# Tales of Success and Failure: Trends in Natural and Reintroduced Populations of *Amsinckia grandiflora* Under Different Management Regimes

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## Abstract

The present study is part of an ongoing recovery effort for *Amsinckia grandiflora* , emphasizing the creation, enhancement, and evaluation of self-sustaining populations. The specific objectives included; 1) evaluation of the five-year-old reintroduced population at Lougher Ridge under an "enhanced" (manipulated) management regime, 2) ongoing monitoring of the natural populations, and 3) fourth year evaluation of the reintroduced populations at Black Diamond II, Los Vaqueros I, Connolly Ranch, and Corral Hollow.

The reintroduced population of *Amsinckia grandiflora* at Lougher Ridge was comprised of 1106 reproductive plants in 1994, an increase of 62 % since 1993. High nutlet production in previous years, combined with low cover by annual grasses, were largely responsible for the increase. Low rainfall, however, constrained plant growth, which led to relatively low fecundity; only 16,590 nutlets were produced, a decrease of 64 % compared to the number produced in 1993. The potential for continued growth and self-maintenance of the population remains high, although continued fluctations in population size and fecundity are expected in the future.

The natural Droptower population at Site 300 consisted of 1606 reproductive individuals in April of 1994, an increase of 384 % since the previous year. Thus, the increased potential for population growth brought on by habitat management during 1992-93 and 1993-1994 was realized. As observed at Lougher Ridge, nutlet production in 1994 was constrained by the lack of rainfall, but the data strongly suggest that the Droptower population has considerable resilience when habitat manipulations are conducted for purposes of recovery. Variations in important environmental variables (e.g. rainfall, temperature) will still cause fluctuations in population size and reproductive output. The size of the untreated, natural population in Draney Canyon declined to 13 plants and plant size decreased, indicating that management intervention is justified.

Despite the use of small-scale, controlled burns to enhance conditions for growth, the reintroduced Black Diamond II, Los Vaqueros I, and Connolly Ranch populations all declined in 1993-94, with no reproductive plants found at the first two sites. Disturbance by gophers probably increased mortality of established plants and kangaroo rats

(probably *Dipodomys heermanni* ) cleared large patches of plant cover by chewing off the stems of grasses and forbs alike (including *A. grandiflora* ). The latter created areas around the openings of burrows that were 40-80% bare and probably used to forage for seeds. Although it is only speculation at this time, stem clipping and seed collection by kangaroo rats may be having a large impact on some populations of *A. grandiflora* . A study of nutlet mortality with respect to nocturnal rodents might help explain the unexpected decline of *A. grandiflora* at Connolly Ranch, and provide data for demographic simulation models (e.g. RAMAS/stage). Live trapping and fecal analysis are also recommended, perhaps comparing rodent densities and diets at this site to those at the new, natural population, the Droptower, or Lougher Ridge (where rodent activity has had minor impacts).

The original population reintroduced to Corral Hollow during 1991-1992 increased, but the surviving plants were small with low nutlet production (again attributed to extremely low rainfall). Additional plants were contributed by precision-sown plots, so that the total for spring 1994 was 157 reproductive plants. However, this population also experienced a considerable amount of rodent distrubance during the late spring. High mortality of seeds due to predation by kangaroo rats, combined with low nutlet production, will very likely decrease the size of the Corral Hollow population during 1994-1995.

The newly-discovered population east of Connolly Ranch decreased in size and extent in 1993-1994, although plants still number in the thousands. As at other sites across the range of the species, mean size and mean maximum size decreased significantly as the result of low rainfall and a contracted period of flower and fruit production (especially when compared to 1992-1993). A bulk collection of nutlets was made for conservation purposes.

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# Tales of Success and Failure: Trends in Natural and Reintroduced Populations of *Amsinckia grandiflora* Under Different Management Regimes

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The recovery of endangered plants requires the creation of new, self-sustaining populations within historic range and the enhancement of natural populations *in situ* (Pavlik 1994a). In the case of *Amsinckia grandiflora* Kleeb. ex Gray, new, reintroduced populations and enhanced natural populations are required by the draft recovery plan (U.S. Fish and Wildlife Service). The present study is part of an ongoing recovery effort for the species (Pavlik 1988, Pavlik and Hiesler 1988, Pavlik 1990, 1991a, 1991b, 1992, Pavlik et al. 1993, Pavlik 1993) that emphasizes the creation, enhancement, and evaluation of self-sustaining populations.

The specific objectives of the present study included; 1) evaluation of the five-year-old reintroduced population at Lougher Ridge under an enhanced (manipulated) management regime, 2) ongoing monitoring of the natural, managed populations at the Droptower on Site 300, and the newly-discovered, natural population in Carnegie Canyon, and 3) fourth year evaluation of the reintroduced populations at Black Diamond II, Los Vaqueros I, Connolly Ranch, and Corral Hollow.

## Methods and Materials

Evaluating the Reintroduced Population at Lougher Ridge

The Lougher Ridge population was manipulated to reduce annual grass competition during 1993-94, allowing evaluation of its performance under an "enhanced", fifth year management regime. Light, patchy application of a 1/10th strength, grass-specific herbicide (Fusilade) was made on 29 December 1993, centered on the 20 original treatment plots of the 1989-90 reintroduction (Pavlik 1990). *Amsinckia* seedlings were observed at that time and the annual grasses were dense and between 8 and 12 cm tall. Just enough spray was used to wet the annual grass leaves and native, perennial grasses (e.g. *Leymus* ) were avoided.

The site was inspected on 15 October, 21 October, 29 December 1993, and 3 March 1994 to observe seedlings, record phenology, read the raingauge and to fix the fence . Census of the population took place on 14 April 1994, when *Amsinckia* plants were robust (10-45 cm tall) and at the peak of floral display. Each of the 20 treatment plots from 1989-1990 (see Figure 2, Pavlik 1991b) served as a reference for counting plants, since it appeared that most nutlets did not disperse far from their place of origin. All plants within a 2 X 2 m area centered on each treatment plot were counted as progeny of the previous generation that originated in that particular plot. Plants that grew between the 2 X 2 m areas were counted as part of the census but their origins were not assigned to plots. Finally, outlying plants that dispersed and grew beyond the fenced area were tallied according to floral morph (pin or thrum) and their heights measured. The distance of each outlier to the fence was also determined.

In order to estimate nutlet production of the 1993-94 population, 100 plants were randomly selected and measured for shoot length on 14 April. Two reference stakes were located *a priori* in each half of the area (= 4 stakes total). A random numbers table was used to generate 25 compass bearings off of each stake (0 to 360$^{o}$) and 25 distances in centimeters (0 to 400 cm). The plant nearest to a point described by each pair of bearing-distance coordinates had its shoot length measured and its floral morph (pin/thrum) determined. Shoot length was translated into nutlet output per plant using a new correlation developed from plants growing at Lougher Ridge in 1992 (Pavlik 1992). Methods for determining the relationship between nutlet output and shoot length and estimating nutlet production of the population as a whole are described in Pavlik (1990, 1991a).

<u>Evaluating the Natural Populations at Site 300</u>

The Droptower population at Site 300 was manipulated to reduce competition with annual grasses during 1993-1994. Light, patchy application of a 1/10th strength, grass-specific herbicide (Fusilade) was made on 10 January 1994, centered on five subpopulation patches (a, b, f, d, and e) that typically support large numbers of plants (the same five described by Pavlik 1991b). Several other patches were left untreated. *Amsinckia* seedlings were observed at this time and the annual grasses were sparse and between 5 and 8 cm tall. Just enough spray was used to wet the annual grass leaves and native, perennial grasses (e.g. *Poa* ) were avoided.

The Droptower site was inspected on 10 January and 10 March 1994. A census was conducted on 7 April and included total population size, pin/thrum ratio, and spatial distribution. In order to estimate nutlet production and to determine the effects of controlling annual grasses on plant growth, 92 plants were randomly selected and measured for shoot length. Four reference stakes were located *a priori* near the top and bottom of the fenced area (two towards the west side, two towards the east). At each stake a random numbers table was used to generate 25 compass bearings (0 to 360$^{o}$) and 25 distances in centimeters (0 to 400 cm). The plant nearest to a point described by each pair of bearing-distance coordinates had its shoot length measured and its floral morph (pin/thrum) determined. Shoot length was translated into nutlet output per plant using the equation developed at Connolly Ranch in 1991 (#nutlets/plant = 3.42 (shoot length in cm) - 65.46, $r = 0.86$ $P<0.01$, Pavlik 1991a).

The Draney Canyon population at Site 300 was censused on 19 April 1994. Every plant was counted, measured for shoot length, and recorded as to floral morph. Never having been treated with herbicide, this population serves as a control for comparisons with the Droptower population.

Evaluating Reintroduced Populations at Black Diamond II, Los Vaqueros I, Connolly Ranch and Corral Hollow

In the fourth year after reintroduction, the Black Diamond II, Los Vaqueros I and Connolly Ranch populations were managed to minimize competition from annual grasses. Controlled burns were respectively conducted on 19 September, 24 October, and 15 October, prior to the onset of major winter rains. The sheetmetal "burnbox" described in Pavlik (1990, 1991b) was used to burn 2m X 2m patches, centered around the 12 original reintroduction treatment plots within the fenced area at each microsite. Additional patches were also burned so that 60-75% of each fenced area received treatment.

These sites were periodically visited during the late winter and spring to observe plants, check rain gauges, and tighten fences. Final census of the Connolly Ranch (CR) site was conducted on 12 April and included total population size, pin/thrum ratio, and spatial distribution. In order to estimate nutlet production and to determine the effects of controlling annual grasses on plant growth, all flowering plants were measured for shoot length and branching. Shoot length was translated into nutlet output per plant using the equation developed at CR in 1991 (#nutlets/plant = 3.42 (shoot length in cm) - 65.46, $r = 0.86$, $P<0.01$, Pavlik 1991a). Final census of the Black Diamond II (BD II) and Los Vaqueros (LV) sites was conducted on 21 April. The same parameters were recorded for those populations, except that shoot length and this was converted to nutlet output using the appropriate 1991 equation (at BD II: #nutlets/plant = 5.61 (shoot length in cm) - 93.14, r = 0.85, P<0.01; and at LV: #nutlets/plant = 0.92 (shoot length in cm) - 3.64, r = 0.64, P<0.05, Pavlik 1991a).

The plots at Corral Hollow were not managed for annual grass competition in 1993-1994. However, six precision-sown plots of 100 nutlets each were added on 10 November 1993 to allow estimation of germination and survivorship using nutlets from two sources. Each plot was sown with 70 nutlets from the Davis 1989 source and 30 nutlets from the Carnegie Canyon 1993 source. Three plots were then burned and three were left as controls. On 10 January 1994 the burned plots were treated with a dilute solution of Fusilade (as described above) to control annual grasses during the late winter and spring. The first census of these plots was also conducted on 10 January 1994, with additional censuses on 10 March and 12 April.

Census of the Newly Discovered Natural Population

This population was mapped, described, censused for density, pin/thrum ratio and plant size, and subsequently sampled for nutlets on 3 June 1994, after obtaining permission from the lease holder, Florence Cubiburu. It has tentatively been named the "Carnegie Canyon" population.

## Results and Discussion

### Weather Patterns and Phenology During 1993-1994

In northern California the 1 November to 31 May growing season of 1993-94 had a deficit of precipitation. Records for San Francisco, Oakland, and Sacramento indicate that rainfall was 66-75% of normal during the 1 Nov to 31 May period, with an overall regional deficit of about 28 % (compared to a 42% regional surplus during 1992-1993 and a 5-25% deficit during the previous three growing seasons). The total precipitation actually received at Lougher Ridge during the October to May period of *Amsinckia* activity was 268 mm mm, the lowest of all previous years (489 mm in 1992-83, 296 mm in 1991-1992, 271 mm in 1990-91, and 289 mm in 1989-90).

In terms of temporal pattern of precipitation, 1993-94 was very different from the previous year (Figure 1). The first significant storm dropped 13.6 mm of rain on 14-15 October. This was sufficient to initiate the germination of *Amsinckia* and the annual grasses. Additional rainfall came at fairly regular intervals until late December, but no storm brought more than 14 mm on a single day. Daily precipitation never exceeded 25 mm (about one inch), in sharp contrast to most other years of the reintroduction project (Pavlik 1992, Figure 1). Significant gaps in the arrival of these weak storms occurred between 15 December and 21 January and between 28 February and 8 April. LIght rains fell again in late April and early May, but these were received after the majority of *Amsinckia grandiflora* plants had begun to senesce and die.

The phenology of the Lougher Ridge population was closely observed during this growing season. Despite dry soil and warm air temperatures, *Amsinckia* germinated in response to the small amount of precipitiation received in mid-October. Many seedlings were observed throughout the microsite on 21 October at densities roughly in the range of 0 to 185 per $m^2$. Annual grasses had also germinated and grew vigorously at this time. By 29 December *Amsinckia* seedlings stood 2-3 cm tall in the 2-6 leaf stage (no infloresences had formed), while the surrounding grasses were dense and between 8 and 10 cm tall. It is likely, therefore, that competition between *Amsinckia* and the annual grasses was intense prior to herbicide treatment (Pavlik et al. 1993). Additional germination occurred in response to the rains of late January and February. Many *Amsinckia* plants were branched and had open flowers by 3 March (a month earlier than in 1992-93). The grass inflorescences (of *Avena, Bromus, Hordeum*) had not yet emerged from the "boot", although vegetative growth was now robust in areas that were not treated. The final census at Lougher Ridge was conducted on 14 April, two weeks earlier than last year. The plants, however, were full-grown and some calyxes contained fully formed, green nutlets. By 5 May all but 10 plants were completely senescent, with green nutlets in the upper third of each drying inflorescence.

The patterns of rainfall and *Amsinckia* phenology at other sites with natural and reintroduced populations were similar to those at Lougher Ridge. At the Droptower site, for example, fall precipitation had simltaneously initiated forb and grass germination. *Amsinckia* seedlings grew slowly, achieving the 4-6 leaf stage by 10 January without any sign of inflorescence formation. Annual grasses were 5-8 cm tall, but cover was sparse across the site. Unlike the winter of 1992-93, the mild temperatures of 1993-94 did not delay germination or significantly slow the growth of herbaceous plants. As a result, the census and measurement of plant heights in virtually all 1994 populations occurred about two weeks earlier than they did in 1992-93.

Long, wet, and mild growing seasons favor the growth of introduced annual grasses in California (Murphy 1970, George et al. 1989) and accentuate the potential for strong competition for annual forbs such as *Amsinckia* (Pavlik 1991a, Pavlik et al. 1993). Such conditions occurred in 1989-90, when it was shown that the grasses significantly increased mortality rates, decreased survivorship to reproduction, and decreased plant size and reproductive output of *Amsinckia*. The 1992-1993 growing season, although long and wet, was disrupted by drought in late fall-early winter (November to December) and freezing January temperatures that slowed the development of the annual grass canopy. The 1993-1994 season was relatively short and dry, but with early rainfall and mild temperatures that caused an overlap of growth between seedlings of *Amsinckia* and the annual grasses. It was predicted, therefore, that 1993-94 would be a year of relatively strong interspecific competition, especially where burning and herbicide treatments were not done in this or in previous years.

## Status of the Reintroduced Population at Lougher Ridge

A total of 1106 flowering plants of *Amsinckia grandiflora* were counted at Lougher Ridge on 14 April, 1994, a 62% increase from the 682 reported in 1993 (Table 1). Most plants were still found in or near the 20 original reintroduction plots, but many had become established between plots and along the access paths, giving a more continuous

Table 1. Comparison of characteristics of the Lougher Ridge population of *Amsinckia*, March or April census, 1990 - 1994.

| | **reproductive plants** | | | **population growth** | | | **pin / thrum ratio** | | |
|---|---|---|---|---|---|---|---|---|---|
| year | inside fence (# pl) | outside fence (# pl) | Σ (#pl) | inside fence (%) | outside fence (%) | Σ (%) | inside fence (dimensionless) | outside fence (dimensionless) | Σ (dimensionless) |
| 1990 | 1101 | --- | 1101 | --- | --- | --- | 1.36 | --- | 1.36 |
| 1991 | 1280 | 21 | 1301 | 16.3 | --- | 18.2 | 1.27 | 0.91 | 1.27 |
| 1992 | 1592 | 48 | 1640 | 24.4 | 128.6 | 26.1 | 0.92 | 2.61 | 0.97 |
| 1993 | 645 | 37 | 682 | -59.5 | -22.9 | -58.4 | 1.50 | 1.47 | 1.49 |
| 1994 | 1094 | 12 | 1106 | 69.5 | -67.6 | 62.2 | 1.44 | 11.00 | 1.67 |

distribution than previously observed. Most dispersal was occurring downslope and to the east, the directions favored by gravity and the prevailing westerly winds. Overall, the floral display in the eastern-most plots was fairly showy. Sampling revealed that the pin/thrum ratio was 1.44 inside the fence, but completely skewed towards pins outside the fence. This was correlated with a large decrease in the number of plants outside and increased impacts by cattle along the site perimeter.

The 1994 plants at Lougher Ridge were smaller than last year, as indicated by their mean and maximum sizes (Table 2). There was also a smaller number of plant size-classes in the 1994 population (14 classes vs. 17 in 1993, 14 in 1992 and 10 in 1991), with fewer individuals found in the largest (30- 66 cm) reproductive categories (Figure 2). There

Table 2. Plant size (length of main shoot, cm, mean ± SD) at four points within the fenced area at Lougher Ridge (n = 25 for mean, n = 10 for maximum) and for all plants outside the fence, at peak of flowering. Overall mean values for 1990 include all treatment means (Table 18, Pavlik 1990). na = data not available.

| | plant size (cm) | | | | | |
|---|---|---|---|---|---|---|
| | upper E | upper W | lower E | lower W | outside fence | overall mean |
| **mean** | | | | | | |
| 1990 | na | na | na | na | na | 21.2 |
| 1991 | 25.3 ± 5.9 | 23.8 ± 7.8 | 29.2 ± 3.6 | 26.5 ± 5.4 | 26.7 ± 7.3 | 26.3 |
| 1992 | 28.5 ± 6.0 | 30.2 ± 9.7 | 28.8 ± 7.3 | 26.9 ± 8.3 | 25.7 ± 8.3 | 28.0 |
| 1993 | 35.9 ± 9.1 | 39.8 ±12.4 | 33.5 ± 9.1 | 33.1 ± 9.8 | 39.0 ±10.9 | 36.5 |
| 1994 | 21.9 ± 7.8 | 22.2 ± 8.7 | 22.9 ± 7.8 | 20.2 ± 6.7 | 25.7 ± 8.3 | 22.2 |
| **maximum** | | | | | | |
| 1990 | na | na | na | na | na | 30.8 |
| 1991 | 31.0 ± 2.8 | 31.6 ± 3.6 | 29.2 ± 2.0 | 31.5 ± 1.5 | 32.5 ± 4.5 | 31.2 |
| 1992 | 33.8 ± 4.8 | 40.1 ± 4.1 | 36.0 ± 5.0 | 34.8 ± 6.3 | 38.0 ± 5.8 | 36.5 |
| 1993 | 44.5 ± 6.6 | 52.5 ± 6.3 | 42.2 ± 7.1 | 42.7 ± 6.6 | 53.6 ± 5.7 | 59.1 |
| 1994 | 29.6 ± 4.2 | 30.9 ± 5.5 | 30.4 ± 4.4 | 26.4 ± 3.9 | 28.0 ± 6.7 | 36.3 |

was a similar decrease of size-class representation for plants outside the fence (Figure 3), with fewer plants in larger, reproductive categories. Compared to the broad size distribution of large *Amsinckia* plants produced during the wet 1992-1993 season (with 489 mm precipitation), the narrow distribution of smaller plants produced during the 1993-1994 season was mostly likely due to the small amount of precipitation (268 mm) and the sparse rains of the critical early spring period. Competition with annual grasses was secondary to the drought effect because there was no difference between the plants inside the fence (treated to reduce competition) and plants outside of the fence (untreated).

The output of nutlets by individual plants at Lougher Ridge in 1990 and 1992 was linearly related to the sum of the inflorescence lengths and shoot length (Pavlik 1992). However, a more detailed analysis of the same data, combined with nutlet output data from the Los Vaqueros I and Connolly Ranch sites has shown that the best relationship was exponential rather than linear (Figure 4). This does not change the convention of using the linear equations to estimate nutlet production of the population. It does underscore the disproportionate reproductive contribution of the largest plants to the seed bank and gene pool of the population (Pavlik 1993). The absence of these plants from the 1993-1994 Lougher Ridge population resulted in the smallest nutlet production of any year since 1990. An estimated 16,590 nutlets were produced in 1994, a 64% decrease compared to total nutlet production in 1993 (Table 3).

Only 12 plants were found outside of the fence in 1994. Some were obviously progeny of plants that had dispersed in previous years, forming clusters around the same locations measured in 1993. Others were either secondary dispersers (having moved from a parental location outside the fence) or newly dispersed (from within the fence). Although quantitative data are lacking, it appeared that cattle had a larger impact on the site than in previous years. Hoof prints and low-browsed grasses were common within a few meters of the fence, an area that has supported 90% of the dispersed *Amsinckia* plants (Pavlik 1993). Signs of disturbance by fossorial mammals were also more common in 1993-1994 outside of the fence. The lack of thrum plants may also slow the spread of *Amsinckia* at Lougher Ridge by limiting seed production at population edges.

Table 3. Estimates of nutlet production by the population at Lougher Ridge. The value for 1990 was derived from every individual in the population, while those for 1991-1994 were based on a random sample of 100 plants from within the fenced area.

| year | # of repro plants | total # nutlets produced | nutlet production growth rate (%/ yr ) |
|---|---|---|---|
| 1990 | 1101 | 35,800 | -- |
| 1991 | 1301 | 51,400 | 43.6 |
| 1992 | 1640 | 66,980 | 30.3 |
| 1993 | 682 | 46,380 | -31.0 |
| 1994 | 1106 | 16,590 | -64.2 |

Status of the Natural Populations at Site 300

The Droptower population consisted of 1606 reproductive individuals in April of 1994, an increase of 384 % since 1993 (Figure 5). Most *Amsinckia* individuals (about 1000) were found in a patch, approximately five meters long, that dominated the upper, western-most third of the old fenced enclosure. The five, discrete patches that occurred on the eastern edge of the fenced area close to the two oak trees in 1993 now consisted of only three, large, coalescing patches of 240 plants. Another 80 plants were found 50 m west of the enclosure. In 1993 this group consisted of 31 plants and only seven plants in 1992. The overall pin/thrum ratio at the Droptower was 1.22.

Compared to 1993, plant size decreased at the Droptower significantly (Table 4). Only 6% of all reproductive plants exceeded 40 cm in height (36% in 1993) and none were greater than 50 cm (14% in 1993). Annual grass cover across the site was low (perhaps less than 10% overall) due to herbicide treatment, with the height of surviving grasses (mostly *Bromus mollis* ) in the range of only 10-25 cm. It is likely, therefore, that

Table 4. Comparison of 1991 -1994 performances of the Droptower population. See Pavlik (1991, 1992, 1993) for descriptions of the management regimes.

| | | plant size | | nutlet production | |
|---|---|---|---|---|---|
| | P/T ratio | mean maximum (cm) | mean (cm) | mean #/repro plant) | total (# in all patches) |
| 1991 unsprayed | 1.70 | 34.6 ± 2.9 | 27.1 ± 6.6 | 31 | 1,126 |
| sprayed | 2.36 | 35.5 ± 4.7 | 22.1 ± 8.9 | 25 | 927 |
| 1992 unsprayed | 0.81 | 34.5 ± 6.6 | 28.0 ± 6.7 | 30 | 4,590 |
| sprayed | 2.00 | 41.9 ± 7.8 | 36.1 ± 8.2 | 58 | 22,330 |
| 1993 unsprayed | 0.99 | 51.4 ± 4.4 | 33.4 ± 12.5 | 49 | 16,270 |
| 1994 sprayed | 1.22 | 40.4 ± 2.5 | 25.4 ± 8.6 | 21 | 33,726 |

the small sizes of *Amsinckia* and annual grass plants this year was not due to competition but instead due to extremely low rainfall. Only 145 mm was measured during the October-May season at the nearby Fish and Game Corral Hollow Reserve (compared to 326 mm during 1992-1993). Evidently, the rains came early enough, in sufficient quantity, to cause a good amount of *Amsinckia* germination but the dry spring contracted the reproductive period. Plants in 1994 had a maximum of 5 flowering branches each (mostly 1-3 per plant), compared to a maximum of 32 each (3-6 per plant) in 1993. Consequently, nutlet output per plant was low in 1994, but the larger population size increased nutlet production by 107 % relative to 1993.

This was the first year since the beginning of the recovery effort in 1987 that the Droptower population of *Amsinckia grandiflora*, once the only known extant population of this species, had exceeded the minimum viable size threshold of 1500 individuals. Although the population can be expected to decrease, as well as increase in size over the next decade, the management objective is to confine those oscillations to a high, demographically-significant range (1000-2000 individuals) rather than the low, deleterious range (23-355 individuals) of recent years. Ongoing manipulation of the annual grass cover, both with dilute herbicide and controlled burns, is needed.

The population in Draney Canyon population decreased in size, with 13 plants found mostly on the east-facing side of the canyon (Figure 6). Other plants may have been present but were senescent and, therefore, difficult to see at the time of census. Mean and mean maximum plant size (26.7 ± 6.5 and 29.4 ± 4.1, respectively) were smaller than in previous years (33.7 ± 15.2 and 50.5 ± 9.8, in 1993, respectively) , again indicating that low rainfall (perhaps combined with low intensity competition with annual grasses) had limited growth and reproductive output. The pin/thrum ratio (4.0) was very skewed towards pins, but some the the senescent plants may have been thrums. Although the Draney Canyon population is valuable for comparative purposes in its unmanipulated, natural state, its small, now fluctating size may necessitate a low-level nutlet collection program in 1995. Careful selection and storage of a small number of ripe nutlets (50-100) may be advisable for preserving any unusual genetic variation found in the population.

Status of the Reintroduced Populations at Black Diamond II, Los Vaqueros I, Connolly Ranch, and Corral Hollow

The Black Diamond II population continued its severe decline in 1993-94 and produced no reproductive plants. Only six plants were found during the April 1993 census and those tended to be smaller than in previous years. Mean maximum size had decreased and the size-class distribution contracted, severely limiting nutlet production. The pin/thrum ratio was 0.50, the largest deviation from unity yet recorded in a population. These demographic characteristics were used to accurately predict the emminent failure of the population (Pavlik 1993), although some live nutlets still persist in the soil seed bank (see below). As in previous years the disturbance by gophers was obvious, affecting 11 of the 12 plots within the fenced area. Pervasive rodent activity, combined with poor demographic performance have significantly decreased the probability of nutlets germinating and surviving in favorable habitat patches. Black Diamond II is not, therefore, a site that will contribute to the recovery of the species.

In 1993-1994 the Los Vaqueros I population produced one small plant which had flowered but produced no nutlets. The steep decline over a four year period was predicted by the 1991 demographic data (Pavlik 1991a, 1992). The data clearly show that vegetative growth leading to the production of flowers was inhibited, resulting in small, unbranched plants with few inflorescences and little potential for nutlet output. Los Vaqueros I is not, therefore, a site that will contribute to the recovery of the species.

The Connolly Ranch population contined to decline dramatically. A total of only 23 reproductive plants were found during the April 1994 census, with only 13 inside the fence and 10 outside. The pin/thrum ratio was extremely skewed in favor of pins (Table 5). Total precipitation was very low (177 mm) at the site and was probably a significant constraint on germination and plant growth. Mean maximum and mean plant size were the smallest ever recorded at the site, so that only 7 nutlets were produced per plant on the average. Although grasses were sparse (15-60% absolute cover) in plots that had been burned, there was no evidence that the reduction in competition had provided any benefit to *A. grandiflora* . In five of the twelve plots there was a high degree of disturbance by rodents. Some pocket gopher activity resulted in bare soil mounds and a few dead, standing forbs (none were *A. grandiflora* ). Perhaps more important was the activity of kangaroo rats (probably *Dipodomys heermanni* ), that cleared large patches of plant cover within the plots by chewing off the stems of grasses and forbs alike (including *A. grandiflora*). This created areas around the opennings of burrows that were 40-80% bare and

Table 5. Characteristics of the Black Diamond II, Los Vaqueros,Connolly Ranch, and Corral Hollow populations, 1994.

| | | | plant size | | nutlet production | |
|---|---|---|---|---|---|---|
| | repro pop size (# pl) | P/T ratio | mean maximum[1] (cm) | mean[2] (cm) | mean (#/repro plant) | total (# in all plots) |
| Black Diamond II | 0 | 0 | 0 | 0 | 0 | 0 |
| Los Vaqueros I | 1 | pin | 0 | 9.0 | 0 | 0 |
| Connolly Ranch | 23 | 9.0 | 24.2 ± 3.0 | 21.3 ± 3.9 | 7 | 161 |
| Corral Hollow | 157 | 1.58 | 32.4 ± 2.0 | 22.4 ± 5.9 | 11 | 1,744 |

[1] n = 10, except at CR n = 5 largest plants [2] n = repro pop size

probably used to forage for seeds (see Tappe 1941, Kelt 1988). Although it is only speculation at this time, stem clipping and seed collection by kangaroo rats may be having a large impact on the Connolly Ranch population of *A. grandiflora* .

The decline at Connolly was significant and unexpected. Unlike at Los Vaqueros I, some plants grew to be large and branched with mean and mean maximum size increasing over the 1991-1993 period (Pavlik 1993). The site was, therefore, physiologically suitable for *A. grandiflora,* allowing a broad size-class distribution and extended period of floral display and nutlet production in the population. Observations made on plants outside of the fence indicated that light grazing by cattle had also promoted branching and inflorescence formation. The impacts of rodents, particularly kangaroo rats, were not observed until spring of 1993 and appear to have increased since then. During a 6 year study of *D. hermanni* , Fitch (1948) found that k-rat population size tended to increase during drought years. Although 1993 was a wet year, the other years of the study have been dry and may have favored growth in the local k-rat population. In the absence of higher predation rates, the seed bank of *A. grandiflora* at Connolly Ranch may have been subjected to intensive foraging during recent years.

The original population at Corral Hollow exhibited a 26% increase over last year, producing 37 individuals among the twelve plots. The three precision-sown plots installed in 1992-1993 contributed an additional 22 plants, while the six precision-sown plots of this year produced another 98 reproductive individuals. The total at Corral Hollow in late March 1994 was 157 plants with a pin/thrum ratio of 1.58 (Table 5). As observed at all other sites, the plants were much smaller than in previous years, with mean maximum and mean size significantly decreasing compared to 1992-1993. Consequently, nutlet production was much lower than in previous years. These results support the conclusions reached at other sites: the regional weather patterns of 1993-1994, particularly the extremely low amount of precipitation, resulted in weak plant growth despite a lack of competition from annual grasses. However, this population also experienced a considerable amount of rodent distrubance during the late spring, especially between 10 March and 14 April. During that period alone, 28% of the reproductive plants had one or more flowering stems clipped off several centimeters above the soil surface. In some cases, the entire shoot had been removed. This behavior has been observed as kangaroo rats forage for seeds on forbs and grasses (Kelt 1988). All six of the precision-sown plots showed signs of kangaroo rat foraging or gopher mounding. High mortality of seeds due to predation by kangaroo rats, combined with low nutlet production, will very likely decrease the size of the Corral Hollow population during 1994-1995.

Newly Discovered Natural Population

The new population of *Amsinckia grandiflora* discovered on private property east of Connolly Ranch occurs in a large, west-draining canyon on the steep north-facing slope at approximately 1000' elevation (see Pavlik 1993 for a full description). The population itself is contained in an area of approximately 50 X 52 meters, the upper edge coming within 25 meters of the ridgecrest and the lower edge within 10 m of the canyon bottom. The distribution of plants is not homogeneous - there are about eight high density patches (some as large as 20 m X 10 m, others only 2 m X 2 m) and at least six to eight low density patches (also variable in size).

Census and nutlet collection took place on June 3, 1994. Most plants were already dead and the inflorescences contained only filled, dry pericarps. A few green, almost succulent plants with open flowers could still be found in shaded depressions on the slope. Rough census of two high and two low density patches produced estimates of 10 - 20 plants/$m^2$ and 1 - 10 plants/$m^2$, respectively, perhaps 30% lower overall than in previous years. There was also some evidence that the population had contracted as well, but not significantly. A conservative estimate of the total population size would still lie in the range of 2000 - 3500 large plants. Using the circular random sampling technique in four patches (n = 25 plants each) across the population, the pin/thrum ratio was 1.41 (n = 41). Most plants were medium or large, but with fewer branches than last year. Mean plant size decreased by 26%, (36.9 ± 11.2 cm vs. 49.7 ± 15.4 cm in 1993), as did mean maximum plant size (55.5 ± 2.4 cm vs. 73.6 ± 6.6 cm in 1993). Estimated mean nutlet output per plant would easily exceed 50 nutlets. These observations are consistent with trends observed in other natural and reintroduced populations of *Amsinckia grandiflora* : low rainfall inhibited plant growth and reproduction, and to a lesser extent, germination and survivorship. There were no obvious signs of disturbance by rodents at this site. It is interesting to note that in the bottom of the canyon below the *Amsinckia* population are at least four large, recently used dens that appear to shelter coyotes or possibly kit fox.

A bulk collection of several thousand nutlets was made from many individuals (more than 60) across the length and width of the population. This collection was allowed to air dry for several weeks and then stored at $4^{o}$ C.

## Conclusions and Management Recommendations

1) The reintroduced population of *Amsinckia grandiflora* at Lougher Ridge was comprised of 1106 flowering plants in April 1994, a 62% increase since 1993 (Table 6). High nutlet production in previous years, combined with low cover by annual grasses, were largely responsible for the increase. Therefore, the Lougher Ridge population demonstrated resilience (the ability to recover from low population size), which is a critical demographic characteristic with respect to the success of reintroduced populations of *Amsinckia grandiflora* (Pavlik 1994b). The potential for continued growth and self-maintenance of the population remains high, although decreases in population size are also possible. Low rainfall during this year (a 28% regional deficit relative to normal) constrained plant growth and reduced nutlet output during 1994. Mean plant size was 39% of that measured in 1993 (a high rainfall year, with a 42 % regional surplus). Nutlet production was estimated at 16,590 nutlets, a decrease of 64 % compared to the number produced in 1993. This population appears to be conforming to predictions based on its demographic attributes and will probably contribute to the overall recovery of the species.

The recommendation for the sixth year of this population is to increase the abundance and quality of low-competition neighborhoods at Lougher Ridge by conducting a large-scale burn (including areas beyond the fence line) and mid-winter treatment of patches with a grass-specific herbicide. An effort has begun to restore a portion of the grassland by transplanting plugs of *Stipa pulchra , Poa scabrella, and Elymus* from local individuals into the fenced area. This effort will be expanded during 1994-1995 after spring and fall burns have been conducted. More *A. grandiflora* nutlets should be released on the site in a controlled, careful manner so that monitoring of the original Lougher Ridge population is not compromised. Concurrently, the entire 3 acre reserve containing the original reintroduction site and a large buffer should be fenced with a least three strands of barbed wire to exclude cattle.

2) The natural Droptower population at Site 300 consisted of 1606 reproductive individuals in April of 1994, an increase of 384 % since the previous year (Table 7). The increase was due to high nutlet production in previous years, combined with low cover by annual grasses. Thus, the increased potential for population growth begun in the 1992-93 season was finally realized, although individual plants were smaller than they had been in previous years regardless of habitat treatment (Table 7). Nutlet production in 1994 was, therefore, low and contracted by the lack of rainfall. These data strongly suggest that the

Droptower population has considerable resilience when habitat manipulations are conducted for purposes of recovery, but that variations in important environmental variables (e.g. rainfall, temperature) will still cause fluctuations in population size and reproductive output. The size of the untreated, natural population in Draney Canyon declined to 13 plants and plant size decreased.

The recommendation for 1994-95 is to allow the Droptower population to return to a natural (unmanipulated) management regime. This should produce higher annual grass cover in preparation for a fall 1995 burn (depending on the results at Lougher Ridge). Monitoring of grass cover and demographic characteristics are required during the spring of 1995. Greater intervention in the form of nutlet collection is required on behalf of the Draney Canyon population, but not until a season with favorable rainfall amounts and patterns stimulates germination and plant growth so that a larger size-class distribution (with greater fecundity) develops *in situ* . This could be promoted by treating the population during the late winter with dilute, grass-specific herbicide, but access to the site is always problematic.

3) Despite the use of a small-scale, controlled burn to enhance conditions for growth, the reintroduced Black Diamond II population continued its severe declined in 1993-94 and produced no reproductive plants. Disturbance by gophers probably increased mortality of established plants and further reduced nutlet production. As a result, this population probably has no potential for self-maintenance and is not going to contribute to the recovery of the species.

This population needs to be observed and censused under a fifth year, natural management regime to conclude if extirpation has occurred. In that event, all recovery activities should be terminated at the site.

4) Despite the use of a small-scale, controlled burn to enhance conditions for growth, the reintroduced Los Vaqueros I population continued its severe declined in 1993-94 and produced only one plant that did not appear to be in fruit. As a result, this population probably has no potential for self-maintenance and is not going to contribute to the recovery of the species.

This population needs to be observed and censused under a fifth year, natural management regime to conclude if extirpation has occurred. In that event, all recovery activities should be terminated at the site.

5) Despite the use of a small-scale, controlled burn to enhance conditions for growth, the reintroduced population at Connolly Ranch declined significantly and was comprised of only 23 reproductive plants. Mean and mean maximum plant size decreased because of low precipitation, producing a narrow size-class distribution and contracted period of floral display and nutlet production. There was also a high degree of disturbance by rodents. Some pocket gopher activity resulted in bare soil mounds and a few dead, standing forbs, but kangaroo rats (probably *Dipodomys heermanni* ), cleared large patches of plant cover within the plots by chewing off the stems of grasses and forbs alike (including *A. grandiflora* ). This created areas around the opennings of burrows that were 40-80% bare and probably used to forage for seeds. Although it is only speculation at this time, stem clipping and seed collection by kangaroo rats may be having a large impact on the Connolly Ranch population of *A. grandiflora* .

This population needs to be observed and censused under a fifth year, natural management regime. A study of nutlet mortality with respect to nocturnal rodents might help explain the unexpected decline of *A. grandiflora* at Connolly Ranch, and provide data for demographic simulation models (e.g. RAMAS/stage). Live trapping and fecal analysis are also recommended, perhaps comparing rodent densities and diets at this site to those at the new, natural population, the Droptower, or Lougher Ridge (where rodent activity has had minor impacts).

6) The original population reintroduced to Corral Hollow during 1991-1992 increased, but the surviving plants were small with low nutlet production (again attributed to extremely low rainfall). Additional plants were contributed by the precision-sown plots, so that the total for spring 1994 was 157 reproductive plants. However, this population also experienced a considerable amount of rodent distrubance during the late spring. High mortality of seeds due to predation by k-rats, combined with low nutlet production, will very likely decrease the size of the Corral Hollow population during 1994-1995. Although the CH population remains small, it has a potential for growth and may contribute to the recovery of the species.

The recommendation for the CH population in its fourth year is to conduct a fall burn in order to begin restoration activities on a larger scale. Additional nutlets from the new population should be precision-sown in order to significantly enhance population size and initiate high rates of nutlet production *in situ* . Demographic monitoring and habitat enhancements should occur concurrently.

7) The newly-discovered population east of Connolly Ranch decreased in size and extent in 1993-1994, although plants still number in the thousands. As at other sites across the range of the species, mean size and mean maximum size decreased significantly as the result of low rainfall and a contracted period of flower and fruit production (especially when compared to 1992-1993).

An ongoing dialogue with the leasee of the property is essential for maintaining access and developing a basis for additional conservation action. A census in spring 1995, including the collection of nutlets, is also recommended.

8) This reintroduction project is transitioning from an experimental phase (concentrating on the basic biology and management of *Amsinckia grandiflora* ) to a restoration phase (concentrating on meeting the goals outlined in the recovery plan). Consequently, a meeting should be held between representatives of the Department of Fish and Game, the U.S. Fish and Wildlife Service, rare plant biologists, and other relevant parties in order to discuss new ways to design and implement this project.

Table 6. A summary of the characteristics and status of created populations of *Amsinckia grandiflora* during the 1990-1994 recovery effort.

| year | management regime | repro population (# of plants) | nutlet production (# of nutlets) | pin/thrum ratio | status |
|---|---|---|---|---|---|
| **Lougher Ridge** | | | | | |
| 1990 | experimental | 1,101 | 35,800 | 1.36 | growing |
| 1991 | enhancement | 1,301 | 51,400 | 1.27 | growing |
| 1992 | natural | 1,640 | 66,980 | 0.97 | growing |
| 1993 | natural | 682 | 46,380 | 1.49 | declining |
| 1994 | enhancement | 1,106 | 16,590 | 1.67 | growing |
| **Black Diamond II** | | | | | |
| 1991 | experimental | 288 | 11,280 | 1.68 | growing |
| 1992 | enhancement | 70 | 2,163 | 1.50 | declining |
| 1993 | natural | 6 | 162 | 0.50 | declining |
| 1994 | enhancement | 0 | 0 | 0 | extirpated? |
| **Los Vaqueros I** | | | | | |
| 1991 | experimental | 374 | 3,200 | 1.32 | declining |
| 1992 | enhancement | 9 | 177 | 0.80 | declining |
| 1993 | natural | 0 | 0 | 0 | extirpated? |
| 1994 | enhancement | 1 | 0 | 0 | declining |
| **Connolly Ranch** | | | | | |
| 1991 | experimental | 580 | 17,030 | 1.43 | growing |
| 1992 | enhancement | 707 | 12,019 | 1.26 | growing |
| 1993 | natural | 133 | 2,530 | 1.16 | declining |
| 1994 | enhancement | 23 | 161 | 1.58 | declining |
| **Corral Hollow** | | | | | |
| 1992 | experimental | 64 | 1,827 | 1.39 | growing |
| 1993 | enhancement | 81 | 6,410 | 1.38 | growing |
| 1994 | enhancement | 157 | 1,744 | 1.58 | growing |

Table 7. A summary of the characteristics and status of natural populations of *Amsinckia grandiflora* during the 1990-1994 recovery effort. na = data not available

| year | management regime | reproductive population (# of plants) | mean plant size (cm) | pin/thrum ratio | status |
|---|---|---|---|---|---|
| **Site 300 - Droptower** | | | | | |
| 1990 | natural | 104 | na | 1.04 | declining |
| 1991 | natural | 92 | 24.3 ± 8.3 | 2.04 | declining |
| 1992 | enhancement | 546 | 31.4 ± 8.5 | 1.17 | growing |
| 1993 | natural | 332 | 33.4 ± 12.5 | 0.99 | declining |
| 1994 | enhancement | 1606 | 25.4 ± 8.6 | 1.22 | growing |
| **Site 300 - Draney Canyon** | | | | | |
| 1990 | natural | 16 | na | 4.33 | ? |
| 1991 | natural | 29 | na | 1.42 | growing |
| 1992 | natural | 28 | 28.5 ± 7.7 | 1.54 | stable |
| 1993 | natural | 28 | 33.7 ± 15.2 | 1.54 | stable |
| 1994 | natural | 13 | 26.7 ± 6.5 | 4.00 | declining |
| **New Population** | | | | | |
| 1993 | natural | 3000-4000 | 49.7 ± 15.4 | 1.13 | ? |
| 1994 | natural | 2500-3000 | 36.9 ± 11.2 | 1.41 | declining |

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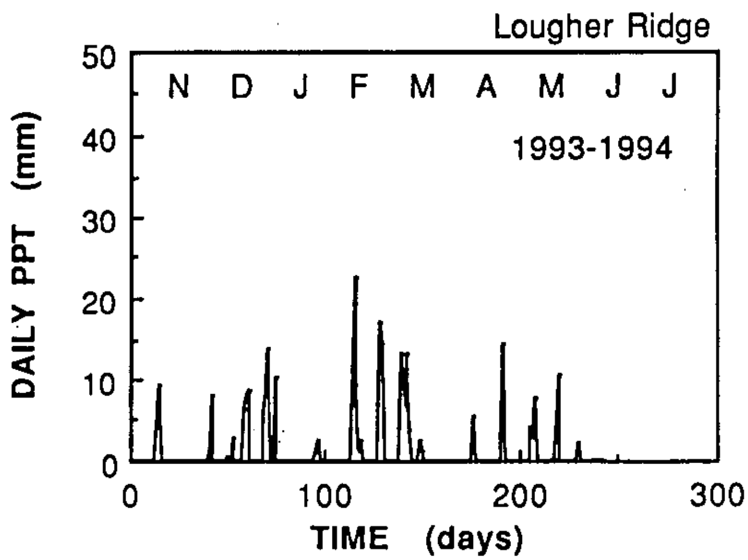


Figure 1. Seasonal pattern of daily precipitation at Lougher Ridge. Day 0 = October 1. Compare to Figure 1 of Pavlik (1993).

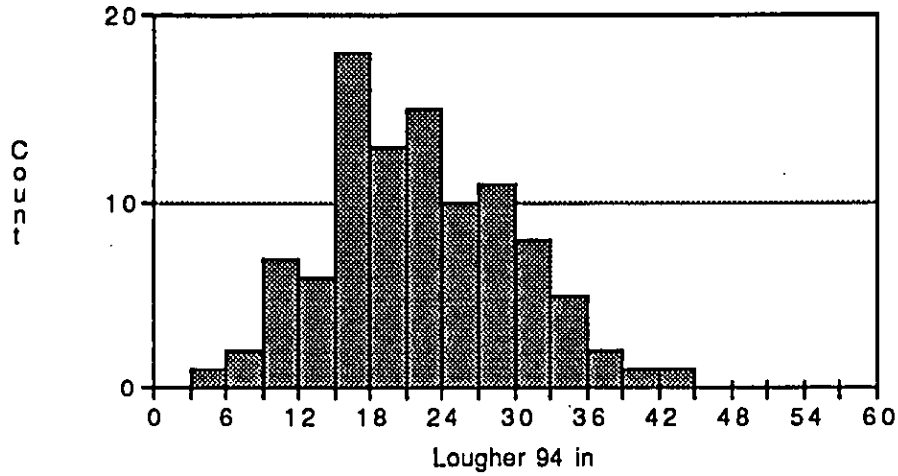


Figure 2. Plant size-class distribution for individuals growing inside the fenced area at Lougher Ridge, 1994. Size-class dimensions on X axis are in cm of shoot length. Compare to Figure 2 of Pavlik (1993).

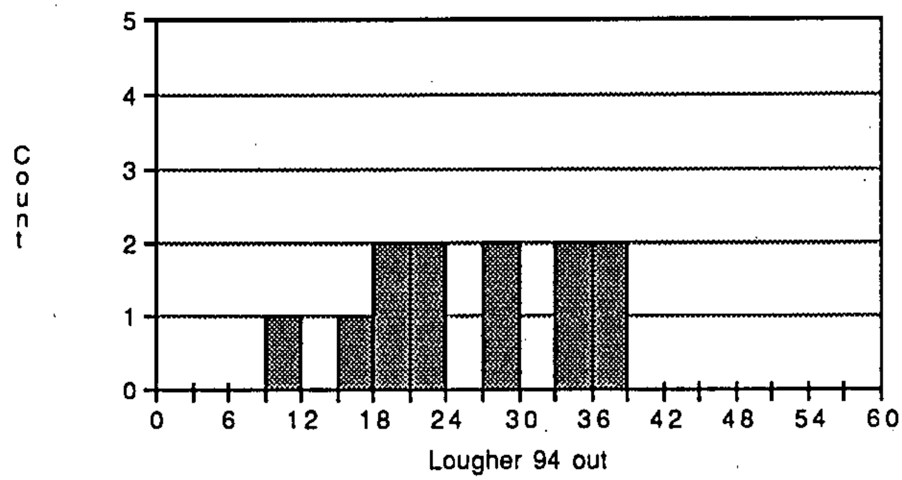


Figure 3. Plant size-class distribution for individuals growing outside the fenced area at Lougher Ridge, 1994. Size-class dimensions on X axis are in cm of shoot length. Compare to Figure 3 of Pavlik (1993).

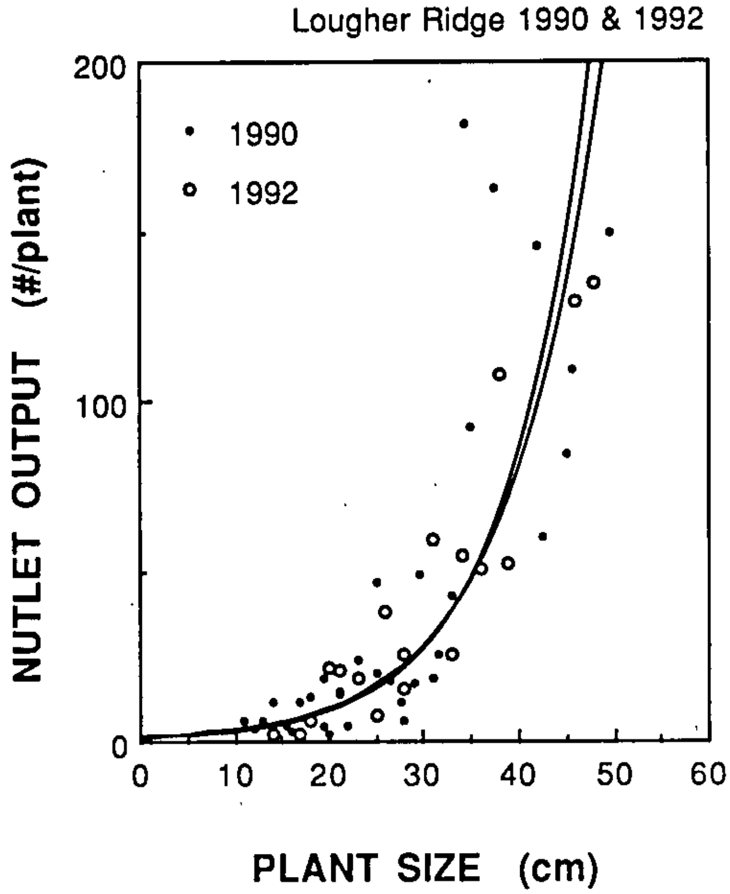


Figure 4. Nutlet output - plant size data from Lougher Ridge fit with exponential, rather than linear, curves.

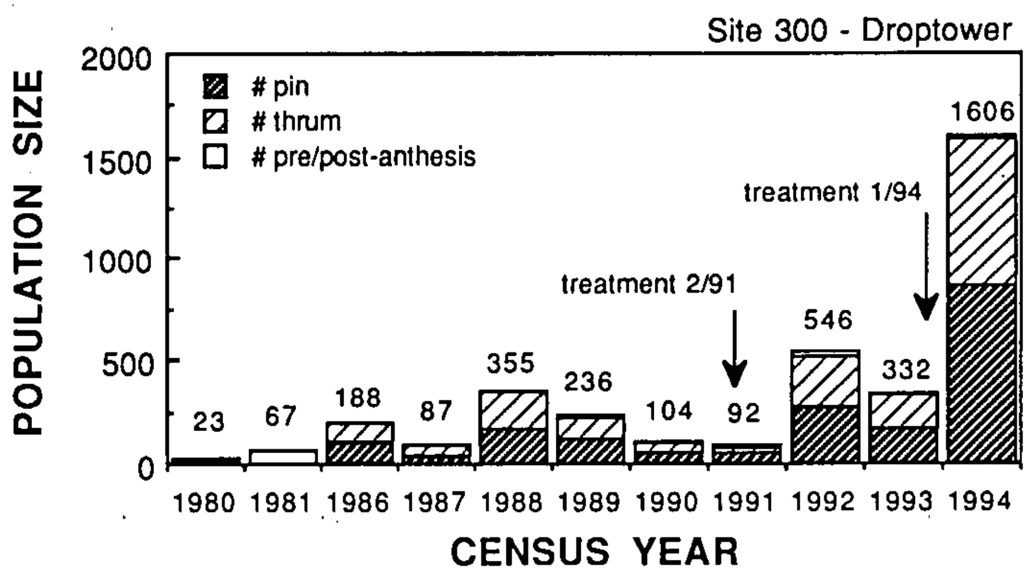


Figure 5. Spring census of the Droptower population of <u>Amsinckia grandiflora</u> at Site 300. Total population size and the proportion of pin and thrum individuals are shown. Approximate timing of treatments to reduce annual grass competition is shown.

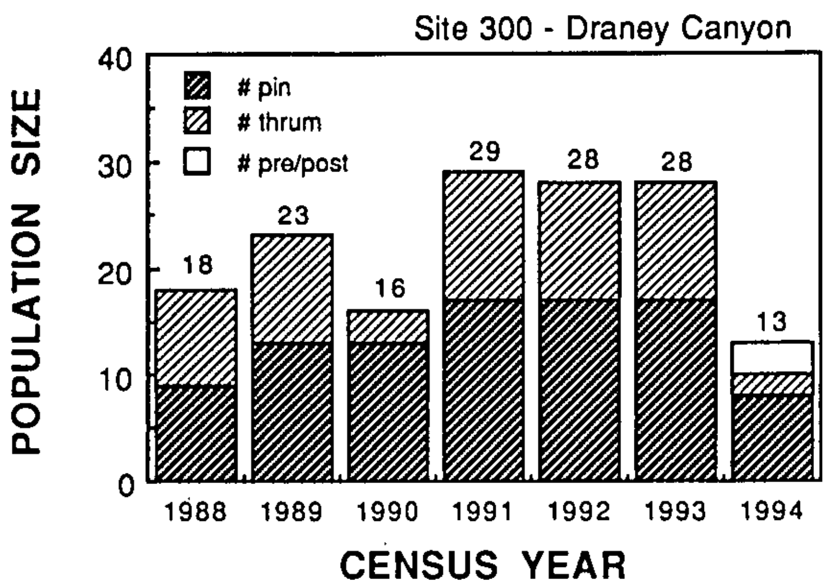


Figure 6. Spring census of the Draney Canyon population of Amsinckia grandiflora at Site 300. This population remains under a natural management regime.