Climate Change Vulnerability Index Report

Howellia aquatilis (Water howellia)

Date: October 2019

Assessor: Walter Fertig, WA Natural Heritage Program (update from Gamon 2014)

Geographic Area: Washington | Heritage Rank: G3/S2S3

Index Result: Extremely 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	68.5
	<3.9° F (2.2°C) warmer	31.5
2. Hamon AET:PET moisture	< -0.119	0
	-0.097 to -0.119	0
	-0.074 to - 0.096	67
	-0.051 to - 0.073	33
	-0.028 to -0.050	0
	>-0.028	0
Section B		**Effect on Vulnerability**
1. Sea level rise		Somewhat Increase
2a. Distribution relative to natural barriers		Somewhat Increase
2b. Distribution relative to anthropogenic barriers		Increase
3. Impacts from climate change mitigation		Neutral
Section C		
1. Dispersal and movements		Increase
2ai Change in historical thermal niche		Somewhat Increase
2aii. Change in physiological thermal niche		Neutral
2bi. Changes in historical hydrological niche		Somewhat Increase
2bii. Changes in physiological hydrological niche		Greatly Increase
2c. Dependence on specific disturbance regime		Somewhat Increase
2d. Dependence on ice or snow-covered habitats		Neutral
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		Neutral
4d. Dependence on other species for propagule dispersal		Somewhat Increase
4e. Sensitivity to pathogens or natural enemies		Neutral
4f. Sensitivity to competition from native or non-native species		Increase
4g. Forms part of an interspecific interaction not covered above		Unknown
5a. Measured genetic diversity		Somewhat Increase

5b. Genetic bottlenecks	Unknown
5c. Reproductive system	Increase
6. Phenological response to changing seasonal and precipitation dynamics	Unknown
Section D	
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: 23 of the 73 known occurrences of *Howellia aquatilis* in Washington (31.5%) occur in areas with a projected temperature increase of less than 3.9˚F (Figure 1). The

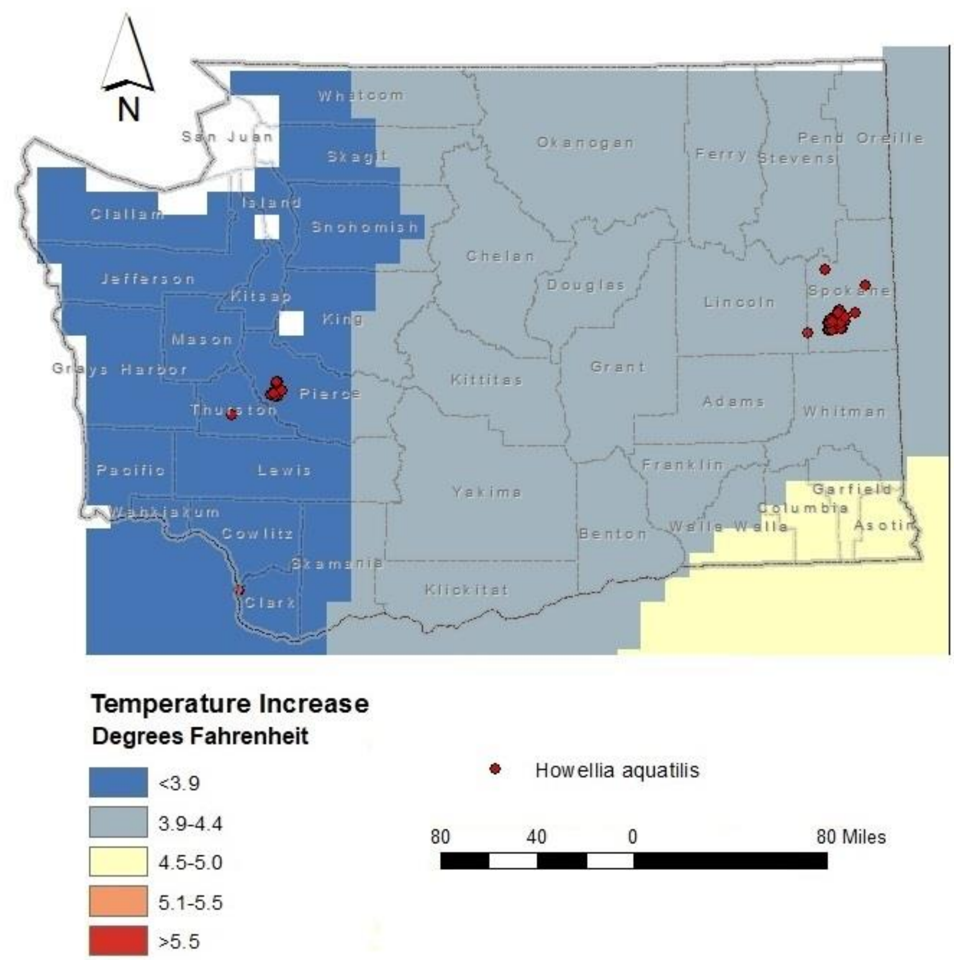

Figure 1. Exposure of *Howellia aquatilis* occurrences in Washington to projected local temperature change. Base map layers from www.natureserve.org/ccvi

remaining 50 known occurrences (68.5%), all from the Spokane area, have a projected temperature increase of 3.9-4.4˚F.

A2. Hamon AET:PET Moisture Metric: 49 of 73 occurrences of *Howellia aquatilis* in Washington (67%) are found in areas of eastern Washington with a projected decrease in available moisture (as measured by the ratio of actual to potential evapotranspiration) in the range of – 0.097 to – 0.074 inches (Figure 2). The remaining 24 occurrences are from the west side of the state in areas with a predicted decrease in available moisture between -0.074 and – 0.051 inches.

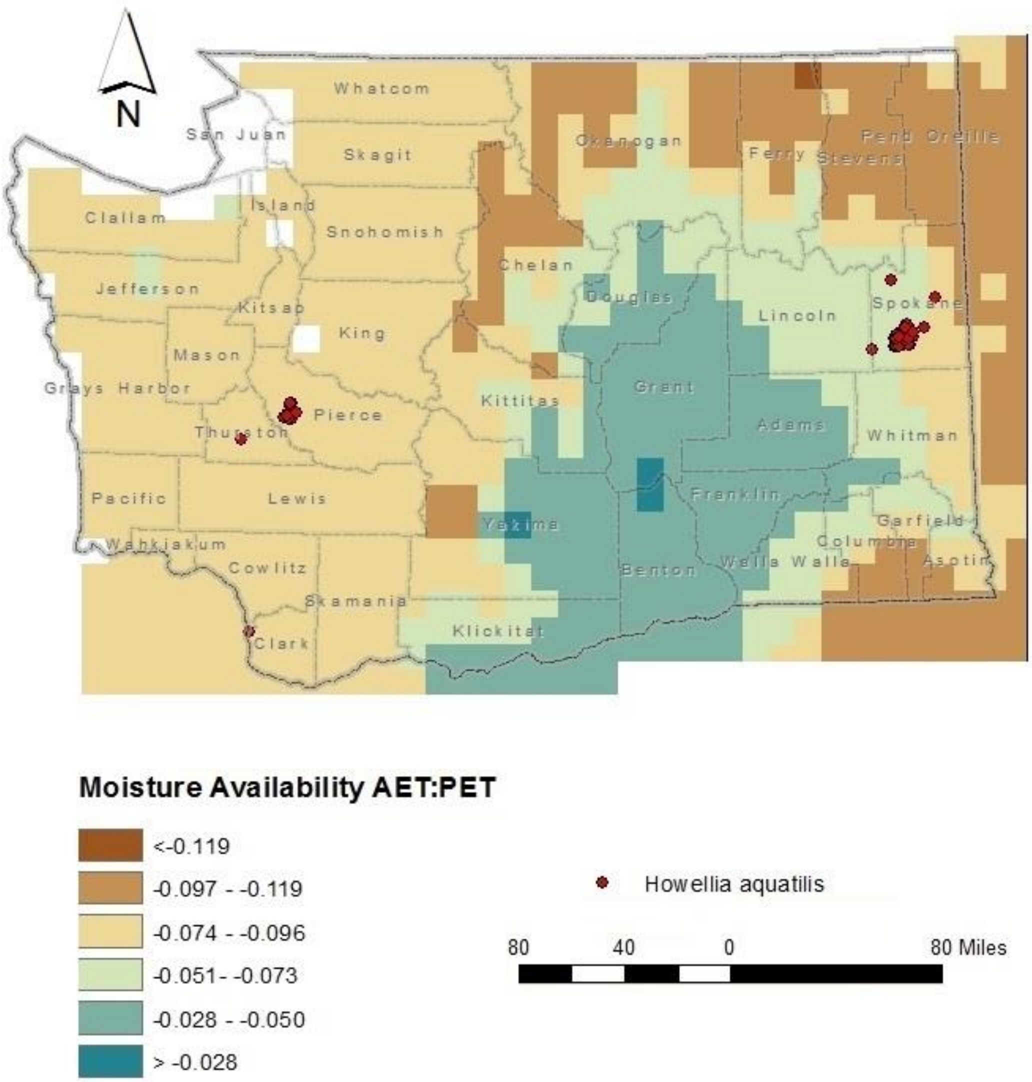

Figure 2. Exposure of *Howellia aquatilis* occurrences in Washington to projected moisture availability (based on ratio of actual to predicted evapotranspiration). Base map layers from www.natureserve.org/ccvi

Section B. Indirect Exposure to Climate Change

B1. Exposure to sea level rise: Somewhat Increase.
One *Howellia aquatilis* occurrence in Clark County occurs at an elevation of 3m (10 ft) above sea level and would likely be impacted by sea level rise. The remaining occurrences (98.6%) are found at elevations between 67-730m (220-2400 ft) and would not be inundated by rising seas.

B2a. Natural barriers: Somewhat Increase.
In Washington, *Howellia aquatilis* is largely restricted to small vernal ponds that dry out in the fall but are flooded in the spring and summer (Gamon 1992). Each occupied pond has traditionally been treated as a separate element occurrence, though many are located within 1.5 km of each other and might be better considered subpopulations (Fertig 2019). Increasingly, these ponds are embedded in a matrix of dense forest vegetation, which could impede dispersal by waterfowl. If a large number of the more shallow ponds occupied by *H. aquatilis* dry out in the future, occurrences would become more isolated from each other, restricting potential dispersal between ponds (Lesica 1992, Mincemoyer 2005).

B2b. Anthropogenic barriers: Increase.
Habitat fragmentation will make it increasingly difficult for *Howellia aquatilis* to disperse over long distances.

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

Section C: Sensitive and Adaptive Capacity

C1. Dispersal and movements: Increase.
Howellia aquatilis fruits and seeds lack any specialized structures, such as wings or hooks, to facilitate their dispersal by wind or animals. Dispersal appears to be largely passive, though facilitated by water currents within ponds. Schierenbeck and Phipps (2010) hypothesized that *Howellia aquatilis* seed might be dispersed in mud picked up by waterfowl. However, the likelihood of waterfowl accessing other small ponds with similar environmental attributes (drawing down in fall, flooded in spring/summer) may be low. Rod Gilbert (personal communication), biologist at Joint Base Lewis McChord, has suggested that black bears or other mammals might disperse seed or fragments of plants to adjacent ponds. Seed or plant fragments are capable of dispersal by water within ponds, but overland flow by flooding is unlikely given the kettle-like terrain of most populations in Washington (but flooding might be a factor in dispersal in riverine habitat in Idaho or other states). Average dispersal distance is probably very short in Washington (less than 100m) and the high habitat specificity of the species (vernal ponds that are dry in the fall but flooded in spring and summer) make rapid dispersal in response to climate change unlikely.

C2ai. Historical thermal niche: Somewhat Increase.
Figure 3 depicts the distribution of known *Howellia aquatilis* occurrences in Washington relative to mean seasonal temperature variation for the period from 1951-2006 ("historical thermal niche"). Twenty-three of the 73 known *H. aquatilis* occurrences in Washington (31.5%) are found on the west side of the Cascades in an area with increased vulnerability for temperature variation. The remaining 50 occurrences from Spokane County (68.5%) are

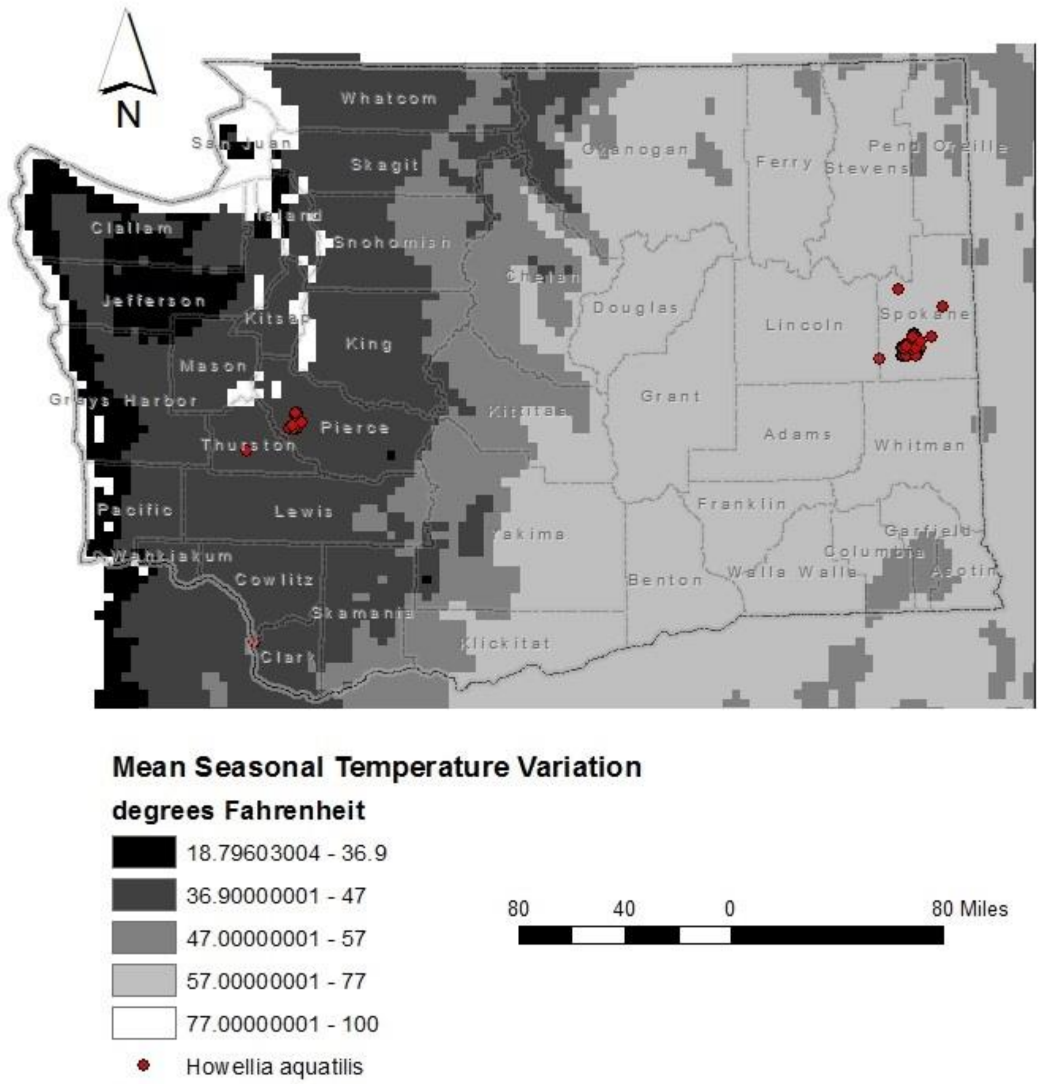

Figure 3. Historical thermal niche (exposure to past temperature variations) of *Howellia aquatilis* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

predicted to have a neutral impact. Averaging among all the populations leads to a score of "somewhat increased" vulnerability.

C2aii. Physiological thermal niche: Neutral.
Howellia aquatilis occurrences in Washington are associated with small vernal ponds within forested areas that are sometimes within a matrix of more open, upland terrain. These sites may be slightly cooler microsites, though not sufficiently cold as to increase the vulnerability of this species to climate change.

C2bi. Historical hydrological niche: Somewhat Increase.
Fifty of 73 occurrences of *Howellia aquatilis* (68.5%) in the Spokane area have received a small change (4-10 inches) in precipitation variability over the past 50 years (Figure 4) and are considered to be at increased vulnerability to climate change (Young et al. 2016). The remaining 23 occurrences on the west side of the Cascades have experienced more than 40 inches of greater precipitation variability in the same time period and are considered Neutral by Young et al. (2016). Averaged across the range of the species in Washington, the score for this factor would be “somewhat increased’ vulnerability.

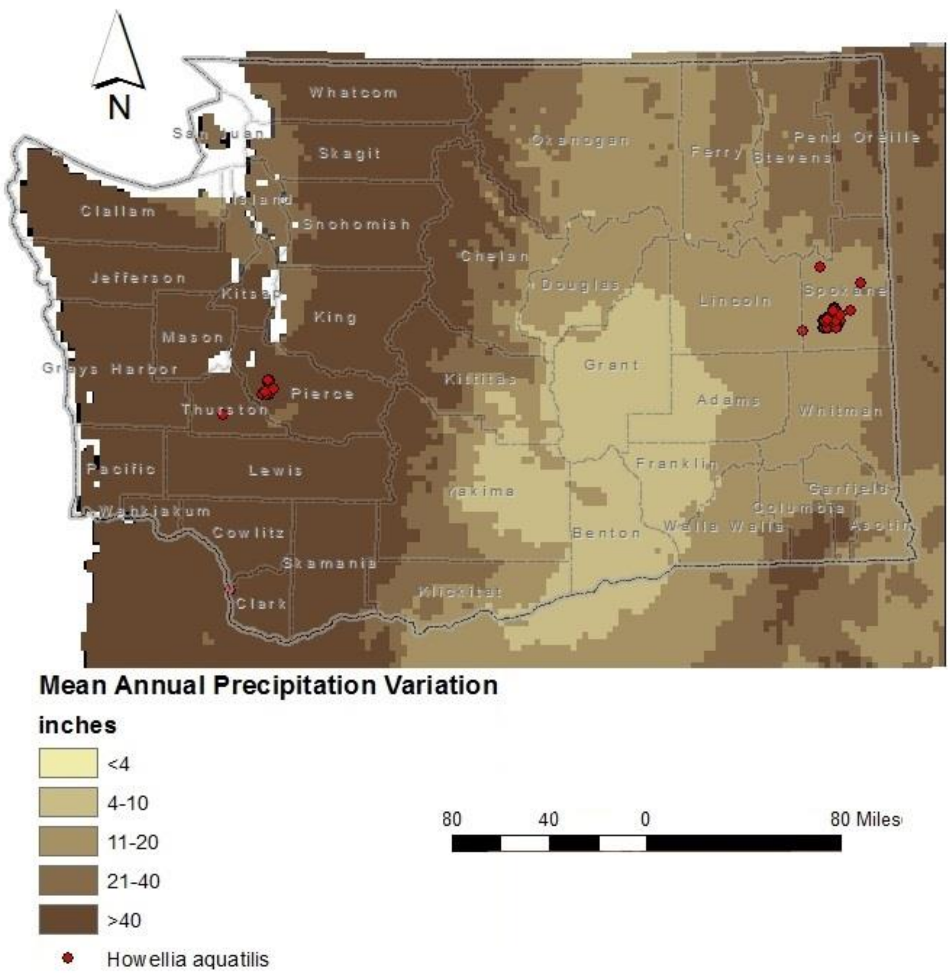

Figure 4 Historical hydrological niche (exposure to past variations in precipitation) of *Howellia aquatilis* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2bii. Physiological hydrological niche: Greatly Increase.
Howellia aquatilis has an extremely specialized hydrological niche that depends on summer/early fall drought to expose mudflats for seed germination alternating with winter/spring rainfall to create flooded conditions for plant growth and reproduction. Compounding this specialization is the plant's annual growth form and relatively short-lived seedbank (Lesica 1992). Changes in hydrology could have significant impacts on this species that will depend in part on the physical contours of its habitat. Lesica (1992) suggests that long term persistence of *Howellia* metapopulations will depend on a mix of shallow and deep ponds being available, with shallow ponds being especially important during wet years and deep ponds important during prolonged drought. Large scale changes in moisture availability are likely to upend this delicate balance.

C2c. Dependence on a specific disturbance regime: Somewhat Increase.
Howellia aquatilis is dependent on annual patterns of summer drought and fall/winter precipitation to maintain its specialized vernal pond habitat and accommodate seed germination on bare soil. Any long-term deviation from this cycle, such as a prolonged drought, or multiple years of excessive precipitation or flooding will disrupt this cycle (Shelly and Gamon 1996). How long the species can persist at a site under these conditions (and without input of new seed from other subpopulations within a metapopulation, as suggested by Lesica, 1992) is not adequately documented. Potential impacts from wildfire on forested habitats in which *Howellia* habitat is embedded is poorly known (Gamon 1992).

C2d. Dependence on ice or snow-cover habitats: Neutral.
Most *Howellia aquatilis* occurrences in Washington are dependent on winter and spring rainfall to refill vernal pond areas that are dry at the end of summer or early fall. The Washington occurrences are at low enough elevation where snow and ice are minor contributors to overall precipitation.

C3. Restricted to uncommon landscape/geological features: Neutral.
While *Howellia aquatilis* is dependent on shallow to deep kettle depressions, this dependency is adequately addressed under historical and physiological hydrologic criteria cited above. According to the guidance provided by Young et al. (2016) for CCVI assessments, physical habitat restrictions address water chemistry or unusual geologic substrates or soil types, which are not an issue for this species (Gamon 1992).

C4a. Dependence on other species to generate required habitat: Neutral.
The vernal pools inhabited by *Howellia aquatilis* in Washington were produced as a result of glacial activity (specifically massive, region-wide, short-term flooding events) and not a consequence of ecosystem engineering by other organisms.

C4b. Dietary versatility: Not applicable for plants.

C4c. Pollinator versatility: Neutral.
Howellia aquatilis produces both chasmogamous flowers that open for out-crossing and cleistogamous flowers that remain closed and are self-pollinated. The actual pollinators of *Howellia* are poorly known. Lesica et al. (1988) found that the majority of seeds were produced by cleistogamous flowers. The ability of this species to produce seed by self-pollination makes it largely impervious to loss of pollinators from climate change.

C4d. Dependence on other species for propagule dispersal: Somewhat Increase.
Although waterfowl have been suggested as dispersers of seed or plant fragments (which can sometimes still flower and set fruit) from one wetland to another, there is little evidence to actually document this (Gamon 2014). *Howellia* lacks physical structures to promote long distance dispersal, so probably is dependent on animals for this to occur.

C4e. Sensitivity to pathogens or natural enemies: Neutral.
There is no evidence that *Howellia aquatilis* populations are being adversely impacted by disease or herbivory.

C4f. Sensitivity to competition from native or non-native species: Increase.
One of the major threats to *Howellia aquatilis* in Washington (and range-wide) is competition from invasive introduced wetland plants, such as reed canarygrass (*Phalaris arundinacea*) (Camp and Gamon 2011, Fertig 2019, Lesica 1997, USFWS 1994). In addition, many Washington populations are being impacted by natural vegetation succession in the absence of disturbances, such as fire, beaver activity, or tree blowdown. Climate change could have a net positive impact on the spread and vigor of reed canarygrass. Increased drought conditions could result in more wildfire, however, which could reduce competing tree cover.

C4g. Forms part of an interspecific interaction not covered above: Unknown.

C5a. Measured genetic variation: Somewhat Increase.
Using isozyme data, Lesica et al. (1988) documented very low genetic diversity within and among populations of *Howellia aquatilis* in Montana. Brunsfeld and Baldwin (1998), however, studied chloroplast DNA and found high genetic divergence between disjunct populations of *Howellia* in Montana and California. Climate change could impact genetic structure of the species through localized extirpation of smaller populations, resulting in greater isolation of populations and potentially reduced opportunities for gene flow between them.

C5b. Genetic bottlenecks: Unknown.
Brunsfeld and Baldwin (1998) suggest that fluctuating population sizes in *Howellia aquatilis* populations might lead to reduced genetic diversity in isolated occurrences, but this remains an area for future research.

C5c. Reproductive System: Increase.
Howellia aquatilis has low genetic diversity and reproduces primarily by self-fertilized cleistogamous flowers (Mincemoyer 2005).

C6. Phenological response to changing seasonal and precipitation dynamics: Unknown.

Section D: Documented or Modeled Response to Climate Change

D1. Documented response to recent climate change: Unknown.

Trend data are lacking for nearly 40% of all Washington occurrences of *Howellia aquatilis* (Fertig 2019). Occurrences that have been monitored are either stable to decreasing in the short term, possibly due to competition with reed canarygrass or habitat succession. Data on trend relating to climate change specifically are lacking.

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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