-burn census, post-burn census and flowering census: 1999-2001. Numbers in columns are n. Bars are one standard error.

Section B
Tables

Table B1. Habitat characteristics of monitored *B. plumosa* and *B. laxa* populations at Site 300.

Population	Number of plants in 1996	Synecology	Elev. (ft)	Aspect	Slope (%)	Soil type	Management practices
B834 Berm **(*B. 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**
Elk Ravine[a] **(*B. plumosa*)**	**500–1500**	**exotic annual – native perennial mixed grassland, *Bromus hordeaceus*, *B. diandrus*, *Amsinckia intermedia*, *B. madritensis* ssp. *rubens*, *Poa secunda*. *Grindelia camporum*. Stands of *Leymus triticoides* along drainage route.**	**≈700**	**north**	**50–75**	**sandy to clay loam, Wisflat-Arburua-San Timoteo complex**	**annually burned**
B850 **(*B. plumosa*)**	**≈100**	**disturbed annual grass-land, *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**
B812 **(*B. plumosa* and *B. laxa*)**	**100–700**	**disturbed annual grassland, wetland herbaceous community in drainage, *Poa secunda* grasses on adjacent slopes**	**≈700**	**south**	**50–75**	**sandy to clay loam, Wisflat-Arburua-San Timoteo complex**	**annually burned**
Middle Canyon **(*B. laxa*)**	**not determined**	**exotic annual grassland, *Avena* sp., *Bromus diandrus*, *B. madritensis* ssp. *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**

Adapted from Preston (1996).

[a] **Known as B834 Drainage in Preston (1996).**

Table B2. Survivorship of plants marked prior to the burn 1998–2001 at B850 and Elk Ravine; B812 and Middle Canyon survivorship for 2001 only.

Year	Population	Species	N	Post-burn survivorship (%)[a]	Survivorship (%) burned area[b]	Survivorship (%) unburned area[c]	Survivorship (%) post-burn to flowering[d]	n in burned area	n in unburned area	n surveyed at flowering[e]
1998[f]	B850	*B. plumosa*	1681	25	–	–	13	ND	ND	414
	Elk Ravine		284	0	–	–	–	ND	ND	0
1999[f]	B850	*B. plumosa*	64	9	–	–	56	ND	ND	41
	Elk Ravine		169	3	–	–	0	ND	ND	4
2000	B850	*B. plumosa*	104	20	8	76	59	87	17	17
	Elk Ravine		170	1	0	50	44	168	2	9
2001	B850	*B. plumosa*	100	0	0	–	pend.	100	0	pend.
	Elk Ravine		146	32	0	96	pend.	98	48	pend.
	B812	*B. laxa*	110	39	0	40	pend.	4	106	pend.
	Middle Canyon		19	75	NA	75	pend.	NA	19	pend.

Notes:

n = Number of plants.

ND = No data.

pend. = Pending Fall 2001 survey.

NA = Not applicable (population unburned).

[a] **Number of surviving plants/n.**

[b] **Number of surviving plants in burned area/n in burned area.**

[c] **Number of surviving plants in unburned area/n in unburned area.**

[d] **Number of marked, flowering plants/total number of markers remaining post-burn. For 1998, all plants were counted at each survey date (1681 were counted pre-burn, 414 were counted post-burn, 52 were counted at flowering).**

[e] **Number of markers counted at flowering (markers sometimes supplemented after post-burn census).**

[f] **Survivorship reported for these years in Carlsen et al., 2001 have been corrected.**

Table B3. Burn data for B850 and Elk Ravine: 1997–2001, plus B812 in 2001. Wind speed, temperature, and relative humidity are average values reported for each date.

Building 850	1997	1998	1999	2000	2001
date of burn	6 June	14 June	10 June	18 July	7 July
temperature (°F)	74	73	68	73	76
wind speed (mph)	20	12	16	15	7
relative humidity (%)	32.94	50.12	30.45	36.13	40.77

Elk Ravine	1997	1998	1999	2000	2001
date of burn	16 May	30 May	1 June	12 July	7 June
temperature (°F)	79	58	57	72	79
wind speed (mph)	9	12	13	17	16
relative humidity (%)	35.03	66.07	64.88	43.72	25.16

Building 812	1997	1998	1999	2000	2001
date of burn	–	–	–	–	6 July
temperature (°F)	–	–	–	–	81
wind speed (mph)	–	–	–	–	10
relative humidity (%)	–	–	–	–	26.04

Note:

– = Not applicable.

Table B4. Germination in pots. n=5.

Year	Morph	% germination burned[a]	St. dev.	% germination control[a]	St. dev.
1996	Disc	2.2 (1)	5.0	0	0
	Ray	1.5 (1)	3.4	0	0
1998	Disc	10.8 (7)	10.3	40.9 (29)	20
	Ray	1.5 (1)	3.4	0	0

Note:

St. dev. = Standard deviation.

[a] **When germination occurred, total number of seeds germinated shown in parentheses.**

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 (Preston, 2000). *Eschscholzia rhombipetala* is an extremely rare spring-flowering annual plant, formerly included on the California Native Plant Society (CNPS) List 1A (Skinner and Pavlik, 1994). The CNPS List 1A includes plants that are presumed extinct. At that time, 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 (Keil, 2001). This population was seen again in 1995 but has not been seen since. At this location, they grow on heavy clay soils that accumulate water in the spring, forming vernal pools. The poppies grow in an ecotone on the higher areas between an *Amsinckia*-dominated mound and a *Layia*-dominated swale, in open patches. They grow as almost an understory to the taller *Lasthenia*, *Phacelia*, and various grasses (Clark, 2000).

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 *Blepharizonia plumosa* and *Blepharizonia laxa*. As a result of the recent discoveries at the Carrizo Plain and Site 300, the CNPS has placed *E. rhombipetala* on its List 1B, R-E-O code 3-3-3, similar to *B. plumosa* (see Section B-1) (Tibor, 2001).

Eschscholzia 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 30 March 01. On this date, a total of 189 plants were censused. 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, or in the interior grassland, more than a meter from the scarp edge) was recorded. Tukey's separation of means was performed on plant height and flower, bud and capsule number data.

C-2.2. Releve Sampling

On 30 March 01, the cover and composition of species in the *E. rhombipetala* population area were recorded using the releve sampling technique (Taylor and Davilla, 1986). The sampling technique in 2001 was different from sampling performed in 1999–2000. In 1999 and 2000, releves were sampled by visually identifying areas with similar vegetation characteristics and collecting cover and vegetation height data from two 60 cm × 60 cm quadrats from each area (Carlsen et al., 2001). In 2001, 60 cm × 60 cm quadrats were placed around 34 clusters of *E. rhombipetala,* and cover and vegetation height were recorded. Then, the slump area was gridded, and locations of 25 additional (non-*E. rhombipetala*) releves were chosen randomly within the grid. Areas with differing dominant species were also mapped in and around the slump.

C-2.2.1. Data Analysis

Releve data were analyzed by calculating constancy, mean cover and Importance Value for each species. Releves containing *E. rhombipetala* were analyzed separately from releves without *E. rhombipetala*. 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.

C-3. Results and Discussion

C-3.1. Census

Plants are typically small, with average heights ranging from 5 to 7.5 cm (Table C1). Plants as small as 1 cm were observed flowering this year and the largest plant recorded in this population, approximately 14 cm tall, also occurred this year. Most plants have only one flower open at a time, but plants with dehisced capsules usually have several per plant. Plants were found in more northern parts of the slump, where they had not been observed before (Figure C2).

Topographic feature had an effect on plant height and the number of reproductive units (buds + flowers + capsules) per plant. Plants were tallest in the grassland (Figure C3). In 2000, plants in the slump and in the grassland were equally tall, but in 2001, grassland plants were the tallest and slump plants were the smallest. Plant heights were more similar among the three areas in 2001. In 2000, plants were fairly evenly distributed among the three types of topography. In 2001, plants were skewed away from the grassland and on to the scarp. *Eschscholzia rhombipetala* plants had the most reproductive units in the grassland, compared to the slump and scarp (Figure C4). Grassland plants averaged over 1.2 reproductive units/plant in 2001 and the more numerous plants in the grassland in 2000 averaged only about 0.8 units/plant. The average number of reproductive units/plant differed by less than 0.2 in the scarp and the slump between years. In both 2000 and 2001, scarp plants had the fewest reproductive units.

C-3.2. Releve Sampling

Figures C5 and C6 show the dominant vegetation types mapped visually in the *E. rhombipetala* population area for 1999–2001. In 1999 and 2000, *Bromus diandrus* had at least a few areas where it appeared to have the most cover (Figure C5). *Avena* appeared to be the dominant grass in almost all areas this year, except in a few locations where *Poa secunda* was dominant (Figure C6). The line across the southern grassland area, where one grass type changes into another, has occurred in each year. The northern grassland area does not appear to be broken from east to west in any year.

Avena and *Bromus diandrus* were important grasses in both *E. rhombipetala* releves and non-*E. rhombipetala* releves (Tables C2 and C3). *Erodium cicutarium* and *Monolopia major* were important forbs in both releve types. Differences between the releve types include the high importance of *Bromus hordeaceous* in non-*E. rhombipetala* releves (I.V. 0.69), but low importance in *E. rhombipetala* releves (I.V. 0.17). *Brassica* sp. was also more important in non-*E. rhombipetala* releves (I.V. 0.38) than *E. rhombipetala* releves (I.V. 0.11). Five California native forb species were observed in *E. rhombipetala* releves (Table C2), compared to eight species in non-*E. rhombipetala* releves (Table C3). The same grass species were found in both releve types, but in different distributions. *Vulpia myros* was more important in *E. rhombipetala* releves (I.V. 0.19) than non-*E. rhombipetala* releves (I.V. 0.06).

The diversity of California native forbs observed over all releves in 2001 was comparable to that found in 2000. Ten native forbs were observed in the releves in 2001, compared to eleven native forbs in 2000 and six in 1999.

C-4. Recommendations and Future Work

The yearly census of *E. rhombipetala* has shown a wide range in population size, from a low of 9 to a high of 273 individuals. This is typical of small, annual plant populations. We have observed differences in community composition over the years and also differences between years in the effect of geographical location (slump versus scarp versus grassland) on plant vigor. It appears that the variety of topography within the population area may be important for population maintenance when rainfall pattern and competitor interactions change between years. We will continue to collect releve and census data to attempt to determine how the interactions of other plant competitors, topography and climatic factors affect *E. rhombipetala* vigor and abundance.

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*. We will maintain 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 when it re-occurs. These exchanges of information will enhance our ability to manage the Site 300 *E. rhombipetala* population.

C-5. References

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Section C
Figures

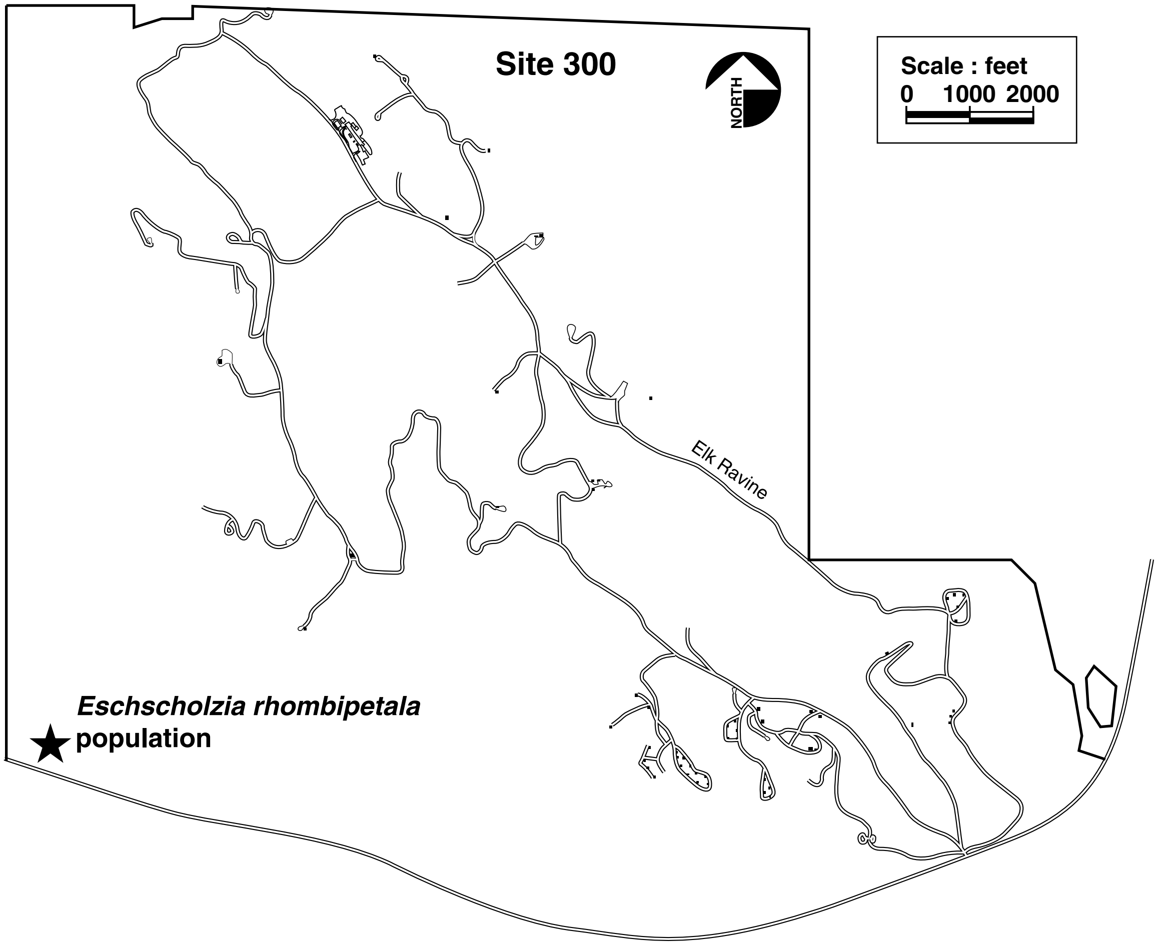

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Figure C1. ***Eschscholzia rhombipetala*** **population location map LLNL Site 300.**

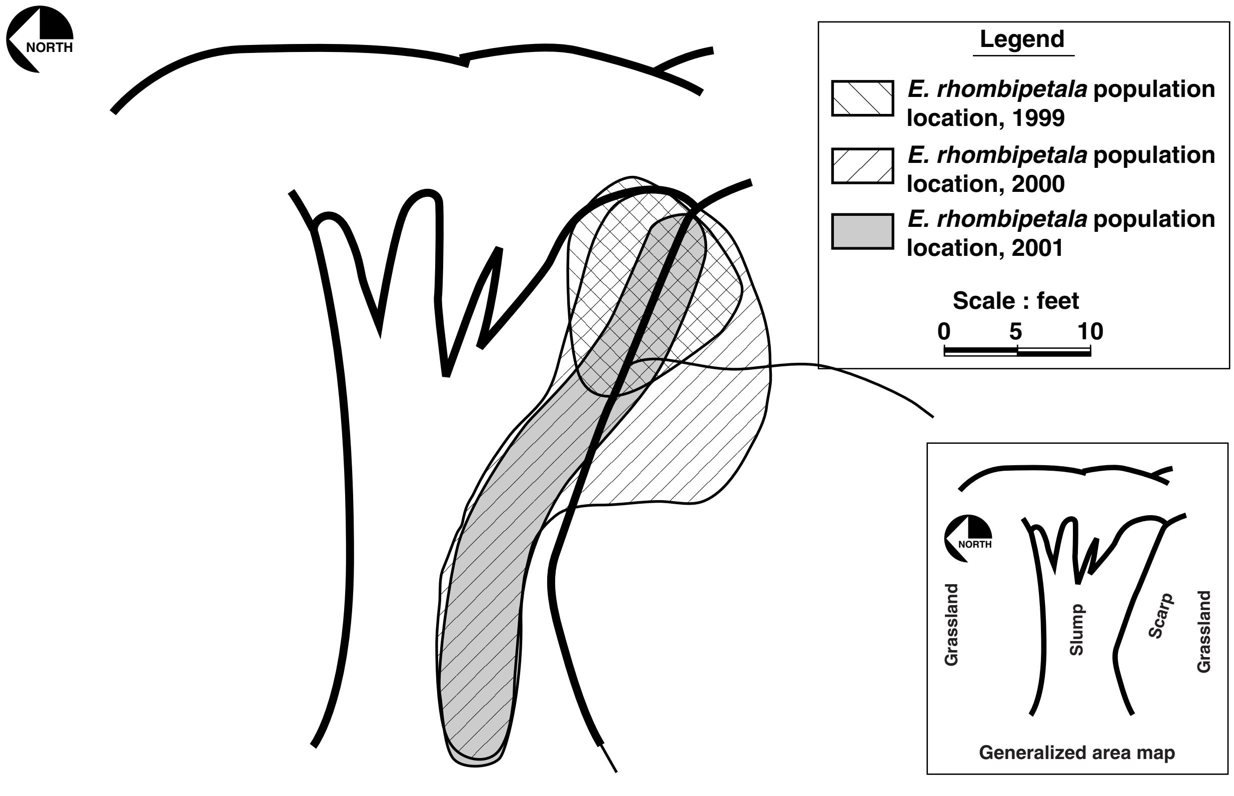

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Figure C2. ***E. rhombipetala*** **population location 1999 – 2001.**

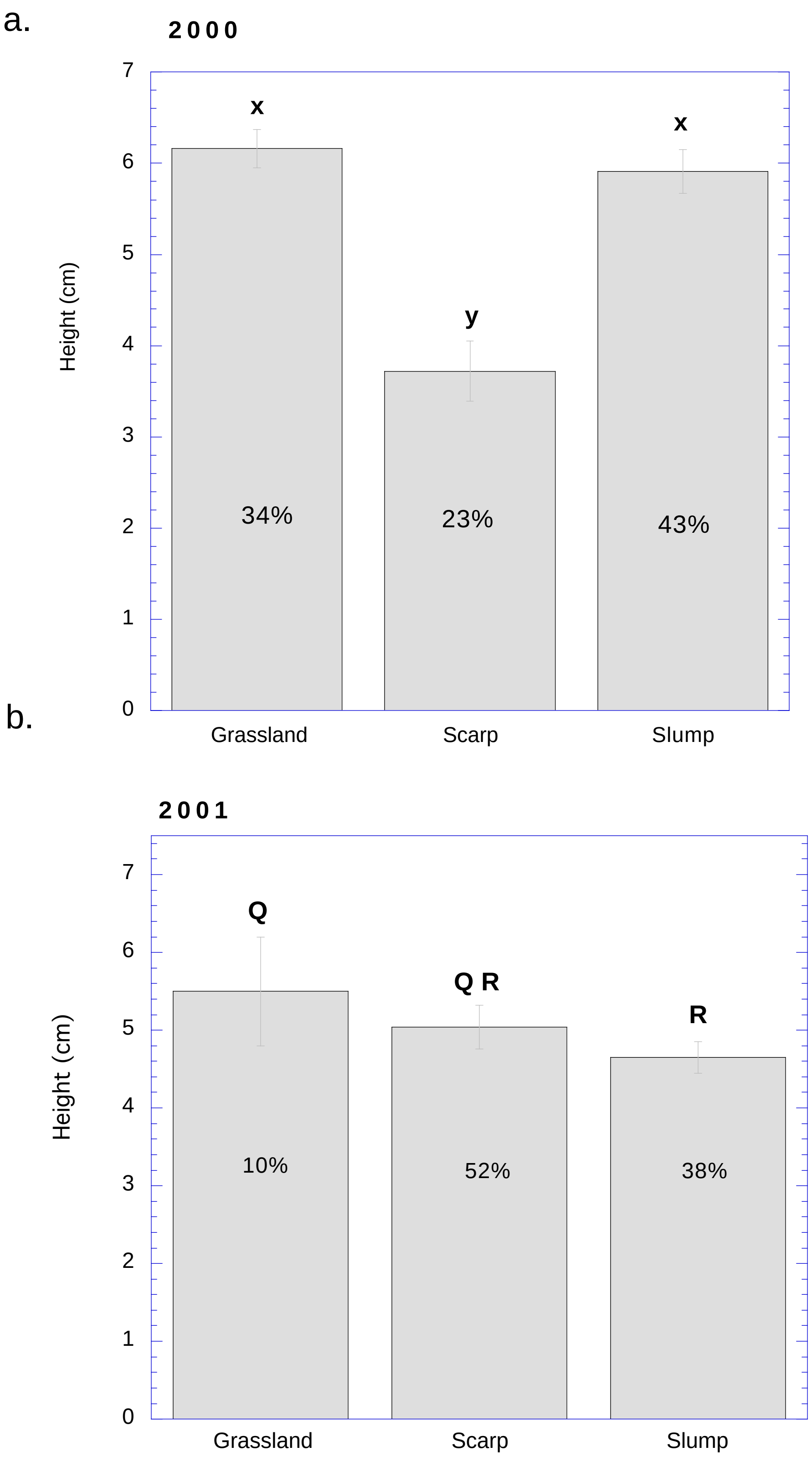

Figure C3. Height of *E. rhombipetala* plants by geographic location: a) 2000, b) 2001. Percent of plants found in each area are shown. Different letters indicate differences between cover types ($p < 0.05$). Bars are one standard error.

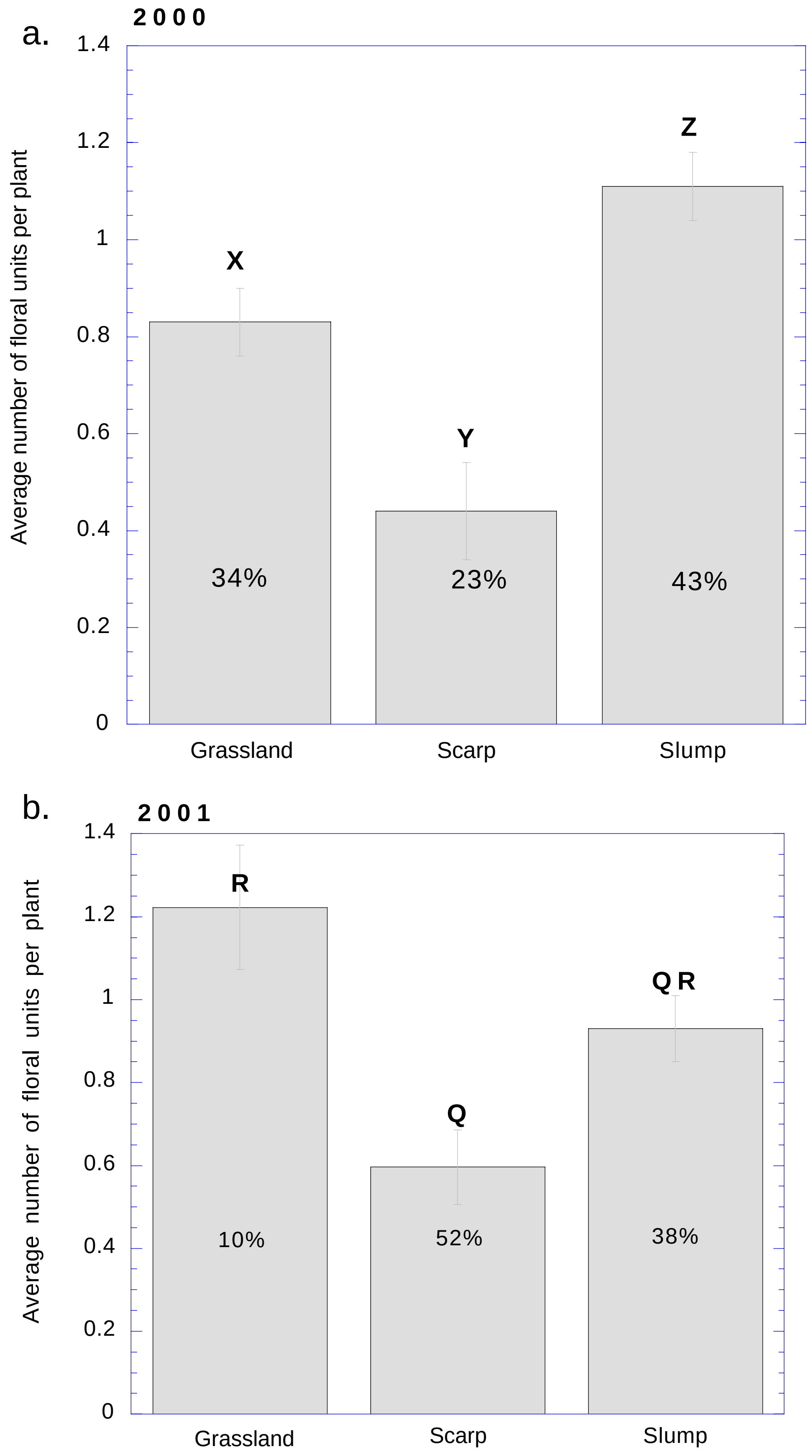

Figure C4. Number of reproductive units (buds + flowers + capsules) of *E. rhombipetala* plants by geographic location: a) 2000, b) 2001. Percent of plants found in each area are shown. Different letters indicate differences between cover types ($p < 0.05$). Bars are one standard error.

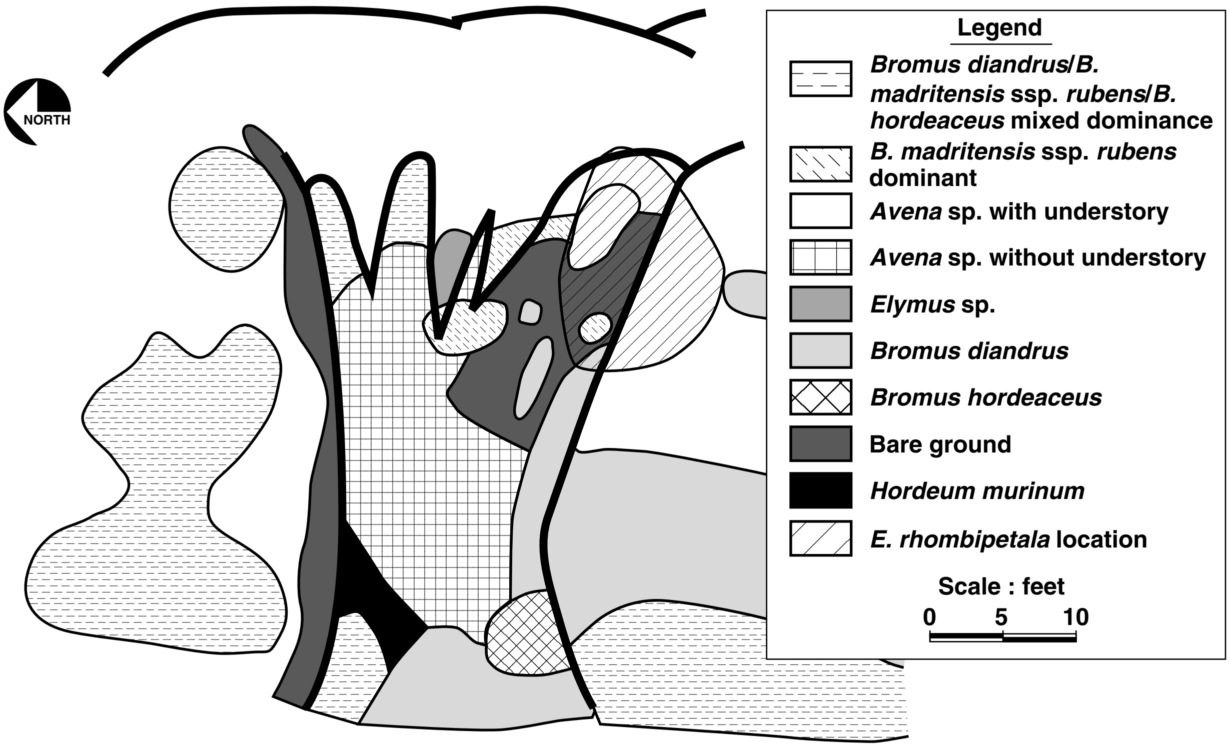

Figure C5a. Dominant vegetation type and *E. rhombipetala* location: 1999.

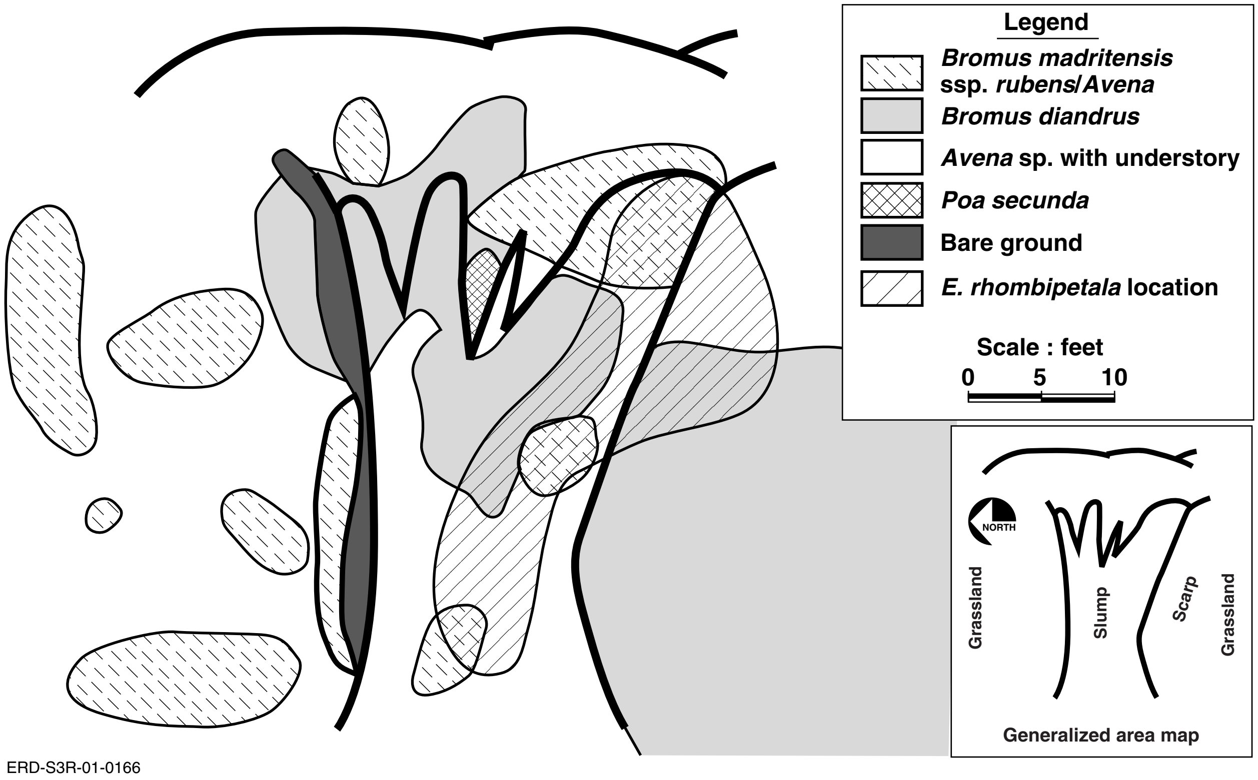

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Figure C5b. Dominant vegetation type and *E. rhombipetala* location: 2000.

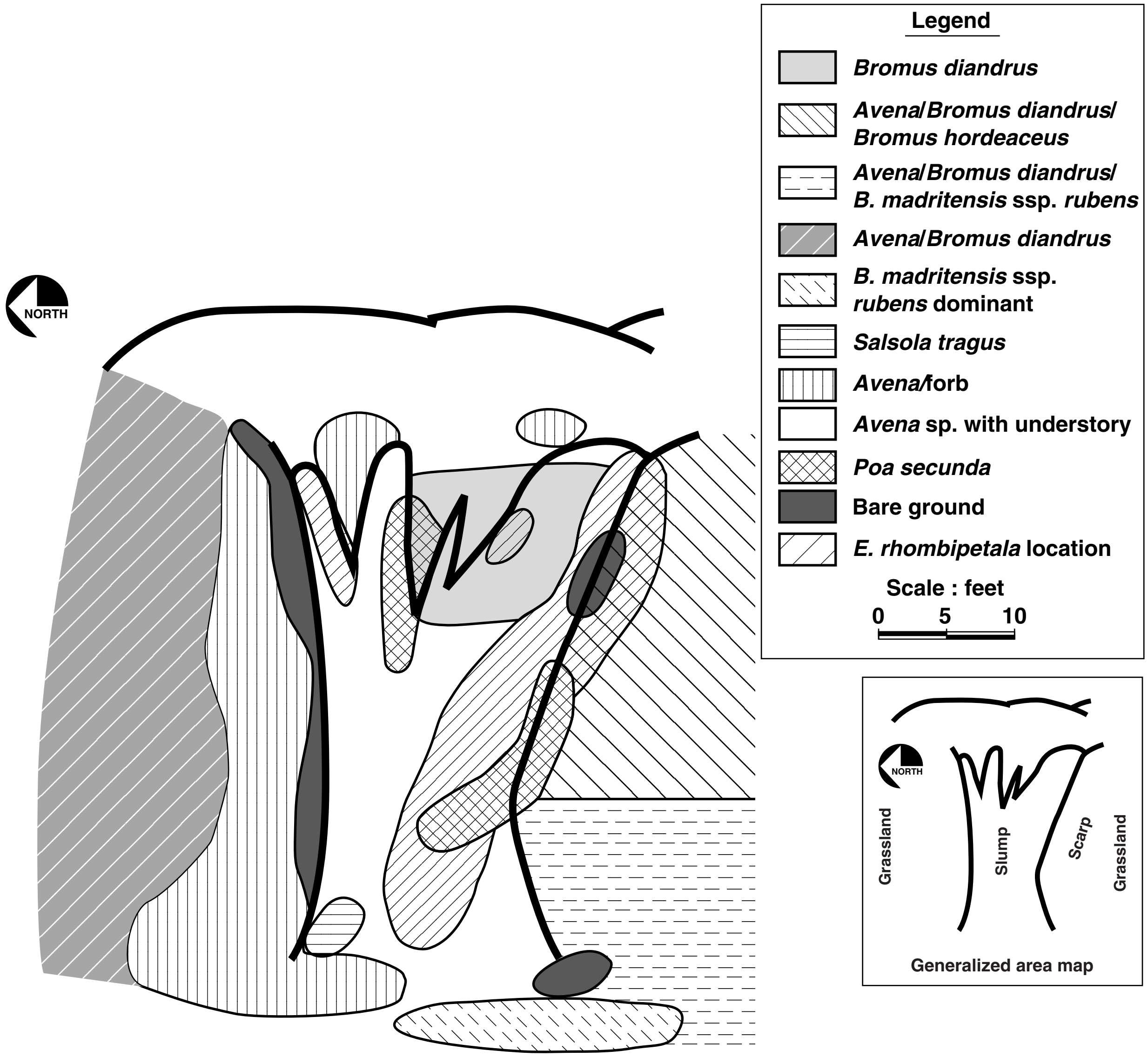

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Figure C6. Dominant vegetation type and *E. rhombipetala* location: 2001.

Section C
Tables

Table C1. Height, number of flowers per plant and capsule length for marked *E. rhombipetala* plants: 1998–2001. All averages are ± one standard deviation.

Date measured	Height (cm)	No. of flowers/plant	n[a]	Capsule length (cm)	n[b]	Population size (no. of plants)
8 Apr 98	7.5 ± 2.8	0.4 ± 0.5	24	2.8 ±1.4	16	24
30 Apr 99	6.0 ± 1.8	0.7 ± 0.7	9	2.1 ± 0.6	6	9
24 Mar 00	5.5 ± 2.1	0.6 ± 0.5	171	2.3 ± 1.4	44	273
30 Mar 01	5.0 ± 2.5	0.3 ± 0.5	189	2.8 ±1.8	72	189

[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.

Table C2. Ranked constancy, mean cover, and importance value for releves containing *E. rhombipetala*: 2001 (n=34).

Species (bold = native)	Constancy	Cover	SE	IV
Avena sp. (g)	91.18	20.84	1.84	1.12
Eschscholzia rhombipetala (f)	100.00	5.00	0.00	1.05
Bromus diandrus (g)	58.82	18.35	1.62	0.77
Erodium cicutarium (f)	52.94	7.28	0.85	0.60
Galium aparine **(f)**	29.41	3.60	0.34	0.33
Sonchus sp. (f)	26.47	4.11	0.46	0.31
Vicia sp. (f)	23.53	5.88	0.83	0.29
Monolopia major (f)	20.59	3.57	0.10	0.24
Trifolium **sp.** (f)	14.71	6.20	0.46	0.21
Bromus madritensis ssp. *rubens* (g)	11.76	8.75	0.33	0.21
Vulpia myuros (g)	11.76	7.50	0.81	0.19
Poa secunda (g)	11.76	7.00	0.70	0.19
Bromus hordeaceus (g)	11.76	5.00	0.44	0.17
Brassica sp. (f)	5.88	5.00	0.00	0.11
Blepharizonia plumosa (f)	5.88	2.50	0.09	0.08
Amsinckia intermedia (f)	2.94	4.00	na	0.07
Lupinus microcarpus (f)	2.94	2.00	na	0.05

Notes:

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

Vicia **sp. probably misidentified; most likely** ***Lotus wrangellianus.***

SE = Standard error.
IV = Importance values.
f = Forb.
g = Grass.
na = Not applicable.

Table C3. Ranked constancy, mean cover, and importance value for releves not containing *E. rhombipetala*: 2001 (n= 25).

Species (bold = native)	Constancy	Cover	SE	IV
Avena sp. *(g)*	**96.00**	**36.17**	**2.45**	**1.32**
Bromus diandrus (g)	**80.00**	**23.70**	**2.21**	**1.04**
Bromus hordeaceus (g)	**56.00**	**13.21**	**1.37**	**0.69**
Brassica sp. (f)	**8.00**	**30.00**	**2.79**	**0.38**
Erodium cicutarium (f)	**32.00**	**5.63**	**0.37**	**0.38**
Monolopia major (f)	**28.00**	**7.00**	**0.81**	**0.35**
Bromus madritensis ssp. *rubens* (g)	**20.00**	**11.00**	**0.86**	**0.31**
Poa secunda (g)	**16.00**	**12.25**	**0.90**	**0.28**
Vicia sp. (f)	**16.00**	**12.25**	**1.65**	**0.28**
***Galium aparine* (f)**	**12.00**	**14.67**	**1.38**	**0.27**
Lupinus microcarpus (f)	**16.00**	**5.25**	**0.43**	**0.21**
***Trifolium* sp.** (f)	**16.00**	**3.75**	**0.07**	**0.20**
Unknown forb (f)	**12.00**	**4.33**	**0.15**	**0.16**
Claytonia parviflora (f)	**12.00**	**3.67**	**0.20**	**0.16**
Sonchus sp. (f)	**12.00**	**3.67**	**0.20**	**0.16**
Amsinckia intermedia (f)	**8.00**	**7.50**	**0.46**	**0.16**
Plantago sp. (f)	**4.00**	**10.00**	**na**	**0.14**
Lupinus bicolor (f)	**8.00**	**4.00**	**0.19**	**0.12**
Blepharizonia plumosa (f)	**4.00**	**4.00**	**na**	**0.08**
Brodiaea elegans (f)	**4.00**	**3.00**	**na**	**0.07**
Dichelostemma capitata (f)	**4.00**	**3.00**	**na**	**0.07**
Vulpia myuros (g)	**0.04**	**0.02**	**na**	**0.06**

Notes:

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

***Vicia* sp. probably misidentified; most likely *Lotus wrangellianus*.**

SE = Standard error.
IV = Importance values.
f = Forb.
g = Grass.
na = Not applicable.