WASHINGTON NATURAL HERITAGE PROGRAM

Status and Conservation Assessment of *Eriogonum codium* (Umtanum desert buckwheat)

Prepared for
US Fish and Wildlife Service

Prepared by
Walter Fertig
June 3, 2022

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ON THE COVER: Umtanum desert buckwheat (*Eriogonum codium*), Umtanum Ridge, Hanford Reach National Monument, Washington.

Photograph by Walter Fertig.

Table of Contents

Page

Figures

Tables

Appendices

Introduction

Umtanum desert buckwheat (*Eriogonum codium*) is a mat-forming perennial herb with gray woolly leaves and ball-like clusters of lemon-yellow flowers. It is restricted to barren rims and upper slopes of volcanic basalt bedrock in desert shrub communities along eastern Umtanum Ridge in Benton County, Washington (Figure 1). The earliest known herbarium collection of this species was made in June 1993, but was initially misidentified. Katy Beck and Florence Caplow collected it 1995 during a biodiversity survey of the Hanford Nuclear Site, and suspecting it was an undescribed species, sent material to *Eriogonum* expert Dr. James Reveal for identification. Reveal, Caplow, and Beck (1995) formally named and described the species in 1995. Indigenous cultures were probably aware of the species for millennia, as the Umtanum Ridge area is rich in archaeological sites and buckwheats are important food plants (Reveal 2005). Due to its small range, high threats, and low population numbers, *E. codium* was designated as a candidate for potential listing under the Endangered Species Act (ESA) in 1999 (USFWS 1999) and was officially listed as Threatened in December 2013 (USFWS 2012, 2013a, 2013c). USFWS has designated critical habitat and produced a draft recovery plan for this species, as well as a species biological report (USFWS 2013b, 2021a, 2021b, 2021d). *Eriogonum codium* is designated as state Endangered by the Washington Natural Heritage Program (WNHP) with a Natural Heritage rank of G1/S1 (Fertig 2021a, 2021b).

Since 1997, USFWS has funded several projects focusing on surveys, monitoring, habitat modeling, population viability, seedling ecology, propagation, and impacts from climate change and fire on Umtanum desert buckwheat (Abel 2013, Arnett 2012, 2013a, 2013b; Beck 1999, Caplow 2003, 2005, Caplow et al. 2007; Dunwiddie et al. 2001; Fertig 2018, 2019, 2021a; Kaye 2007, Kleinknecht and Fertig 2020; Newsome 2020; Newsome and Abel 2020, 2021; Newsome and Goldie 2013, 2016, 2017; Rush and Gamon 1999; Shank 2019). In 2019, USFWS contracted with WNHP to continue annual population monitoring of the single native occurrence (established in 1997 to assess trends and estimate population viability) and evaluate whether this monitoring program is still providing meaningful information. WNHP was also tasked with developing a potential habitat model for *Eriogonum codium* based on the intersection of environmental attributes (such as bedrock geology, land cover, monthly mean temperature and precipitation, and other variables) that could be used to identify additional native occurrences or suitable areas for out-planting new populations. Lastly, USFWS asked WNHP to compile information on seed collection, storage, and propagation methods. The following report is a summary of monitoring, modeling, and research on seed storage and propagation undertaken from 2019-2021.

Methods

<u>Population Census</u>

A complete census of the Umtanum Ridge occurrence of *Eriogonum codium* was conducted in July 2019. Six people walked in a single file through each of the three main subpopulations and carefully placed colored pin flags next to each flowering or vegetative *E. codium* plant (seedlings were not included). The flags were then retrieved to derive a total count of all plants. The numbers of vegetative and flowering plants were not differentiated.

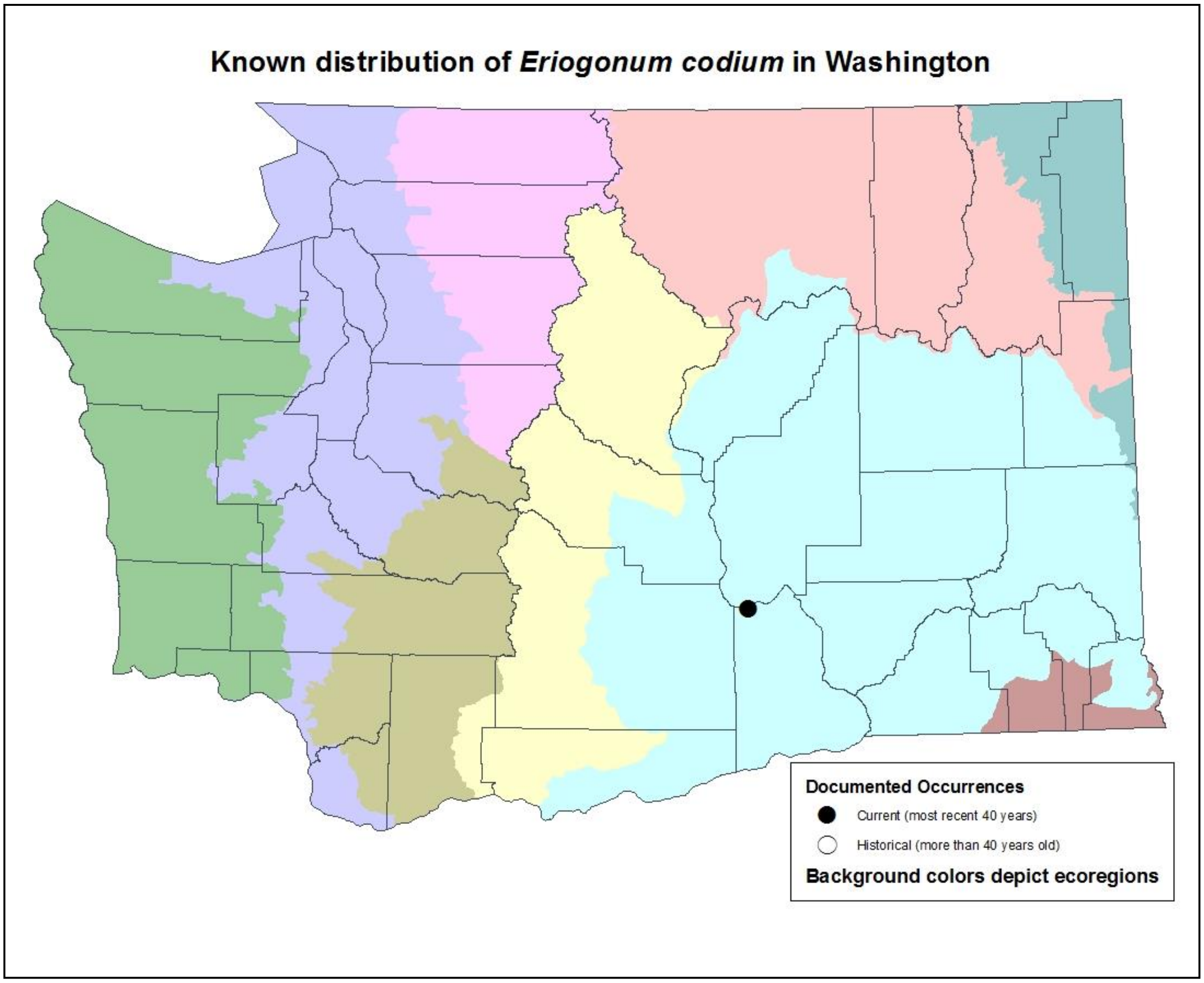


Figure 1. Rangewide Distribution of *Eriogonum codium*. Map derived from WNHP (2022).

<u>Annual Demographic and Out-Planting Monitoring</u>

Twenty-four 1 x 2 m demographic monitoring plots were randomly established in three transects in the easternmost subpopulation of *Eriogonum codium* on Umtanum Ridge in 1997 (Arnett 2013b, Beck 1999, Dunwiddie et al. 2001) and have been re-read every year since (except 2017). Within each plot, all reproductive and vegetative plants over 2 cm^2 and second-year seedlings (< 2 cm^2) were marked with aluminum tags with a unique identification number. The location of each tagged plant was recorded along the x and y axes of a PVC-pipe monitoring frame.

Each year data are recorded on the length and width of each tagged plant (in cm), the number of inflorescences present, and the percentage of dead growth based on 6 classes (0-1%, 2-5%, 6-25%, 26-50%, 51-75%, 76-100%). Dead plants are also recorded and assigned a mortality class based on 6 condition classes (see Arnett 2013b for complete details). Demographic monitoring typically occurs in the first half of July each year.

First-year seedlings (with cotyledons still present and presumed to have germinated during the current winter/spring) are also counted in the 24 demographic monitoring plots and their x, y coordinates and nearest mature plant are recorded. Seedling counts take place in mid-April and again in early July (in conjunction with monitoring of mature plants) to assess survivorship over the intervening 3 months (Arnett 2013b).

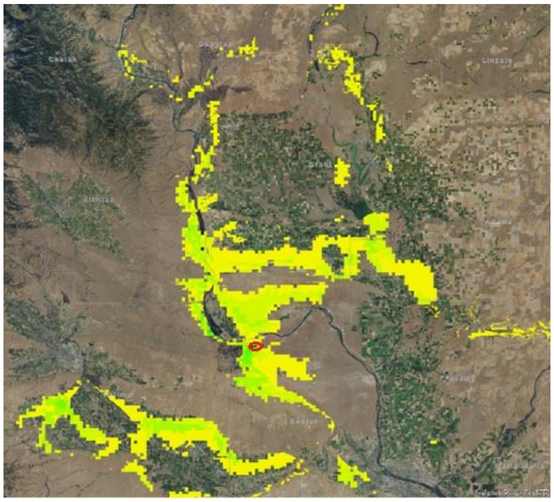
Each year, the total number of living, reproductive and vegetative plants from monitoring plots are recorded, as well as the number of plants that survived from the previous year, the number that died during the previous 12 months, and the number of new recruits added to the plot since the previous year. All field data forms that are archived in the WNHP manual files and transcribed to an excel database and summarized in the WNHP element occurrence database (Biotics).

Out-planted populations are revisited yearly, when possible (some sites have not been revisited recently because the access road washed out, or the out-planting is believed to have failed; Newsome 2020). Site visits focus on confirming if *Eriogonum codium* plants are still present, and the number that have survived or perished. Formal monitoring transects were not established for these populations, or are no longer being maintained.

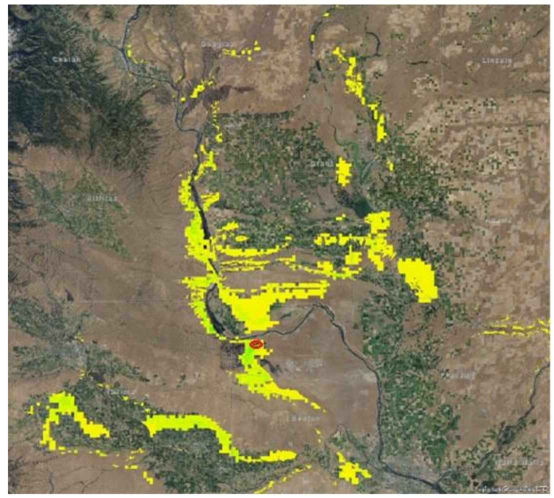
Potential Habitat Modeling

A simple GIS distribution model was developed to identify areas of potential habitat for survey or out-plantings (Kleinknecht and Fertig 2020) based on correlations between selected environmental variables and the known distribution of *Eriogonum codium*. We developed a base model using mean monthly temperature and precipitation for January, April, July, and October for the time period 1980-2010 (AdaptWest 2015), surface geology (DNR Geology program; https://www.dnr.wa.gov/programs-and-services/geology/geologic-maps/surface-geology), and soil suborders (Natural Resource Conservation Service (NRCS) Gridded Soil Survey Geographic (gSSURGO; Soil Survey Staff 2020). Categorical variables for geology and soils that intersected with the known distribution of *E. codium* were identified and scored as 1 for predicted present, while all others were scored as 0 for absent. Results from geology and soils were combined into a single raster. For the continuous climate variables, we identified the range of temperature and precipitation values present at known *E. codium* sites and then buffered these by 5% (95% of the minimum to 105% of the maximum values). Values falling within the selected range were assigned a score of 1 for present, while other values were assigned 0 for absent. Separate rasters were initially created for temperature and precipitation, but these were then combined into one climate raster and rescored so that only pixels where values of 1 intersected were selected (pixels with mix of 0 and 1 or both 0 were scored as 0). A "base" model was then created by intersecting the combined geology/soils and temperature/precipitation rasters into one data layer (Figure 2A) and color-coded to reflect areas of strong overlap between the datasets (green), moderate overlap (yellow), or no overlap (clear).

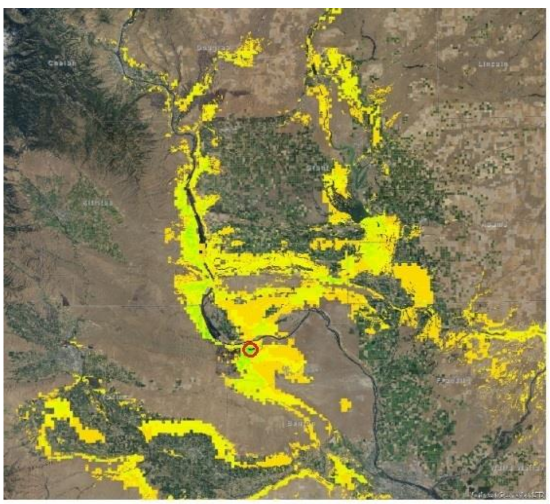
Figure 2. Development of a simple GIS potential habitat model for *Eriogonum codium*. Pixels in green represent the most likely habitat based on correlations between selected environmental layers and their overlap with known *E. codium* habitat (shown in red ellipse). Yellow pixels indicate less likely habitat, and clear areas indicate no likely habitat (see text for details on model development). 2A: Base Model. 2B: Base Model with elevation/relief added. 2C: Base Model, with elevation/relief and ecosystems included. 2D: Final Model, with less likely habitat removed.



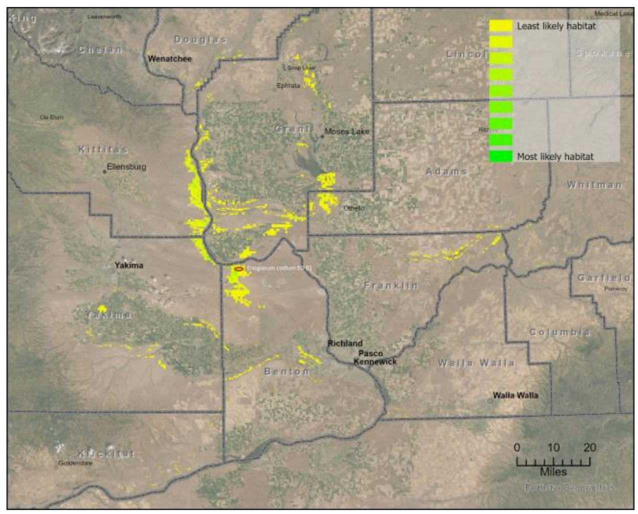
2A. Base Model (Geology/soils, January, April, July, and October mean precipitation, January, April, July, October mean temperature). Area of predicted most likely habitat (green areas): 412 acres



2B. Base Model with elevation/relief added. Area of predicted most likely habitat (green areas): 118 acres



C. Base Model with elevation/relief and ecosystems (NLCD) data added. Area of predicted most likely habitat (green areas): 115 acres.



D. Final model derived from base model with elevation/relief and ecosystems (NLCD) added. Area of predicted most likely habitat (green areas): 115 acres. Red ellipse shows *E. codium* Occurrence 01.

Additional environmental variables were used in subsequent models. We created an elevation/relief raster by calculating the elevation and slope of known *Eriogonum codium* sites, buffering these values by 5%, and then using a digital elevation model (DEM; USGS 2020) to calculate similar areas in central Washington. Pixels matching the buffered values were scored 1 and those not matching scored 0. The intersected raster is shown in Figure 2B.

The third iteration of the model added an ecosystems layer from the National Land Cover Dataset (NLCD; Dewitz 2019) to the combined base model and elev/relief raster. Ecosystem types that matched the known *Eriogonum codium* site were selected and scored 1. The revised model is shown in Figure 2C. A fourth version of the model included a raster of January and July solar radiation (AdaptWest 2015) added to the preceding data sets. The results were only marginally different from the third iteration and are not shown (see Kleinknecht and Fertig 2020). The final model (Fertig 2021a) is based on the third iteration, but with low-probability habitat removed (Figures 2D, 4).

Due to COVID-19 restrictions, field work in 2020-21 to ground truth the model was limited to publicly accessible sites in Ginkgo State Park, Babcock Bench, and Saddle Mountain. Other areas of potentially suitable habitat identified by the model on the Yakima Training Center, Yakama Nation, and Hanford Site were not available for survey work.

Climate Change Vulnerability Index

A Climate Change Vulnerability Index (CCVI) report was prepared using the NatureServe Climate Change Vulnerability Calculator Release 3.02 in MS Office Excel (https://www.natureserve.org/conservation-tools/climate-change-vulnerability-index) (Appendix B). GIS maps of projected local temperature change, moisture availability (based on the ratio of actual to predicted evapotranspiration), historical thermal niche, and historical hydrological niche were developed for *Eriogonum codium* by intersecting base map layers from NatureServe (www.natureserve.org/ccvi and www.fs.usda.gov/ccrc/tool/climate-wizard) with element occurrence records from the WNHP Biotics database. Values from these maps were entered directly into the CCVI calculator or scored following criteria in the document *Guidelines for Using the NatureServe Climate Change Vulnerability Index* (Young et al. 2016).

Scores for environmental and life history traits of each species were derived from a review of pertinent literature (Appendix A). Each of the 29 climatic and biological factors were scored as Greatly Increase, Increase, Somewhat Increase, or Neutral based on the likely response of each target species to climate change (Appendix B) and using scoring criteria defined by Young et al. (2016). If data were lacking, a score of “unknown” was given. A final Index Score was derived from these factor scores by the CCVI calculator and a confidence score provided based on the number of criteria assessed. CCVI scores fall into five categories ranging from Extremely Vulnerable to Less Vulnerable, depending on the degree to which a species is likely to be impacted by climate change in the state by 2050 (Fertig 2022; Young et al. 2016).

Seed Storage and Propagation

Information on *Eriogonum codium* seed collection, storage, and propagation are summarized in Appendix C.

Results

Population Census: The first population count of *Eriogonum codium* took place in 1995 (Beck 1999) and resulted in the documentation of 4,917 reproductive and vegetative plants (rounded to "approximately 5,000 plants" by Reveal et al. 1995) in three main subpopulations (Table 1). This census was made by a team of three people walking side-by-side and counting plants with a hand-held clicker. The following year, the first of several recent wildfires occurred along the east end of Umtanum Ridge, impacting part of the *E. codium* occurrence. Another full census (using hand clickers) was conducted in May and July 1997 and included some areas of occupied habitat (and at least 311 additional plants) that had been omitted from the 1995 count (USFWS 2021a). Beck (1999) reported 5,228 living reproductive and vegetative (non-seedling) individuals in the 1997 census (Table 1) and another 813 plants that had died as a result of the 1996 fire. Accounting for unsurveyed areas and mortality from the wildfire, USFWS (2021a) estimated that as many as 6,041-6,352 mature *E. codium* plants may have been present in 1995 (the higher number, however, appears to be an accounting error – see Table 1).

The next full population census occurred in 2005 (Caplow 2005), in which 4,408 reproductive and vegetative (non-seedling) plants were observed (Table 1). This census was done by a team of individuals walking through the occurrence and placing pin flags next to each individual plant and then deriving population numbers by counting the number of pin flags after they were retrieved. This same method was used again in 2011, at which time 5,169 reproductive and vegetative (non-seedling) plants were counted (Table 1; Arnett and Goldner 2017). The higher

Table 1. *Eriogonum codium* Census Data. Counts have been conducted using 3 or more people walking in a line and counting reproductive and vegetative plants (not seedlings) using hand clickers, or 4-6 people walking through the population and marking each separate reproductive and vegetative plant with a colored pin flag. Accuracy is considered higher with the pin flag method (Fertig 2021a). The east end subpopulation includes subpopulations A, B, and C of Beck (1999) and is sometimes referred to as the "main" population (Caplow 2005). Middle subpopulation is equivalent to subpopulation D and west end subpopulation to subpopulation E of Beck (1999).

Year	Census Method	Umtanum Ridge Occurrence # 01			Total
		East End (includes demographic monitoring plots)	Middle (next to and E of old wooden power pole)	West End	
1995	Clicker	3,700	200	1,017	4,917-6,041*
1997	Clicker	4,400	163	665	5228
2005	Flags	3,367	168	873	4408
2011	Flags	4,061	168	940	5169
2018	Clicker	1,860	100	555	2515
2019	Flags	2,239	120	657	3016

*The population was originally reported as 4,917 by Beck (1999). USFWS (2021a) noted that the population was probably higher in 1995 based on 311 additional plants discovered outside the original surveyed area in 1997 and another 813 dead plants from the fire in 1996 that were counted separately in 1997. This was reported as 6,352 plants (USFWS 2021a), but this figure appears to be based on the 311 missing plants being counted twice and is adjusted here to 6,041.

numbers found in 2011 were probably due to the discovery of some additional out-lying subpopulations that were not known in 1995-2005 censuses, rather than a population increase (USFWS 2021a).

Another full population census had been planned for July 2017, but was cancelled due to the Silver Dollar fire. That fire burned about 60% of the habitat of *Eriogonum codium* on Umtanum Ridge. Heidi Newsome, Joe Arnett, and Mark Darrach visited the site shortly after the wildfire and estimated that 23.9% of the population was completely burned (1,233 plants) and 19.6% were partially burned (1,015 plants) and not expected to survive (Newsome 2017; Fertig 2018). Newsome (2017) predicted that 2,921 plants from the 2011 census would survive the fire (Table 2).

In 2018, the entire population was censused over two days by a team using hand clickers, resulting in the documentation of 2,515 reproductive and vegetative (non-seedling) plants (Table 1; Fertig 2019). This count represented a decrease of 51% from the total in 2011 and was even lower than the number of survivors predicted by Newsome (2017). Recognizing that our census method differed from that employed in 2005 and 2011, USFWS recommended that we re-do the complete census in 2019 using the pin-flag method.

On 11-12 July 2019, we counted 3,016 *Eriogonum codium* plants (Fertig 2021a), an increase of 501 plants from the previous year (20%) (Table 1). This increase was likely the result of more thorough coverage using the pin-flag method and counting some subpopulations that might have been missed, rather than an actual increase in numbers through recruitment. While the flagging method is more accurate, it does introduce additional trampling to the site and thus population censuses should be undertaken only once every 3-5 years to minimize impacts (Fertig 2021a). Other technology, such as photo interpretation of drone imagery, or extrapolation from randomly located sampling plots, could also be used for estimating population size.

Overall population trends for *Eriogonum codium* are down from 1995 to 2019, reflecting similar declines in monitoring plots (Tables 1, 2, 3, Figure 3). Using the revised population estimate of 6,041 reproductive and vegetative plants in 1995, abundance has decreased by 50% to 3,016 plants in 2019. Periods of apparent population growth in 1997, 2011, and 2019 are likely the result of more thorough sampling with pin flags (2011 and 2019) and discovery of additional, previously uncounted subpopulations (1997, 2011, 2019) than actual increases in numbers (Fertig 2021a, USFWS 2021a).

The population viability analysis (PVA) conducted by Kaye (2007) based on monitoring data from 1995-2006 found there was a 72% chance that the population of *E. codium* would decline by 50% in 100 years. The PVA was based on a population growth rate of 0.9935 that predicted a long-term, but steady decline as deaths exceeded successful recruitment (Kaye 2007). In reality, the population declined by 50% in just 25 years, primarily due to mortality of mature plants from wildfire and poor seedling recruitment, possibly due to long term drought (Fertig 2021a, USFWS 2021a).

Individual subpopulations of *Eriogonum codium* have also been censused since 1995 and show similar trends as the entire occurrence (Table 1). The east end subpopulation (originally treated as three separate subpopulations by Beck 1999 and Dunwiddie et al. 2001, but now considered a single, essentially continuous subpopulation) contained approximately 4,400 reproductive and vegetative (non-seedling) plants in 1997 and has dropped to 2,239 in 2019, a decrease of 49% (Table 1). The west end subpopulation had 1,017 individuals in 1995, but dropped to 665 in 1997 following the 1996 wildfire. This may have been an under-count, however, as the number of recorded plants was as high as 940 in 2011 using the more-accurate flagging method. It has since declined to 657 reproductive and vegetative plants in 2019, for an overall decrease of 35%. The smallest subpopulation is from the middle of the ridge adjacent to the old wooden power pole, which had 200 plants in 1995 and 120 in 2019, a drop of 40% (Table 1).

Annual Demographic Monitoring 1997-2021: Annual monitoring of *Eriogonum codium* has taken place at three permanent transects in the easternmost subpopulation since 1997, with the exception of 2017 when work was interrupted by the Silver Dollar Fire (Fertig 2021b). In 1997, the 24 demographic plots within these transects contained 105 mature flowering or vegetative individuals (Tables 2, 3). From 1997 through 2005 the number of plants declined from 105 to 88, a decrease of 16%. In 2006, a small recruitment event occurred, in which 3 plants were added to the population in the plots and only one existing plant died (Table 2, Figure 3). A second large recruitment event happened in 2010, when 6 new plants joined the population, although this was negated by the death of 7 plants (Tables 2, 3). From 2004 through 2010, the plots were relatively stable, with only a net loss of 4 plants and an overall decline of just 4.4% (Table 2).

In the period from 2011 through 2016, deaths exceeded small recruitment episodes, resulting in a decrease from 83 to 65 reproductive and vegetative (non-seedling) plants in the plots (21.6% decrease) (Table 2, Figure 3). The wet winter and spring of 2017 resulted in the largest documented recruitment event in 25 years of monitoring, in which 10 plants were added to the population (Tables 2, 3), increasing the number of individuals by 13.3% to 75. Unfortunately, these same climatic conditions contributed to extensive growth of annual plants (especially cheatgrass, *Bromus tectorum*) which provided fuel for the Silver Dollar Fire in July 2017. This fire burned nearly 60% of the sagebrush steppe habitat of *E. codium* (Newsome 2017). The fire was most severe in transect 3, where the number of tagged plants dropped from 10 in 2016 to 3 in 2018 (70% decrease). Transect 1 was moderately burned, with the number of plants dropping from 33 to 26 following the fire (21% decrease) (Table 3). Transect 2 did not burn in 2017, and actually increased from 22 to 26 plants from 2016-2018 (18%) (Table 3).

Table 2. *Eriogonum codium* demographic plot and census data from 1995-2021. Demographic monitoring is divided between April counts of seedlings and July counts and measurements of mature plants within 24 permanent monitoring plots in three transects. New recruits are plants added to the population that were not detected the previous year and may be either surviving seedlings, mature plants that have split in two due to tissue mortality at the center of the plant, or mature plants that were originally outside the plot, but later expanded into a corner of the plot through new growth.

Year	April Seedling Count	July Mature Plant Count				Total Population Census
		Alive	Survivors from previous year	New Recruits	Dead since previous year	
1995						4917-6,041
1996	4					
1997	26	105	na	na	na	5228
1998	3	105	105	0	0	
1999	20	102	101	1	4	
2000	73	101	101	0	1	
2001	37	97	97	0	4	
2002	0	96	96	0	1	
2003	3	93	93	0	3	
2004	6	90	90	0	3	
2005	0	88	88	0	2	4408
2006	5	90	87	3	1	
2007	154	89	89	0	1	
2008	12	88	87	1	2	
2009	5	87	87	0	1	
2010	67	86	80	6	7	
2011	79	83	81	2	5	5169
2012	6	80	79	1	4	
2013	7	77	77	0	3	
2014	7	74	74	0	3	
2015	6	66	65	1	9	
2016	76	65	63	3	4	
2017	333	75	65	10	na	Estimated 2921
2018	9	55	52	3	23	Estimated 2515
2019	124	53	47	6	8	3016
2020	No data	52	50	2	3	
2021	No data	48	48	0	4	

Table 3. Yearly population numbers and survival of *Eriogonum codium* plants in demographic monitoring plots and transects from 1997 to 2021. Data for each year includes total number of living mature plants per plot (Alive), number of plants surviving from the previous year (Surv), number of new mature plants recruited into the population since the previous year (Recr) and number of newly dead plants since the previous year (Dead). Transect 1 was lightly burned, transect 2 was unburned, and transect 3 was severely burned in the July 2017 Silver Dollar Fire.

Trans/ Plot # Year Status	1/0206	1/0212	1/0401	1/0416	1/1403	1/1407	1/1605	1/1611	1/3006	1/3024	2/0205	2/0601	2/0607	2/3004	2/3008	2/3408	2/3804	2/3810	3/0408	3/1813	3/3007	3/3408	3/3411	3/4206	Total
1997 Alive	10	7	2	1	7	5	10	2	9	2	7	10	1	1	2	5	9	1	2	1	3	5	1	2	105
1997 Surv	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1997 Recr	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1997 Dead	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1998 Alive	10	7	2	1	7	5	10	2	9	2	7	10	1	1	2	5	9	1	2	1	3	5	1	2	105
1998 Surv	10	7	2	1	7	5	10	2	9	2	7	10	1	1	2	5	9	1	2	1	3	5	1	2	105
1998 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998 Dead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999 Alive	10	7	2	1	7	6	10	2	9	2	7	9	1	1	2	4	7	1	2	1	3	5	1	2	102
1999 Surv	10	7	2	1	7	5	10	2	9	2	7	9	1	1	2	4	7	1	2	1	3	5	1	2	101
1999 Recr	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1999 Dead	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2	0	0	0	0	0	0	0	4
2000 Alive	10	7	2	1	7	6	10	2	9	1	7	9	1	1	2	4	7	1	2	1	3	5	1	2	101
2000 Surv	10	7	2	1	7	6	10	2	9	1	7	9	1	1	2	4	7	1	2	1	3	5	1	2	101
2000 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2000 Dead	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2001 Alive	9	7	2	1	7	4	10	2	9	1	6	9	1	1	2	4	7	1	2	1	3	5	1	2	97
2001 Surv	9	7	2	1	7	4	10	2	9	1	6	9	1	1	2	4	7	1	2	1	3	5	1	2	97
2001 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2001 Dead	1	0	0	0	0	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	4
2002 Alive	9	7	2	1	7	4	10	2	9	1	6	9	1	1	2	3	7	1	2	1	3	5	1	2	96
2002 Surv	9	7	2	1	7	4	10	2	9	1	6	9	1	1	2	3	7	1	2	1	3	5	1	2	96
2002 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2002 Dead	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
2003 Alive	9	6	2	1	7	4	9	2	9	1	6	9	1	1	2	3	7	1	2	1	3	5	1	1	93
2003 Surv	9	6	2	1	7	4	9	2	9	1	6	9	1	1	2	3	7	1	2	1	3	5	1	1	93
2003 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2003 Dead	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3
2004 Alive	8	6	2	1	7	4	8	2	9	1	6	9	1	1	2	3	7	1	2	1	3	4	1	1	90
2004 Surv	8	6	2	1	7	4	8	2	9	1	6	9	1	1	2	3	7	1	2	1	3	4	1	1	90
2004 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2004 Dead	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3

Trans/ Plot # Year Status	1/0206	1/0212	1/0401	1/0416	1/1403	1/1407	1/1605	1/1611	1/3006	1/3024	2/0205	2/0601	2/0607	2/3004	2/3008	2/3408	2/3804	2/3810	3/0408	3/1813	3/3007	3/3408	3/3411	3/4206	Total
2005 Alive	8	6	2	1	6	4	8	2	9	1	6	9	1	1	2	3	7	1	2	1	3	3	1	1	88
2005 Surv	8	6	2	1	6	4	8	2	9	1	6	9	1	1	2	3	7	1	2	1	3	3	1	1	88
2005 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2005 Dead	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2
2006 Alive	9	7	2	1	6	4	8	2	8	2	6	9	1	1	2	3	7	1	2	1	3	3	1	1	90
2006 Surv	8	6	2	1	6	4	8	2	8	1	6	9	1	1	2	3	7	1	2	1	3	3	1	1	87
2006 Recr	1	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2006 Dead	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2007 Alive	9	6	2	1	6	4	8	2	8	2	6	9	1	1	2	3	7	1	2	1	3	3	1	1	89
2007 Surv	9	6	2	1	6	4	8	2	8	2	6	9	1	1	2	3	7	1	2	1	3	3	1	1	89
2007 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2007 Dead	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2008 Alive	8	6	2	1	6	4	7	2	8	2	6	9	1	1	2	3	7	1	2	1	3	4	1	1	88
2008 Surv	8	6	2	1	6	4	7	2	8	2	6	9	1	1	2	3	7	1	2	1	3	3	1	1	87
2008 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1*	0	0	1
2008 Dead	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2009 Alive	8	6	2	1	5	4	7	2	8	2	6	9	1	1	2	3	7	1	2	1	3	4	1	1	87
2009 Surv	8	6	2	1	5	4	7	2	8	2	6	9	1	1	2	3	7	1	2	1	3	4	1	1	87
2009 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2009 Dead	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2010 Alive	7	6	2	1	4	4	7	2	7	2	4	8	1	1	2	3	7	1	2	1	6	6	1	1	86
2010 Surv	7	6	2	1	4	4	7	2	7	2	4	8	1	1	2	3	7	1	2	1	2	4	1	1	80
2010 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	2*	0	0	6
2010 Dead	1	0	0	0	1	0	0	0	1	0	2	1	0	0	0	0	0	0	0	0	1	0	0	0	7
2011 Alive	6	6	2	1	5	4	8	2	7	2	4	7	1	1	2	3	7	1	2	0	5	5	1	1	83
2011 Surv	6	6	2	1	4	4	7	2	7	2	4	7	1	1	2	3	7	1	2	0	5	5	1	1	81
2011 Recr	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2011 Dead	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	0	0	5
2012 Alive	5	6	2	0	5	4	8	2	7	2	4	7	0	1	2	3	7	1	2	0	5	5	1	1	80
2012 Surv	4	6	2	0	5	4	8	2	7	2	4	7	0	1	2	3	7	1	2	0	5	5	1	1	79
2012 Recr	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
2012 Dead	2	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4
2013 Alive	3	6	2	0	5	4	7	2	7	2	4	7	0	1	2	3	7	1	2	0	5	5	1	1	77
2013 Surv	3	6	2	0	5	4	7	2	7	2	4	7	0	1	2	3	7	1	2	0	5	5	1	1	77
2013 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013 Dead	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3

Trans/ Plot # Year Status	1/0206	1/0212	1/0401	1/0416	1/1403	1/1407	1/1605	1/1611	1/3006	1/3024	2/0205	2/0601	2/0607	2/3004	2/3008	2/3408	2/3804	2/3810	3/0408	3/1813	3/3007	3/3408	3/3411	3/4206	Total
2014 Alive	3	6	2	0	4	3	7	2	7	2	4	6	0	1	2	3	7	1	2	0	5	5	1	1	74
2014 Surv	3	6	2	0	4	3	7	2	7	2	4	6	0	1	2	3	7	1	2	0	5	5	1	1	74
2014 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014 Dead	0	0	0	0	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
2015 Alive	3	5	2	0	4	3	6	2	7	1	4	6	0	1	2	3	5	1	2	0	1	5	1	2	66
2015 Surv	3	5	2	0	4	3	6	2	7	1	4	6	0	1	2	3	5	1	2	0	1	5	1	1	65
2015 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1*	1
2015 Dead	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0	0	2	0	0	0	4	0	0	0	9
2016 Alive	3	5	2	0	4	3	5	3	7	1	4	6	0	1	2	3	5	1	2	0	1	5	0	2	65
2016 Surv	3	4	2	0	4	3	5	2	7	1	4	6	0	1	2	3	5	1	2	0	1	5	0	2	63
2016 Recr	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	3
2016 Dead	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	4
2017 Alive	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	75?
2017 Surv	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	73?
2017 Recr	3*	na	1*	na	na	na	4*	na	na	na	na	1*	na	na	na	na	na	na	1*	na	na	na	na	na	10
2017 Dead	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
2018 Alive	3	2	0	0	2	0	9	3	7	0	7	7	0	1	2	3	5	1	0	0	0	1	0	2	55
2018 Surv	3	2	0	0	2	0	9	3	7	0	4	7	0	1	2	3	5	1	0	0	0	1	0	2	52
2018 Recr	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
2018 Dead	3*	3	3*	0	2	3	0	0	0	1	0	0	0	0	0	0	0	0	3	0	1	4	0	0	23
2019 Alive	4	2	0	0	2	0	6	2	5	0	6	8	0	2	2	3	7	2	0	0	0	0	0	2	53
2019 Surv	3	2	0	0	2	0	6	2	5	0	6	7	0	1	2	3	5	1	0	0	0	0	0	2	47
2019 Recr	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	2*	1*	0	0	0	0	0	0	6
2019 Dead	0	0	0	0	0	0	3	1	2	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	8
2020 Alive	5	2	0	0	2	0	6	2	4	0	7	8	0	2	2	3	5	2	0	0	0	0	0	2	52
2020 Surv	4	2	0	0	2	0	6	2	4	0	6	8	0	2	2	3	5	2	0	0	0	0	0	2	50
2020 Recr	1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
2020 Dead	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	3
2021 Alive	5	2	0	0	1	0	6	2	4	0	7	7	0	2	2	3	5	0	0	0	0	0	0	2	48
2021 Surv	5	2	0	0	1	0	6	2	4	0	7	7	0	2	2	3	5	0	0	0	0	0	0	2	48
2021 Recr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021 Dead	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	0	0	4
Net Change 1997-2021	-5	-5	-2	-1	-6	-5	-4	0	-5	-2	0	-3	-1	+1	0	-2	-4	-1	-2	-1	-3	-5	-1	0	-57

Since 2017, the number of plants in the monitoring plots has decreased from 75 to 48 in 2021, a decrease of 36%. A moderate recruitment event of 6 new plants occurred in 2019, but was negated by the death of 8 plants. Overall, the monitored plants have declined from 105 to 48 over the 25 years of monitoring, for a decrease of 54.3% (Tables 2 and 3, Figure 3). Presently, unburned transect 2 contains 26 living plants (54.2% of the total), lightly burned transect 1 has 20 surviving plants (41.6% of the total), and severely burned transect 3 has only 2 living plants (4.2% of the total) (Table 3).

Recruitment has been detected in just 12 of 25 years of monitoring demographic plots for *Eriogonum codium* (Table 2). The number of new plants in the plots has ranged from 1 to a high of 10 in 2017. Over the entire study, average annual recruitment has been 1.56 plants. During the same period, 96 new recruits and established plants have died, with average mortality being 3.84 individuals. Recruits can fall into three categories: second-year seedlings that germinated the previous year and successfully over-wintered, older plants that "split" into two due to death of stem and leaf tissue at the center of the plant, and mature plants originally found outside the plot that have slowly grown into the plot (Table 3). The latter two recruit types are not truly "new" individuals. Over time, nearly all of the second-year seedlings ultimately died within 1-3 years and before reaching reproductive maturity (Fertig 2021a). Caplow (2003) reported a single seedling (germinated in 1998) that survived long enough to flower 5 years later. This plant survived until 2017, when it was burned in the Silver Dollar fire.

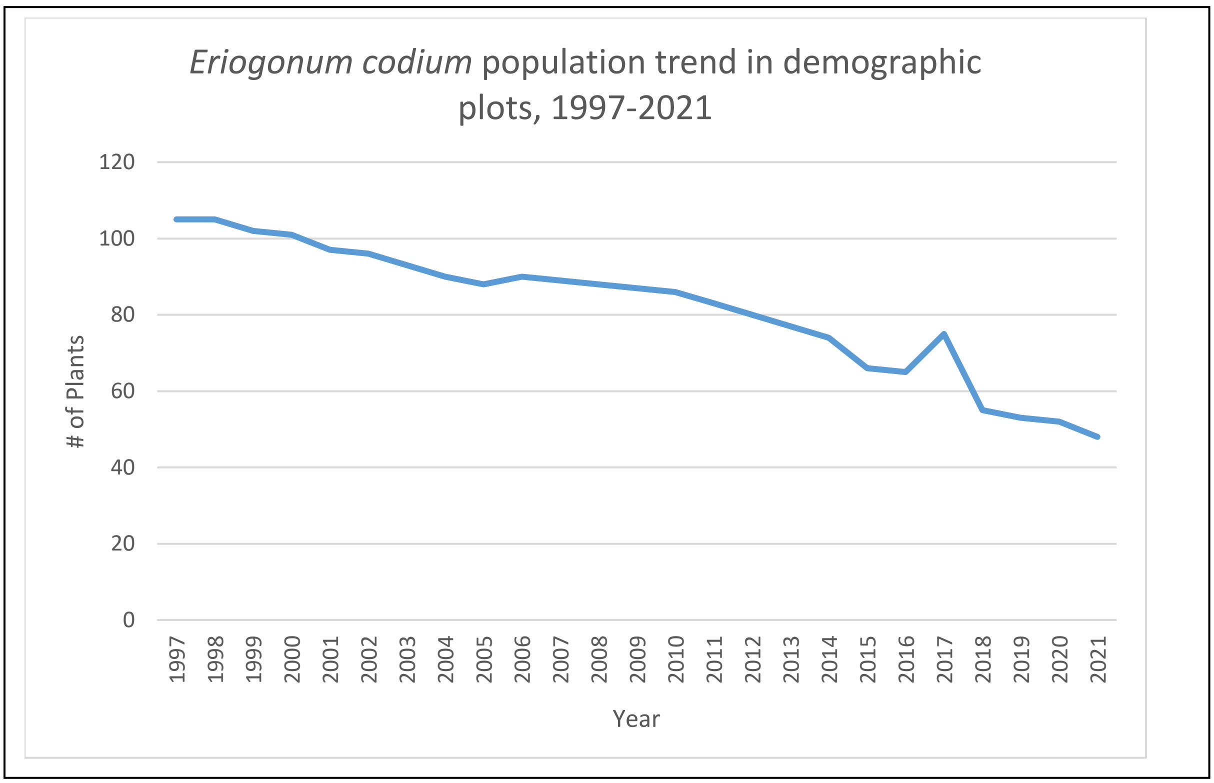


Figure 3. *Eriogonum codium* population trend data from demographic plots at Umtanum Ridge, 1997-2021.

Data on first-year seedlings was collected from the 24 permanent demographic monitoring plots from 1997 through 2019 (Table 2). Counts were made twice a year, in April and again in July in conjunction with monitoring tagged mature plants. Numbers of seedlings varied widely from 0 (in 2002 and 2005) to 333 (2017), averaging 46 per year (standard deviation 75.7) (Table 2). Seedling survival, however, has been consistently low. Caplow (2005) reported seedling mortality of 67-91% for first-year seedlings during their first 3-4 months during the period from 1997-2005. These data were used in the PVA developed by Kaye (2007) in which the intrinsic growth rate was documented as 0.99335, indicative of a slow, long term net decrease in abundance as deaths exceed seedling recruitment (Caplow et al. 2007). Since 2007, seedling germination and short-term survival has been variable, often depending on spring moisture and temperature conditions, but nearly all seedlings have ultimately died before reaching their second year (Fertig 2021a). In the meantime, mortality of mature plants has increased by 46%, largely due to wildfires and drought (Fertig 2021a).

Due to the COVID-19 pandemic, seedling monitoring was suspended in 2020-21. The existing monitoring plots are better suited for monitoring reproductive and vegetative plants than seedlings due to issues with detection and potential trampling. Seedling mortality rates are well-documented after 25 years and are no longer necessary to refine the PVA. Information is still needed on environmental factors that affect seedling germination and survival in the field, but are best answered by monitoring tagged seedlings weekly through the growing season. Wendy Gibble and Allie Howell of the University of Washington Rare Care program initiated a new study in 2022 to more specifically assess the factors that contribute to poor seedling survival rates.

<u>Out-planting Monitoring</u>: Experimental out-plantings of *Eriogonum codium* have been attempted at four sites in central Washington (Fertig 2021a). These plantings were undertaken to increase the number of occurrences in the wild to meet recovery goals and to reduce the risk of extinction in case the one native occurrence was extirpated (USFWS 2021a). The first out-planting sites were selected based on having comparable soils, aspect, and elevation to the Umtanum Ridge occurrence and because of their proximity to that site (Newsome and Goldie 2017). More recently, additional sites were chosen that might be less impacted by drought, or that are more readily accessible for management. Most of these areas fall within the predicted distribution of the species, based on habitat modeling (Fertig 2021a).

Two experimental out-plantings of *Eriogonum codium* were established in 2011 at Yakima Ridge and Saddle Mountain within the Hanford Reach National Wildlife Refuge (Newsome and Goldie 2013, 2017). A total of 102 seedling plants were planted at three sites on Yakima Ridge in 2011 and 2012. After 20 months, only 10 of the original cohorts were still alive (9.8% survival) and by July 2016 only 3 stressed plants were still alive (2.9%). This area subsequently burned in the Range 12 fire in July 2016 and all plants are now presumed dead (Newsome and Goldie 2017). Although suitable habitat may still be present, the area has not been replanted, and is currently inaccessible due to road damage following recent fires (Heidi Newsome, personal communication, in Fertig 2021a).

In November 2012, 100 seedling Umtanum buckwheat plants were planted at one site on Saddle Mountain. From 2013-2017, an additional 386 seedling plugs were introduced at three more sites on the mountain (Newsome and Goldie 2017). Only 9% of these outplanted seedlings were still alive in 2017, of which just 4 had been present for more than 21 months and considered "established" (Newsome and Goldie 2017). In November, 2019, 88 new seedling plugs were planted to augment two plants that had survived fires in 2017 and 2018. One year later, 21 plants were still alive (23.8%). Since out-planting efforts began in 2011, no introduced plants at Yakima Ridge or Saddle Mountain have become large enough to flower (Newsome 2020).

In 2020, a new out-planting was attempted at the Badger Mountain Centennial Preserve south of Richland (Newsome and Abel 2020). Twelve one-year old plugs were planted at sites on the north and south side of the mountain in March 2020, and in the fall seed was directly sown. As of September 2020, 11 plants were still alive (Fertig 2021a). In November, 2021, another 21 plugs were planted on the south side. Jane Abel revisited the population on 22 April 2022 and found one plant still alive on the north side and 24 living plants on the south side (J. Abel, personal communication, May 2022).

The fourth out-planting consisted of 59 seedlings placed at three sites in Snow Mountain Ranch (managed by the Cowiche Canyon Conservancy) in fall 2020 (Newsome and Abel 2021). Snow Mountain is at a higher elevation than the native populations at Umtanum Ridge and has deeper soils, but otherwise has similar rocky rim habitat. A second out-planting of 264 nursery-reared seedlings was done in fall 2021 (USFWS 2022).

<u>Potential Habitat Model for *Eriogonum codium*</u>: The final model of potential habitat for *Eriogonum codium* is shown in Figures 2d and 4. This version is slightly modified from the selected model in Kleinknecht and Fertig (2020) and Fertig (2021a) shown in Figure 2c. Only 115 acres of central Washington are identified by the model as areas of high probability suitable habitat for *E. codium*. These areas are centered along Umtanum Ridge in the Hanford Reach National Monument (NM) and adjacent Yakima Training Center, Yakima Ridge and nearby buttes (Hanford Reach NM), east end of Saddle Mountain (Hanford Reach NM), and Ryegrass Mountain and adjacent ridges in Ginkgo Petrified Forest State Park and L.T. Murray Wildlife Area (Figure 4). This entire area is contained within a 30 x 30 mile block in northern Benton, northeastern Yakima, southeastern Kittitas, and southwestern Grant counties (Figure 4).

Surveys of potential habitat in Ryegrass Mountain, Babcock Bench, and Saddle Mountain in 2020-21 were unsuccessful in locating new populations of *Eriogonum codium*. Past surveys have covered much of this same area, as well as portions of the Yakima Training Center and Hanford Site, but have all failed to locate additional native populations (Beck 1999, Rush and Gamon 1999; Mark Darrach and Debra Salstrom personal communication, 2021).

The potential habitat model has been used to identify new sites for out-plantings (Fertig 2021a, Fertig and Kleinknecht 2022). Among the most suitable sites are other areas of Umtanum Ridge, Ryegrass Mountain and vicinity, Rattlesnake Hills (BLM portions), eastern Saddle Mountain, Chandler Butte, Thornton Wildlife Area, and Badger Mountain (Figure 4). Two other sites not identified by the model have also been recommended for out-plantings: Gable Mountain

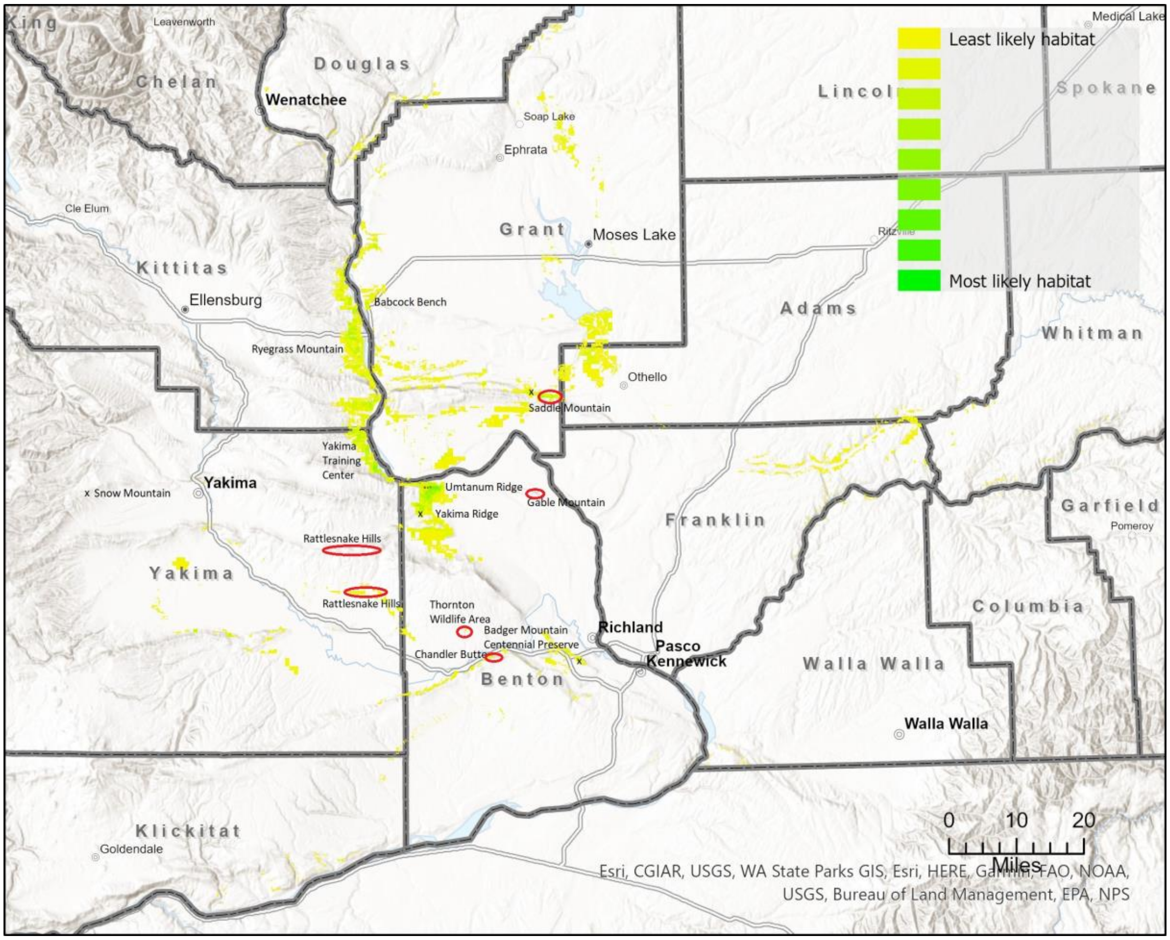


Figure 4. Potential habitat model for *Eriogonum codium* in central Washington. This model is derived from the intersection of January, April, July, and October mean temperature and precipitation, geology and soils, elevation, landform relief, and ecological systems (Kleinknecht and Fertig 2020). Areas in green contain the most likely habitat, while areas in yellow are of lower suitability. Less suitable areas identified in an earlier iteration of this model (Fertig 2021a), shown in Figure 2c, have been dropped from the current version. The extant occurrence at Umtanum Ridge is depicted by 3 small red dots. Out-planted populations (Badger Mountain Centennial Preserve, Saddle Mountain, Snow Mountain, and Yakima Ridge) are shown with an X. Other areas identified as potential areas for out-planting or survey are depicted by red ellipses and named.

(Hanford Site) and the Rattlesnake Hills in the Yakama Nation (Fertig 2021a). Three of the four existing out-plantings (Badger Mountain, Saddle Mountain, and Yakima Ridge; Figure 4) were in areas identified as suitable habitat by the model (Newsome and Abel 2020, 2021; Newsome and Goldie 2017). The fourth site, at Snow Mountain, is significantly higher in elevation than Umtanum Ridge, and so is not identified as a high priority based on model parameters, but could be an important out-planting in light of climate adaptation and because of its protected status (Fertig and Kleinknecht 2022).

Climate Change Vulnerability Index (CCVI): I evaluated *Eriogonum codium* using the NatureServe Climate Change Vulnerability Index (Fertig 2022, Young et al. 2016). *Eriogonum codium* scored as Moderately Vulnerable despite greatly increased changes in its historical hydrological niche, increased projected temperatures, reduced dispersal ability due to anthropogenic barriers, increased threat from competing weed species, and documented decline due to wildfire. See Appendix B for the complete report and detailed information on each of the 29 climatic and biological ranking factors.

Seed Storage and Propagation

Seed Collections

The earliest collections of seed from *Eriogonum codium* were made by Katy Beck in 1997 (Beck 1999). Beck collected 401 achenes from 40 inflorescences and 20 individual plants from the extensive eastern subpopulation of *E. codium* for the Rae Selling Berry Seed Bank at Portland State University. Additional seed was collected for the Berry Seed Bank in 2001 and 2002 from the eastern and middle subpopulations (Caplow 2005) and shared with the US Department of Agriculture National Laboratory of Genetic Resources Preservation in Fort Collins, Colorado (USFWS 2021a). Presently, 757 *E. codium* seeds are stored at the Berry Seed Bank and 378 seeds at the USDA facility (K. Freitag in USFWS 2021a). Another 4,400 *E. codium* seeds were collected in 2011 and 2017 from over 50 plants in the eastern subpopulation for the Miller Seed Vault at the University of Washington, maintained by Washington Rare Plant Care and Conservation (“Rare Care”). In 2019, a new collection of approximately 1,200 seeds from 49 individuals from all three subpopulations and separated by maternal lines was made for the Miller Seed Vault. This latest accession will be used for future seed banking and recovery actions (USFWS 2021a).

Seed Germination and Viability

The Berry Botanical Garden conducted the first germination tests of *Eriogonum codium* in 1999 (Shank 2019), using seed collected in 1997 and stored for two years under cold, dry conditions. Germination ranged from 17-86% (average 52%) based on different treatments. Highest germination occurred when seeds were cold-moist stratified at 5° C in the dark for 8 weeks, followed by incubation at 20° C during the day and 10° C at night and 16 hours of light and 8 hours of dark for 8 weeks (Shank 2019).

From 2002-2005, the viability of *Eriogonum codium* seed was tested by the Ransom Seed Laboratory based on fresh and buried seed (Caplow 2005). These seeds were subjected to a germination and viability protocol that included the following:

1. Physical examination of the seed
2. Seed left for 21 days on blotter in light at 20° C; germinants counted
3. Cotyledons of remaining ungerminated seed cut and treated with 400 ppm GA3 added to medium; germinants counted after 3 additional days on blotter in light at 20° C
4. Remaining ungerminated seed tested with tetrazolium chloride

Based on this treatment, 2-5% of seeds germinated without requiring a cold-moist stratification, 65-76% were viable but dormant, and 22-30% were non-viable (dead or empty) (Caplow 2005).

In 2013, Rare Care researchers tested seed viability under four conditions: winter temperatures/untreated ("winter control"), summer temperatures/untreated ("summer control"), 12-week winter stratification, and 8-week summer stratification (Shank 2019). Germination was highest under summer stratification (24° C daytime/14° C nighttime temperature and 14 hours daylight/10 hours dark) with 88% of seed germinating.

Shank (2019) studied viability and germination rates of seed from burned, partially burned, and unburned *Eriogonum codium* plants collected after the Silver Dollar fire in 2017. Randomly chosen lots of seeds were subjected to one of three treatments: winter control and summer control (following the 2013 Rare Care protocol mentioned previously) and "Long Winter" with a longer winter stratification period. Unburned seed had higher initial viability (20-61%) than lightly burned (25%) and partially burned seed (5%), as well as higher total viability (25.6-41.6% vs 15.3% for lightly burned and 4% for partially burned seeds) (Shank 2019). Highest germination rates were observed using the summer control treatment. Overall, 22.6-35.1% of seed remained viable but dormant (Shank 2019).

Reveal et al (1995) reported less than 5% of flowers produced viable seed in the wild, while Dunwiddie et al. (2001) found seed viability to be closer to 10%. Caplow (2003, 2005) observed that the majority of seedlings were often produced by a small number of adults each year. Seeds are produced in 1-seeded dry achenes and dispersed by gravity or wind. Seeds may be harvested and transported by harvester ants, but have not been observed to germinate at ant burrows (Dunwiddie et al. 2001). Long-term seedling monitoring at Umtanum Ridge plots has shown wide variability in annual seedling germination, ranging from 0-333 (Fertig 2018). Mortality between spring and summer ranges from 67-91% (Caplow 2005) to 100% (Fertig 2021a).

Propagation

Douglas Reynolds of Rain Shadow Nursery in Kittitas, WA (ca 40 miles northwest of Umtanum Ridge) developed the first propagation techniques for *Eriogonum codium* in 2002 (Caplow 2005). Reynolds subjected newly collected *E. codium* seed to cold moist stratification for 60 days in late winter and early spring. Germination was staggered over several weeks and some seeds germinated without cold stratification. Seeds were germinated in 10 cubic inch tubes using #5 Sunshine mix or native soils derived from Umtanum Ridge. Tubes were fertilized every 2-4 weeks with half-strength Peterson's soluble fertilizer (Caplow 2005). Tubelings were successfully transplanted in 50/50 coarse sand/topsoil mix outdoors.

Jane Abel, an amateur botanist and gardener from Richland, Washington, developed a propagation protocol for *Eriogonum codium* in collaboration with the USFWS Mid-Columbia River National Wildlife Refuge Complex (Abel 2013). The propagation protocol is included in Appendix C. Abel notes that *E. codium* is "not that difficult to grow in a nursery where we have better control over the growing conditions, but growing plants in pots in our summer hear is a challenge" (Jane Abel, personal communication, 2022).

Shank (2019) planted *E. codium* seed after testing their viability for her fire response study and found that 57% of the seedlings survived, while the rest died within a few days. Successfully transplanted individuals experienced low rates of mortality once they were established.

Discussion

<u>Current Conservation Assessment</u>: The 2021 Recovery Plan for *Eriogonum codium* (USFWS 2021b) identified five goals necessary for recovery of this species (Table 4). Currently, only one of these goals is being partially met (seed collections), while targets for minimum number of occurrences, minimum abundance, habitat integrity/management, and protection from wildfire are not being met (Table 4, USFWS 2021b, 2021c). Only the native occurrence meets the minimum number of desired individuals, although it should be noted that this threshold (1,200 individuals for 15 years) is significantly lower than the current population size of 3,016 plants and former population size of 6,041 (Table 1). Four out-plantings have been attempted to boost the number of occurrences (one short of the recovery goal), but to date, none of these appear to be successfully established and none are meeting abundance targets. Additional out-plantings in areas of suitable habitat (Figure 4) and augmentation of existing out-plantings will be necessary to meet these goals. Possible areas for new out-plantings include the east end of Saddle Mountain (including Hanford Reach National Monument and Bureau of Reclamation and Bureau of Land Management [BLM] lands to the east), Ryegrass Mountain and vicinity in Ginkgo Petrified Forest State Park and L.T. Murray Wildlife Area, Babcock Bench (Columbia Basin Wildlife Area), ridges west of Priest Rapids (Yakima Training Center), Gable Mountain (Hanford Site), Rattlesnake Hills (Yakama Nation and BLM), Chandler Butte (BLM) and Thornton Wildlife Area (Fertig 2021a, Fertig and Kleinknecht 2022).

The Silver Dollar fire in 2017 burned at least 60% of the Umtanum Ridge occurrence and destroyed much of the sagebrush steppe vegetation. While native perennial herbs and grasses have recovered, shrub species have not and the vegetation of rim areas is being replaced by an annual community of cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola tragus*). Fire has also impacted much of central Washington during the past 30 years, including sites where out-plantings have occurred or might be planned (Newsome and Goldie 2017). Active restoration may be necessary to restore habitat conditions for pollinators at Umtanum Ridge and other out-planting sites to meet recovery objectives (Table 4). Likewise, fire management efforts

Table 4. Recovery Criteria for Umtanum desert buckwheat. Derived from USFWS (2021b).

Recovery Criteria	Progress Towards Completion	Actions Still Needed
1. There are Six Umtanum desert buckwheat populations	Not met. Presently, just one native occurrence of *Eriogonum codium* is known. Four additional out-plantings have been attempted, but none can be considered successfully established and self-sustaining yet.	Five additional out-plantings or native occurrences are needed to meet recovery criteria. No new native populations have been documented since the species was described in 1995. The four existing out-plantings may need to be augmented with additional seed or plugs to become viable. Additional sites may be better suited for out-planting based on the potential habitat model (Figure 4).
2. All of the populations are self-sustaining with an average size of 1,200 individuals for at least 15 years.	Not met. The native population at Umtanum Ridge is the only occurrence with more than 1,200 individuals for 15 years. This population once contained at least 6,041 plants and has declined by 50% since 1997. None of the attempted out-plantings have reached the minimum abundance threshold.	Five additional out-plantings need to become successfully established and self-sustaining. Due to difficulties in getting new occurrences going, this target may be several decades away from being met.
3. Populations are in a matrix of native shrub-steppe habitat within effective pollinator distance of 300 meters and threats managed by partners with long-term management commitments.	Not met. The adjacent shrub steppe habitat of the Umtanum Ridge occurrence has been converted to an annual grassland due to recurring large-scale wildfires. Sagebrush and other shrubs have not recovered on their own since the last major fire in 2017.	Active restoration may be needed to re-establish shrub steppe plants, including species necessary for pollinators at Umtanum Ridge. Five additional populations need to be established, and these need to be protected under long-term management agreements.
4. Populations are adequately protected from wildfire.	Not met. The Umtanum Ridge population remains under high threat of future wildfire due to the dense cover of annual grasses and forbs in the vicinity.	The current access road to Umtanum Ridge is inadequate for firefighting equipment to access the site. Archaeological clearances are underway to assess the impacts from improving the access road for firefighting. Herbicide treatment of introduced annuals and re-seeding with native perennial herbs, grasses, and shrubs has not been attempted.
5. Seed collections are established, stored, and maintained at seed banks.	Partially met. Accessions from plants from the main subpopulations are present in three seed repositories. Recently, efforts have been made to collect and store seed based on maternal lines.	Additional quantities of seed are desirable for long-term storage and developing seed stock or plugs for introduction to new sites or augmenting the single native occurrence.

are still needed to prevent the recurrence of a significant fire at Umtanum Ridge and will likely be needed to protect other out-planted populations.

The future prognosis for *Eriogonum codium* is not bright. On-going drought, and the threat of additional wildfires are the immediate threats to this species. Poor seedling recruitment is a long-term threat, as the population does not appear able to replace older plants lost to drought or fire. Establishing additional out-plantings, including in areas that may be at higher elevations (with cooler and moister conditions) or rearing plants in captivity will be necessary to maintain this species should the Umtanum Ridge population ultimately fail.

<u>Future Directions for Monitoring</u>: Monitoring of the Umtanum Ridge occurrence has provided essential information on the life history, longevity, seedling survivorship, and population trends of *Eriogonum codium* since 1997. The long-term demographic monitoring plots should continue to be re-visited each year, but with some modifications. Photographic monitoring should be implemented at each plot (with the plot frame present and a dry-erase board with the plot and transect numbers and date) to visually record the location and vigor of all tagged plants. The data sheet should also be modified to include information on associated species and their cover. Seedling monitoring in the plots can be discontinued, as survivorship patterns have been well documented and a revised PVA is no longer necessary, given the high threats to the species from wildfire and potentially deleterious impacts to the plots from spring seedling monitoring. Seedling studies are still valuable, however, but should be more targeted on tagged seedlings in smaller plots, as is being initiated by Rare Care researchers.

A population census should be re-done every 5 years to gather useful data on abundance and trend, while reducing annual impacts to the site. Use of drone technology and imagery should be explored to further reduce trampling to the site. The pin flag method has been demonstrated to be more accurate and should be used for population censusing instead of hand clickers.

Acknowledgements

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Appendix A. Species Abstract for *Eriogonum codium*

Classification:

Scientific Name: *Eriogonum codium* Reveal, Caplow, & Beck (Reveal et al. 1997).

Common Name: Umtanum desert buckwheat, Umtanum desert wild buckwheat.

Family: Polygonaceae (buckwheat family).

Synonyms: None.

Phylogenetic Relationships: *Eriogonum* is the fourth largest plant genus in North America, with 291 taxa recognized in 8 subgenera (224 full species and 67 varieties). Only *Carex*, *Astragalus*, and *Penstemon* have more species native to North America (Reveal 2005). *Eriogonum codium* belongs to subgenus *Eucycla*, the most species-rich subgenus of *Eriogonum* with 107 species restricted to the western United States, southwestern Canada, and northwestern Mexico (Reveal 2005). *Eriogonum codium* is unique within this group in having capitate to slightly umbellate inflorescences with hairy, lemon-yellow corollas. It may be most closely related to *E. chrysops*, a narrow endemic of volcanic outcrops with sparsely glandular yellow flowers from Malheur County, Oregon (Reveal 2005, Reveal et al. 1997)

Legal Status: Listed as Threatened under the ESA in 2013 (US Fish and Wildlife Service 2013c).

Natural Heritage Rank: G1/S1; WA Endangered

Description: *Eriogonum codium* is a densely matted perennial herb from a woody taproot forming tufts 10-70 cm across. The basal leaves are elliptic and densely white or gray woolly on both surfaces. Flowering stems are leafless, erect, and often brittle and terminate in a ball-like or slightly branched inflorescence. Individual clusters of flowers are contained within a hairy, cup-like involucre with 5 short, erect teeth. The perianth is comprised of 6 equal, lemon-yellow tepals that are hairy on the outside. Flowers are jointed directly to the pedicels (flowering stalks) and lack a slender, stipe-like base Camp and Gamon 2011; Fertig 2021a, Reveal 2005, Reveal et al. 1995). Flowering occurs from late May to early September (Beck 1999), but has been observed as late as early October (Fertig 2021a).

Similar Species: *Eriogonum douglasii* and *E. caespitosum* have yellow or dirty whitish flowers with stipe-like bases. *E. ovalifolium* var. *ovalifolium* has glabrous yellow flowers with the outer 3 tepals broader than the inner 3 and leaves that are oval (Hitchcock and Cronquist 2018).

Geographic Range: Local endemic of the east end of Umtanum Ridge in Benton County, Washington (Columbia Plateau ecoregion) (Figure 1). Additional outplantings have been established at sites in Benton, Grant, and Yakima counties.

Habitat**:** Found on the rim of north-facing basalt cliffs on fine pebbly or pumice-like basalt of the Kiona Silt loam series in a sparse cushion plant-bunchgrass community bordered by sagebrush grassland. Prior to the Silver Dollar fire, the surrounding vegetation was dominated by *Artemisia tridentata, Grayia spinosa, Salvia dorrii, Poa secunda,* and *Elymus spicatus* (Dunwiddie et al. 2001). Today, the rim vegetation consists primarily of 20-25% cover of

Eriogonum codium, Bromus tectorum, Salsola tragus, Poa secunda, Achnatherum hymenoides, Achillea millefolium, Astragalus purshii, Elymus elymoides, Sphaeralcea grossulariifolia, Dieteria canescens, and *Balsamorhiza careyana* (Fertig 2019; WNHP 2022). Elevation 340-400m (1120-1300 ft).

Population Size and Trends: Umtanum desert buckwheat is known from a single native occurrence consisting of three subpopulations located along a 1.2 mile long stretch of rim. The entire population was censused in 2019 using pin flags and 3,016 flowering and mature vegetative plants were found (Fertig 2021a). In 2011, a similar census documented 5,169 flowering and vegetative plants (seedlings were not counted in either study).

Overall trends are downward. Kaye (2007) conducted a population viability assessment based on 10 years of monitoring data and predicted a 72% chance of the population declining by half within 100 years. About 60% of the population burned in the Silver Dollar wildfire in July 2017, resulting in a population decrease of 41% from 2011 to 2019 (Fertig 2019). Based on long-term monitoring of demographic plots, the number of flowering and mature plants dropped from 105 in 1997 to 48 in 2021, a decrease of 54% (Table 1).

Population Biology and Ecology: *Eriogonum codium* is a long-lived perennial (mature plants may live more than 100 years) capable of producing 350-900 flowers per inflorescence and 5-27 or more inflorescences per year (Dunwiddie et al. 2001). Seeds are produced in about 10% of all flowers. The central bumblebee (*Bombus centralis*) has been observed pollinating *E. codium*, but other insects (including other bees, ants, beetles, flies, spiders, moths, and butterflies have been found on inflorescences (Beck 1999; USFWS 2021a). If pollinators are excluded, seed set is reduced to 0-2.5% (Beck 1999; Reveal et al. 1995). Fertilized fruits mature in late summer, though the timing is variable within a population (Shank 2019). Seed production may vary from 1.88 to 3.4 seeds per inflorescence (Caplow 2005). Seed viability is 70-78% in the first year, but then drops precipitously to 5% after two years (Caplow 2005), suggesting that the seed bank is transitory to short-lived (USFWS 2021a). Seed may be dispersed passively by gravity and strong winds, or facilitated by ants, though these insects may primarily be seed predators (Dunwiddie et al. 2001; Fertig 2021a). Seedling recruitment is episodic, probably enhanced by moist winters and cool spring temperatures. The number of germinating seeds in the wild may range from 0-333 in 1 x 2 m plots, with 67-91% dying within 3 months and nearly 100% mortality within 1 year (Caplow 2005; Fertig 2021a). Mature plants may "split" into two smaller plants due to death of inter-connecting stem and leaf tissue (Fertig 2021a). Monitoring studies over the past 25 years indicate that mortality of established plants is exceeding successful recruitment of new individuals from seed, even without the impacts of stochasitc wildfires.

Existing and Potential Threats: Umtanum desert buckwheat is highly vulnerable to wildfire (Newsome 2020), competition from invasive annuals (especially flammable species such as *Bromus tectorum* and *Salsola tragus*), trampling, poor seedling recruitment, and loss of pollinators (Fertig 2019). Long-term drought may also be negatively affecting seedling recruitment (USFWS 2021a). Climate change impacts (increased temperatures, reduced precipitation, greater seasonal instability, poor dispersal, competition from invasive annual weeds, and contracting habitat) may increase in the future (Fertig 2021a).

Managed Areas/Ownership: The native population is found in the Hanford Reach National Monument on lands jointly managed by the Department of Energy & US Fish and Wildlife Service. Out-plantings have been attempted at two additional sites on the Hanford Reach National Monument (managed by USFWS), at a county park near Richland, and on private lands owned by the Cowiche Canyon Conservancy (Newsome and Abel 2021; Fertig 2021a; Fertig and Kleinknecht 2022).

Appendix B. Climate Change Vulnerability Index (CCVI) Report for *Eriogonum codium* (Umtanum wild buckwheat)

Date: 20 February 2020
Assessor: Walter Fertig, WA Natural Heritage Program
Geographic Area: Washington — Heritage Rank: G1/S1
Index Result: Moderately Vulnerable — Confidence: Very High

Climate Change Vulnerability Index Scores

Section A	**Severity**	**Scope (% of range)**
1. Temperature Severity	>6.0° F (3.3°C) warmer	0
	5.6-6.0° F (3.2-3.3°C) warmer	0
	5.0-5.5° F (2.8-3.1°C) warmer	0
	4.5-5.0° F (2.5-2.7°C) warmer	0
	3.9-4.4° F (2.2-2.4°C) warmer	100
	<3.9° F (2.2°C) warmer	0
2. Hamon AET:PET moisture	< -0.119	0
	-0.097 to -0.119	0
	-0.074 to - 0.096	0
	-0.051 to - 0.073	0
	-0.028 to -0.050	100
	>-0.028	0
Section B		**Effect on Vulnerability**
1. Sea level rise		Neutral
2a. Distribution relative to natural barriers		Neutral
2b. Distribution relative to anthropogenic barriers		Somewhat Increase
3. Impacts from climate change mitigation		Neutral
Section C		
1. Dispersal and movements		Somewhat Increase
2ai Change in historical thermal niche		Neutral
2aii. Change in physiological thermal niche		Neutral
2bi. Changes in historical hydrological niche		Greatly Increase
2bii. Changes in physiological hydrological niche		Increase
2c. Dependence on specific disturbance regime		Neutral
2d. Dependence on ice or snow-covered habitats		Neutral
3. Restricted to uncommon landscape/geological features		Increase
4a. Dependence on others species to generate required habitat		Neutral
4b. Dietary versatility		Not Applicable
4c. Pollinator versatility		Neutral
4d. Dependence on other species for propagule dispersal		Neutral
4e. Sensitivity to pathogens or natural enemies		Neutral
4f. Sensitivity to competition from native or non-native species		Somewhat Increase
4g. Forms part of an interspecific interaction not covered above		Neutral
5a. Measured genetic diversity		Unknown

5b. Genetic bottlenecks	Unknown
5c. Reproductive system	Neutral
6. Phenological response to changing seasonal and precipitation dynamics	Somewhat Increase
Section D	
D1. Documented response to recent climate change	Somewhat Increase
D2. Modeled future (2050) change in population or range size	Unknown
D3. Overlap of modeled future (2050) range with current range	Unknown
D4. Occurrence of protected areas in modeled future (2050) distribution	Unknown

Section A: Exposure to Local Climate Change

A1. Temperature: The single known occurrence of *Eriogonum codium* in Washington occurs in an area with a projected temperature increase of 3.9-4.4˚ F (Figure 1).

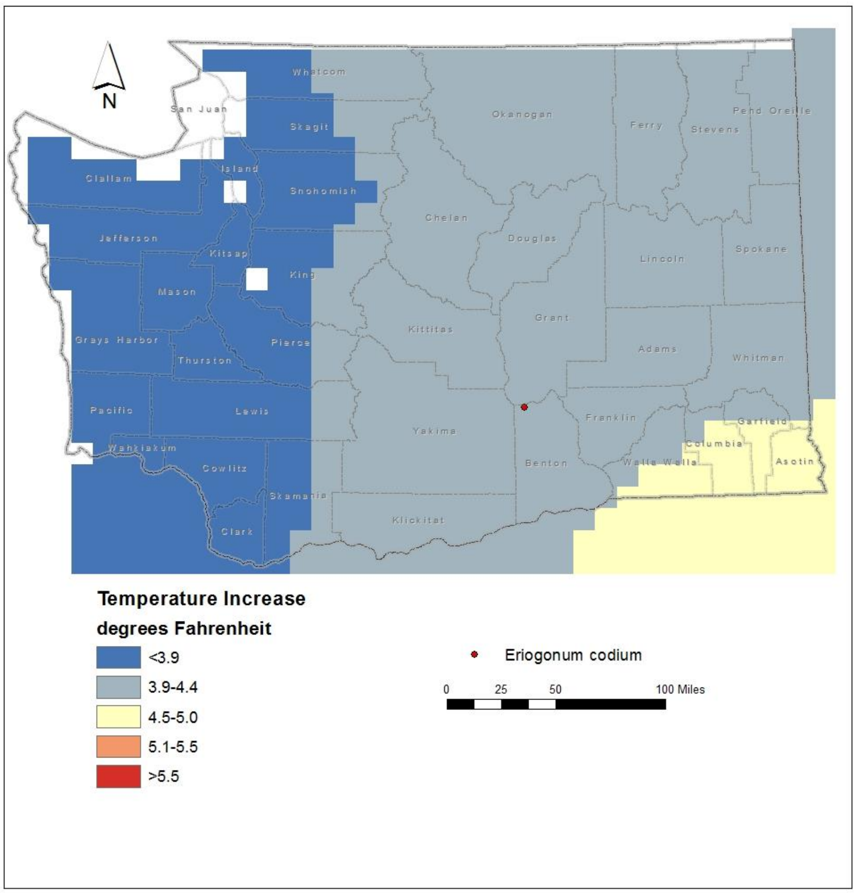

Figure 1. Exposure of *Eriogonum codium* occurrences in Washington to projected local temperature change. Base map layers from www.natureserve.org/ccvi

A2. Hamon AET:PET Moisture Metric: The Washington occurrence of *Eriogonum codium* is found in an area with a projected decrease in available moisture (as measured by the ratio of actual to potential evapotranspiration) in the range of -0.028 to -0.050 (Figure 2).

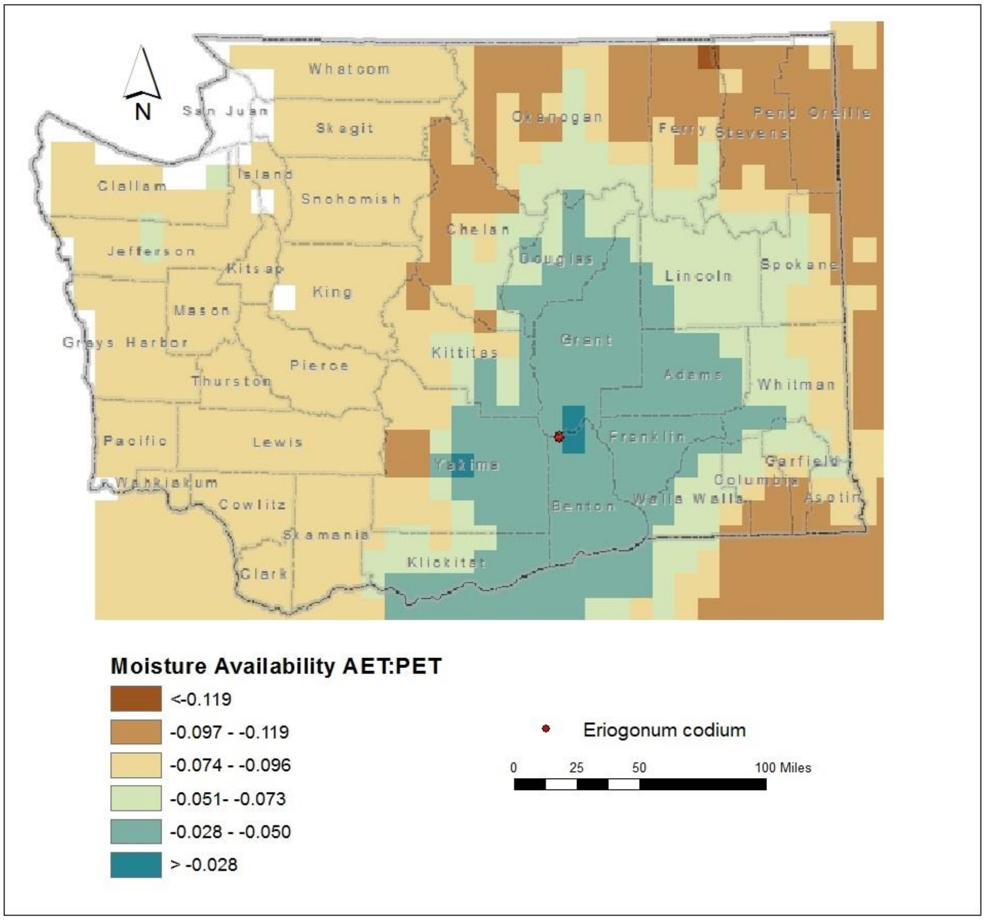

Figure 2. Exposure of *Eriogonum codium* occurrences in Washington to projected moisture availability (based on ratio of actual to predicted evapotranspiration). Base map layers from www.natureserve.org/ccvi

Section B. Indirect Exposure to Climate Change

B1. Exposure to sea level rise: Neutral.

Washington occurrences of *Eriogonum codium* are found at 1120-1300 ft (340-400 m) and would not be inundated by projected sea level rise.

B2a. Natural barriers: Neutral.

In Washington, *Eriogonum codium* occurs in a sparsely vegetated cushion plant and bunchgrass community on the rim and uppermost north slope of basalt cliffs with thin, fine, pebbly or pumice-like soils of the Kiona silt loam series (Fertig 2019). This habitat is a component of the Inter-Mountain Basins Cliff and Canyon ecological system (Rocchio and Crawford 2015). The population extends discontinuously for about 1.5 km (1 mile). No other populations have been documented in central or southern Washington, although similar basal ridges occur elsewhere in Yakima, Kittitas, and Grant counties. These potential sites are separated by areas of unsuitable habitat. Whether the range of *E. codium* is constrained by its dispersal ability or lack of additional habitat is not known.

B2b. Anthropogenic barriers: Somewhat Increase.
The range of *Eriogonum codium* is restricted to the east end of Umtanum Ridge near the Hanford Reach of the Columbia River. Human development (including the Hanford Site, agricultural lands, and roads) surrounds much of this area, and could restrict potential expansion or migration of the species beyond Umtanum Ridge.

B3. Predicted impacts of land use changes from climate change mitigation: Neutral.

Section C: Sensitive and Adaptive Capacity
C1. Dispersal and movements: Somewhat Increase.
Seed of *Eriogonum codium* is dispersed primarily by gravity or wind (Dunwiddie et al. 2001). The majority of seeds are dispersed a short distance from their parents, though strong winds along Umtanum Ridge are likely to transport them at least 1 km. Movement of seed by Western harvester ants (*Pogonomyrmex occidentalis*) has been observed, but it is believed that ants are more significant as seed predators than dispersal agents (Dunwiddie et al. 2001; Rush and Gamon 1999). Concentrations of seeds near mature plants may be due to poor dispersal or an artifact of the limited number of microenvironments suitable for germination (these may be positively associated with nurse plants) (Dunwiddie et al. 2001).

C2ai. Historical thermal niche: Neutral.
Figure 3 depicts the distribution of *Eriogonum codium* in Washington relative to mean seasonal temperature variation for the period from 1951-2006 ("historical thermal niche"). The single occurrence is found in an area that has experienced average (57.1-77˚F/31.8-43.0˚C) temperature variation during the past 50 years. This population is considered "neutral" in terms if climate change vulnerability by Young et al. (2016).

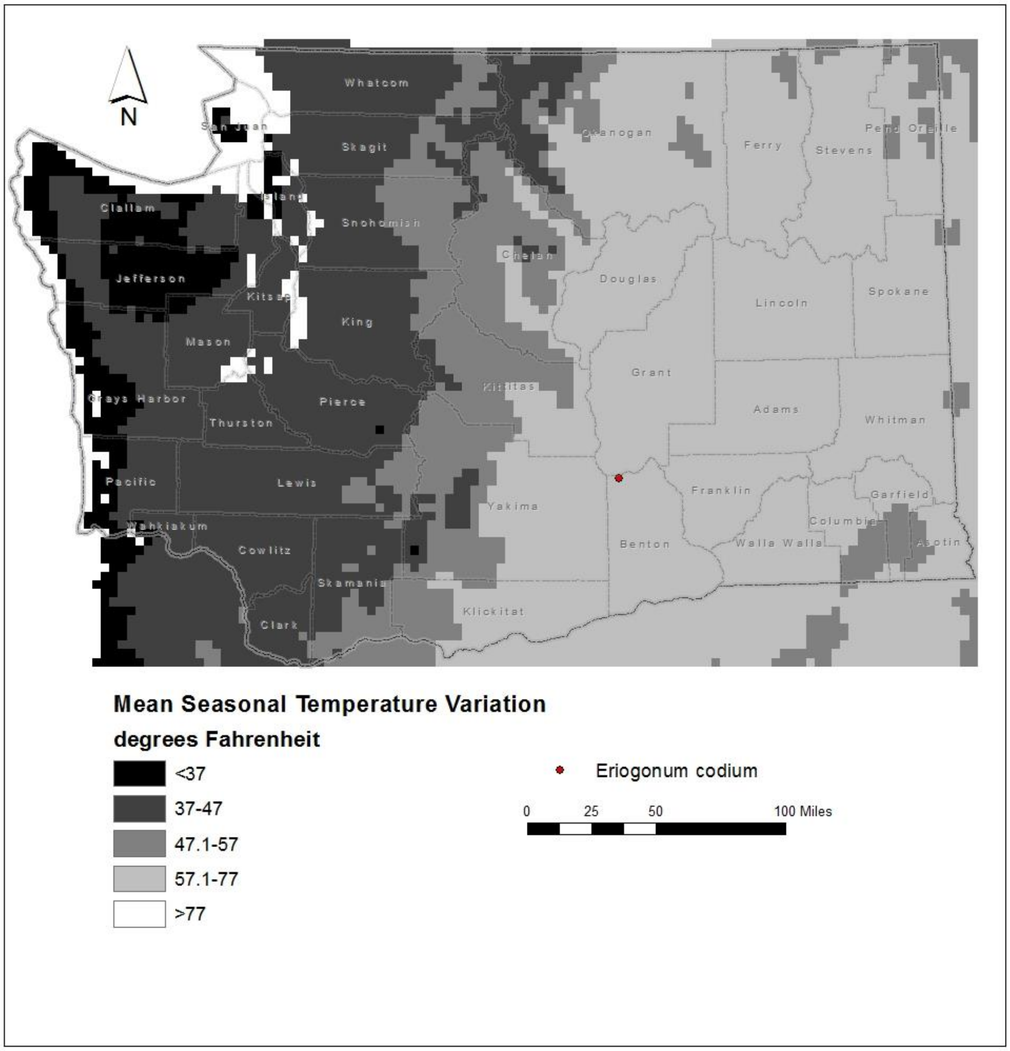

Figure 3. Historical thermal niche (exposure to past temperature variations) of *Eriogonum codium* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2aii. Physiological thermal niche: Neutral.
The sparsely vegetated basalt rim habitat occupied by *Eriogonum codium* is cooled by exposure to wind but is not otherwise associated with cold air drainage, especially during the growing season and would have neutral vulnerability to climate change.

C2bi. Historical hydrological niche: Greatly Increase.
The single population of *Eriogonum codium* in Washington is found in an area that has experienced very small (< 4 inches/100 mm) precipitation variation in the past 50 years (Figure 4). According to Young et al. (2016), this occurrence is at "Greatly Increased" vulnerability to climate change.

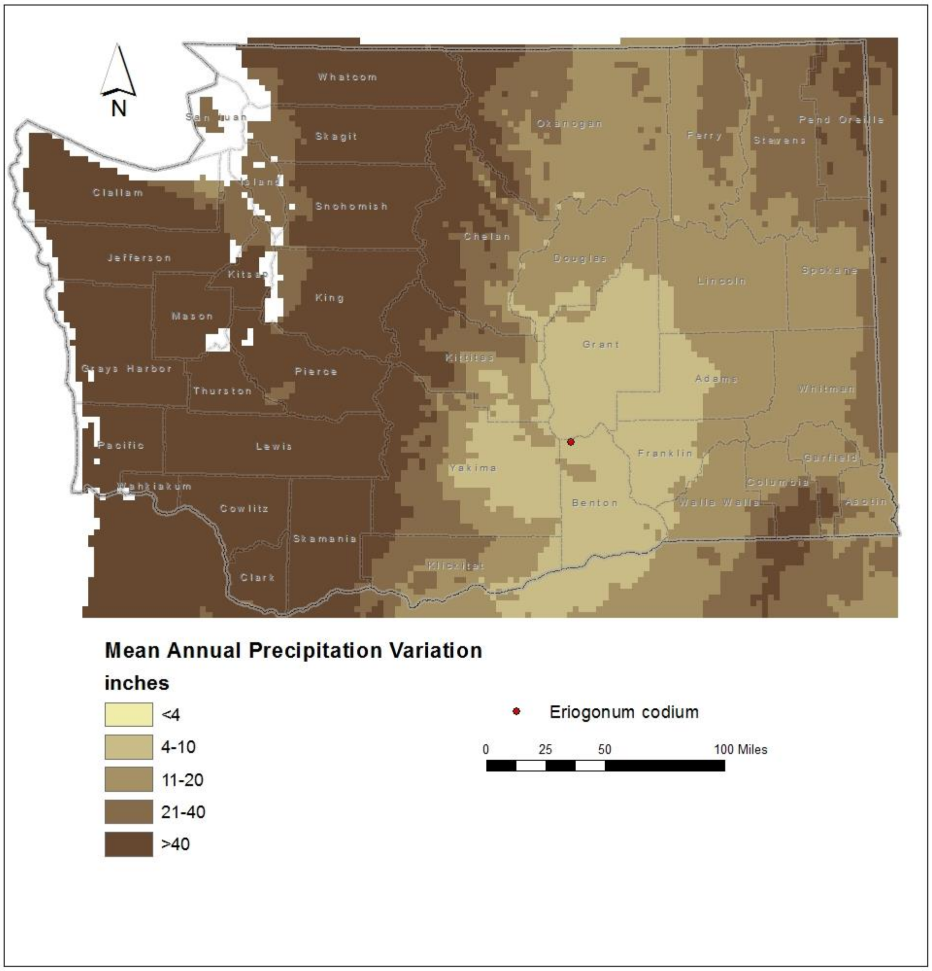

Figure 4. Historical hydrological niche (exposure to past variations in precipitation) of *Eriogonum codium* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2bii. Physiological hydrological niche: Increase.
This species is dependent on winter and spring rainfall and winter snow for its moisture requirements because its cliff habitat is not associated with springs, streams, or groundwater. The Inter-Mountain Basins Cliff and Canyon ecological system is vulnerable to changes in the timing or amount of precipitation and increases in temperature (Rocchio and Ramm-Granberg 2017). Drought, replacement of native vegetation by annual exotics (especially cheatgrass, *Bromus tectorum*) and wildfire are the leading threats to this species (Fertig 2019) and likely to increase due to climate change.

C2c. Dependence on a specific disturbance regime: Neutral.
Eriogonum codium is not adapted to disturbance to maintain its partially barren basalt rim habitat and in fact is negatively impacted by disturbances, such as vehicle trampling, mineral prospecting, and wildfire (Camp and Gamon 2011, Rush and Gamon 1999)

C2d. Dependence on ice or snow-cover habitats: Neutral.
Snowpack is low in the Umtanum Ridge areas and a minor component of the annual water budget.

C3. Restricted to uncommon landscape/geological features: Increase
Eriogonum codium is restricted to the exposed top of the mid-Miocene age Lolo Flow of basalt, which is part of the Priest Rapids Member of the Wanapum Formation (Goff 1981). It is further restricted to fine pebbly or pumice-like soils of the Kiona silt loam series. The combination of ridgecrest exposure and soil type is apparently limited in south-central Washington.

C4a. Dependence on other species to generate required habitat: Neutral
The basalt rim and upper slope habitat occupied by *Eriogonum codium* is maintained by natural climatic phenomena, and not strongly influenced by animal species.

C4b. Dietary versatility: Not applicable for plants

C4c. Pollinator versatility: Neutral.
Most *Eriogonum* species are generalists and not dependent on specific pollinators (J.R. Reveal, cited in Beck 1999). *Eriogonum codium* has been observed to be visited by ants, beetles, flies, spiders, moths, butterflies, and bumblebees (Beck 1999, Fleckenstein 2014). Inflorescence bagging studies suggest that *E. codium* may be capable of limited self-pollination (Beck 1999).

C4d. Dependence on other species for propagule dispersal: Neutral.
Dispersal of *Eriogonum codium* seeds is primarily by passive means (wind and gravity). Harvester ants have been observed moving seeds, but these insects are primarily seed predators (Dunwiddie et al. 2001). Occasionally, however, uneaten seeds might germinate and survive.

C4e. Sensitivity to pathogens or natural enemies: Neutral.
No natural pathogens are known. Inflorescences and seeds may be consumed by rodents and ants. The low, compact growth form protects this species from herbivory by ungulates or livestock.

C4f. Sensitivity to competition from native or non-native species: Somewhat Increase.
Historically, *Eriogonum codium* probably was not affected by competition from other plant species in its sparsely vegetated basalt rim habitat. Recent wildfires have removed much of the native cover and allowed invasive annual weeds to become established, such as cheatgrass and Russian-thistle (*Salsola tragus*). These species now compete for limited soil and moisture resources and make this habitat more prone to subsequent fires.

C4g. Forms part of an interspecific interaction not covered above: Neutral.
Does not require an interspecific interaction.

C5a. Measured genetic variation: Unknown.
No data are available on the genetic diversity of *Eriogonum codium*.

C5b. Genetic bottlenecks: Unknown.

C5c. Reproductive System: Neutral
Eriogonum codium is primarily an outcrosser capable of producing large numbers of flowers each year, although fruit production may be as low as 10% (Beck 1999). The species potentially should have average levels of genetic diversity based on its life history.

C6. Phenological response to changing seasonal and precipitation dynamics: Somewhat Increase.
Eriogonum codium has a long flowering period, extending from May to late August (Camp and Gamon 2011). After the Silver Dollar Fire in 2017, plants were still flowering in early October (W. Fertig, personal observation).

Section D: Documented or Modeled Response to Climate Change
D1. Documented response to recent climate change: Somewhat Increase.
The population of *Eriogonum codium* has declined from 5169 plants in 2011 to 3016 in 2019 in large part due to mortality from several wildfires, including the Silver Dollar fire of 2017 that burned nearly 60% of its habitat (Fertig 2019). The increase in fire frequency is associated with drought and rising temperatures experienced over the past two decades, which may be related to ongoing climate change.

D2. Modeled future (2050) change in population or range size: Unknown

D3. Overlap of modeled future (2050) range with current range: Unknown

D4. Occurrence of protected areas in modeled future (2050) distribution: Unknown

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Appendix C.

Propagation Protocol for *Eriogonum codium* developed by Jane Abel (derived from Abel 2013)

1. Seed collection: seeds were collected from 8 plants on Umtanum Ridge on 3 July 2010. Target plants were selected from different areas of the main colony (presumably the easternmost subpopulation near the long-term monitoring transects).

2. Seed storage: Seeds were stored in paper envelopes at room temperature until planting.

3. Soil mix: At the time, there was limited information available on the soil characteristics of the Umtanum Ridge site. Soil recipes from standard rock garden references (such as Nicholls 2002) recommended more peat than would be expected for a species like *Eriogonum codium* and its xeric, rocky habitat. The mix that was used instead was approximately 35% coarse sand, 30% top soil, and 35% crushed quartz. These products were purchased from a local nursery and mixed in a wheelbarrow. A small amount of White Bluffs caliche (from the White Bluffs formation on the east bank of the Columbia River, east of Umtanum Ridge) was added to the soil mix when seedlings were transferred to 4 inch pots.

4. Planting: Seed was planted on 15 October 2010 (about 3 ½ months after being collected) using a standard 10 x 20 inch nursery flat. The flats were lined with newspaper and filled with the soil mix (see #3 above). Seeds were placed on the surface of the soil and covered only slightly with additional soil. Planted flats were left outside and exposed to winter weather. November 2010 was colder than normal, and there were several snow storms and freezing events between November and January 2011.

5. Germination: Seeds began to germinate on 17 January, following several days of warm weather. Approximately 60 seeds in all germinated. Seedlings remained in the cotyledon phase until mid-April, though they were adding 2-3 inches of root growth. At this time, 10 seedlings perished (the cotyledons turned rusty red and no new leaves were added).

6. Transplanting to larger pots: In mid-April, surviving seedlings developed true leaves. At this stage they were transferred to 4 inch pots. After re-potting, a dilute liquid fertilizer was used about once per week, but was changed to “Dr. Earth” (4-4-4) in late May and applied every 3-4 weeks.

7. Care and maintenance: The 4 inch pots were kept outdoors. As temperatures increased in mid-June, seedlings were transferred to 1-gallon nursery pots. Several plants died from overheating. Shade cloth was used to protect plants from too much sun in the afternoon.