



Species Status Assessment
CLAY-LOVING WILD BUCKWHEAT
Eriogonum pelinophilum

Prepared by the Western Colorado Ecological Services Field Office
U. S. Fish and Wildlife Service
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Executive Summary

This species status assessment (SSA) is a comprehensive biological status review by the U.S. Fish and Wildlife Service (Service) of clay-loving wild buckwheat (*Eriogonum pelinophilum*). Clay-loving wild buckwheat is a narrow-endemic, perennial plant known to occur in Delta and Montrose Counties, Colorado. The species was listed as endangered in 1984 under the Endangered Species Act of 1973, as amended. The Service cited the extremely limited range of clay-loving wild buckwheat habitat and the high risk of habitat loss due to grazing by livestock and off-highway vehicle use as reasons for listing (49 FR 28562, July 13, 1984). This SSA provides a thorough account of the species' overall viability and, therefore, extinction risk and is intended to inform a subsequent five-year review. The five-year review will recommend whether the species' listing status should be changed (i.e., whether the species should remain listed as "endangered," be downlisted to "threatened," or delisted).

We assessed species' viability using "the three R's"—resiliency, redundancy, and representation—across the range of the species. We divided the species' range into three representative analytical units (Figure 7). The boundaries for these analytical units were delineated by natural geological and ecological features, biological and genetic variation, environmental conditions, and land management. The three analytical units incorporate all known occurrences of the species.

To support species' viability, clay-loving wild buckwheat requires certain resources and demographic factors to provide for resiliency, redundancy, and representation. Individual plants need substrate derived from the Mancos Shale Formation, adequate soil moisture, and appropriate soil temperature. Populations of clay-loving wild buckwheat (defined in terms of analytical units throughout this SSA) need adequate abundance, recruitment, and survivorship across age classes to maintain or expand the unit and have strong genetic connectivity within a unit and with other analytical units. Clay-loving wild buckwheat, as a species, needs multiple diverse, resilient analytical units distributed across the species' range to reduce risk associated with catastrophes (redundancy) and with long-term environmental changes (representation).

We evaluated a number of stressors that could influence the viability of clay-loving wild buckwheat, including incompatible livestock grazing, presence of invasive species, off-highway vehicle (OHV) use, commercial and residential development, irrigation operations, development and maintenance of utility corridors, and climate change. Many of these stressors occur throughout the species' range on both public and private lands. Most public lands have management in place to protect the species (e.g., special land designations, fencing, and no surface occupancy stipulations). Private lands, however, have few known protections in place, though there are exceptions (e.g., fencing enclosures and monitoring at Montrose Model Aircraft Association). The amount of public and private land and associated protections varies among the three analytical units.

In our evaluation of species condition, we considered analytical units for clay-loving wild buckwheat to be most resilient when habitat condition is high, fall and winter precipitation and average spring temperature are similar to historical climate, seedling frequency is 20 percent or greater, the average analytical unit growth rate (λ) is greater than one, and connectivity within and between analytical units is high.



Based on these factors, two of the three analytical units, Fairview and Selig, currently have moderate resiliency, and one analytical unit, Delta, has low resiliency (Tables 1 and 8). No clay-loving wild buckwheat analytical unit has high resiliency, and range-wide monitoring efforts demonstrate a decreasing trend in plant densities over the last ten years in all analytical units.

Redundancy for narrow endemic species is inherently limited, and redundancy of clay-loving wild buckwheat is at risk of further decline due to the lack of any highly resilient analytical units and low numbers of plants. Additionally, clay-loving wild buckwheat plants are distributed unevenly across the range of the species with most plants occurring in the Fairview analytical unit. The three analytical units border one another and cover only 173 square miles (448 square kilometers), further reducing the redundancy of the species and its ability to withstand catastrophic events, as a single catastrophic event could affect a large portion of the species' range.

In terms of representation, the species' habitat exhibits some ecological variability (i.e., precipitation and temperature regimes vary across the species' range), and the species maintains limited genetic diversity and high connectivity within and among analytical units.

Given uncertainty regarding the future trend of the stressors and conservation efforts influencing clay-loving wild buckwheat, we projected the future resiliency, redundancy, and representation of clay-loving wild buckwheat under three different future scenarios. These three scenarios are intended to capture the range of plausible future conditions the species might experience. We forecasted the resiliency of clay-loving wild buckwheat analytical units and the redundancy and representation of the species through mid-century (i.e., 2055). Unfortunately, we are uncertain of a specific timescale that is biologically relevant to the species, since we do not know how long individual plants persist, though we know they are long-lived (i.e., >20 years). Thus, we selected mid-century because this timeframe is short enough to realistically predict changes in stressors, in conservation efforts, and in climatic conditions, and long enough to begin to understand the ecosystem response to those changes. Each future scenario predicts climatic conditions based on a different climate model. The climate models used in the three scenarios represent the range of plausible future climates occurring in the area around mid-century. These models and associated data were obtained from the [Climate Toolbox](#) (Hegewisch and Abatzoglou 2022, entire).

The three future scenarios include:

an **optimistic** scenario in which land management prescriptions are similar to current land management and the climate becomes slightly more favorable (i.e., a one-inch increase in fall/winter precipitation compared to the current levels);

a **continuation** scenario in which land management prescriptions are similar to current land management, but climatic conditions worsen¹ (i.e., average spring temperature increases by at least 4 °F); and

¹ The continuation scenario does not represent a future scenario in which conditions remain the same. Rather, the continuation scenario is a future scenario in which current *trends* in stressors and in conservation efforts continue. For example, the average spring temperature continues to warm.



a **pessimistic** scenario in which both land management prescriptions and climate are less favorable for clay-loving wild buckwheat (i.e., restrictions on grazing, OHV use, and development are lifted, fall/winter precipitation does not increase, and average spring temperature exceeds 55 °F).

We evaluated the future condition of clay-loving wild buckwheat under each of these scenarios by determining how the changes in stressors and conservation efforts would impact resiliency, redundancy, and representation of the species by mid-century (Tables 1, 13, 14, and 15). Our evaluations of future condition incorporated input from our technical team.

Under the optimistic scenario, resiliency is expected to increase slightly for each analytical unit. Redundancy and representation of the species will also increase as resiliency of each analytical unit increases. Under the continuation and pessimistic future scenarios, changes in climate will likely reduce the resiliency of each analytical unit. With only three analytical units, the loss of one unit due to catastrophic, natural, or human-caused events would cause a severe loss of redundancy and representation of the species. Redundancy and representation of the species will decrease as resiliency of each analytical unit decreases.

Table 1. The overall condition of the three analytical units for clay-loving wild buckwheat currently and under an optimistic, continuation, and pessimistic scenario.

Condition Summary				
Analytical Unit	Current	Optimistic	Continuation	Pessimistic
Fairview Analytical Unit	MODERATE	HIGH	MODERATE	LOW
Selig Analytical Unit	MODERATE	MODERATE	LOW	LOW
Delta Analytical Unit	LOW	LOW	LOW	LOW



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1 Introduction

Clay-loving wild buckwheat (*Eriogonum pelinophilum*) is a low-growing, rounded, densely branched sub-shrub in the buckwheat family (Polygonaceae). The species is a long-lived perennial and is found in the rolling clay (adobe) hills and flats in Delta and Montrose Counties in Colorado. Clay-loving wild buckwheat was listed as an endangered species in 1984 under the Endangered Species Act of 1973, as amended (Act) due to the extremely limited range of its habitat and the high risk of habitat loss (49 FR 28562, July 13, 1984). Additionally, about 120 acres (49 hectares) of habitat were designated as critical habitat in Delta County (49 FR 28562, July 13, 1984).

We conducted this species status assessment (SSA) to characterize the viability of clay-loving wild buckwheat. We compiled the best available scientific and commercial information on the species' biology and the factors that influence the species' viability. This SSA will be the biological underpinning of the Service's forthcoming five-year status review for the species. We also intend this report to support all functions of our Endangered Species Program. We will update the SSA as new information becomes available, and the SSA will be a living document upon which we will base other future documents, such as listing rules, recovery plans, and additional five-year status reviews. The SSA process and this SSA do not represent a regulatory decision by the Service under the ESA. Instead, this report provides a review of the best available scientific and commercial information regarding the biology and viability of clay-loving wild buckwheat.

1.1 Analytical Framework

The SSA framework is meant to characterize species' viability (i.e., the ability of a species to sustain populations in the wild over time). To sustain populations over time, a species must have the capacity to withstand

- environmental and demographic stochasticity and disturbances,
- catastrophes, and
- novel changes in its biological and physical environment.

We define these capacities using the conservation biology principles of resiliency, redundancy, and representation (i.e., the three R's), and we use the three R's to assess viability (Shaffer and Stein 2000, pp. 308-311). A species with a high degree of resiliency, representation, and redundancy is generally more viable (Smith et al. 2018, p. 306).

Resiliency is the ability of a species to withstand environmental stochasticity (i.e., normal, year-to-year variations in environmental conditions such as temperature and precipitation), demographic stochasticity (i.e., normal variation in demographic rates such as mortality and fecundity), and normal, periodic disturbances (e.g., fire, floods, and storms) (Redford et al. 2011, p. 40). Simply stated, resiliency is the ability of a species to sustain populations through the natural range of favorable and unfavorable conditions.



We gauge resiliency by evaluating individual- and population-level needs, such as demographic rates, genetic health, connectivity, and habitat quantity, quality, distribution, and heterogeneity.

Redundancy is the ability of a species to withstand catastrophes. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely (Mangal and Tier 1993, p. 1083).

We gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated catastrophes. We also assess the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or for narrow-ranged species, at the species level.

Representation is the ability of a species to adapt to near-term and long-term changes in its physical environment (e.g., climate conditions, habitat conditions, habitat structure) and in its biological environment (e.g., pathogens, competitors, predators). The ability to adapt to new environments—referred to as adaptive capacity—is essential for viability, as species must constantly adapt to the changing environment (Nicotra et al. 2015, p. 1269). Species adapt to novel changes in their environment by moving to new, suitable environments or by altering their physical or behavioral traits to match new environmental conditions. Species may alter their physical or behavioral traits through plasticity or genetic change (Beever et al. 2016, p. 132; Nicotra et al. 2015 p. 1270). The latter occurs via the evolutionary processes of natural selection, gene flow, mutation, and genetic drift (Crandall et al. 2000, p. 290-291; Sgro et al. 2011, p. 327; Zackay 2007, p. 1).

We gauge representation by examining the species' ability to disperse and colonize new areas and by examining the genetic, phenotypic, and ecological diversity found within a species. In assessing dispersal ability, it is important to consider the ability and likelihood of the species to track suitable habitat and climate over time. In assessing diversity, it is important to consider large-scale variation (e.g., morphological, behavioral, or life history differences and environmental or ecological variation across the range), and small-scale variation (e.g., inter-population genetic diversity). Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess natural levels and patterns of gene flow, degree of ecological diversity occupied, and effective population size. In an SSA, we assess all facets of diversity to the best of our ability based on available data.

The SSA framework has three assessment stages (Figure 1):

- 1. Species' Needs (Chapter 2)** An SSA begins with a compilation of the best available biological information on the species (e.g., taxonomy, life history, and habitat). We summarize the species' ecological needs at the individual, population, and species levels.

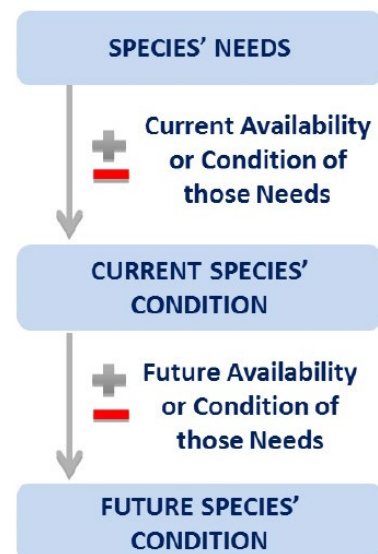


Figure 1. Species Status Assessment (SSA) stages (Service 2016, entire).



2. Current Species' Condition (Chapter 3) Next, an SSA describes the current condition of the species by examining whether the species' individual-, population-, and species-level ecological needs are being met. We characterize current condition in terms of the three R's. We also explore probable explanations for past and ongoing changes in species' abundance and distribution.

3. Future Species' Condition (Chapter 4) Lastly, an SSA forecasts the species' response to probable future scenarios. We consider future scenarios which capture the range of environmental conditions and conservation efforts the species is most likely to encounter, and we examine if the species' individual-, population-, and species-level ecological needs will be met under those scenarios. We characterize future condition in terms of the three R's and then characterize a species' ability to sustain populations in the wild over time (i.e., viability).

2 Species Ecology

In this chapter, we provide basic biological information about clay-loving wild buckwheat, including a physical description, taxonomic review, and information on life history and reproduction, habitat, species range and distribution, and genetic diversity. We then outline the resource needs of individuals, populations, and the species as a whole.

2.1 Biological Background

2.1.1 Physical Description

Clay-loving wild buckwheat is a low-growing, rounded, densely branched subshrub in the buckwheat family (Polygonaceae; Figures 2a and 2b). The species is a long-lived perennial (>20 years), and generally grows to about four inches (in) (10 centimeters [cm]) high and about seven 7 in (20 cm) across. The plants have a woody stem base that emerges from a large taproot. As plants age, bark comes off in strips or plates. Clay-loving wild buckwheat has dark green leaves that roll inward and appear needle-like. Small white



Figures 2a (top) and 2b (bottom). Clay-loving wild buckwheat *E. pelinophilum* in Montrose County, Colorado. Photos taken by James Reveal.



to cream colored flowers with pink veins are clustered at the end of each branch. Each cluster is about half an inch to one inch (2 to 3 cm) in length (Figures 2b). The fruits of clay-loving wild buckwheat are light brown and are about one-tenth of an inch (3 to 3.5 millimeters [mm]) in length.

2.1.2 Taxonomy

Clay-loving wild buckwheat was first collected by Harold Gentry near Hotchkiss, Colorado in 1958. In 1969, *E. pelinophilum* was recognized as a distinct species in an analysis of the species group by James Reveal. Reveal made repeated searches for the plant before he relocated the species in 1972 and officially described the species in 1973 (Reveal 1973, pp. 120-122).

Early on, there was question about whether *E. pelinophilum* might be a variety of *E. clavellatum* or *E. contortum* (The Nature Conservancy 1991, entire; Service 2009, pp. 10-11). Since then, multiple studies have confirmed that although they exhibit similar habits, each entity is a distinct species (Grady 2012, entire; Naibauer and McGlaughlin 2022, pp. 9-10). The three species are also geographically separated, with *E. clavellatum* occurring in the Four Corners area and *E. contortum* occurring in Mesa and Garfield Counties of Colorado (Colorado Natural Heritage Program [CNHP] 2014, entire). For a full taxonomic description of *E. pelinophilum*, see Reveal (1973, entire).

The current accepted classification (Integrated Taxonomic Information System 2022):

Kingdom: Plantae

Phylum: Anthophyta

Class: Dicotyledoneae

Order: Polygonales

Family: Polygonaceae

Genus: *Eriogonum*

Species: *pelinophilum*

2.1.3 Life Stages and Reproduction

Previous and ongoing surveys and demographic studies confirm that clay-loving wild buckwheat is a long-lived species (i.e., >20 years; Bureau of Land Management [BLM] 2019, entire; BLM 2021, entire). Flowering typically occurs from late May to early September with individual flowers lasting fewer than three days (Bowlin et al. 1992, pp. 297-298). However, individual plants can flower for three to six weeks. Clay-loving wild buckwheat requires a pollinator and has a mixed breeding system with some pollination occurring between flowers on the same plant and some pollination occurring between flowers from different plants (Bowlin et al. 1992, p. 300). For much of its flowering season, clay-loving wild buckwheat is the most abundant species in bloom in its habitat. Fruiting occurs from June to September (Table 2).



Table 2. Gantt chart illustrating the life stages of clay-loving wild buckwheat (*E. pelinophilum*).

		January	February	March	April	May	June	July	August	September	October	November	December
Life Stage	Important Phases												
Seeds	Dormancy												
Juveniles	Emergence												
Mature Adults	Flowering												
	Fruiting												
	Dormancy												

There are no species-specific studies on a potential seed bank for clay-loving wild buckwheat. Studies on other *Eriogonum* spp. have demonstrated that seeds can be viable for up to five years (O’Kane 1985, pp. II-32). Clay-loving wild buckwheat exhibits whole plant dormancy when conditions are unfavorable. For example, after multiple hot and dry years, some clay-loving wild buckwheat individuals did not produce leaves or flowers and were recorded as “dead” by the Bureau of Land Management (BLM) in 2020 during their annual monitoring. However, many of those same plants were found alive with leaves and flowers during 2021 annual monitoring (BLM 2021, entire).

Over 50 species of insects visit clay-loving wild buckwheat flowers (Bowlin et al. 1992, p. 300; Tepedino et al. 2011, p. 60). Roughly half of these species are native bees, and 18 species are native ants. Seed set is similar between plants pollinated by ants and plants pollinated by flying pollinators, which suggests that ants are important pollinators of the species (Bowlin et al. 1992, p. 298). Some fruits are removed by harvester ants, but no information suggests this is a major dispersal mechanism.

2.1.5 Habitat

Clay-loving wild buckwheat is endemic to the rolling clay (adobe) hills and flats immediately adjacent to the communities of Delta and Montrose, Colorado (Figure 3). Clay-loving wild buckwheat grows in alkaline clay barrens derived from the Mancos Shale Formation, often on white strata from the Smoky Hill member (Appendix I). Between the communities of Delta and Montrose, the Mancos Shale forms a ring on the east side of the valley along the base of the rim of the Black Canyon of the Gunnison. Clay-loving wild buckwheat habitat generally occurs in that ring along the toe slopes of the Mancos Shale hills between steep barren slopes above and broad flatlands below.

The habitat occupied by clay-loving wild buckwheat is harsh. Montrose and Delta Counties averaged less than three inches of precipitation annually in 2017 and 2018 (BLM 2019, p. 1). Furthermore, water infiltration in the clay soil is slow, and the extreme swelling and shrinking of the soil limits water availability and oxygen exchange for plant roots. Clay-loving wild buckwheat plants are generally found in microhabitats within swales or drainages where moisture lingers.



Plant communities associated with clay-loving wild buckwheat are characterized by low species diversity, low productivity, and minimal canopy cover. The associated vegetation is sparse, with clay-loving wild buckwheat generally one of the dominant species. In lower elevations near Delta, the dominant plant species is *Atriplex corrugata* (mat saltbrush), but at higher elevations near Montrose, the dominant plant species is *Artemisia nova* (black sagebrush), though *Atriplex corrugata* is still abundant. Other associated species include *Atriplex confertifolia* (shadscale), *Atriplex gardneri* (Gardner's saltbush), *Picrothamnus desertorum* (formerly *Artemisia spinescens*) (bud sagebrush), *Xylorhiza venusta* (charming woody aster), and another local endemic, *Penstemon retrorsus* (Adobe Hills beardtongue).

In 2021, the Colorado Natural Heritage Program (CNHP) drafted a species distribution model, and the BLM drafted a habitat suitability model for clay-loving wild buckwheat. The former used inductive modeling using the maximum entropy (Maxent) modeling procedure to find places on the landscape where environmental conditions are similar to conditions at known occurrences for the species, effectively modeling potential species distribution (Figures 4a). Variables in this model include distance to the Mancos formation, average percent of sand in the soil, spring precipitation, average percent of clay in the soil, fall precipitation, average percent of silt in

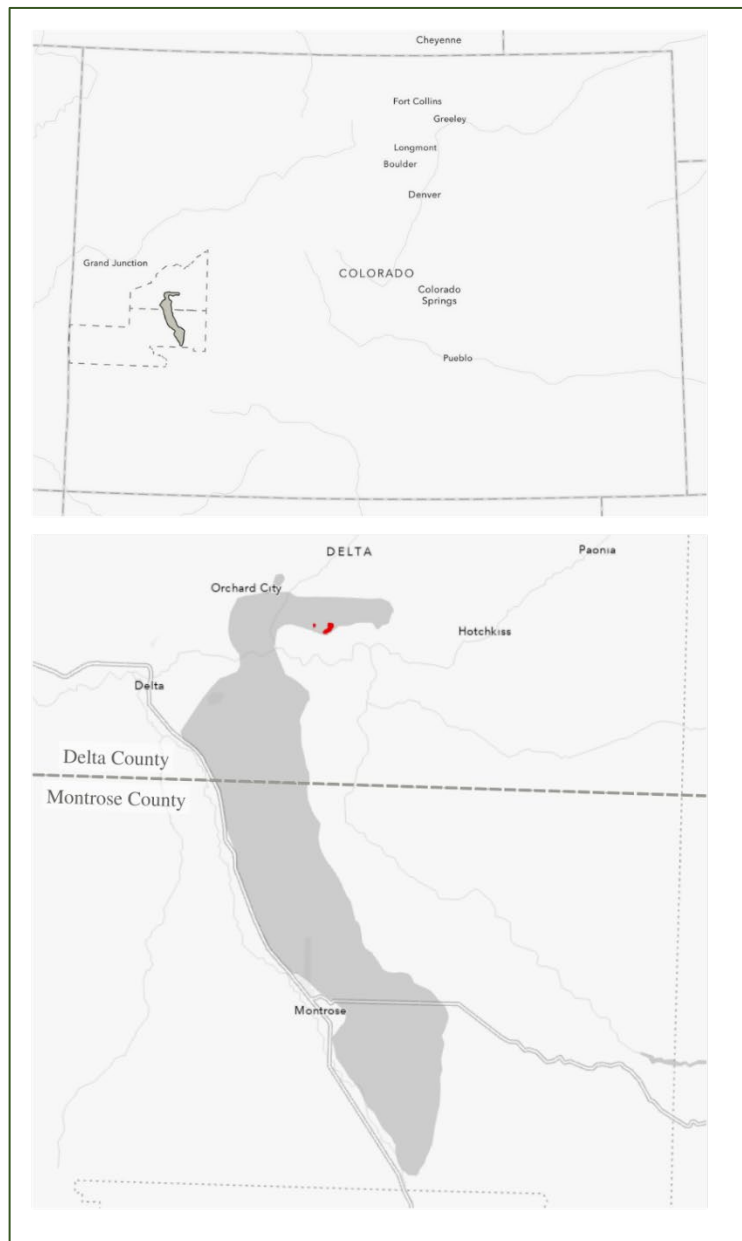
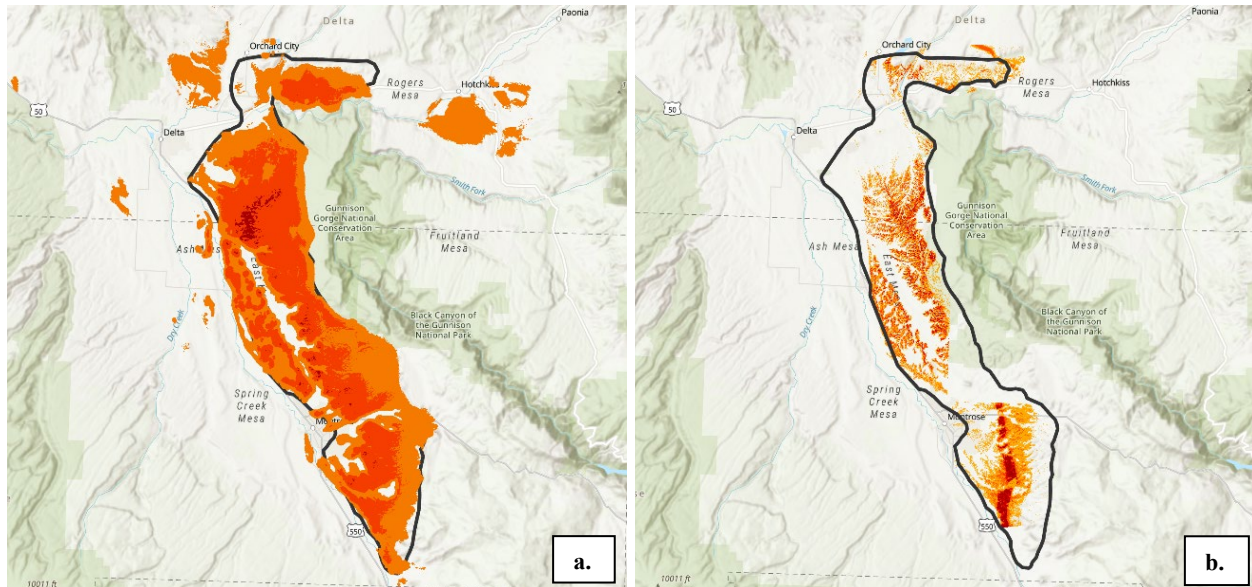


Figure 3. Current range of clay-loving wild buckwheat *E. pelinophilum* in Delta and Montrose Counties, Colorado, in grey. Designated critical habitat is shown in red.





Figures 4a and 4b. Habitat suitability models for clay-loving wild buckwheat created by the CNHP (a) and BLM (b). Darker shading indicates that the habitat is more likely to be suitable for the species. The CNHP model begins to refine the range for clay-loving wild buckwheat. The BLM model further refines the range with finer scale data and more geologic information and highlights some of the important microhabitats throughout the species' range.

the soil, biophysical vegetation type, summer precipitation, winter precipitation, and a terrain roughness index. Due to project constraints, fine-scale LiDAR and geology data could not be incorporated.

The BLM model was able to take advantage of alternate modeling techniques, one-meter resolution LiDAR data, and geologic formation data to model clay-loving wild buckwheat occurrences and more precisely predict suitable habitat, including capturing many of the microhabitats where the plant is often found (Figures 4b). Due to its refined inputs and techniques, the BLM model more accurately illustrates suitable habitat for the purposes of this SSA. Variables in this model included elevation data from LiDAR, slope degree, northness and eastness from the elevation, and geologic formation.

Overall, the BLM model accurately predicted 95.86% of occurrences not used in setting up the model. The results of this model highlight a strong association with the Smoky Hill member of the Mancos Shale Formation (Figure 5). Of the points where clay-loving wild buckwheat presence was predicted (i.e., highly suitable habitat was predicted), 89.9% were within a meter of the Smoky Hill member. Unfortunately, geologic formation data was not available throughout the entire range of the species, so the model has several gaps. Despite these gaps, the BLM model is able demonstrate the highly restricted range occupied by clay-loving wild buckwheat, especially in the northern parts of the species' range. For more information on how the CNHP and BLM models were developed, see Decker et al. (2022, entire) and Appendix I, respectively.



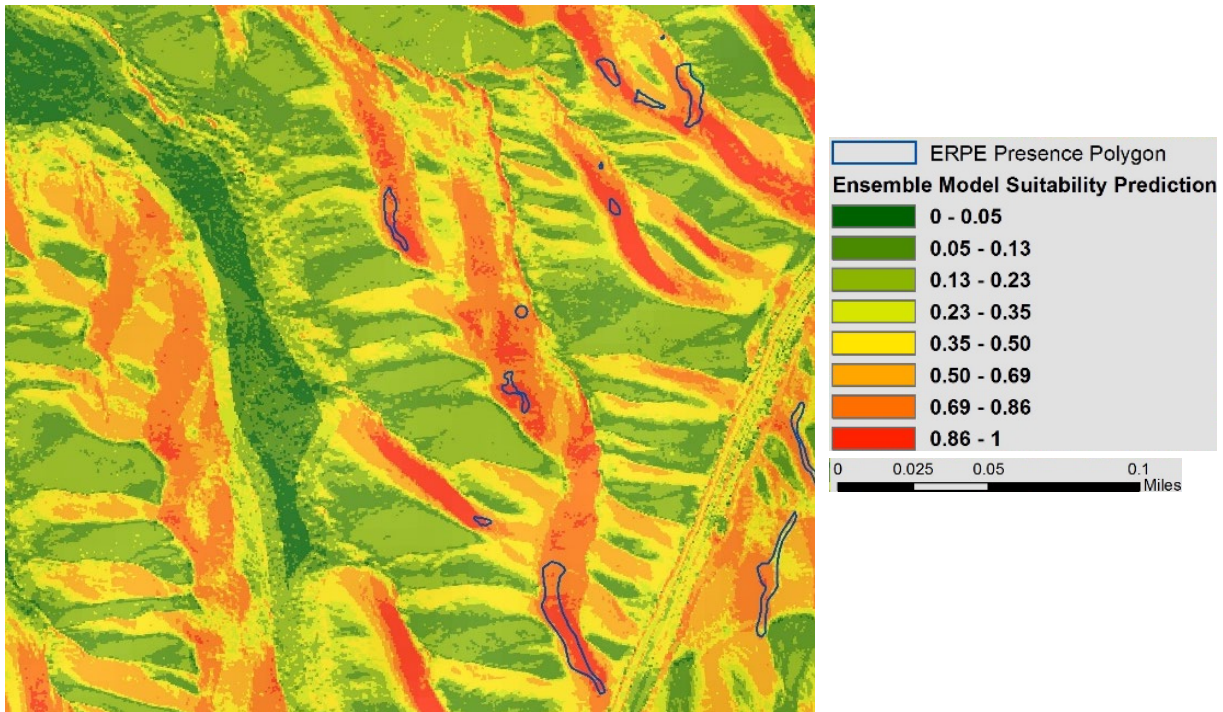


Figure 5. The BLM's habitat suitability model highlights important microhabitats for clay-loving wild buckwheat. Model predictions closely align with mapped occurrences of clay-loving wild buckwheat (occurrences in blue).

2.1.6 Species Range and Distribution

Clay-loving wild buckwheat extends from just west of Lazear, Colorado on the northern end of the species' range, to the southeastern edge of Montrose on the southern end of the species' range (Figure 3). The plant occurs at elevations of 5,180 to 6,350 feet (ft) (1,580 to 1,940 meters [m]).

The CNHP continues to catalog 15 active element occurrences (EOs)² of clay-loving wild buckwheat, and retains records of an additional five historical EOs (Figure 6 and Table 3). An EO is considered historical if no surveys have been conducted at the EO within the last 20 years. Two EOs previously described in the Service's 2009 five-year review for clay-loving wild buckwheat, EO 022 and EO 024, have since been combined with other EOs, EO 021 and EO 011 respectively. Two new EOs have been identified since the 2009 five-year review (EO 044 and EO 045).

² The EOs are used by CNHP to track rare species and are defined as an area where a species is or was present. EOs are comprised of one to many sites based on a standardized maximum separation distance (i.e., approximately 1.2 miles across suitable habitat and 0.6 miles across unsuitable habitat; CNHP 2007, p. 1).



Table 3. Clay-loving wild buckwheat element occurrences (EOs). Last observation refers to the date that the site was last visited. Sites that have not been recently visited may still support occurrences of clay-loving wild buckwheat. Non-active and historical EOs are highlighted in gray.

EO Number	First Observation	Last Observation	Land Ownership
001	1972	2014	private
003	1984	2011	public and private
006	1984	2013	public and private
007	1984	2021	public and private
011	1984	2020	public and private
012	1985	2014	public and private
014	1985	2004	public
016	1985	2016	public
018	1985	2020	public and private
021	1984	2013	public and private
025	1990	2011	public and private
041	2007	2007	public and private
042	2004	2012	public
044	2012	2012	public
045	2011	2013	public
022	--	--	--
024	--	--	--
015	1985	1985	private
004	1984	1998	private
019	1985	1985	private
013	1985	1985	private
017	1985	1987	private



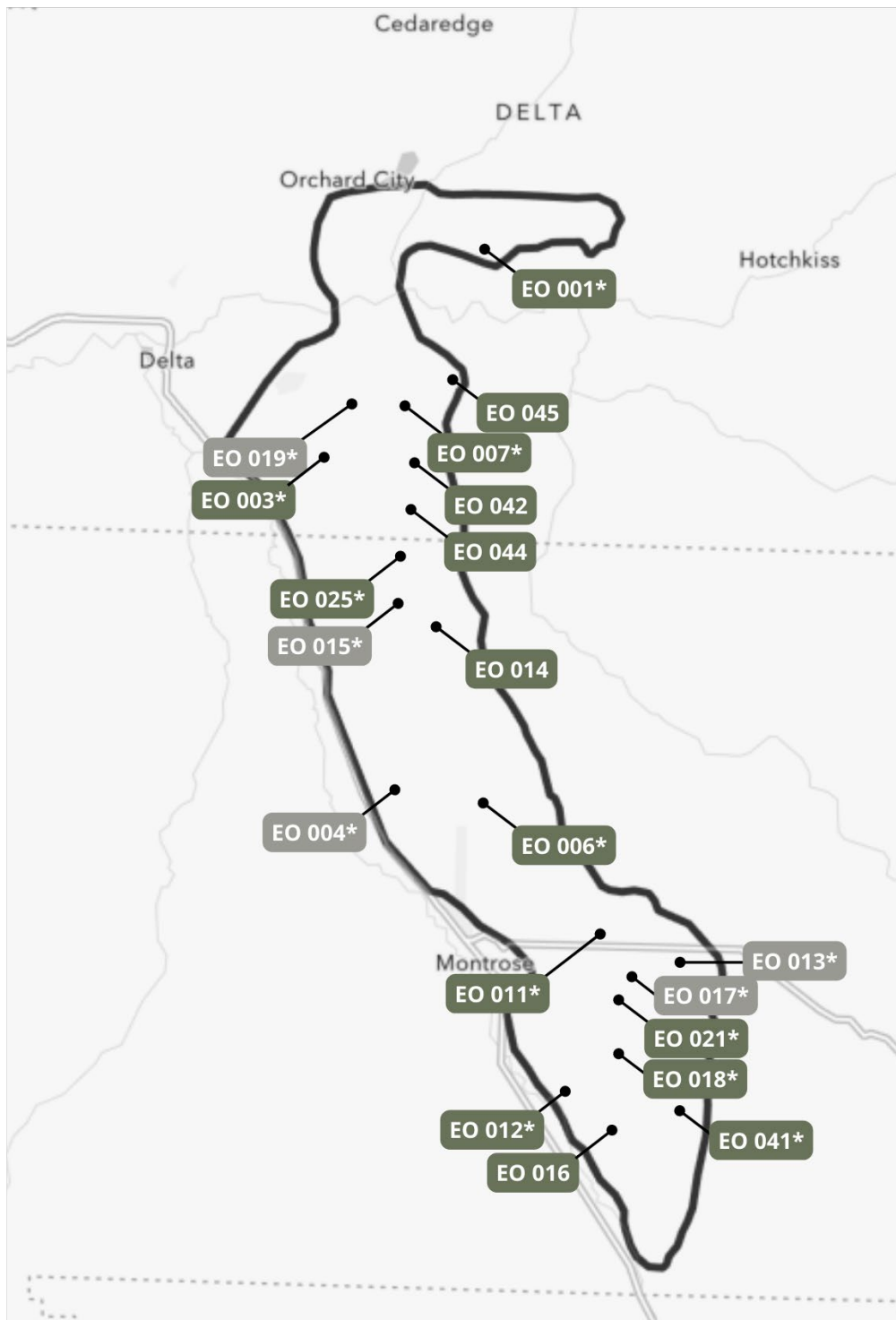


Figure 6. Distribution of element occurrences (EOs) of clay-loving wild buckwheat. There are a total of 15 active EOs. Locations identified in this map are not precise, but are meant to give the reader a general understanding of the distribution of clay-loving wild buckwheat across the landscape. * indicates the EO occurs at least partially on private land. Grey indicates that the EO is historical.



Though we are unsure of the status of the historical EOs, to the best of our knowledge, no entire EOs of clay-loving wild buckwheat have been lost. We are, however, aware of several instances where portions of EOs have been lost (e.g., bulldozing in EOs 003 and 001; Service 2009, p. 22). Additionally, several EOs near Olathe and Montrose (EOs 004, 006, 011, 012, 013, 016, 018, 021, 022, 024, and 041) have agricultural fields or development immediately adjacent to occurrences suggesting that some habitat and plants were likely destroyed when these areas were developed. Individual plants of the species are not distributed equally throughout the range. EOs 011, 021, and 018 account for more than one-third of the known plants.

About 45 percent of clay-loving wild buckwheat's range occurs on private land based on suitable habitat identified by Zimmer and Holsinger (2022, entire). Many individuals of clay-loving wild buckwheat are distributed across this private land. Plants and habitat on private land generally do not benefit from Federal protections under the Act unless management or activity on those lands involves a Federal agency. Some protections and conservation efforts have been initiated on private land (i.e., Montrose Model Aircraft Association); however, no other protections exist for the species on private land to our knowledge. The stressors impacting clay-loving wild buckwheat also differ in intensity and magnitude across public and private lands. This is discussed further in Section 3.1 Stressors).

2.1.7 Genetic Diversity

Clay-loving wild buckwheat exhibits limited genetic differentiation and high gene flow among sites distributed throughout the species' range (Naibauer and McGlaughlin 2022, entire). Though overall genetic differentiation is minimal, analyses of fine-scale population structure distinguished two dominant genetic types distributed across a north-to-south geographic gradient. Clay-loving wild buckwheat plants in the middle of the range are a combination of those genetic types and facilitate gene flow across the range of the species. Furthermore, additional substructure exists between plants from the Powerline area (EO 045) and plants from all other sites. Inbreeding is low at sites across the species' range, and generally there are no significant concerns about population-level genetic resilience.

2.1.8 Analytical Units

Occurrences of clay-loving wild buckwheat do not fit neatly into traditional populations as the entire range shares some connectivity. However, given the fine-scale genetic structure described in Naibauer and McGlaughlin (2022, entire), we have grouped occurrences of clay-loving wild buckwheat into three analytical units—Delta, Selig, and Fairview (Figure 7). These analytical units highlight what limited genetic diversity clay-loving wild buckwheat does exhibit, and the units also align well with natural geological and ecological features (e.g., differences in topography and precipitation) and management boundaries. Delineating clay-loving wild buckwheat into these three analytical units allows us to discern the nuances in conditions that occur across the range of the species and to discern the stressors that are influencing those conditions. Boundaries for these analytical units include all known plant occurrences and suitable habitat.

The outer borders of each unit rely on the habitat suitability model described in Section 2.1.5 (Habitat) and on on-the-ground knowledge about where clay-loving wild buckwheat occurs on the landscape (e.g.,



no clay-loving wild buckwheat has been observed west of highway 50, which provides much of the western border of the three analytical units).

The BLM maintains annual monitoring plots in each analytical unit. Given the relatively small area included in each analytical unit, data from those monitoring plots serve as indicators of trends and conditions likely present throughout the analytical unit.

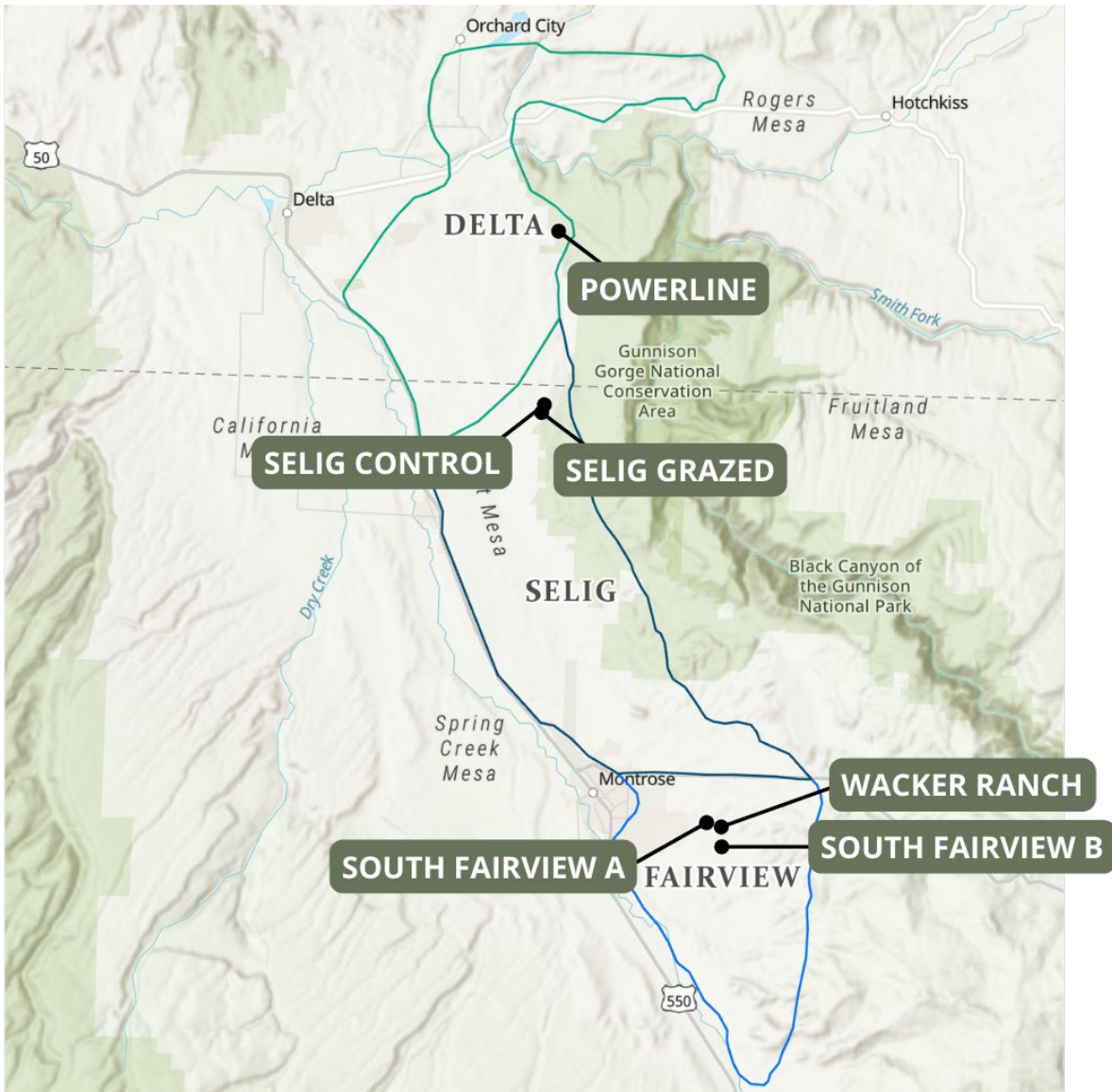


Figure 7. Clay-loving wild buckwheat analytical units used to analyze resiliency, redundancy, and representation. Callouts show BLM monitoring sites in each analytical unit.



2.2 Needs of Clay-loving Wild Buckwheat

2.2.1 Individual Needs

Below, we summarize the resources and conditions necessary for clay-loving wild buckwheat to persist at an individual level in each life stage.

Substrate Structure and Characteristics | All Life Stages - Clay-loving wild buckwheat is found in white, alkaline clay barrens derived from the Mancos Shale Formation. Substrate is usually silty loam or silty, clay loam. The species correlates particularly well with the Smoky Hill member. Shale must be close to reference state (i.e., loose, not compacted) to be suitable for the species. The shale is limited, so the range of clay-loving wild buckwheat is limited by habitat. Because of the harsh environment, vegetation on this substrate has low productivity and sparse canopy cover and density.

Soil Moisture | All Life Stages - Water availability often limits plant growth throughout arid environments in western Colorado, including those in Montrose and Delta counties where clay-loving wild buckwheat is found. Due to the dry conditions, many native shrub species, such as sagebrush (*Artemisia tridentata*) and shadscale (*Atriplex confertifolia*), have adapted to take advantage of water deep in the soil profile using a process called “hydraulic lift” (BLM 2021, p. 14). During times of low water availability, deep-rooted plants take in water from deep within the soil profile and redistribute that water into the drier soil layers above (Horton and Hart 1998, entire). BLM analyses suggest that clay-loving buckwheat likely has similar capability (BLM 2021, pp. 13-22). Additionally, clay-loving wild buckwheat is generally found within toe slopes, swales, or drainages that accumulate more moisture than surrounding areas. These small areas are where snow drifts in and lingers because of their north-, northeast-, and east-facing aspects. These microhabitats are often located in low-lying areas with rolling topography.

In addition to the amount of soil moisture, the timing of precipitation and soil moisture is also important for clay-loving wild buckwheat. Many shrubs are thought to have less efficient water uptake when soil temperatures are high and when precipitation events are of high intensity and short duration (BLM 2021, pp. 21-22). This may be because high soil temperatures during the summer and spring drought likely inactivate shallow roots and prevent root growth reducing the efficiency of water uptake (BLM 2021, pp. 21-22). Additionally, the clay substrate that clay-loving wild buckwheat inhabits is slow to absorb water and to make it available to plants. Thus, low intensity, long duration precipitation events are best at recharging the soil.

Soil Temperature | All Life Stages - The clay in the soils occupied by clay-loving wild buckwheat means that the recharge of moisture in the soil is slow. Water is slow to



infiltrate the clay, and the clay is slow to make that water available to plants. Cool temperatures in the fall and winter along with precipitation events of low intensity and long duration (e.g., snow slowly melting) are most effective at recharging the soil typical of clay-loving buckwheat habitats. As mentioned above, clay-loving wild buckwheat may also experience reduced water uptake if average spring temperatures are high (BLM 2021, pp. 13-22). Average spring temperatures as warm as 51° Fahrenheit (10.6° Celsius) have been correlated with decreasing plant density (BLM 2021, p. 21).

Exact moisture and temperature requirements may vary by life stage. For example, seedlings may be less able to access water deeper in the soil. Currently, no information is available on how moisture and temperature requirements might vary by life stage for clay-loving wild buckwheat specifically. Additionally, clay-loving wild buckwheat plants may have other individual needs regarding germination and dispersal. Specific germination requirements or seed dispersal mechanisms for clay-loving buckwheat are currently unknown. General seed dispersal mechanisms for other *Eriogonum* spp. include insects, animals, wind, and rain (Anderson 2006, p. 31). Additionally, some *Eriogonum* spp. require a cold period to break seed dormancy and germinate (O'Kane 1985, p. II-32; Meyer and Paulsen 2000, entire). The required length of cold period appears to be correlated with site elevation (Meyer and Paulsen 2000, entire). No studies have tested clay-loving wild buckwheat germination and dispersal specifically. Information regarding moisture and temperature requirements by life stage, germination requirements, and seed dispersal may inform additional individual-level needs in the future.

2.2.2 Analytical Unit Needs

To be resilient, clay-loving wild buckwheat populations (referred to in terms of analytical units) need sufficient plant abundance distributed across age classes with adequate levels of recruitment, analytical unit growth, survival, and genetic connectivity. Clay-loving wild buckwheat analytical units also require insect pollinators to facilitate reproduction. These demographic needs are impacted by the availability of the resources needed by plants at the individual level (see Section 2.2.1 Individual Needs). Below, we summarize the demographic and environmental needs for clay-loving wild buckwheat analytical units to persist.

Plant Abundance Distributed across Age Classes Clay-loving wild buckwheat analytical units need cohorts with enough individuals to overcome adverse years or conditions, including a portion of the cohort at the reproductive stage. Generally, clay-loving wild buckwheat individuals are not distributed equally throughout the species' range. Several sites, like EO 018 in the Fairview analytical unit, contain the majority of individuals. Sites range in number of plants from about 200 plants to upwards of 250,000 plants.

Although entire analytical units have not been surveyed, survey records maintained by the CNHP provide some indication of the size of each analytical unit. The CNHP maintains records of visits made to 20 EOs containing clay-loving wild buckwheat.



Occurrences are visited by various botanists from multiple agencies, who report information to CNHP. CNHP organizes all visit information and highlights the most complete estimate of occurrence size across occupied habitat at each EO (CNHP 2022, entire). The analytical unit estimates, derived from EO estimates, sum to 4,582 individuals in the Delta analytical unit, 30,700 individuals in the Selig analytical unit, and 261,245 to 264,220 individuals in the Fairview analytical unit (Table 4). The total number of clay-loving wild buckwheat plants is estimated at approximately 296,527 to 299,502 individuals (CNHP 2022, entire). However, this estimate is likely an overestimate of current clay-loving wild buckwheat abundance as some data are older than ten years. Many reports on occurrences surveyed over the last five years document observations of declining abundance and plant density, including observations made by BLM of mortality of approximately 50 percent of mature plants. EO estimates of abundance are also not the result of exhaustive surveys. Despite these uncertainties, these estimates do provide an indication of abundance within analytical units and total number of clay-loving wild buckwheat individuals.

Table 4. Occurrence estimates from each EO by analytical unit. Estimates come from survey reports collected by CNHP. *The report associated with EO 001 notes destruction of all plants in a portion of the EO. No occurrence estimate was available for that EO before or after that observation.

Delta Analytical Unit		Selig Analytical Unit		Fairview Analytical Unit	
EO #	Occurrence Estimate	EO #	Occurrence Estimate	EO #	Occurrence Estimate
001	unknown*	006	8,000	012	2,000
003	217	011	2,700	016	1,800 - 3,300
007	625	014	>10,000	018	250,000
042	1,200	025	10,000	021	6,350 - 7,825
044	540			041	1,095
045	2,000				
Total	4,582		30,700		261,245 - 264,220

Recruitment and Analytical Unit Growth Rate To be resilient, clay-loving wild buckwheat analytical units need a rate of recruitment which is equal to or which outpaces mortality. In general, the more recruitment in an analytical unit, the more likely an analytical unit is to be able to sustain itself over time and withstand stochastic events. Clay-loving wild buckwheat is a hardy, long-lived perennial species, which has demonstrated sporadic natural recruitment (BLM 2019 and 2021, entire). Because clay-loving wild buckwheat has naturally low levels of annual recruitment, we would not expect recruitment each year to equal or outpace mortality. Rather, the rate of recruitment over five to ten years should equal or outpace mortality in a resilient



analytical unit (BLM 2019, entire). For example, the BLM saw a decline in plant densities at all monitoring sites from 2016 to 2019. However, over the last ten years that the BLM has conducted the monitoring program, several sporadic recruitment events have occurred, and observed densities of clay-loving wild buckwheat in 2019 are similar to densities observed in 2013.

Individual Survival across Age Classes Clay-loving wild buckwheat analytical units need survival across different age classes to ensure there will be another cohort of plants to replace older, mature individuals. An analytical unit needs enough surviving individuals to overcome years with less-than-ideal conditions (e.g., drought) to maintain cohorts that reach the reproductive stage and contribute to analytical unit recruitment. Ideally, different age classes are moving toward reproductive age simultaneously, such that, at any given time, there will be enough mature individuals to support analytical unit growth or maintenance.

A study conducted by Carpenter and Schultz (1994, p. 3) found that survival of clay-loving wild buckwheat averaged 94 percent, but varied from 98.8 to 73.9 percent across transects. Mortality of plants was spread across age classes and not concentrated in any particular age class. (1994, p. 3). Growth rates and the number of seedlings observed also varied considerably by transect during the study.

More recent monitoring by BLM has documented mortality events of up to 68% at a given site over consecutive years (BLM 2021, pp. 5-11). Recent surveys have also documented several seedling die-offs. For example, following a surge in seedlings in 2016, the BLM saw mass seedling die-offs in 2017 after a particularly dry year (BLM 2019, entire). These observations highlight the importance of favorable conditions for seed set and of separate favorable conditions for germination and recruitment. Because conditions must be favorable for several years, seed set for clay-loving wild buckwheat does not necessarily translate to recruitment. Thus, survival of seedlings can be a limiting factor for clay-loving wild buckwheat analytical units.

The proportion of plants within an age class varies by site and by year. Healthy occurrences of clay-loving wild buckwheat have shown seedling frequencies higher than 20% (Lyon 2008, entire).

Connectivity Clay-loving wild buckwheat analytical units need connectivity between sites to maintain healthy genetic diversity and increase analytical unit resiliency. Observed pairwise genetic differentiation (F_{st}) and estimated number of migrants per generation (N_m) suggest that there is gene flow (i.e., connectivity) within and among all three analytical units (Naibauer and McGlaughlin 2022, entire). Though overall genetic differentiation is minimal, analyses of fine-scale population structure distinguished two dominant genetic types distributed across a north-to-south geographic gradient. Clay-



loving wild buckwheat plants in the middle of the range are a combination of those genetic types and facilitate gene flow across the range of the species.

In the Delta analytical unit, additional genetic substructure exists within EO 045, also called Powerline (Figure 6), as compared to all other sampled occurrences. The genetic distinction of Powerline is also supported by the fact that it is the most genetically diverged relative to the entire distribution. While the overall genetic differentiation is limited, these results highlight the importance of maintaining what diversity the species has across its range. Given the unique genetic signal associated with Powerline, this EO should be prioritized for conservation.

Insect Pollinators Clay-loving wild buckwheat requires insect pollinators to reproduce. Over 50 species of insects (including bees, ants, and beetles) have been found to visit clay-loving wild buckwheat (Bowlin et al. 1992, p. 300; Tepedino et al. 2011, p. 60). Of all *Eriogonum* spp. studied to date, none has as many pollinators as clay-loving wild buckwheat (Tepedino 2009, p. 39). The pollinators cover a wide array of taxonomic and functional types of insects with no single pollinator or group of pollinators being more important than another (Tepedino 2009, pp. 38-39). Despite the relatively large number of pollinator species that visit clay-loving wild buckwheat, maintaining adequate pollinator habitat within the range of the species is still important for sustaining clay-loving wild buckwheat reproduction and genetic exchange.

Though various agencies continue to collect several long-term datasets on clay-loving wild buckwheat, no studies fully encompass the entire lifespan of the plant, which is known to be greater than 20 years. Thus, our ability to draw conclusions on the life history and demographic needs of clay-loving wild buckwheat analytical units is somewhat limited. Monitoring activities and monitoring data are further complicated by the fact that environmental conditions of microhabitats vary considerably over relatively short distances. Data must be extrapolated with caution and with the understanding that each site and occurrence are likely experiencing at least slightly different climatic conditions.

Regarding genetic diversity, recent genetic studies capture the genetic data of the plants sampled, many of which are likely ten or more years old. Thus, current studies are reviewing past genetic diversity and connectivity, and changes in genetic diversity would likely take generations to manifest. Impacts from stressors currently acting on the species may not be evident in genetic studies for many years to come.

2.2.3 Species' Needs

To be viable at the species level, clay-loving wild buckwheat needs a sufficient number and distribution of resilient analytical units to withstand catastrophic events (redundancy) and a range of variation that allows the species to adapt to changing environmental conditions (representation). These needs are influenced by the availability of the resources needed by plants at the individual level (see Section 2.2.1 Individual Needs) and by needs at the analytical unit level (see Section 2.2.2 Analytical Unit Needs). Below, we summarize what clay-loving wild buckwheat needs at the species level to persist as a species.



Sufficient Number and Distribution of Analytical Units Clay-loving wild buckwheat needs a sufficient number of resilient analytical units distributed across its range to withstand catastrophic events (redundancy). We evaluate the redundancy of the species by the number and distribution of resilient clay-loving wild buckwheat analytical units. Having multiple resilient analytical units distributed across a large area lessens the risk that a catastrophic event might impact one or more analytical units simultaneously, thereby having a greater effect on the entire species. Multiple analytical units distributed broadly across the species' range reduces catastrophic risk to the species and provides increased redundancy; few analytical units distributed narrowly across the range increases catastrophic risk and reduces redundancy. When analytical units are also highly resilient, they are better able to recover the species if one or more analytical units are lost due to a catastrophic event.

Range of Variation Variation demonstrates the ability of a species to adapt to changing environmental conditions (representation). We evaluate representation of the species by the presence of genetic, ecological, and morphological variation across the range of the species and their respective contributions to species' adaptive capacity. Clay-loving wild buckwheat needs to maintain genetic variability within and between analytical units to adapt to changing environmental conditions. The species does exhibit some ecological variation in the form of precipitation and temperature regimes across the range of occupied habitat. Generally, precipitation increases and temperature decreases along a north to south gradient (i.e., precipitation is highest and temperatures are lowest in the Fairview analytical unit). This variation demonstrates the species' ability to adapt to some environmental change.

2.2.4 Summary of Needs

To summarize, clay-loving wild buckwheat needs multiple diverse, resilient analytical units distributed across the species' range to reduce species-level impacts of catastrophic events (redundancy) and to adapt to long-term environmental change (representation). A resilient analytical unit of clay-loving wild buckwheat will have adequate abundance, recruitment, and survivorship across age classes to maintain or expand the unit, abundant pollinators, and strong genetic connectivity within the unit and with other analytical units. Individual plants need substrate derived from the Mancos Shale Formation with adequate soil moisture and adequate soil temperature.

3 Current Condition

In this chapter, we provide a summary of potential stressors affecting the species, as well as positive influences on the species, followed by our methodology for evaluating the current condition, and the results of our current condition analysis. We describe the current condition of clay-loving wild buckwheat in terms of the same demographic and habitat factors that we identified as individual, analytical unit, and species needs in (Chapter 2 Species Ecology).



3.1 Stressors

At the time of listing, the Service identified a local grazing operation and off-road vehicle use as the primary threats to clay-loving wild buckwheat (49 28562, July 13, 1984). Though livestock grazing is still a stressor that influences the species, the discovery of additional occurrences since the species' original listing has shifted concern from any one particular grazing operation to livestock grazing across the species' range. New stressors have also been identified. Currently, stressors that influence clay-loving wild buckwheat include incompatible livestock grazing, invasive species, off-highway vehicle (OHV) use, commercial and residential development, irrigation operations, development and maintenance of utility corridors, and climate change. These stressors are described below, depicted in Figure 8, and are carried forward in our SSA analyses.

We also considered the effects of oil and gas development and conversion of land to agriculture. Although conversion of land to agriculture likely affected the species in the past, and both conversion of land to agriculture and oil and gas development have the potential to impact clay-loving wild buckwheat, we have no evidence to suggest these stressors are regularly impacting clay-loving wild buckwheat at more than an individual level currently or into the future. Therefore, we do not carry these stressors forward in our SSA analyses of current and future condition.



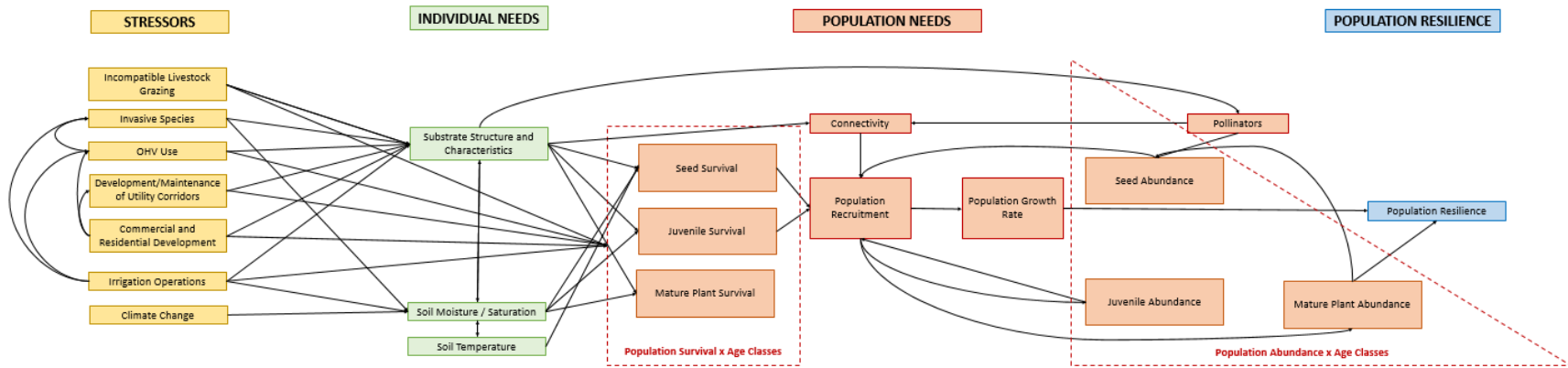


Figure 8. Conceptual model of interrelated stressors which influence needs at the individual and analytical unit level and impact analytical unit level resiliency.

Incompatible Livestock Grazing

Livestock grazing was cited as a primary threat to the species in the initial listing decision (49 28562, July 13, 1984). Livestock grazing can result in loss or harm of plants via compaction of soil and mechanical damage to individual plants. Livestock grazing can also facilitate the spread of invasive weed species. Some monitoring reports suggest that minimal grazing may not impact clay-loving wild buckwheat at the analytical unit level (CNHP 2022, entire). However, other monitoring reports suggest negative impacts from intensive livestock grazing, so proper management of grazing is key (CNHP 2022, entire). The BLM implements many grazing restrictions on lands they administer (see Section 3.2 Conservation Efforts). The BLM also conducts annual monitoring on two sites strategically fenced and unfenced to better understand the impacts of livestock grazing (most notably sheep) on clay-loving wild buckwheat. This study started in 2011 and is ongoing. While no statistically significant differences have been observed to date, this study does not assess grazing of all types or at all intensities. The future results of this monitoring may help inform additional SSAs and livestock management as it relates to clay-loving wild buckwheat.

In addition to grazing on public lands, livestock grazing also occurs throughout occurrences of clay-loving wild buckwheat on private lands. Unfortunately, we do not know the full extent of where grazing is occurring, the intensity of grazing on private lands, how grazing overlaps with clay-loving wild buckwheat, or the impacts that result from that grazing. While clay-loving wild buckwheat and clay-loving wild buckwheat habitat on public land benefit from Federal protections under the Act, most of these protections are not applicable on private land. With the exception of a few efforts, most private lands do not have management plans in place which restrict grazing for the protection of clay-loving wild buckwheat. We anticipate that grazing is likely impacting clay-loving wild buckwheat in the areas in which grazing and the species overlap.

Invasive Species

Impacts from introduced and invasive species could result in competition for resources within clay-loving wild buckwheat microhabitat and could reduce available suitable habitat. Negative effects resulting from resource competition include decreased availability of sunlight and moisture for clay-loving wild buckwheat individuals. Invasive and introduced species have been observed near the species (e.g., *Halogeton glomeratus* (halogeton), *Acroptilon repens* (Russian knapweed), *Eremopyrum triticeum* (annual wheatgrass), and *Bromus tectorum* (cheatgrass)), but the harsh conditions of the habitat have likely kept many invasives at bay. Though invasives are prevalent throughout the species' range, no negative impacts from invasive species have been documented in surveys of clay-loving wild buckwheat occurrences. However, we anticipate the threat of invasive species to increase under some future scenarios.

Off-highway Vehicle (OHV) Use

Disturbance from OHV use can negatively influence clay-loving buckwheat in all life stages. OHV use can injure or kill individual plants, disturb conditions necessary for germination, or disrupt retention of new seeds through deeply burying seeds or crushing individual plants. In addition to direct individual impacts, OHV use can physically damage habitat (e.g., by compacting the soil), the surrounding plant community, and the hydrology of the area. OHVs can also carry invasive plants to new sites and present a risk of spilled contaminants, such as oil, gasoline, and grease. The impacts of OHV use are compounded by the fact that habitat throughout the range of clay-loving wild buckwheat is slow to recover from disturbance.

OHV use is prevalent throughout the range of clay-loving wild buckwheat on public and private lands. The area has open, rolling dunes and many terrain features that attract OHV recreationalists, as well as an extensive trail system, which makes the area a local favorite for OHV recreation.

On public lands, the most problematic OHV use is when users travel off designated recreational or system roads and trails located near clay-loving wild buckwheat habitat. Although BLM limits OHV use on many administered lands, non-compliant OHV use has been documented at several clay-loving wild buckwheat occurrences (e.g., EOs 003, 007, 014, and 025) (Service 2009, p. 26; CNHP 2022, entire). Many designated roads and trails are clearly marked with fences or signs to help users identify appropriate spaces for OHV use; however, even with those markers, it may sometimes be difficult for users to determine exactly where designated roads and trails begin and end because often there are no explicit boundaries between designated trails and non-designated social trails.

Non-compliant OHV use has also been documented on private lands. For example, private lands not fenced or posted with no trespassing signs have experienced non-compliant OHV use. A portion of EO 001 in the Delta analytical unit was documented as being largely destroyed by OHV use in 2001 (Reveal 2006, p. 1). Other EOs on private land where OHV use has been documented include EO 003, EO 007, and EO 025 (CNHP 2022, entire). OHVs are also used for routine activities, like maintaining agricultural lands. While we know OHV use on private lands is prevalent and that OHV use on private lands is impacting clay-loving wild buckwheat at some EOs, we do not know the full extent to which OHV use and clay-loving wild buckwheat overlap on private lands. Our access to and understanding of clay-loving wild buckwheat on private land is limited.

Commercial and Residential Development

The human populations of Delta and Montrose Counties and the surrounding area are growing (U.S. Census Bureau 2022, entire), and the Service estimated in 2009 that 40% of clay-loving wild buckwheat habitat has already been impacted by development (Service 2009, p. 25). Increasing development continues to fragment and impact clay-loving wild buckwheat and its habitat. This development includes residential and industrial buildings, power lines, canals, and roads. At least two occurrences (EOs 004 and 006) are completely surrounded by development and now occupy a very limited area of habitat.

On public lands, Federal and State agencies can construct additional roads, trailheads, trails, campgrounds, or other recreation facilities. This development may lead to indirect effects due to increased recreation in or near clay-loving wild buckwheat habitat; however, public land managers currently incorporate minimization and avoidance measures to limit impacts on the species (see Section 3.2 Conservation Efforts).

Conversely, private landowners are not required by the Act to incorporate minimization and avoidance measures or undertake any conservation efforts, which is why development is a particularly important stressor on private land. Impacts from commercial and residential development have been documented throughout the range of clay-loving wild buckwheat (e.g., EOs 001 and 003 in the Delta analytical unit). Ultimately, we have a limited understanding of where clay-loving wild buckwheat occurs on private land



and the extent to which commercial and residential development overlaps with occurrences of clay-loving wild buckwheat. Monitoring of known occurrences of clay-loving wild buckwheat does occur on some of these lands, but it is irregular (CNHP 2022, entire). Development on private land is not restricted by the Act unless the development involves a Federal agency. We know of no existing local or state laws that restrict development for the protection of clay-loving wild buckwheat, though some local organizations do implement conservation measures for the species on their lands (e.g., Montrose Model Aircraft Association).

Irrigation Operations

Delta and Montrose Counties are traversed by a multitude of canals and ditches used for irrigation. The North Selig, Selig, Peach Valley, East, South, and Loutzenhizer Canals are all large canals that run along the eastern side of the Uncompahgre Valley and through clay-loving wild buckwheat habitat. Because of their proximity to the species and suitable habitat, plants may have been lost during the construction of these canals.

Large canals and some laterals run through or are immediately adjacent to many occurrences of clay-loving wild buckwheat (i.e., EOs 003, 004, 007, 015, 016, 018, and 025). Smaller laterals and ditches run through or are immediately adjacent to EOs 011, 012, 013, 017, 019, 021, 022, and 041. All canals and laterals have roads on at least one side, and most have roads running along both sides. These canals and associated roads support the spread of invasive species and fragment habitat.

At least two occurrences (EOs 013 and 025) have been impacted by canal maintenance through the excavation of accumulated sediment onto adjacent habitat, which buried plants and suitable habitat (Service 2009, p. 24). Clay-loving wild buckwheat plants at the North Fairview Area of Critical Environmental Concern (ACEC) were impacted in 2007 during pipeline construction activities. This site has been subsequently restored, though follow-up observations indicate that restoration has generally been unsuccessful (CNHP 2022, entire). Canal maintenance projects, including the lining of canals and laterals, are ongoing throughout the species' range on public and private land.

Clay-loving wild buckwheat habitat is rich in salts and selenium. When unlined canals and laterals pass through these soils, the water dissolves the salts and carries them into waterways. To reduce salt loading, a salinity control program was initiated in 1990. This program is now working to line many laterals throughout Delta and Montrose Counties. Because many clay-loving wild buckwheat occurrences are located along laterals prioritized for lining, further impact to the species from these activities is likely (Service 2009, p. 24).

Development and Maintenance of Utility Corridors

Development and maintenance of utility corridors can lead to damage or loss of plants, fragmentation of habitat, and increases in invasive species. Existing transmission lines currently run adjacent to or through several clay-loving wild buckwheat occurrences (e.g., EOs 001, 012, 014, and 016; Service 2009, p. 22). Currently, utility managers/companies are working closely with land managers to avoid impacting clay-loving wild buckwheat plants. This cooperation has been successful, but is not formalized in any way.



Climate Change

Climate change refers to the change in the mean or variability of one or more measures of climate (e.g., temperature or precipitation) that persists for an extended period, typically decades or longer, whether the change is due to natural variability, human activity, or both (IPCC 2014, p. 120). Climate change can impact clay-loving wild buckwheat by altering the prevalence of several other stressors, such as nonnative invasive plants and periodic drought. Additionally, climate change can reduce the availability of the specific moisture and temperature regimes the species needs for survival and reproduction.

3.2 Conservation Efforts

Several Federal and state agencies, private landowners, and community members are committed to the conservation and preservation of clay-loving wild buckwheat (e.g., BLM, Colorado Natural Areas Program/Colorado Parks and Wildlife, CNHP, and Montrose Model Aircraft Association (MMAA)). Land ownership and management across the species' range are comprised primarily of BLM and private landowners. The BLM owns and manages approximately 45 percent of the land located within the species' analytical units based on suitable habitat identified by Zimmer and Holsinger (2022, entire). The BLM has implemented measures in planning documents to minimize and avoid impacts to clay-loving wild buckwheat and its habitat and actively contribute to its conservation and recovery. The majority of the remaining habitat is privately owned. The Colorado Natural Areas Program of Colorado Parks and Wildlife owns and manages about 20 percent of the land at Wacker Ranch (i.e., EO 018).

The range of clay-loving wild buckwheat is fully contained within the jurisdiction of one BLM field office (the Uncompahgre Field Office). Since the late 2000s, BLM has implemented travel management activities to minimize and avoid impacts to clay-loving wild buckwheat and its habitat and to contribute to its conservation and recovery (e.g., fencing, interpretive signs, and closing non-system trails to reduce impacts from OHV use) (Holsinger 2019, personal communication).

Additionally, BLM designates Areas of Critical Environmental Concern (ACECs) in areas where special management attention is needed to protect important historical, cultural, and scenic values, or fish and wildlife or other natural resources. Two of the three analytical units have some occupied habitat within an ACEC. ACEC designations limit or exclude the authorization of certain land uses, and some designations are specifically created for the conservation of natural resources. The specific protections an ACEC provides depends on the ACEC and the Resource Management Plan (RMP) associated with the ACEC (described below).

Conservation efforts made by the state include the purchase and management of the Wacker Ranch property, where a significant number of clay-loving wild buckwheat plants occur. Two State Natural Area designations, Fairview and Wacker Ranch, have also been put in place to assist in the protection of the species.

In total, 38 percent of the Delta analytical unit, 42 percent of the Selig analytical unit, and 54 percent of the Fairview analytical unit are managed by federal or state agencies.

Special land management designations and conservation projects include:



North Fairview ACEC | 2008 | 140 acres

The BLM Uncompahgre Field Office (UFO) closed a portion of the North Fairview ACEC to motorized and mechanized travel. Additionally, the area is not permitted for grazing by domestic livestock. The BLM has also implemented restoration treatments for the roads and buried water pipeline that occur within the fenced area, though those treatments have been largely unsuccessful. Removal of disturbance seems to be the best mechanism for restoration as natural colonization of native *Atriplex*, grasses, and a few clay-loving wild buckwheat seedlings have been observed on the edges of the reclaimed areas. The protection and conservation of clay-loving wild buckwheat and clay-loving wild buckwheat habitat are explicitly defined in the decisions and management objectives of the Gunnison Gorge National Conservation Area RMP (p. 2-26).

South Fairview ACEC | 2020 | 610 acres

The 2020 BLM Uncompahgre Field Office Resource Management Plan increased the ACEC size from 213 acres to 610 acres. The South Fairview ACEC is closed to domestic livestock grazing, closed to motorized and mechanized travel, managed as a right-of-way exclusion, closed to mineral materials disposal, closed to non-energy solid mineral leasing, and has a “no surface occupation” for fluid minerals development. The protection and conservation of clay-loving wild buckwheat and clay-loving wild buckwheat habitat are explicitly defined as an action for the ACEC in the UFO RMP (p.II-98).

Fairview State Natural Area | 1992 | 377 acres

This State Natural Area designation includes two parcels within both the North and South Fairview BLM ACECs, for the purpose of protecting clay-loving wild buckwheat and its associated habitat. The designation consists of a voluntary conservation agreement between the BLM and the Colorado Department of Natural Resources/Colorado Parks & Wildlife/Colorado Natural Areas Program (CNAP). The Colorado Natural Areas Program conducts regular monitoring of the parcels including clay-loving wild buckwheat element occurrence monitoring.

Wacker Ranch State Natural Area | 2008 | 43 acres

This State Natural Area designation encompasses 43 acres of land purchased from a private landowner, adjacent to the North Fairview ACEC and State Natural Area, for the purpose of protecting clay-loving wild buckwheat and its associated habitat. The property is owned and managed by Colorado Parks and Wildlife. The CNAP conducts regular monitoring on the parcels including clay-loving wild buckwheat element occurrence monitoring.

Wacker Ranch Land Purchase | 2007 | 43 acres

Colorado State Parks (now Colorado Parks and Wildlife), through the facilitation of the CNAP, purchased the Wacker Ranch in 2007 for the sole purpose of protecting clay-loving wild buckwheat in the North Fairview area. Funds from a Service Section 6 Recovery Lands Acquisition grant and Great Outdoors Colorado were utilized to purchase and protect the property. A management plan was written and implemented by CNAP in 2007, with support from The Nature Conservancy (TNC). The property is currently managed by Colorado Parks and Wildlife/CNAP. Public access is not currently allowed, due to the highly sensitive nature of the habitat. Numerous research and monitoring projects have taken place on



the property, with partners including TNC, the CNHP, and the BLM. The BLM and CNAP currently conduct regular monitoring of the clay-loving wild buckwheat on the property.

Montrose Model Aircraft Association Fencing | 2011 | 13.7 fenced acres

The BLM UFO, the Montrose Model Aircraft Association (MMAA), and the Service collaborated to fence three areas crossing BLM and MMAA lands. These lands contain numerous sub-populations of clay-loving wild buckwheat. The project closed some areas of occupied habitat from OHV use and livestock grazing which were previously being adversely affected by OHV use and domestic sheep grazing. The project also initiated BLM's robust monitoring of the Selig Canal fenced and unfenced monitoring plots to investigate what effects sheep grazing might have on clay-loving wild buckwheat.

Elephant Skin Protection | 2013 | 17 acres

Surveys for a proposed Tri-State powerline in 2012 found a large previously unknown occurrence of clay-loving wild buckwheat (EO 006). The area is a popular off-highway vehicle area. At the time of discovery, there was one full-size vehicle route and three single-track motorcycle trails through the occurrence. The BLM UFO implemented a fence closure project to close the occurrence off to OHV traffic and domestic livestock grazing. Since the closure in 2013, the BLM has detected clay-loving wild buckwheat seedlings in the single-track routes, and the disturbances are passively being restored.

Carnation Road Closure | 2014 | 300 acres

The BLM UFO closed 0.74 miles of authorized full-size vehicle route and designated 0.7 miles of previously open route to authorized use only for Tri-State powerline maintenance. This project removed illegal off-route vehicle travel on approximately 300 acres of occupied clay-loving wild buckwheat habitat. The project was not popular with the public and since 2014 when the fences and closures were implemented, the BLM has made 37 fence repairs due to damage caused by recreationalists. BLM has not needed to repair this fence since 2017 and is hopeful that the public has become accepting to the closure.

Delta County 2100 Road and Last Chance Road Realignment Project | 2015 | 3.5 acres

In 2015 Delta County completed a project to realign two county roads which brought the roads close to two occurrences of clay-loving wild buckwheat. Through the project negotiation process the BLM UFO was able to successfully fence the occurrences to remove illegal off-highway impacts and domestic sheep grazing.

BLM Uncompahgre Field Office Resource Management Plan | 2020

The Uncompahgre Field Office Resource Management Plan (2020) provides conservation provisions for clay-loving wild buckwheat including a threatened and endangered plants stipulation which prohibits surface occupancy and use and applies restrictions within a 200-meter (656-foot) buffer of the edge of habitat of federally listed, proposed, or candidate threatened or endangered plant species (page II-31 of the ROD).



Table 5. Conservation efforts and the respective land manager, acreage, analytical unit, and percent of analytical unit covered.

*The acreage of the Fairview State Natural Area is accounted for in the acreage of the South Fairview and North Fairview ACECs. **The acreage of the Wacker Ranch Land Purchase is accounted for in the acreage of the Wacker Ranch State Natural Area.

Conservation Effort	Land Manager	Acres	Analytical Unit	% of Analytical Unit
South Fairview ACEC	BLM	610	Fairview	2.20%
Fairview State Natural Area*	BLM	377	Selig and Fairview	--
North Fairview ACEC	BLM	140	Selig	0.32%
Wacker Ranch State Natural Area	CPW - CNAP	43	Selig	0.10%
Wacker Ranch Land Purchase**	CPW - CNAP	43	Selig	--
Montrose Model Aircraft Association Fencing	Private	13.7	Selig	0.03%
Elephant Skin Protection	BLM	17	Selig	0.04%
Carnation Road Closure	BLM	300	Selig	0.69%
Delta County 2100 Road and Last Chance Road Realignment Project	BLM	3.5	Delta	0.01%

3.3 Current Status and Viability

In this section, we analyze the current status of clay-loving wild buckwheat in terms of resiliency, redundancy, and representation. Table 6 outlines our understanding of what constitutes a resilient analytical unit of clay-loving wild buckwheat in relation to the resource needs of the species. We used the following metrics and thresholds to evaluate the current and future availability of a subset of the resource needs discussed in Chapter 2 (Table 6); this subset includes the needs for which we had data available to consistently measure the need across analytical units.



Table 6. Condition Category Table: the demographic and habitat factors used to categorize the resiliency of clay-loving wild buckwheat analytical units. An analytical unit’s resiliency is calculated by weighting each metric equally and calculating the total score. Green shading indicates a high score of three, yellow indicates a moderate score of two, and red indicates a low score of one.

Condition Category Table							
Condition Category	Individual Needs / Habitat Factors			Analytical Unit Needs / Demographic Factors			Overall Condition
	Habitat Condition Index	Climate Metric		Seedling Frequency	10-year Average Analytical Unit Growth Rate	F_{st}	
Need being Measured	Substrate Structure and Characteristics	Soil Moisture	Soil Temperature	Analytical Unit Abundance Distributed across Age Classes	Analytical Unit Growth Rate and Recruitment	Connectivity	Total Score
High (healthy)	> 2.33	Fall/winter precipitation AND spring temperature are good.		> 20%	$\lambda > 1$	$F_{st} \leq 0.05$	11.67 – 15
Moderate (moderately healthy)	1.67 - 2.33	Fall/winter precipitation OR spring temperature is good.		10 - 20%	$\lambda = 1$	$0.05 < F_{st} < 0.15$	8.34 – 11.66
Low (unhealthy)	< 1.67	Fall/winter precipitation AND spring temperature are bad.		< 10%	$\lambda < 1$	$F_{st} \geq 0.15$	5 – 8.33

3.3.1 Habitat Condition Index *measures* Substrate Structure and Characteristics

To assess the current and future condition of clay-loving wild buckwheat habitat, we developed a “Habitat Condition Index” (HCI). The HCI produces a single habitat condition score from the aggregated rankings of three biologically relevant condition categories: habitat quality, habitat size, and habitat type. The result of the HCI is a habitat condition score (high, moderate, and low) for each analytical unit.

Habitat quality was determined using open-source data from the Rangeland Analysis Platform (RAP). The RAP interprets a series of indicators of rangeland health by comparing an array of sampled field plots to Landsat imagery. Using cloud computing, the RAP predicts estimates of various indicators at a 30-meter resolution across the landscape. Due to a lack of representative habitat assessment data, such as Assessment, Inventory, and Monitoring (AIM) or Landscape Management Framework (LMF) data, the RAP provides the best means of approximating current indicators of rangeland health across management boundaries within clay-loving buckwheat habitat.

Three separate indicators were used to evaluate habitat quality: annual forbs and grasses cover (a proxy for invasive species cover), percent bare ground cover, and percent foliar cover. Data extraction was stratified by Federal and state management (BLM, Bureau of Reclamation, and State) and private ownership for each of the three analytical units.

The ranking classification for percent annual grasses and forbs follows standard land health guidance relative to arid western shrublands. Areas with a lower percentage of annual grasses and forbs are considered to be of better quality since these annuals are generally non-native and/or invasive species and are typically associated with disturbed or otherwise degraded landscapes. Therefore, any analytical unit with less than 4 percent annual grass and forb cover ranked “high,” any analytical unit with 4 to 10 percent annual grass and forb cover ranked “moderate,” and any analytical unit with greater than 10 percent annual grass and forb cover ranked “low.”

The ranking classifications for bare ground and foliar cover were defined based on the range of variability present within the RAP outputs for each of those indicators. To derive the mean and 80% confidence intervals, the 21-year average (2000 - 2021) was used for the indicator outputs. Analytical unit outcomes within one standard deviation of the mean ranked “high,” analytical unit outcomes greater than one standard deviation from the mean but within two standard deviations of the mean ranked “moderate,” and analytical unit outcomes greater than two standard deviations ranked “low.”

All three habitat quality indicators were weighted equally and scored three points for a “high” rank, two points for a “moderate” rank, and one point for a “low” rank. The final analytical unit habitat quality score was derived from the average of the six values per analytical unit (i.e., three for public lands and three for private lands).

Habitat size relies on abundance as a proxy for size and was determined for each of the analytical units using two indicators—the raw number of acres of mapped occupied clay-loving buckwheat habitat and the average density of sampled occupied sites based on BLM’s annual monitoring program (site locations in Figure 7). Occupied acreage was determined using CNHP and BLM spatial data and stratified by BLM-managed lands and privately managed lands.

For occupied habitat, any analytical unit containing greater than 100 acres of occupied clay-loving buckwheat habitat ranked “high,” any analytical unit containing 20 to 100 acres ranked “moderate,” and any analytical unit containing less than 20 acres ranked “low.” For average density, any analytical unit with an average plant density of greater than two plants per meter-squared ranked “high,” any analytical unit with an average plant density of 0.5 to 2 plants per meter-squared ranked “moderate,” and any analytical unit with an average plant density of less than 0.5 plants per meter-squared ranked “low.”

Both habitat size indicators (i.e., acres of occupation and plant density) were weighted equally and scored three points for a “high” rank, two points for a “moderate” rank, and one point for a “low” rank. Acres of occupation were divided by BLM-managed lands and privately managed lands; therefore, the maximum score either ownership type could receive was 1.5 for a minimum score of one and a maximum of three for the entire analytical unit. The final score for each analytical unit was derived from the average of the three indicator values (i.e., BLM-managed occupied acres, privately managed occupied acres, and average plant density).

The habitat type score was evaluated for each analytical unit based on two indicators—the number of acres considered suitable clay-loving buckwheat habitat and the proportion of suitable clay-loving buckwheat habitat occurring on BLM-managed lands versus privately managed lands. The latter classification was used based on the fact the ESA protections and assurances are only extended to plants occurring on public lands or those private lands where there is designated critical habitat or some other federal nexus.

Habitat type was determined for each of the three analytical units using outputs from the predictive habitat model for clay-loving buckwheat (Zimmer and Holsinger 2022, entire). The ensemble model (see Appendix I) employed a series of relevant bioclimatic and geographic variables including high resolution geologic and LiDAR data to predict habitat suitability, or probability of clay-loving buckwheat occupation, at a fine scale across the species’ range. The array of outputs from the model ranged from <0.001 to 0.997. Values of 0.5 or greater (i.e., greater than 50 percent likely to be suitable habitat) coincided with over 90 percent of mapped clay-loving buckwheat occurrences and were chosen to represent “suitable” clay-loving buckwheat habitat for the purposes of this indicator. Values less than 0.5 were considered “unsuitable.”

For the number of acres of suitable clay-loving buckwheat habitat, any analytical unit containing more than 10,000 acres of suitable habitat ranked “high,” any analytical unit containing 1,000 to 10,000 acres of suitable habitat ranked “moderate,” and any analytical unit containing less than 1,000 acres of suitable habitat ranked “low.” For the proportion of BLM-managed and privately managed lands, any analytical units with greater than 50 percent of suitable habitat occurring on BLM-managed lands ranked “high,” any analytical unit with 40 to 50 percent of suitable habitat occurring on BLM-managed lands ranked “moderate,” and any analytical unit with less than 40 percent of suitable habitat occurring on BLM-managed lands ranked “low.”

Both indicators (i.e., number of acres of suitable clay-loving buckwheat habitat and proportion of suitable habitat on BLM-managed land to privately managed land) were weighted equally and scored three points



for a “high” rank, two points for a “moderate” rank, and one point for a “low” rank. The final analytical unit scoring outcomes were derived from the average of the two indicator values.

For a summary of ranking criteria for the Habitat Condition Index, see Table 7. Additional information on the Habitat Condition Index can be found in Appendix III.



Table 7. Ranking criteria for the Habitat Condition Index (HCI) developed by members of the Tech Team. The HCI uses three sub-metrics—habitat quality, habitat size, and habitat type.

Habitat Condition Index							
	Habitat Quality			Habitat Size		Habitat Type	
	Annual Grass and Forb Cover	Bare Ground	Foliar Cover	Occupied Acreage	Average Plant Density	Acres of Suitable Habitat	Percent of Suitable Habitat on BLM-managed Land
High	> 4%	within one standard deviation of reference condition		> 100 acres	> 2 plants/m ²	> 10,000	> 50%
Moderate	4 - 10%	within two standard deviations of reference condition		20 - 100 acres	0.5 - 2 plants/m ²	1,000 - 10,000	40 - 50%
Low	> 10%	greater than two standard deviations from reference condition		< 20 acres	< 0.5 plants/m ²	< 1,000	< 40%

3.3.2 Climate Metric *measures* Soil Moisture and Soil Temperature

Analyses by the BLM suggest that cumulative fall and winter precipitation and spring temperature play an important role in shaping occurrences of clay-loving wild buckwheat (BLM 2021 pp. 13-22; see Section 2.2.1 Individual Needs). In our assessment of current condition, we reviewed cumulative fall and winter precipitation and average spring temperature to characterize whether the needs of soil moisture and soil temperature are being met.

To assess the climate conditions, we used data downscaled to the range of clay-loving wild buckwheat from 1979-2021, obtained from the Climate Toolbox (Hegewisch and Abatzoglou 2022, entire). Using the data from 1979–2000, we calculated historical baseline climate conditions, then compared those baselines to current climate conditions (2011-2021).

Climate variables, including fall and winter precipitation and spring temperature, fluctuate annually to some extent. Because of this, clay-loving wild buckwheat has experienced and withstood a range of conditions in the past. However, changes in climate outside the range of normal variation over time have been observed to affect the species (BLM 2019, entire; BLM 2021, entire; CNHP 2022, entire). Consequently, thresholds used to describe “high,” “moderate,” and “low” condition are based on deviation from historic averages and calibrated using species expert knowledge and additional analysis of temperature thresholds (Figure 9; BLM 2021, pp. 13-22). For example, the BLM’s annual monitoring and observed climate trends between 2012 and 2021 indicate that even with sufficient fall and winter moisture, high spring temperatures (i.e., 51°F or greater—a 1.5-degree increase from the historic average)

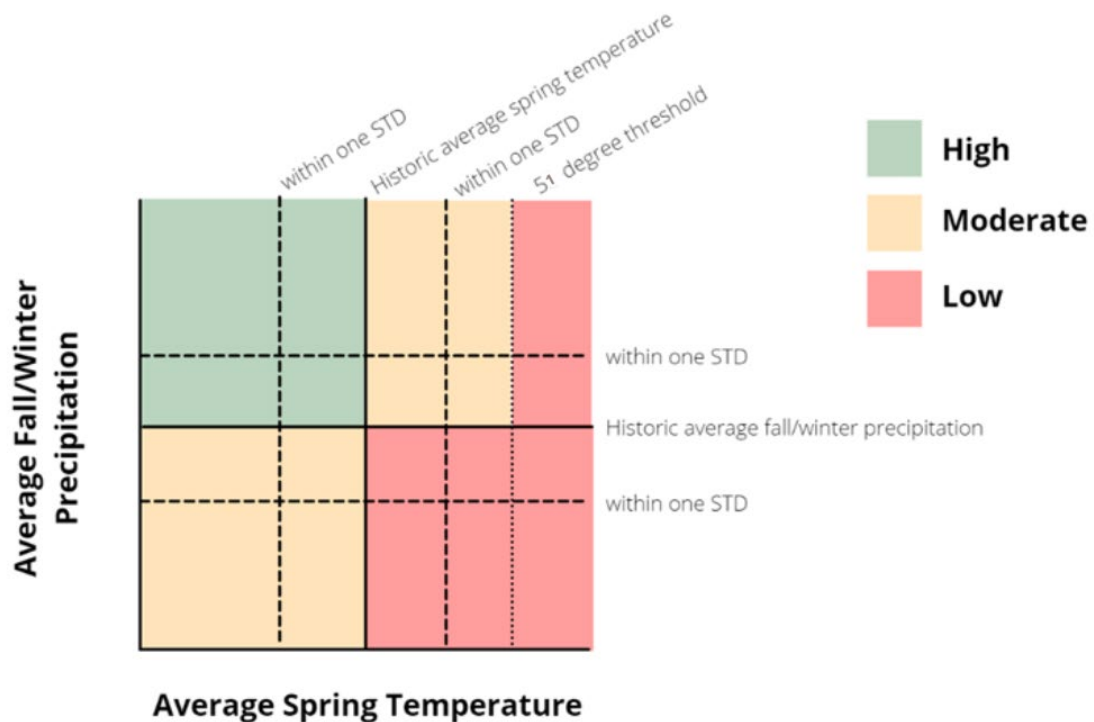


Figure 9. Bins for current and future climate conditions. A current or predicted future climate will be measured as high (green), moderate (yellow), or low (red) depending on where it falls in this chart. For example, a climate with average fall/winter precipitation at or above the historic average and an average spring temperature greater than one standard deviation above the historic average would be measured as “moderate.”

during clay-loving buckwheat's most active growth period may limit water uptake by the plant (BLM 2021, p. 21).

Any analytical unit with current cumulative fall and winter precipitation and average spring temperature better than the historical average (more moisture, not as much warming) was ranked as "high." If only one of those indicators was worse than average (drier and/or hotter), but within one standard deviation of the historical average, the analytical unit was ranked "moderate." If both indicators were worse than the historical average, the analytical unit was ranked "low." Additionally, any analytical unit with an average spring temperature of 51 or greater was ranked "low" based on temperature thresholds identified by the BLM (Figure 9; BLM 2021, p. 21).

3.3.3 Analytical Unit Growth Rate *measures* Recruitment and Analytical Unit Growth Rate

Since 2012, the BLM has recorded demographic data at six monitoring sites distributed across the species' range with at least one monitoring site in each of the three analytical units. These data were used to estimate growth rates for each analytical unit for the purposes of this SSA analysis. Analytical units that are stable or increasing will be better able to withstand stochastic events than units that are in decline. Analytical units that are growing ($\lambda > 1$) will thus have higher resiliency than those that are stable ($\lambda = 1$) or declining ($\lambda < 1$).

3.3.4 Analytical Unit Abundance Distributed across Age Classes *measures* Analytical Unit Abundance Distributed across Age Classes

Clay-loving wild buckwheat needs sufficient abundance at each life stage to maintain an analytical unit and withstand stochastic events. While vegetative and reproductive individuals are vital to the resiliency of clay-loving wild buckwheat analytical units, neither stage seems to have been a limiting factor over the last ten years (BLM 2019, entire; BLM 2021, entire). Consequently, we focused on abundance of seedlings, which has been limiting. The BLM collects information on stage classes during their annual monitoring and began collecting data on seedling frequency in 2016 (i.e., percent of monitored plants that are seedlings, vegetative, or reproductive; also known as stage class frequency). These data on seedling frequency provide the most relevant information on clay-loving wild buckwheat analytical unit abundance distributed across age classes. While BLM does collect plant density data, extrapolating those data across entire analytical units is complicated because of the microhabitats that clay-loving wild buckwheat inhabits. For this reason, plant density likely varies greatly across an analytical unit, and we felt that seedling frequency would more accurately measure a healthy distribution of abundant plants.

Data and literature suggest that clay-loving wild buckwheat recruitment is episodic (CNHP 2022, entire; Service 2009, p. 26). While we don't completely understand the frequency of recruitment events, BLM data and observations suggest two substantial recruitment events circa 2011 and 2016. Seedling frequencies during the 2016 recruitment event were as high as 53 percent at one monitoring site. However, at all monitoring sites, 2016 was followed by years of falling seedling frequency (i.e., at or below 5 percent). Ultimately, the monitoring sites in each analytical unit demonstrated five-year averages of seedling frequency at or below 5 percent. Given that the average growth rate is less than one at each of



these monitoring sites over the same time period, we believe that a five-year average of 5 percent seedling frequency is not enough to sustain an analytical unit.

Furthermore, while these averages account for the last five years (i.e., 2016 to 2021), BLM calculations of annual growth rates greater than one from 2011 to 2015 suggest that many monitoring sites likely had high seedling frequency from 2011 to 2015. Even with those additional seedlings, the average growth rate of the clay-loving wild buckwheat occurrence at each monitoring site from 2011 to 2021 is less than one.

The ten-year average growth rates for several of the monitoring sites were calculated at about 0.95, meaning some number of seedlings were still needed for a stable or growing analytical unit. Given that even a five-year average of seedling frequency as high as 14 percent at one monitoring site still did not result in a five-year average growth rate greater than one over that same time period, we binned seedling frequencies of 0 to 9.9 percent and 10 to 20 percent as “low” and “moderate” respectively. We binned “high” as seedling frequencies greater than 20 percent. Seedling frequencies at or higher than 20 percent have been observed (Lyon 2008, entire).

3.3.5 Connectivity measures Connectivity

We used pairwise genetic differentiation (F_{st}) values as a measure of demographic connectivity. These values measure the likelihood that alleles are similar between occurrences within an analytical unit or between analytical units. Low F_{st} values indicate low levels of differentiation or high levels of demographic connectivity between occurrences (Naibauer and McGlaughlin 2022, p. 11). Higher levels of demographic connectivity can also indicate lower levels of habitat fragmentation (i.e., high levels of demographic connectivity mean there are limited barriers throughout the analytical unit that could reduce genetic exchange). The greater the demographic connectivity within and between analytical units (i.e., the lower the F_{st} values), the better able the analytical unit will be to withstand stochastic events.

We used the following accepted ranges of F_{st} values (Naibauer and McGlaughlin 2022, pp. 11-13) in our assessment of our condition: $F_{st} \leq 0.05$ (low differentiation, high demographic connectivity) was ranked as “high;” $0.05 < F_{st} < 0.15$ was ranked as “moderate;” $F_{st} \geq 0.15$ (high differentiation, low demographic connectivity) was ranked as “low.”

3.3.6 Other Considerations

Pollination of clay-loving wild buckwheat is carried out by a variety of bees, ants, and beetles (Bowlin et al. 1992, p. 300; Tepedino et al. 2011, p. 60). Since clay-loving wild buckwheat does not require a specialist pollinator, abundance of pollinators is likely not a limiting factor and is not measured in our analysis of current or future condition.



3.3.7 Analytical Unit Overall Resiliency Score

To calculate the overall resiliency of each analytical unit, we first gave each metric a rank of “high,” “moderate,” or “low” with a respective three-point, two-point, or one-point score for each metric’s ranking. Based on the total of those scores, we categorized the resiliency of each analytical unit as “high,” “moderate,” or “low” condition. We decided on scoring thresholds which evenly divided the range of the highest and lowest possible scores (Table 6).

3.4 Current Condition

When measured against the metrics outlined in Table 6, the analytical units vary in their overall condition and resiliency. The Fairview and Selig analytical units have moderate resiliency, and the Delta analytical unit has low resiliency (Table 8). Differences in current condition between each analytical unit are driven by differences in habitat size, habitat type, and climate.

Table 8. Measure of current resiliency in each clay-loving wild buckwheat analytical unit based on current habitat conditions and demographics. Green shading indicates a high score, yellow indicates a moderate score, and red indicates a low score.

Current Condition							
Analytical Unit	Individual Needs / Habitat Factors			Analytical Unit Needs / Demographic Factors			Overall Condition
	Habitat Condition Index	Climate Metric		Seedling Frequency	10-year Average Analytical Unit Growth Rate	F _{st}	
	Substrate Structure and Characteristics	Soil Moisture	Soil Temperature	Analytical Unit Abundance Distributed across Age Classes	Analytical Unit Growth Rate and Recruitment	Connectivity	
	Fairview Analytical Unit	HIGH	LOW		LOW	LOW	
Selig Analytical Unit	MODERATE	MODERATE		LOW	LOW	HIGH	MODERATE
Delta Analytical Unit	LOW	LOW		LOW	LOW	HIGH	LOW

Within the Habitat Condition Index (HCI), the analytical units differed in their rankings for two of the three HCI indicators. While all three analytical units ranked “moderate” in terms of habitat quality, the Fairview, Selig, and Delta analytical units ranked “high,” “moderate,” and “low” respectively for both habitat size and habitat type. These rankings lead to their overall ranking for the HCI of “high,” “moderate,” and “low” for the Fairview, Selig, and Delta analytical units respectively.

In terms of habitat size, the Delta analytical unit ranked “low” with a mean plant density of 0.43 plants/m², less than 20 acres of occupied habitat on BLM land, and more than 100 acres of occupied habitat on private land. The Selig analytical unit ranked “moderate” with a mean of 0.95 plants/m², less than 20 acres of occupied habitat on BLM land, and more than 100 acres of occupied habitat on private land. The Fairview analytical unit ranked “high” with a mean plant density of 3.86 plants/m², more than 100 acres of occupied habitat on BLM land, and between 20 and 100 acres of occupied habitat on private land. For more information, see Appendix III.

In terms of habitat type, all three analytical units ranked as “moderate” for number of acres of suitable clay-loving buckwheat habitat (i.e., 1,000 – 10,000 acres). In terms of the percent of suitable habitat on BLM land to private land, Delta ranked “low” at 38 percent, Selig ranked “moderate” at 42 percent, and Fairview ranked “high” at 54 percent. The stratification by ownership and management of land is important as plants on private lands are generally not afforded federal protections under the Act unless an activity on the land involves a Federal agency.

Within the climate metric, two analytical units ranked “low.” Current cumulative fall and winter precipitation in the Delta and Fairview analytical units is worse (i.e., lower) than the historical average, though still within one standard deviation of the historical baseline (Table 9). Similarly, current (i.e., 2011 to 2021) average spring temperature in the Delta and Fairview analytical units was slightly worse (i.e., higher) than the historical (i.e., 1979 to 2000) baseline (Table 9). While cumulative fall and winter precipitation in the Selig analytical unit was also lower (worse) than the historical average, average spring temperature was slightly below the historical average.

Table 9. Cumulative fall/winter precipitation and average spring temperatures for each analytical unit. Data includes a historical baseline (1979 – 2000) and current levels of precipitation and average spring temperature (2011 – 2021).

Fairview Analytical Unit			
	Historic Average	Within 1 STD	Current (2011 - 2021)
Sept. - Feb. Precipitation (in)	5.32	3.89 - 6.74	4.9
Spring Temperature (°F)	47.51	45.7 - 49.32	47.97
Selig Analytical Unit			
	Historic Average	Within 1 STD	Current (2011 - 2021)
Sept. - Feb. Precipitation (in)	4.16	2.97 - 5.34	3.8
Spring Temperature (°F)	50.27	48.54 - 52	50.24
Delta Analytical Unit			
	Historic Average	Within 1 STD	Current (2011 - 2021)
Sept. - Feb. Precipitation (in)	4.17	2.98 - 5.37	3.92
Spring Temperature (°F)	50.88	48.39 - 51.95	50.95

None of the analytical units have demonstrated a fully successful recruitment event since monitoring began in 2012. Many seedlings were observed in 2016, but unfavorable conditions the following years caused most of those seedlings to die. The South Fairview and Wacker Ranch monitoring sites (in EO 018 in the Fairview analytical unit) showed seedling frequencies of 10 and 53 percent in 2016, respectively, and those seedling frequencies declined to 1 and 14 percent in 2017 respectively. These observations highlight the need for several consecutive years of favorable conditions for the successful transition from seedlings to juveniles. Four of the five years from 2017 to 2021 had exceptionally low fall/winter precipitation and high average spring temperature relative to historical conditions, though all levels of fall/winter precipitation and average spring temperature fell within one standard deviation of the historic average for each analytical unit.

Table 10. Occurrence growth rates per site and year (λ) and their average over the duration of monitoring. Values are a ratio of the number of plants in year $t+1$ / the number of plants in year t . Therefore, 1 = no change, <1 – a decrease, and >1 = an increase.

Plot	λ t+1	λ t+2	λ t+3	λ t+4	λ t+5	λ t+6	λ t+7	λ t+8	λ t+9	Average λ
MAC Inside	0.97452	1.00654	1.05844	0.98160	0.9375	1.06	0.29612	1.29646	0.70307	0.923805
MAC Outside	0.90038	0.96170	1.07522	0.83128	0.97030	1.06633	0.24115	1.55655	0.61568	0.913176
Powerline	1.00881	1.02183	1.08120	1.10277	0.85663	1.02929	0.55302	1.04441	0.88710	0.953894
Fairview 1		1.09576	1.07400	1.36933	0.71086	0.81190	0.71287	0.96667	0.83319	0.946815
Fairview 2		1.02896	1.15760	1.27229	0.67643	0.91337	0.75866	0.91031	0.94940	0.958377
Wacker Ranch						0.93866	0.84714	0.68311	0.73800	0.801728
Mean	0.96124	1.02296	1.08928	1.1115	0.83034	0.96993	0.56816	1.07625	0.78774	0.935261
SD	0.05542	0.04837	0.03910	0.21668	0.13203	0.10008	0.25149	0.30799	0.12435	

Growth rates measured at each analytical unit were all less than one (Table 10), indicating decreasing analytical units of clay-loving wild buckwheat. Over the last four years, the BLM observed mortality of plants in each analytical unit following several years of unfavorable conditions (i.e., hot and dry). Though some plants have only gone dormant, many have desiccated and died. This mortality paired with very little recruitment over the last 10 years, has led to shrinking analytical units of clay-loving wild buckwheat.

Connectivity within and between analytical units remains high. Pairwise genetic differentiation values (F_{st} ; Table 11) indicate there is none to limited differentiation between analytical units. The highest differentiation values are seen when comparing the Powerline site in the Delta analytical unit to all other sampled occurrences and the Uncompahgre site in the Fairview analytical unit to the northern sampled occurrences. The estimated number of migrants per generation (N_m) indicates that gene flow is occurring among most occurrences, with the highest N_m values observed within the same analytical units. The Powerline site shared the least migrants with any other occurrence.



Table 11. Pairwise number of migrants per generation (N_m ; above the diagonal) and F_{st} measures (below the diagonal) across all sampled occurrences of clay-loving wild buckwheat. N_m values > 10 migrants per generation have been highlighted in green. F_{st} values > 0.05 have been highlighted in yellow. Data from Naibauer and McGlauglin (2022, p. 13).

	Powerline	Mountain View	Trisate	EQ	2100	Last Chance	Selig Canal	Peach	Elephant Skin	NFV	SFV	Sider's	UNCO	South Canal
Powerline	--	4	3.5	4.1	4.7	3.8	5.2	4.6	4.1	4.3	4.6	4.4	2.5	3.7
Mountain View	0.059	--	4.1	5.1	7.1	4.1	5.8	5.4	4.5	5	5.3	5.1	3	4.4
Trisate	0.066	0.057	--	5.4	5.6	4.2	5.6	4.8	4.3	4.6	4.4	4.6	2.9	3.7
EQ	0.057	0.047	0.044	--	7.3	5.3	6.7	6.5	5	5.7	5.1	5.3	3	4
2100	0.051	0.034	0.043	0.033	--	7.6	9.4	10.2	7.6	7.6	7.6	6.9	3.9	5.4
Last Chance	0.061	0.058	0.056	0.045	0.032	--	7.3	6.2	5.6	6.3	5.8	5.8	3.3	4.9
Selig Canal	0.046	0.041	0.043	0.036	0.026	0.033	--	12.9	7.8	10.6	10.6	11.7	4.3	6.9
Peach	0.052	0.044	0.05	0.037	0.024	0.039	0.019	--	8.4	11.1	10.2	9.8	4.7	6.5
Elephant Skin	0.057	0.053	0.055	0.048	0.032	0.043	0.031	0.029	--	9.8	10.6	11.1	4.3	6.3
NFV	0.055	0.048	0.052	0.042	0.032	0.038	0.023	0.022	0.025	--	35.5	31	6	16.4
SFV	0.052	0.045	0.054	0.047	0.032	0.041	0.023	0.024	0.023	0.007	--	249.8	6.9	22.5
Sider's	0.054	0.047	0.052	0.045	0.035	0.041	0.021	0.025	0.022	0.008	0.001	--	6.5	22.5
UNCO	0.09	0.078	0.079	0.077	0.06	0.071	0.055	0.051	0.055	0.04	0.035	0.037	--	9.4
South Canal	0.063	0.054	0.063	0.059	0.044	0.049	0.035	0.037	0.038	0.015	0.011	0.011	0.026	--

None of the analytical units demonstrate high resiliency. Two of the three analytical units, Fairview and Selig, currently have moderate resiliency and one analytical unit, Delta, has low resiliency. Range-wide monitoring efforts have demonstrated a decreasing trend in plant densities over recent years in all analytical units.

Redundancy for narrow endemic species is inherently limited, and redundancy of clay-loving wild buckwheat is further limited given that no individual analytical unit currently demonstrates high resiliency. Additionally, clay-loving wild buckwheat plants are distributed unevenly across the range of the species with most plants occurring in the Fairview analytical unit. In the event of a catastrophe in the Fairview analytical unit (e.g., a wildfire), a disproportionate number of plants would be wiped out, and the remaining analytical units would struggle to recover the species. The three analytical units also border one another and cover only 173 square miles (448 square kilometers), further reducing the redundancy of the species and its ability to withstand catastrophic events.



In terms of representation, the species exhibits some ecological variability (i.e., precipitation and temperature regimes vary across the species' range). Generally, precipitation increases and temperature decreases along a north to south gradient (i.e., precipitation is highest and temperatures are lowest in the Fairview analytical unit). The species also maintains limited genetic diversity and high connectivity within and among analytical units. These forms of representation give the species some ability to adapt to changing environmental conditions (e.g., some warming or drought).

3.5 Summary of Current Condition

None of the analytical units demonstrate high resiliency. Two of the three analytical units, Fairview and Selig, currently have “moderate” resiliency and one analytical unit, Delta, has “low” resiliency. Redundancy of clay-loving wild buckwheat is limited because there are only three analytical units, no individual analytical unit demonstrates high resiliency, the species is unevenly distributed across its range, and the species' range is small. All of these factors reduce the redundancy of the species and its ability to withstand catastrophic events. The species exhibits some ecological variability and maintains limited genetic diversity and high connectivity within and among analytical units. These forms of representation give the species some ability to adapt to changing environmental conditions.

4 Future Condition

We have described the life history and distribution of clay-loving wild buckwheat (Chapter 2). We considered the ecological needs for the species (Chapter 2) and its current condition (Chapter 3). In this chapter, we evaluate the species' expected future conditions using projections of plausible future scenarios. We use the current condition as the baseline from which to evaluate changes to those factors considered important to clay-loving wild buckwheat into mid-century.

4.1 Development of Future Scenarios

In this chapter, we forecast the resiliency of clay-loving wild buckwheat analytical units and the redundancy and representation of the species over the next 33 years (to the year 2055 – the midpoint of the average of projected climate conditions between 2040 and 2069) using a range of plausible future scenarios. We selected a timeframe of approximately 30 years because this timeframe is short enough for us to realistically predict changes in climate conditions and species stressors, yet long enough to begin to understand the response of ecosystems to those changes. We are uncertain of a specific timescale that is biologically relevant to this species, since we do not know its full lifespan or generation time; thus, we relied on the timeframe over which we could reliably project climate condition and land management actions to establish the time period for our future condition analysis.

We used future climate models downscaled to the range of the species, in combination with forecasted changes in the location and intensity of stressors, to develop three future scenarios and evaluate the condition of the species under each of those scenarios. Since the conservation of the species depends on state and Federal agencies' ability to effectively mitigate the negative impacts of stressors to clay-loving wild buckwheat and its habitat through protections afforded by their resource management plans, future



scenarios were developed with input from the agencies about likely changes in land management on these properties. Given some level of uncertainty about the conditions that will actually be present by 2055, the three scenarios represent a range of plausible future changes in stressors and conservation efforts to capture the plausible range of future conditions the species may experience. Therefore, our evaluation of future conditions presents a plausible range of expected species responses. While the metrics used to assess the current resiliency of clay-loving wild buckwheat analytical units are quantitative, we do not have a reliable way to quantitatively forecast these metrics into the future. Instead, future conditions are expressed qualitatively, using the results of current condition (Chapter 4) as the baseline. Species experts used professional judgement to predict how the species and its habitats would respond to each future scenario.

4.1.1 Climate Scenarios

Using data from 1979–2000, we calculated a baseline of historical climate conditions for each analytical unit (i.e., average cumulative fall/winter precipitation and average spring temperature). We then selected three future climate models that represent the range of projected future climate conditions in the area: warmer and moderately wetter; moderately hot and moderately dry; and hot and dry (Table 12). We used modeled future climate data obtained from the Climate Toolbox (Hegewisch and Abatzoglou 2022, entire) to calculate projected future cumulative fall/winter precipitation and mean spring temperature under these scenarios.



4.1.2 Description of Future Scenarios

Table 12 describes the three future scenarios used to evaluate the plausible range of conditions clay-loving wild buckwheat may experience by 2055. By capturing a range of plausible future scenarios, we can assume that actual future conditions will likely fall somewhere between these projected scenarios.

Table 12. Description of each stressor under three future scenarios—optimistic, continuation, and pessimistic. These three future scenarios are expected to cover the range of plausible conditions that clay-loving wild buckwheat might experience.

Future Scenarios			
Stressor	Plausible Future States		
	Scenario 1: Optimistic	Scenario 2: Continuation	Scenario 3: Pessimistic
Incompatible Livestock Use	BLM livestock grazing restrictions remain in place at the North Fairview ACEC and South Fairview ACEC, and livestock exclosures remain at the Montrose Model Aircraft Association, Elephant Skin, Delta County 2100 Road, and Last Chance Road. Critical habitat is designated on BLM land providing additional protection for clay-loving wild buckwheat from the effects of grazing. Management for and protection of clay-loving wild buckwheat by the Colorado Natural Areas Program (CNAP) and The Nature Conservancy (TNC) continues.	BLM livestock grazing restrictions remain in place at the North Fairview ACEC and South Fairview ACEC, and livestock exclosures remain at the Montrose Model Aircraft Association, Elephant Skin, Delta County 2100 Road, and Last Chance Road. Management for and protection of clay-loving wild buckwheat by the CNAP and TNC continues.	The Uncompahgre Field Office Resource Management Plan is revised to permit livestock grazing in the ACECs, exclosures are removed, and private landowners allow livestock to graze clay-loving wild buckwheat and clay-loving wild buckwheat habitat. Management for and protection of clay-loving wild buckwheat by the CNAP and TNC continues.

Invasive Species	Passive restoration occurs by limiting grazing and OHV use.	While invasive species occur throughout occupied and suitable clay-loving wild buckwheat habitat, they do not outcompete clay-loving wild buckwheat. Agencies and project proponents implement invasive species prevention and management when soil-disturbing activities occur.	Ground-disturbing activities increase, invasive species treatments are not adequate to control new infestations, and invasive plant species establish and outcompete clay-loving wild buckwheat and further restrict clay-loving wild buckwheat.
Off-highway Vehicle (OHV) Use	BLM OHV restrictions remain in place at the North Fairview ACEC and South Fairview ACEC, and exclosures remain at the Montrose Model Aircraft Association, Elephant Skin, Carnation Road, Delta County 2100 Road, and Last Chance Road. Critical habitat is designated on BLM land providing additional protection to clay-loving wild buckwheat from the effects of OHV use.	BLM OHV restrictions remain in place at the North Fairview ACEC and South Fairview ACEC, and exclosures remain at the Montrose Model Aircraft Association, Elephant Skin, Carnation Road, Delta County 2100 Road, and Last Chance Road.	The Uncompahgre Field Office Resource Management Plan is revised to permit OHV access in ACECs, exclosures are removed, and use of OHVs increases on private lands within clay-loving wild buckwheat habitat.
Commercial and Residential Development	The human population of Montrose and Delta Counties stabilizes, and new residential and commercial development is minimal.	The human populations of Montrose and Delta Counties continue to grow at the current rate, and residential and commercial development continues to occur on private lands.	Growth of the human populations of Montrose and Delta Counties accelerates, along with residential and commercial development on private lands and potentially on public lands.



Irrigation Operations	The piping and maintenance of irrigation canals and laterals continues.	The piping and maintenance of irrigation canals and laterals continues.	The piping and maintenance of irrigation canals and laterals continues.
Development and Maintenance of Utility Corridors	Formal arrangements are made with utility companies to protect clay-loving wild buckwheat and clay-loving wild buckwheat habitat on rights-of-way (ROWs). The impacts of additional utility development are balanced by BLM's restrictions on ROWs in the North and South Fairview ACECs and Section 7 consultations under the Act.	Informal cooperation with utility companies provides protection to clay-loving wild buckwheat and clay-loving wild buckwheat habitat on ROWs. BLM restrictions on ROWs in the North and South Fairview ACECs remain in place.	There is no formal or informal cooperation with utility companies and BLM revises the Uncompahgre Field Office and Gunnison Gorge National Conservation Area Resource Management Plans and lifts ROW restrictions in the North and South Fairview ACECs. The impact on clay-loving wild buckwheat and clay-loving wild buckwheat habitat grows as the need for additional utility development matches human population growth in the area.
Climate Change	Average spring temperature warms by about 0.5°F. Fall/winter precipitation increases by about one inch.	Average spring temperature increases by at least 4°F. Fall/winter precipitation increases by about three quarters of an inch.	Average spring temperature is above 55°F at every analytical unit except the Fairview analytical unit. Fall/winter precipitation does not increase.



4.2 Scenario 1: Optimistic

In the optimistic scenario, resiliency of the Fairview analytical unit increases and moves to a “high” condition, and the Selig and Delta analytical units remain in “moderate” and “low” condition, respectively. Continued restrictions on grazing, OHV use, and development, allow for some passive restoration of clay-loving wild buckwheat habitat and prohibit additional disturbances from impacting the analytical units. Most notably, fall and winter precipitation increases by about one inch, meaning more water is available for germination, growth, and reproduction. Because of the continued restrictions on ground-disturbing activities and increases in fall and winter precipitation, we anticipate the ten-year average growth rate to increase under this scenario for all three analytical units.

Table 13. Measure of future resiliency in each clay-loving wild buckwheat analytical unit based on habitat conditions and demographics under an optimistic scenario. Green shading indicates a high score, yellow indicates a moderate score, and red indicates a low score.

Optimistic Scenario							
Analytical Unit	Individual Needs / Habitat Factors			Analytical Unit Needs / Demographic Factors			Overall Condition
	Habitat Condition Index	Climate Metric		Seedling Frequency	10-year Average Analytical Unit Growth Rate	F _{st}	
	Substrate Structure and Characteristics	Soil Moisture	Soil Temperature	Analytical Unit Abundance Distributed across Age Classes	Analytical Unit Growth Rate and Recruitment	Connectivity	
Fairview Analytical Unit	HIGH	MODERATE		MODERATE	MODERATE	HIGH	HIGH
Selig Analytical Unit	MODERATE	LOW		LOW	MODERATE	HIGH	MODERATE
Delta Analytical Unit	LOW	LOW		LOW	MODERATE	HIGH	LOW

However, in the Selig and Delta analytical units, improvements in soil moisture are outpaced by increases in soil temperature. Spring temperatures average more than the 51-degree threshold which will stress plants and may cause reduced reproduction as clay-loving wild buckwheat is known to enter into whole plant dormancy in times of stress. This increase in average spring temperature results in a “low” rank for climate for the Selig and Delta analytical units (Table 13).

Redundancy and representation for this species may increase slightly under this scenario compared to current condition, due to an increase in resiliency in the Fairview analytical unit.

4.3 Scenario 2: Continuation of Current Trends

In the continuation scenario, compared to current condition, resiliency declines across all three analytical units. The Selig analytical unit moves to a “low” condition, resulting in two of the species’ three analytical units to be in “low” condition. The Fairview analytical unit remains in “moderate” condition (Table 14).

Table 14. Measure of future resiliency in each clay-loving wild buckwheat analytical unit based on habitat conditions and demographics under a continuation scenario. Green shading indicates a high score, yellow indicates a moderate score, and red indicates a low score.

Continuation Scenario							
Analytical Unit	Individual Needs / Habitat Factors			Analytical Unit Needs / Demographic Factors			Overall Condition
	Habitat Condition Index	Climate Metric		Seedling Frequency	10-year Average Analytical Unit Growth Rate	F _{st}	
	Substrate Structure and Characteristics	Soil Moisture	Soil Temperature	Analytical Unit Abundance Distributed across Age Classes	Analytical Unit Growth Rate and Recruitment	Connectivity	
	Fairview Analytical Unit	HIGH	LOW		LOW	LOW	
Selig Analytical Unit	MODERATE	LOW		LOW	LOW	HIGH	LOW
Delta Analytical Unit	LOW	LOW		LOW	LOW	HIGH	LOW

Though land management prescriptions are similar to current land management under this scenario, climatic conditions worsen due to continuation of current climate change trends. Fall/winter precipitation increases by three-quarters of an inch, but the increase in soil moisture is outpaced by average spring temperatures that climb by at least 4°F. Warmer spring temperatures will reduce the recharge of moisture in the soil profile and the plant's ability to uptake water. All analytical units will likely experience a reduction in growth and reproduction. Plants across the species' range may exhibit whole plant dormancy or mortality, especially in the Delta analytical unit where spring temperatures are expected to average more than 55°F.

Redundancy and representation for this species may decrease under this scenario compared to current condition, due to decreased resiliency across all three analytical units.

4.4 Scenario 3: Pessimistic

In the pessimistic scenario, compared to current condition, resiliency declines for all analytical units. All analytical units now rank as “low” (Table 15). In this scenario, land management is less favorable to clay-loving wild buckwheat, and grazing, OHV use, and development in clay-loving wild buckwheat habitat increase. This further fragments the analytical units and causes the loss of plants and habitat. The climate also becomes less favorable. Cumulative fall and winter precipitation does not increase in any analytical unit, and average spring temperatures are greater than 55°F. Connectivity also begins to decrease as plants are lost and fragmentation increases. All analytical units experience reductions in growth, reproduction, and abundance as plants go dormant or die.

Table 15. Measure of future resiliency in each clay-loving wild buckwheat analytical unit based on habitat conditions and demographics under a pessimistic scenario. Green shading indicates a high score, yellow indicates a moderate score, and red indicates a low score.

Pessimistic Scenario							
Analytical Unit	Individual Needs / Habitat Factors			Analytical Unit Needs / Demographic Factors			Overall Condition
	Habitat Condition Index	Climate Metric		Seedling Frequency	10-year Average Analytical Unit Growth Rate	F _{st}	
	Substrate Structure and Characteristics	Soil Moisture	Soil Temperature	Analytical Unit Abundance Distributed across Age Classes	Analytical Unit Growth Rate and Recruitment	Connectivity	
Fairview Analytical Unit	MODERATE	LOW		LOW	LOW	HIGH	LOW
Selig Analytical Unit	LOW	LOW		LOW	LOW	MODERATE	LOW
Delta Analytical Unit	LOW	LOW		LOW	LOW	MODERATE	LOW

Redundancy and representation for this species may decrease under this scenario compared to current condition, due to decreases in resiliency at all three analytical units.

5 SSA Summary

In this SSA, we describe the ecological needs of clay-loving wild buckwheat, identify stressors on the species and conservation efforts, assess the current condition of the species, and analyze the effects of plausible future scenarios on the viability of the species.

Stressors that influence clay-loving wild buckwheat include incompatible livestock grazing, invasive species, off-highway vehicle (OHV) use, commercial and residential development, irrigation operations, development and maintenance of utility corridors, and climate change.

Currently, two analytical units—Fairview and Selig—have moderate resiliency, and one analytical unit—Delta—has low resiliency. Range-wide monitoring efforts show a decreasing trend in plant densities over the last ten years in all analytical units. The Delta analytical unit stands apart from the species' other two analytical units as it has the fewest occupied acres of any of the analytical units and the fewest number of occupied acres with Federal protection (i.e., less than 2 acres). Additionally, the climate in the Delta analytical unit is generally warmer and drier than the Selig and Fairview analytical units. These habitat and climatic factors mean that the Delta analytical unit has the lowest resiliency of any analytical units.

Ultimately, none of the analytical units currently demonstrate high resiliency, which influences the redundancy and representation of the species. Redundancy can be influenced by resiliency in that analytical units with low resiliency are less able to spur recovery if there is a catastrophic event which wipes out another analytical unit (e.g., a wildfire). Representation can be influenced by resiliency because unique ecological and genetic varieties may exist in an analytical unit with low resiliency. If a catastrophic event wiped out that analytical unit, that variation and representation would be lost. The same catastrophic event might not completely eliminate all members of the analytical unit if it were more resilient, thus potentially retaining more genetic and ecological variation within the species. With this greater retention of genetic and ecological variation would come a greater ability for the species to adapt to changing future conditions.

This is especially relevant in the Delta analytical unit, where additional genetic substructure exists within a site called Powerline (Figure 7). The genetic distinction of Powerline is also supported by the fact that it is the most genetically diverged occurrence relative to the entire distribution. While the overall genetic differentiation is limited, these results highlight the importance of maintaining what diversity the species has across its range, including genetic diversity found at the Powerline site. Given the unique genetic signal associated with Powerline, this occurrence should be prioritized for conservation and managers should avoid transplanting individuals outside of their analytical units and to or from Powerline.

In terms of redundancy, redundancy for narrow endemic species is inherently limited. Additionally, clay-loving wild buckwheat individuals are distributed unevenly across the range of the species with most occurring in the Fairview analytical unit. A catastrophe in the Fairview analytical unit would severely impact the species' viability. The range of the three analytical units is also contained within 173 square

miles (448 square kilometers) which further reduces the redundancy of the species and the ability of clay-loving wild buckwheat to withstand a catastrophic event.

In terms of representation, the species exhibits some ecological variability (i.e., precipitation and temperature regimes vary across the species' range) and maintains limited genetic diversity and high connectivity within and among analytical units. These forms of representation give the species some ability to adapt to changing environmental conditions (e.g., some warming or drought).

Under the optimistic scenario, resiliency is expected to increase for the Fairview analytical unit due to increased restrictions on ground-disturbing activities and to increases in cumulative fall and winter precipitation. Unfortunately, high average spring temperatures outpace the benefits from conservation and improved precipitation in the Selig and Delta analytical units. Overall, redundancy and representation of the species is likely to increase slightly as the resiliency of the Fairview analytical unit increases.

Under the continuation and pessimistic future scenarios, changes in climate will likely reduce the resiliency of each analytical unit. Fall and winter precipitation cannot keep pace with increases in average spring temperature. Plants experience reduced water uptake and some plants go dormant or die. The analytical units experience reduced growth, reproduction, and germination. With only three known analytical units, the loss of one due to catastrophic, natural, or human-caused events would cause a severe loss of redundancy and representation of the species. Redundancy and representation of the species tends to decrease as resiliency of each analytical unit decreases.



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Appendices



Introduction

Clay-loving wild buckwheat (*Eriogonum pelinophilum*, hereafter “ERPE”) is a rounded, spreading subshrub found only in Montrose and Delta counties in western Colorado (Taliga 2011). ERPE is restricted to high clay soils derived from Mancos Shale, and is found only in a range from roughly 11.5 miles east to west and 28.5 miles north to south (USFWS 2009). The species has been federally listed as an endangered species since 1984.

Much of ERPE’s habitat occurs on Bureau of Land Management lands managed by the Uncompahgre Field Office. To predict areas of likely ERPE occurrence within its range, we modeled ERPE occurrence and produced raster predictions of its habitat suitability. This model was produced using 1-meter resolution LiDAR data collected in the Uncompahgre Field Office in 2015 and 2019. This extremely high resolution data allowed us to very precisely map the species’ suitable habitat.

Methods

We utilized 1,009 points of ERPE presence. 858 of these points represented locations where ERPE individuals were observed in the field and had their position collected. The remaining 151 points were manually generated within more coarsely mapped polygons of ERPE occurrence. These points were generated only in polygons far from any mapped points of occurrence, in order to obtain a more representative sample of conditions across the species’ habitat. The ERPE presence points spanned much of the species’ known range (Figure 1).

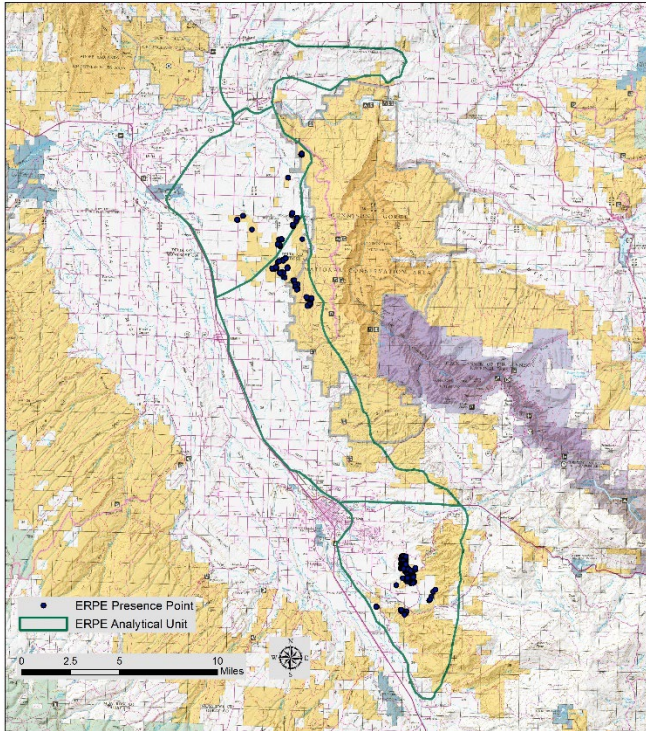


Figure 1. ERPE presence points included in modeling, overlain with ERPE Analytical Units.

A basic issue exists in modeling species habitat from records of species presence. Models based on species presence are often called presence-only models, but they require the generation of presumed species absence for comparison. These points are typically called either “pseudo-absence” or “background points”. We obtained these points by simply generating many random points within the study area, and treating them as samples of ERPE absence (Valavi et al. 2021b). Though some of these points fall within suitable habitat or even overlapping points of ERPE presence, the very large number of background points generated ensures that these points as a whole substantially differ from the presence points.

At the presence and background points we sampled environmental covariates we believed would be associated with ERPE presence. Many of these covariates were calculated from a 1-meter resolution elevation model derived from LiDAR. This dataset was selected because of its

extremely high resolution, and coverage overlapping the majority of the ERPE range. In addition to the elevation data from LiDAR, we also calculated slope degree, northness, and eastness from the elevation. Northness was calculated by generating aspect in degrees, then transforming by the following equation: $northness = \cos (aspect * \pi / 180)$. Eastness was similarly calculated by the following equation: $eastness = \sin (aspect * \pi / 180)$. Transforming aspect into eastness and northness is necessary because aspect is circular, meaning very disparate values are in fact very similar to one another (i.e., both 1° and 359° are north-facing). Transforming into eastness and northness more accurately represents aspect.

We also included geologic formation as a covariate. Since EPRE is strongly associated with a single geologic formation (the Smoky Hill member of the Mancos Shale, formation kms), we generated a buffer of distance from this formation. We included distances from 0 to 1 meters from this formation, 1 to 10 meters, 10 to 100 meters, and farther than 100 meters. We then converted this buffer polygon into a raster at 1-m resolution. We utilized a high resolution 24k layer of geology to generate this layer. The Red Rock Canyon quad was not available at this resolution, so we could not include this area in modeling.

Lastly, we included 30-year normal precipitation from PRISM (PRISM 2014). To include this data with the geology and data derived from LiDAR, we resampled the precipitation data to 1-meter resolution by bilinear interpolation from the original 1-km resolution data.

We sampled the values of each of these covariates onto the presence and background points, then used these values in modeling. We ran four modeling approaches: two different implementations of Random Forest (a downsampled random forest from the “randomForest” package, and a shallow random forest from the “ranger” package), Boosted Regression Tree, and Maxent. These modeling methods are widely-used in species distribution modeling (Ramirez-

Reyes et al. 2021; Valavi et al. 2021b). In the downsampled random forest, each tree of the random forest includes a random subset of an equal number of presence and background points, improving model performance (Valavi et al. 2021a). In the shallow random forest, each tree is restricted to a maximum depth of only two splits (Valavi et al. 2021a).

To validate these models most accurately, we randomly selected a subset of two-thirds of both the presence and background points to include in modeling. This allowed one-third of the points to serve as true model validation points which were never included in model construction.

With the models, we calculated rasters of predictions corresponding to all pixels in the predictor rasters. These represent predictions of habitat suitability for ERPE, which should be interpreted as the similarity to ERPE's currently occupied habitat (Latif et al. 2015) because current ERPE presence was the basis of our model.

We calculated numerous metrics of model accuracy, but focused mainly on the AUC-PR, which is seen as the most appropriate metric in modeling rare species such as ERPE (Sofaer et al. 2019). This metric showed Maxent was significantly less accurate than the other models, so we ignored the Maxent model going forward. Using the three other models (RF-Downsample, RF-Shallow, and BRT), we calculated a weighted ensemble model. This weighted ensemble was produced by first dividing each model's AUC-PR by the sum of all models' AUC-PR to obtain each model's weight. Each model was then multiplied by its respective weight, and all three rasters were added to obtain the ensemble prediction (Ramirez-Reyes, 2021).

All analysis, modeling, and model prediction was carried out in R 4.0.2 (R Core Team, 2021).

Results

The models were extremely accurate in predicting presence and absence of ERPE. Considering only the validation points not used in model calculation, the weighted ensemble model's overall accuracy was 95.86% accurate, meaning 95.86% of points were correctly predicted. The AUC-ROC (area under the receiver operating characteristic curve) summarizes model accuracy and is often used in model evaluation. This metric is bound from 0 to 1, with 0.5 representing a random model. The ensemble model had an AUC-ROC of 0.9894.

The AUC-PR (area under the precision recall curve) is a more robust metric for evaluating models of rare species. This metric is also bound from 0 to 1, but for this metric a random model has an AUC-PR equal to the positive prevalence in the dataset. Positive prevalence in our validation dataset equals 0.0228 (meaning 2.28% of the points represented ERPE presence). The AUC-PR of the ensemble model was 0.7929, significantly above this benchmark. Validation metrics for all models are shown in Table 1. Performance of all models was extremely similar, but the weighted ensemble performed best in AUC-PR.

Table 1: Model validation metrics of all models, utilizing validation data. Sensitivity is how often the model predicted presence at the presence points, and specificity is how often the model predicted absence at the background points.

Metric	Downsampled RF	Shallow RF	BRT	Weighted Ensemble
Sensitivity	0.9347	0.9377	0.9466	0.9436
Specificity	0.9612	0.9452	0.9640	0.9590
AUC-ROC	0.9894	0.9867	0.9894	0.9894
AUC-PR	0.7920	0.7729	0.7279	0.7929

The rasters of model prediction show areas of high habitat suitability throughout ERPE's range (Figure 2). This includes areas where no points of ERPE presence were included in modeling, indicating new locations of potential habitat of the species.

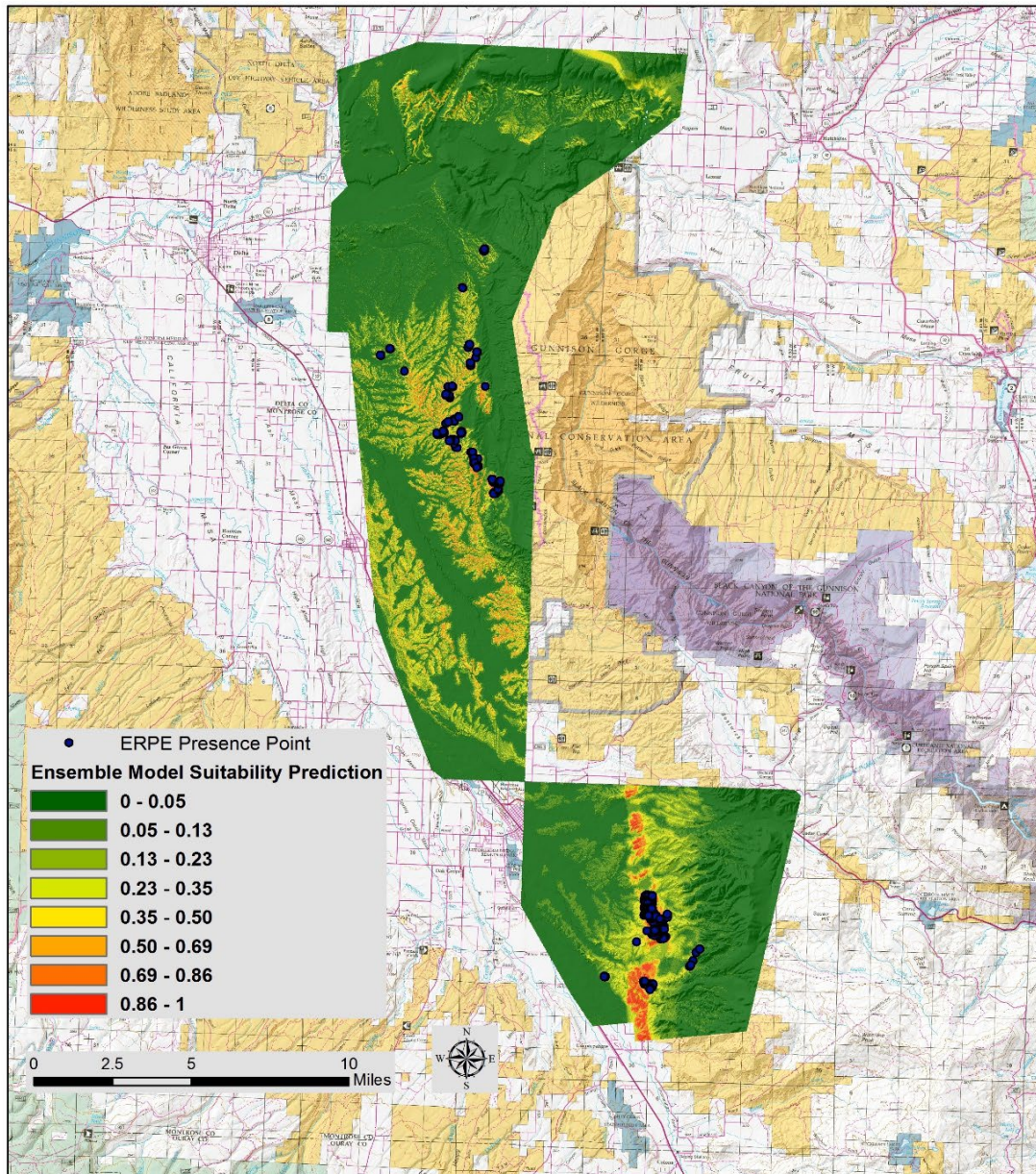


Figure 2. Map of ensemble model predictions, and the ERPE presence points included in modeling.

The model predictions closely aligned with the borders of ERPE presence polygons not included in model construction (Figure 3), increasing our confidence that the model tracks real-world boundaries of the species' suitable habitat.

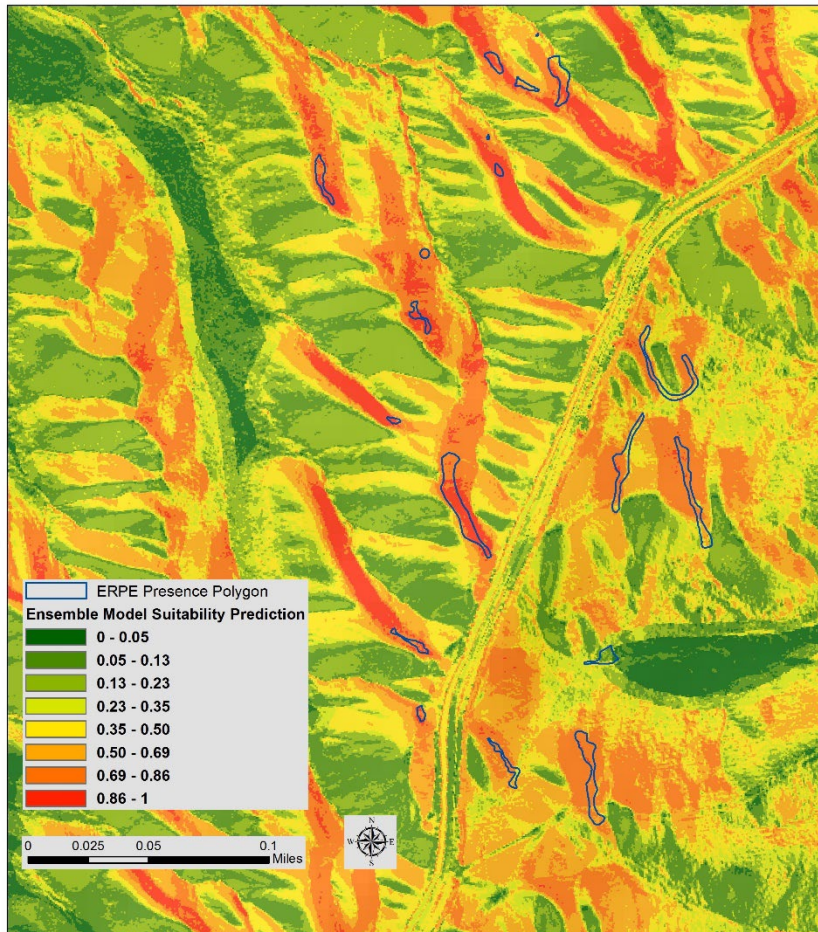


Figure 3. Close-up of ensemble model predictions northeast of Olathe, overlain with polygons of mapped habitat.

The models help reveal some characteristics of ERPE's suitable habitat. At points where the ensemble model predicted ERPE presence, for example, median northness was 0.56, with interquartile range (IQR) from -0.13 to 0.88. Of all points where ERPE presence was predicted, 72% were on north-facing slopes. Northness at these points was significantly higher ($p < 0.0001$)

than at points where presence was not predicted (Figure 4). At points where ERPE presence was not predicted, median northness was 0.12, with IQR from -0.62 to 0.74.

Eastness was also significantly higher at points where ERPE was predicted ($p < 0.0001$). Median eastness where ERPE was predicted was 0.26, with interquartile range from -0.55 to 0.81. Where presence was not predicted, median eastness was -0.34, with IQR from -0.84 to 0.47 (Figure 4).

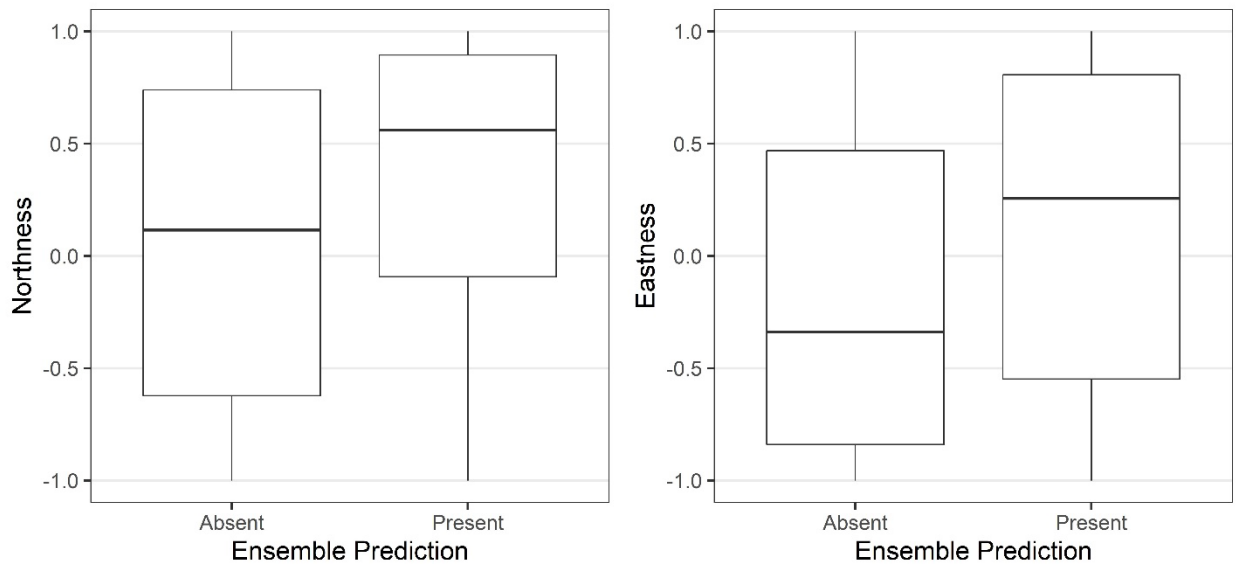


Figure 4. Northness and eastness at points, split by the ensemble model's prediction.

ERPE presence fell in a narrow range of elevation and precipitation. Median elevation was 6092 feet, with IQR from 5491 to 6185. Similarly, median precipitation was 12.4 inches where ERPE presence was predicted, with IQR from 9.3 to 12.5 inches. Median slope where ERPE presence was predicted was 5.6 degrees, with IQR from 3.5 to 10.0 degrees.

Unsurprisingly, ERPE presence was very strongly associated with the geology covariate, which in our model was distance from the Smoky Hill member of the Mancos Shale. Of the

points where ERPE presence was predicted, 89.9% were within this formation or less than one meter away. This leaves 3.1% which were located from 1 to 10 meters from the formation, and 7.0% from 10 to 100 meters.

Conclusion

Our model predicted presence of *Eriogonum pelinophilum* with very high accuracy, and identified areas of high habitat suitability where we have no records of the species' occurrence. These are high priority areas to survey for ERPE occurrence. Many areas that were mapped as high suitability areas may fall on private land or areas that have been disturbed. A next step is to more deeply scrutinize the high probability areas to eliminate these locations where the species may no longer occur, and determine the highest probability habitat on Bureau of Land Management lands. The model also helped identify characteristics of the ERPE's habitat, and suggests it typically grows on gentle north to east-facing slopes. This further focuses the areas of likely habitat of the species.

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Habitat Condition Index (HCI) for clay-loving buckwheat (*Eriogonum pelinophilum*)

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Habitat Condition Index –

The Habitat Condition Index (HCI) is a tool used to evaluate the current condition of clay-loving buckwheat (*Eriogonum pelinophilum*) habitat. The result of the composite index is a single score from the aggregated rankings of three biologically relevant condition categories: habitat quality, habitat type, and habitat size. The HCI results in a habitat condition score (high, moderate, or low) for each of the three clay-loving buckwheat Analytical Units (AUs).

Based on the ranking procedure, which is described in detail below, the Delta AU received a habitat condition score of Low, the Selig AU received a habitat condition score of Moderate, and the Fairview AU received a habitat condition score of High (Table 1).

Table 1. Final habitat condition outcomes for the three clay-loving buckwheat AUs

AU	Quality	Type	Size	HCI score
Delta	Moderate	Low	Low	Low
Selig	Moderate	Moderate	Moderate	Moderate
Fairview	Moderate	High	High	High

Quality –

Habitat quality was determined for each of the three clay-loving buckwheat AUs using opensource data from the Rangeland Analysis Platform (RAP). The RAP interprets a series of indicators of rangeland health by comparing an array of sampled field plots to Landsat imagery. Using cloud computing the RAP predicts estimates of various indicators at a 30m resolution across the landscape. Due to a lack of representative habitat assessment data, such as Assessment, Inventory, and Monitoring (AIM) or Landscape Management Framework (LMF), the RAP provides the best means of approximating current indicators of rangeland health across management boundaries within clay-loving buckwheat habitat.

Habitat quality was evaluated using three standard indicators of rangeland health: percent annual forbs and grasses cover (proxy for invasive species cover), percent bare ground cover, and percent foliar cover. Data extraction was stratified by federal and state management (BLM, BOR, and State) and private for each of the three AUs. Dividing the landscape by ownership offers insight into whether meaningful differences occur between public and private landscapes within the range of the species.

Quality ranking classification –

The ranking classification for percent annual grasses and forbs follows standard land health guidance relative to arid western shrublands. Areas with a lower percentage of annual grasses

and forbs are considered better since these annuals are generally non-native and/or invasive species and typically associate themselves with disturbed or otherwise degraded landscapes. Therefore, any AU with <4% annual grass and forb cover ranked High, any AU with 4-10% annual grass and forb cover ranked Moderate, and any AU with >10% annual grasses and forb cover rank Low (Figure 1).

Due to the lack of an understanding of reference conditions across the variety of ecological sites present within the clay-loving buckwheat AUs that the RAP reports on, the ranking classifications for bare ground and foliar cover were defined based on the range of variability present within the RAP outputs for each indicator. To derive the mean and 80% confidence intervals the 21-year average (2000 - 2021) was used for the three indicator outputs (Figures 1-3). AU outcomes within one standard deviation of the mean ranked High, AU outcomes within two standard deviations of the mean ranked Moderate, and AU outcomes greater than two standard deviations ranked Low.

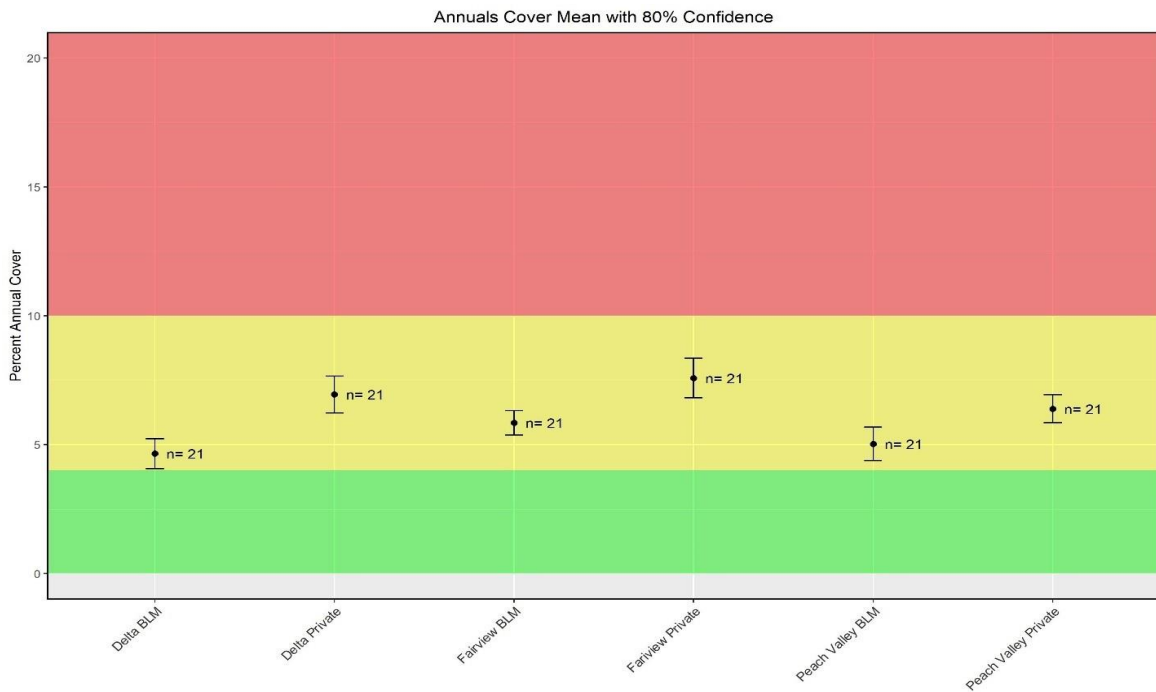


Figure 1. Percent annual forbs and grasses: “high” = <4% annual forb and grass cover, “moderate” = 4-10% annual forb and grass cover, and “low” = >10% annual forb and grass cover.

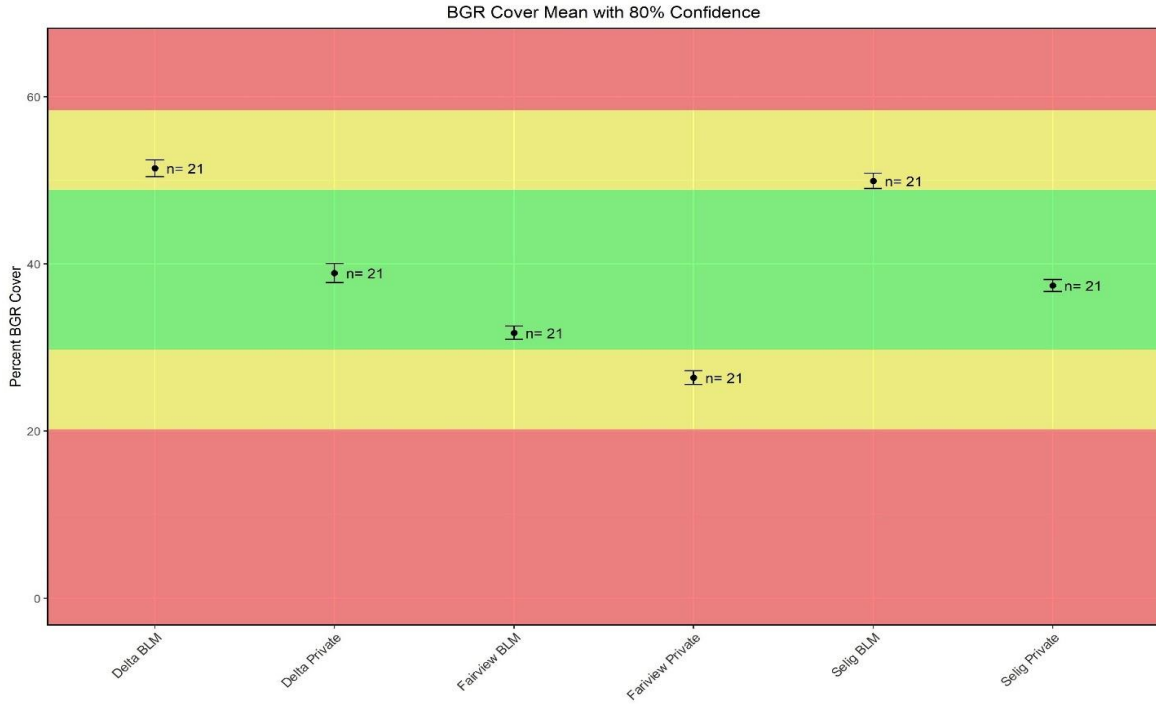


Figure 2. Percent bare ground: “high”= w/in 1 standard deviation of the mean (30-48% bare ground), “moderate” = between 1 and 2 standard deviations of the mean (20-30% and 48-58% bare ground, and “low”= greater than 2 standard deviations of the mean (<20% and >58% bare ground).

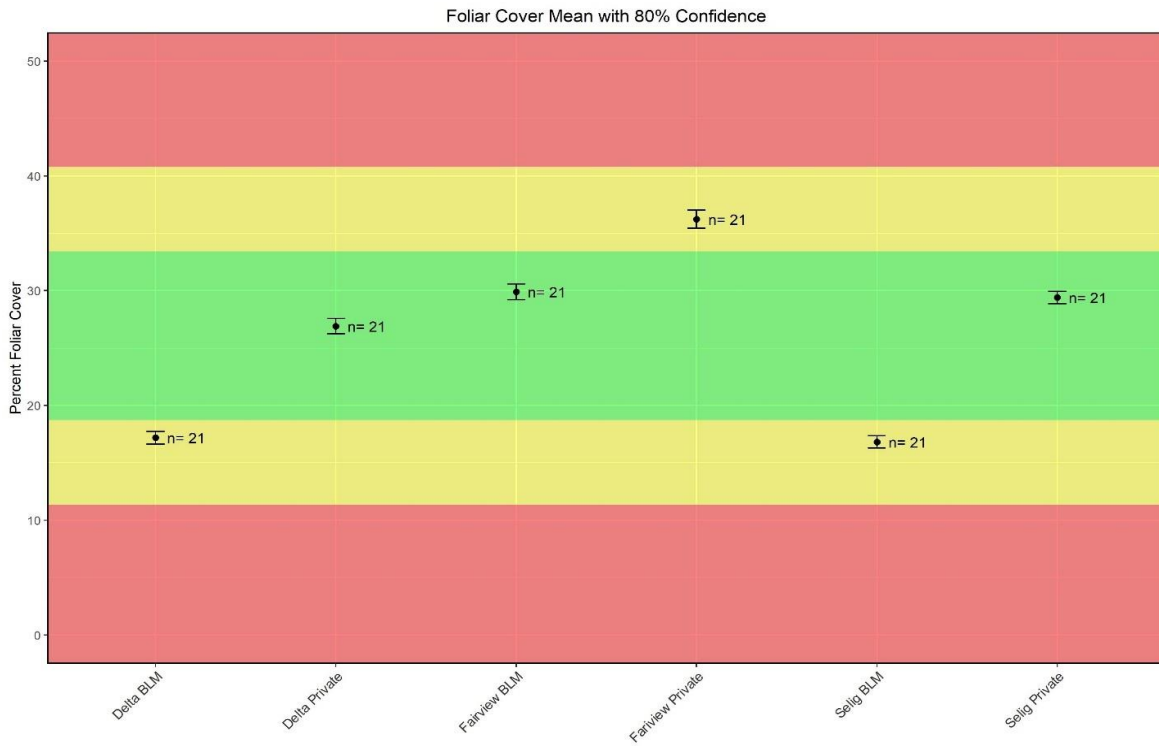


Figure 3. Percent foliar cover: “high”= w/in 1 standard deviation of the mean (19-34% foliar cover), “moderate”= between 1 and 2 standard deviations of the mean (11-19% and 33-41% foliar cover), and “low”= greater than 2 standard deviations of the mean (<11% and >41 foliar cover).

Habitat quality scoring outcomes –

All three habitat quality indicators were weighted proportionately and ranked 3 = high, 2 = moderate, 1 = low. The final AU habitat quality score was derived from the average of the six values per AU (3 BLM and 3 private). All three AUs ranked Moderate in terms of habitat quality. Private lands in the Delta and Selig AUs ranked higher than BLM lands in terms of percent bare ground cover and percent foliar cover. Conversely, BLM lands in the Fairview AU ranked higher than the private based on the same two indicators (Table 2).

Table 2. Habitat quality scoring outcomes and thresholds

AU		Annual grass and forb cover	Bare ground cover	Foliar cover	Score
Delta	private	2	3	3	2.33
	BLM	2	2	2	
Selig	private	2	3	3	2.33
	BLM	2	2	2	
Fairview	private	2	2	2	2.33
	BLM	2	3	3	
High		2.34 - 3			
Moderate		1.67 - 2.33			
Low		1 - 1.66			

Type –

Habitat type was determined for each of the three AUs using outputs from the predictive habitat model for clay-loving buckwheat (Zimmer and Holsinger 2022). The ensemble model employed a series of relevant bioclimatic and geographic variables including high resolution geologic data and lidar to predict habitat suitability, or probability of clay-loving buckwheat occupation, at a fine scale across the species range. The array of outputs from the model range from <0.001 to 0.997. Values of >0.5 (greater than 50%) coincided with over 90% of mapped clay-loving buckwheat occurrences and were chosen to represent “suitable clay-loving buckwheat habitat”. Values of <0.5 are considered unsuitable.

The habitat type score was evaluated for each AU based on two indicators 1. the raw number of acres considered suitable clay-loving buckwheat habitat (>0.5) and 2. the proportion of suitable clay-loving buckwheat acreage that occurs on federal or state administered land (BLM, BOR, State) compared to private ownership. These classifications were based on the fact the ESA protections and assurances are only extended to plants occurring on public lands or those private lands where there is designated critical habitat or some other federal nexus. Therefore,

areas with a higher proportion of suitable habitat occurring on public lands were considered better for the conservation of the species.

Type ranking classification –

For the raw number of acres of suitable clay-loving buckwheat habitat any AU containing >10,000 acres of suitable habitat ranked High based on >0.5 output from the habitat model, any AU containing 1,000-10,000 acres of suitable habitat ranked Moderate, and any AU containing <1,000 acres of suitable habitat ranked Low.

For the proportion of federally managed to privately managed acres of suitable clay-loving buckwheat habitat any AU with >50% of the suitable clay-loving buckwheat habitat occurring on federal or state administered lands ranked High, any AU with 40-50% of the suitable clay-loving buckwheat habitat occurring on federal or state administered lands ranked Moderate, any AU with <40% of the suitable clay-loving buckwheat habitat occurring on federal or state administered lands ranked Low.

Habitat type scoring outcomes –

Both type indicators (raw # of acres of suitable clay-loving buckwheat habitat (>0.5) and proportion of federal state administration to private ownership of suitable clay-loving buckwheat habitat) were weighted proportionately and ranked 3 = High, 2 = Moderate, 1 = Low. The final AU scoring outcomes were derived from the average of the two indicator values. All three AUs ranked as moderate for raw number of acres of suitable clay-loving buckwheat habitat (1,000 – 10,000 acres). In terms of the proportion of federal and state administration to private ownership of suitable clay-loving buckwheat habitat Delta ranked low (38%), Selig ranked moderate (42%), and Fairview ranked high (54%) (Table 3).

Table 3. Habitat type scoring outcomes and thresholds

AU	Proportion BLM/PRV	Raw acres	Score
Delta	1	2	1.50
Selig	2	2	2.00
Fairview	3	2	2.50
High	2.34 - 3		
Moderate	1.67 - 2.33		
Low	1 - 1.66		

Size –

Perhaps the most important indicator of habitat condition is abundance of clay-loving buckwheat plants. The size condition category relies on abundance as a proxy for size (abundance = density x area) and was determined for each of the three AUs using two indicators 1. the raw number of acres of mapped occupied clay-loving buckwheat habitat and 2. the average density of sampled occupied sites based on range wide population monitoring.

Occupied acreage was determined using CNHP and BLM spatial data and stratified by BLM and private management. Individual points not contained within polygons were buffered by 3.59m to provide a conservative measure of area. The number of acres and polygons per AU are reported in Table 4. Density values are the product of the average density of the six long-term clay-loving buckwheat monitoring sites (Delta AU = powerline, Selig AU = model airplane club 1 and model airplane club 2, and Fairview AU = Fairview 1, Fairview 2, and Wacker Ranch). Individual density values and their average are reported in Table 5.

Table 4. The number of mapped clay-loving buckwheat polygons and their total area (acres) for BLM and private lands in the three AUs

AU	Ownership	# polygons	Acres
Delta	AU Total	68	118.7
	BLM	21	1.6
	PRV	47	117.2
Fairview	AU Total	81	229.4
	BLM	57	130.2
	PRV	24	99.2
Selig	AU Total	154	166.5
	BLM	126	15.2
	PRV	28	151.3
Grand Total		303	514.6

Table 5. Average plant densities per monitoring site and year

AU	plot (u)	Macroplot density (du)										mean
		2013	2014	2015	2016	2017	2018	2019	2020	2021		
Delta	Powerline	0.47	0.48	0.52	0.57	0.49	0.50	0.28	0.29	0.26		0.43
Selig	MAC Inside	1.02	1.03	1.09	1.07	1.00	1.06	0.31	0.41	0.29		0.81
	MAC Outside	1.57	1.51	1.62	1.35	1.31	1.39	0.34	0.52	0.32		1.10
Fairview	Fairview 1	3.02	3.31	3.55	4.86	3.46	2.81	2.00	1.93	1.61		2.95
	Fairview 2	4.32	4.44	5.14	6.54	4.43	4.04	3.07	2.79	2.65		4.16
	Wacker Ranch					6.09	5.71	4.84	3.31	2.44		4.48

Size ranking classification –

For the raw number of acres of occupied clay-loving buckwheat habitat any AU containing >100 acres ranked High, any AU containing 20-100 acres ranked Moderate, and any AU containing <20 acres ranked Low.

For the average density of population monitoring sites across sampling years any AU with an average plant density of >2 clay-loving buckwheat plants/m² ranked High, any AU with an

average plant density of 0.5-2 clay-loving buckwheat plants/m² ranked Moderate, and any AU with an average plant density of <0.5 clay-loving buckwheat plants/m² ranked Low.

Habitat size scoring outcomes –

Both habitat size indicators (acres of occupation and plant density) were weighted proportionately and ranked 3 = High, 2 = Moderate, and 1 = Low. Acres of occupation was divided by BLM and private lands, therefore the maximum score either ownership type could receive was 1.5, for a minimum AU score of 1 and a maximum of 3. The final AU scoring outcomes were derived from the average of the three indicator values.

In terms of mean plant density, the Delta AU ranked Low having an average of 0.43 plants/m² over the duration of monitoring, the Selig AU ranked Moderate with an average of 0.95 plants/m² over the duration of monitoring, and the Fairview AU ranked High with an average of 3.86 plants/m² over the duration of monitoring.

For acres of occupation, both the Delta and Selig AUs ranked High for private land having >100 acres of mapped occupied clay-loving buckwheat habitat while BLM lands ranked Low with <20 acres of mapped occupied clay-loving buckwheat habitat. In the Fairview AU BLM ranked High and private ranked Moderate. Final scoring outcomes for the size category are Low for the Delta AU, Moderate for the Selig AU, and High for the Fairview AU (Table 6).

Table 6. Habitat size scoring outcomes and thresholds

AU		Acres of occupation	Density	Score
Delta	private	1.5	1	1.00
	BLM	0.5		
Selig	private	1.5	2	1.33
	BLM	0.5		
Fairview	private	1	3	1.83
	BLM	1.5		
High		1.56 - 2.00		
Moderate		1.12 - 1.55		
Low		0.67 - 1.11		

Final HCI scoring outcomes –

The AU scoring outcomes for quality, type, and size were combined to reach a final habitat condition score. Each of the three categories was weighted proportionately 3 = High, 2 = Moderate, 1 = Low. The final habitat condition score was derived for each AU based on the average of the three categories (Table 7).

The Delta AU received a habitat condition score of Low, the Selig AU received a habitat condition score of Moderate, and the Fairview AU received a habitat condition score of High.

Table 7. Habitat condition scoring outcomes and thresholds

AU	Quality	Type	Size	HCI score
Delta	2.00	1.00	1.00	1.33
Selig	2.00	2.00	2.00	2.00
Fairview	2.00	3.00	3.00	2.67
High	2.34 - 3			
Moderate	1.67 - 2.33			
Low	1 - 1.66			