

Climate Change Vulnerability Index Report

Dendrolycopodium dendroideum (Treelike clubmoss)

Date: 11 October 2021

Synonym: *Lycopodium dendroideum*

Assessor: Walter Fertig, WA Natural Heritage Program

Geographic Area: Washington

Heritage Rank: G5/S2

Index Result: Moderately Vulnerable

Confidence: 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	83.3
	<3.9° F (2.2°C) warmer	16.7
2. Hamon AET:PET moisture	< -0.119	0
	-0.097 to -0.119	22.2
	-0.074 to -0.096	77.8
	-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		Neutral/Somewhat Increase
2ai Change in historical thermal niche		Increase
2aii. Change in physiological thermal niche		Somewhat Increase
2bi. Changes in historical hydrological niche		Neutral
2bii. Changes in physiological hydrological niche		Somewhat Increase
2c. Dependence on specific disturbance regime		Neutral/Somewhat Increase
2d. Dependence on ice or snow-covered habitats		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		Not Applicable
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		Unknown

5b. Genetic bottlenecks	Unknown
5c. Reproductive system	Neutral/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
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: Fifteen of the 18 occurrences of *Dendrolycopodium dendroideum* in Washington (83.3%) occur in areas with a projected temperature increase of 3.9-4.4 ° F (Figure

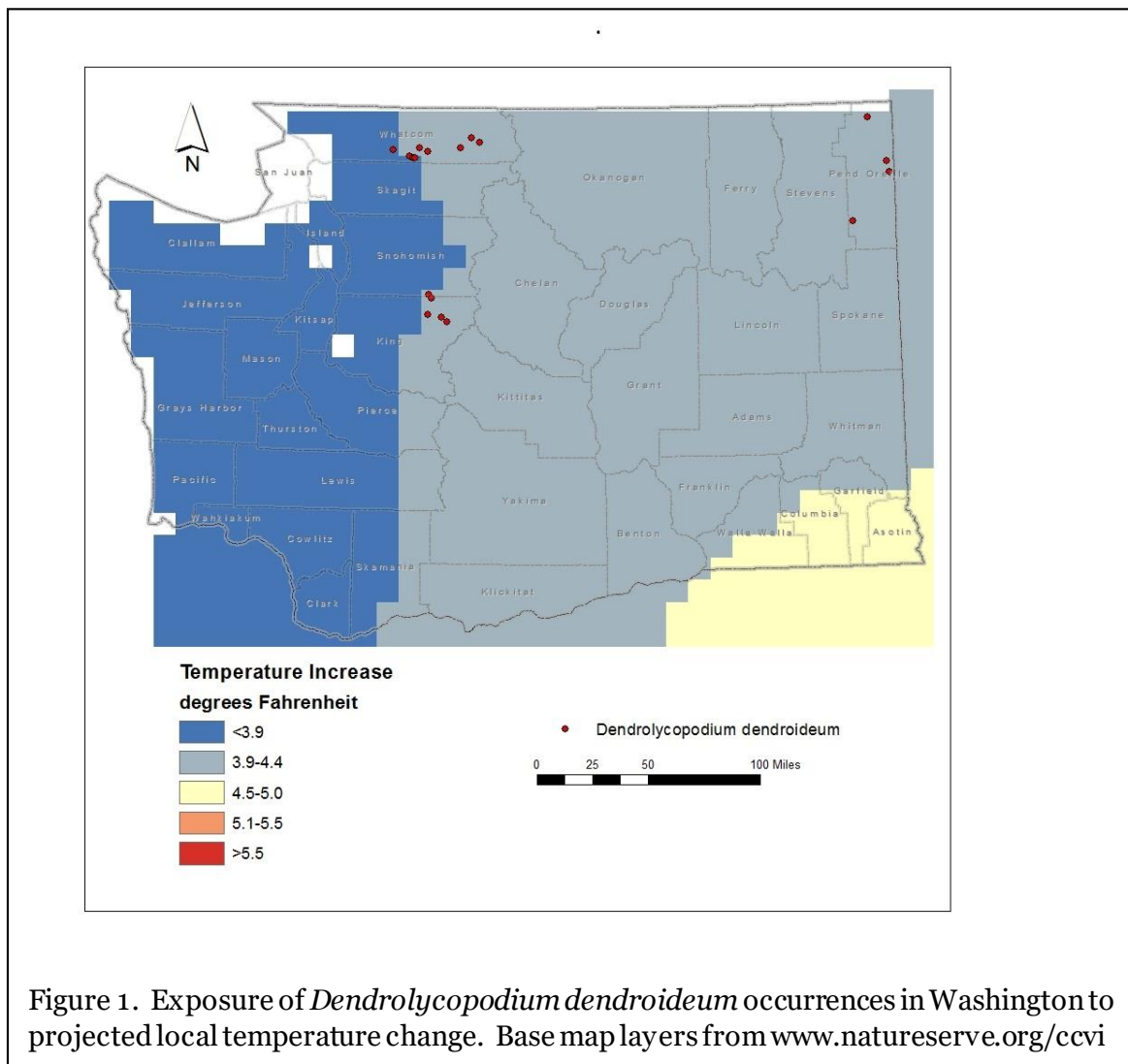


Figure 1. Exposure of *Dendrolycopodium dendroideum* occurrences in Washington to projected local temperature change. Base map layers from www.natureserve.org/ccvi

1). Three other populations (16.7%) are from areas with a projected temperature increase of < 3.9° F.

A2. Hamon AET:PET Moisture Metric: Fourteen of the 18 occurrences (77.8%) of *Dendrolycopodium dendroideum* 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). Four other populations (22.2%) are from areas with a predicted decrease of -0.097 to -0.119.

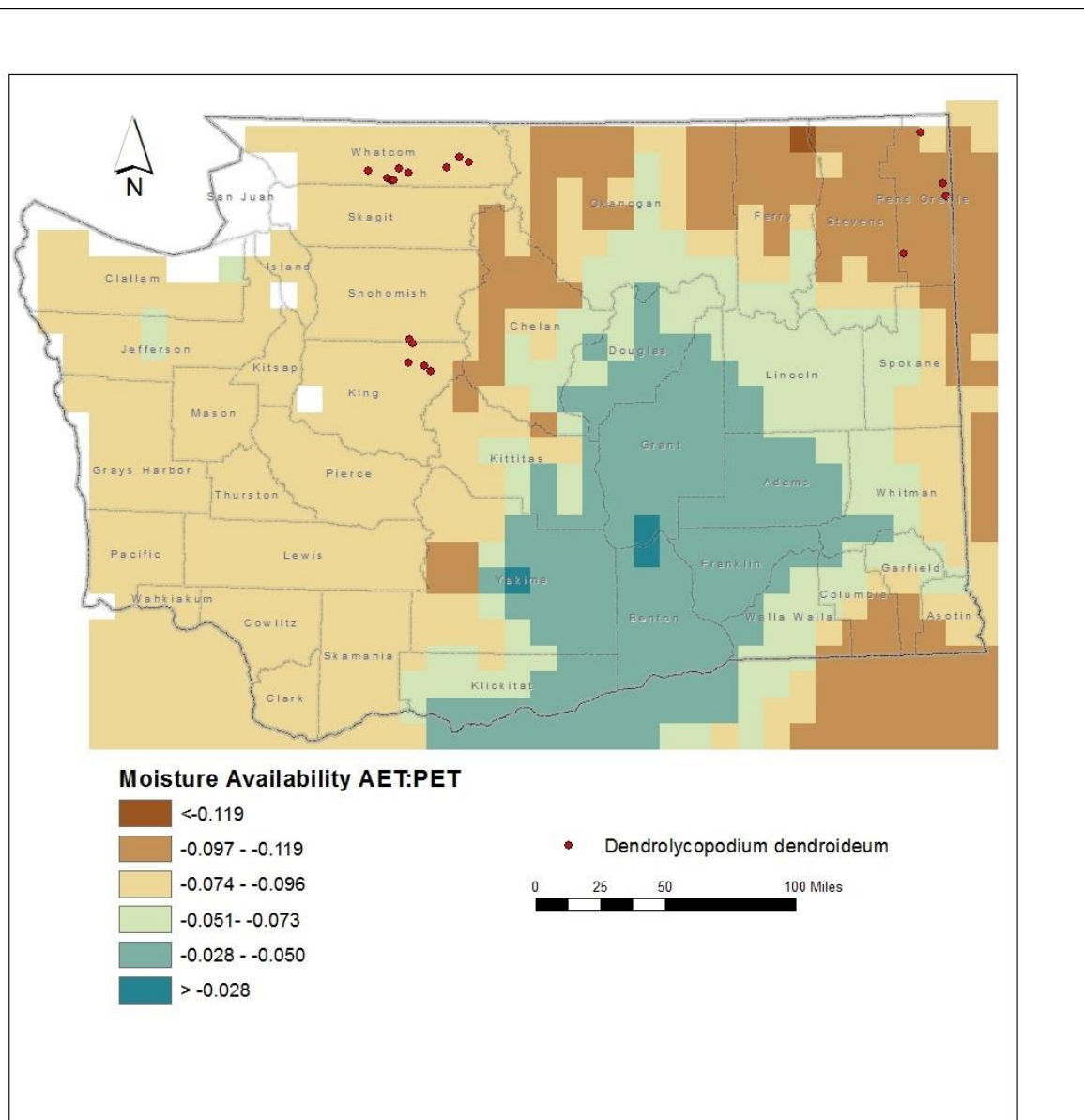


Figure 2. Exposure of *Dendrolycopodium dendroideum* occurrences in Washington to projected moisture availability (based on ratio of actual to predicted evapotranspiration). Base map layers from www.natureserve.org/ccvi

Section B. Indirect Exposure to Climate Change

B1. Exposure to sea level rise: Neutral.

Washington occurrences of *Dendrolycopodium dendroideum* are found at 800-3650 feet (240-1110 m) and would not be inundated by projected sea level rise.

B2a. Natural barriers: Somewhat Increase.

Dendrolycopodium dendroideum occurs mostly on mossy, rock outcrops and boulder fields at the edge of conifer forests dominated by western hemlock (*Tsuga heterophylla*), Douglas-fir (*Pseudotsuga menziesii*), Pacific silver fir (*Abies amabilis*), or Engelmann spruce (*Picea engelmannii*) (Camp and Gamon 2011; Washington Natural Heritage Program 2021). These habitats are part of the North Pacific Massive Bedrock, Cliff, & Talus; Rocky Mountain Cliff, Canyon, & Massive Bedrock; and Rocky Mountain Subalpine Mesic Spruce-Fir Forest & Woodland ecological systems (Rocchio and Crawford 2015). Populations are mostly isolated from each other by 1-26 miles (1.6-44 km), but are separated by up to 187 miles (300 km) between the North Cascades and Canadian Rockies. This species disperses by tiny wind-borne spores which may have reduced mobility within densely forested areas.

B2b. Anthropogenic barriers: Neutral.

The habitat of *Dendrolycopodium dendroideum* in northern Washington is entirely within National Forest or National Park lands where direct human impacts are primarily roads, trails, logging, and livestock grazing. Anthropogenic barriers are probably no more significant than natural ones for impacting dispersal of this species.

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

Section C: Sensitive and Adaptive Capacity

C1. Dispersal and movements: Neutral/Somewhat Increase.

Dendrolycopodium dendroideum, like other ferns and fern-allies, has a complex life cycle involving alternation of two distinct growth phases: the familiar sporophyte phase and a much-reduced gametophyte phase. Sporophyte plants produce large numbers of tiny, seed-like spores that are capable of long-distance dispersal by wind. Spores germinate to form gametophyte plants which reproduce sexually by gametes (sessile eggs retained within the plant and motile sperm that require moist surfaces to travel very short distances for fertilization). Sporophyte plants are produced from fertilized eggs within their parent gametophyte plant, and thus are incapable of further dispersal. Overall, dispersal by spores is not limiting, but the survival of sporophyte plants is strongly tied to gametophytes being able to survive in suitable microhabitats.

C2ai. Historical thermal niche: Increase.

Figure 3 depicts the distribution of *Dendrolycopodium dendroideum* in Washington relative to mean seasonal temperature variation for the period from 1951-2006 ("historical thermal niche"). Eleven of the 18 occurrences in the state (61.1%) are found in areas that have experienced small variation in temperature (37-47°F/20.8-26.3°C) during the past 50 years and are considered at increased vulnerability to climate change (Young et al. 2016). Six populations (33.3%) are from areas with slightly lower than average temperature variation (47.1-57°F/26.3-

31.8°C) over the same period and are at somewhat increased vulnerability to climate change. One other occurrence (5.6%) is from an area with average temperature variation (57.1-77°F/31.8-43.0°C) and is at neutral vulnerability to climate change (Young et al. 2016).

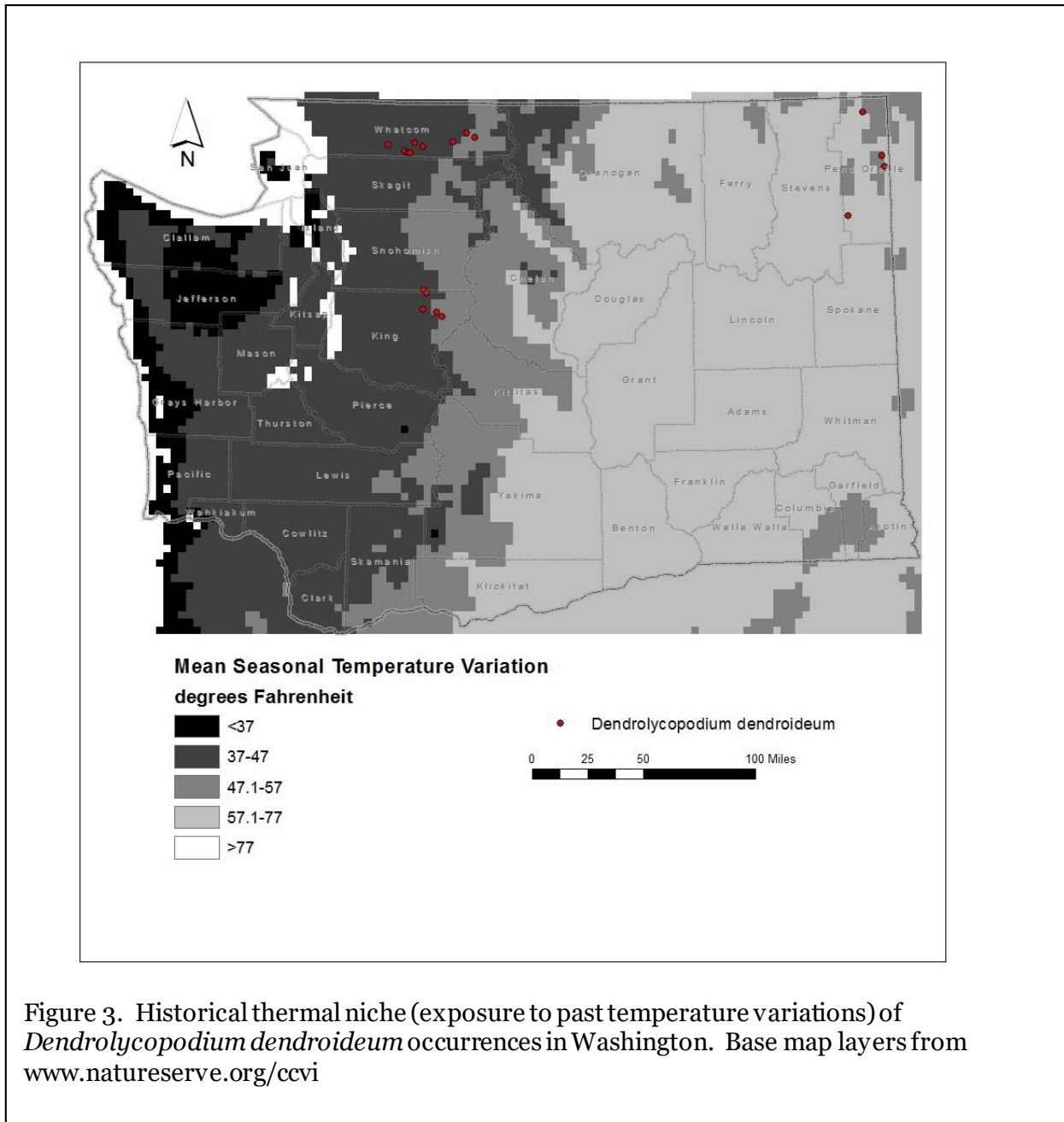


Figure 3. Historical thermal niche (exposure to past temperature variations) of *Dendrolycopodium dendroideum* occurrences in Washington. Base map layers from www.natureserve.org/ccvi

C2a.ii. Physiological thermal niche: Somewhat Increase.

The forested rock outcrop and boulder field habitat of *Dendrolycopodium dendroideum* is often associated with cold air drainages that could be adversely impacted by warming temperatures (Rocchio and Ramm-Granberg 2017).

C2bi. Historical hydrological niche: Neutral.

All of the populations of *Dendrolycopodium dendroideum* in Washington (100%) 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.

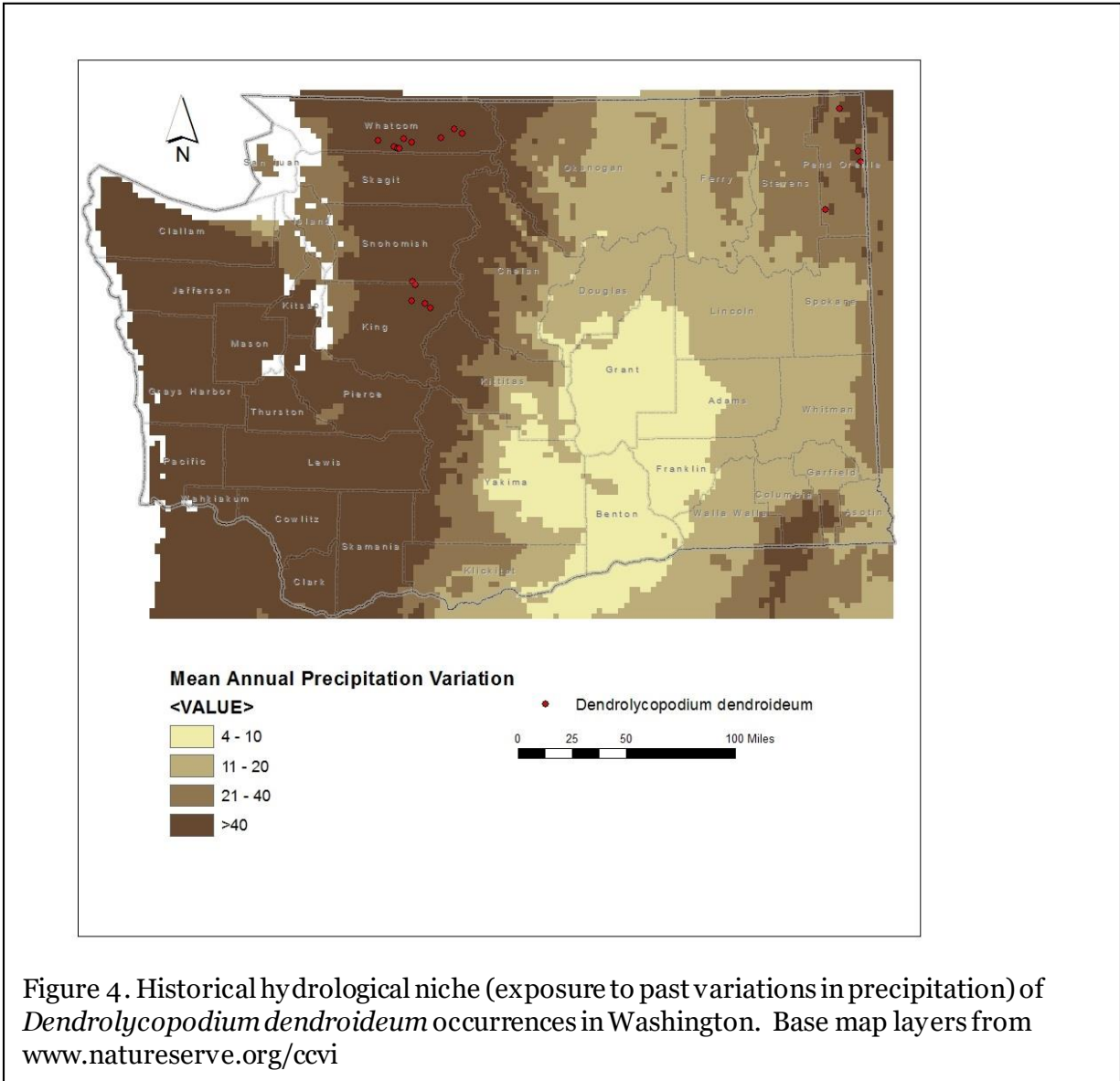


Figure 4. Historical hydrological niche (exposure to past variations in precipitation) of *Dendrolycopodium dendroideum* occurrences in Washington. Base map layers from www.natureserve.org/cvi

C2bii. Physiological hydrological niche: Somewhat Increase.

This species is dependent on adequate winter snowfall and spring/summer precipitation to maintain its forested habitat and mossy microhabitat. Projected climate change is likely to make these areas warmer and drier and more prone to wildfire (Rocchio and Ramm-Granberg 2017) which would make rocky sites less shaded and less suitable for *Dendrolycopodium*

dendroideum. Lycophytes and ferns of mesic environments are often poorly adapted for drought and vulnerable to drying and warming conditions (Link-Perez and Laffan 2018).

C2c. Dependence on a specific disturbance regime: Neutral/Somewhat Increase.

Dendrolycopodium dendroideum occurs on bedrock and boulder fields within forested areas and is not dependent on periodic disturbance to maintain its habitat. Under predicted future climate change, these forested sites could be more vulnerable to wildfire due to increased drought and reduced precipitation (Rocchio and Ramm-Granberg 2017). Newly opened rock outcrop sites could become too dry to sustain this species or be invaded by competing plant species.

C2d. Dependence on ice or snow-cover habitats: Somewhat Increase.

Populations of *Dendrolycopodium dendroideum* in Washington are found in montane areas with moderate to high amounts of snow. Changes in the quantity of snow or the timing of snowmelt under future climate scenarios could impact the persistence of this species by making its microhabitat drier and making forests more prone to wildfire (Rocchio and Ramm-Granberg 2017)

C3. Restricted to uncommon landscape/geological features: Neutral.

Dendrolycopodium dendroideum is found primarily on basalt outcrops that are widespread in the mountains of northern Washington (Washington Division of Geology and Earth Resources 2016).

C4a. Dependence on other species to generate required habitat: Neutral

The rock outcrop and conifer forest habitat occupied by *Dendrolycopodium dendroideum* is maintained largely by natural abiotic conditions.

C4b. Dietary versatility: Not applicable for plants

C4c. Pollinator versatility: Not applicable.

The sporophyte generation of *Dendrolycopodium dendroideum* reproduces by spores and does not require pollinators. The gametophyte phase reproduces by motile sperm that do not require pollinators for assistance.

C4d. Dependence on other species for propagule dispersal: Neutral.

The spores and gametes of *Dendrolycopodium dendroideum* do not require animal species for assistance in dispersal.

C4e. Sensitivity to pathogens or natural enemies: Neutral.

Dendrolycopodium dendroideum is not an edible species and is not known to be attacked by pathogens.

C4f. Sensitivity to competition from native or non-native species: Somewhat Increase.

Under present conditions, competition from non-native species is minor, as few introduced plants are adapted to forested rock outcrops. Under future climate change, conifer forests inhabited by this species will become drier, hotter, and more vulnerable to fire. Exposed rock outcrops would become more likely to be invaded by weedy annuals or native perennials adapted to more open and drier sites (Rocchio and Ramm-Granberg 2017).

C4g. Forms part of an interspecific interaction not covered above: Neutral.
Does not require an interspecific interaction.

C5a. Measured genetic variation: Unknown.

Petlewski (2020) examined genetic diversity across the range of *Dendrolycopodium dendroideum* and found distinct genotypes from northwestern and northeastern North America and eastern Asia (which may represent an undescribed taxon). Data are lacking for genetic diversity within and between populations of *D. dendroideum* in Washington. Since the species is near the southern edge of its range in Washington, it may have lower overall genetic diversity in the state due to inbreeding or founder effects.

C5b. Genetic bottlenecks: Unknown.
Not known.

C5c. Reproductive System: Neutral/Somewhat Increase.

Dendrolycopodium dendroideum has a complex life history involving an alternation between diploid spore-producing sporophytes (the familiar form of the species) and minute, gamete-producing haploid gametophytes. While spores are capable of long-distance dispersal, gametes are not and so genetic variability could be constrained in populations at the edge of the species' range, like those in Washington.

C6. Phenological response to changing seasonal and precipitation dynamics: Neutral.
The timing of reproduction in *Dendrolycopodium dendroideum* has not been altered in response to climate change.

Section D: Documented or Modeled Response to Climate Change

D1. Documented response to recent climate change: Neutral.

The distribution of *Dendrolycopodium dendroideum* has not changed significantly in Washington since it was first discovered in the state in 1909.

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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