Climate Change Vulnerability Index Report

Orthocarpus bracteosus (Rosy owl's-clover)

Date: 11 February 2021

Assessor: Walter Fertig, WA Natural Heritage Program

Geographic Area: Washington Heritage Rank: G3?/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	76.9
	<3.9° F (2.2°C) warmer	23.1
2. Hamon AET:PET moisture	< -0.119	0
	-0.097 to -0.119	0
	-0.074 to -0.096	46.2
	-0.051 to -0.073	53.8
	-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/Somewhat Increase
3. Impacts from climate change mitigation		Neutral
Section C: Sensitivity and Adaptive Capacity		
1. Dispersal and movements		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		Increase
2c. Dependence on specific disturbance regime		Neutral
2d. Dependence on ice or snow-covered habitats		Neutral/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		Unknown
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		Somewhat Increase
5a. Measured genetic diversity		Unknown
5b. Genetic bottlenecks		Unknown
5c. Reproductive system		Neutral

6. Phenological response to changing seasonal and precipitation dynamics	Neutral
Section D: Documented or Modeled Response	
D1. Documented response to recent climate change	Unknown
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: Ten extant occurrences of *Orthocarpus bracteosus* in Washington (76.9%) are found in areas with a projected temperature increase of 3.9-4.4˚ F (Figure 1). Three other historical populations (23.1%) are from areas with a projected temperature <3.9˚ F.

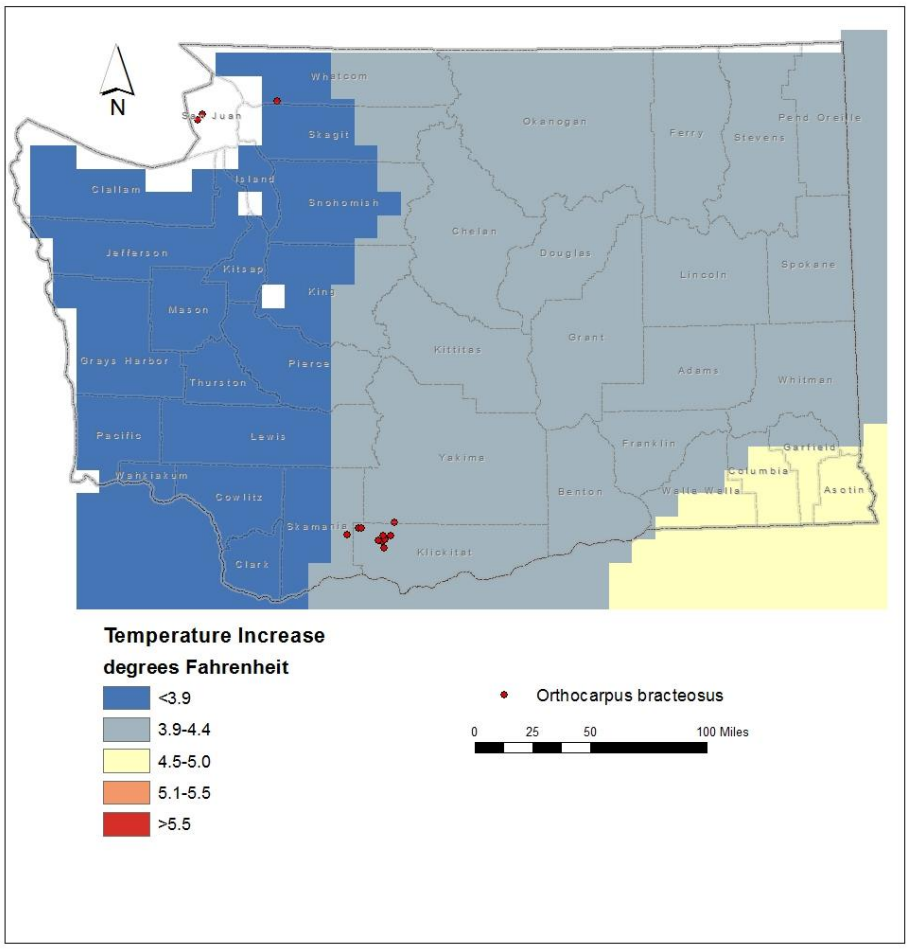

Figure 1. Exposure of *Orthocarpus bracteosus* occurrences in Washington to projected local temperature change. Base map layers from www.natureserve.org/ccvi

A2. Hamon AET:PET Moisture Metric: Seven of the 13 occurrences of *Orthocarpus bracteosus* (53.8%) 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 -0.051 to -0.073 (Figure 2). The other six populations (including three historical records from NW Washington) are from areas with a projected decrease in moisture in the range of -0.074 to -0.096 (46.2%).

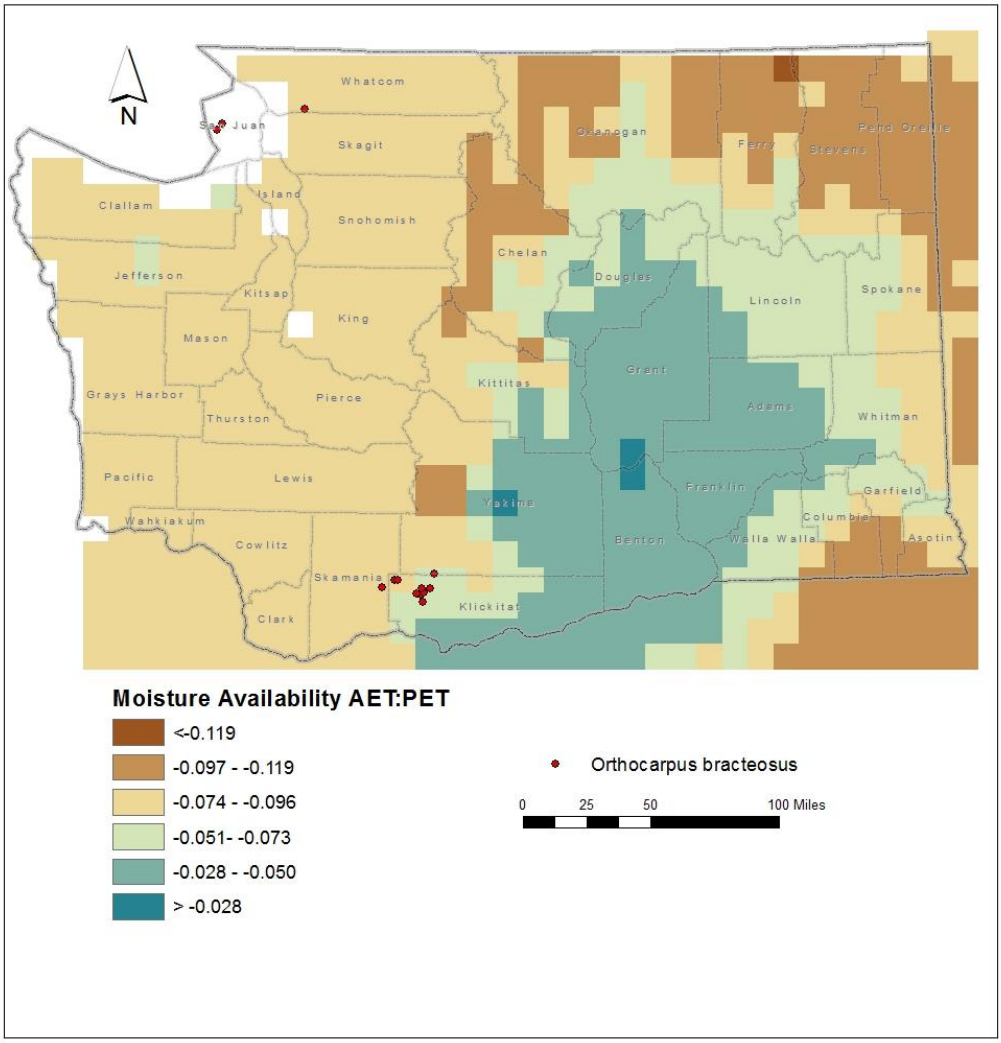

Figure 2. Exposure of *Orthocarpus bracteosus* occurrences in Washington to projected moisture availability (based on ratio of actual to predicted evapotranspiration). Base map layers from www.natureserve.org/ccvi

Section B. Indirect Exposure to Climate Change

B1. Exposure to sea level rise: Neutral.
The Washington occurrences of *Orthocarpus bracteosus* are found at 80-3000 feet (25-1000 m) and would not be inundated by projected sea level rise.

B2a. Natural barriers: Somewhat Increase.
In Washington, *Orthocarpus bracteosus* is found in moist meadows that may be seasonally flooded in the winter or spring before becoming drier in the summer. These areas are dominated by grasses and herbaceous species, rather than shrubs (Camp and Gamon 2011; Fertig and Kleinknecht 2020). Some populations occur in depressions or channels. Populations on the east slope of the Cascade Mountains conform to the Rocky Mountain Alpine-Montane Wet Meadow ecological system (Rocchio and Crawford 2015). Historical occurrences from the Puget Trough and San Juan Islands were found on lakeshores that fit the Temperate Pacific Subalpine-Montane Wet Meadow ecological system (Rocchio and Crawford 2015). The single extant occurrence in Canada from Trial Island is associated with vernal pools and would conform to the North Pacific Hardpan Vernal Pool ecological system (COSEWIC 2004). Over a dozen historical occurrences are known from the Willamette Valley of western Oregon and probably belonged to the Willamette Valley Wet Prairie ecological system (Rocchio and Crawford 2015).

Washington populations are separated by distances of 1.2 to 187 miles (2-300 km) with large areas of unsuitable habitat between population clusters in the southern Cascades and northern Puget Trough. Dispersal between populations is naturally restricted by oceanic barriers (for the San Juan Islands) or unsuitable forest matrix habitat between occurrences in the Cascades.

B2b. Anthropogenic barriers: Neutral/Somewhat Increase.
The range of *Orthocarpus bracteosus* in Washington is bisected by roads, farmland, and human infrastructure that contributes to a fragmented landscape matrix. Areas of suitable habitat for this species, however, are naturally limited to sites that favor winter/spring flooding and summer drying. Natural factors are likely to be more significant to limiting dispersal.

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

Section C: Sensitive and Adaptive Capacity

C1. Dispersal and movements: Increase.
Orthocarpus bracteosus produces numerous, showy flowers in a dense spike-like inflorescence. Fruit capsules contain 10-15 seeds that are 18-25 mm long with reticulate markings, but lack hooks, hairs, or other appendages to facilitate dispersal by wind or animals. Seeds are released passively when the dry capsule splits open at maturity. Chuang and Heckard (1983) suggested that the reticulations on the seed coat coupled with the light weight of the seed improved their aerodynamic qualities for wind dispersal. The reticulations might also trap air and increase the seed's buoyancy (COSEWIC). Most seed probably falls close to their parent (<100 m) (Chuang and Heckard 1983).

C2ai. Historical thermal niche: Somewhat Increase.
Figure 3 depicts the distribution of *Orthocarpus bracteosus* in Washington relative to mean seasonal temperature variation for the period from 1951-2006 ("historical thermal niche"). Nine of the 13 known occurrences in Washington (69.2%) are found in areas that have experienced slightly lower than average (47.1-57˚F/26.3-31.8˚C) temperature variation during the past 50 years and are considered at somewhat increased vulnerability to climate change (Young et al. 2016). Two historical populations from the San Juan Islands (15.4%) have very small temperature variation (<37˚F/20.8˚C) during the same period and are at greatly increased vulnerability. The historical Whatcom County occurrence (7.7% of the state's populations) has experienced small (37-47˚F/20.8-26.3˚C) temperature variation in the past 50 years and is

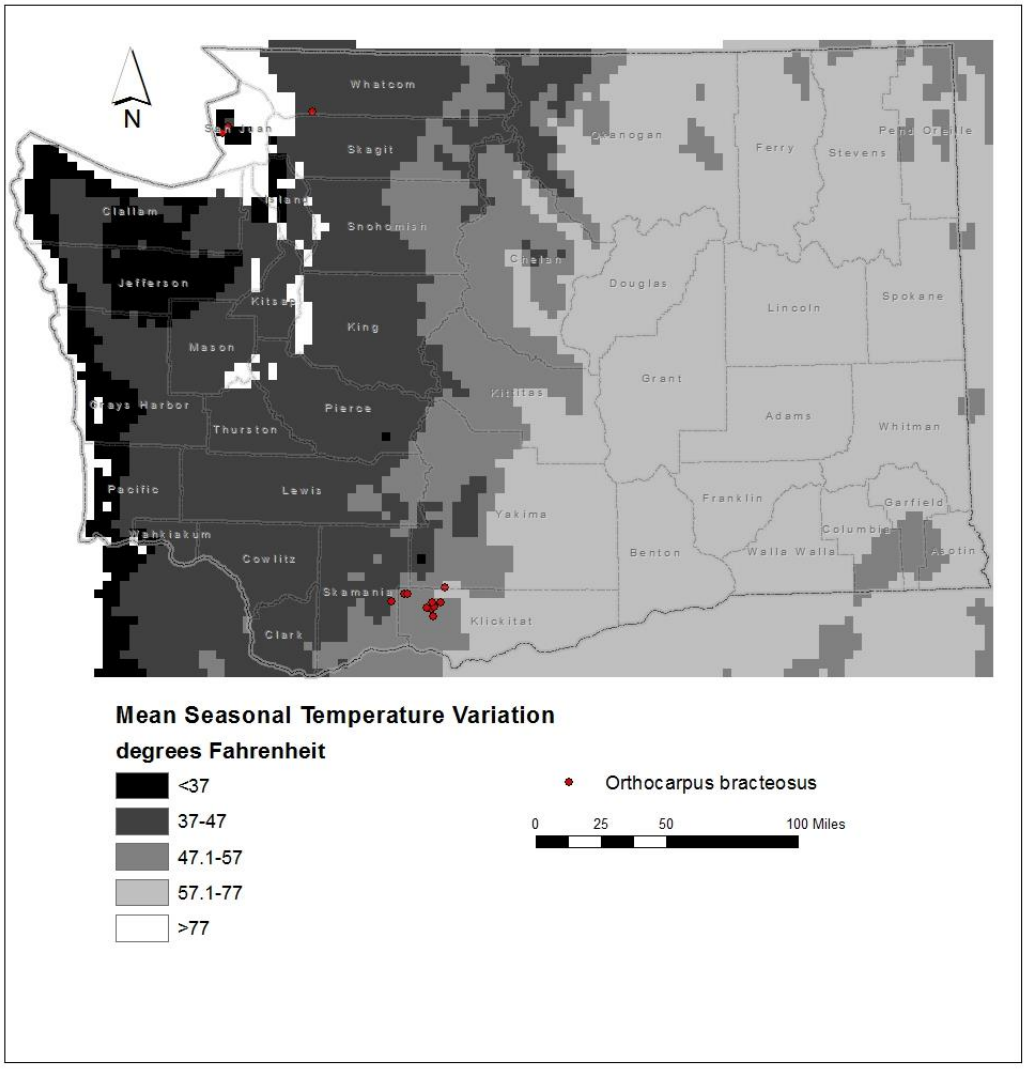

Figure 3. Historical thermal niche (exposure to past temperature variations) of *Orthocarpus bracteosus* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

rated at increased vulnerability from climate change. Lastly, one occurrence (7.7%) has experienced average temperature variation (57.1-77˚F/31.8-43.0˚C) in the last 50 years and would have neutral impacts (Young et al. 2016).

C2aii. Physiological thermal niche: Somewhat Increase.
The wetland habitats of *Orthocarpus bracteosus* are often associated with cold air drainage during the growing season and would have somewhat increased vulnerability to climate change.

C2bi. Historical hydrological niche: Neutral.
Nine of the 13 occurences of *Orthocarpus bracteosus* in Washington (69.2%) are found in areas that have experienced average (21-40 inches/508-1016 mm) precipitation variation in the past 50 years (Figure 4). The other four occurrences (30.8%) are from areas with greater than

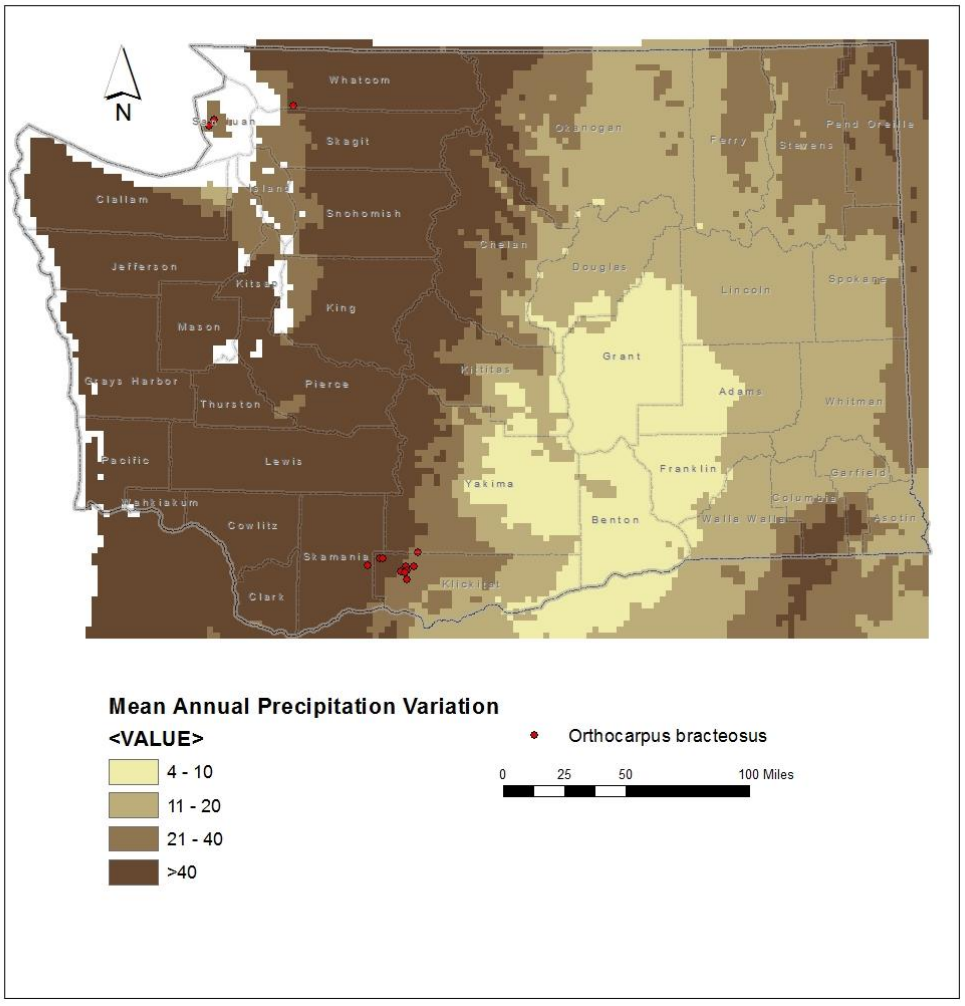

Figure 4. Historical hydrological niche (exposure to past variations in precipitation) of *Orthocarpus bracteosus* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

average precipitation variation (>40 inches/1016 mm) during the same time period. According to Young et al. (2016), these areas are all at neutral vulnerability to climate change.

C2bii. Physiological hydrological niche: Increase.
Extant occurrences of *Orthocarpus bracteosus* in Washington occur in seasonally wet meadows dominated by graminoids that become dry in the summer. Such communities are vulnerable to changes in the timing of precipitation, especially in sites that are not fed by perennial springs. Hydrological changes, such as a drop in the water table, associated with long-term drought could result in the conversion of seasonally wet meadows to dry meadows dominated by upland plant species (Rocchio and Ramm-Granberg 2017). Historical populations in the Puget Trough region were associated with lakeshores and could be impacted by changes in the timing of precipitation or increased drought. Open meadow sites could be maintained, however, by increased wildfire resulting from drought and reduced precipitation, preventing these areas from converting to shrublands (Rocchio and Ramm-Granberg 2017). In Canada, *O. bracteosus* is known from hardpan vernal pool sites that are dependent on precipitation for adequate spring moisture conditions, and so would be vulnerable to extended drought or changes in the timing or amount of rainfall.

C2c. Dependence on a specific disturbance regime: Neutral.
Orthocarpus bracteosus is dependent on a specific hydrological environment (high water table from winter/spring precipitation and summer drought) to maintain its graminoid-dominated meadow habitat. Wildfire, which could be enhanced by summer drought, may play a role in keeping these sites from becoming invaded by shrub species (Rocchio and Ramm-Granberg 2017). Climate change may actually increase the frequency of wildfire.

C2d. Dependence on ice or snow-cover habitats: Neutral/Somewhat Increase.
Snowpack is low within the range of *Orthocarpus bracteosus* in the Puget Trough and San Juan Islands, but is moderate to high along the east slope of the Cascades near Mount Adams. Changes in the amount of snowfall, or in the timing of snow melt, can have ramifications for wet meadow sites that are dependent on springs or underground recharge enhanced by snowpack (Rocchio and Ramm-Granberg 2017).

C3. Restricted to uncommon landscape/geological features: Neutral.
In the East Cascades of Washington, *Orthocarpus bracteosus* occurs primarily on Quaternary alluvium derived from volcanic parent material. These deposits are widespread in the vicinity of Mount Adams. The historical occurrences from northwestern Washington are found on soils derived from metasedimentary marine deposits found in the San Juan Islands and along the coast in the northern Puget Sound/Salish Sea area (Washington Division of Geology and Earth Resources 2016). The geologic setting for the species is not restricted, although precise hydrological conditions that contribute to winter/spring flooding and summer drying may be uncommon.

C4a. Dependence on other species to generate required habitat: Neutral.
The vernal conditions of wet meadows inhabited by *Orthocarpus bracteosus* are maintained primarily by hydrological factors (timing and amount of rainfall and snowpack), topographic drainage patterns, or wildfire rather than herbivory by wildlife.

C4b. Dietary versatility: Not applicable for plants

C4c. Pollinator versatility: Unknown.
Orthocarpus bracteosus has showy pink-purple flowers and is presumed to be an obligate outcrosser, pollinated primarily by bees (COSEWIC 2004). The exact pollinators of this species in Washington are not known.

C4d. Dependence on other species for propagule dispersal: Neutral.
The capsules of *Orthocarpus bracteosus* dehisce when dry to release seeds passively. These seeds lack barbs or hooks associated with dispersal by animals.

C4e. Sensitivity to pathogens or natural enemies: Neutral.
Impacts from pathogens are not known. Many *Orthocarpus* species contain secondary compounds, such as alkaloids, that reduce herbivory. Herbivory has been identified as a potential threat (Camp and Gamon 2011), though is likely to be of less significance than herbicide application, conversion of habitat to agriculture, or changes in hydrology.

C4f. Sensitivity to competition from native or non-native species: Somewhat Increase.
Orthocarpus bracteosus occurs in moist meadow sites that become dry in the summer. These areas could be vulnerable to invasion by annual weed species under conditions of prolonged drought and increased wildfire (Rocchio and Ramm-Granberg 2017). Competition with invasive weeds is considered an important threat for Canadian populations (COSEWIC 2004).

C4g. Forms part of an interspecific interaction not covered above: Somewhat Increase.
Orthocarpus bracteosus is a hemiparasite that produces its own food through photosynthesis but also forms haustorial connections to other plant hosts to obtain supplemental water, nutrients, or photosynthates. Other *Orthocarpus* species are known to partially parasitize members of the legume, grass, and sunflower families (Matthies 1997). This species does not appear to be restricted to particular hosts, at least in the Canadian Trial Islands (COSEWIC 2004). In Canada, *O. bracteosus* overlaps with a population of the endangered Taylor's checkerspot butterfly (*Euphydryas editha taylori*) but is not thought to be a significant food source or host species (COSEWIC 2004). These two species are not known to co-occur in the Puget Trough in Washington.

C5a. Measured genetic variation: Unknown.
Species in *Orthocarpus* section *Orthocarpus* are diploids with a chromosome count of $n = 14$, except for *O. bracteosus* which is $n = 15$ (Chuang and Heckard 1982). No genetic data are available for *Orthocarpus bracteosus* in Washington.

C5b. Genetic bottlenecks: Unknown.

C5c. Reproductive System: Neutral.
Orthocarpus bracteosus is presumed to be an outcrosser, rather than self-pollinated. Presumably, genetic variation is average, compared to other species, but no studies have been done to confirm this. Due to founder effects or genetic drift, disjunct occurrenes (such as those in the San Juan Islands of Washington and British Columbia) might be expected to have lower genetic diversity than those in the core of its range in the eastern Cascades of Washington and central to southern Oregon.

C6. Phenological response to changing seasonal and precipitation dynamics: Neutral.
Based on herbarium records from the Consortium of Pacific Northwest herbaria website, no significant changes in the phenology of *Orthocarpus bracteosus* populations in Washington have been detected over the past 20 years.

Section D: Documented or Modeled Response to Climate Change

D1. Documented response to recent climate change: Unknown.
The three occurrences from the San Juan Islands and Puget Trough in northwestern Washington are all historical and have not been observed since 1923. These populations are from lakeshore areas and may be extirpated due to development, or have not been surveyed in recent years. Climate change is not known to be a factor in their disappearance. Other populations in the East Cascades Range may fluctuate greatly in abundance from year to year, perhaps following trends in annual precipitation (Fertig and Kleinknecht 2020). Such populations could be vulnerable to long term climate change.

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

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

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

References

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