Climate Change Vulnerability Index Report

Astragalus australis var. *cottonii* (Cotton's milkvetch)

Date: 1 February 2021

Synonym: *A. australis* var. *olympicus*

Assessor: Walter Fertig, WA Natural Heritage Program

Geographic Area: Washington

Heritage Rank: G5T2Q/S2

Index Result: Highly 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	0
	<3.9° F (2.2°C) warmer	100
2. Hamon AET:PET moisture	< -0.119	0
	-0.097 to -0.119	0
	-0.074 to - 0.096	100
	-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		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		Increase
2ai Change in historical thermal niche		Greatly Increase
2aii. Change in physiological thermal niche		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		Somewhat Increase
4d. Dependence on other species for propagule dispersal		Neutral
4e. Sensitivity to pathogens or natural enemies		Somewhat Increase
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		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/Somewhat Increase
D2. Modeled future (2050) change in population or range size	Increase
D3. Overlap of modeled future (2050) range with current range	Neutral
D4. Occurrence of protected areas in modeled future (2050) distribution	Neutral

Section A: Exposure to Local Climate Change

A1. Temperature: All eight of the occurrences of *Astragalus australis* var. *cottonii* in Washington (100%) are found in areas with a projected temperature increase of < 3.9° F (Figure 1).

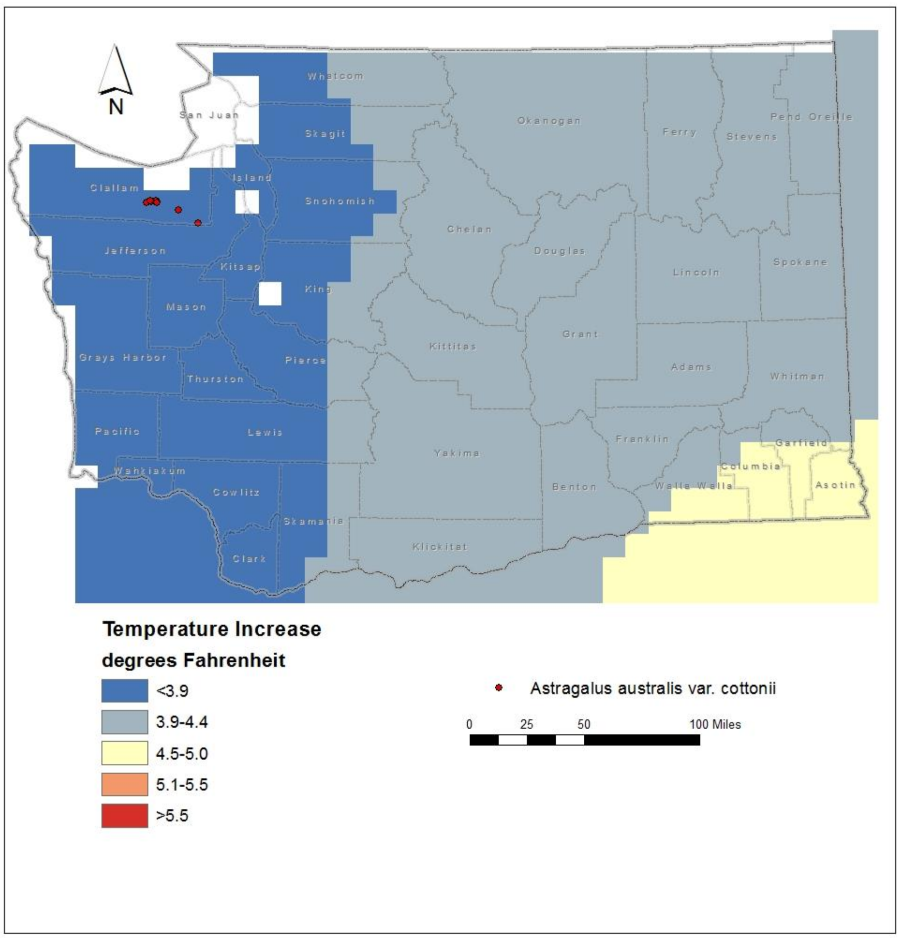

Figure 1. Exposure of *Astragalus australis* var. *cottonii* occurrences in Washington to projected local temperature change. Base map layers from www.natureserve.org/ccvi

A2. Hamon AET:PET Moisture Metric: The eight occurrences of *Astragalus australis* var. *cottonii* (100%) 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).

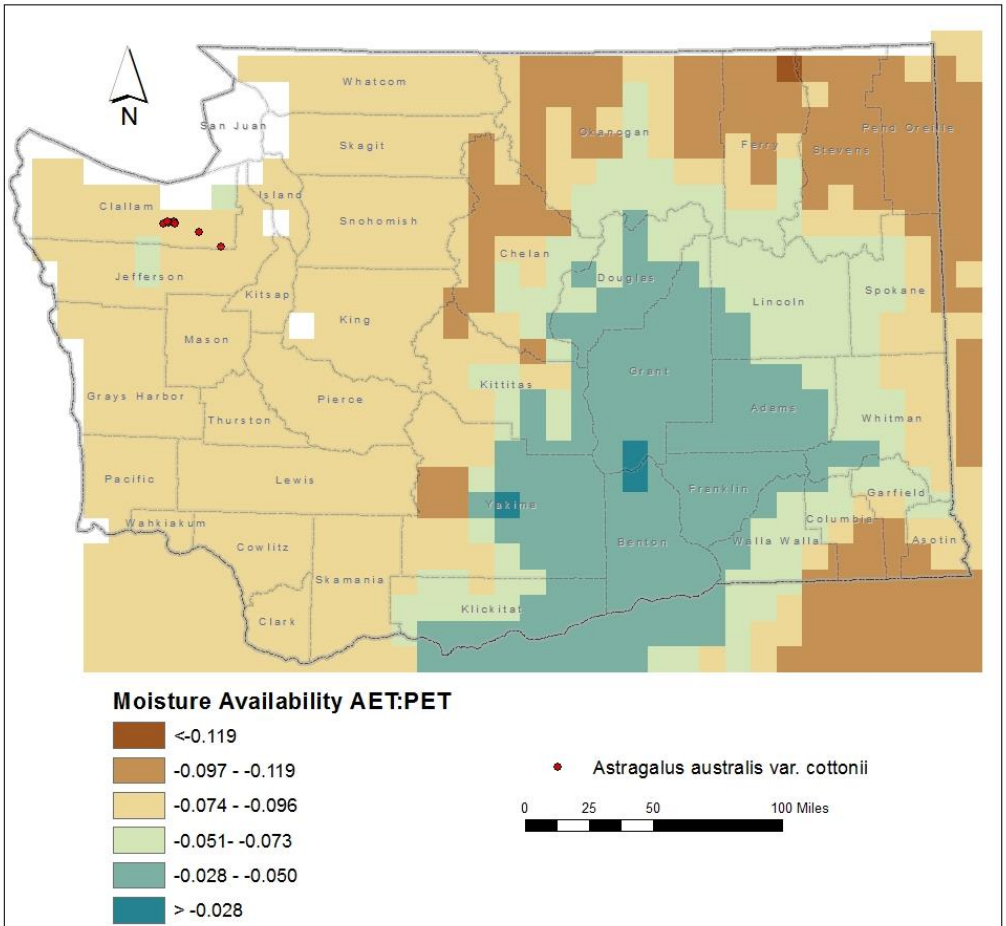

Figure 2. Exposure of *Astragalus australis* var. *cottonii* occurrences in Washington to projected moisture availability (based on ratio of actual to predicted evapotranspiration). Base map layers from www.natureserve.org/ccvi

Section B. Indirect Exposure to Climate Change

B1. Exposure to sea level rise: Neutral.
The Washington occurrences of *Astragalus australis* var. *cottonii* are found at 4800-6000 feet (1460-1830 m) and would not be inundated by projected sea level rise.

B2a. Natural barriers: Increase.
Astragalus australis var. *cottonii* is endemic to the northeastern Olympic Range in Washington, where it is found in sparsely vegetated cushion plant or meadow communities on unstable scree slopes and ridges, often associated with limestone. Most sites are on southern or western exposures (Kaye 1989). Occasionally, plants are associated with rock outcrops, nearly barren slopes, or small clusters of trees. These habitats are a component of the North Pacific Alpine and Subalpine Bedrock and Scree ecological system (Rocchio and Crawford 2015). The entire range of var. *cottonii* is restricted to an area of 10 x 20 miles (6 x 12 km) (Camp and Gamon 2011). Individual occurrences are naturally separated by valleys between alpine ridges, which create a barrier to local dispersal and gene flow. The isolation of the Olympic Range also constrains potential migration to other alpine mountain ranges north and east of the Salish Sea/Puget Sound.

B2b. Anthropogenic barriers: Neutral.
The range of *Astragalus australis* var. *cottonii* in Washington is primarily above treeline in Olympic National Park and Olympic National Forest. These areas have some hiking trails but otherwise the human footprint is small and does not present a significant barrier to dispersal.

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

Section C: Sensitive and Adaptive Capacity

C1. Dispersal and movements: Increase.
Astragalus australis var. *cottonii* plants produce an average of 20 inflorescences, 314 flowers, 56 fruits, and 154 seeds (Kaye 1999). Seeds are released passively from the dry legume pod after it has dehisced from the infructescence. The inflated pods potentially could be transported short distances by high winds. Dispersal distances are probably relatively short (well under 100 m).

C2ai. Historical thermal niche: Greatly Increase.
Figure 3 depicts the distribution of *Astragalus australis* var. *cottonii* in Washington relative to mean seasonal temperature variation for the period from 1951-2006 ("historical thermal niche"). Seven of the eight known occurrences (87.5%) are found in areas that have experienced very small (<37˚F/20.8˚C) temperature variation during the past 50 years and are considered at greatly increased vulnerability to climate change (Young et al. 2016). One other occurrence is from an area with small (37-47˚F/20.8-26.3˚C) temperature variation over the same time period and is at increased vulnerability to climate change.

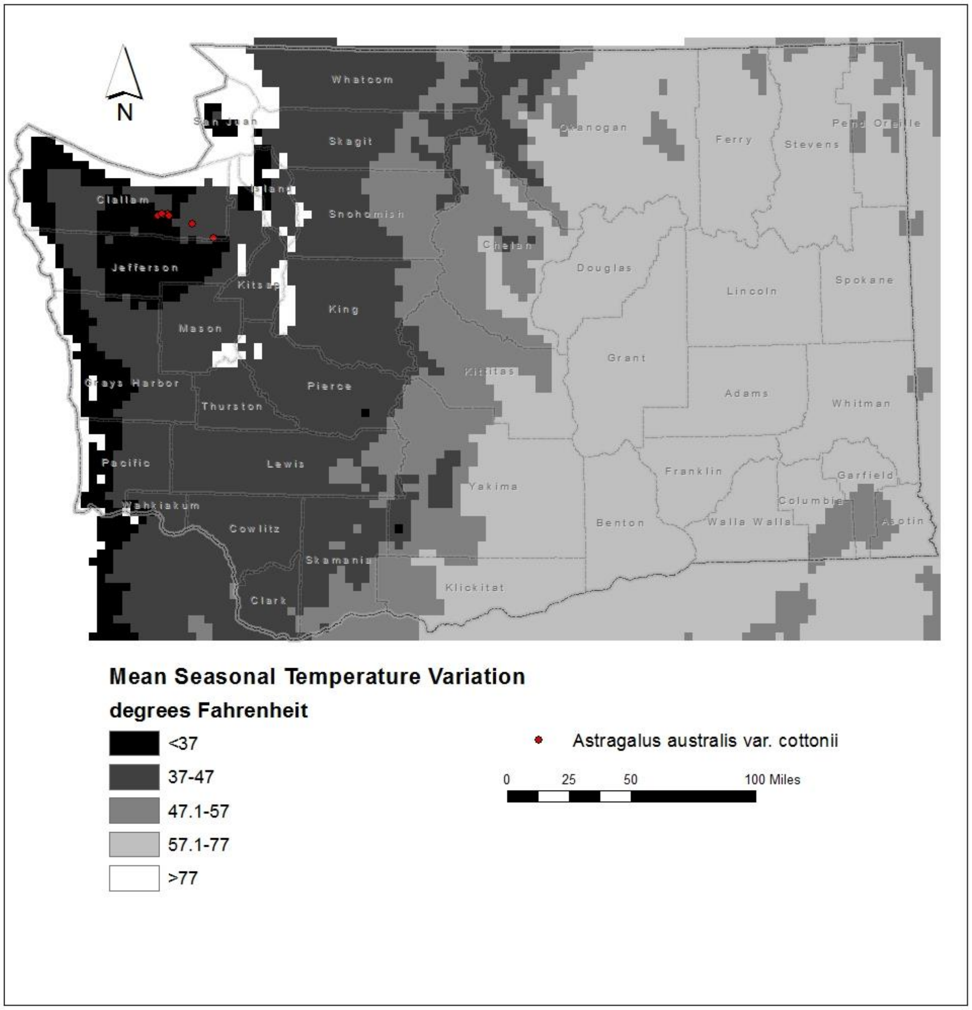

Figure 3. Historical thermal niche (exposure to past temperature variations) of *Astragalus australis* var. *cottonii* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2aii. Physiological thermal niche: Increase.
The range of *Astragalus australis* var. *cottonii* is restricted to alpine areas exposed to high winds and cold winter temperatures. Most populations occur on south-facing slopes that are warmer than adjacent slopes. Increased temperatures could extend the growing season (Rocchio and Ramm-Granberg 2017), but might also put this species under increased moisture stress. Kaye (1999) showed that drought stress was a factor in the abortion of ovules and overall reduction of seed set in this species. A prolonged growing season could favor other plant species expanding into the habitat of *A. australis* var. *cottonii* and lead to increased competition for space and resources.

C2bi. Historical hydrological niche: Neutral.
All eight of the occurrences of *Astragalus australis* var. *cottonii* in Washington (100%) are found in areas that have experienced greater than average (>40 inches/1016 mm) precipitation variation in the past 50 years (Figure 4). According to Young et al. (2016), these areas are at neutral vulnerability to climate change.

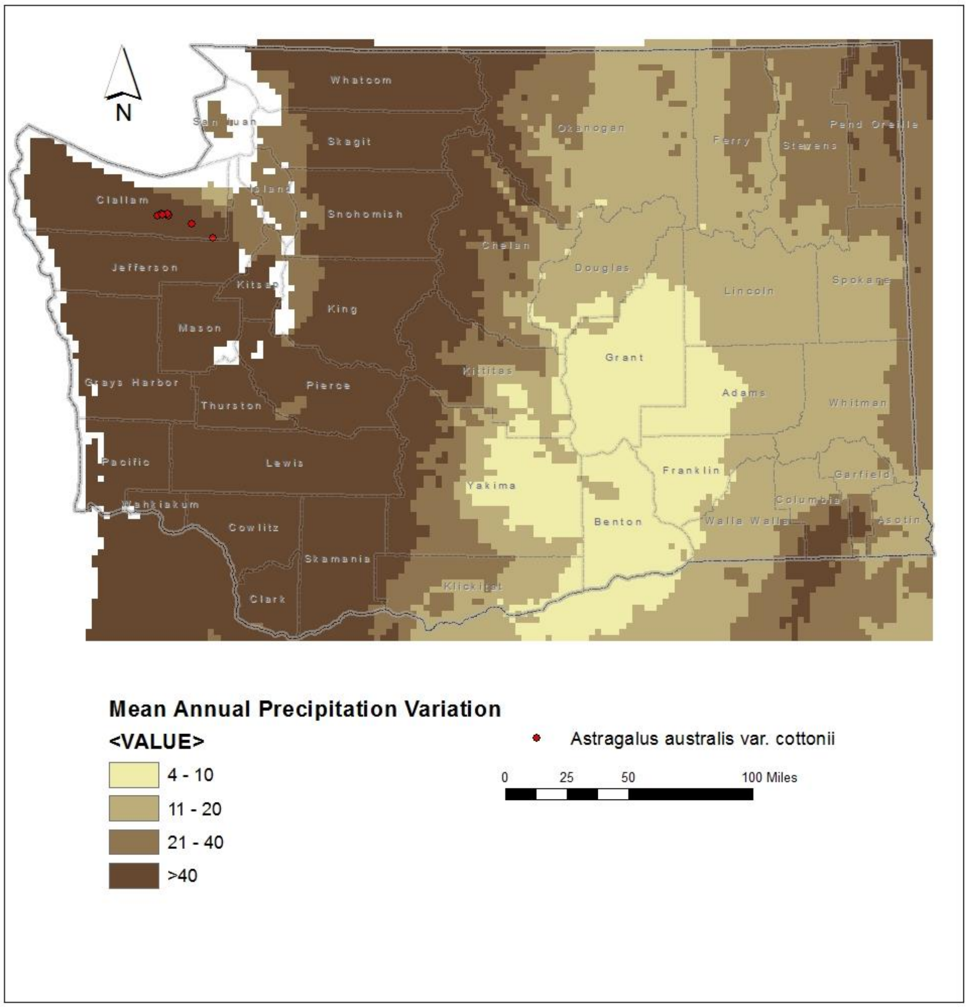

Figure 4. Historical hydrological niche (exposure to past variations in precipitation) of *Astragalus australis* var. *cottonii* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2bii. Physiological hydrological niche: Somewhat Increase.
Kaye (1989) found that *Astragalus australis* var. *cottonii* occurs primarily on drier, south and west-facing slopes with unstable soils where snowpacks do not persist. Increased temperatures from climate change are likely to change the timing of snowmelt, leading to earlier runoff

(Rocchio and Ramm-Granberg 2017). Changes in the timing or amount of summer precipitation could have negative impacts on development of ovules in fruit pods, which is currently a factor contributing to reduced seed production (Kaye 1999).

C2c. Dependence on a specific disturbance regime: Neutral.
Astragalus australis var. *cottonii* may depend on frost heaving or landslides to maintain its sparsely vegetated barren rocky slope habitat. These natural processes could be reduced if total vegetation cover were to increase in response to warming conditions and a longer growing season in the alpine zone (Rocchio and Ramm-Granberg 2017).

C2d. Dependence on ice or snow-cover habitats: Somewhat Increase.
The Olympic Mountains average over 10 meters (400 inches) of snow. The alpine areas inhabited by *Astragalus australis* var. *cottonii* are on open or steep slopes where snow is more exposed to wind and sun and less likely to accumulate late into the summer, making the local microenvironment droughtier than surrounding areas.

C3. Restricted to uncommon landscape/geological features: Somewhat Increase.
Astragalus australis var. *cottonii* is restricted to steep, barren, high elevation calcareous substrates derived from uplifted sea floor sediments (Kaye 1989, Washington Division of Geology and Earth Resources 2016). The distribution of these sites is limited within the northeastern Olympics.

C4a. Dependence on other species to generate required habitat: Neutral.
The barren slope and sparsely vegetated conditions favored by this species are maintained in part by natural processes, such as landslides and wind erosion. Feral mountain goats (*Oreamnos americanus*) released in the Olympic Mountains in the 1920s may have contributed to the creation of barren sites through herbivory, trampling, or dust wallows (Schreiner et al. 1994).

C4b. Dietary versatility: Not applicable for plants

C4c. Pollinator versatility: Somewhat Increase.
Kaye (1989) observed potential pollination of *Astragalus australis* var. *cottonii* flowers by three species of bumblebee (*Bombus appositus, B. bifarius nearcticus*, and *B. occidentalis occidentalis*), and three species of solitary bee (*Anthidium tenuiflorae, Megachile melanophaea calogaster*, and *Osmia* sp.). In any given population, however, no more than three pollinator species were present, and there was little overlap in pollinators present at sites on the east and west ends of its range. *Astragalus australis* var. *cottonii* is self-compatible, though with reduced seed production (Kaye 1999). Fruit set averages 25% and is limited in part by pollinator availability, adequate resources (especially summer moisture) for seed development, and seed predation (Kaye 1999).

C4d. Dependence on other species for propagule dispersal: Neutral.
The fruits of *Astragalus australis* var. *cottonii* dehisce when dry to release seeds passively by gravity or wind. These seeds lack wings, barbs, or hooks for dispersal by wind or animals. Dispersal distances are probably relatively short.

C4e. Sensitivity to pathogens or natural enemies: Somewhat Increase.
Reproduction can be impacted by loss of seeds to predation by weevil larvae (*Tychius* sp). Rates of seed predation ranged from 28.4-60.9% over two years at two study sites in the Olympics (Kaye 1999). Introduced mountain goats have been observed grazing on *Astragalus australis* var. *cottonii,* as well as trampling and wallowing in *Astragalus* habitat. Grazing by mountain goats was observed on 72% of individual *A. australis* var. *cottonii* plants in study plots, with 76-100% of the plants consumed (Schreiner et al. 1994). The National Park Service and WA Department of Fish and Wildlife are actively working to cull or translocate mountain goats with the ultimate goal of eliminating them from the Olympic Range (Harris et al. 2019).

C4f. Sensitivity to competition from native or non-native species: Somewhat Increase.
Astragalus australis var. *cottonii* occurs mostly in sparsely vegetated scree slopes and open alpine meadows. Kaye (1989) found that the cover and density of *A. australis* var. *cottonii* was negatively correlated with density and cover of other plant species in stable meadow sites. Populations on barren, steep, unstable talus were less affected by competition. This species is probably a poor competitor but can persist in less optimal sites where other plant species are less adapted. Under projected future climate change, the alpine habitats of *A. australis* var. *cottonii* are likely to be warmer and have a longer growing season (Rocchio and Ramm-Granberg 2017), which may allow subalpine species to expand their range or increase the cover of other alpine plants, resulting in increased competition. Herbivory or trampling by introduced mountain goats has been identified as a potential threat (Schreiner et al. 1994).

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 *Astragalus australis* var. *cottonii* in Washington.

C5b. Genetic bottlenecks: Unknown.
Small populations of *Astragalus australis* var. *cottonii* may have been restricted to unglaciated refugia within the Olympic Mountains during the Pleistocene and subjected to genetic bottlenecks (Buckingham et al. 1995), but corroborating genetic data are not available.

C5c. Reproductive System: Somewhat Increase.
Astragalus australis var. *cottonii* is capable of self-pollination, but is primarily an outcrosser pollinated by bees. Kaye (1989) observed different bee pollinators at study sites in the east and west ends of the species' range, with no overlap, suggesting that pollen dispersal within its range may be limited. The geographic isolation of var. *cottonii* (perhaps due to its persistence in glacial refugia) has likely resulted in genetic diversification from other varieties of *A. australis* found in the Rocky Mountains from SW British Columbia and Alberta to Utah and Wyoming.

C6. Phenological response to changing seasonal and precipitation dynamics: Neutral.
Based on Washington Natural Heritage Program data, no significant changes in the phenology of *Astragalus australis* var. *cottonii* populations have been detected over the past 20 years.

Section D: Documented or Modeled Response to Climate Change

D1. Documented response to recent climate change: Neutral/Somewhat Increase.
The overall abundance and range of *Astragalus australis* var. *cottonii* appears to be stable since the late 1980s (4000-4400 individuals in 8 occurrences in four main clusters; Kaye 1989; Fertig 2020). One occurrence has not been relocated since 1981 and is now considered historical. Short term monitoring studies in the late 1980s documented a decline in density at some sites that may be more attributable to mountain goat herbivory than climate change (Schreiner et al. 1994).

D2. Modeled future (2050) change in population or range size: Increase.
Populations of *Campanula piperi* and *Viola flettii* overlap with *Astragalus australis* var. *cottonii* in the northeastern Olympic Range (Kaye 1989). Wershow and DeChaine (2018) modeled the projected future habitat of *C. piperi, V. flettii*, and three other Olympic alpine endemics and found that 85-99% of their current habitat would no longer be suitable by 2080 due to rising temperatures and reduced moisture availability.

D3. Overlap of modeled future (2050) range with current range: Neutral.
Based on the projected future range of other alpine endemic plants found in similar habitats in the Olympic Mountains (Wershow and Dechaine 2018), the range of *Astragalus australis* var. *cottonii* is expected to contract rather than shift in distribution.

D4. Occurrence of protected areas in modeled future (2050) distribution: Neutral.
Despite the likely contraction of potential suitable habitat due to climate change, the entire range of *Astragalus australis* var. *cottonii* will still be restricted to Olympic National Park.

References

Buckingham, N.M., E.G. Schriener, T.N. Kaye, J.E. Burger, and E.L. Tisch. 1995. Flora of the Olympic Peninsula. Northwest Interpretive Association, Seattle, WA.

Camp, P. and J.G. Gamon, eds. 2011. Field Guide to the Rare Plants of Washington. University of Washington Press, Seattle. 392 pp.

Fertig, W. 2020. Potential federal candidate plant species of Washington. Natural Heritage Report 2020-01. Washington Natural Heritage Program, WA Department of Natural Resources, Olympia, WA. 97 pp.

Harris, R., P. Happe, and B. Murphie. 2019. Olympic National Park Mountain goat removal and translocation to the North Cascades. Progress Report II. Washington Department of Fish and Wildlife Report 02110.

Kaye, T.N. 1989. Autecology, reproductive ecology, and demography of *Astragalus australis* var. *olympicus* (Fabaceae). Master's thesis, Oregon State University, Department of Botany, Corvallis, OR. 114 pp.

Kaye, T.N. 1999. From flowering to dispersal: Reproductive ecology of an endemic plant, *Astragalus australis* var. *olympicus* (Fabaceae). American Journal of Botany 86(9): 1248-1256.

Rocchio, F.J. and R.C. Crawford. 2015. Ecological systems of Washington State. A guide to identification. Natural Heritage Report 2015-04. Washington Natural Heritage Program, WA Department of Natural Resources, Olympia, WA. 384 pp.

Rocchio F.J. and T. Ramm-Granberg. 2017. Ecological System Climate Change Vulnerability Assessment. Unpublished Report to the Washington Department of Fish and Wildlife. Washington Natural Heritage Program, Department of Natural Resources, Olympia, WA.

Schreiner, E.G., M.B. Gracz, T.N. Kaye, A. Woodward, and N.M. Buckingham. 1994. Effects of mountain goats on rare plants. Pp. 173-188. In: Houston, D.B., E.G. Schreiner, and B.B. Moorhead, eds. Mountain goats in Olympic National Park: Biology and management of an introduced species. Scientific Monograph NPS/NROLYM/NRSM-94/25. US Department of Interior, National Park Service.

Washington Division of Geology and Earth Resources. 2016. Surface geology, 1:100,000--GIS data, November 2016: Washington Division of Geology and Earth Resources Digital Data Series DS-18, version 3.1, previously released June 2010.
http://www.dnr.wa.gov/publications/ger_portal_surface_geology_100k.zip

Wershow and E. DeChaine. 2018. Retreat to refugia: Severe habitat contraction projected for endemic alpine plants of the Olympic Peninsula. American Journal of Botany 105(4): 760-778.

Young, B.E., E. Byers, G. Hammerson, A. Frances, L. Oliver, and A. Treher. 2016. Guidelines for using the NatureServe Climate Change Vulnerability Index. Release 3.02. NatureServe, Arlington, VA. 48 pp. + app.