Climate Change Vulnerability Index Report

Parnassia kotzebuei (Kotzebue's grass-of-Parnassus)

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Assessor: Walter Fertig, WA Natural Heritage Program

Geographic Area: Washington Heritage Rank: G5/S1

Index Result: Highly Vulnerable Confidence: Very High

Climate Change Vulnerability Index Scores

Section A	**Severity**	**Scope (% of range)**
1. Temperature Severity	>6.0° F (3.3°C) warmer	0
	5.6-6.0° F (3.2-3.3°C) warmer	0
	5.0-5.5° F (2.8-3.1°C) warmer	0
	4.5-5.0° F (2.5-2.7°C) warmer	0
	3.9-4.4° F (2.2-2.4°C) warmer	100
	<3.9° F (2.2°C) warmer	0
2. Hamon AET:PET moisture	< -0.119	0
	-0.097 to -0.119	50
	-0.074 to - 0.096	50
	-0.051 to - 0.073	0
	-0.028 to -0.050	0
	>-0.028	0
Section B		**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		
1. Dispersal and movements		Somewhat Increase
2ai Change in historical thermal niche		Increase
2aii. Change in physiological thermal niche		Greatly 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		Somewhat Increase
4a. Dependence on others species to generate required habitat		Neutral
4b. Dietary versatility		Not Applicable
4c. Pollinator versatility		Neutral
4d. Dependence on other species for propagule dispersal		Neutral
4e. Sensitivity to pathogens or natural enemies		Neutral
4f. Sensitivity to competition from native or non-native species		Somewhat Increase
4g. Forms part of an interspecific interaction not covered above		Neutral
5a. Measured genetic diversity		Unknown
5b. Genetic bottlenecks		Unknown
5c. Reproductive system		Neutral/Somewhat Increase

6. Phenological response to changing seasonal and precipitation dynamics	Somewhat Increase
Section D	
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: All four extant and historical occurrences of *Parnassia kotzebuei* in Washington (100%) occur in areas with a projected temperature increase of 3.9-4.4˚ F (Figure 1).

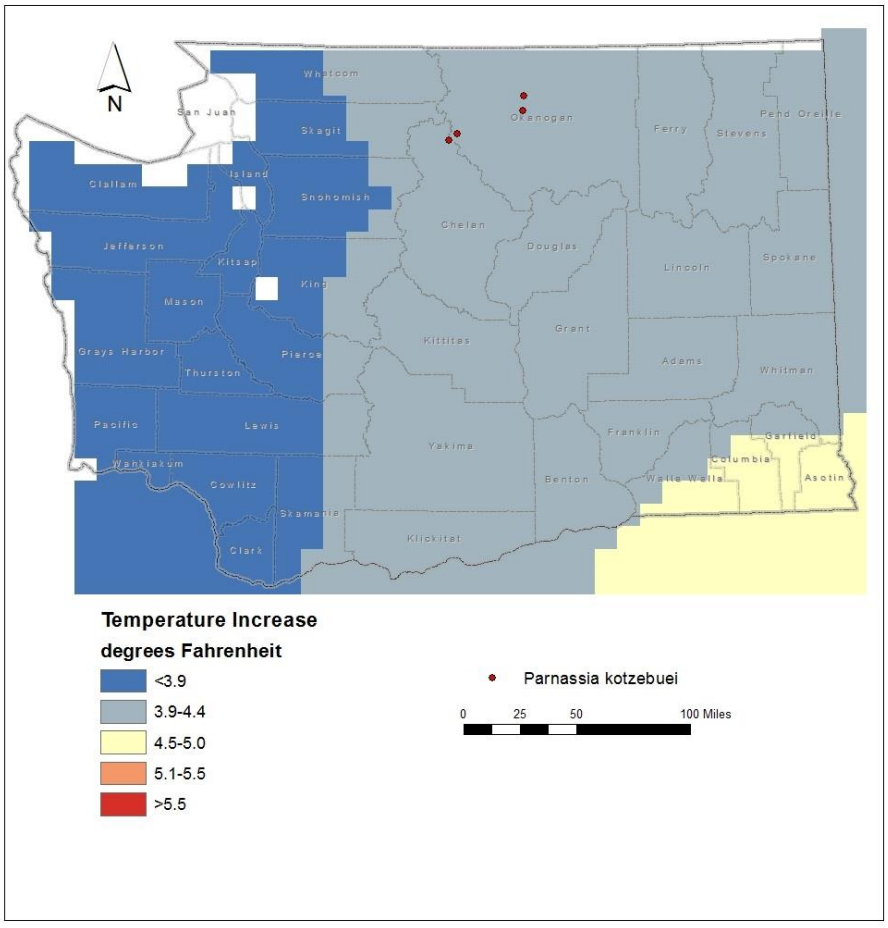

Figure 1. Exposure of *Parnassia kotzebuei* occurrences in Washington to projected local temperature change. Base map layers from www.natureserve.org/ccvi

A2. Hamon AET:PET Moisture Metric: Two of the four occurrences of *Parnassia kotzebuei* (50%) 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 -0.097 to -0.119 (Figure 2). The other 50% of the state's occurrences are in areas with a projected decrease in AET:PET of – 0.074 to – 0.096.

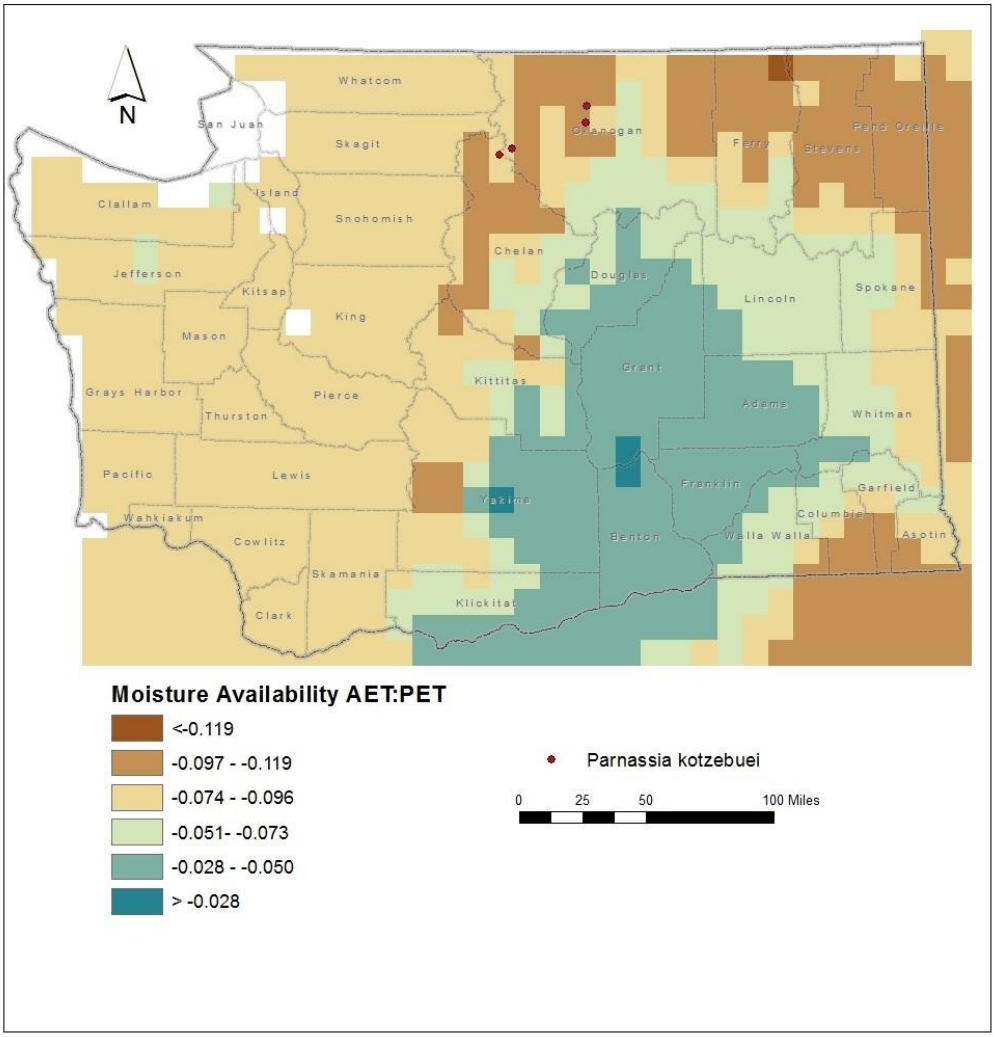

Figure 2. Exposure of *Parnassia kotzebuei* occurrences in Washington to projected moisture availability (based on ratio of actual to predicted evapotranspiration). Base map layers from www.natureserve.org/ccvi

Section B. Indirect Exposure to Climate Change

B1. Exposure to sea level rise: Neutral.
The Washington occurrences of *Parnassia kotzebuei* are found at 4800-6700 feet (1460-2030 m) and would not be inundated by projected sea level rise.

B2a. Natural barriers: Somewhat Increase.
In Washington, *Parnassia kotzebuei* is found on shady, moist, north-facing talus slopes or ledges of granitic or gneiss cliffs with high cover of moss and forbs but without shrubs or trees (Camp and Gamon 2011, Fertig and Kleinknecht 2020). These sites are mostly in the upper subalpine zone. This habitat is a component of the Rocky Mountain Alpine Dwarf Shrubland, Fell-Field, and Turf ecological system (Rocchio and Crawford 2015). Washington occurrences are separated by distances of 4.5-30 miles (7.4-49 km) and extensive areas of unsuitable habitat. The natural patchiness of the habitat creates a barrier for dispersal.

B2b. Anthropogenic barriers: Neutral.
Human impacts in the alpine and subalpine areas of the Okanogan Plateau and North Cascades are limited and do not impose a significant barrier.

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

Section C: Sensitive and Adaptive Capacity

C1. Dispersal and movements: Somewhat Increase.
Parnassia kotzebuei produces fruit capsules and numerous small seeds that lack any physical structures to assist with dissemination by wind or animals. Seeds are dispersed primarily by water, wind, and gravity (Spackman Panjabi and Anderson 2007). Dispersal distances are probably relatively short (less than 1000 m).

C2ai. Historical thermal niche: Increase.
Figure 3 depicts the distribution of *Parnassia kotzebuei* in Washington relative to mean seasonal temperature variation for the period from 1951-2006 ("historical thermal niche"). Two extant occurrences (50%) are found in areas that have experienced small (37-47˚F/20.8-26.3˚C) temperature variation during the past 50 years and are considered at increased vulnerability to climate change. The other occurrences (one extant and one historical) are found in areas that have experienced slightly lower than average (47.1-57˚F/26.3-31.8˚C) temperature change and would be at somewhat increased vulnerability to climate change (Young et al. 2016). Based on the greater number of extant populations being at increased risk, this factor is scored as such for the whole state.

C2aii. Physiological thermal niche: Greatly Increase.
The north-facing subalpine rock ledge habitat of *Parnassia kotzebuei* is strongly correlated with cold air drainage during the growing season and would have greatly increased vulnerability to climate change.

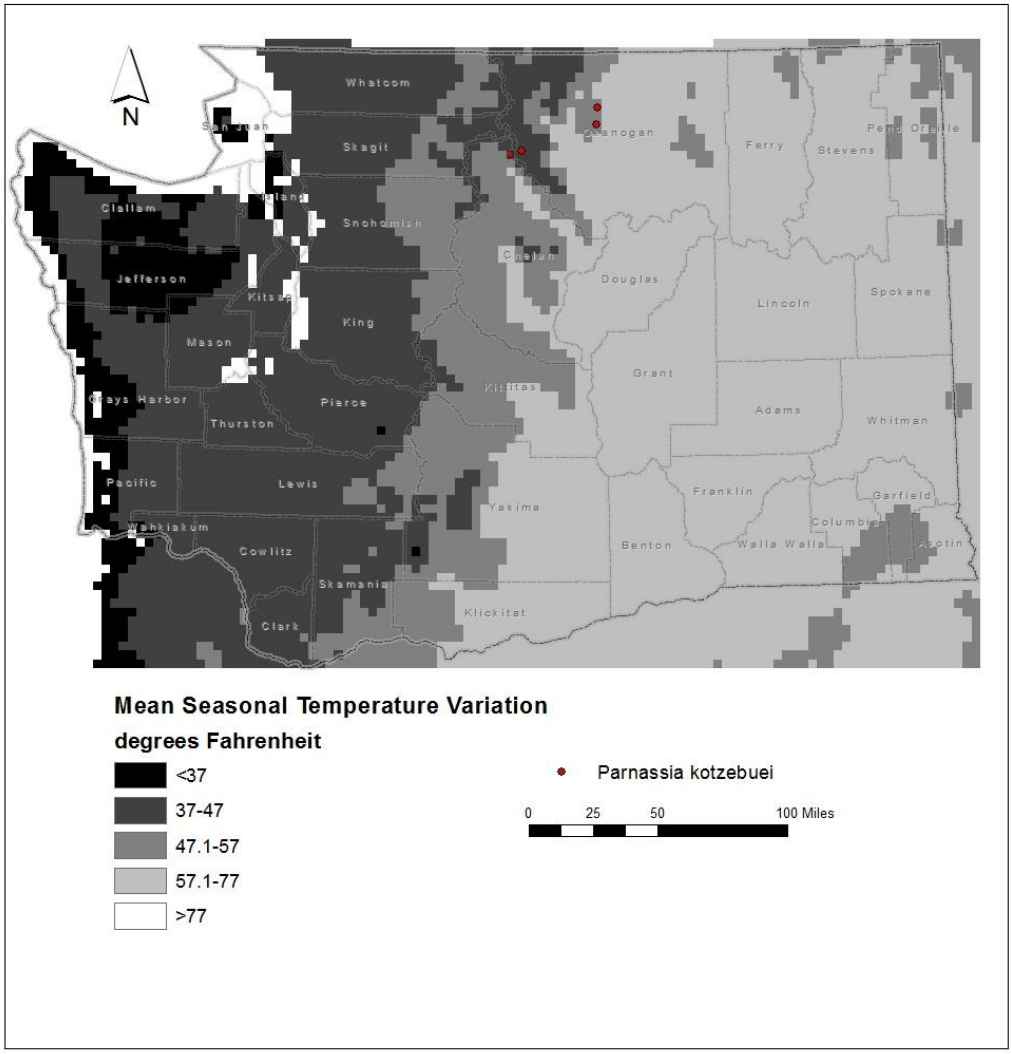

Figure 3. Historical thermal niche (exposure to past temperature variations) of *Parnassia kotzebuei* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2bi. Historical hydrological niche: Neutral.
All four populations of *Parnassia kotzebuei* in Washington (100%) are found in areas that have experienced average or greater than average (>20 inches/5080 mm) precipitation variation over the past 50 years (Figure 4). According to Young et al. (2016), these occurrences are at neutral vulnerability to climate change.

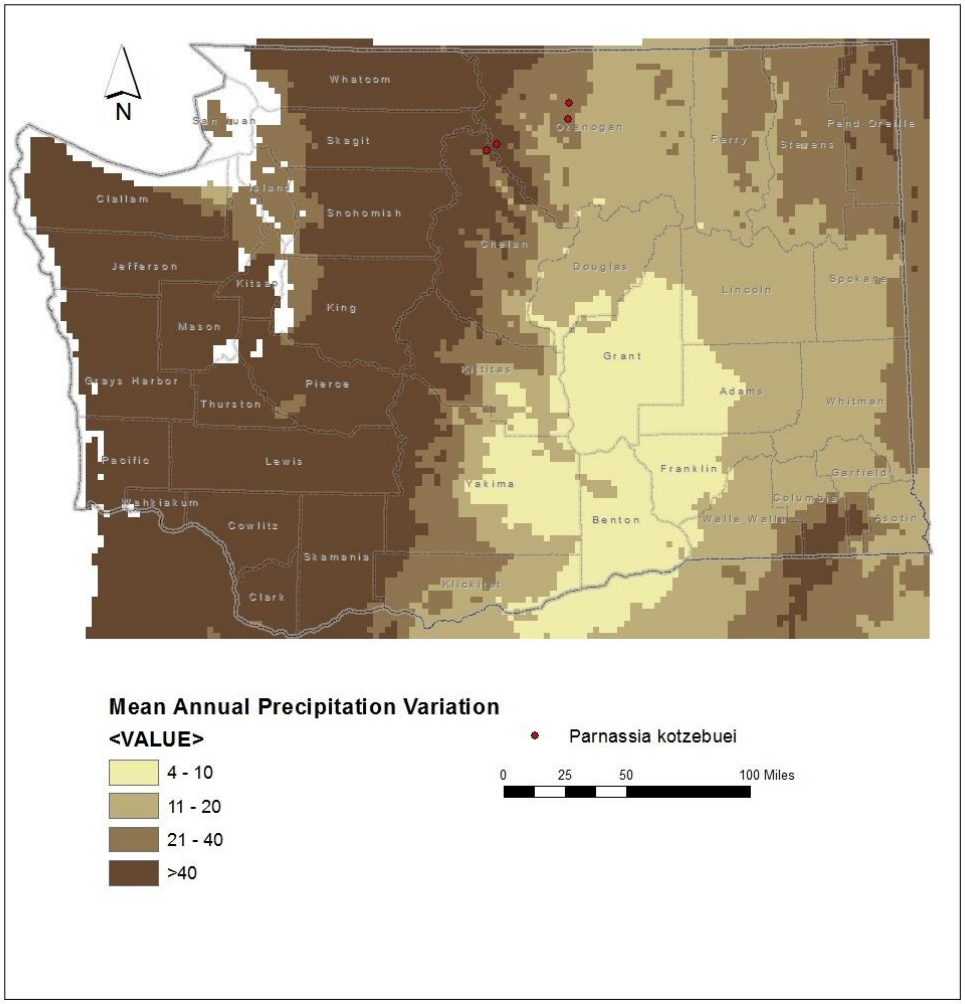

Figure 4. Historical hydrological niche (exposure to past variations in precipitation) of *Parnassia kotzebuei* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2bii. Physiological hydrological niche: Somewhat Increase.
This species is often associated with small seeps that keep the habitat moist year round. The ultimate source of this moisture is precipitation and slow-melting snow. Changes in the amount and timing of precipitation could be detrimental to the habitat of *Parnassia kotzebuei*, allowing shrubs or dry meadow species to displace alpine talus and rock field taxa (Rocchio and Ramm-Granberg 2017). See "Dependence on ice or snow-cover habitats" below.

C2c. Dependence on a specific disturbance regime: Neutral.
Parnassia kotzebuei occurs in alpine rock ledge and scree habitats that are potentially subject to high winds. Other than occasional rock fall, these are largely undisturbed sites at present.

Under future climate change scenarios, these sites could become invaded by tree or shrub species or lower elevation forbs and grasses, resulting in increased soil accumulation, more litter, and enhanced probability of fire (Rocchio and Ramm-Granberg 2017).

C2d. Dependence on ice or snow-cover habitats: Somewhat Increase.
The populations of *Parnassia kotzebuei* in Washington are found in subalpine talus and cliff sites associated with springs and seeps that are derived from late-lying and slow-melting snow for moisture in the growing season. Reduced snowpack due to climate change would lessen the amount of moisture available through runoff (Rocchio and Ramm-Granberg 2017).

C3. Restricted to uncommon landscape/geological features: Somewhat Increase.
Parnassia kotzebuei is found mostly on gneiss talus or cliff ledges on shady, north-facing aspects. Although the geologic substrate is widespread, the combination of rock type, aspect, and moist seeps is uncommon and widely scattered, accounting for the sporadic distribution of this species.

C4a. Dependence on other species to generate required habitat: Neutral
The subalpine talus/cliff habitat occupied by *Parnassia kotzebuei* is maintained by natural abiotic processes and geologic conditions, rather than by interactions with other species.

C4b. Dietary versatility: Not applicable for plants

C4c. Pollinator versatility: Neutral.
The specific pollinators of *Parnassia kotzebuei* are not known, but related species of *Parnassia* are pollinated by flies, bees, and ants (Spackman Panjabi and Anderson 2007). *Parnassia* species are primarily outcrossers and protandrous (pollen ripens on the flower before the stigmas are fertile), but selfing is possible.

C4d. Dependence on other species for propagule dispersal: Neutral.
The seeds off *Parnassia kotzebuei* are primarily passively dispersed by wind, water, or gravity and are not dependent on animal species.

C4e. Sensitivity to pathogens or natural enemies: Neutral.
Impacts from pathogens are not known. The cliff and talus habitat of *Parnassia kotzebuei* are difficult to access for domestic livestock, and threats from grazing are probably very low (Spackman Panjabi and Anderson 2007). Impacts from native grazers are poorly known, but probably low.

C4f. Sensitivity to competition from native or non-native species: Somewhat Increase.
Under present conditions, competition from non-native species is minimal, as few introduced plants are adapted to the harsh environmental conditions of subalpine talus slopes and cliffs. Under projected climate change, competition could increase if lower elevation plant species are able to expand their range into formerly uninhabitable habitat (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.
No genetic data are available for *Parnassia kotzebuei* populations from Washington. Washington populations from Okanogan County have been recognized as a separate variety (var. *pumila*) distinguished from typical var. *kotzebuei* based on the shape of the staminodia (sterile stamens) in the flower and degree of venation of the petals (Hitchcock and Cronquist 1961). Var. *pumila* is not currently recognized as taxonomically distinct (Hitchcock and Cronquist 2018), and the genetic basis of the morphological differences have not been determined, but it is plausible that Washington populations have diverged from those in adjacent states and provinces.

C5b. Genetic bottlenecks: Unknown.

C5c. Reproductive System: Neutral/Somewhat Increase
Parnassia kotzebuei is presumed to be an outcrosser with modest seed dispersal ability. Pollen vectors could potentially travel over 1 km (Spackman Panjabi and Anderson 2007). Populations in Washington and elsewhere in the Rocky Mountains are often widely scattered and isolated, suggesting that gene flow between occurrences is probably low and individual populations may have reduced genetic diversity due to inbreeding depression or the legacy of founder effects.

C6. Phenological response to changing seasonal and precipitation dynamics: Somewhat Increase.
Based on herbarium records from 1978-2007 in the Consortium of Pacific Northwest herbaria website, *Parnassia kotzebuei* populations in Washington flower from late July to early August. Earlier records from 1939-1958 indicate flowering occurring from late June to mid July.

Section D: Documented or Modeled Response to Climate Change

D1. Documented response to recent climate change: Neutral?
Significant changes in the distribution of *Parnassia kotzebuei* have not been documented. One of the four known occurrences in Washington is considered historical (last found in 1980) and may be extirpated, as it has not been relocated in repeat visits by Rare Care volunteers from 2004-2018. The other three occurrences have all been relocated since 2004 (most recently in 2018) (Fertig and Kleinknecht 2020). Whether climate change or other factors are responsible for the loss of one population is not known.

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

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

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

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