Climate Change Vulnerability Index Report

Pellaea breweri (Brewer's cliffbrake)

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Assessor: Walter Fertig, WA Natural Heritage Program

Geographic Area: Washington Heritage Rank: G5/S2

Index Result: Moderately Vulnerable Confidence: Very High

Climate Change Vulnerability Index Scores

Section A: Local Climate	**Severity**	**Scope (% of range)**
1. Temperature Severity	>6.0° F (3.3°C) warmer	0
	5.6-6.0° F (3.2-3.3°C) warmer	0
	5.0-5.5° F (2.8-3.1°C) warmer	0
	4.5-5.0° F (2.5-2.7°C) warmer	0
	3.9-4.4° F (2.2-2.4°C) warmer	84.6
	<3.9° F (2.2°C) warmer	15.4
2. Hamon AET:PET moisture	< -0.119	0
	-0.097 to -0.119	46.2
	-0.074 to -0.096	53.8
	-0.051 to -0.073	0
	-0.028 to -0.050	0
	>-0.028	0
Section B: Indirect Exposure to Climate Change		**Effect on Vulnerability**
1. Sea level rise		Neutral
2a. Distribution relative to natural barriers		Somewhat Increase
2b. Distribution relative to anthropogenic barriers		Neutral
3. Impacts from climate change mitigation		Neutral
Section C: Sensitivity and Adaptive Capacity		
1. Dispersal and movements		Somewhat Increase
2ai Change in historical thermal niche		Somewhat Increase
2aii. Change in physiological thermal niche		Somewhat Increase
2bi. Changes in historical hydrological niche		Neutral
2bii. Changes in physiological hydrological niche		Somewhat Increase
2c. Dependence on specific disturbance regime		Neutral
2d. Dependence on ice or snow-covered habitats		Somewhat Increase
3. Restricted to uncommon landscape/geological features		Neutral
4a. Dependence on others species to generate required habitat		Neutral
4b. Dietary versatility		Not Applicable
4c. Pollinator versatility		Not Applicable
4d. Dependence on other species for propagule dispersal		Neutral
4e. Sensitivity to pathogens or natural enemies		Neutral
4f. Sensitivity to competition from native or non-native species		Somewhat Increase
4g. Forms part of an interspecific interaction not covered above		Neutral
5a. Measured genetic diversity		Unknown

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

Section A: Exposure to Local Climate Change

A1. Temperature: Eleven of the 13 confirmed occurrences of *Pellaea breweri* in Washington (84.6%) occur in areas with a projected temperature increase of 3.9-4.4˚ F (Figure 1). Two other

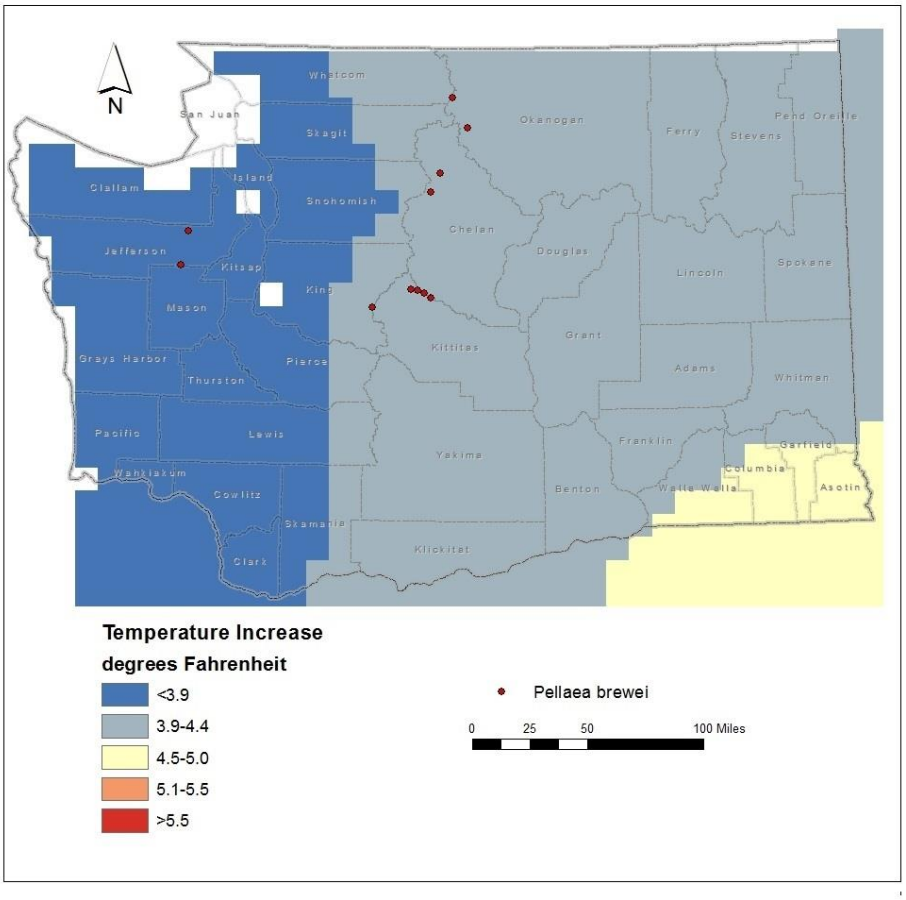

Figure 1. Exposure of *Pellaea breweri* occurrences in Washington to projected local temperature change. Base map layers from www.natureserve.org/ccvi

populations (15.4%) are from areas with a projected temperature increase of < 3.9˚ F. A report from Stevens County has been excluded because it is a misidentification.

A2. Hamon AET:PET Moisture Metric: Seven of the 13 occurrences (53.8%) of *Pellaea breweri* in Washington are found in areas with a projected decrease in available moisture (as measured by the ratio of actual to potential evapotranspiration) in the range of -0.074 to -0.096 (Figure 2). Six other populations (46.2%) are from areas with a predicted decrease of -0.097 to -0.119.

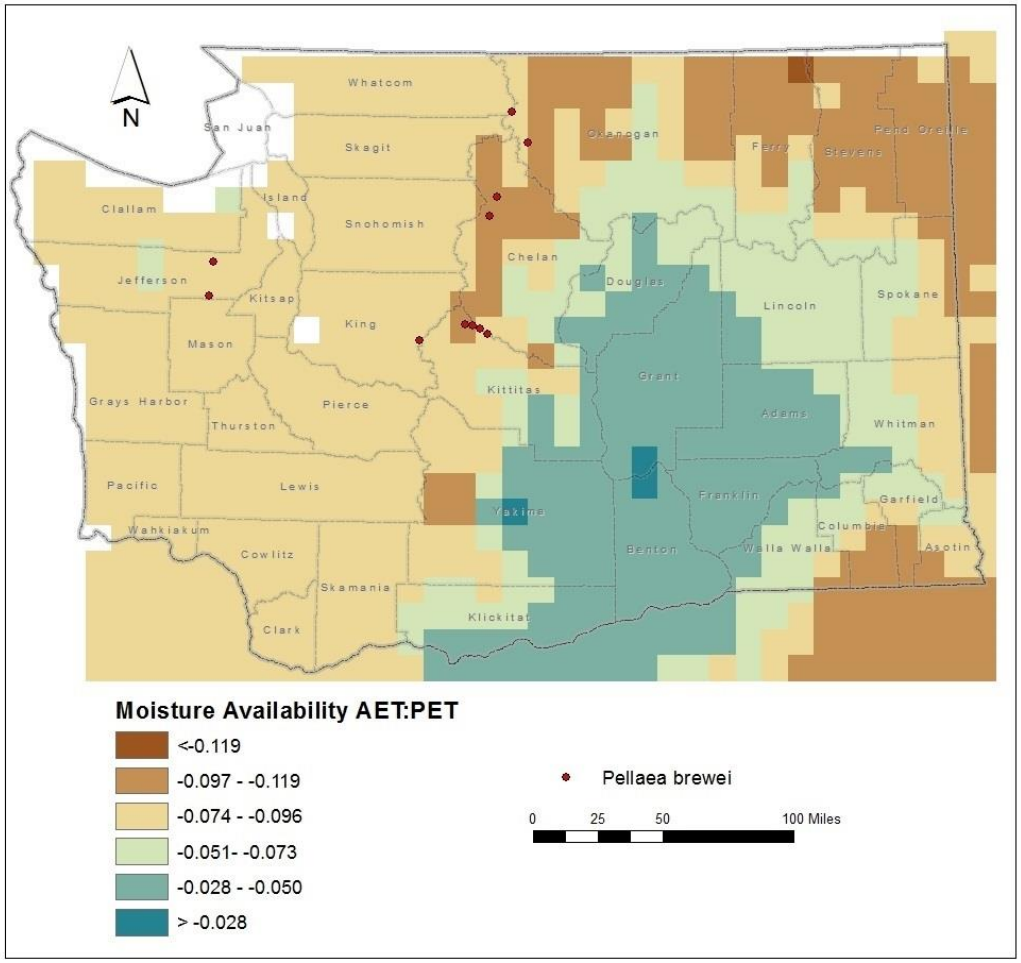

Figure 2. Exposure of *Pellaea breweri* occurrences in Washington to projected moisture availability (based on ratio of actual to predicted evapotranspiration). Base map layers from www.natureserve.org/ccvi

Section B. Indirect Exposure to Climate Change

B1. Exposure to sea level rise: Neutral.
Washington occurrences of *Pellaea breweri* are found at 4700-6700 feet (1430-2040 m) and would not be inundated by projected sea level rise.

B2a. Natural barriers: Somewhat Increase.
In Washington, *Pellaea breweri* occurs in crevices and ledges of cliffs and talus slopes in glacial cirques and openings in montane to subalpine forests. It occurs on a variety of substrates, including basalt, sandstone, serpentine, granite, and marble (and limestone elsewhere in its range). Populations are often on southerly exposures but in shady microsites (Camp and Gamon 2011; Washington Natural Heritage Program 2021). These habitats are part of the North Pacific Alpine & Subalpine Bedrock & Scree and Rocky Mountain Alpine Bedrock & Scree ecological systems (Rocchio and Crawford 2015). Populations are separated by 1.3-102 miles (1.6-164 km) of unoccupied or unsuitable habitat.

B2b. Anthropogenic barriers: Neutral.
Most populations of *Pellaea breweri* in Washington are found on National Park or Forest Service Wilderness lands with relatively few direct human impacts to negatively affect dispersal.

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

Section C: Sensitive and Adaptive Capacity

C1. Dispersal and movements: Somewhat Increase.
Pellaea breweri, like other ferns and fern-allies, has a complex life cycle involving alternation of two distinct growth forms: the familiar sporophyte phase and a much-reduced gametophyte phase. Sporophyte plants produce large numbers of tiny, seed-like spores that are capable of long-distance dispersal by wind. Spores germinate to form gametophyte plants which reproduce sexually by gametes (sessile eggs retained within the plant and motile sperm that require moist surfaces to travel very short distances for fertilization). Sporophyte plants are produced from fertilized eggs within their parent gametophyte plant, and thus are incapable of further dispersal. Overall, dispersal by spores is not limiting, but the survival of sporophyte plants is strongly tied to gametophytes reaching and persisting in suitable microhabitats. The dependence on proper conditions for gametophyte survival makes ferns more vulnerable to dispersal bottlenecks.

C2ai. Historical thermal niche: Somewhat Increase.
Figure 3 depicts the distribution of *Pellaea breweri* in Washington relative to mean seasonal temperature variation for the period from 1951-2006 ("historical thermal niche"). Eight of the 13 occurrences in the state (61.5%) are found in areas that have experienced slightly lower than average variation in temperature (47.1-57˚F/26.3-31.8˚C) during the past 50 years and are considered at somewhat increased vulnerability to climate change (Young et al. 2016). Three populations (23.1%) have experienced small (37-47˚F/20.8-26.3˚C) temperature variation during the same period and are at increased vulnerability to climate change. Two other

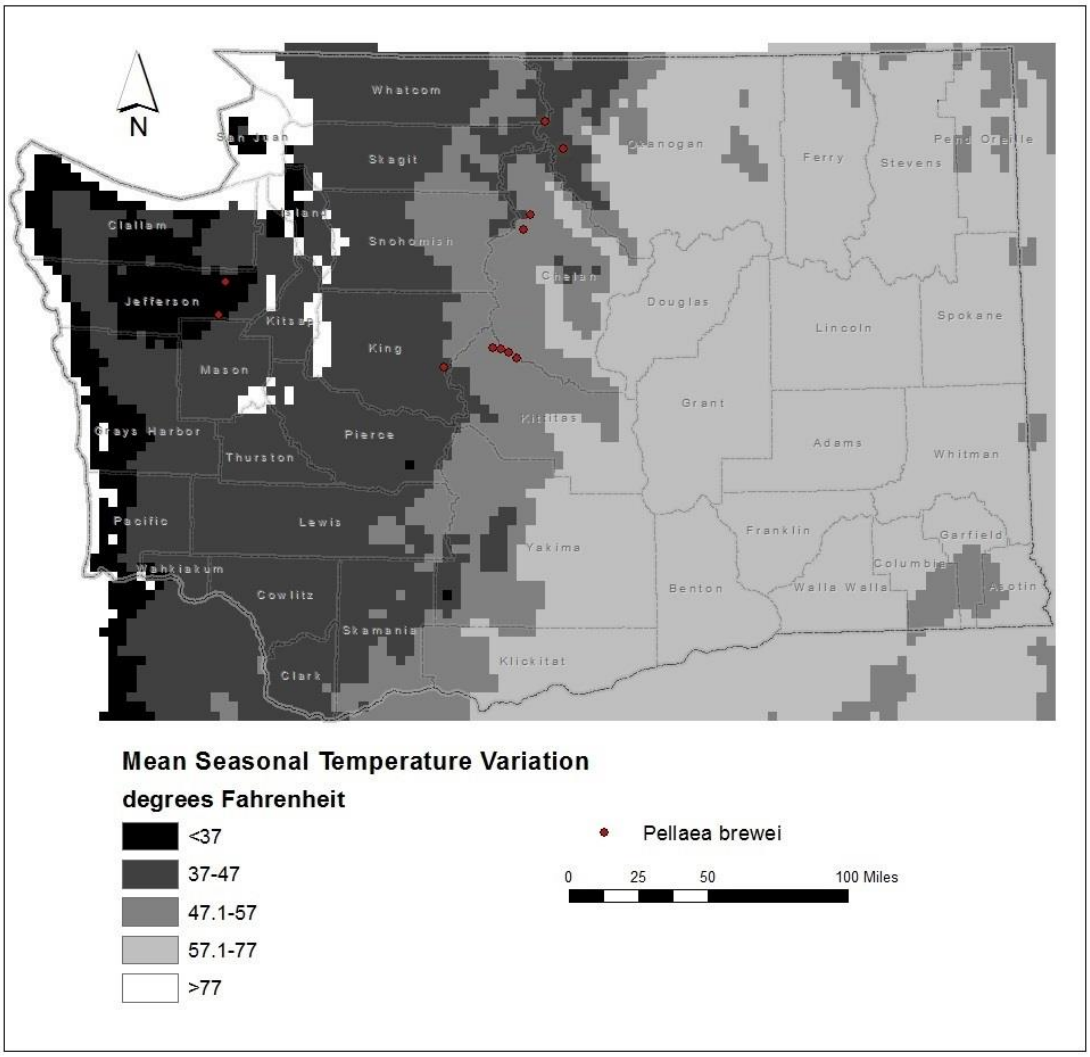

Figure 3. Historical thermal niche (exposure to past temperature variations) of *Pellaea breweri* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

populations (15.4%) from the Olympic Range are from areas with very small (<37˚F/20.8˚C) temperature variation and are at greatly increased vulnerability to climate change (Young et al. 2016).

C2aii. Physiological thermal niche: Somewhat Increase.
The rock outcrop and talus field habitat of *Pellaea breweri* occur at high elevations and may be associated with cold air drainages and would be adversely impacted by warming temperatures (Rocchio and Ramm-Granberg 2017).

C2bi. Historical hydrological niche: Neutral.
All of the populations of *Pellaea breweri* in Washington are found in areas that have experienced greater than average precipitation variation in the past 50 years (>40 inches/1016 mm) (Figure 4). According to Young et al. (2016), these occurrences are neutral for climate change.

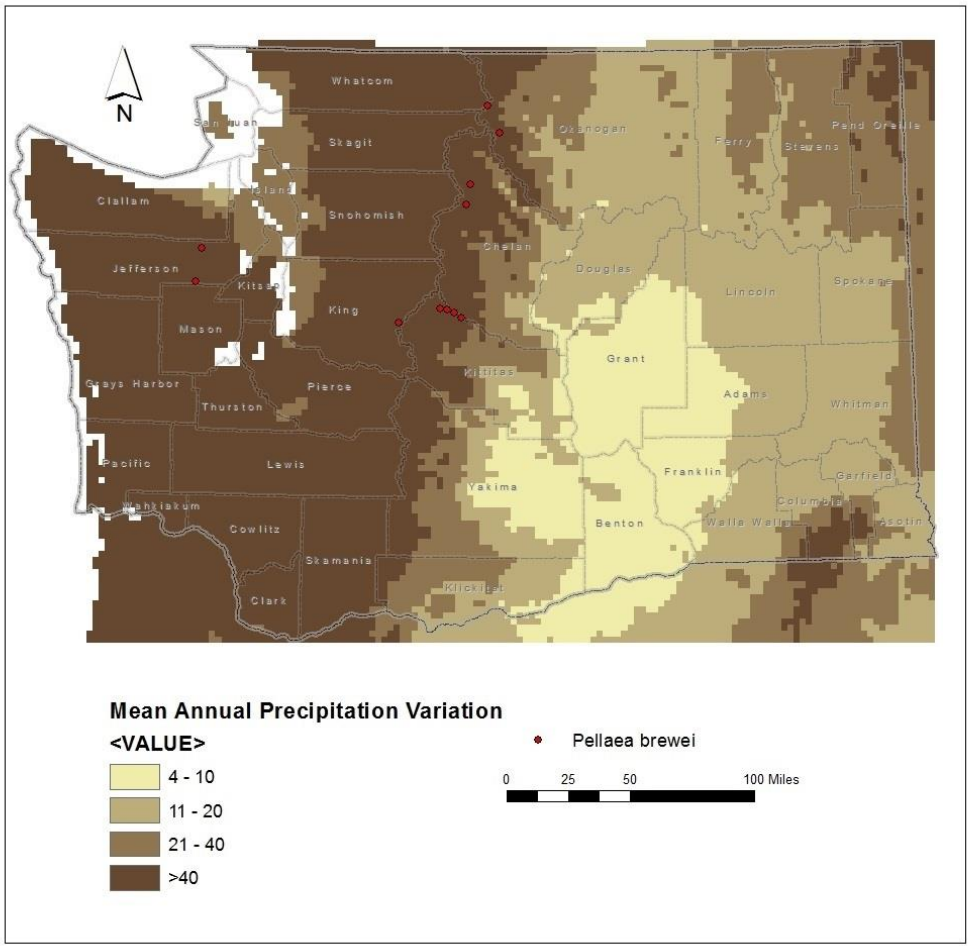

Figure 4. Historical hydrological niche (exposure to past variations in precipitation) of *Pellaea breweri* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2bii. Physiological hydrological niche: Somewhat Increase.
The high elevation rock outcrop habitat of *Pellaea breweri* is not associated with perennial water sources or a high water table. This species is dependent on adequate winter snowfall and spring/summer precipitation. Projected climate change is likely to make these areas warmer and extend the growing season, which over the long term will increase soil production and make

these rocky sites more amenable to invasion by plants from lower elevations (Rocchio and Ramm-Granberg 2017).

C2c. Dependence on a specific disturbance regime: Neutral.
Pellaea breweri occurs on bedrock and boulder fields and is not dependent on periodic disturbance to maintain its habitat.

C2d. Dependence on ice or snow-cover habitats: Somewhat Increase.
In Washington, *Pellaea breweri* is found in montane to lower alpine areas with moderate to high amounts of snow. Changes in the quantity of snow or the timing of snowmelt under future climate scenarios could impact the persistence of this species by making its microhabitat too dry (Rocchio and Ramm-Granberg 2017).

C3. Restricted to uncommon landscape/geological features: Neutral.
Pellaea breweri occurs on a variety of rock outcrops in the Olympic and North Cascades mountains, including serpentine, basalt, sandstone, granite, and marble (Washington Natural Heritage Program 2021). Formations include the Crescent basalt, Naches, Swauk, Ingalls, Goat Creek, and Harts Pass formations (Washington Division of Geology and Earth Resources 2016). Many of these outcrops occur widely in central Washington and the Olympic Peninsula.

C4a. Dependence on other species to generate required habitat: Neutral.
The rock outcrop and talus habitat occupied by *Pellaea breweri* is maintained largely by natural abiotic conditions.

C4b. Dietary versatility: Not applicable for plants

C4c. Pollinator versatility: Not applicable.
The sporophyte generation of *Pellaea breweri* reproduces by spores and does not require pollinators. The gametophyte phase reproduces by motile sperm that do not require pollinators for assistance.

C4d. Dependence on other species for propagule dispersal: Neutral.
The spores and gametes of *Pellaea breweri* do not require animal species for dispersal.

C4e. Sensitivity to pathogens or natural enemies: Neutral.
Pellaea breweri is not an edible species and is not known to be attacked by pathogens.

C4f. Sensitivity to competition from native or non-native species: Somewhat Increase.
Currently, competition from non-native species is minor, as few introduced plants are adapted to the extreme climatic conditions of alpine and subalpine cliffs and boulder fields. Under future climate change, warmer temperatures could extend the growing season, making these areas more susceptible to invasion by annual introduced species or native perennials adapted to more open and drier sites (Rocchio and Ramm-Granberg 2017).

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

C5a. Measured genetic variation: Unknown.
Data are lacking on the genetic diversity within and between populations of *Pellaea breweri* in Washington. This species is at the northern edge of its range in Washington and so may have lower overall genetic diversity in the state due to inbreeding or founder effects.

C5b. Genetic bottlenecks: Unknown.
Not known.

C5c. Reproductive System: Neutral/Somewhat Increase.
Pellaea breweri is a sexual diploid and does not reproduce by apogamy (Tryon and Britton 1958). Like other ferns, it has a complex life history involving an alternation between diploid spore-producing sporophytes (the familiar form of the species) and minute, gamete-producing haploid gametophytes. While spores are capable of long-distance dispersal, gametes are not and so genetic variability could be constrained in populations at the edge of the species' range, like those in Washington.

C6. Phenological response to changing seasonal and precipitation dynamics: Neutral.
The timing of reproduction in *Pellaea breweri* has not been altered in response to climate change.

Section D: Documented or Modeled Response to Climate Change

D1. Documented response to recent climate change: Neutral.
The distribution of *Pellaea breweri* has not changed significantly in Washington since it was first discovered in the state in 1932.

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

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

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

References

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