And the Beat Goes On: 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 six-year-old reintroduced population at Lougher Ridge under an "enhanced" (manipulated) management regime that employed spring and summer burns, 2) ongoing monitoring of the natural populations, 3) fifth year evaluation of the reintroduced populations at Black Diamond II, Los Vaqueros I, Connolly Ranch, and Corral Hollow and 4) measurement of seed bank size and quality of apparently successful and failing populations.

The reintroduced population of *Amsinckia grandiflora* at Lougher Ridge was comprised of 442 reproductive plants in 1995, a decrease of 62 % since 1994. The decrease was predicted in part by the low nutlet production of the previous, extremely dry, year. It is also possible that the fall burn resulted in some nutlet mortality. Plant size (and presumably nutlet output, increased significantly in 1995, thus restoring the potential for continued growth and self-maintenance of the population. A sturdy fence with gates was installed around the original reintroduction site, excluding livestock from a 3 acre area, yet permitting access for grazing management in the future.

The natural Droptower population at Site 300 consisted of 1104 reproductive individuals in April of 1995, a decrease from the high of 1606 last year. As observed at Lougher Ridge, nutlet production significantly increased and 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 increased to 27 plants and plant size increased, but a restriction to the north-facing canyon wall indicated that management intervention could be justified.

The reintroduced Black Diamond II, Los Vaqueros I, and Connolly Ranch populations were either extirpated or seriously declining in 1994-95, with no reproductive plants found at the first two sites. Previous 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 is currently being conducted to 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 underway.

The 1991-1992 reintroduction at the Corral Hollow Ecological Reserve produced a 80 reproductive plants with high nutlet production. Additional plants were contributed by precision-sown plots (established in 1993 and 1994), so that the total for spring 1995 was 173 reproductive plants. This site appears favorable with respect to recovery, although it also supports a very large population of weedy fiddlenecks that may outcompete *A. grandiflora* in the future.

The newly-discovered population east of Connolly Ranch decreased in size and extent in 1994-1995, although plants still number in the thousands. As at other sites across the range of the species, mean size and mean maximum size increased significantly as the result of high rainfall (especially when compared to 1993-1994). A bulk collection of nutlets was made for conservation purposes.

The size and quality of *A. grandiflora* seed banks were correlated with the overall demographic characteristics of apparently successful and failing populations. Apparently successful populations (Lougher Ridge and Droptower) which had large numbers of individuals (500 - 1600) during previous years with favorable plant size distributions and high nutlet output per plant had significantly higher nutlet densities than failing populations (Black Diamond 2, Los Vaqueros I, Connolly Ranch). The pattern was strongest when differences in nutlet quality were taken into account.

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And the Beat Goes On: 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, 1994, 1995) that emphasizes the creation, enhancement, and evaluation of self-sustaining populations.

The specific objectives of the present study included; 1) evaluation of the six-year-old reintroduced population at Lougher Ridge under a management regime that included spring and summer burns, 2) ongoing monitoring of the natural populations at the Droptower on Site 300, and the large, natural population in Carnegie Canyon, 3) fifth year evaluation of the reintroduced populations at Black Diamond II, Los Vaqueros I, Connolly Ranch, and Corral Hollow, and 4) measurement of seed bank size and quality at successful and failing populations.

Methods and Materials

Managing and Evaluating the Reintroduced Population at Lougher Ridge

The Lougher Ridge reintroduction site was manipulated to reduce annual grass cover during 1994 with two controlled burns, one during spring and one during fall. Both were conducted by a fire crew from the East Bay Regional Parks District which included eight people, two type 3 grass rigs (300 gallons each), one type 4 engine (400 gallons) and two water tenders (1000 gallons each).

The spring burn took place the morning of 24 May 1994, a sunny and warm day with a 10-15 mph intermittent breeze from the west. Ten randomly-placed biomass samples (30 cm X 30 cm, see below) indicated that the herbage had a moisture content of 23 ± 7 % relative to fresh weight (30 ± 11 % relative to dry weight). The annual grasses were mostly in fruit, with the herbage mostly senescent (green cover was 25-50% of the total grass cover). Four metal heat collectors with heat-sensitive waxes were placed at random points outside of the original fenced area for the *Amsinckia* reintroduction. The seven waxes had seven different melting points between 100° and 700° F so that some estimate of fire temperatures could be made. The fire was lighted with fuel oil driptorches at 1120 hours and kept away from the reintroduced population with hand tools (no water was sprayed into the fenced area). Under these rather moist conditions, the fire had to be repeatedly set in order to increase evenness of the treatment. Approximately 3 acres were burned around the *Amsinckia* population until the fire was finally extinguished at 1300 hours.

The fall burn took place the morning of 28 September 1994, a misty, humid, overcast day with almost no breeze. The biomass samples indicated that the herbage had a moisture content of 11 ± 1 % relative to fresh weight (12 ± 1 % relative to dry weight). The annual grasses and *Amsinckia* were long dead and brown, and the fruits had all dispersed. Four metal heat collectors with heat-sensitive waxes were placed at random points inside of the original fenced area for the *Amsinckia* reintroduction so that some estimate of fire temperatures could be made. The fire was lighted on the uphill edge with fuel oil driptorches at 1000 hours and kept from spreading outside of the fenced area with hand tools and water (no water was sprayed into the fenced area). Under these humid conditions with dry grass, the fire spread slowly but evenly downhill. The entire area of the reintroduced *Amsinckia* population was burned and the fire was extinguished at 1100 hours.

Estimates of cover (by species) and standing biomass (of all grasses and forbs) were made at six randomly-located points outside of the fenced area and four points inside of the fenced area before the burns and during the late spring of several field seasons (1991, 1992, 1994, 1995). Three of the points outside of the fence were never burned and could serve as controls. At each sample point cover estimates were made within a 1 X 1 m quadrat. A metal 30 cm X 30 cm sampling frame was then placed into the bottom left corner of the quadrat and all standing crop, stubble and new litter (not any decomposed organic material) were cut from the ground level and placed into large paper bags. The bags were returned to the lab, weighed, and put into a 80° C drying oven until achieving constant weight (about four days).

The site was inspected on 12 October 1994 to observe seedlings, record phenology, read the raingauge and to fix the fence. Additional visits were not possible until the spring because of very heavy and persistent rains during the entire growing season (which also prevented more native grass restoration work). Census of the population took place on 21 April 1995, when *Amsinckia* plants were robust (20-70+ 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 original 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 1994-95 population, 100 plants were randomly selected and measured for shoot length on 21 April 1995. 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 are described in Pavlik (1991a).

A fenced exclosure was built around a 3 acre area surrounding the original fenced reintroduction site in February 1995. Metal posts and four strands of barbed wire, braced at all corners, should act as an effective livestock barrier. Two large (14') gates on the west and east sides will allow site managers to permit livestock entry during certain times of the year in order to reduce grass cover. The fence was built by Southwest Fence and Supply (Livermore, 510-373-4715) at a cost of $3598.50.

Evaluating the Natural Populations at Site 300

The Droptower population at Site 300 was not manipulated to reduce annual grass competition during 1994-1995, and was thus under a "natural" management regime (Pavlik 1995). A census was conducted on 14 April 1995 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 25 April 1995. 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 fifth year after reintroduction, the Black Diamond II, Los Vaqueros I and Connolly Ranch populations were not manipulated to reduce annual grass competition during 1994-1995, and were thus under a "natural" management regime (Pavlik 1995). Due to heavy rains these sites could not be periodically visited during the late winter and early spring. Final census of the Connolly Ranch (CR) site was conducted on 10 April 1995 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 and 23 May 1995, respectively. The same parameters were recorded for those populations, except that shoot length 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 Ecological Reserve were not managed for annual grass competition in 1994-1995. However, eight precision-sown plots of 50 nutlets each were added on 31 October 1994 to allow estimation of germination and survivorship using nutlets from two sources. Each of four plots were sown with 50 nutlets from the Davis 1989 source and four others were sown with 50 nutlets from the Carnegie Canyon 1994 source. On 5 December 1994 the plots were checked for germination and phenology. The final census of these and previous years plots was conducted on 5 April 1995.

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 5 May 1995, after obtaining permission from the lease holder, Florence Cubiburu. It has tentatively been named the "Carnegie Canyon" population.

Seed Banks of Successful and Failing Populations

In order to quantify variations in seed bank (=nutlet bank) density and quality, half of the original plots at the Lougher Ridge, Black Diamond II, Los Vaqueros I and Connolly Ranch reintroduction sites were randomly selected after stratification by plant density. The plots were arrayed from high to low census values (for reproductive plants in spring 1993) and arbitrarily stratified in groups of two with similar densities. Selection of a plot from each group was made using a random numbers table (odd random digit = selected). Consequently, 10 plots were selected at Lougher Ridge and 6 at all other sites, with representation that spanned the entire range of recent nutlet production and past nutlet dormancy. A sample point was located exactly in the center of each plot.

Sampling at the Droptower, however, where there were no reintroduction plots, was done by locating five points within the western and eastern portions of the population. The upper origins for two transects ("west" and "east") were positioned along the upslope edge of the population using a tape stretched from west to east along the old metal fenceposts. The actual origins along the tape were assigned with a random numbers table (4 random digits = cm from western end of tape). Transects ran down from the origins, perpendicular to the slope. At points 2.0, 4.0 and 6.0 m down from the western origin (selected *a priori*) three sample points were permanently marked with metal stakes. At points 4.0 and 6.0 m down from the eastern origin (selected *a priori*) two sample points were permanently marked with metal stakes.

Seed bank samples were collected in the late summer and early fall of 1993, several months after nutlet dispersal had taken place and just before the first rains of the season. Two subsamples were obtained from each plot by anchoring metal sample frames to the soil surface exactly 40 cm to the left and 40 cm to the right of each sample point (as viewed from a downslope position). The 20 cm X 20 cm frames had stake-like protrusions on their bottom edge that required light hammering to establish a firm position. Standing dead plant material within and around the frame was clipped to a height of 3 cm and removed. A square trowel was then used to remove all litter and topsoil material from within the frame until firm, unyielding subsoil was reached, usually by a depth of 10-12 cm. The material from each subsample was carefully transfered to its own ziplock bag and labeled.

Subsamples were analyzed separately in the laboratory by physically separating the nutlets from soil and litter. First, coarse soil, rocks and large pieces of plant material were removed by pouring the subsample into a large-mesh sieve (size 5, 4 mm opening) and shaking for 1 min. The through-flow material (the "grade") was collected and transfered into another sieve (size 18, 1 mm opening) whose mesh did not permit *A. grandiflora* nutlets to pass through. This sieve was then sandwiched between two other sieves; the one above was another size 18, while the one below had a smaller mesh (size 20, 0.8 mm opening). The sieve sandwich containing the grade was then submersed in a large tub of water and plunged up (hard) and down (soft) for 2 min. Water flowed through the sieve sandwich, removing fine soil particles, silt and clay and leaving behind medium soil particles, small bits of organic material, grass caryopses and most of the *A. grandiflora* nutlets in the center sieve. The lower sieve sometimes contained a few, very small nutlets while the upper sieve was usually empty. After removing the obvious nutlets and nutlet pieces, the grade in each sieve was gently floated in water, allowing better visual inspection (up to 2 hr per subsample). Using this method we obtained 90-100% recovery efficiencies when blank subsamples were spiked with *A. grandiflora* nutlets (tested on three occasions).

The nutlets and nutlet pieces from each subsample were judged for quality before storage. Whole, well-formed and uncracked nutlets were considered the highest quality because they probably contained robust, living embryos. They constituted the "vigorous" fraction of the total *A. grandiflora* seed bank. Damaged nutlets were those which appeared to be whole (i.e. containing viable embryos) but with a cracked or otherwise damaged pericarp. These nutlets, when added to the high quality nutlets, constituted the "viable" fractions of the total *A. grandiflora* seed bank. Finally, partial nutlets (perhaps the result of granivory) or empty pericarps (either from granivory or having been shed during previous germination) were considered as the lowest quality nutlets. Adding these to the viable fraction (high quality + damaged + partial or empty) gives an estimate of the total *A. grandiflora* seed bank (# nutlets/m^2, after muliplying by a factor of 25).

Results and Discussion

Weather Patterns and Phenology During 1994-1995

In northern California the 1 November to 31 May growing season of 1994-95 had a large surplus of precipitation. Records for San Francisco, Oakland, and Sacramento indicate that rainfall was 154-175% of normal during the 1 Nov to 31 May period, with an overall regional surplus of about 66% (compared to a 28% regional deficit during 1993-1994, 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 724 mm, almost three times as much as in 1993-1994 and the highest of all previous years (268 mm in 1993-94, 489 mm in 1992-93, 296 mm in 1991-1992, 271 mm in 1990-91, and 289 mm in 1989-90).

In terms of temporal pattern of precipitation, 1994-95 was similar to 1989-90. The first significant storm dropped 12 mm of rain on 11-12 October. This was sufficient to initiate the germination of *Amsinckia* and the annual grasses. Additional rainfall came frequently until February, with daily amounts approaching 74 mm in mid-January. February was unusually dry (only 8 mm recorded for the month), but large storms resumed in March. LIght rains fell in 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 not closely observed during this wet growing season. *Amsinckia* germinated in response to the small amount of precipitiation received in mid-October. Some seedlings were observed throughout the microsite on 12 October at densities in the range of 0 to 300 per m^2. Annual grasses had also germinated and grew vigorously at that time. It is likely, therefore, that competition between *Amsinckia* and the annual grasses was intense during the early portion of the growing season (Pavlik et al. 1993). The final census at Lougher Ridge was conducted on 21 April, one week later than last year. The plants were tall and wiry, with few branches and some calyxes contained fully formed, green nutlets. By 23 May plants were completely senescent, with mature nutlets that had already dispersed from the dry inflorescences. The patterns of rainfall and *Amsinckia* phenology at other sites with natural and reintroduced populations were similar to those at Lougher Ridge.

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 1994-1995 season was extemely long and wet, 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 1994-95 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 442 flowering plants of *Amsinckia grandiflora* were counted at Lougher Ridge on 21 April, 1995, a 62% decrease from the 1106 reported in 1994 (Table 1). Most plants were still found in or near the 20 original reintroduction plots, but many had become

Table 1. Comparison of characteristics of the Lougher Ridge population of *Amsinckia*, March or April census, 1990 - 1995.

	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	Σ
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
1995	402	20	422	-63.2	66.7	-61.8	1.46	2.33	1.50

established between plots and along the access paths, giving a more continuous 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 was overwhelmed by the tall, dense grass canopy. Sampling revealed that the pin/thrum ratio was 1.46 inside the fence, but skewed towards pins outside the fence.

The 1994 plants at Lougher Ridge were much taller than last year, as indicated by their mean and maximum sizes (Table 2). There was also a very large number of plant size-classes represented in the 1995 population (25 classes vs. 14 in 1994, 17 in 1993, 14 in 1992 and 10 in 1991), with many individuals found in the largest (30- 90 cm) reproductive

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
1995	41.2 ± 14.3	37.4 ± 10.1	45.8 ± 12.6	45.4 ± 10.1	43.4 ± 9.7	42.6
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
1995	55.3 ± 6.9	46.0 ± 6.6	58.1 ± 9.2	55.5 ± 4.8	55.7 ± 4.8	64.9

categories (Figure 2). There was a similar increase of size-class representation for plants outside the fence (Figure 3). Although plants were tall, they were less branched than in previous years and many had weak stems. This may have been a response to rapid and tall grass growth stimulated by ample rain and low plant densities (similar to the burn treatment of Pavlik et al. 1993).

An estimated 39,871 nutlets were produced in 1995, an 140% increase compared to total nutlet production in 1994 (Table 3). This analysis assumes that the size-nutlet output relationship was not affected by the tall grass growth (e.g. that pollinator movements between *Amsinckia* flowers were not inhibited). Otherwise, it is possible that nutlet output was substantially lower and that next year's population could be thereby reduced.

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 1991-1995 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
1995	422	39,871	140.3

Status of the Natural Populations at Site 300

The Droptower population consisted of 1114 reproductive individuals in April of 1995, fewer than in 1994 but still several times larger than before the population was enhanced by annual grass management (Figure 4). Most *Amsinckia* individuals (about 700) were found in a patch, approximately five meters long, that dominated the 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 1994 now consisted of only three, large, coalescing patches of 136 plants. Another 60 plants were found 50 m west of the enclosure. In 1993 this group consisted of 31 plants and only seven plants in 1992. Furthermore, a total of 73 plants could be found downslope (north) of the original fenced area where only a handful could be found before. Despite the large number of plants in the population, the overall pin/thrum ratio at the Droptower was 2.00.

Compared to 1994, plant size increased at the Droptower significantly (Table 4). Approximately 62% of all reproductive plants exceeded 40 cm in height (6% in 1994, 36% in 1993) and 23% were greater than 50 cm (0% in 1994, 14% in 1993). Annual grass cover across the site was moderate (40% overall) due to the wet, mild winter, with the height of *Avena* in the range of 50-60 cm (only 10-25 cm in 1994). Plants in 1995 had a maximum of 13 flowering branches each (mostly 3-5 per plant), compared to a maximum of 32 each (3-6 per plant) in 1993 (even less branching in 1994). The large number of large reproductive plants this year produced a very showy display that lasted until 19 May. Consequently, nutlet output per plant was very high in 1995, with nearly 100,000 new nutlets added to the seed bank.

This was the second 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 lower management threshold of 1000 individuals and approached the estimated minimum viable size threshold of 1500 individuals. Although the population can be expected to both decrease and 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 necessary.

Table 4. Comparison of 1991-1995 performances of the Droptower population. See Pavlik (1991, 1992, 1993, 1994) for descriptions of the management regimes.

	P/T ratio	plant size: mean maximum (cm)	plant size: mean (cm)	nutlet production: mean #/repro plant)	nutlet production: 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
1995 unsprayed	2.00	67.7 ± 5.3	44.1 ± 12.2	85	94,690

The population in Draney Canyon population increased in size relative to 1994, with 27 plants found only on the east-facing side of the canyon (Figure 5). 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 (31.0 ± 10.8 and 41.8 ± 3.2 cm, respectively) were larger than last year (26.7 ± 6.5 and 29.4 ± 4.1, respectively) and comparable to that in previous years (33.7 ± 15.2 and 50.5 ± 9.8, in 1993, respectively). Unfortunately the plants seldom had more than two or three branches and resembled those observed at Lougher Ridge. Grass cover and height were both very high in this unmanaged population, indicating that the wet, mild conditions of the growing season produced intense competition. The pin/thrum ratio (1.6) was only slightly skewed towards pins. Although the Draney Canyon population is valuable for comparative purposes in its unmanipulated, natural state, its small, fluctating size and confinement to one wall of the canyon (apparently by severe erosion) requires some active management to improve growth and reproductive output.

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

The Black Diamond II population was in its second year since extirpation, with no reproductive plants emerging from the seed bank in 1994-1995. 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 had contracted by 1993, 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 imminent failure of the population (Pavlik 1993), although some live nutlets could still persist in the soil seed bank (see below). Unlike in previous years, the disturbance by gophers was nil, affecting none of the 12 plots within the fenced area (11 out of 12 were so affected in 1993-1994). 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.

Complete extirpation appears to have occurred at Los Vaqueros I, with no reproductive plants emerging from the seed bank. 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 8 reproductive plants were found during the April 1995 census, with only 1 inside the fence and 7 outside. The pin/thrum ratio was skewed in favor of pins (Table 5). Unlike at other sites in this particular year, mean maximum and mean plant size were only slightly larger than last year, so that only 10 nutlets were produced per plant on the average. Although grasses were not as dense or tall as at other sites (50-70% absolute cover), there was no evidence that previous management had reduced competition and provided benefits to *A. grandiflora* . In seven of the twelve plots there was a low degree of disturbance by rodents, with much less mounding of soil and clearing of plant cover than in previous years. Although it is only speculation at this time, stem clipping and seed collection by kangaroo rats may have had a large impact on the Connolly Ranch population of *A. grandiflora* .

Table 5. Characteristics of the Black Diamond II, Los Vaqueros,Connolly Ranch, and Corral Hollow populations, 1995.

	repro pop size (# pl)	P/T ratio	plant size: mean maximum[1] (cm)	plant size: mean[2] (cm)	nutlet production: mean (#/repro plant)	nutlet production: total (# in all plots)
Black Diamond II	0	0	0	0	0	0
Los Vaqueros I	0	0	0	0	0	0
Connolly Ranch	8	3.0	28.8 ± 3.9	22.0 ± 8.9	10	80
Corral Hollow	173	1.48	58.7 ± 3.0	46.4 ± 6.6	93	16,089

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

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 by spring of 1994 and decreased by 1995. 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. The decline in rodent activity observed in this wet year is consistent with Fitch's observations. Nevertheless, the seed bank of *A. grandiflora* at Connolly Ranch may have been subjected to intensive foraging during recent years.

The population reintroduced to Corral Hollow in 1991-1992 exhibited a 116% increase over last year, producing 80 individuals among the twelve plots. The three precision-sown plots installed in 1992-1993 contributed an additional two plants, while the six precision-sown plots of 1993-1994 produced another 41 reproductive individuals. An additional eight precision-sown plots (four containing 1994 Carnegie Canyon nutlets, four containing 1989 Davis nutlets) contributed 50 reproductive plants. The total at Corral Hollow on 5 April 1995 was 173 plants with a pin/thrum ratio of 1.48 (Table 5). As observed at most other sites, the plants were much larger than in previous years, with mean maximum and mean size significantly increasing compared to 1993-1994. Consequently, nutlet production was much higher than in previous years. Annual grasses were tall but cover was sparse to moderate (10-60%) depending on previous management and/or degree of rodent disturbance in the past. This year all of the precision-sown plots showed little sign of kangaroo rat foraging or gopher mounding even though such activities were intense last year. These results support the conclusions reached at other sites: the regional weather patterns of 1994-1995, particularly the extremely high amount of precipitation, resulted in strong but somewhat aberrant plant growth. In the absence of site management and/or gopher disturbance, competition from annual grasses would have had more deleterious effects.

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 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 5 May 1995, just past the peak of the floral display. There was some evidence that the population had contracted by as much as 40% compared to last year, but the density of plants remained high. 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 1.23 (n = 96). Most plants were large but with fewer branches than in previous years. Mean plant size increased (46.1 ± 13.4 cm vs. 36.9 ± 11.2 cm in 1994 vs. 49.7 ± 15.4 cm in 1993), as did mean maximum plant size (71.7 ± 5.7 cm vs. 55.5 ± 2.4 cm in 1994 vs. 73.6 ± 6.6 cm in 1993). Estimated mean nutlet output per plant would easily exceed 80 nutlets. 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.

<u>Seed Banks of Successful and Failing Populations</u>

The size and quality of *A. grandiflora* seed banks were correlated with the overall demographic characteristics of apparently successful and failing populations (Table 6). Apparently successful populations (Lougher Ridge and Droptower) which had large numbers of individuals (500 - 1600) during previous years with favorable plant size distributions and high nutlet output per plant had significantly higher nutlet densities than failing populations (Black Diamond 2, Los Vaqueros I, Connolly Ranch). The pattern was especially strong when differences in nutlet quality were taken into account.

The reintroduced population at Lougher Ridge had the highest nutlet densities in all three quality categories, ranging from 429 nutlets/m^2 (total density of all nutlets) to 202 nutlets/m^2 (density of the highest quality, vigorous nutlets). The highest quality nutlets constituted an average of 40% of the total seed bank. Although population size had declined from its peak in 1992 (1640 reproductive plants), the large number of large plants produced in the spring of 1993 (four months before seed bank sampling) contributed significantly to the high quality of the Lougher Ridge seed bank. In the spring of 1994 the Lougher Ridge population increased to 1106 reproductive plants.

The natural population at the Droptower also had a high density of nutlets in the seed bank (212 nutlets/m^2 total), statisically similar to that of Lougher Ridge. Nutlet quality was higher overall, with the vigorous fraction (140 nutlets/m^2) constituting 66% of the total. The number of reproductive plants in the population had peaked in 1992 (546) and declined in 1993 (342) , but again there had been a large number of large plants prior to seed bank sampling. In the spring of 1994 the Droptower population achieved its largest size since the late 1960's with 1606 reproductive plants.

The total density of nutlets in the seed bank at Connolly Ranch was equal to that of the Droptower popuation, yet the reintroduced Connolly Ranch population had begun a sharp decline after its 1992 peak (707 reproductive individuals). The difference was in seed bank quality. Only 9% of the total seed bank at Connolly Ranch was in the vigorous fraction; many whole pericarps appeared cracked or were missing in part. The low

Table 6. Density (# nutlets/m^2) and quality of the *A. grandiflora* seed bank at four reintroduction sites (LR = Lougher Ridge, BD2 = Black Diamond 2, LVI = Los Vaqueros I, CR = Connolly Ranch) and at one natural population (DT = Droptower), late summer and fall 1993. n = number of samples (with 2 subsamples per sample combined). Values in a column followed by the same letter are not significantly different ($P < 0.05$, Mann-Whitney U test).

		seed bank density				
		total	viable		vigorous	
site	n	(# / m^2)	(# /m^2)	(% of total)	(# /m^2)	(% of total)
LR	10	429 ± 118[a]	285 ± 96[a]	66 ± 12[a]	202 ± 77[a]	40 ± 15[a]
BD2	6	50 ± 23[b]	21 ± 8[b]	42 ± 16[a]	4 ± 3[b]	8 ± 10[b]
LVI	6	2 ± 2[c]	0 ± 0[c]	0 ± 0[b]	0 ± 0[b]	0 ± 0[b]
CR	6	204 ± 64[a]	96 ± 20[a]	47 ± 11[a]	8 ± 4[b]	9 ± 8[b]
DT	5	212 ± 62[a]	175 ± 54[a]	82 ± 13[a]	140 ± 44[a]	66 ± 12[a]

quality of the seed bank foreshadowed the severe population declines of 1994 and 1995 and was correlated with observations of intense rodent disturbance at this site (Pavlik 1994).

The failing, reintroduced populations at Black Diamond II and Los Vaqueros I had seed banks with very low nutlet densities and quality. Nutlet production had been weak at both sites, especially the latter where it was concluded that conditions had been physiological unsuitable for the species (Pavlik 1991, 1992). High quality nutlets constituted less than 10% of the total seed bank.

Conclusions and Management Recommendations

1) The reintroduced population of *Amsinckia grandiflora* at Lougher Ridge was comprised of 442 flowering plants in April 1995, a 62% decrease since 1994 (Table 6). Low nutlet production in 1994 was largely responsible for the decrease, but increased nutlet mortality due to the fall burn could not be ruled out. In the past the Lougher Ridge population has 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. Mean plant size increased significantly in this high rainfall year, and total nutlet production exceeded 39,000. 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 seventh year of this population is to increase the abundance and quality of low-competition neighborhoods at Lougher Ridge by conducting a large-scale spring burn (including areas beyond the original fence line) and mid-winter treatment of patches with a grass-specific herbicide. Efforts to restore a portion of the grassland by transplanting plugs of *Stipa pulchra , Poa scabrella, and Elymus* from local individuals into the fenced area also needs to be resumed. 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.

2) The natural Droptower population at Site 300 consisted of 1104 reproductive individuals in April of 1995, a decrease since the previous year (Table 7). The decrease was due to low nutlet production in 1994. Individual plants were larger than they had been in previous years, even in the absence of recent habitat treatment (Table 7). 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 increased to 27 plants and plant size increased.

The recommendation for 1995-96 is to enhance the Droptower population by controlling annual grasses with grass-specific herbicide during the late fall or early winter. Given the large decrease in the Lougher Ridge population (perhaps due to the fall burn), a prescribed burn at the Droptower should be delayed for at least one year. Monitoring of grass cover and demographic characteristics are required during the spring of 1996.

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 is always problematic.

3) The reintroduced Black Diamond II population remained extirpated during 1994-1995 and produced no reproductive plants. Previous 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. All recovery activities should be terminated at the site.

4) The reintroduced Los Vaqueros I population remained extirpated during 1994-1995 and produced no reproductive plants. As a result, this population probably has no potential for self-maintenance and is not going to contribute to the recovery of the species. All recovery activities should be terminated at the site.

5) The reintroduced population at Connolly Ranch declined significantly and was comprised of only 8 reproductive plants. Mean and mean maximum plant size increased insignificantly. Although it is only speculation at this time, stem clipping and seed collection by kangaroo rats may have had 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). These studies have already begun.

6) The original population reintroduced to Corral Hollow Ecological Reserve during 1991-1992 increased, and the surviving plants were large with high nutlet production. Additional plants were contributed by the precision-sown plots, so that the total for spring 1995 was 173 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 1995-1996. 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 fifth 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 1995-1996, although plants still number in the thousands. As at other sites across the range of the species, mean size and mean maximum size increased significantly as the result of high rainfall, but there appeared to be intense competition from annual grasses that produced tall, unbranched *A. grandiflora* plants. A conservation collection of bulk nutlets was made and stored at Mills College.

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 1996, including the collection of nutlets, is also recommended.

8) The size and quality of *A. grandiflora* seed banks were correlated with the overall demographic characteristics of apparently successful and failing populations. Apparently successful populations (Lougher Ridge and Droptower) which had large numbers of individuals (500 - 1600) during previous years with favorable plant size distributions and high nutlet output per plant had significantly higher nutlet densities than failing populations (Black Diamond 2, Los Vaqueros I, Connolly Ranch). The pattern was especially strong when differences in nutlet quality were taken into account.

These results justify management activities aimed at enhancing seed production in natural and reintroduced populations. Large, high quality seed banks (>140 nutlets/m2 in the vigorous fraction) are capable of producing large numbers of reproductive plants and appear to be more resilient in the face of environmental stochasticity. Efforts to reduce sources of nutlet mortality (e.g. rodent predation) would also enhance the seed bank, but may prove impractical. Further studies of seed predation in successful and failing populations are needed to document the causes for variations in seed bank characteristics between sites.

Table 6. A summary of the characteristics and status of created populations of *Amsinckia grandiflora* during the 1990-1995 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
1995	enhancement	442	39,870	1.50	declining
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?
1995	natural	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
1994	natural	0	0	0	extirpated
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
1995	natural	8	80	3.00	declining

Table 6. (cont.)

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
1995	enhancement	173	16, 090	1.48	growing

Table 7. A summary of the characteristics and status of natural populations of *Amsinckia grandiflora* during the 1990-1995 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
1995	natural	1104	44.1 ± 12.2	2.00	stable
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
1995	natural	27	31.0 ± 10.8	1.60	stable
New Population - Carnegie Canyon					
1993	natural	3000-4000	49.7 ± 15.4	1.13	?
1994	natural	2500-3000	36.9 ± 11.2	1.41	declining
1995	natural	2000-3000	46.1 ± 13.4	1.23	stable

Literature Cited

George, M.R., W.A. Williams, N.K. McDougald, W.J. Clawson, and A.H. Murphy. 1989. Predicting peak standing crop on annual range using weather variables. J. of Range Management 42, 508-513.

Fitch, H.S. 1948. Habits and economic relationships of the Tulare kangaroo rat. J. Mammology 29, 5-35.

Kelt, D.A. 1988. *Dipodomys heermanni* . Mammalian Species 323, 1-7.

Murphy, A.H. 1970. Predicting forage yield based on fall precipitation in California annual grasslands. J. of Range Management 23, 363-365.

Pavlik, B. M. 1988. Nutlet production and germination of *Amsinckia grandiflora.* I. Measurements from cultivated populations. California Department of Fish and Game, Endangered Plant Program, Sacramento, CA. 27 pp.

Pavlik, B. M. 1990. Reintroduction of *Amsinckia grandiflora* to Stewartville. California Department of Fish and Game, Endangered Plant Program, Sacramento, CA. 59 pp.

Pavlik, B. M. 1991a. Reintroduction of *Amsinckia grandiflora* to three sites across its historic range. California Department of Fish and Game, Endangered Plant Program, Sacramento, CA. 50 pp.

Pavlik, B. M. 1991b. Management of reintroduced and natural populations of *Amsinckia grandiflora* . California Department of Fish and Game, Endangered Plant Program, Sacramento, CA. 17 pp.

Pavlik, B. M. 1992. Inching towards recovery: Evaluating the performance of *Amsinckia grandiflora* populations under different management regimes. California Department of Fish and Game, Endangered Plant Program, Sacramento, CA. 39 pp.

Pavlik, B. M. 1993. Current status of natural and reintroduced populations of *Amsinckia grandiflora* under different management regimes. California Department of Fish and Game, Endangered Plant Program, Sacramento, CA. 31 pp.

Pavlik, B.M. 1994a. Demographic monitoring and the recovery of endangered plants. In: Bowles, M. and C. Whelan (eds.) Recovery and Restoration of Endangered Species. Cambridge University Press, Cambridge. pp. 322-350.

Pavlik, B.M. 1994b. Defining and measuring success in rare plant reintroductions. In: Falk, D., P. Olwell, and C. Millar (eds.) Restoring Diversity. Island Press (in press).

Pavlik, B.M. 1994c. Tales of Success and Failure: Trends in Natural and Reintroduced Populations of *Amsinckia grandiflora* Under Different Management Regimes. California Department of Fish and Game, Endangered Plant Program, Sacramento, CA. 31 pp.

Pavlik, B.M. 1995. The Recovery of an Endangered Plant. II. A Three-Phased Approach to Restoring Populations. In: Urbanska, K.M. and K. Grodzinska (eds.) Restoration Ecology in Europe. Geobotanical Institute SFIT, Zurich, Switzerland. 49-69.

Pavlik, B.M. and K. Heisler. 1988. Habitat characterization and selection of potential sites for establishment of new populations of *Amsinckia grandiflora* . California Department of Fish and Game, Endangered Plant Program, Sacramento, CA. 17 pp.

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

Tappe, D.T. 1941. Natural history of the Tulare kangaroo rat. J. Mammology 22, 117-148.

U.S. Fish and Wildlife Service. 1987. Draft Recovery Plan for the Large-flowered Fiddleneck *Amsinckia grandiflora* . Department of the Interior, U.S. F. W.S., Sacramento, CA.

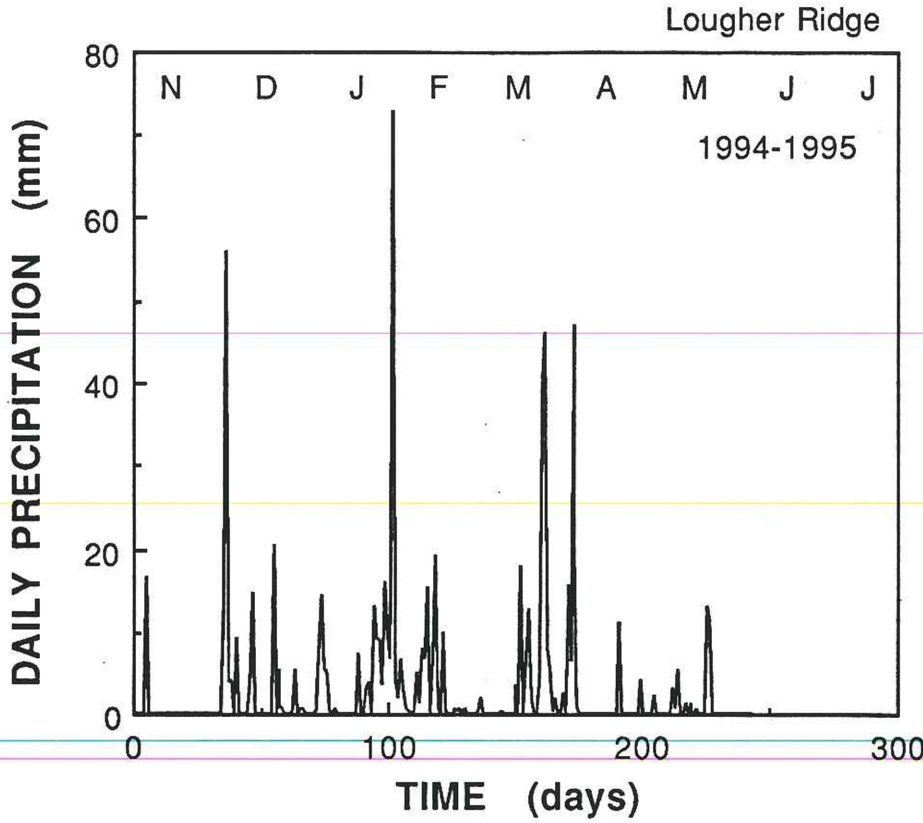

Figure 1. Seasonal pattern of daily precipitation at Lougher Ridge. Day 0 = October 1. Compare to Figure 1 of Pavlik (1994).

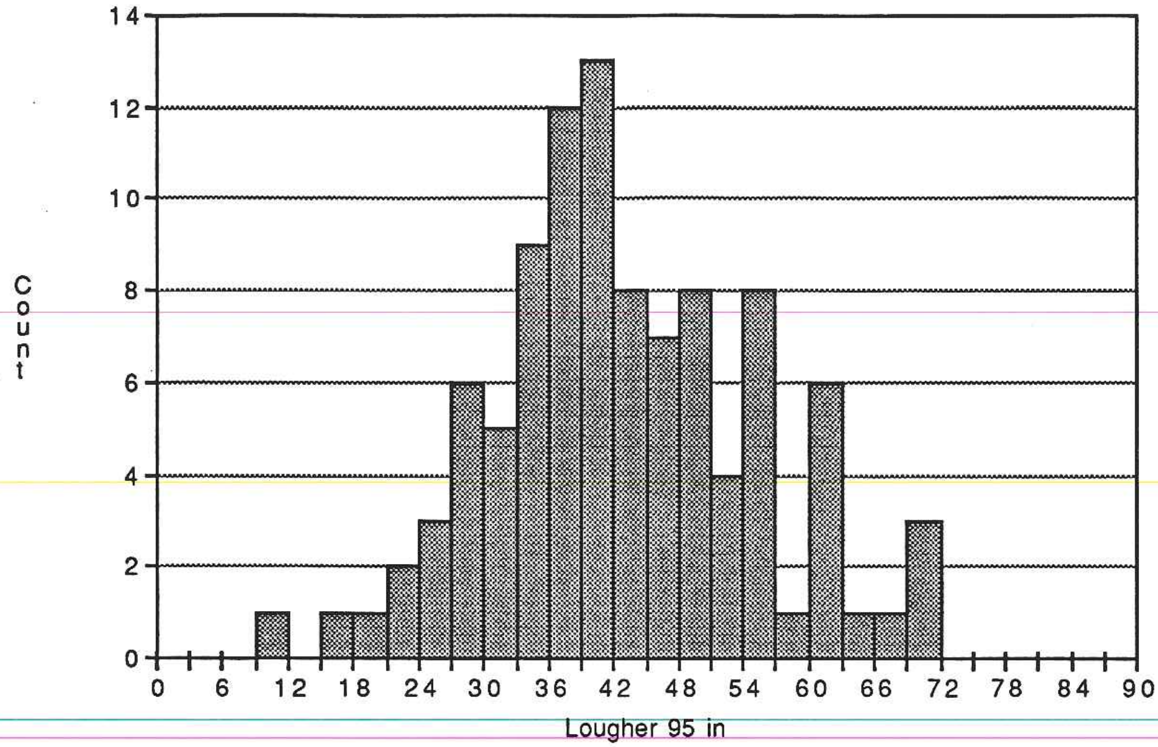

Figure 2. Plant size-class distribution for individuals growing inside the original fenced area at Lougher Ridge, 1995. Size-class dimensions on X axis are in cm of shoot length. Compare to Figure 2 of Pavlik (1994).

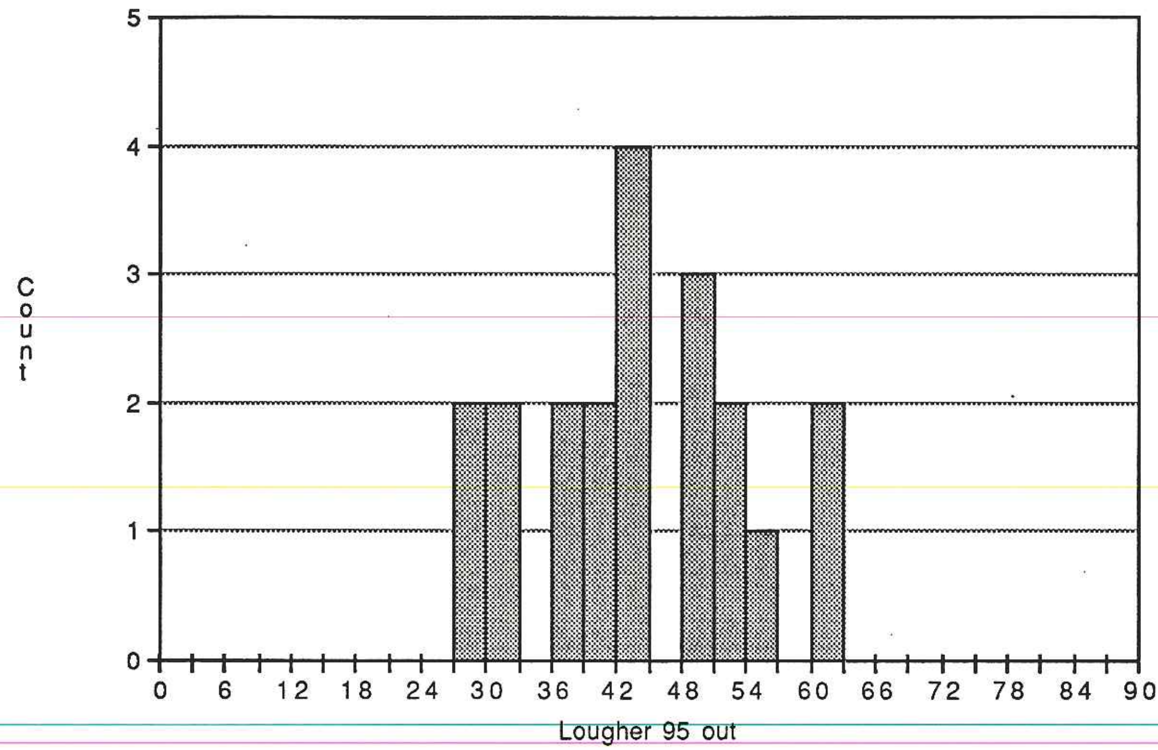

Figure 3. Plant size-class distribution for individuals growing outside the fenced area at Lougher Ridge, 1995. Size-class dimensions on X axis are in cm of shoot length. Compare to Figure 3 of Pavlik (1994).

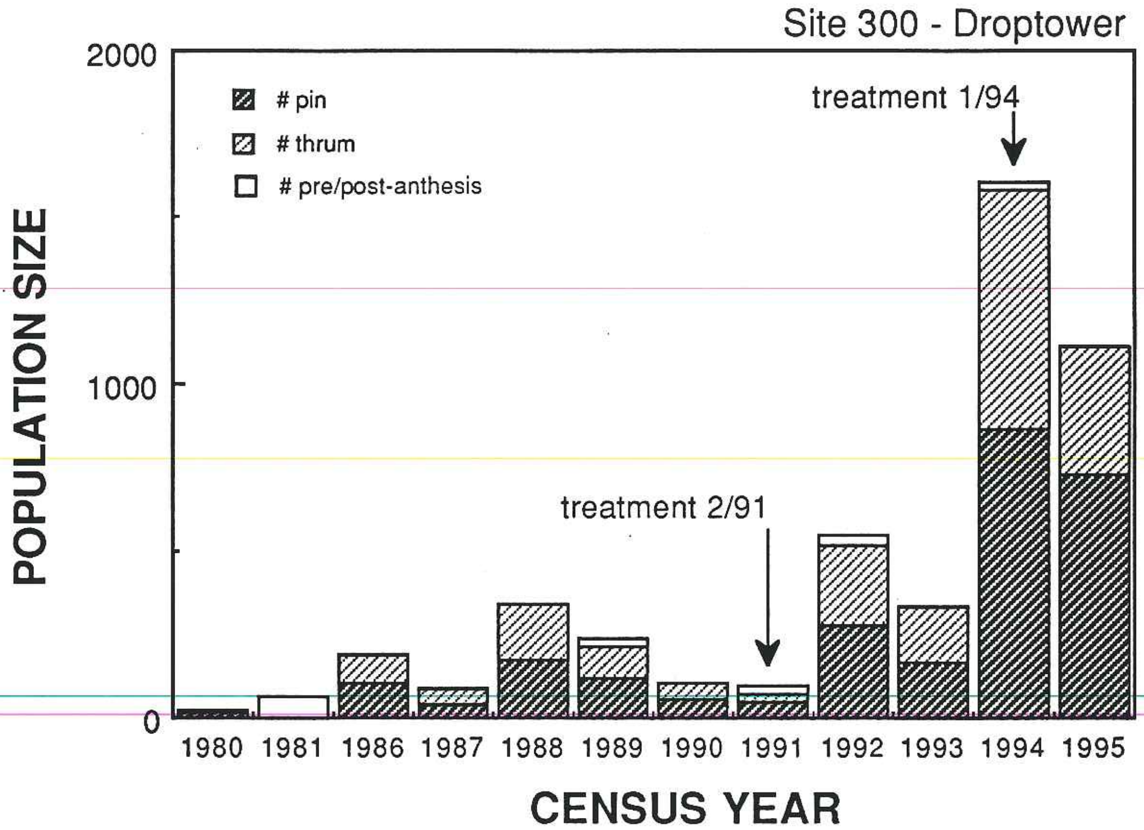

Figure 4. Spring census of the Droptower population of <u>Amsinckia grandiflora</u> at Site 300. Total population size and the proportion of pin and thrum individuals are shown. Approximate timing of treatments to reduce annual grass competition is shown.

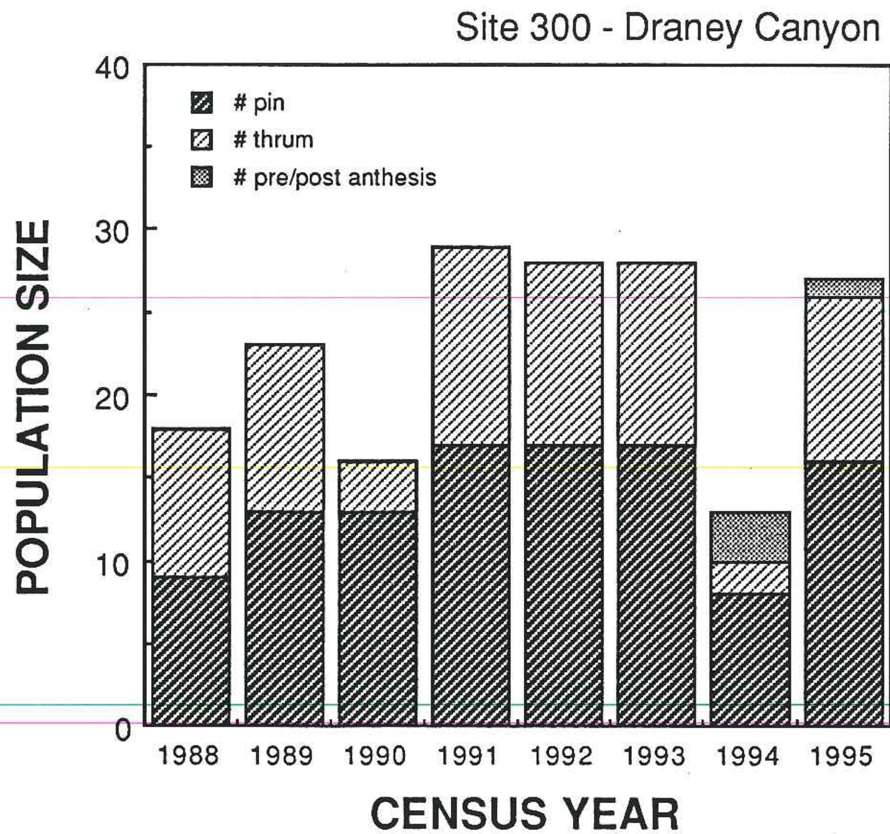

Figure 6. Spring census of the Draney Canyon population of *Amsinckia grandiflora* at Site 300. This population remains under a natural management regime.