WASHINGTON NATURAL HERITAGE PROGRAM

Population Viability Analysis: *Eriogonum codium* (Umtanum desert buckwheat)

Prepared for Region 1, U.S. Fish and Wildlife Service

Prepared by

Florence Caplow
Thomas N. Kaye
Joseph Arnett

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Doug Sutherland - Commissioner of Public Lands

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Prepared by

Florence Caplow
Washington Natural Heritage Program

Thomas N. Kaye
Institute for Applied Ecology
563 SW Jefferson Ave.
Corvallis, Oregon

Joseph Arnett
Washington Natural Heritage Program

Washington Natural Heritage Program
Department of Natural Resources
Olympia, Washington

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Executive Summary

Eriogonum codium (Umtanum desert buckwheat) is a Candidate species with the USFWS and is Endangered in Washington. This species was described in 1995 as *Eriogonum codium* Reveal, Caplow & Beck (Polygonaceae) (Reveal et. al 1995). The global extent of the species consists of approximately 5,000 plants occurring along a one-mile linear area on Umtanum Ridge. It is not closely related to any other Washington species of *Eriogonum* (Reveal et. al 1995). It forms low mats up to 1 meter in diameter.

E. codium has been the subject of an intensive demographic monitoring project since 1997. Initial findings from 1997 through 1999 were reported in 2000 (Dunwiddie *et al.* 2000). In 2000 we concluded that *Eriogonum codium* is a long lived species (greater than 100 years) with high flower production, low germination rates, high seedling mortality, and high variability of growth between individuals and years. Annual adult mortality ranged from 0% to 4%. One hundred and sixty-nine new seedlings were observed in 1997-1999, and none survived more than one year. Most died between May and July. Mortality exceeded recruitment in the three growing seasons between 1997 and 1999.

E. codium appears to be in very gradual decline. The stochastic growth rate for the population, as measured from 1997-2006, was 0.9935, which is very close to stable, but still suggests an annual decline of about 2/3 of one percent. A projection of the population from 1997 for 100 years suggests that the population may decline over time modestly or greatly, and that it is unlikely to grow substantially if current conditions remain the same.

The probability of extinction to less than 10% of the initial population size was estimated at zero for all time scenarios through 100 years. However, dropping to 50% of 1997 levels is more likely in 50 or 100 years. A fifty percent decline in 20 years was not likely to occur (0% probability), but in 50 years there was a 12.8% probability of this level of decline and in 100 years there was a 72% chance.

Acknowledgments

Many people have participated in collecting the extensive data that was used in this analysis. Participants have included Jenny Barnett, Katy Beck, Katie Birkhauser, Anna Constance, Mark Darrach, Peter Dunwiddie, Jim Evans, Eliza Habegger, Lindsey Hayes, Tyson Kemper, Terry Knoke, K. Lawlor, Betsy Lyons, Merita Lih, Tim McCracken, Jennifer Meisel, Heidi Newsome, Doug Reynolds, and Tracy Rush. Other individuals may have also been part of this effort, and we apologize if we have missed their names in the records. Our thanks to all who have participated.

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Introduction

Eriogonum codium (Umtanum desert buckwheat) is a Candidate for listing as an Endangered species by the U.S. Fish and Wildlife Service. It is a narrow endemic known from a small geographic range on Umtanum Ridge in Washington State. Annual demographic monitoring has been conducted on this species since 1997, with the last sample monitored in 2006. The substantial demographic data available for this species makes possible a population viability analysis based on transition matrix modeling.

Objectives: The purposes of this report are to:

1. Present transition matrix models for *E. codium* based on data collected from 1997-2006 by the Washington Department of Natural Resources, The Nature Conservancy, and collaborators.
2. Conduct a Population Viability Analysis to estimate extinction probability, stochastic population growth rate, and elasticities.
3. Present the results of these analyses with a discussion of their implications.

Methods

The following population viability analysis (pva) was conducted by Thomas N. Kaye of the Institute for Applied Ecology, on contract with the Washington Natural Heritage Program.

Available data: Data available for this analysis were collected by the Washington Department of Natural Resources (Natural Heritage Program), The Nature Conservancy, and their collaborators (Dunwiddie et al 2000). Demographic monitoring was initiated in 1997 and plots were sampled annually through 2006. Twenty-four 1x2 m permanent plots were randomly placed along three 50 meter belt transects within the largest subpopulation of *E. codium*. More than 100 individually tagged adult were mapped and measured each year. Measurements included plant length and width, number of inflorescences, and "percent dead" for each adult. Plant area was calculated as elliptical crown cover (½ length * ½ width * π). Seedlings were mapped in May and again in July of each year, although the May seedling search was omitted in 1998 and 2002. For a detailed discussion of monitoring methods, see Dunwiddie et al. (2000). The full database was managed in an Excel spreadsheet.

Plant stages: A stage-based approach to modeling this population was used instead of an age-based approach because individual plants could not be aged without destructive sampling (the only age estimates for this species have come from measuring growth rings on dead plants [Dunwiddie et al. 2000]). All plants in each year were assigned to one of four life-history stages based on seedling status or plant area. The stages were defined as follows:

1. seedling
2. area <200 cm^2
3. area 200-500 cm^2
4. area >500 cm^2

These stages were developed to reflect the range of plant sizes and serve two functions: 1) provide adequate numbers of individuals in each stage to make accurate estimates of life-history processes, and 2) identify size categories with internal consistency in observed reproductive effort as measured by inflorescence production. In this way, the various stages group individuals of like reproductive capacity in sufficient numbers to estimate transition probabilities each year.

Calculation of survival rates and estimates of fertility: The pivot table function in Excel was used to calculate the proportion of each stage that entered another stage (or remained the same) between consecutive years. To estimate the number of seedlings produced by an individual in each reproductive stage (i.e., the fecundity of each stage) in each year, we used the average number of flowers on plants in each stage, the number of plants in each stage, and the number of seedlings observed the following year to prorate seedling production among individuals in each stage. These survival rates and estimates of fertility were arranged in transition matrices for each pair of years from 1997 through 2006. See Kaye and Pyke (2003), Kaye et al. (2001), Caswell and Kaye (2001), or Menges (1986) for more complete discussions of transition matrix models for plant population dynamics and viability analyses.

Population Viability Analysis:

Deterministic and stochastic modeling – Population growth rate and viability with the transition matrices was evaluated using data from 1997-2006. For this analysis, both deterministic (for each year) and stochastic measures of population growth, lambda (λ) and stochastic lambda (λs), were calculated for the population. Lambda is the equilibrium population growth rate (and the dominant eigenvalue of the transition matrix), and can be used as a single measure of population viability to compare sites or years. Stochastic lambda (λs) does not assume equilibrium population dynamics and incorporates observed environmental variability. If either type of growth rate is less than 1.0, the population will be projected to decrease in size, and eventually become extinct (a non-viable population). If lambda is greater than 1.0, the population will grow (a viable population), given that current conditions remain constant.

Assumptions of the model – This use of the transition matrix model assumed that fertility and transition rates were independent of plant density. This is an acceptable assumption for many species with population densities below the density-dependent threshold (density-vague populations). However, density dependence eventually limits growth of populations with lambda greater than one. Demographic stochasticity was also ignored by our models, but it usually generates little variation in population dynamics relative to environmental stochasticity, except at very low population sizes (Menges 1992). In addition, our model assumed that population growth is a first-order Markov process, in

which the probability that a plant will make a transition is independent of its stage in the previous year.

Analysis – Population viability was evaluated in two different ways, stochastic population growth rate and extinction probability. This involved projecting future population dynamics by randomly selecting survival and fecundity measures from past years. Environmental variability was included in the model process through the matrix selection method, which involved selecting a whole matrix at each time step, selected at random from the matrices available since monitoring began in 1997. The matrices represent each year of the study, and the variation between them is considered to be environmental stochasticity. We used the program LAMS (Kaye et al. 2001) to calculate stochastic population growth rate with 100,000 iterations. The program SHUFFLE (Kaye, unpublished program) was used to calculate extinction probability by randomly selecting survival and fecundity measures from past years with the matrix selection method, as above. Both programs were written for and implemented with the software Matlab. More detailed descriptions of this method can be found elsewhere (Kaye and Pyke 2003).

Simulations to calculate extinction probabilities were run for three time scenarios: 20, 50 and 100 years. Initial population size was assumed to be 5228 plants distributed among the four stages according to the average population structure measured across all years of sampling. This population size was the census total from 1997 (Dunwiddie et al. 2000). These simulations ran for 10,000 iterations and stopped at the quasi-extinction thresholds of 50% decline or 90% decline to provide conservative estimates of extinction dynamics.

In addition, elasticities of the average matrix were calculated. Elasticities are the proportional sensitivity of lambda to small changes in transition probabilities. Elasticities provide valuable information about the extent to which population growth depends on survival, growth, and reproduction at different stages in the life-cycle (Caswell 2001). Elasticities were summed across stages to provide an overall stage-specific value of the importance for survival and reproduction for population growth.

Results and Discussion

Basic life-history: Over the course of this study a total of 105 established individuals of *E. codium* have been mapped and measured, and an additional 178 seedlings have been tracked. Only five of these seedlings established and persisted for more than 1 year. The basic life-history of the species as modeled here involves four stages, from seedling through large reproductive plants (Figure 4). The pathways plants can follow through time include growth from one stage to another, stasis (remaining in the same size class from one year to the next), or decline (reduction in size). Stage 2 plants have the potential to grow quickly and become stage 4 plants in one year (although this is a very rare event), and vice versa. Stages 2, 3 and 4 are capable of reproduction but many individuals in these stage classes, especially the smallest class, may be vegetative in any given year.

Transition matrix: The transition matrix for *E. codium* (Table 1) is based on the life-history diagram in Figure 1. Average fertility rates (top row of the matrix) range from about 0.4 seedlings per stage 4 plant down to only 0.01 for stage 2 plants. Seedlings themselves only survive to stage 2 at an average rate of 0.07. Individual plants have a strong tendency to remain in the same size class from one year to the next. For example, stasis for stage 2 and 3 plants is over 80%, and over 90% for stage 4 plants.

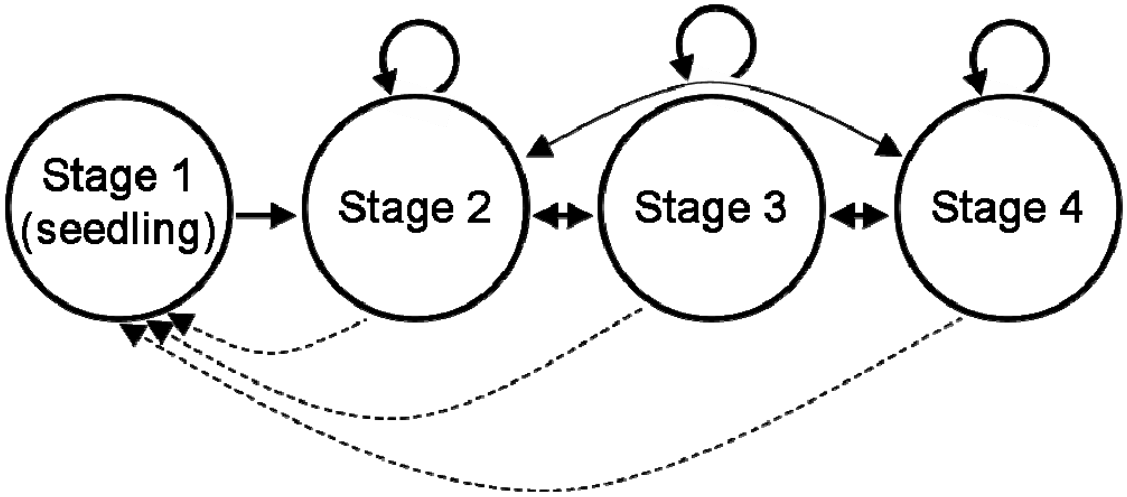

Figure 1. Life-cycle diagram of *Eriogonum codium* with four stages. Solid arrows represent the transitions individuals can make from one year to the next. Note that most stages can progress to the next larger stage, remain the same, or die back to a smaller stage. In addition, stages 2 and 4 can skip stage 3 in their annual growth or decline. Dashed arrows represent reproduction, i.e., stages 2 through 4 can produce seedlings because they can flower. Stage 1 (seedling) plants are defined as first year individuals. They are non-reproductive and have only been observed to grow to stage 2. Stage 2 plants are less than 200 cm^2 in crown area, stage 3 are between 200 and 500 cm^2, and stage 4 plants are greater than 500 cm^2.

Table 1. Average transition matrix for *Eriogonum codium*. Each value represents the mean of nine observed transitions from 1997 through 2006, except for stage 1 (seedlings). Values in this column are the mean from only seven observed transitions because no seedlings were observed in 2002 or 2005. The transitions representing stasis (remaining in the same stage from one year to the next) are shown in bold.

		Stage at time t			
		1	2	3	4
Stage at time t+1	1	--	0.010	0.094	0.416
	2	0.070	**0.820**	0.070	0.018
	3	0.000	0.114	**0.805**	0.056
	4	0.000	0.023	0.109	**0.912**
	mortality	93.0%	4.3%	1.5%	1.4%

Plant mortality was very low for all stages except seedlings. Less than 2% of stage 3 and 4 plants died annually, but annual seedling mortality was 93% (Table 1).

Elasticities: Elasticity analysis indicated that stasis of stage 4 plants had the single greatest impact (0.468) on population growth rate. In addition, stasis of stage 3 (elasticity=0.226) and stage 2 (elasticity=0.164) plants had the second and third strongest effects on population growth (Table 2). Overall, seedling dynamics (recruitment and survival) had very little impact on population growth rate.

Table 2. Elasticies of the mean matrix (Table 1) for *Eriogonum codium*. Each value represents the proportional sensitivity of the population growth rate to small changes in vital rates. Column sums are the cumulative elasticities for each stage.

		Stage at time t			
		1	2	3	4
Stage at time t+1	1	0	0.0001	0.0015	0.0106
	2	0.0123	**0.1644**	0.0159	0.0067
	3	0	0.0281	**0.2258**	0.0248
	4	0	0.0067	0.0354	**0.4676**
	Sum	**0.0123**	**0.1993**	**0.2786**	**0.5097**

Population viability: *E. codium* appears to be in very gradual decline. The stochastic growth rate for the population as measured from 1997-2006 was 0.9935, which is very close to stable, but still suggests an annual decline of about 2/3 of one percent. A projection (Figure 2) of the population from 1997 for 100 years suggests that the

population may decline over time modestly or greatly, and it is unlikely to grow substantially if current conditions remain the same.

The probability of extinction to less than 10% of the initial population size was estimated at zero for all time scenarios through 100 years. However, dropping to 50% of 1997 levels is more likely in 50 or 100 years. A fifty percent decline in 20 years was not likely to occur (0% probability), but in 50 years there was a 12.8% probability of this level of decline and in 100 years there was a 72% chance (Table 3).

Table 3. Extinction probability of *Eriogonum codium* under three time scenarios and two extinction thresholds.

	Extinction threshold	
Time frame	90%	50%
20 yr	0	0 (± 0)
50 yr	0	0.128 (± 0.003)
100yr	0	0.722 (± 0.005)

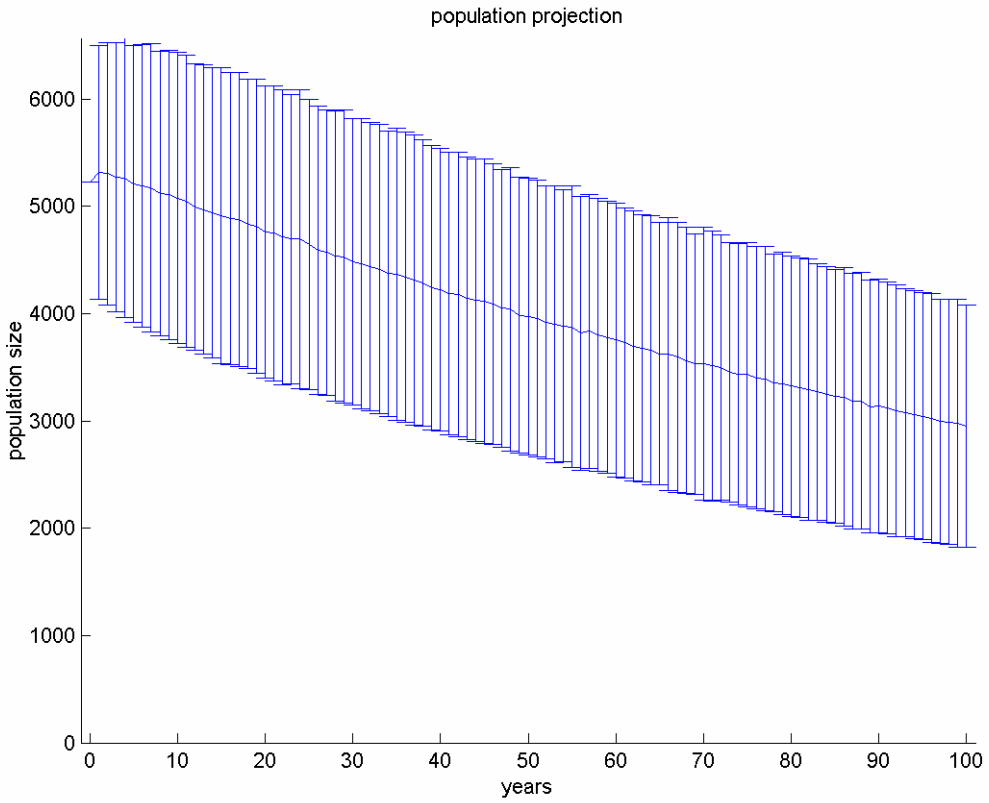

Figure 2. Population projection for *Eriogonum codium* based on 10,000 iterations and an initial population size of 5,228 individuals (the 1997 census). Error bars represent +/- 1 standard deviation from the mean.

Summary and Conclusions

- *Eriogonum codium* appears to be in decline in its only known population. As modeled with data collected from 1997-2006, this decline will be gradual and take several decades to accumulate significant impacts.

- The projected decline is consistent with the 2005 census of 4,418 plants, which is down from 5,228 in 1997. However, the model does not consider stochasticity, which in this population may be a significant threat. This is demonstrated by the 15.5% decline in the eight years between 1997 and 2006, presumably mostly because of loss in a fire in 1996.

- The estimated stochastic population growth rate is 0.9935.

- There is little or no risk of a population decline greater than 90% in the next century, but there is a 72% chance of a 50% decline in the next 100 years.

- Seedling dynamics appear to be highly episodic, with numerous seedlings observed in only a few years since monitoring began.

- Artificially increasing seedling recruitment and survival may be necessary to change the downward trend in population size for this species. The low elasticity measured for seedlings suggests that large increases in seedlings will be required to change the projected population trend. Small changes in adult plant survival could also have strong effects on population growth, but survival of mature plants is already so high that further increases seem unlikely. However, the mature plants are extremely vulnerable to stochastic events, particularly fire, and disturbance of this type could have a profound influence on the continued existence of the species.

Management Recommendations

The extremely narrow distribution of *E. codium* makes it particularly vulnerable to stochastic events, and wildfire is a major threat to this species. During the summer of 1996, a fire escaped from the Yakima Training Center and traveled down the ridge occupied by *E. codium*. The fire was most severe where vegetative cover was dense and less severe on thinner soils with little or no vegetation. Shrub and grass fuels on parts of the ridge are sparse, and the fire was patchy in the area where *E. codium* is located (J. Soll, TNC, pers. comm. 1997). However, the fire killed an estimated 800 plants, or roughly 15 percent of the entire population (P. Dunwiddie, TNC, pers. comm. 2001). The plants appear to be quite sensitive to heat and were easily killed. Plants that were singed, but not visibly charred, appeared to be negatively effected and many died the year following the fire. The fire did not stimulate vigorous new growth on established *E. codium* plants, or sprouting from the plants' root crowns. In addition, there was no

apparent flush of seedlings the following spring. This lack of regeneration indicates that the species is not fire-tolerant (Dunwiddie et al. 2001). The long-term impact of the fire to the population is unknown, but is likely to be significant given the low recruitment potential documented for this species.

Fire may be the primary threat to *E. codium* (Dunwiddie, pers. comm. 2001), and it could become an even greater threat if the frequency of fires increases (TNC 1998; Dunwiddie et al. 2001). Fires promote the invasion of some nonnative species, particularly cheatgrass (*Bromus tectorum*). In turn, the establishment and growth of highly flammable cheatgrass increases the likelihood of fire, potentially further impacting the *E. codium* population. Protecting this population from fire, where feasible, should be incorporated into strategic fire management planning for the Hanford Reach National Monument.

Fire fighting activities also pose a threat to the species. The location of the *E. codium* population is a natural fire break overlooking steep slopes, and fire lines and fire fighting equipment tend to be concentrated in such areas (Heidi Brunkal, U.S. Fish and Wildlife Service (USFWS), pers. comm. 2001). Fire fighting plans for the area should identify that this is an extremely vulnerable area, and that fire lines should be located away from the edge of the slope break where *E. codium* grows.

There has been an increasing incidence of trespassing by off-road vehicles (ORVs) and hikers in the vicinity of and within the *Eriogonum codium* population (F. Caplow, pers. comm. 2001). The open cliff edge where the plants grow is an attractive place for human traffic because of the compact substrate, sparse vegetative cover, and the view overlooking the Columbia River. The entire known population exists within a narrow corridor where human traffic would be expected to concentrate. *Eriogonum codium* plants are easily damaged by trampling or crushing by ORVs, and appear to be extremely sensitive following such damage. Within two days of being run over by trespassing dirt bikes, portions of damaged plants showed signs of further decline. Some of the damaged plants have since died (TNC 1998). Care should be taken in management plans to direct traffic away from this population. Because of the attraction of the scenic overlook, it may be useful to provide a scenic access away from the *Eriogonum codium* population.

Prospecting by rock collectors may also threaten *Eriogonum codium*. Holes up to 1.5 meters (5 feet) in diameter and 1.2 meters (4 feet) deep dug with a pick-axe and shovel are found throughout area occupied by the species (T. Thomas, USFWS, pers. obs. 1996). The age of these excavations is unclear. Some may remain from before 1943, when the Department of Energy acquired the land as part of the Hanford Nuclear Reservation. However, others may be the result of more recent, illegal collecting. Continued rock collecting on the Monument could threaten a large portion of the *Eriogonum codium* population. The species would be better protected if rock collecting was restricted in the area of this population.

In 2004-2005, BPA re-opened and improved a steep road up the power-lines on the top of the ridge from the substation on China Bar. The road is now passable to 2WD vehicles,

and as of the summer of 2005, was inadequately gated to prevent trespass (Caplow, pers. com. 2005). This increases the threats described above. We recommend that as much as possible, public access to this area should be restricted or routed away from the *E. codium* population.

Research Needs

Although mature plants demonstrate longevity, low seedling survival pf *E. codium*, even in years with fairly high seedling initiation, suggests that survival of seedings in the first year of life is a weak link in the continued survival of this species. Observations of seedlings dying during the dry summer months suggest that while mature plants may be resistant to summer drought, seedlings may not be. Climatic warming and drying would likely increase the rate of seedling death and, consequently, population decline. Determining strategies to enhance seedling survival would be a suitable research topic, as would be developing a methodology for attempting propagation methods for augmentation planting or establishing additional populations in the general vicinity of the extant population.

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Appendix A

Transition matrices for all years. Values in red are means from remaining years used to fill missing seedling values in years where seedlings were not observed in sample plots.

	stage97			
stage98	1	2	3	4
1	0	0.0053524	0.0283534	0.097935
2	0.1	0.9230769	0	0
3	0	0.0769231	0.9189189	0.0714286
4	0	0	0.0810811	0.9285714
mortality	0.9	0	0	0

	stage98			
stage99	1	2	3	4
1	0	0.0203974	0.1110527	0.5128773
2	0.25	0.8461538	0.1025641	0
3	0	0.0769231	0.7692308	0.0689655
4	0	0	0.0769231	0.8965517
5	0.75	0.0769231	0.0512821	0.0344828

	stage99			
stage00	1	2	3	4
1	0	0.0246289	0.4660387	1.9225085
2	0	0.8684211	0.0285714	0
3	0	0.1052632	0.8571429	0.0344828
4	0	0	0.0857143	0.9655172
5	1	0.0263158	0.0285714	0

	stage00			
stage01	1	2	3	4
1	0	0.0208117	0.1670573	0.9821095
2	0	0.8235294	0.0571429	0
3	0	0.0882353	0.7714286	0.1290323
4	0	0.0294118	0.1142857	0.8709677
5	1	0.0588235	0.0571429	0

	stage01			
stage02	1	2	3	4
1	0.0000	0	0	0
2	0	0.8666667	0.1176471	0.03125
3	0	0.1333333	0.7352941	0.03125
4	0	0	0.1470588	0.90625
5	1	0	0	0.03125

	stage02			
stage03	1	2	3	4
1	0.0000	0.0029142	0.0154087	0.0719823
2	0.0704	0.8387097	0.0666667	0
3	0.0000	0.0967742	0.8666667	0.0588235
4	0.0000	0.0322581	0.0666667	0.9117647
5	0.9296	0.0322581	0	0.0294118

	stage03			
stage04	1	2	3	4
1	0	0.0143353	0.057565	0.1415911
2	0	0.8571429	0	0.0294118
3	0	0.1071429	0.8064516	0.0294118
4	0	0.0357143	0.1935484	0.9117647
5	1	0	0	0.0294118

	stage04			
stage05	1	2	3	4
1	0.0000	0	0	0
2	0.1428571	0.8	0.1034483	0.0789474
3	0	0.08	0.7931034	0.0263158
4	0	0.04	0.1034483	0.8947368
5	0.8571429	0.08	0	0

	stage05			
stage06	1	2	3	4
1	0.0000	0.001634	0.0007726	0.0156664
2	0.0704	0.5555556	0.1538462	0.0263158
3	0.0000	0.2592593	0.7307692	0.0526316
4	0.0000	0.0740741	0.1153846	0.9210526
5	0.9296	0.1111111	0	0

Appendix B: Eriogonum codium data for PVA,1997-2006

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	plot #	Plant No.	1=Top;2=Sl	97Are	97#Infl	stage	98Area	98#Infl	stage	99Are	99#Inf	stage	00#Inf
2	10401	1	1	1744	78		1791	98		2078	30		49
3	10401	3	1	86	0		92	0		102	0		0
4	10416	4	2	471	0		542	37		578	33		76
5	11403	5	1	110	0		112	0		99	0		0
6	11403	6	1	636	97		633	64		633	15		10
7	11403	7	1	484	30		569	8		424	0		0
8	11403	8	1	328	21		343	8		377	2		0
9	11403	9	1	280	19		264	0		236	0		0
10	11403	10	1	134	2		170	5		14	0		0
11	11403	11	1	572	71		408	25		358	3		33
12	11407	12	2	289	16		320	19		314	7		32
13	11407	13	2	251	15		339	27		353	16		2
14	11407	14	2	224	0		280	19		267	3		3
15	11407	15	2	254	0		254	0		199	0		0
16	11407	16	2	55	5		102	15		153	3		20
17	13006	17	1	94	11		79	3		47	0		1
18	13006	18	1	177	32		154	12		153	0		4
19	13006	19	1	346	0		346	0		271	0		0
20	13006	20	1	110	11		99	2		141	0		3
21	13006	21	1	318	26		255	12		295	3		15
22	13006	22	1	569	43		551	17		531	2		30
23	13006	23	1	1513	142		1587	78		1843	11		71
24	13006	24	1	418	13		424	4		518	0		29
25	13006	25	1	742	49		990	70		1075	5		6
26	13024	26	2	170	0		220	1		289	7		30
27	13024	27	2	1081	0		660	12		396	12		
28	11605	28	1	467	13		467	20		577	6		0
29	11605	29	1	212	30		212	6		184	3		0
30	11605	30	1	102	1		102	0		82	0		0
31	11605	31	1	147	20		147	9		156	0		0
32	11605	32	1	226	32		200	1		239	1		0
33	11605	33	1	42	1		42	0		49	0		0
34	11605	34	1	358	52		393	15		449	2		0
35	11605	35	1	200	32		212	6		212	5		0
36	11605	36	1	31	0		27	0		27	0		0
37	11605	37	1	721	188		797	70		797	10		1
38	11611	38	2	674	114		584	5		622	16		15
39	11611	39	2	78	0		57	0		51	0		0
40	20601	40	1	99	11		99	3		132	0		1
41	20601	41	1	160	4		176	0		227	8		0
42	20601	42	1	118	5		69	0		163	0		0
43	20601	43	1	104	0		104	0		121	0		0
44	20601	44	1	255	17		121	0					
45	20601	45	1	163	1		198	0		239	0		0
46	20601	46	1	220	0		220	7		220	0		8
47	20601	47	1	33	0		33	0		44	0		0
48	20601	48	1	1255	38		1292	65		1470	30		89
49	20601	49	1	141	3		121	0		141	1		1
50	23408	50	2	942	209		1015	215		1072	42		108
51	20607	51	2	251	23		280	55		432	30		75

Appendix B: Eriogonum codium data for PVA,1997-2006

	A	B	C	D	E	F	G	H	I	J	K	L	M
52	23408	52	2	518	54		641	44					
53	23408	53	2	254	32		346	73		379	3		39
54	23408	54	2	170	6		179	17		179	0		17
55	23408	55	2	69	5		75	8		99	0		2
56	10206	56	1	75	1		75	1		75	0		0
57	23804	57	1	153	0		188	10		212	0		1
58	23804	58	1	240	5		314	14		346	1		2
59	23804	59	1	198	0		235	5		253	0		0
60	23804	60	1	1100	123		1451	65		1417	2		3
61	23804	61	1	132	0		154	0		153	0		0
62	23804	62	1	102	2		110	12		130	0		4
63	23804	63	1	452	29		452	28					
64	23804	64	1	334	48		307	13		330	0		0
65	23804	65	1	55	0		47	0					
66	23810	67	2	628	69		628	189		841	61		296
67	10206	69	1	294	7		314	0		347	0		0
68	10206	70	1	346	28		220	0		194	0		8
69	10206	71	1	259	18		259	9		294	0		0
70	10206	72	1	57	1		69	0		69	0		0
71	10206	73	1	57	2		44	0		57	0		0
72	10206	74	1	339	15		373	20		429	1		8
73	10206	75	1	143	12		163	0		141	0		0
74	10206	76	1	174	2		118	0		153	0		0
75	10206	77	1	141	0		141	1		156	0		0
76	10212	78	2	110	6		110	1		153	0		3
77	10212	79	2	269	32		254	4		314	2		2
78	10212	80	2	726	195		726	45		848	9		52
79	10212	82	2	531	21		432	4		470	1		3
80	10212	83	2	1517	1		1348	1		1373	0		0
81	10212	84	2	63	1		75	0		75	0		0
82	10212	85	2	364	14		330	2		352	0		3
83	23004	86	1	801	78		814	50		843	3		16
84	23008	87	2	1501	48		1578	28		1616	8		24
85	23008	88	2	471	2		462	12		478	1		6
86	33007	89	1	432	5		488	50		113	0		13
87	33007	90	1	271	0		294	8		259	0		0
88	33007	91	1	3738	35		3738	160		3952	0		40
89	34206	93	1	368	0		424	17		592	1		25
90	34206	94	1	650	0		754	4		679	0		0
91	30408	95	1	912	19		1244	26		1255	12		99
92	31813	96	2	1806	67		2463	105		2417	14		100
93	33408	97	1	950	15		1068	45		1041	10		55
94	33408	98	1	71	1		71	0		79	0		0
95	33408	99	1	1071	14		975	56		813	17		43
96	33408	100	1	1104	9		1348	77		1555	24		17
97	33408	101	1	1873	36		2095	142		2026	31		103
98	33411	102	2	484	62		542	51		700	20		104
99	20205	103	1	353	37		424	30		471	8		28
100	20205	104	1	950	83		820	24		697	5		72
101	20205	105	1	212	27		226	0		254	2		36
102	20205	107	1	393	25		424	21		495	3		41

Appendix B: Eriogonum codium data for PVA, 1997-2006

	A	B	C	D	E	F	G	H	I	J	K	L	M
103	20205	108	1	170	0		194	0		184	0		3
104	30408	109	1	9	0		9	0		13	0		5
105	33007	111		3	0		4	0		6	0		0
106	11407	112	2						1			2	0
107	20205	106	1	184	1		226	4		254	1		2
108	11605	S1				1			6				
109	20205	S2				1			2			6	
110	20205	S3				1			2			2	
111	20205	S4				1			6				
112	10206	S5				1			2			6	
113	10206	S6				1			6				
114	11403	S7				1			6				
115	11403	S8				1			6				
116	11403	S9				1			6				
117	11403	S10				1			6				
118	11403	S11				1			6				
119	11403	S12				1			6				
120	11403	S13				1			6				
121	11403	S14				1			6				
122	11403	S15				1			6				
123	11403	S16				1			6				
124	11403	S17				1			6				
125	11403	S18				1			6				
126	11403	S19				1			6				
127	13006	S20				1			6				
128	13006	S21				1			6				
129	13006	S22				1			6				
130	13006	S23				1			6				
131	13006	S24				1			6				
132	13006	S25				1			6				
133	13006	S26				1			6				
134	13006	S27				1			6				
135	20205	S28				1			6				
136	20601	S29				1			6				
137	23810	S30				1			6				
138	11403	S31							1			6	
139	11605	S32							1			6	
140	20205	S33							1			6	
141	11407	S34										1	
142	10516	S35										1	
143	10516	S36										1	
144	23408	S37										1	
145	23408	S38										1	
146	23408	S39										1	
147	23408	S40										1	
148	23408	S41										1	
149	23408	S42										1	
150	23408	S43										1	
151	23408	S44										1	
152	23408	S45										1	
153	23408	S46										1	

	A	B	C	D	E	F	G	H	I	J	K	L	M
154	23408	S47										1	
155	23408	S48										1	
156	23408	S49										1	
157	23408	S50										1	
158	23408	S51										1	
159	23408	S52										1	
160	23408	S53										1	
161	10416	S54											
162	10416	S55											
163	10416	S56											
164	10416	S57											
165	10416	S58											
166	10416	S59											
167	10416	S60											
168	11403	S61											
169	11403	S62											
170	11605	S63											
171	11611	S64											
172	11611	S65											
173	13006	S66											
174	13006	S67											
175	13006	S68											
176	13006	S69											
177	13006	S70											
178	13006	S71											
179	13006	S72											
180	20205	S73											
181	20601	S74											
182	20601	S75											
183	20601	S76											
184	20607	S77											
185	23004	S78											
186	23408	S79											
187	23408	S80											
188	23408	S81											
189	23408	S82											
190	23408	S83											
191	23408	S84											
192	23408	S85											
193	23408	S86											
194	23408	S87											
195	23408	S88											
196	23408	S89											
197	23408	S90											
198	23408	S91											
199	23408	S92											
200	23408	S93											
201	23408	S94											
202	23408	S95											
203	23408	S96											
204	23408	S97											

	A	B	C	D	E	F	G	H	I	J	K	L	M
205	23408	S98											
206	23408	S99											
207	23408	S100											
208	23408	S101											
209	23408	S102											
210	23408	S103											
211	23408	S104											
212	23408	S105											
213	23408	S106											
214	23804	S107											
215	23804	S108											
216	23804	S109											
217	23804	S110											
218	23804	S111											
219	23804	S112											
220	23804	S113											
221	23804	S114											
222	23810	S115											
223	23810	S116											
224	31813	S117											
225	33007	S118											
226	33007	S119											
227	33007	S120											
228	33007	S121											
229	33007	S122											
230	33408	S123											
231	33411	S124											
232	33411	S125											
233	33411	S126											
234	10206	S127											
235	10206	S128											
236	10206	S129											
237	10212	S130											
238	10401	S131											
239	10401	S132											
240	10401	S133											
241	10416	S134											
242	10416	S135											
243	11403	S136											
244	11407	S137											
245	13006	S138											
246	13006	S139											
247	13006	S140											
248	13006	S141											
249	13006	S142											
250	13006	S143											
251	13006	S144											
252	13006	S145											
253	13006	S146											
254	20205	S147											
255	20205	S148											

	A	B	C	D	E	F	G	H	I	J	K	L	M
256	20205	S149											
257	20205	S150											
258	20205	S151											
259	20205	S152											
260	20205	S153											
261	23008	S154											
262	23408	S155											
263	23408	S156											
264	23804	S157											
265	23810	S158											
266	23810	S159											
267	31813	S160											
268	31813	S161											
269	31813	S162											
270	33408	S163											
271	11605	S164											
272	11605	S165											
273	11605	S166											
274	10212	S167											
275	13024	S168											
276	23804	S169											
277	23804	S170											
278	23804	S171											
279	33007	S172											
280	33411	S173											
281													
282													
283													
284													
285													
286													
287													
288													

Appendix B: Eriogonum codium data for PVA, 1997-2006

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
1	00Are	stage	01#Inf	01Are	stage	02#Inf	02Are	stage	03#infl	03Area	stage	04#Infl	04Area	stage
2	1814		53	1513		42	1409		75	1192		68	1847	
3	112		0	112		0	141		2	141		0	154	
4	880		16	950		135	1313		110	1100		112	1626	
5	99		0	283		0	126		0	19		0	22	
6	679		0	748		34	754		67	828		33	959	
7	433		7	518		18	524		32	478		19	448	
8	361		0	393		1	412		23	452		4	528	
9	280		4	307		3	294		26	358		2	339	
10	113		0	28		2	28		2	50		0	47	
11	572		7	578		29	603		41	470		14	694	
12	352		3	352		36	414		13	478		19	550	
13	368													
14	283		0	328		8	363		11	449		11	467	
15	199													
16	212		24	280		57	283		6	379		31	452	
17	78		1	66		0	60		3	69		6	69	
18	177		1	214		0	163		19	165		17	138	
19	361		0	283		0	302		0	247		0	204	
20	106		0	147		5	160		5	126		15	239	
21	295		1	396		5	387		10	364		13	365	
22	531		17	424		26	506		18	542		22	511	
23	1885		14	2036		20	2040		22	1920		46	2375	
24	560		15	544		4	518		9	565		2	194	
25	880		2	1011		4	1100		5	797		12	327	
26	424		22	495		66	584		38	721		66	814	
27														
28	467		0	478		1	456		20	432		0	449	
29	320		0	368		32	388		35	429		4	327	
30	102		0	99		0	110		0	118		0	118	
31	174		0	179		6	163		0	153			0	
32	254		0	239		3	298		15	415		2	380	
33	49		0	50		0	49		0	572		3	683	
34	393		0	445		25	424		18	467		4	700	
35	226		0	267		0	280		37	313		3	328	
36	22		0	27		0	22							
37	674		0	797		21	848		59	836		13	1414	
38	603		0	700		88	726		75	729		73	855	
39	66		0	66		1	82		10	120		0	94	
40	99		0	126		4	141		4	127		4	149	
41	214		1	198		0	209		7	269		3	276	
42	69		0	134		1	283		3	134		5	156	
43	132		0	165		0	153		0	187		0	198	
44														
45	220		1	149		1	157		9	164		0	198	
46	259		0	259		2	231		6	247		7	224	
47	38		0	42		0	50		3	49		0	49	
48	1501		33	1562		81	1665		126	1748		18	1522	
49	113		0	121		2	143		3	143		12	650	
50	1195		26	511										
51	449		62	592		67	530		57	704		29	778	

Appendix B: Eriogonum codium data for PVA,1997-2006

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
52														
53	396		34	509		66	528		93	589		45	730	
54	204		1	214		13	242		8	259		4	253	
55	123		1	153		4	147		12	170		4	184	
56	92		0	92		3	194		1	130		0	77	
57	201		0	298		8	280		4	311		5	361	
58	346		1	415		3	452		36	594		5	682	
59	235		0	319		1	264		1	314		1	347	
60	1106		0	298		12	1624		89	1414		65	1583	
61	151		0	1661		10	198		30	280		11	328	
62	121		0	187		14	200		53	198		2	212	
63														
64	307		0	235		2	199		3	339		4	320	
65														
66	994		168	1012		147	1056		267	1178		115	1178	
67	339													
68	170		1	236		1	149		14	184		7	297	
69	280		0	242		3	343		14	254		8	236	
70	69		0	71		0	64		0	78		0	86	
71	49		0	63		0	63		1	69		0	57	
72	412		0	396		51	506		31	547		6	592	
73	153		0	141		0	141		0	153		0	163	
74	16		0	16		0	16		0	16				
75	149		0	149		1	149		5	165		0	184	
76	163		0	188		0	214		35	209		0	251	
77	313		0	373		4	397		49	528		18	509	
78	792		19	352		86	368		93	418		38	452	
79	147		0	156		28	138		16	318		13	632	
80	1445		0	1337		12	1313		36	1578		38	1610	
81	85		0	110		3	94							
82	330		0	364		7	337		17	374		24	452	
83	785		0	814		51	843		77	1011		119	1095	
84	1546		5	1520		44	1590		29	1520		32	1590	
85	408		1	518		25	596		24	648		5	614	
86	276		2	251		31	280		22	328		52	294	
87	264		0	235		6	264		10	339		5	339	
88	4210		1	4281		195	4281		124	4059		73	3859	
89	518		2	578		6	657		6	704		12	752	
90	746		0	716		0	627							
91	1169		202	1307		1	1374		17	1389		24	1362	
92	2168		51	2815		195	2903		33	2808		68	2903	
93	1072		31	1224		97	1221		54	1250		51	1221	
94	86		0	123		0	113		0	104		0	104	
95	1025		8	775		117	849		25	1253		47	1348	
96	1011		3	1550		70	1772		15	1308		17	847	
97	2178		1	2622		168	2622		36	1155				
98	748		84	888		161	942		80	925		59	901	
99	518		4	622		17	694		40	735		12	792	
100	797		17	622		24	467		69	492		22	522	
101	267		1	380		13	297		60	434		1	449	
102	536		12	495		16	622		61	632		25	686	

Appendix B: Eriogonum codium data for PVA,1997-2006

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
103	164													
104	13		2	33		7	44		2	49		9	123	
105	13		0	24		0	20		0	44		0	49	
106	4		0	13		0	24		6	38		1	50	
107	212		0	313		7	346		16	379		1	434	
108														
109														
110		6												
111														
112														
113														
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139														
140														
141			6											
142			6											
143			6											
144			6											
145			6											
146			6											
147			6											
148			6											
149			6											
150			6											
151			6											
152			6											
153			6											

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
154			6											
155			6											
156			6											
157			6											
158			6											
159			6											
160			6											
161			1			6								
162			1			6								
163			1			6								
164			1			6								
165			1			6								
166			1			6								
167			1			6								
168			1			6								
169			1			6								
170			1			6								
171			1			6								
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195			1			6								
196			1			6								
197			1			6								
198			1			6								
199			1			6								
200			1			6								
201			1			6								
202			1			6								
203			1			6								
204			1			6								

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
205			1			6								
206			1			6								
207			1			6								
208			1			6								
209			1			6								
210			1			6								
211			1			6								
212			1			6								
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Appendix B: Eriogonum codium data for PVA,1997-2006

	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	AA
256						1			6					
257						1			6					
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	AB	AC	AD	AE	AF	AG
1	05#Infl	05Area	stage			
2	9	1571				
3	0	151				
4	1	1414				
5						
6	0	959				
7	0	596				
8	0	550				
9	0	358				
10	0	78				
11	0	679				
12	2	537				
13						
14						
15						
16	4	373				
17	0	69				
18	0	165				
19	0	157				
20	0	212				
21	0	157				
22	0	578				
23	1	2243				
24	0	220				
25	0	569				
26	26	872				
27						
28	0	467				
29	0	382				
30	0	118				
31						
32	0	415				
33	0	700				
34	0	694				
35	0	346				
36						
37	0	694				
38	0	88				
39	0	694				
40	0	141				
41	0	264				
42	1	141				
43	0	187				
44						
45	0	283				
46	0	251				
47	0	44				
48	20	1499				
49	0	701				
50						
51	7	855				

	AB	AC	AD	AE	AF	AG
52						
53	4	774				
54	6	271				
55	0	198				
56	0	88				
57	0	343				
58	0	638				
59	0	347				
60	0	1470				
61	0	311				
62	0	224				
63						
64	0	320				
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66	49	1205				
67						
68	0	224				
69	0	251				
70	0	78				
71	0	63				
72	0	63				
73	0	163				
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75	0	184				
76	0	259				
77	0	613				
78	0	503				
79	0	209				
80	0	1477				
81						
82	0	374				
83	0	1068				
84	7	1554				
85	2	622				
86	0	358				
87	0	308				
88	15	4166				
89	3	754				
90						
91	34	1527				
92	19	2872				
93		0				
94	0	130				
95	5	1322				
96	16	1124				
97						
98	91	1063				
99	3	785				
100	7	537				
101	0	432				
102	5	806				

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104	2	132				
105	0	44				
106	0	57				
107	1	449				
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272	6					
273	6					
274	1					6
275	1					2
276	1					6
277	1					6
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