Introducing Two Federally Listed Carbonate-Endemic Plants onto a Disturbed Site in the San Bernardino Mountains, California

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Abstract: *Erigeron parishii* and *Eriogonum ovalifolium* var. *vineum* are federally listed local-endemic plants occurring almost exclusively on carbonate soils in the northeastern San Bernardino Mountains. In 1991 and 1992, both species were planted onto a barren cut slope above a limestone quarry haul road. The plants were irrigated through the first summer and fall after planting. No soil amendments were provided other than the nursery potting mix surrounding their roots at planting. No effort was made to restore other components of natural habitat (e.g., soil conditions or plant associates). Each plant was tagged. Growth and survival were monitored for 2–3 years after planting, and again 6–7 years after planting. Of the initial plantings, 77 percent of *E. ovalifolium* var. *vineum* and 66 percent of *E. parishii* survived to the 1998 monitoring period. We estimated average half-lives of established *Eriogonum ovalifolium* var. *vineum* and *Erigeron parishii* as 20 years and 28 years, respectively. Both species have grown, flowered, and reproduced so that hundreds of progeny of both species now occur at the site. Most progeny of the two taxa were within a few meters of parent plants, and none were found beyond about 30 m from the study site. Progeny of both taxa became established on granitic material adjacent to the study site. *E. parishii* seems to have greater seedling production but lower establishment rates than *E. ovalifolium* var. *vineum*.

Eriogonum ovalifolium Nutt. var. *vineum* (Small) Jepson (Cushenbury buckwheat) and *Erigeron parishii* Gray (Parish's daisy) are narrow-endemic taxa of carbonate substrates in the northern San Bernardino Mountains, listed as endangered and threatened, respectively (U.S. Fish and Wildlife Service 1994).

Both are long-lived perennials with deep woody taproots (Sanders 1998a, 1998b, Neel 2000). *Eriogonum ovalifolium* var. *vineum* is a cushion-forming plant, only a few inches tall, but older plants on stable sites sometimes become quite wide. It generally occurs in rocky sites, in either talus or crevices in bedrock outcrops, but also on deeper colluvial soils. Its elevational range is about 4800–6500 ft. It is uncommon in washes or human-disturbed sites, but occasionally will colonize abandoned roads or quarry benches. Its pollinator is unknown, but observations of insect visitors suggest a generalist rather than specialist pollinator (Sanders 1998a, S. Morita personal communication).

Erigeron parishii is an erect plant with herbaceous stems rising to about 30 cm from a much-branched woody caudex at and just above the ground's surface. It occurs at about 3700–6200 ft elevation, most often in washes and canyon bottoms, but sometimes also on alluvial benches or steep rocky mountainsides.

Typical of the Asteraceae, *Erigeron parishii* produces plumed achenes adapted for wind dispersal. *Eriogonum ovalifolium* Nutt. var. *vineum* may also be wind dispersed; its achenes remain with the tepals as they dry, perhaps forming a "plane winged seed" (Burrows 1986). Neither taxon appears to have a seed dormancy mechanism (Mistretta 1994).

Both plants are generally considered carbonate-endemic, and the overwhelming majority of all known occurrences are on soils derived from limestone, dolomite, or other material high in calcium carbonate. There are scattered occurrences of these and other carbonate-endemic taxa on other parent materials. For example, *Erigeron parishii* occurs on quartz monzonite at the eastern end of its range (Neel 2000). Both taxa were successfully grown in soil mixes containing little or no carbonate material during propagation work at the Rancho Santa Ana Botanic Garden (Mistretta 1994).

Omya, Inc. (formerly Pluess-Staufer of California) contracted with the Rancho Santa Ana Botanic Garden (RSABG) to experiment with propagation of both taxa near its limestone quarry at White Knob, in the northern San Bernardino Mountains. One goal of the project was to establish populations of both plants on a barren cut slope above the quarry haul road. The planting site is a north-facing slope at about 5200 ft. elevation, on partially consolidated carbonate alluvial and colluvial subsoil, exposed by grading for the haul road. The site is at the northern margin of the San Bernardino Mountains, just above the toeslopes and bajadas where the mountain range grades into the Mojave Desert. The site itself is nearly unvegetated; surrounding vegetation is dominated by *Pinus monophylla, Juniperus osteosperma, Cercocarpus ledifolius, Arctostaphylos glauca*, and *Coleogyne ramosissima* (Neel 2000). A natural population of Eriogonum ovalifolium var. vineum occurs about 200 m upslope from the planting site.

Methods

Propagules (seeds and cuttings) were salvaged from the quarry site prior to initial grading. Nursery stock was propagated from seeds or cuttings at RSABG during the year preceding each year's planting. They were planted at the site as 4-inch container stock in May of 1991, and as 2-inch stock in May of 1992 (Table 1). They were planted without soil amendments other than the nursery planting mix included in their root balls. Each plant was marked with a numbered metal tag for follow-up monitoring. Irrigation was supplied through the summer and fall following initial planting, and some limited weeding was done, but no other supplemental care was given the plants. The 1991 cohort was watered thoroughly at the initial planting and through the following dry season by manually supplying enough water to fill the small soil berm around each plant, twice weekly, from the planting date until November 1991. The 1992 cohort was irrigated with a drip system. Each plant was supplied with a 1 gal per hr emitter. They were irrigated for 2 hours 2 days after planting, for 1 hour daily for the following week, and for 1 hour 2–3 times weekly through October 1992.

The planting sites were monitored monthly by Rancho Santa Ana Botanic Garden staff through November of 1993, providing survival and seedling establishment data over two and three growing seasons for the 1992 and 1991 cohorts, respectively. (The term "cohort" is used throughout this report to describe a group of individual plants of either species, planted at the site in the same year.) Tables 1 and 2 summarize monitoring data through November of 1993 (Mistretta 1993, 1994). Scott White revisited the site in August of 1998 to monitor survival of the original plantings and establishment of progeny.

Plants were censused by systematically walking over the entire planting site along parallel belt transects marked in the field to ensure a thorough census and to avoid double-counting plants. Every individual *Eriogonum ovalifolium* var. *vineum* and *Erigeron parishii* seen during the census was noted, along with its metal tag number (if present), length (longest cross-sectional distance), and flowering condition.

Results

Both species had high survivorship and reproduction through the monitoring period, and appear to have become established as self-sustaining populations at the site (Table 3).

In total, 454 *Eriogonum ovalifolium* var. *vineum* were censused: 128 of the original plantings and 326 of their presumed progeny. Survival from planting to 1998 was 77 percent, with most mortality occurring in the first year following planting (Figure 1; note that two plants were mistakenly recorded as dead in 1992, but they survived and were recorded as living in 1993). The average size

Table 1. Survival and reproduction of 1991 and 1992 plantings after 1 year (Mistretta 1993, 1994).

Species	Cohort	No. planted	Survival	Progeny
Eriogonum ovalifolium var. *vineum*	1991	70	54 (77%)	0
	1992	97	89 (92%)	See Table 2
Erigeron parishii	1991	81	55 (68%)	266
	1992	74	61 (82%)	See Table 2

Table 2. Survival and reproduction of 1991 cohort after 2 years (Mistretta 1994).

Species	Survival	Avg. length	Progeny
Eriogonum ovalifolium var. *vineum*	56 (80%)	6 in	3
Erigeron parishii	52 (64%)	8 in	±180

Table 3. Summary of 1998 monitoring results.

Species	Cohort	Survival of initial plantings[1]	Progeny number	Total number	Average length	Repro-ductive
Eriogonum ovalifolium var. *vineum*	1991	43/70 (61%)			7.8 in	35 (81%)
	1992	77/97 (79%)			6.1 in	74 (96%)
	Sum 91+92	128/167 (77%)			6.8 in	116 (90%)
	Progeny		325		3.2 in	141 (43%)
	Total			453	4.2 in	257 (57%)
Erigeron parishii	1991	44/81 (54%)			8.4 in.	44 (100%)
	1992	55/74 (74%)			4.3 in.	55 (100%)
	Sum 91+92	101/155 (65%)			6.9 in.	101 (100%)
	Progeny		452		2.9 in.	423 (94%)
	Total			553	3.6 in.	425 (95%)

1. Summed survival reported here is greater than the sum of 1991 and 1992 due to inclusion of plants whose tags were illegible.

of surviving plants of the 1991 cohort increased from 6 inches in 1993 to 7.8 inches in 1998; the 1992 cohort averaged about 6.1 inches (1993 sizes not available). Of the surviving plants, 90 percent produced flowers in 1998. The 326 *E. ovalifolium* var. *vineum* not tagged are presumed to be progeny resulting from reproduction among the original plantings and probably also second-generation reproduction. The ratio of original plantings to progeny was about 1:2.

The total count for *Erigeron parishii* was 553, consisting of 102 of the original plantings and 451 presumed progeny (Figure 2). Since the 1993 monitoring, mortality in the *Erigeron parishii* cohorts was about 10 percent, and overall survival of the two cohorts to 1998 was 66 percent. The average size of surviving plants in the 1991 cohort increased from 8 inches in 1993 to 8.4 inches in 1998; the 1992 cohort average was about 4.3 inches in length. All surviving plants were reproductive. The 451 *E. parishii* presumed to be progeny included second and later generations of the original plantings. The ratio of original plantings to progeny was about 1:3.

In some cases, metal tags were found but their corresponding plants were missing or dead. These plants were considered dead for this analysis. In other cases, tags were not found, and those plants are also considered dead, but note that in some cases tags may have been lost or concealed by plants. Actual survival was probably slightly higher than reported here.

Survivorship among 1992 cohorts of both species was markedly improved over the 1991 cohorts. This effect may be due to different planting or irrigation methods, or it may be due to external effects such as rainfall (the 1991-92 July-June rainfall year was slightly below average, whereas the 1992-93 year was well above average). Since 1993, survival of 1991 and 1992 cohorts was comparable; that is, plants that survived beyond their first year have had similar survival rates in the ensuing years.

Discussion

Survival and reproduction patterns on the Omya site provide some insights into *Eriogonum ovalifolium* var. *vineum* and *Erigeron parishii* seed dispersal, pollination, and other biotic interactions, as well as demography and life history strategies. This small study cannot provide precise or detailed descriptions of these ecological parameters, but these inferences should be useful hypotheses for further ecological research.

Progeny of both taxa became established a few meters beyond the bounds of the original planting areas, especially downslope. No progeny were seen more than about 30 meters from the original plantings. *Erigeron parishii* is surely wind dispersed and *Eriogonum ovalifolium* var. *vineum* may also be. Presumably, seeds of both taxa, especially *E. parishii*, dispersed well beyond the bounds of the study site. Observed seedling establishment suggests that most "seed rain" falls within about 2 m of parent plants for both species. This is consistent with patterns reviewed by Willson (1992), who thought that wind-dispersed seeds tend to have greater maximum dispersal distances than

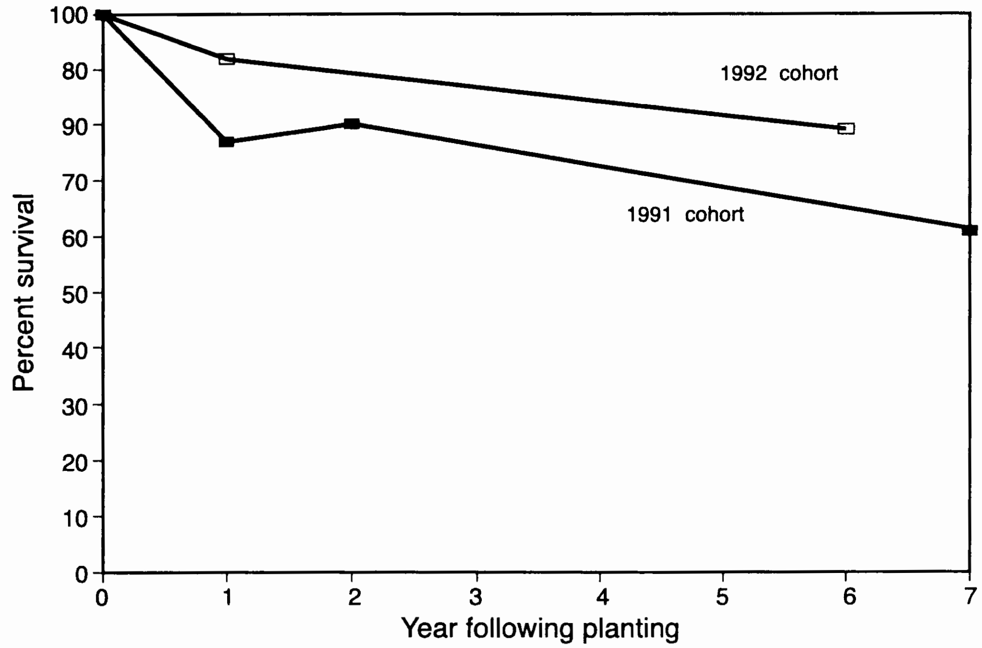

Figure 1. Survivorship of *Eriogonum ovaliflium* var. *vineum* initial plantings (1991 and 1992 cohorts).

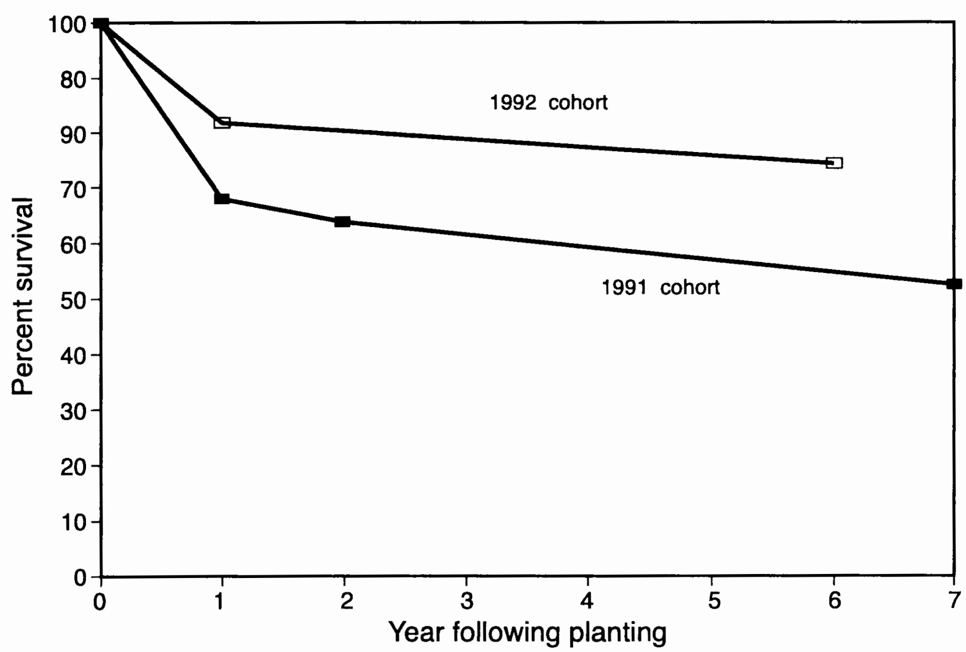

Figure 2. Survivorship of *Erigeron parishii* initial plantings (1991 and 1992 cohorts).

"ballistically" dispersed seed, but that peak distances were about the same for both mechanisms.

Progeny establishment beyond the original planted areas is particularly noteworthy at the northeastern corner of the original planting area, where there is a contact between carbonate-dominated alluvial and colluvial substrate (where the plantings were made) and the underlying granitic bedrock. Seventy-two *Eriogonum ovalifolium* var. *vineum* progeny and five *Erigeron parishii* progeny had become established in the weathered granitic bedrock. The higher establishment rate of *E. ovalifolium* var. *vineum* on non-carbonate material is likely due to the short dispersal distance rather than a greater tolerance for non-carbonate substrate. This granitic material is directly downslope from *E. ovalifolium* var. *vineum* plantings, and more distant from *E. parishii* plantings.

Both taxa set seed and produced progeny on the study site and in experimental planting boxes at RSABG. Breeding systems and pollinators are unknown for both plants, but successful reproduction in these settings indicates that neither plant is dependent upon a specialized pollinator. Successful seedling establishment in these habitats further suggests that neither plant is dependent upon specialized soil microorganisms.

We estimated seed production for the 1991 *Eriogonum ovalifolium* var. *vineum* cohort in 1993 at roughly 10,000 by multiplying mean seed number per inflorescence (6.2, N = 45) by the total number of infloresences (1612) on plants of the 1991 cohort. We estimated seed viability at 96 percent (Mistretta 1993). Only three *E. ovalifolium* var. *vineum* seedlings were found on the site in 1993. Presuming similar seed production in 1992, we calculate the survivorship rate from seed to established seedling for *E. ovalifolium* var. *vineum* at 0.0003 (3×10^{-4}). *E. parishii* seed viability was about 50 percent (Mistretta 1993). We did not calculate seed production or survivorship rates for *Erigeron parishii*, but it produces many more seeds per inflorescence, over a larger part of the growing season, and on many more inflorescences per plant. Its seed production is probably at least 2–3 orders of magnitude greater than for *E. ovalifolium* var. *vineum*.

Seedling production and recruitment for the two taxa was markedly different during the first years of the study, but was similar by 1998 (Figures 3 and 4). *Eriogonum ovalifolium* var. *vineum* produced no seedlings the first year and only three the second year, but had produced 325 progeny by 1998. Because we have no data for 1994–1997, we have no explanation for this pattern. We suggest that *E. ovalifolium* var. *vineum* may have infrequent years of very high recruitment, whereas most years have little or no recruitment due to climate variation (cf. *Larrea tridentata*; Barbour 1969). A second hypothesis is that seed set may generally be low, but very high in infrequent years, following a "mast fruiting" pattern (cf. *Coleogyne ramosissima*; Pendleton et al. 1995). Or, third, the large increase in seedling establishment over the later years of the study may simply have resulted from a large increase in seed production by the parent plants as they became better established, grew, and increased their inflorescence numbers.

Erigeron parishii produced 266 seedlings in the first year of the study (1992, Figure 4). By the second year (1993), only about 180 progeny were present, including any surviving seedlings from 1992 and any new seedlings produced during 1993. Of the 180 progeny, 35 were in flower. We infer that these 35 plants were seedlings germinated in 1992 that survived the intervening year and became reproductive in 1993. We presume that many, and perhaps all, of the remaining 1992 progeny died before spring 1993. If the 35 flowering progeny represent the entire recruitment cohort from 1992, then the survivorship rate was 13 percent of the previous year's seedlings, and the additional 145 progeny present in 1993 represented that year's reproduction. Alternately, if more than 35 1992 seedlings survived to 1993 but did not flower, then survivorship of the 1992 progeny would have been greater, but new reproduction during 1993 would have been less.

Table 3 and Figure 4 indicate surprisingly little increase in *Erigeron parishii* progeny by 1998. We believe that this is largely an artifact of census methods rather than a real decline in reproductive rates. Monitoring was done monthly through the growing seasons in 1992 and 1993, and all seedlings present during spring and early summer were censused. But in 1998, monitoring was done during August, near the end of the annual boom/bust cycle. Of the progeny counted in 1998, 94 percent were in flower, indicating that they were established plants from previous years. We believe that the 1998 data represent well-established plants, whereas the 1992 and 1993 data represent, in large part, seedlings that never became established. *Erigeron parishii* seems to have high annual seedling production and mortality, with only a moderate annual increase in established plants, as illustrated by Silvertown (1982, Figure 3.5b).

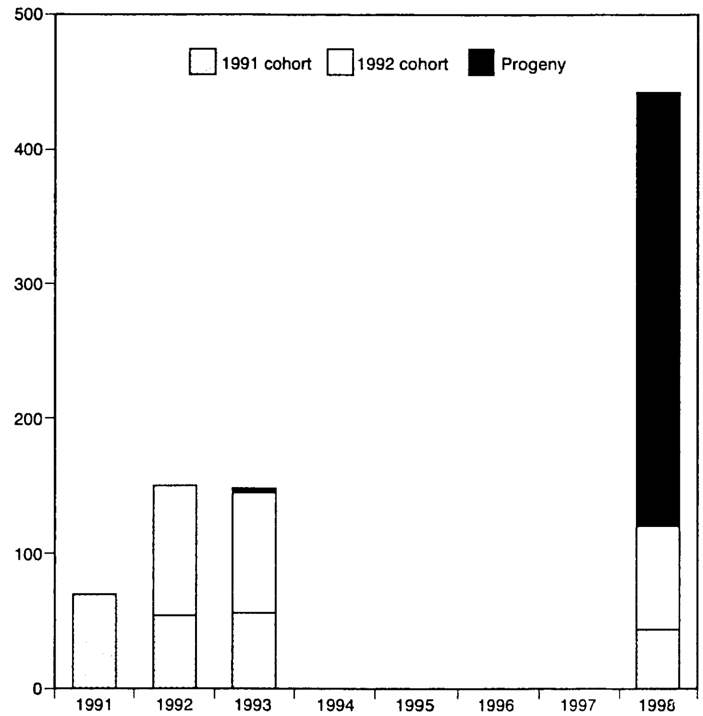

Figure 3. Total number of *Eriogonum ovaliflium* var. *vineum*, by year and cohort.

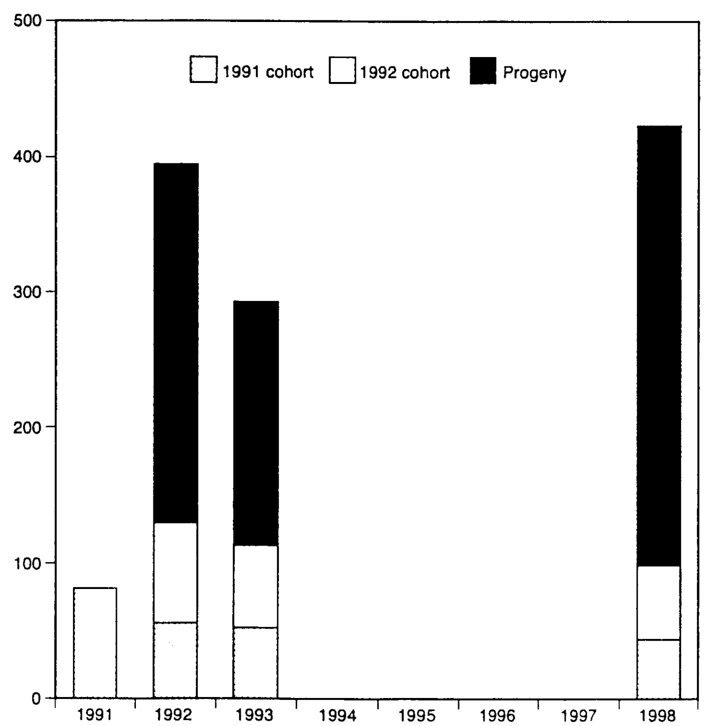

Figure 4. Total number of *Erigeron parishii*, by year and cohort.

The increase in number of *Erigeron parishii* progeny from 1993 to 1998 is considerable, but not nearly so striking as the increased establishment of *Eriogonum ovalifolium* var. *vineum* (Figure 3). Note also that only 43 percent of the *E. ovalifolium* var. *vineum* progeny produced flowers in 1998, compared with 95 percent of *E. parishii* progeny. These survival and reproductive patterns suggest that *E. ovalifolium* var. *vineum* is slower growing and slower to reach reproductive condition than *E. parishii*. The contrasting progeny numbers suggest greater seedling production but lower establishment rates for *E. parishii* than for *E. ovalifolium* var. *vineum*. We infer that *E. ovalifolium* var. *vineum's* survivorship curve resembles the Deevy type II form (Silvertown 1982), whereas *E. parishii's* survivorship curve resembles the Deevy type III form.

After plants became established, mortality was low for both taxa. Using Silvertown's (1982) formula, we calculated the average half-lives for an individual *Eriogonum ovalifolium* var. *vineum* and *Erigeron parishii* surviving beyond the first year after planting as about 20 years and 28 years, respectively. Both plants appear to be long-lived.

Acknowledgments

We thank John Dolan, Mike Wall, Linda Aberbom, Bart O'Brien, and Tom Hayduk for assistance with horticulture and monitoring; Howard Brown and Omya for logistical assistance and irrigation; Claudia Steiding for data entry; and Tasha LaDoux and Andrew C. Sanders for reviewing earlier drafts. Special thanks to Kitty Blassey for assistance throughout the first years of the project. O.M. dedicates this work to Mike Hammit who knew, grew, and loved the plants.

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