Climate Change Vulnerability Index Report

Gentiana douglasiana (Swamp gentian)

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Assessor: Walter Fertig, WA Natural Heritage Program

Geographic Area: Washington Heritage Rank: G5/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	10
	<3.9° F (2.2°C) warmer	90
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		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		Greatly Increase
2aii. Change in physiological thermal niche		Greatly Increase
2bi. Changes in historical hydrological niche		Neutral
2bii. Changes in physiological hydrological niche		Greatly Increase
2c. Dependence on specific disturbance regime		Somewhat Increase
2d. Dependence on ice or snow-covered habitats		Somewhat Increase
3. Restricted to uncommon landscape/geological features		Neutral/Somewhat Increase
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	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: Nine of the 10 extant and historical occurrences of *Gentiana douglasiana* in western Washington (90%) occur in areas with a projected temperature increase of < 3.9˚ F

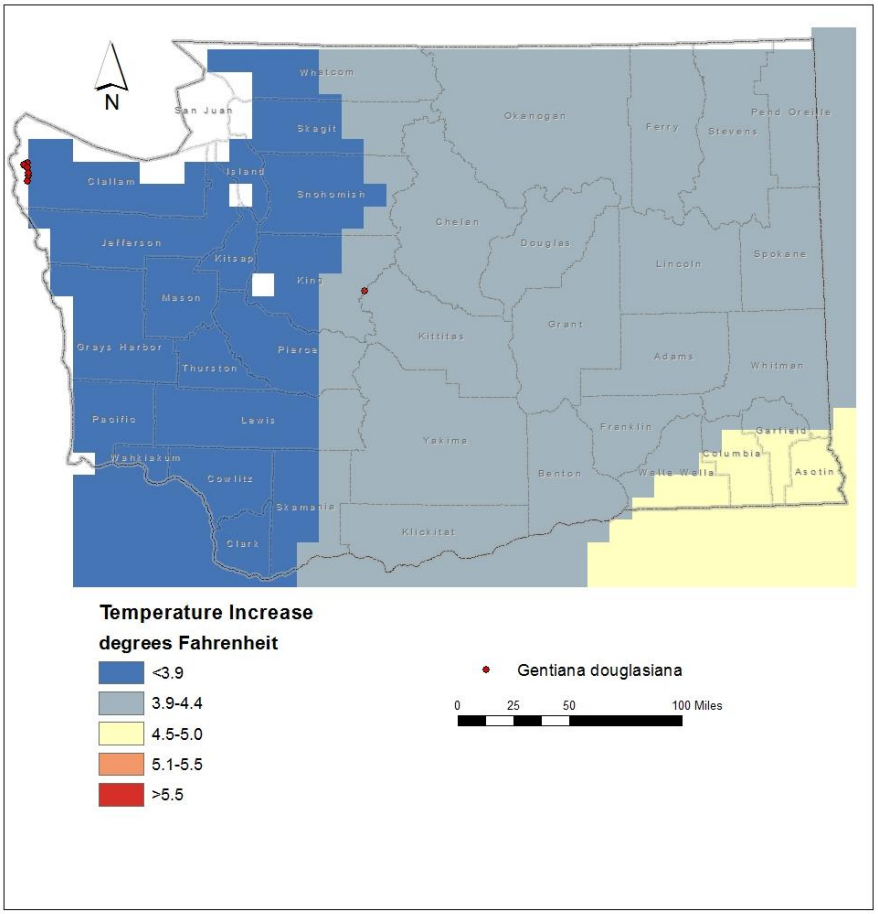

Figure 1. Exposure of *Gentiana douglasiana* occurrences in Washington to projected local temperature change. Base map layers from www.natureserve.org/ccvi

(Figure 1). One population (10%) from the Cascade Range is from an area with a projected temperature increase of 3.9-4.4˚.

A2. Hamon AET:PET Moisture Metric: All ten of the occurrences (100%) of *Gentiana douglasiana* 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).

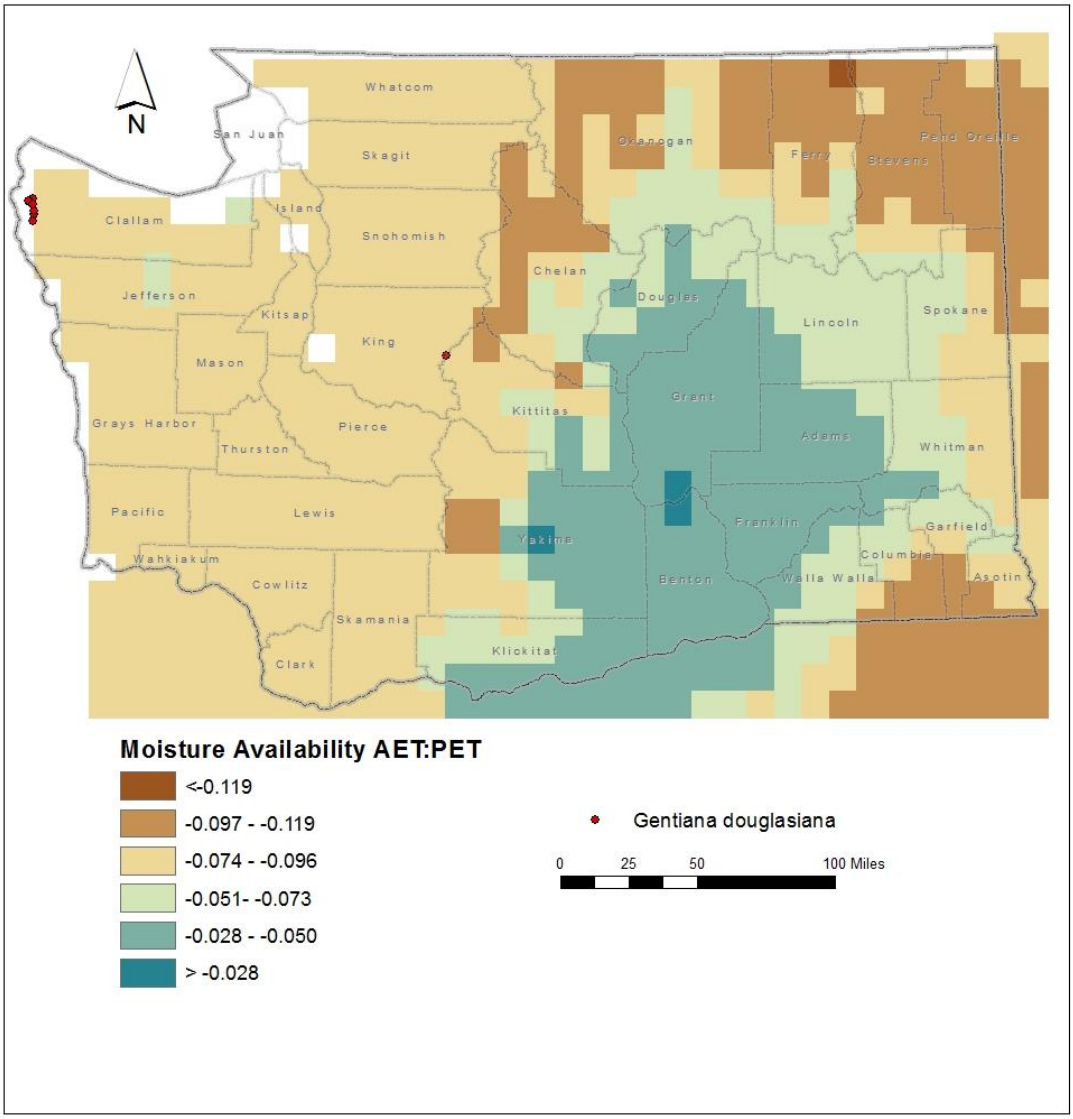

Figure 2. Exposure of *Gentiana douglasiana* occurrences in Washington to projected moisture availability (based on ratio of actual to predicted evapotranspiration). Base map layers from www.natureserve.org/ccvi

Section B. Indirect Exposure to Climate Change

B1. Exposure to sea level rise: Neutral.
Washington occurrences of *Gentiana douglasiana* from the Pacific Coast are found at 20-240 feet (5-75 m) and one occurrence from the Cascade Range is at 2920-3050 feet (890-930 m). These sites would not be inundated by projected sea level rise of 0.5-2 m by 2100 (Young et al. 2016).

B2a. Natural barriers: Somewhat Increase.
In the Olympic Peninsula, *Gentiana douglasiana* occurs in bogs and wet meadows ('prairies') dominated by sweetgale (*Myrica gale*), bog Labrador tea (*Rhododendron groenlandicum*), sedges (*Carex livida* and others), cranberry (*Vaccinium oxycoccos*), and sphagnum moss (*Sphagnum* spp.) in openings in western red cedar (*Thuja plicata*) and western hemlock (*Tsuga heterophylla*) forests. The population from Snoqualmie Pass is from a sloping bog surrounded by conifer forest (Camp and Gamon 2011, Washington Natural Heritage Program 2021). These habitats are part of the North Pacific Bog & Fen and Rocky Mountain Subalpine-Montane Fen ecological systems (Rocchio and Crawford 2015). Populations in the Olympic Peninsula are separated by 0.6-2.5 miles (0.8-4 km). The disjunct population in the Snoqualmie Pass area is isolated by 157 miles (253 km) of mostly unsuitable habitat. Natural barriers and the patchy distribution of bog and fen habitats restrict dispersal of this species.

B2b. Anthropogenic barriers: Neutral.
The bog and fen habitat of *Gentiana douglasiana* in western Washington is naturally constrained by suitable environmental and topographic factors. Although extensive areas between the northwest Olympic Peninsula and Snoqualmie Pass have been altered by human activities, most of these areas are not suitable habitat. Anthropogenic barriers are less significant for this species than natural ones.

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

Section C: Sensitive and Adaptive Capacity

C1. Dispersal and movements: Somewhat Increase.
Gentiana douglasiana produces dry capsule fruits that split open at maturity to release numerous seeds. The fruits are flattened and wing-margined and might be capable of dispersal by water. Individual seeds are small and lack wings, barbs, hooks, or feathery hairs to facilitate dispersal by animals or wind. Dispersal distances are probably relatively short, though occasional long-distance dispersal on mud on birds or large mammals may explain large range disjunctions.

C2ai. Historical thermal niche: Greatly Increase.
Figure 3 depicts the distribution of *Gentiana douglasiana* in Washington relative to mean seasonal temperature variation for the period from 1951-2006 ("historical thermal niche"). Nine of the 10 occurrences in the state (90%) 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 (10%) is

from an area with small variation (37-47˚F/20.8-26.3˚C) in temperature over the same period and is at increased vulnerability to climate change.

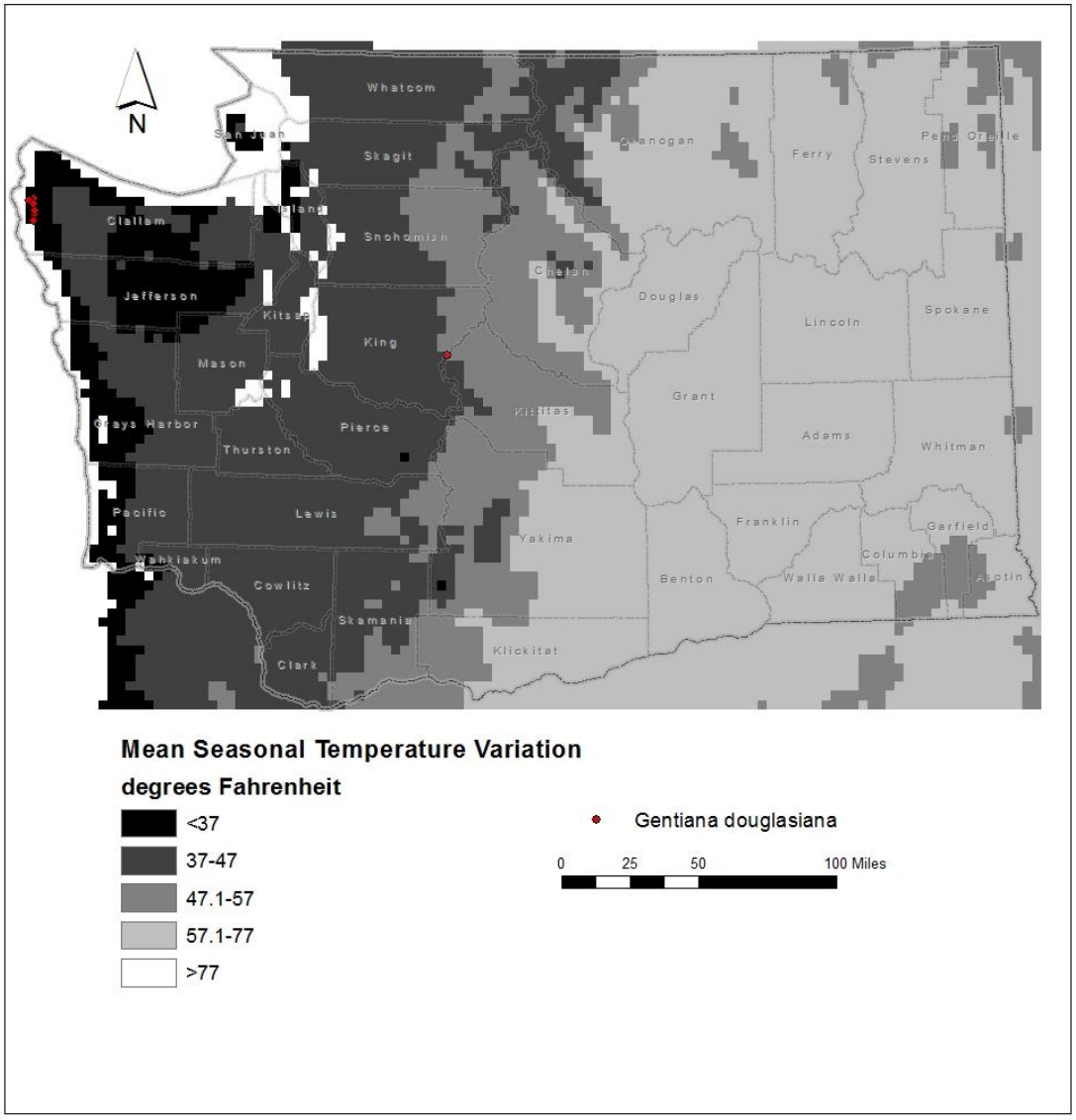

Figure 3. Historical thermal niche (exposure to past temperature variations) of *Gentiana douglasiana* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2aii. Physiological thermal niche: Greatly Increase.
The coastal bog and montane fen habitats of *Gentiana douglasiana* in Washington are associated with cold air drainages and would be negatively impacted by increasing temperatures from climate change.

C2bi. Historical hydrological niche: Neutral.
All of the populations of *Gentiana douglasiana* 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.

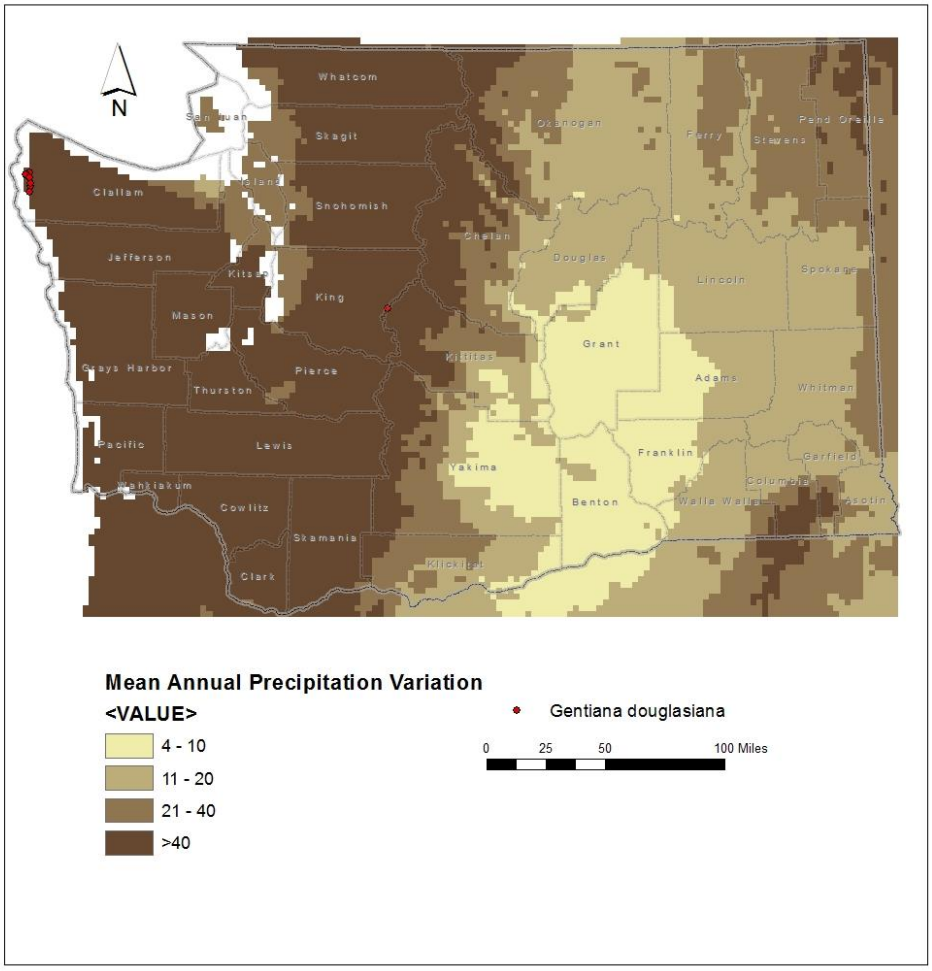

Figure 4. Historical hydrological niche (exposure to past variations in precipitation) of *Gentiana douglasiana* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2bii. Physiological hydrological niche: Greatly Increase.
This species is strongly dependent on precipitation and groundwater (along with cool temperatures) to maintain a high water table necessary for accumulation of peat. Reductions in the amount of precipitation and increased temperatures could shift the balance from peat accumulation to peat decomposition in coastal bog areas, accelerating their conversion to wet meadow habitats, or favoring encroachment by conifer forests (Rocchio and Ramm-Granberg

2017). These areas are also strongly influenced by coastal fog (Rocchio and Crawford 2015). In the Snoqualmie Pass area, a reduction in the amount of snow or shift from snow to rainfall would accelerate the loss of peat and shifts from fen to other wetland types (Rocchio and Ramm-Granberg 2017).

C2c. Dependence on a specific disturbance regime: Somewhat Increase.
Gentiana douglasiana occurs in coastal bog and montane fen habitats in Washington found in openings in conifer forests. These areas are maintained by high water tables fed by groundwater and augmented by rainfall or melting snow. Historically, fire was utilized by indigenous cultures to keep coastal prairie wetlands more open for game habitat and to promote edible plants (Anderson 2009). These fires could have prevented encroachment of conifer species from adjacent forests.

C2d. Dependence on ice or snow-cover habitats: Somewhat Increase.
The populations of *Gentiana douglasiana* in the Cascade Range are found in areas with high snowfall. Changes in the amount of snow, the timing of its melting, or shifts from snow to rain due to warming temperatures, would adversely affect the amount of groundwater recharge in fen habitats (Rocchio and Ramm-Granberg 2017). Coastal populations primarily receive winter rain due to their proximity to the Pacific Ocean and are not dependent on groundwater recharge from snow.

C3. Restricted to uncommon landscape/geological features: Neutral/Somewhat Increase.
Gentiana douglasiana populations from the northwest Olympic Peninsula occur on Quaternary continental glacial drift of the Vashon Strade. The occurrence from the Snoqualmie Pass area is on alpine glacial drift of Fraser-age (Washington Division of Geology and Earth Resources 2016). These geologic types are relatively widespread in western Washington. The local topographic relief associated with high water tables and peat accumulation, such as glacial scours, kettles, ox-bows, or old ponds and lakes are more limited features on the landscape (Rocchio and Crawford 2015).

C4a. Dependence on other species to generate required habitat: Neutral.
The coastal bog and montane fen habitat of *Gentiana douglasiana* is maintained largely by edaphic and drainage patterns that favor the accumulation of thick organic soil layers favoring peatland vegetation over conifer forests (Banner et al. 1983).

C4b. Dietary versatility: Not applicable for plants

C4c. Pollinator versatility: Unknown.
The specific pollinators of *Gentiana douglasiana* are poorly known, though the rare Makah copper butterfly (*Lycaena mariposa charlottensis*), is known to use *G. douglasiana* as a nectar source and thus would likely be a pollinator (Pyle 2002). Additional pollinators might include other butterfly species or bees.

C4d. Dependence on other species for propagule dispersal: Neutral.
The fruits of *Gentiana douglasiana* are dry capsules that split open at maturity to passively release small seeds. Dispersal of seeds is mostly by water or gravity, but could be augmented by animals caching seed or transporting seed in mud on feathers or feet. This species is not dependent on a specific animal vector, so is ranked neutral.

C4e. Sensitivity to pathogens or natural enemies: Neutral.
Impacts from pathogens are not known. This species does not appear to be an important forage species.

C4f. Sensitivity to competition from native or non-native species: Somewhat Increase.
Under present conditions, competition from non-native species is low, as relatively few introduced plants are adapted to the harsh environmental conditions of coastal bogs and montane fens. This could change under projected climate change, as higher temperatures, reduced precipitation, and more frequent drought are likely to shift these sites from accumulating peat to losing organic material from increased decomposition. Resulting changes in soil moisture could shift these communities to wet meadows or conifer forests. If drying also brings increased wildfire, these areas would be more prone to invasion by native and introduced plant species adapted to drier conditions (Rocchio and Ramm-Granberg 2017).

C4g. Forms part of an interspecific interaction not covered above: Somewhat Increase.
Gentiana douglasiana is the main nectar source for the rare Makah copper butterfly (*Lycaena mariposa charlottensis*), a rare species in Washington and potential pollinator (Jordan 2011, Pyle 2002).

C5a. Measured genetic variation: Unknown.
Research has not been done on the genetic variability of Washington populations of *Gentiana douglasiana*. Being at the far southern end of its range, and isolated from the nearest populations on Vancouver Island, *G. douglasiana* populations in Washington may have lower overall genetic variability due to inbreeding or founder effects.

C5b. Genetic bottlenecks: Unknown.
Not known.

C5c. Reproductive System: Neutral.
Gentiana douglasiana appears to be an obligate outcrosser and is likely to have average genetic variation. Isolated populations in Washington are likely to have reduced genetic variability from those in British Columbia and Alaska due to inbreeding or founder effects.

C6. Phenological response to changing seasonal and precipitation dynamics: Neutral.
Based on herbarium records in the Consortium of Pacific Northwest Herbaria website (pnwherbaria.org), *Gentiana douglasiana* has not changed its typical blooming time since the 1920s.

Section D: Documented or Modeled Response to Climate Change

D1. Documented response to recent climate change: Neutral.
No major changes have been detected in the distribution of *Gentiana douglasiana* in Washington since it was first scientifically documented in the state in 1925.

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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