Climate Change Vulnerability Index Report

Castilleja levisecta (Golden paintbrush)

Date: October 2019

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

Geographic Area: Washington | Heritage Rank: G2/S2

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	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		**Effect on Vulnerability**
1. Sea level rise		Neutral
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		Greatly Increase
2aii. Change in physiological thermal niche		Neutral
2bi. Changes in historical hydrological niche		Neutral
2bii. Changes in physiological hydrological niche		Neutral
2c. Dependence on specific disturbance regime		Neutral
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		Somewhat Increase
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		Neutral

5b. Genetic bottlenecks	Unknown
5c. Reproductive system	Neutral
6. Phenological response to changing seasonal and precipitation dynamics	Unknown
Section D	
D1. Documented response to recent climate change	Increase
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

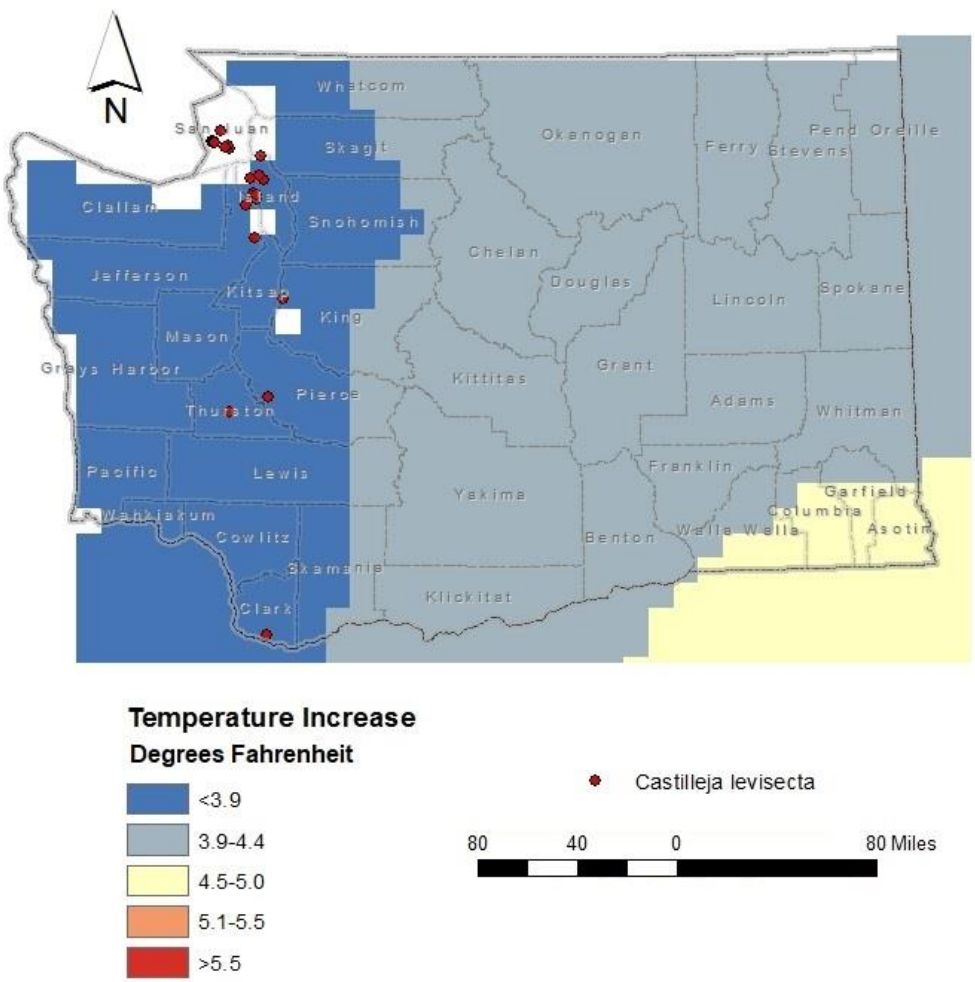

Figure 1. Exposure of *Castilleja levisecta* occurrences in Washington to projected local temperature change. Base map layers from www.natureserve.org/ccvi

A1. Temperature: All 22 native occurrences of *Castilleja levisecta* in Washington (11 of which are extant and 11 extirpated or historical) occur in areas with a projected temperature increase less than 3.9˚F (Figure 1).

A2. Hamon AET:PET Moisture Metric: All 22 native occurrences of *Castilleja levisecta* 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).

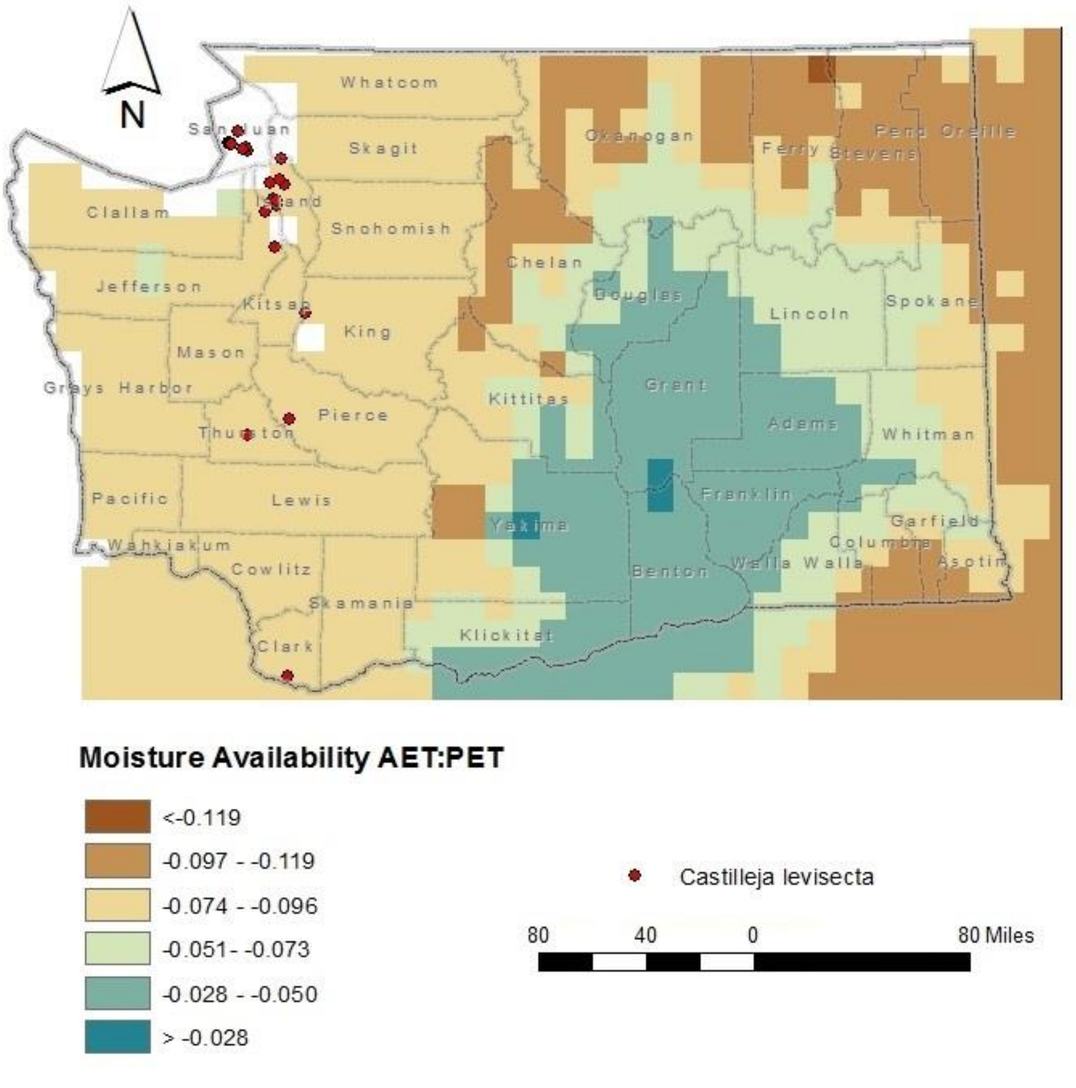

Figure 2. Exposure of *Castilleja levisecta* occurrences in Washington to projected moisture availability (based on ratio of actual to predicted evapotranspiration). Base map layers from www.natureserve.org/ccvi

Section B. Indirect Exposure to Climate Change

B1. Exposure to sea level rise: Neutral.
Of the 11 extant native occurrences of *Castilleja levisecta* only a portion of one occurs below 1 m of sea level (and would be inundated under average climate change scenarios), while the remaining populations are at elevations from 2-76 m above sea level. Historical native occurrences and recently reintroduced populations are also found above 1 m of elevation and are unlikely to be flooded due to sea water increase.

B2a. Natural barriers: Somewhat Increase.
Mainland occurrences of *Castilleja levisecta* in Washington are found in remnant prairies dominated by *Festuca roemeri* and *F. rubra* on gravelly or clayey glacial outwash. Island occurrences are often found on the upper slopes of steep west or southwest-facing sandy bluffs and patches of coastal prairie that may be exposed to salt spray (Chappell and Caplow 2004; Gamon 1995; Fertig 2019). Traditionally, these habitats were maintained by periodic wildfire, abetted by summer drought or anthropogenic actions. Today, more than 97% of the state's historic prairie sites have become replaced by forests, agriculture, or human development (Chappell et al. 2001) and are more fragmented and isolated.

B2b. Anthropogenic barriers: Increase.
Conversion of western Washington prairies to agriculture, roads, and human settlements and suppression of wildfires that historically kept grassland sites open from tree encroachment have greatly increased the fragmentation of prairie habitats and acts as a barrier to dispersal of *Castilleja levisecta* seed and pollinators (USFWS 2000).

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

Section C: Sensitive and Adaptive Capacity

C1. Dispersal and movements: Increase.
Castilleja levisecta produces abundant seed. These seeds are dispersed passively through rupture of the dry fruit capsule wall and have no specialized structures for further dispersal. The seeds are quite small, however, (1 mm long) and could be dispersed by strong winds. The majority of seeds, however, probably fall within a few meters of their parent plant (Caplow 2004).

C2ai. Historical thermal niche: Greatly Increase.
Figure 3 depicts the distribution of extant and historical native *Castilleja levisecta* occurrences in Washington relative to mean seasonal temperature variation for the period from 1951-2006 ("historical thermal niche"). Seventeen of the 22 native *C. levisecta* occurrences in Washington (77%) are found on islands in the northern Puget Sound and Salish Sea in an area that has experienced very small temperature variation (< 37˚F) during the past 50 years. These populations are considered to have greatly increased vulnerability under projected climate change (Young et al. 2016). The remaining native occurrences (23%) are found in areas with a small (37-47˚F) temperature variation over the past 50 years and are considered to have an increased vulnerability.

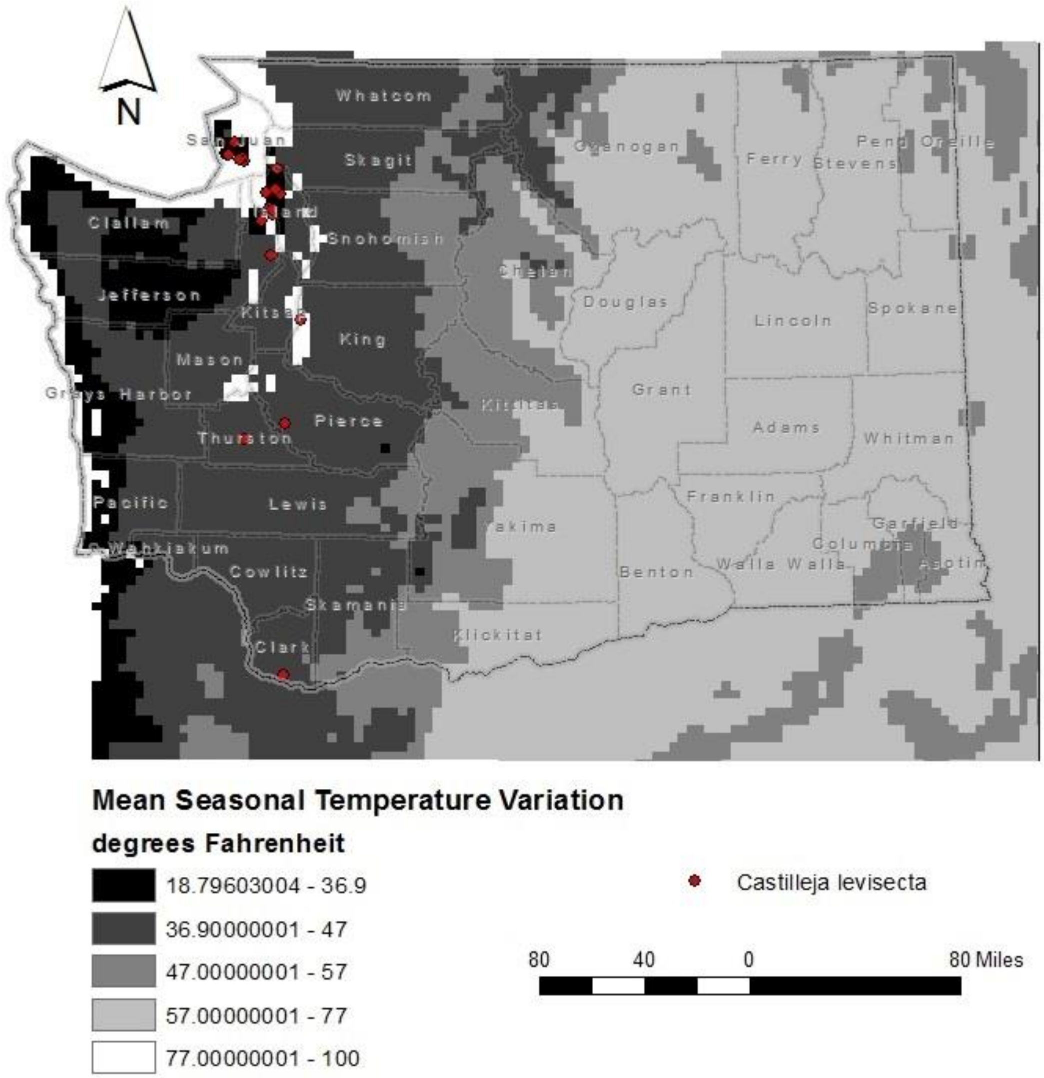

Figure 3. Historical thermal niche (exposure to past temperature variations) of *Castilleja levisecta* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2aii. Physiological thermal niche: Neutral.
Castilleja levisecta occurrences in Washington are found in remnant prairie habitats that are not associated with cold air pockets or other microsites that are more vulnerable to climate change.

C2bi. Historical hydrological niche: Neutral.
All 22 extant and historical native occurrences of *Castilleja levisecta* in Washington (Figure 4) are found in areas that have experienced average or greater than average precipitation variation (> 20 inches) over the past 50 years and are considered Neutral in terms of risk from climate change (Young et al. 2016).

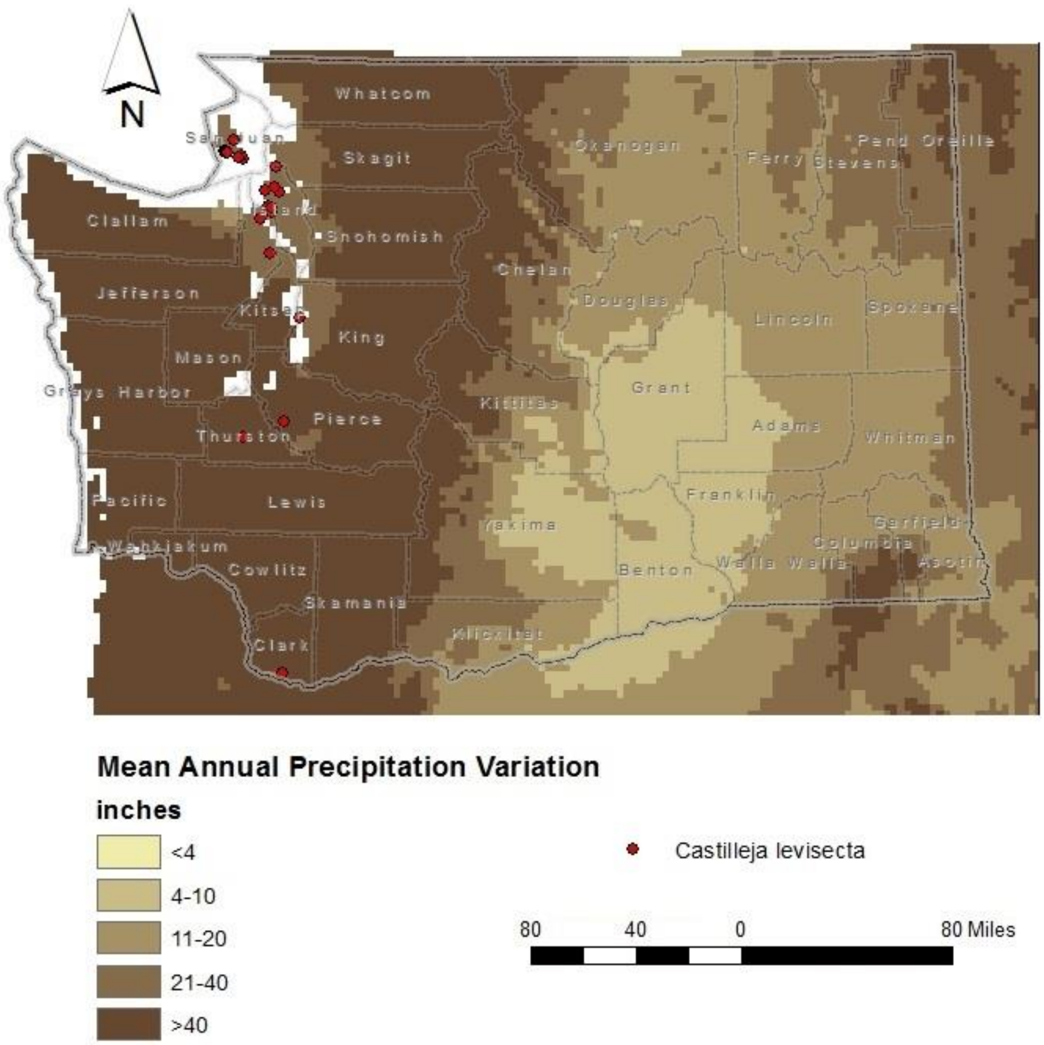

Figure 4. Historical hydrological niche (exposure to past variations in precipitation) of *Castilleja levisecta* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2bii. Physiological hydrological niche: Neutral.
Castilleja levisecta is an upland species that is not strongly dependent on aquatic/wetland habitats or a seasonal hydrologic regime.

C2c. Dependence on a specific disturbance regime: Neutral.
The prairie grassland habitat occupied by *Castilleja levisecta* is largely dependent on periodic drought or wildfire to curb the expansion of conifer forest or oak woodland habitat (Dunwiddie et al. 2001; USFWS 2000). Climate change is likely to increase the frequency of drought within the range of this species. The potential incidence of wildfire might also increase, though the fragmentation of the region by roads, farms, and urban infrastructure may reduce this risk. These effects of climate change could have a net positive impact on the habitat of *Castilleja levisecta*.

C2d. Dependence on ice or snow-cover habitats: Neutral.
The Washington occurrences of *Castilleja levisecta* are at low enough elevation where snow and ice are minor contributors to overall precipitation.

C3. Restricted to uncommon landscape/geological features: Neutral.
Most *Castilleja levisecta* occurrences are found on gently sloping areas. One native and at least one introduced occurrence are found in areas with prominent mima mounds, though these features are not the main reason for the presence of this species. A few island populations are on steep sandy slopes along the coast that are a product of extreme wind erosion. Overall, the native and introduced occurrences of *C. levisecta* are not associated with areas of unusual geology or water chemistry.

C4a. Dependence on other species to generate required habitat: Neutral.
Castilleja levisecta is largely dependent on natural phenomena (drought, fire) or anthropogenic assistance (controlled fire), rather than other animal species to create and maintain its grassland habitat.

C4b. Dietary versatility: Not applicable for plants.

C4c. Pollinator versatility: Somewhat Increase.
Castilleja levisecta is insect pollinated. The primary pollinators are probably bumblebees (genus *Bombus*, including *B. californicus*) (USFWS 2000, Waters 2018). Self-pollination is possible in *C. levisecta* (Kaye and Lawrence 2003), but resulting seed production is exceptionally low compared to crosses between sibling or neighboring plants. Wentworth (1994) found that fruit set was 5 times greater in unbagged (outcrossed) vs. bagged (selfed) inflorescences. Long term persistence of *C. levisecta* populations may be dependent on the survival of its pollinators and maintenance of pollinator habitat, including other food plants and appropriate nesting sites (USFWS 2000).

C4d. Dependence on other species for propagule dispersal: Neutral.
Castilleja levisecta seed is dispersed passively and not by animals (with the possible exception of short distance transport of seed-bearing fruits by small rodents).

C4e. Sensitivity to pathogens or natural enemies: Neutral.
Castilleja levisecta is edible and leaves, stems, and inflorescences may be browsed by voles, rabbits, or deer. Herbivory can be an important factor in periodically reducing reproductive success in some populations (Gamon 1995; USFWS 2000). Caterpillars of several butterfly and

moth species also feed on *C. levisecta*. No pathogens are known. Overall, the impacts of herbivores are relatively low at present, or not expected to increase due to climate change.

C4f. Sensitivity to competition from native or non-native species: Somewhat Increase.
Two major threats to *Castilleja levisecta* in Washington (and range-wide) are competition from invasive introduced species and vegetation succession in the absence of fire or other disturbance (Camp and Gamon 2011; Fertig 2019, USFWS 2000). Increased drought conditions could result in more wildfire, however, which could reduce competing tree cover. The abundance and density of competing invasive plant species may increase due to climate change.

C4g. Forms part of an interspecific interaction not covered above: Neutral.
Castilleja levisecta is a facultative hemiparasite that is capable of photosynthesis but also may derive additional nutrition from host plants via underground root-like structures (haustoria). The species is not host-specific, although recent monitoring studies of outplantings have found it is especially successful when using *Eriophyllum lanatum* as a host (Pearson and Dunwiddie 2006). The Endangered Taylor's checkerspot butterfly (*Euphydras editha taylori*) utilizes *C. levisecta* as a host plant for its eggs and larvae (Waters 2018).

C5a. Measured genetic variation: Neutral.
Godt et al. (2005) found unusually high genetic diversity in sampled populations of *Castilleja levisecta* in Washington compared to other narrowly endemic plant species.

C5b. Genetic bottlenecks: Unknown.
Individual occurrence of *Castilleja levisecta* (such as Ebey's Landing) have lower genetic diversity and fewer alleles per polymorphic loci than the entire population of the species as a whole, suggesting there has been a past genetic bottleneck or the population had a limited number of founders (Godt et al. 2005). Whether there has been a significant genetic bottleneck for all populations of *C. levisecta* is not known.

C5c. Reproductive System: Neutral.
Castilleja levisecta is essentially an obligate outcrosser (it is self-compatible, but with very low viability of seed) with relatively high genetic diversity, and thus not highly vulnerable to impacts from climate change.

C6. Phenological response to changing seasonal and precipitation dynamics: Unknown.
Changes in the onset of flowering or fruiting have not yet been detected in *Castilleja levisecta*.

Section D: Documented or Modeled Response to Climate Change

D1. Documented response to recent climate change: Increase .
The five largest native occurrences of *Castilleja levisecta* in Washington have declined by 52-85% from 2012 through 2018 (Fertig 2019) and continued to decline in 2019 (Fertig unpublished data). Total abundance in Washington has increased significantly over this same time period due to the successful establishment of 9 new occurrences created by outplanting plugs or direct seeding (Caplow 2004). In 2018 the total population in the state reached 195,324 reproductive plants, of which 97.4% were from introduced occurrences (Fertig 2019). These numbers declined by 28.6% in 2019 to 139,293 reproductive plants (Fertig unpublished

data). The greatest decreases came in outplanted populations which may be self-thinning to reach a lower, but more sustainable population threshold. Native occurrences continue to decline as well, and this may be related to recent unseasonable warm and dry weather in the spring growing season.

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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