WetEco CCVA: North Pacific Open Bog & Acidic Fen (G284)

State Threatened (G3?/S2)

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Figure 1. A stand of North Pacific Open Bog & Acidic Fen at Elk Lake (Clallam County, WA; Photo by Joe Rocchio).

Climate Change Vulnerability Rank:	High Vulnerability (50)
Exposure Rank:	Moderate Exposure (44)
Adaptive Capacity Rank:	High Vulnerability (54)
Threats Rank:	High Vulnerability (63)

Group Description

[Adapted from US National Vegetation Classification Concept Summary] This wetland group consists of acidic (pH <5.5) peatlands along the Pacific coast from the Aleutian Islands, Alaska Peninsula, Kodiak Islands, southern and southeastern coastal Alaska, coastal British Columbia south to northern California, west of the coastal mountain summits and including the Puget Sound lowlands. Mosses such as *Sphagnum* spp. or liverworts characterize the ground cover. Vegetation can be stunted conifer trees, dwarf-shrubs or herbaceous (vascular or nonvascular) plants or a mosaic; nearly all have a moss-dominated ground layer. Peatlands are often interspersed with small lakes and ponds and can be a mosaic with non-peat wetlands such as wet meadows. Shrub species include *Andromeda polifolia*, *Betula nana*, *Empetrum nigrum*, *Kalmia polifolia*, *Ledum* spp. (= *Rhododendron*), *Myrica gale*, *Salix pulchra*, and *Vaccinium* spp. Herbaceous species include *Carex anthoxanthea*, *Carex aquatilis* var. *dives*, *Carex livida*, *Carex pauciflora*, *Carex pluriflora*, *Comarum palustre*, *Drosera rotundifolia*, *Equisetum fluviatile*, *Eriophorum angustifolium*, *Geum calthifolium*, *Nephrophyllidium crista-galli*, *Parnassia kotzebuei*, *Rubus chamaemorus*, *Sanguisorba menziesii*, and *Trichophorum cespitosum*. Mosses include *Philonotis fontana* var. *americana*, *Sphagnum fuscum*, and other *Sphagnum* spp. Liverworts include *Marsupella* spp., *Nardia* spp., *Scapania* spp., and *Siphula* spp. Tree species include stunted *Callitropsis nootkatensis*, *Picea sitchensis*, *Pinus contorta* var. *contorta*, or *Tsuga mertensiana*. Elevation ranges from sea level to higher than 500 m (1650 feet), and most stands are found under 457 m (1500 feet). The annual precipitation ranges from 890-3050 mm (35-120 inches). These wetlands are relatively abundant in Alaska and British Columbia but diminish rapidly in size and number farther south. They occur in river valleys, in basins, around lakes and marshes, or on gentle to steep slopes. The group includes well-developed bogs, raised bogs and poor fens. Soils are deep (>40 cm), organic, acidic (pH <5.5) and are usually saturated throughout the growing season (Kittel et al., 2015).

In Washington, vegetation is characterized by acid-loving shrubs and sedges, especially *Rhododendron groenlandicum, Kalmia microphylla, Vaccinium oxycoccos, Gaultheria shallon, Empetrum nigrum, Carex utriculata*, *C. obnupta*, *C. aquatilis* var. *dives*, *C. lasiocarpa*, *C. livida*, *Dulichium arundinaceum*, *Eriophorum chamissonis*, and *Rhynchospora alba*. Other indicator species include *Drosera rotundifolia*, *Triantha occidentalis* ssp. *brevistyla* (=*Tofieldia glutinosa*), *Maianthemum dilatatum*, *Trientalis europaea* ssp. *arctica*, *Myrica gale, Malus fusca,* and *Spiraea douglasii*. Scattered *Tsuga heterophylla*, *Thuja plicata* and *Pinus contorta* var. *contorta* are often present. *Sphagnum* is typically dominant in the ground layer but can be absent in some areas; *Pleurozium schreberi* can be abundant at the top of *Sphagnum* hummocks or in "drier" bogs; *Cladina* spp. are common in many sites. In Washington, these peatlands are most common in areas affected by continental or alpine glaciation, such as the Puget Trough and outer Northwest Coast. They are also scattered throughout the North Cascades and West Cascades ecoregions.

Alliances

The North Pacific Open Bog & Acidic Fen Group is subdivided into three alliances: North Pacific Montane Acidic Fen, North Pacific Shrub & Open Bog, and North Pacific Lowland Acidic Fen.

North Pacific Shrub & Open Bog (A4409)

This alliance is known from lowland (below 1800 feet) areas in the Puget Trough and Northwest Coast ecoregions with a history of continental or alpine glaciation. Bogs are usually more acidic

than fens, with little or no groundwater influence (ombrotrophic). Vegetation is shrub-dominated (*Rhododendron groenlandicum*, *Kalmia microphylla*, and low-growing *Vaccinium oxycoccos*) with low sedge cover outside of soaks and wet hollows. The ground layer is nearly always dominated by *Sphagnum*, except in some degraded stands with very dense shrub cover. Like fens, bogs are permanently saturated, but water tables are more likely to fluctuate seasonally. Coastal bogs in Washington receive more rain and summer fog than those in the Puget Trough and typically occur on alpine glacial deposits instead of those left by continental glaciers. This alliance includes raised bogs—one of the rarest ecosystem types in Washington (only one confirmed site). These remarkable wetlands are much higher at the center than the edges and are entirely ombrotrophic (Rocchio et al., 2021). This alliance has a provisional conservation status rank of S2? in Washington. For more information on conservation status ranking, see NatureServe's conservation status ranking methodology (Faber-Langendoen et al., 2012; Master et al., 2012).

***North Pacific Lowland Acidic Fen* (A4411)**

This alliance also occurs at low elevations (below 1800 feet) in the Puget Trough and Northwest Coast ecoregions with a history of continental or alpine glaciation. It can also be found on the margins of the West Cascades ecoregion. As with montane fens, these are more minerotrophic and usually less acidic than bogs, with ground and surface water reaching the rooting zone. Unlike bogs, the vegetation can be entirely sedge-dominated (above the typically *Sphagnum*-dominated ground layer). When acid-loving shrubs (*Rhododendron groenlandicum* and *Kalmia microphylla*) are abundant, they are always accompanied by high sedge cover. Lowland fens are floristically differentiated from montane fens by *Vaccinium oxycoccos*, *Spiraea douglasii*, *Malus fusca*, *Rhododendron groenlandicum*, *Hypericum anagalloides*, *Frangula purshiana*, *Eriophorum chamissonis*, and *Gaultheria shallon* (Rocchio & Ramm-Granberg, 2022). This alliance has a provisional conservation status rank of S2? in Washington.

***North Pacific Montane Acidic Fen* (A4412)**

This alliance occurs in montane (above 1800 feet) to subalpine areas of the North Cascades, West Cascades, and Northwest Coast ecoregions. Fens are more minerotrophic and usually less acidic than bogs, with ground and surface water reaching the rooting zone. Vegetation is typically sedge-dominated (above the typically *Sphagnum*-dominated ground layer), though dwarf *Kalmia microphylla* is common in montane fens. Relative to lowland fens, *Caltha leptosepala*, *Calamagrostis canadensis*, *Trientalis europaea*, *Triantha occidentalis*, *Pedicularis groenlandica*, and *Eriophorum angustifolium* ssp. *angustifolium* (as opposed to *E. chamissonis*) are good floristic indicators of montane fens (Rocchio & Ramm-Granberg, 2022). This alliance has a provisional conservation status rank of S3? in Washington.

Exposure

Exposure may have multiple definitions when discussing climate change vulnerability. In this document, exposure refers to the modeled changes in climate variables that are related to a wetland's ecological integrity (as in Williams et al., 2008; Lyons et al., 2024).

Data Sources

We used data extracted from the Washington Climate Impacts Group (WA CIG) Climate Mapping for a Resilient Washington's Climate Mapping Tool (Raymond & Rogers, 2022) and summarized for us by Stewart et al. (2024). WA CIG data is derived from the Coupled Intercomparison Project

Phase 5 (CIMP5) models (Taylor et al., 2012). We chose to use the data from the Representative Concentration Pathway (RCP) 8.5, a "business as usual" emissions scenario that assumes continued increases in greenhouse gas emissions and no additional climate change mitigation (Thorne et al., 2016; Kerns et al., 2018; Halofsky et al., 2022).

Locations

In Washington, most occurrences of the North Pacific Open Bog & Acidic Fen Group are found at lowland elevations (below 1800 feet) in the Northwest Coast and Puget Trough ecoregions. Occurrences of the North Pacific Montane Acidic Fen are the exception, occurring primarily at montane and higher elevations in the North Cascades, Northwest Coast, and West Cascades ecoregions (Figure 2) (Rocchio & Ramm-Granberg, 2022).

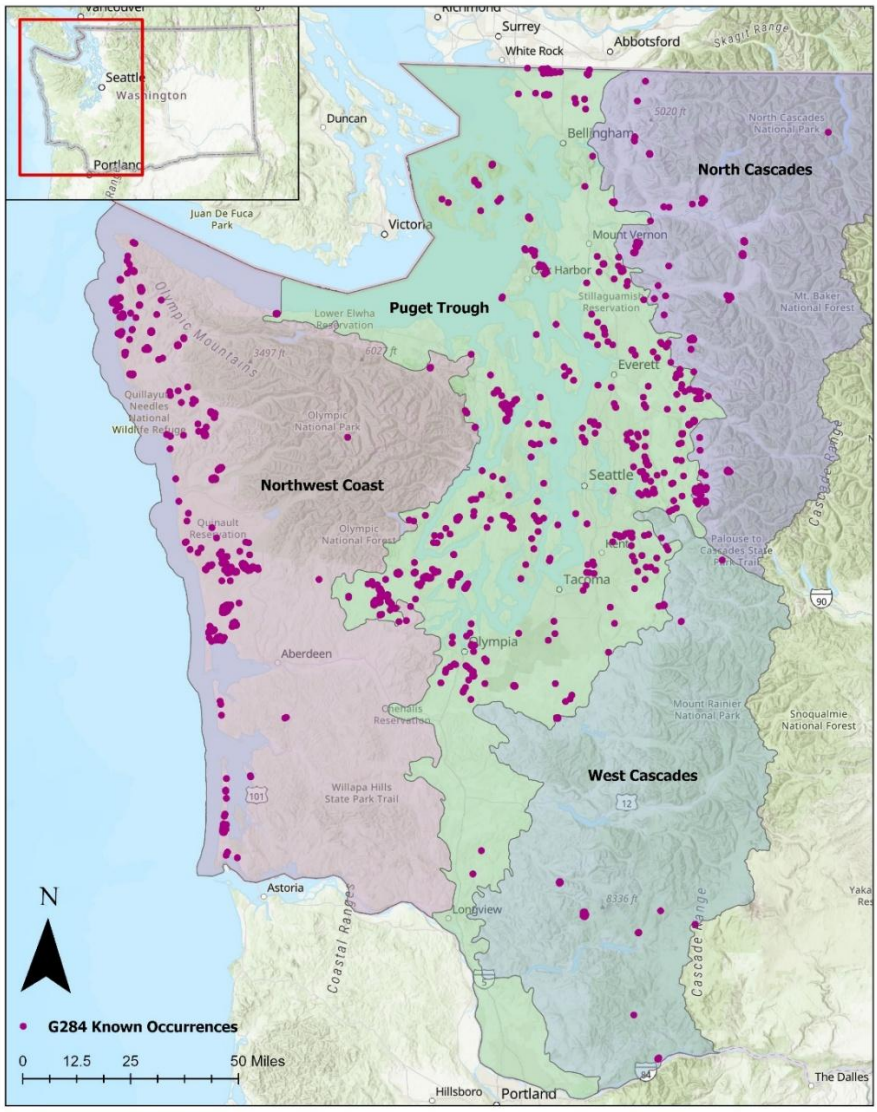

Figure 2. Distribution of known North Pacific Open Bog & Acidic Fen occurrences across Washington ecoregions (Kunze, 1994; Diaz & Mellen, 1996; Crawford et al., 2009; Rocchio et al., 2015, 2025; Ramm-Granberg et al., 2021; WNHP, 2025; and misc. plot data). Montane occurrences are likely under-sampled.

Exposure Summary

Exposure values for the group are reported as the range across ecoregions and elevation classes, though incidental occurrences in some ecoregion/elevation class combinations have been excluded (e.g., Puget Trough > 1800 feet, North Cascades and West Cascades < 1800 feet). Overall exposure values for the North Pacific Open Bog & Acidic Fen Group are moderate, driven mainly by modeled increases in maximum temperatures during the summer (Table 1).

Table 1. Exposure values and metric ratings for the North Pacific Open Bog & Acidic Fen Group and associated alliances. Ratings are reported as the range across ecoregions and elevations where the classification unit primarily occurs.

	North Pacific Open Bog & Acidic Fen (G284)			Overall
	North Pacific Shrub & Open Bog (A4409)	**North Pacific Lowland Acidic Fen (A4411)**	**North Pacific Montane Acidic Fen Alliance (A4412)**	
Metric	**Rating** (Range of Modeled Change)			
EX1. Total Annual Precipitation	Low (7-10%)	Low (7-10%)	Low (1-5%)	Low (1-10%)
EX2. Extreme Precipitation Magnitude	Low (18-20%)	Low (18-20%)	Low (15-23%)	Low (15-23%)
EX3. Snowpack	Not Rated	Not Rated	High to Very High	Not Rated
EX3.1 Snow Drought by April 1st			Moderate - Very High (0.48-0.82)	
EX3.2 Snowpack Change			Very High (76-94%)	
EX4. Summer Maximum Temperature (°F)	High (8-10°F)	High (8-10°F)	Moderate – High (9-11°F)	High (8-11°F)
EX5. Precipitation Drought in Summer	Moderate (0.34-0.38)	Moderate (0.34-0.38)	Moderate (0.36-0.40)	Moderate (0.34-0.40)
EX6. Sea Level Rise	Not Rated	Not Rated	Not Rated	Not Rated
Exposure Rank	**Moderate**	**Moderate**	**High**	**Moderate**

Metric Ratings

EX1. Total Annual Precipitation

Models suggest that the North Pacific Open Bog & Acidic Fen Group will see a small increase in precipitation (Table 2, Figure 3). This group occurs in areas with annual precipitation amounts that ranged from 32 – 140 inches (80 – 355 cm) in the baseline period (1980 – 2009) (PRISM Climate Group, 2025). The model we used suggests that total annual precipitation may increase by 1% – 10% from the 1980 – 2009 baseline in western Washington. However, these modeled increases fall

well within the standard deviation of precipitation records from 1980 – 2009 (PRISM Climate Group, 2025). Precipitation amounts in western Washington are expected to remain within the historic range of variation until the end of the century (Coops & Waring, 2011; Mauger et al., 2015), but uncertainty is high regarding this prediction (Mauger et al., 2015; Halofsky et al., 2020). Increases in total annual precipitation will likely be insufficient to counterbalance the effects of higher temperatures on evapotranspiration rates. Additionally, increases in total annual precipitation are likely to be accompanied by increases in extreme precipitation events, reduced snowpack, and greater risk of summer drought (Perry et al., 2012).

Table 2. Exposure to changes in Total Annual Precipitation (EX1) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	**Rating** (Range of Modeled Change)
North Pacific Open Bog & Acidic Fen	**Low Exposure** (1-10%)
North Pacific Shrub & Open Bog	Low Exposure (7-10%)
North Pacific Lowland Acidic Fen	Low Exposure (7-10%)
North Pacific Montane Acidic Fen	Low Exposure (1-5%)

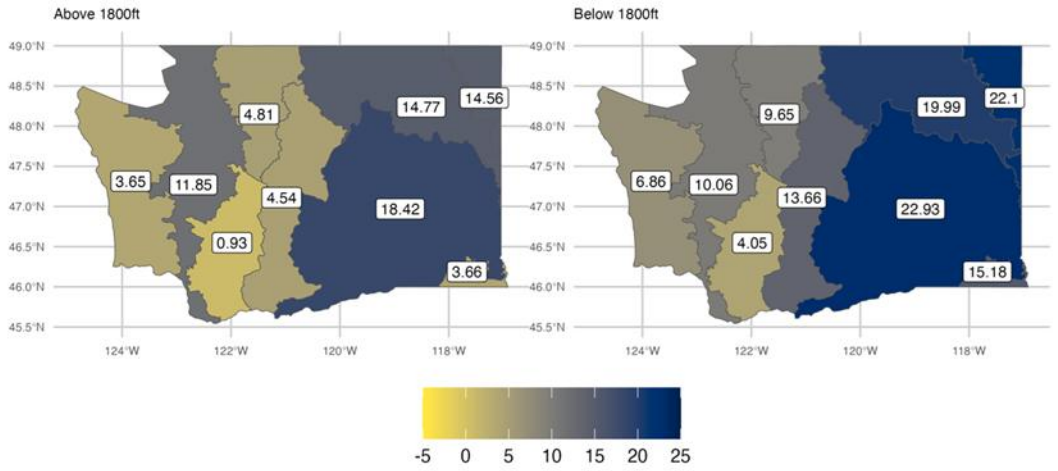

Figure 3. Modeled percent increase in Total Annual Precipitation (EX1) under future climate conditions (2070 – 2099) compared to baseline annual averages (1980 – 2009) by ecoregion (Raymond & Rogers, 2022). Data derived from CIMP5 models using RCP 8.5 (Taylor et al., 2012). Map created by Anthony J. Stewart.

EX2. Extreme Precipitation Magnitude

The magnitude of extreme precipitation events is predicted to increase by 15 – 23% from the 1980 – 2009 baseline (Table 3, Figure 4) for the North Pacific Open Bog & Acidic Fen Group. Increased precipitation magnitude and number of extreme events are the likely mechanisms for increased total annual precipitation (see EX1) in Washington (Mauger et al., 2015; Halofsky et al., 2020).

Table 3. Exposure to changes in Extreme Precipitation Magnitude (EX2) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	**Rating** (Range of Modeled Change)
North Pacific Open Bog & Acidic Fen	**Low Exposure** (15-23%)
North Pacific Shrub & Open Bog	Low Exposure (18-20%)
North Pacific Lowland Acidic Fen	Low Exposure (18-20%)
North Pacific Montane Acidic Fen	Low Exposure (15-23%)

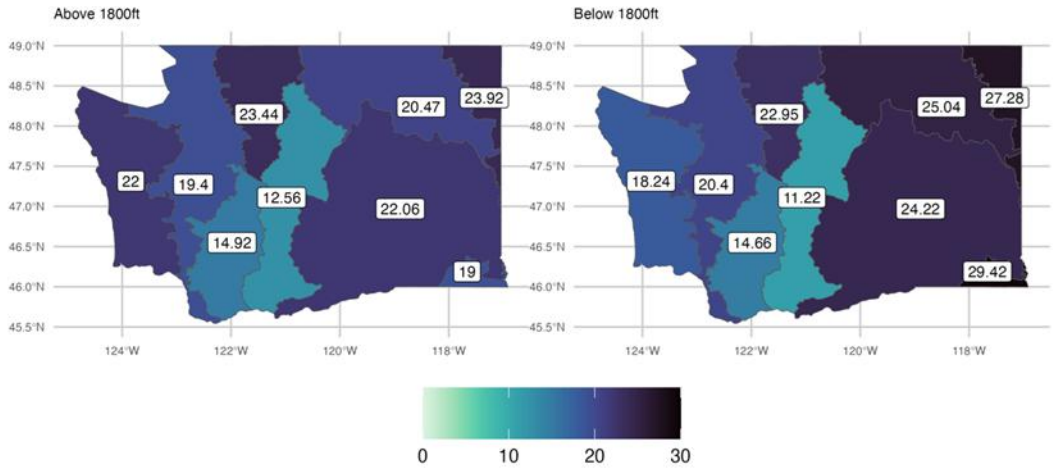

Figure 4. Modeled percent increase in Extreme Precipitation Magnitude (EX2) for 24 hours of extreme precipitation under future climate conditions (2070 – 2099) compared to baseline annual averages (1980 – 2009) by ecoregion (Raymond & Rogers, 2022). Data are derived from CIMP5 models using RCP 8.5 (Taylor et al., 2012). Map created by Anthony J. Stewart.

EX3. Snowpack

This metric integrates two submetrics: Snow Drought by April 1st (EX3.1) and Snowpack Change (EX3.2).

The North Pacific Open Bog & Acidic Fen Group primarily occurs at low elevations without seasonal snowpacks and thus EX3 was not rated at the group level (Table 4). However, note that the North Pacific Montane Acidic Fen Alliance occurs at higher elevations and will be exposed to reductions in snowpack and earlier snowmelt.

Snowpack is modeled to diminish significantly by the end of the century at all elevations west of the Cascades. Areas above 1800 feet in the North Cascades, Northwest Coast, and West Cascades ecoregions are expected to have snowpack reductions of 76-94%. Chances of snow drought by April 1st are expected to increase by 48-82% (Figure 5, Figure 6).

Table 4. Exposure to changes in Snowpack (EX3) for North Pacific Open Bog & Acidic Fen and associated alliances.

	EX3. Snowpack		
Classification Unit	**Submetric EX3.1 Snow Drought by April 1st** (Range of Modeled Change)	**Submetric EX3.2 Snowpack Change** (Range of Modeled Change)	**Overall**
North Pacific Open Bog & Acidic Fen	**Not Rated**	**Not Rated**	**Not Rated**
North Pacific Shrub & Open Bog	Not Rated	Not Rated	Not Rated
North Pacific Lowland Acidic Fen	Not Rated	Not Rated	Not Rated
North Pacific Montane Acidic Fen	Moderate to Very High Exposure (0.48-0.82)	Very High Exposure (76-94%)	High to Very High Exposure

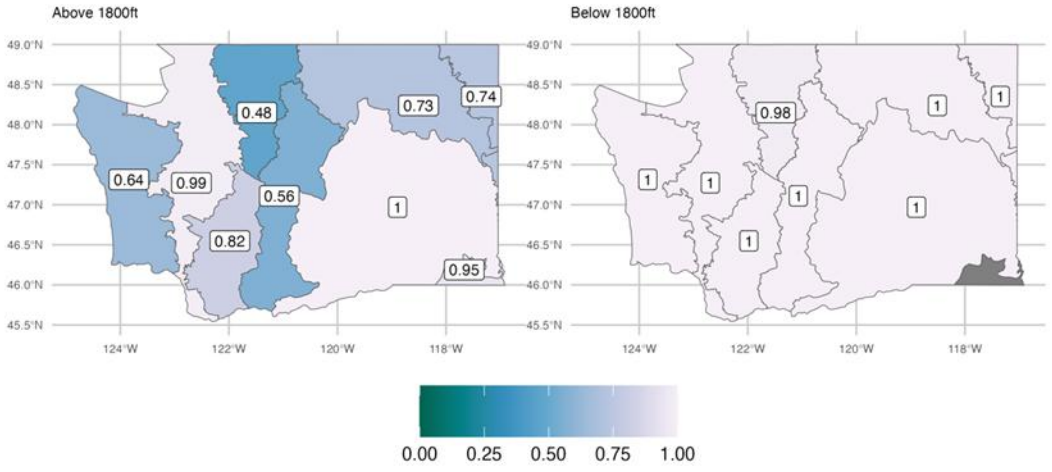

Figure 5. Modeled increase in Snow Drought by April 1st (EX3.1), as measured by snow received by April 1st is 75% or less than historical norms, under future climate conditions (2070 – 2099) compared to baseline conditions (1980 – 2009) by ecoregion (Raymond & Rogers, 2022). The Blue Mountains ecoregion (in gray) does not have snow drought data below 1800 feet. Data are derived from CIMP5 models using RCP 8.5 (Taylor et al., 2012). Map created by Anthony J. Stewart.

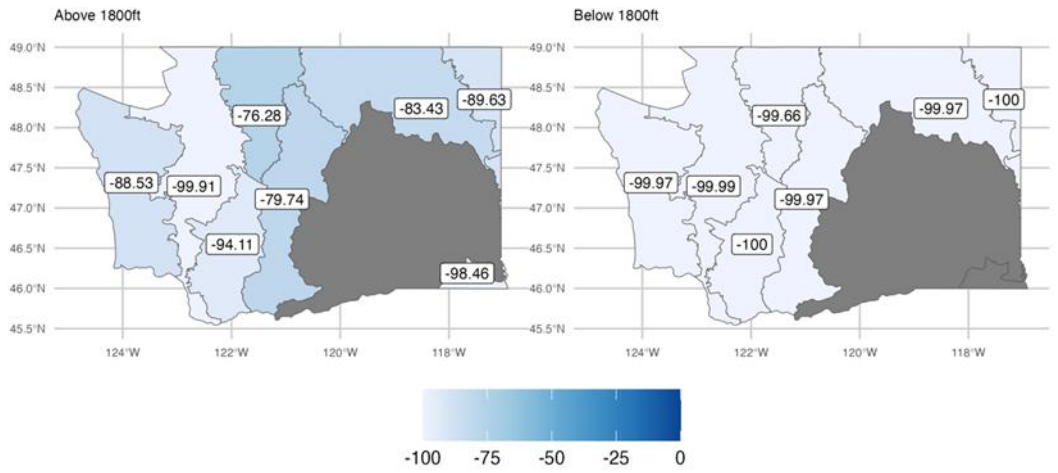

Figure 6. Modeled percent change for Snowpack Change (EX3.2), as measured by snow depth on April 1st, under future climate conditions (2070 – 2099) compared to baseline annual averages (1980 – 2009) by ecoregion (Raymond & Rogers, 2022). Ecoregions in gray (Columbia Basin at all elevations, Blue Mountains below 1800 feet) do not have available observations for this metric. Data are derived from CIMP5 models using RCP 8.5 (Taylor et al., 2012). Map created by Anthony J. Stewart.

EX4. Summer Maximum Temperature

Summer maximum temperatures are expected to increase by 8 – 11 °F where the North Pacific Open Bog & Acidic Fen Group occurs (Table 5, Figure 7). The smallest increases in temperature are anticipated on the Northwest Coast and the largest increases are likely in the North Cascades. The West Cascades had the most variable baseline period (greatest standard deviation) among ecoregions where these ecosystems occur and is the only ecoregion where exposure to EX4 was rated moderate instead of high. Regions that experience more variable climates during the baseline period may have greater adaptive capacity to changes in climate (Girvetz et al., 2009).

Table 5. Exposure to changes in Summer Maximum Temperature (EX4) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	**Rating** (Range of Modeled Change)
North Pacific Open Bog & Acidic Fen	High Exposure (8-11°F)
North Pacific Shrub & Open Bog	High Exposure (8-10°F)
North Pacific Lowland Acidic Fen	High Exposure (8-10°F)
North Pacific Montane Acidic Fen	Moderate to High Exposure (9-11°F)

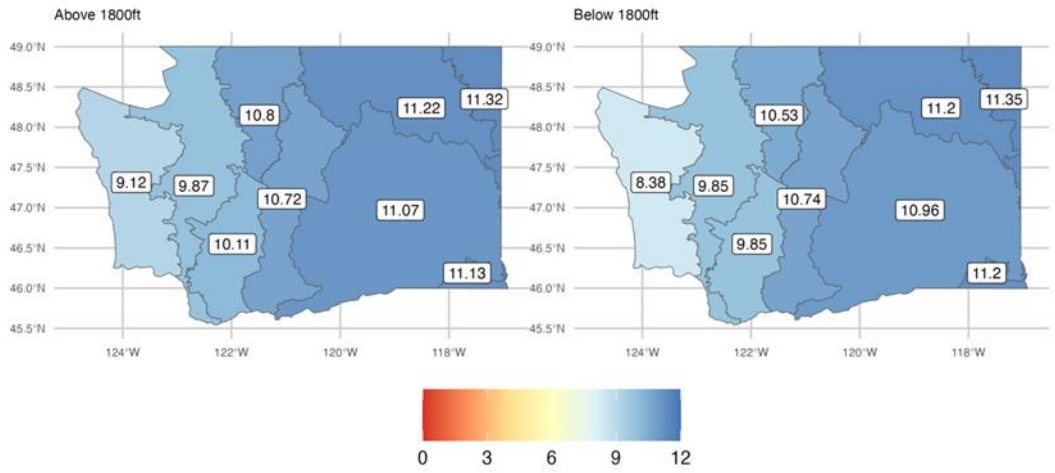

Figure 7. Modeled increase in temperature in °F in Summer Maximum Temperature (EX4) under future conditions (2070 – 2099) compared to baseline conditions (1980 – 2009) by ecoregion (Raymond & Rogers, 2022). Data are derived from CIMP5 models using RCP 8.5 (Taylor et al., 2012). Map created by Anthony J. Stewart.

EX5. Precipitation Drought in Summer

While Washington already receives most of its precipitation outside the summer months (Perry et al., 2012) it is also expected to see an increase in summer drought (Mauger et al., 2015; Halofsky et al., 2020). The likelihood of summer drought is expected to increase by 34 – 40% where the North Pacific Open Bog & Acidic Fen Group occurs (Table 6, Figure 8).

Table 6. Exposure to Precipitation Drought in Summer (EX5) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	**Rating** (Range of Modeled Change)
North Pacific Open Bog & Acidic Fen	**Moderate Exposure** (0.34-0.40)
North Pacific Shrub & Open Bog	Moderate Exposure (0.34-0.38)
North Pacific Lowland Acidic Fen	Moderate Exposure (0.34-0.38)
North Pacific Montane Acidic Fen	Moderate Exposure (0.36-0.40)

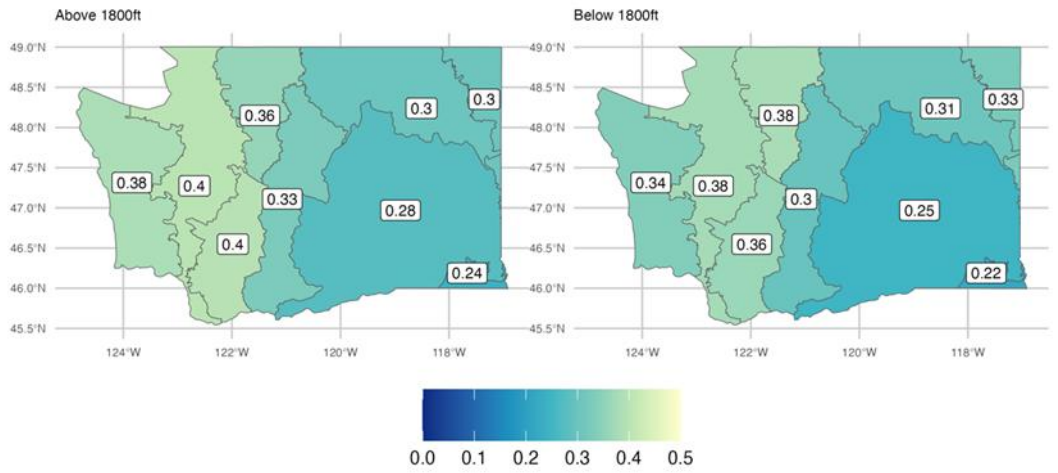

Figure 8. Modeled increase in Precipitation Drought in Summer (EX5) under future climate conditions (2070 – 2099) compared to baseline conditions (1980 – 2009) by ecoregion (Raymond & Rogers, 2022). Data are derived from CIMP5 models using RCP 8.5 (Taylor et al., 2012). Map created by Anthony J. Stewart.

EX6. Sea Level Rise

Few or no occurrences of the North Pacific Open Bog & Acidic Fen Group are expected to be affected by sea level rise by 2099 (Table 7).

Table 7. Exposure to Sea Level Rise (EX6) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	**Rating** (Range of Modeled Change)
North Pacific Open Bog & Acidic Fen	**Not Rated**
North Pacific Shrub & Open Bog	Not Rated
North Pacific Lowland Acidic Fen	Not Rated
North Pacific Montane Acidic Fen	Not Rated

Adaptive Capacity

Adaptive capacity is defined as the natural characteristics that allow an ecosystem to adapt and respond to changes in climate exposure (Comer et al., 2019). Many climate change vulnerability analysis methods consider adaptive capacity and sensitivity as separate attributes, but in our review, we found sensitivity to be frequently defined by a species or ecosystem's adaptive capacity or as the response mediated by a species or ecosystem's adaptive capacity (e.g., Williams et al., 2008; Thorne et al., 2016; Defne et al., 2020; Halofsky et al., 2022). In order to avoid redundant metrics, we considered ecosystem sensitivity as part of our Adaptive Capacity metrics instead of as a separate section.

Adaptive Capacity is subdivided into three sections. Abiotic Factors and Climate Niche addresses the direct effects of climate exposure as well as abiotic conditions that affect ecosystems. Distribution and Range addresses how ecosystem extent and abundance contribute to its adaptive

capacity. Diversity, Community Structure, and Community Dynamics addresses how biotic conditions affect an ecosystem's adaptive capacity.

Adaptive Capacity Summary

Bridgham et al. (2008) describe peatlands as particularly sensitive to climate change, and the North Pacific Open Bog & Acidic Fen Group appears to be relatively vulnerable to changes in climate exposure (Table 8). Peatland development is largely controlled by climate factors, and warmer and drier climate will likely reduce abundance of peatlands, especially at the southern end of the their range (Gignac & Vitt, 1994). Peat cores suggest that peatlands can be extremely long lived and have historically shifted between ecosystem types when climate exposure change (Rigg, 1925; Mauquoy & Yeloff, 2008; Klein et al., 2013). However projected future climate change exceeds historic patterns and therefore could potentially exceed peatlands' abilities to adapt to changing climate exposures (Mauquoy & Yeloff, 2008). Bogs and fens are expected to have differences in adaptive capacity related to differences in hydrology (Rocchio & Ramm-Granberg, 2017).

Table 8. Adaptive Capacity ratings for the North Pacific Open Bog & Acidic Fen Group and associated alliances.

	North Pacific Open Bog & Acidic Fen (G284)			Overall
	North Pacific Shrub & Open Bog (A4409)	North Pacific Lowland Acidic Fen (A4411)	North Pacific Montane Acidic Fen Alliance (A4412)	
Metric	**Rating**			
Abiotic Factors and Climate Niche				
AC1. Adaptive Capacity to Total Annual Precipitation	Very High Vulnerability	High Vulnerability	High Vulnerability	High to Very High Vulnerability
AC2. Adaptive Capacity to Extreme Precipitation Magnitude	High Vulnerability	High Vulnerability	High Vulnerability	High Vulnerability
AC3. Adaptive Capacity to Snowpack Change	Not Rated	Not Rated	Very High Vulnerability	Not Rated
AC4. Adaptive Capacity to Summer Maximum Temperature (°F)	Very High Vulnerability	High Vulnerability	High Vulnerability	High to Very High Vulnerability
AC5. Adaptive Capacity to Precipitation Drought in Summer	High Vulnerability	High Vulnerability	High Vulnerability	High Vulnerability
AC6 Adaptive Capacity Sea Level Rise	Not Rated	Not Rated	Not Rated	Not Rated
AC7. Diversity of Hydrological Conditions and Variability of Biophysical Settings	High Vulnerability	High Vulnerability	High Vulnerability	High Vulnerability

Distribution and Range				
AC8. Current Extent	Low Vulnerability	Low Vulnerability	Low Vulnerability	Low Vulnerability
AC9. Location within Geographic Range	Moderate - High Vulnerability	Moderate - High Vulnerability	Moderate - High Vulnerability	Moderate - High Vulnerability
Diversity, Community Structure, and Community Dynamics				
AC10. Vulnerability and Redundancy of Key Component Species	Moderate to High Vulnerability	Moderate Vulnerability	Moderate Vulnerability	Moderate Vulnerability
AC10.1 Vulnerability of Key Species	Moderate Vulnerability	Moderate Vulnerability	Moderate Vulnerability	Moderate Vulnerability
AC10.2 Redundancy of Key Species	High Vulnerability	Moderate Vulnerability	Moderate Vulnerability	Moderate Vulnerability
Adaptive Capacity Rank	**High Vulnerability**	**High Vulnerability**	**High Vulnerability**	**High Vulnerability**

Abiotic Factors and Climate Niche Metric Ratings

AC1. Adaptive Capacity to Total Annual Precipitation

Peatlands require precipitation to exceed evapotranspiration in order to develop (Gignac & Vitt, 1994; Gignac et al., 2000), suggesting that all alliances in the North Pacific Open Bog & Acidic Fen Group have high to very high vulnerability to decreases in precipitation (Table 9). Compared to ombrotrophic peatlands, minerotrophic types may be somewhat buffered from reductions in total annual precipitation because of significant contributions from ground and/or surface water. However, all occurrences of this group depend on saturated conditions that could be disrupted by decreases in total annual precipitation. Decreases in precipitation could result in drying and decomposition of peat, reversing peat accumulation and potentially shifting peatland ecosystems to other ecosystem types (Gignac & Vitt, 1994; Bridgham et al., 2008; Kolka et al., 2018; Daugherty et al., 2019).

While only one entirely ombrotrophic peatland has been confirmed in Washington, vegetative indicators suggest that the North Pacific Shrub & Open Bog Alliance (A4409) as a whole relies on precipitation for maintaining saturated conditions (Rocchio et al., 2021, 2025). This alliance is likely more vulnerable to reductions in precipitation or changes in precipitation patterns than peatlands that are more reliant on ground or surface water.

Table 9. Ratings for Adaptive Capacity to Total Annual Precipitation (AC1) ratings for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	Rating
North Pacific Open Bog & Acidic Fen	**High to Very High Vulnerability**
North Pacific Shrub & Open Bog	Very High Vulnerability

North Pacific Lowland Acidic Fen	High Vulnerability
North Pacific Montane Acidic Fen	High Vulnerability

AC2. Adaptive Capacity to Extreme Precipitation Magnitude

The North Pacific Open Bog & Acidic Fen Group likely has high vulnerability to increases in the magnitude of extreme precipitation events (Table 10). Altered precipitation regimes can change hydrology in wetlands (Kolka et al., 2018). An increase in the magnitude of extreme precipitation events will likely lead to increased runoff and reduced infiltration into soil and aquifers (Trenberth, 2011), especially in watersheds with a high amount of impervious surfaces. An increase in the magnitude or frequency of extreme precipitation events could also result in greater fluctuation of water tables, and dryer overall soil conditions (Trenberth, 2011; Flint et al., 2013), which can increase decomposition rates in peatlands.

Intact peatlands can slow runoff and mitigate flooding to some extent (e.g., Marcotte et al., 2024). In particular, bogs that are already saturated typically shed excess water to surrounding laggs, demonstrating some adaptive capacity to extreme precipitation events. Similarly, sloping fens will generally pass on excess water to downstream ecosystems. However, this capacity may still be overwhelmed when extreme events are paired with large impervious areas within the watershed (Rocchio et al., 2025) or in peatlands that are topographically restricted.

Increases in runoff can also increase the influx of pollutants or nutrients in peatlands and their laggs, particularly where anthropogenic activities affect the buffer around the peatland (Rocchio et al., 2025). Storm water can cause temporary increases in pH in some Puget Lowland peatlands (Rocchio et al., 2025). Increases in nutrient and other inputs could shift peatlands toward a greater percentage of vascular plant species, more minerotrophic vegetation, or towards different wetland types (Mauquoy & Yeloff, 2008; Kittel et al., 2015; Barel et al., 2021; Rocchio & Ramm-Granberg, 2022). Increased water table fluctuations can lead to increases in decomposition and decreases in peat accumulation, potentially shifting peatland ecosystems to other ecosystem types (Gignac & Vitt, 1994; Barel et al., 2021). Extreme precipitation events are also correlated with droughts and heat waves (Trenberth, 2011). Precipitation patterns that lead to drier peatlands in the summer may increase their potential vulnerability to fire (Swanston et al., 2011), though the likelihood of fire conditions are not modeled to increase very much in these systems (Stewart et al., 2024).

Table 10. Ratings for Adaptive Capacity to Extreme Precipitation Magnitude (AC2) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	Rating
North Pacific Open Bog & Acidic Fen	**High Vulnerability**
North Pacific Shrub & Open Bog	High Vulnerability
North Pacific Lowland Acidic Fen	High Vulnerability
North Pacific Montane Acidic Fen	High Vulnerability

AC3. Adaptive Capacity to Snowpack Change

This group is most abundant at low elevations where seasonal snowpacks are not a direct part of existing ecological processes, so AC3 was not rated at the group level. AC3 was also not rated for the North Pacific Lowland Acidic Fen or North Pacific Shrub & Open Bog alliances. The North

Pacific Montane Acidic Fen Alliance was still assessed because it occurs at higher elevations with seasonal snowpack (Table 11). Loss of snowpack is likely to result in lower water tables and increased temperatures, especially late in the season (Halofsky et al., 2022; Reyes & Kramer, 2023; Liu et al., 2024). This suggests increases in decomposition and decreases in peat accumulation, potentially resulting in changes in species composition and ecosystem types (Gignac & Vitt, 1994). Fens supported by small or shallow aquifers will be more susceptible to changes in precipitation and snowpack. Snowmelt is more effective at recharge than rainfall, so shallower snowpacks coupled with earlier snowmelt will likely result in decreased recharge for small and shallow aquifers, with a significant impact (i.e., drying effect) on the hydrology of montane fens (Pitz, 2016). Based on the importance of snowpack to maintaining its stable hydrologic conditions, the North Pacific Montane Acidic Fen Alliance likely has very high vulnerability to decreases in snowpack amounts and earlier snow melt dates.

Table 11. Ratings for Adaptive Capacity to Snowpack Change (AC3) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	Rating
North Pacific Open Bog & Acidic Fen	**Not Rated**
North Pacific Shrub & Open Bog	Not Rated
North Pacific Lowland Acidic Fen	Not Rated
North Pacific Montane Acidic Fen	Very High Vulnerability

AC4. Adaptive Capacity to Summer Maximum Temperature

The North Pacific Open Bog & Acidic Fen Group likely has high to very high vulnerability to increases in summer maximum temperatures (Table 12), particularly because of accompanying increases in water deficit (Abatzoglou et al., 2014). Groundwater sources are known to maintain cooler temperatures in wetlands and can buffer against temperature changes (Poff et al., 2002; Seavy et al., 2009), suggesting fens may have less vulnerability to increased summer maximum temperatures than bogs. Areas where peatland ecosystems occur have experienced relatively little historical temperature variability (Lawler & Mathias, 2007) and associated taxa are less likely to have pre-adapted traits (Girvetz et al., 2009) or genetic variation (e.g., Sheth & Angert, 2014) to help adjust to summer maximum temperature increases (Girvetz et al., 2009).

Changes in temperature can affect soil biogeochemistry, decomposition, and water availability (Brown et al., 2015). Cool temperatures and high water tables are important for maintaining and accumulating peat, and bogs and poor fens are usually restricted to cooler areas (Gignac & Vitt, 1994; Gignac et al., 2000). While some studies suggest that temperate peatlands may be able to maintain peat accumulation under warmer temperatures as long as precipitation outweighs evapotranspiration (Cai & Yu, 2011), increases in temperatures are likely to increase peat decomposition more than they increase plant productivity (Gignac & Vitt, 1994). Some models have shown a 40% loss of soil organic carbon in mostly ombrotrophic peatland ecosystems under a scenario where average annual temperature increases 4 ºC (Ise et al., 2008).

Table 12. Ratings for Adaptive Capacity to Summer Maximum Temperature (AC4) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	Rating
North Pacific Open Bog & Acidic Fen	**High to Very High Vulnerability**
North Pacific Shrub & Open Bog	Very High Vulnerability
North Pacific Lowland Acidic Fen	High Vulnerability
North Pacific Montane Acidic Fen	High Vulnerability

AC5. Adaptive Capacity to Precipitation Drought in Summer

The North Pacific Open Bog & Acidic Fen Group likely has high vulnerability to summer droughts (Table 13). While ombrotrophic bogs rely on precipitation, suggesting they may be more sensitive to drought than groundwater-fed fens, bogs also have mechanisms that maintain water tables and saturation during droughts. Extended drought may eventually disrupt these mechanisms, but in the short term, these systems have some adaptive capacity to withstand drought (Rydin & Jeglum, 2013; Väliranta et al., 2016; Oke & Hager, 2017; Rocchio & Ramm-Granberg, 2017). Increases in winter precipitation are unlikely to alleviate summer drought in these systems (Rocchio & Ramm-Granberg, 2017).

Droughts favor non-*Sphagnum* mosses such as *Pleurozium schreberi* (Foster, 1985; Gignac et al., 1991; Lachance & Lavoie, 2004; Benscoter & Vitt, 2008; Pellerin et al., 2016). Reducing or eliminating *Sphagnum* spp. has cascading impacts on the pH and nutrient content of the soil and porewater (Rice, 2009). Drying can increase the release of soil carbon in peatlands (Fellman et al., 2017), potentially leading to altered community composition and structure. Low water tables increase oxygen exposure which increases decomposition in peatlands, potentially resulting in shifts in ecosystem type, and turning peatlands from a carbon sink to a carbon source (Gignac & Vitt, 1994; Bridgham et al., 2008; Kolka et al., 2018; Daugherty et al., 2019).

Lower water tables caused by summer drought, higher temperatures, and lower snowpack could also increase the risk of fires in peatlands (Markle et al., 2022). Evidence suggests that some Washington peatlands were traditionally managed with cultural fire (Bach & Conca, 2004; Anderson, 2009), but fires under exceptionally dry conditions risk combustion of the peat substrate itself.

Table 13. Ratings for Adaptive Capacity to Precipitation Drought in Summer (AC5) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	Rating
North Pacific Open Bog & Acidic Fen	**High Vulnerability**
North Pacific Shrub & Open Bog	High Vulnerability
North Pacific Lowland Acidic Fen	High Vulnerability
North Pacific Montane Acidic Fen	High Vulnerability

AC6. Adaptive Capacity to Sea Level Rise

Few or no occurrences of the North Pacific Open Bog & Acidic Fen Group are expected to be affected by sea level rise by 2099 (Table 14).

Table 14. Ratings for Adaptive Capacity to Sea Level Rise (AC6) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	Rating
North Pacific Open Bog & Acidic Fen	**Not Rated**
North Pacific Shrub & Open Bog	Not Rated
North Pacific Lowland Acidic Fen	Not Rated
North Pacific Montane Acidic Fen	Not Rated

AC7. Diversity of Biophysical Settings and Variability of Supporting Hydrological Conditions

Most occurrences of The North Pacific Open Bog & Acidic Fen Group occur in one of two HGM classes (depressional and slope) (Brinson, 1993; Gignac et al., 2000). This group also occurs in organic flat settings, and the North Pacific Lowland Acidic Fen Alliance also occurs in Lacustrine-fringe or in Riverine classes (Table 15). All ecosystems within this group rely on saturated hydrological regimes to persist (Gignac et al., 2000; Rocchio & Ramm-Granberg, 2022). Because of the limited number of biophysical settings and hydrological regimes supporting this group, it is likely to have high vulnerability to climate change (Table 16). While many fens are supported by groundwater, we have still assigned high vulnerability ratings to those alliances because of the limited number of HGM classes in which they occur and their dependence on stable hydrological conditions.

Peatlands associated with groundwater may be less susceptible to increases in variability in hydrological conditions due to climate change than those that are fed by precipitation or surface water (Rocchio & Ramm-Granberg, 2017). Changes in hydrologic conditions, such as reduction and/or increased variation in water table depth can decrease peat accumulation and increase peat decomposition and carbon loss (Gignac & Vitt, 1994; Klein et al., 2013; Kolka et al., 2018). These changes in soil dynamics in turn can shift peatlands to different ecosystem types (Gignac & Vitt, 1994; Klein et al., 2013). Reduction of water tables also increases encroachment from trees and other upland species, with the potential to shift ecosystem type over time (Gignac & Vitt, 1994; Moore, 2002; Rydin & Jeglum, 2013; Väliranta et al., 2016; Jones et al., 2024).

Table 15. Hydrogeomorphic (HGM) classes by alliance for North Pacific Open Bog & Acidic Fen and associated alliances.

Diversity of HGM classes: North Pacific Open Bog & Acidic Fen Group (G284)		
Alliance		**HGM classes**
A4409	North Pacific Shrub & Open Bog	Slope, Depressional, Organic Flats
A4411	North Pacific Lowland Fen	Slope, Depressional, Lacustrine-fringe, Riverine
A4412	North Pacific Montane Acidic Fen	Slope, Depressional

Table 16. Ratings for Diversity of Biophysical Settings and Variability of Supporting Hydrological Conditions (AC7) for the North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	Rating
North Pacific Open Bog & Acidic Fen	**High Vulnerability**
North Pacific Shrub & Open Bog	High Vulnerability
North Pacific Lowland Acidic Fen	High Vulnerability
North Pacific Montane Acidic Fen	High Vulnerability

Distribution and Range Metric Ratings

AC8. Current Extent

Due to available data, which focuses on occurrences with significant conservation value and found in areas with relatively few barriers to access, current extent of the North Pacific Open Bog & Acidic Fen Group and associated alliances is rated on range extent only. We used the GeoCAT tool (Bachman et al., 2011) to calculate range extents. Estimated range extent for the North Pacific Open Bog & Acidic Fen group is 72,000 km^2 (low vulnerability) (Table 17). All alliances also rate as low vulnerability, though the North Pacific Montane Acidic Fen Alliance has a much smaller extent (38,000 km^2) and fewer documented occurrences than the other two alliances in this group. The North Pacific Open Bog & Acidic Fen Group occurs in four ecoregions in Washington, but none of the component alliances occur across all these ecoregions. The North Pacific Montane Acidic Fen Alliance occurs in three ecoregions. Both the North Pacific Shrub & Open Bog Alliance (A4409) and the North Pacific Lowland Acidic Fen Alliance (A4411) occur mainly in the Northwest Coast and Puget Trough ecoregions, with incidental occurrences of A4411 in the West Cascades ecoregion.

Table 17. Current Extent (AC8) ratings for the North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	Rating
North Pacific Open Bog & Acidic Fen	**Low Vulnerability**
North Pacific Shrub & Open Bog	Low Vulnerability
North Pacific Lowland Acidic Fen	Low Vulnerability
North Pacific Montane Acidic Fen	Low Vulnerability

AC9. Location within Geographic Range

The North Pacific Open Bog & Acidic Fen Group occurs from Alaska to Northern California. Washington is in the southern third of the geographic range. Occurrences of this group are smaller and fewer in Washington and south (Kittel et al., 2015), and though Washington is not at the edge of the range, this group likely experiences a moderate to high increase in vulnerability due to its geographic location (Table 18).

Table 18. Ratings for Location within Geographic Range (AC9) for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	Rating

North Pacific Open Bog & Acidic Fen	**Moderate - High Vulnerability**
North Pacific Shrub & Open Bog	Moderate - High Vulnerability
North Pacific Lowland Acidic Fen	Moderate - High Vulnerability
North Pacific Montane Acidic Fen	Moderate - High Vulnerability

Diversity, Community Structure, and Community Dynamics Metric Ratings

AC10. Vulnerability and Redundancy of Key Component Species

Key component species consist of dominant, diagnostic, or other species known to be critical to ecosystem processes.

Peatlands are an important source of diversity in forested landscapes (Hedwall et al., 2017; Sutheimer et al., 2021). Increases in vegetation diversity within peatlands are expected with climate change (Gignac & Vitt, 1994), but increases in diversity are often a sign of reduced ecological integrity in these ecosystems. The key plant taxa associated with the North Pacific Open Bog & Acidic Fen Group may indicate moderate vulnerability to climate change (Table 19). Key taxa in these systems are primarily stress tolerators, but may be somewhat dependent on cool temperatures or otherwise demonstrate stress at the southern extents of their range.

AC10.1 Vulnerability of Key Species

Many bog and fen species are highly tolerant of stressful growing conditions (e.g., acidic, low nutrients) (Bell, 2002). For example, *Empetrum nigrum* also grows on xeric, wind-scoured ridgelines at high elevations (Rigg, 1940; Bell & Tallis, 1973; Matthews, 1992; NRCS, 2025). *Rhododendron groenlandicum* is also resilient to disturbance and may be the last peatland species remaining in disturbed sites (Rigg, 1925). A primary vulnerability for these stress-tolerant taxa lies in ecosystem changes that provide a less stressful environment, opening the wetland community to more competitive generalist species. For peatlands, changes in water tables that reduce soil saturation, or changes in pH or nutrient levels are potential effects of climate change that could increase competition with generalist plant taxa.

The following key component taxa were assessed: *Sphagnum* spp., *Caltha leptosepala*, *Carex aquatilis* var. *dives*, *Carex utriculata*, *Eriophorum angustifolium* ssp. *angustifolium*, *Empetrum nigrum*, *Kalmia microphylla*, *Ledum groenlandicum*, *Myrica gale*, and *Vaccinium oxycoccos*. Climate change vulnerability was initially rated using NatureServe's Climate Change Vulnerability Index (CCVI) 4.0 protocol (Lyons et al., 2024). In order to rate many different species, rapid assessments were completed using the minimum number of CCVI metrics permitted by the method (see 0 for an explanation of minimum responses needed to assess climate change vulnerability for a plant taxon). All key species were ranked as less vulnerable, expect *Kalmia microphylla*, which ranked as moderately vulnerable (Table 20, 0). The CCVI factor that appeared to result in the greatest reduction in adaptive capacity for all assessed species was Life Span, with longer-lived species having lower adaptive capacity. The two other similarly long-lived species assessed, *Empetrum nigrum* and *Ledum groenlandicum*, also were rated as having reduced adaptive capacity by the CCVI 4.0 calculator, though overall they were still ranked as less vulnerable. More complete assessments incorporating additional plant traits could impact these results (e.g., more complete data on demography or rarity).

It is possible that CCVI 4.0 assessments may underestimate species vulnerability. Most of the readily available ecological information suggests that peatland species are generally better adapted to cool or cold temperatures and stable hydrological conditions (Rigg, 1940; Gignac & Vitt, 1994). Additional evidence for some species regarding disturbance tolerance, genetic diversity and reproductive success, and documented responses to climate change (including northward range shifts) also suggest higher climate change vulnerability. In the Pacific Northwest, some losses of *Rhododendron groenlandicum* populations have been attributed to climate change (Gucker, 2006). Loss of southern populations of *Empetrum nigrum* due to human threats (including climate change) have been reported from Great Britain and Sweden (Bell & Tallis, 1973; Hedwall et al., 2017). *Sphagnum* species may also be decreasing at the southern extent of their ranges in Sweden due to human impacts, including climate change (Hedwall et al., 2017). Given this evidence, we rated taxa in this group as moderately vulnerable to climate change (Table 19).

One key taxon in the North Pacific Montane Acidic Fen Alliance is adapted to colder conditions. *Caltha leptosepala* occurs in cold microsites, is one of the first plants to flower after snowmelt (Germino & Smith, 2001), and increases in biomass in areas with later snowmelt dates (Andersen et al., 1979). This suggests that this species may be vulnerable to decreased snowpack and increased temperatures with climate change.

Ecosystems are not rated on the vulnerability of their rare species, but communities in the North Pacific Open Bog & Acidic Fen Group also contain a high number of rare species relative to the amount of area this ecosystem occupies (Rocchio et al., 2025). Many of these species have been assessed as highly vulnerable or extremely vulnerable to climate change using NatureServe's CCVI 3.0 protocols (Wessel & Wiebush, 2024).

AC10.2 Redundancy of Key Species

Though most of the key component taxa appear to have some redundancy in ecosystem processes, many of these systems have comparatively limited floristic diversity, suggesting The North Pacific Open Bog & Acidic Fen Group also has at least moderate vulnerability to loss of key species (Table 19). Within this group, the North Pacific Shrub and Open Bog Alliance has less vascular plant diversity than the fen alliances, so it was assigned a rating of high vulnerability to loss of key component species.

Redundancy of vascular taxa in peatlands—especially bogs—is limited. However, *Sphagnum* mosses are key building blocks of acidic fens and bogs (Rocchio et al., 2025). The Flora of North America currently recognizes 89 species of *Sphagnum* moss (McQueen & Andrus, 2020), with at least 27 reported for western Washington (Crum, 1984) that occur across a gradient of environmental tolerances (e.g., minerotrophic to oligotrophic conditions). This diversity may suggest that if one *Sphagnum* species is lost from a site due to changing conditions, there may be another *Sphagnum* species available to replace it and potentially maintain ecosystem processes.

Sphagnum species create and maintain the acidic conditions in the North Pacific Open Bog & Acidic Fen Group, and loss of these taxa could result in significant changes to ecosystem structure and type (Rigg, 1958). *Sphagnum* species also account for the majority of peat accumulation in this group, making them very important for carbon dynamics (Bridgham et al., 2008). Lack of vascular tissue leaves *Sphagnum* particularly vulnerable to drought (Barel et al., 2021). Increased drought, increased nutrient inputs, and increased atmospheric CO_2 are all expected to favor vascular plants over non-vascular plants (Heijmans et al., 2002; Hedwall et al., 2017; Barel et al.,

2021), potentially resulting in shifts in ecosystem type or community structure with climate change. Two of the assessed component taxa, *Eriophorum angustifolium* ssp. *angustifolium*, and *Vaccinium oxycoccos*, are peatland specialists, potentially relying on the presence of *Sphagnum* species to help maintain appropriate ecological conditions for their persistence.

Vascular plant taxa have less redundancy in this group. We evaluated only one forb (*Caltha leptosepala*). As one of the first plants to flower after snowmelt (Germino & Smith, 2001), *C. leptosepala* may be important for providing early season resources for pollinators. However, several of the shrubs evaluated are also pollinator resources (Rathcke, 2003; Gucker, 2006), providing some redundancy for at least part of the growing season.

The shrub *Myrica gale* is the only species we evaluated that was described as a nitrogen fixer (Skene et al., 2000), meaning it could play an important role in structuring peatland communities where it occurs, particularly since nitrogen is limiting in these ecosystems.

Table 19. AC10. (Vulnerability and Redundancy of Key Species) ratings for North Pacific Open Bog & Acidic Fen and associated alliances.

	AC10. Vulnerability and Redundancy of Key Species		
Classification Unit	**Submetric AC10.1 Vulnerability of Key Species**	**Submetric AC10.2 Redundancy of Key Species**	**Overall**
North Pacific Open Bog & Acidic Fen	**Moderate Vulnerability**	**Moderate Vulnerability**	**Moderate Vulnerability**
North Pacific Shrub & Open Bog	Moderate Vulnerability	High Vulnerability	Moderate to High Vulnerability
North Pacific Lowland Acidic Fen	Moderate Vulnerability	Moderate Vulnerability	Moderate Vulnerability
North Pacific Montane Acidic Fen	Moderate Vulnerability	Moderate Vulnerability	Moderate Vulnerability

Table 20. Scores for rapid CCVI assessments of key component plant species in North Pacific Open Bog & Acidic Fen.

CCVI Scores for AC10 (Key Component Species)					
Taxon	**Adaptive Capacity Category**	**Adaptive Capacity Score**	**CCVI category (RCP 8.5)**	**CCVI Vulnerability score**	**% of CCVI answered**
Myrica gale	High	1.15	Less Vulnerable	1.98	38%
Carex utriculata	High	1.25	Less Vulnerable	2.16	57%
Sphagnum spp.[1]	High	1.27	Less Vulnerable	2.19	38%

Carex aquatilis var. dives	High	1.69	Less Vulnerable	2.91	51%
Caltha leptosepala	High	1.73	Less Vulnerable	3.14	40%
Eriophorum angustifolium ssp. angustifolium	High	2.1	Less Vulnerable	3.82	41%
Vaccinium oxycoccos	High	2.29	Less Vulnerable	3.95	43%
Empetrum nigrum	Moderately High	2.56	Less Vulnerable	4.36	46%
Ledum groenlandicum	Moderately High	2.65	Less Vulnerable	4.57	41%
Kalmia microphylla	Moderately Low	3.19	Moderately Vulnerable	5.5	46%

[1] Note that there are many species of *Sphagnum* in Washington, with varying environmental tolerances and potentially different vulnerabilities to climate change.

Threats

This section evaluates how anthropogenic stressors affect the ecosystem's ability to adapt to climate change and how climate change may exacerbate existing stressors. Anthropogenic stressors can change how effectively a population or community can respond to climate change (Lyons et al., 2024). Anthropogenic stressors can also change ecosystem processes and how those changes interact with climate change can potentially affect an ecosystem's ability to adapt to changes in climate exposure (Comer et al., 2019).

Threats Summary

Anthropogenic stressors can have significant effects on peatlands (e.g., Mauquoy & Yeloff, 2008; Kirkland et al., 2023). While most of WNHP's documented occurrences of the North Pacific Open Bog & Acidic Fen Group have good-to-excellent ecological integrity, anthropogenic threats are still concerning for this group (Table 21), particularly since the majority of occurrences are at low elevations and many are in the Puget Trough, where they are more likely to be affected by human activities. Climate change is expected to exacerbate anthropogenic stressors for this group in Washington.

Table 21. Threats scores and ratings for the North Pacific Open Bog & Acidic Fen Group and associated alliances.

	North Pacific Open Bog & Acidic Fen (G284)				**Overall**
	North Pacific Shrub & Open Bog (A4409)	**North Pacific Lowland Acidic Fen (A4411)**	**North Pacific Montane Acidic Fen Alliance (A4412)**		
Metric	**Rating**				

TH1. Current Ecological Integrity of Extant Occurrences	Moderate Vulnerability	Low Vulnerability	Low Vulnerability	Moderate Vulnerability
TH2. Potential for Climate Change to Exacerbate Existing Stressors	High Vulnerability	High Vulnerability	High Vulnerability	High Vulnerability
Threats Rank	**High Vulnerability**	**High Vulnerability**	**High Vulnerability**	**High Vulnerability**

Threats Metric Ratings

TH1. Current Ecological Integrity of Extant Occurrences

WNHP has 178 total occurrences of the North Pacific Open Bog & Acidic Fen Group in our database (WNHP, 2025). Of those 178 occurrences, 131 (74%) have element occurrence ranks (EO Ranks) of excellent or good (A or B), suggesting that this group is moderately vulnerable to anthropogenic activities (Table 22). Note that WNHP data focus on occurrences with significant conservation value and do not represent a comprehensive assessment of ecological integrity across all occurrences of this ecosystem type.

In Washington, threats to ecological integrity of the North Pacific Open Bog & Acidic Fen Group include development, logging, agriculture, and peat mining (Rocchio & Ramm-Granberg, 2022). These stressors destabilize hydrological dynamics, increase sediment and nutrient inputs, reduce the ecosystem's ability to adapt to increases in extreme precipitation events, and change species composition. Logging in adjacent uplands can increase water flow into peatlands by reducing evapotranspiration from neighboring forests (Rocchio & Ramm-Granberg, 2022). Fragmentation and altered hydrology are threats to a wetland ecosystem's adaptive capacity (Swanston et al., 2011). Drainage, drying, and warming can all disrupt carbon dynamics in wetlands (Daugherty et al., 2019). Worldwide, peatlands that have been subject to anthropogenic disturbance are more sensitive to fire than undisturbed peatlands with intact hydrology (Mauquoy & Yeloff, 2008; Kirkland et al., 2023). A CCVA of peatland ecosystems from Ireland found that anthropogenic disturbance left peatlands more vulnerable to increases in temperature and effects of summer drought (Renou-Wilson & Wilson, 2018).

Table 22. TH1 (Current Ecological Integrity of Extant Occurrences) ratings for North Pacific Open Bog & Acidic Fen and associated alliances.

Classification Unit	Rating
North Pacific Open Bog & Acidic Fen	**Moderate Vulnerability**
North Pacific Shrub & Open Bog	Moderate Vulnerability
North Pacific Lowland Acidic Fen	Low Vulnerability
North Pacific Montane Acidic Fen	Low Vulnerability

TH2. Potential for Climate Change to Exacerbate Existing Stressors

The North Pacific Open Bog & Acidic Fen Group likely has high vulnerability to climate change exacerbating existing anthropogenic stressors (Table 23). The most common anthropogenic stressors in this group are development, logging, agriculture, and peat mining (Rocchio & Ramm-Granberg, 2022). Climate change, particularly an increase in the intensity of extreme precipitation events, or earlier and larger spring floods, could increase the effects of runoff from impervious surfaces created by development and roads (Trenberth, 2011; Flint et al., 2013). Climate change could also exacerbate disruptions to hydrology due to the above stressors (Kolka et al., 2018) potentially contributing to peat decomposition and changes in vegetation community (Gignac & Vitt, 1994; Barel et al., 2021). If climate change interacts with anthropogenic stressors to change nutrient dynamics and water chemistry, increases in presence or abundance of invasives species are also possible (Gignac & Vitt, 1994; Barel et al., 2021).

Table 23. TH2 (Potential for Climate Change to Exacerbate Existing Stressors) ratings for North Pacific Open Bog & Acidic Fen and associated alliances

Classification Unit	Rating
North Pacific Open Bog & Acidic Fen	**High Vulnerability**
North Pacific Shrub & Open Bog	High Vulnerability
North Pacific Lowland Acidic Fen	High Vulnerability
North Pacific Montane Acidic Fen	High Vulnerability

Assessment Summary

The WetEco CCVA estimates high vulnerability to climate change for the North Pacific Open Bog & Acidic Fen Group (Table 24). This group is expected to have moderate climate exposure, driven mainly by high exposure to increases in Summer Maximum Temperature (EX4). Adaptive capacity for this group is estimated to be moderate, indicating high vulnerability to these changes in climate. These acidic peatlands depend on stable hydrological conditions, positive water balance, and cool temperatures. The North Pacific Open Bog and Acidic Fen Group likely has high vulnerability to anthropogenic threats, and these threats may be exacerbated by climate change. Alliances were not used as an assessment unit. Metric ratings for alliances were displayed to highlight potential variability within the group.

Table 24. Summary of Exposure, Adaptive Capacity, and Threat metrics for the North Pacific Open Bog & Acidic Fen Group in Washington. Roll-up scores reflect the percentage of points the group received out of the total number of points possible for each section.

		Score	Rating / Rank
Exposure	EX1. Total Annual Precipitation	1	Low Exposure
	EX2. Extreme Precipitation Magnitude	1	Low Exposure
	EX3. Snowpack[1] *Submetrics* EX3.1 Snow Drought by April 1st EX3.2 Snowpack Change	NA	NA
	EX4. Summer Maximum Temperature	3	High Exposure

	EX5. Precipitation Drought in Summer	2	Moderate Exposure
	EX6. Sea Level Rise	NA	NA
	Exposure Rank	**44**	**Moderate Exposure**
Adaptive Capacity	AC1. Adaptive Capacity to Total Annual Precipitation	3.5	High to Very High Vulnerability
	AC2. Adaptive Capacity to Extreme Precipitation Magnitude	3	High Vulnerability
	AC3. Adaptive Capacity to Snowpack Change[1]	NA	NA
	AC4. Adaptive Capacity to Summer Maximum Temperature	4	High to Very High Vulnerability
	AC5. Adaptive Capacity to Precipitation Drought in Summer	3	High Vulnerability
	AC6. Adaptive Capacity to Sea Level Rise	NA	NA
	AC7. Diversity of Biophysical Settings and Variability of Supporting Hydrological Conditions	3	High Vulnerability
	AC8. Current Areal Extent	1	Low Vulnerability
	AC9. Location within Geographic Range	2	Moderate - High Vulnerability
	AC10. Vulnerability and Redundancy of Key Component Species *Submetrics* AC10.1 Vulnerability of Key Species AC10.2 Redundancy of Key Species	2 1 1	Moderate Vulnerability Moderate Vulnerability Moderate Vulnerability
	Adaptive Capacity Rank	**54**	**High Vulnerability**
Threats	TH1. Current Ecological Integrity of Extant Occurrences	2	Moderate Vulnerability
	TH2. Potential for Climate Change to Exacerbate Existing Stressors	3	High Vulnerability
	Threats Rank	**63**	**High Vulnerability**
Overall Vulnerability		**50**	**High Vulnerability**

[1]Only the North Pacific Montane Acidic Fen Alliance (A4412) occurs in areas directly influenced by snowpack in Washington. This alliance received ratings of Very High Exposure and Very High Vulnerability to EX3 (Snowpack) and AC3 (Adaptive Capacity to Snowpack Change).

References

Abatzoglou J.T., D.E. Rupp, and P.W. Mote. 2014. Seasonal climate variability and change in the Pacific Northwest of the United States. *Journal of Climate* 27(5):2125–2142.

Andersen D.C., R.S. Hoffman, and K.B. Armitage. 1979. Aboveground productivity and floristic structure of a high subalpine herbaceous meadow. *Arctic and Alpine Research* 11(4):467–476.

Anderson M.K. 2009. The Ozette Prairies of Olympic National Park: their former indigenous uses and management (final report to Olympic National Park, Port Angeles, Washington). US Department of Agriculture, Natural Resources Conservation Service, Davis, CA.

Bach A. and D. Conca. 2004. Final report: natural history of the Ahlstrom's and Roose's Prairies, Olympic National Park, Washington. Prepared for Olympic National Park. Department of Environmental Studies, Huxley College, Western Washington University, Bellingham, WA.

Bachman S., J. Moat, A.W. Hill, J. de la Torre, and B. Scott. 2011. Supporting Red List threat assessments with GeoCAT: Geospatial Conservation Assessment Tool. *ZooKeys* 150:117–126.

Barel J.M., V. Moulia, S. Hamard, A. Sytiuk, and V.E.J. Jassey. 2021. Come rain, come shine: Peatland carbon dynamics shift under extreme precipitation. *Frontiers in Environmental Science* 9:659953.

Bell J.M. 2002. An assessment of selected Sphagnum-dominated peatlands of King County, WA, and their decline. MS Thesis. The Evergreen State College, Olympia, WA,

Bell J.N.B. and J.H. Tallis. 1973. Empetrum nigrum L. *The Journal of Ecology* 61(1):289.

Benscoter B.W. and D.H. Vitt. 2008. Spatial Patterns and Temporal Trajectories of the Bog Ground Layer Along a Post-Fire Chronosequence. *Ecosystems* 11(7):1054–1064.

Bridgham S.D., J. Pastor, B. Dewey, J.F. Weltzin, and K. Updegraff. 2008. Rapid carbon response of peatlands to climate change. *Ecology* 89(11):3041–3048.

Brinson M.M. 1993. A hydrogeomorphic classification for wetlands. US Army Corps of Engineers, Washington, DC. WRP-DE-4.

Brown L.E., S.M. Palmer, K. Johnston, and J. Holden. 2015. Vegetation management with fire modifies peatland soil thermal regime. *Journal of Environmental Management* 154:166–176.

Cai S. and Z. Yu. 2011. Response of a warm temperate peatland to Holocene climate change in northeastern Pennsylvania. *Quaternary Research* 75(3):531–540.

Comer P.J., J.C. Hak, M.S. Reid, S.L. Auer, K.A. Schulz, H.H. Hamilton, R.L. Smyth, and M.M. Kling. 2019. Habitat Climate Change Vulnerability Index applied to major vegetation types of the western interior United States. *Land* 8(7):108.

Coops N.C. and R.H. Waring. 2011. Estimating the vulnerability of fifteen tree species under changing climate in Northwest North America. *Ecological Modelling* 222(13):2119–2129.

Crawford R.C., C.B. Chappell, C.C. Thompson, and F.J. Rocchio. 2009. Vegetation classification of Mount Rainier, North Cascades, and Olympic National Parks. US Department of the Interior, National Park Service, Fort Collins, CO. NPS/NCCN/NRTR—2009/211.

Crum H. 1984. *North American Flora: Sphagnopsida, Sphagnaceae*. New York Botanical Gardens, New York, NY.

Daugherty E.E., G.A. McKee, R. Bergstrom, S. Burton, C. Pallud, R.M. Hubbard, E.F. Kelly, C.C. Rhoades, and T. Borch. 2019. Hydrogeomorphic controls on soil carbon composition in two classes of subalpine wetlands. *Biogeochemistry* 145(1–2):161–175.

Defne Z., A.L. Aretxabaleta, N.K. Ganju, T.S. Kalra, D.K. Jones, and K.E.L. Smith. 2020. A geospatially resolved wetland vulnerability index: Synthesis of physical drivers. *PLOS ONE* 15(1):e0228504.

Diaz N.M. and T.K. Mellen. 1996. Riparian ecological types: Gifford Pinchot and Mt. Hood National Forests, Columbia River Gorge National Scenic Area. US Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR. R6-NR-TP-10–96.

Faber-Langendoen, J.N. D., L. Master, K. Snow, A. Tomaino, R. Bittman, G. Hammerson, B. Heidel, L. Ramsay, A. Teucher, and B. Young. 2012. NatureServe Conservation Status Assessments: methodology for assigning ranks. NatureServe, Arlington, VA.

Fellman J.B., D.V. D'Amore, E. Hood, and P. Cunningham. 2017. Vulnerability of wetland soil carbon stocks to climate warming in the perhumid coastal temperate rainforest. *Biogeochemistry* 133(2):165–179.

Flint L.E., A.L. Flint, J.H. Thorne, and R. Boynton. 2013. Fine-scale hydrologic modeling for regional landscape applications: the California Basin Characterization Model development and performance. *Ecological Processes* 2(1):25.

Foster D.R. 1985. Vegetation development following fire in Picea Mariana (black spruce)-Pleurozium forests of southeastern Labrador. *Canad J Ecol* 73:517–534.

Germino M.J. and W.K. Smith. 2001. Relative importance of microhabitat, plant form and photosynthetic physiology to carbon gain in two alpine herbs. *Functional Ecology* 15(2):243–251.

Gignac L.D., L.A. Halsey, and D.H. Vitt. 2000. A bioclimatic model for the distribution of Sphagnum-dominated peatlands in North America under present climatic conditions. *Journal of Biogeography* 27(5):1139–1151.

Gignac L.D. and D.H. Vitt. 1994. Responses of northern peatlands to climate change: Effects on bryophytes. *The Journal of the Hattori Botanical Laboratory* 75:119–132.

Gignac L.D., D.H. Vitt, S.C. Zoltai, and S.E. Bayley. 1991. Bryophyte response surfaces along climatic, chemical, and physical gradients in peatlands of western Canada. *Nova Hedwigia* 53(1–2):27–71.

Girvetz E.H., C. Zganjar, G.T. Raber, E.P. Maurer, P. Kareiva, and J.J. Lawler. 2009. Applied climate-change analysis: the Climate Wizard tool. *PLoS One* 4(12):e8320.

Gucker C.L. 2006. Ledum groenlandicum. In: Fire Effects Information System, [Online]. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. https://www.fs.usda.gov/database/feis/plants/shrub/ledgro/all.html. Accessed: June 27, 2025.

Halofsky J.E., D.L. Peterson, and R.A. Gravenmier. 2022. Climate change vulnerability and adaptation in southwest Oregon. US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR. PNW-GTR-995.

Halofsky J.E., D.L. Peterson, and B.J. Harvey. 2020. Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA. *Fire Ecology* 16(1):4.

Hedwall P., J. Brunet, and H. Rydin. 2017. Peatland plant communities under global change: negative feedback loops counteract shifts in species composition. *Ecology* 98(1):150–161.

Heijmans M.M.P.D., H. Klees, and F. Berendse. 2002. Competition between *Sphagnum magellanicum* and *Eriophorum angustifolium* as affected by raised CO_2 and increased N deposition. *Oikos* 97(3):415–425.

Ise T., A.L. Dunn, S.C. Wofsy, and P.R. Moorcroft. 2008. High sensitivity of peat decomposition to climate change through water-table feedback. *Nature Geoscience* 1(11):763–766.

Jones E.A., L.E. Chasmer, K.J. Devito, and C.D. Hopkinson. 2024. Shortening fire return interval predisposes west-central Canadian boreal peatlands to more rapid vegetation growth and transition to forest cover. *Global Change Biology* 30(2):e17185.

Kerns B.K., D.C. Powell, S. Mellmann-Brown, G. Carnwath, and J.B. Kim. 2018. Effects of projected climate change on vegetation in the Blue Mountains ecoregion, USA. *Climate Services* 10:33–43.

Kirkland M., P.W. Atkinson, J.W. Pearce-Higgins, M.C. De Jong, T.P.F. Dowling, D. Grummo, M. Critchley, and A. Ashton-Butt. 2023. Landscape fires disproportionally affect high conservation value temperate peatlands, meadows, and deciduous forests, but only under low moisture conditions. *Science of The Total Environment* 884:163849.

Kittel G., K. Boggs, T. Boucher, and D. Faber-Langendoen. 2015. North Pacific Open Bog & Acidic Fen Group. https://explorer.natureserve.org/Taxon/ELEMENT_GLOBAL.2.856676/North_Pacific_Acidic_Open_Bog_Fen_Group. Accessed: June 2, 2025.

Klein E.S., R.K. Booth, Z. Yu, B.G. Mark, and N.D. Stansell. 2013. Hydrology-mediated differential response of carbon accumulation to late Holocene climate change at two peatlands in Southcentral Alaska. *Quaternary Science Reviews* 64:61–75.

Kolka R., C.T. Trettin, W. Tang, K. Krauss, S. Bansal, J. Drexler, K. Wickland, R. Chimner, D. Hogan, E.J. Pindilli, B. Benscoter, B. Tangen, E. Kane, S. Bridgham, and C. Richardson. 2018. Chapter 13: Terrestrial wetlands. In Second State of the Carbon Cycle Report (SOCCR2): A Sustained Assessment Report [Cavallaro, N., G. Shrestha, R. Birdsey, M. A. Mayes, R. G. Najjar, S. C. Reed, P. Romero-Lankao, and Z. Zhu (eds.)]. U.S. Global Change Research Program, Washington, DC, USA.

Kunze L.M. 1994. Preliminary classification of native, low elevation, freshwater wetland vegetation in western Washington. Washington Natural Heritage Program, Department of Natural Resources, Olympia, WA.

Lachance D. and C. Lavoie. 2004. Vegetation of Sphagnum bogs in highly disturbed landscapes: relative influence of abiotic and anthropogenic factors. *Applied Vegetation Science* 7(2):183–192.

Lawler J.J. and M. Mathias. 2007. Climate change and the future of biodiversity in Washington. Report prepared for the Washington Biodiversity Council. College of Forest Resources, University of Washington, Seattle, WA.

Liu H., P. Xiao, X. Zhang, Y. Liang, B. Tang, S. Chen, and Y. Liu. 2024. Winter snowpack loss increases warm-season compound hot-dry extremes. *Communications Earth & Environment* 5(1):567.

Lyons M.P., J.R. Stevenson, L.L. Thurman, and B.E. Young. 2024. Guidelines for Using the Climate Change Vulnerability Index. NatureServe, Arlington, VA. Release 4.0.

Marcotte A.L., J. Limpens, J.P. Nunes, B.C. Howard, A.G. Hurley, K. Khamis, S. Krause, D. Croghan, A. Kourmouli, S. Leader, T. Singh, C.R. Stoof, S. Ullah, and N. Kettridge. 2024. Enhanced hydrologic connectivity and solute dynamics following wildfire and drought in a contaminated temperate peatland catchment. *Water Resources Research* 60(7).

Markle C.E., H.J.M. Gage, A.M. Tekatch, S.L. Wilkinson, and J.M. Waddington. 2022. Wetland successional state affects fire severity in a boreal shield landscape. *Wetlands* 42(7):87.

Master L.L., D. Faber-Langendoen, R. Bittman, G.A. Hammerson, B. Heidel, L. Ramsay, K. Snow, A. Teucher, and A. Tomaino. 2012. NatureServe Conservation Status Assessments: factors for evaluating species and ecosystem risk. NatureServe, Arlington, VA.

Matthews R.F. 1992. Empetrum nigrum. In: Fire Effects Information System, [Online]. US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. https://www.fs.usda.gov/database/feis/plants/shrub/empnig/all.html. Accessed: April 21, 2025.

Mauger G.S., J.H. Casola, H.A. Morgan, R.L. Strauch, B. Jones, B. Curry, T.M. Busch Isaksen, L. Whitely Binder, M.B. Krosby, and A.K. Snover. 2015. State of knowledge: climate change in Puget Sound. Report prepared for the Puget Sound Partnership and the National Oceanic and Atmospheric Administration. Climate Impacts Group, University of Washington, Seattle, WA.

Mauquoy D. and D. Yeloff. 2008. Raised peat bog development and possible responses to environmental changes during the mid- to late-Holocene. Can the palaeoecological record be used to predict the nature and response of raised peat bogs to future climate change? *Biodiversity and Conservation* 17(9):2139–2151.

McQueen C.B. and R.E. Andrus. 2020. Sphagnum. https://floranorthamerica.org/Sphagnum. Accessed: September 10, 2025.

Moore P.D. 2002. The future of cool temperate bogs. *Environmental conservation* 29(1):3–20.

Natural Resources Conservation Service (NRCS). 2025. Empetrum nigrum: USDA PLANTS Database. https://plants.usda.gov/plant-profile/EMNI. Accessed: April 21, 2025.

Oke T.A. and H.A. Hager. 2017. Assessing environmental attributes and effects of climate change on Sphagnum peatland distributions in North America using single- and multi-species models. *PLOS ONE* 12(4):e0175978.

Pellerin S., M. Lavoie, A. Boucheny, M. Larocque, and M. Garneau. 2016. Recent vegetation dynamics and hydrological changes in bogs located in an agricultural landscape. *Wetlands*:159–168.

Perry L.G., D.C. Andersen, L.V. Reynolds, S.M. Nelson, and P.B. Shafroth. 2012. Vulnerability of riparian ecosystems to elevated CO2 and climate change in arid and semiarid western North America. *Global Change Biology* 18(3):821–842.

Pitz C.F. 2016. Predicted impacts of Climate Change on groundwater resources of Washington State. Washington State Department of Ecology, Olympia, WA.

Poff N.L., M.M. Brinson, and J.W. Day. 2002. Aquatic ecosystems & global climate change: potential impacts on inland freshwater and coastal wetland ecosystems in the United States. Pew Center on Global Climate Change.

PRISM Climate Group. 2025. PRISM Gridded Climate Data. Oregon State University, http://prism.oregonstate.edu. Accessed: March 20, 2025.

Ramm-Granberg T., F.J. Rocchio, C. Copass, R. Brunner, and E. Nielsen. 2021. Revised vegetation classification for Mount Rainier, North Cascades, and Olympic National Parks: project summary report. National Park Service, Fort Collins, CO. NPS/NCCN/NRR—2021/2225.

Rathcke B.J. 2003. Floral longevity and reproductive assurance: seasonal patterns and an experimental test with *Kalmia latifolia* (Ericaceae). *American Journal of Botany* 90(9):1328–1332.

Raymond C. and M. Rogers. 2022. Climate Mapping for a Resilient Washington. Prepared by the Climate Impacts Group, University of Washington, Seattle and Research Data & Computing Services, University of Idaho, Moscow. https://cig.uw.edu/resources/analysis-tools/climate-mapping-for-a-resilient-washington/. Accessed: June 18, 2025.

Renou-Wilson F. and D. Wilson. 2018. Vulnerability assessment of peatlands: exploration of impacts and adaptation options in relation to climate change and extreme events (VAPOR): 2014-CCRP-MS.20. Environmental Protection Agency, Johnstown Castle, Co. Wexford, Ireland. Report No. 250.

Reyes L. and M.G. Kramer. 2023. High-elevation snowpack loss during the 2021 Pacific Northwest heat dome amplified by successive spring heatwaves. *npj Climate and Atmospheric Science* 6(1):208.

Rice S.K. 2009. Mosses (Bryophytes). *Encyclopedia of Inland Waters* (ed. by G.E. Likens), pp. 88–96.

Rigg G.B. 1925. Some Sphagnum bogs of the North Pacific Coast of America. *Ecology* 6(3):260–278.

Rigg G.B. 1940. Comparisons of the development of some Sphagnum bogs of the Atlantic coast, the interior, and the Pacific coast. *American Journal of Botany* 27(1):1–14.

Rigg G.B. 1958. Peat resources of Washington. Division of Mines and Geology, Washington Department of Conservation, Olympia, WA.

Rocchio F.J., R.C. Crawford, and R. Niggemann. 2015. Wetland ecosystem conservation priorities for Washington State. An update of Natural Heritage classification, inventory, and prioritization of Wetlands of High Conservation Value. Prepared for U.S. Environmental Protection Agency, Region 10. Washington Natural Heritage Program, Department of Natural Resources, Olympia, WA.

Rocchio F.J., E. Gage, T. Ramm-Granberg, A.K. Borkenhagen, and D.J. Cooper. 2021. Ecohydrological characteristics of a newly identified coastal raised bog on the western Olympic Peninsula, Washington State, USA. *Ecohydrology* 14(4).

Rocchio F.J. and T. Ramm-Granberg. 2017. Ecological System Climate Change Vulnerability Assessment. Unpublished report to the Washington Department of Fish and Wildlife. Washington Natural Heritage Program, Department of Natural Resources, Olympia, WA.

Rocchio F.J. and T. Ramm-Granberg. 2022. Wetland types of Washington State: a classification framework based on the U.S. National Vegetation Classification (2022 Draft). Washington Natural Heritage Program, Department of Natural Resources, Olympia, WA. NHR-20XX-XX.

Rocchio F.J., T. Ramm-Granberg, J.R. Shaw, and D.J. Cooper. 2025. Hydrogeochemical and vegetation characterization of Sphagnum-dominated peatlands in the Puget Lowlands of Washington State, USA. *Wetlands* 45(5):49.

Rydin H. and J.K. Jeglum. 2013. *The Biology of Peatlands*. Oxford University Press, London, United Kingdom.

Seavy N.E., T. Gardali, G.H. Golet, F.T. Griggs, C.A. Howell, R. Kelsey, S.L. Small, J.H. Viers, and J.F. Weigand. 2009. Why climate change makes riparian restoration more important than ever: recommendations for practice and research. *Ecological Restoration* 27(3):330–338.

Sheth S.N. and A.L. Angert. 2014. The evolution of environmental tolerance and range size: a comparison of geographically restricted and widespread *Mimulus*. *Evolution* 68(10):2917–2931.

Skene K.R., J.I. Sprent, J.A. Raven, and L. Herdman. 2000. Myrica gale L. *Journal of Ecology* 88(6):1079–1094.

Stewart A.J., L.M. Moskal, and M. Halabisky. 2024. Assessing climate change vulnerability of wetland habitats. Unpublished report to the Washington Natural Heritage Program. University of Washington, Seattle, WA.

Sutheimer C.M., J. Meunier, S.C. Hotchkiss, E. Rebitzke, and V.C. Radeloff. 2021. Historical fire regimes of North American hemiboreal peatlands. *Forest Ecology and Management* 498:119561.

Swanston C., M. Janowiak, L. Iverson, L. Parker, D. Mladenoff, L. Brandt, P. Butler, M. St. Pierre, A. Prasad, S. Matthews, M. Peters, D. Higgins, and Avery. Dorland. 2011. Ecosystem vulnerability assessment and synthesis: a report from the Climate Change Response Framework Project in northern Wisconsin. U.S. Department of Agriculture, Forest Service, Northern Research Station, Newtown Square, PA. GTR-NRS-82.

Taylor K.E., R.J. Stouffer, and G.A. Meehl. 2012. An overview of CMIP5 and the experiment design. *Bulletin of the American Meteorological Society* 93(4):485–498.

Thorne J.H., R.M. Boynton, A.J. Holguin, J.A.E. Stewart, and J. Bjorkman. 2016. A climate change vulnerability assessment of California's terrestrial vegetation. California Department of FIsh and Wildlife, Sacramento, CA.

Thurman L.L., B.A. Stein, E.A. Beever, W. Foden, S.R. Geange, N. Green, J.E. Gross, D.J. Lawrence, O. LeDee, J.D. Olden, L.M. Thompson, and B.E. Young. 2020. Persist in place or shift in space? Evaluating the adaptive capacity of species to climate change. *Frontiers in Ecology and the Environment* 18(9):520–528.

Trenberth K. 2011. Changes in precipitation with climate change. *Climate Research* 47(1):123–138.

Väliranta M., N. Salojärvi, A. Vuorsalo, S. Juutinen, A. Korhola, M. Luoto, and E.-S. Tuittila. 2016. Holocene fen-bog transitions, current status in Finland and future perspectives. *The Holocene* 27(5).

Washington Natural Heritage Program (WNHP). 2025. Washington Natural Heritage Program Data Explorer. Washington Department of Natural Resources, Natural Heritage Program.

Olympia, WA. https://dnr.wa.gov/natural-heritage-program/wnhp-data-explorer. Accessed: June 30, 2025.

Wessel S.A. and M.S. Wiebush. 2024. Climate Change Vulnerability Index reports for selected Washington state rare plant species: Phase IV. Prepared for US Forest Service, Region 6. Washington Natural Heritage Program, Department of Natural Resources, Olympia, WA. Natural Heritage Report 2024-09.

Williams S.E., L.P. Shoo, J.L. Isaac, A.A. Hoffmann, and G. Langham. 2008. Towards an integrated framework for assessing the vulnerability of species to climate change. *PLoS biology* 6(12):2621–2626.

Appendix A. Climate Change Vulnerability Index Ratings for Key Component Species

Climate Change Vulnerability Indices may be calculated for taxa without populating every possible field. In order to complete an assessment, CCVI 4.0 requires complete data for Module A (Climate Exposure) and Module B (Sea Level Rise), one factor documented in 6 of 7 Adaptive Capacity modules (C-I), and 3 of 5 factors for Module J (Threat Multipliers) (Lyons et al., 2024). Module K (Documented or Modeled Response to Climate Change) is optional (Lyons et al., 2024).

The adaptive capacity factors used in CCVI 4.0 are based on Thurman et al. (2020), who identify 12 core attributes for assessment: Extent of Occurrence, Habitat Specialization, Commensalism with Humans, Dispersal Distance, Genetic Diversity, Population Size, Diet Breadth (which we did not consider for plant taxa), Climatic Niche Breadth, Physiological Tolerances, Reproductive Phenology, Fecundity, and Life Span. At list six of the factors included in CCVI 4.0 are animal-specific (e.g., several traits focused on migration, and Behavioral Regulation of Physiology) (Lyons et al., 2024).

Table A-1. CCVI 4.0 results for key component species in the North Pacific Open Bog and Acidic Fen Group. CCVI factors are defined in Lyons et al. (2024). Climate Exposure 8.5 Category was used for exposure metrics. Adaptive Capacity Category is the overall adaptive capacity assigned by CCVI, and CCVI Category (RCP 8.5) is the overall climate change vulnerability assigned by CCVI.

Factor	***Eriophorum angustifolium* ssp. *angustifolium***	***Caltha leptosepala***	***Carex aquatilis* var. *dives***	***Carex utriculata***	***Myrica gale***	***Sphagnum* spp.**	***Empetrum nigrum***	***Kalmia microphylla***	***Ledum groenlandicum***	***Vaccinium oxycoccos***
Common Name	Many-Spiked Cottongrass	Elkslip	Sitka Sedge	Northwest Territory Sedge	Sweetgale	Peat Moss	Crowberry	Western Bog Laurel	Labrador Tea	Small Cranberry
G-Rank	G5T5	G5	G5	G5	G5	NA	G5	G5	G5	G5
S-Rank	SNR	SNR	SNR	SNR	SNR	NA	SNR	SNR	SNR	SNR
Sea Level Rise	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Extent of Occurrence	High	High	High	High	High	High	High	High	High	High
Area of Occupancy	U/NA	U/NA	U/NA	U/NA	U/NA	High	U/NA	U/NA	U/NA	U/NA
Habitat Specialization	Low	Low	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Low	Low
Commensalism with Humans	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Geographic Rarity	Moderately High	Moderately High	Moderately High	Moderately High	Moderately High	Moderately High	High	Moderately High	Moderately High	Moderately High
Dispersal Syndrome (plant)	High	Moderately High	High	High	High	High	Moderately Low	High	High	Moderately Low

Factor	*Eriophorum angustifolium* ssp. *angustifolium*	*Caltha leptosepala*	*Carex aquatilis* var. *dives*	*Carex utriculata*	*Myrica gale*	*Sphagnum* spp.	*Empetrum nigrum*	*Kalmia microphylla*	*Ledum groenlandicum*	*Vaccinium oxycoccos*
Dispersal Distance	Moderately Low	Moderately High	Moderately High	Moderately High	Moderately High	High	U/NA	Moderately High	U/NA	U/NA
Dispersal Phase	U/NA	U/NA	U/NA	high	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Site Fidelity	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	Moderate	U/NA	U/NA
Migration Frequency	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Migration Demography	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Migration Timing	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Migration Distance	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Genetic Diversity	High	High	High	High	High	U/NA	High	High	High	High
Population Size	High	High	High	High	High	High	High	High	High	High
Hybridization Potential	U/NA	U/NA	Moderate	Moderate	Low	U/NA	U/NA	Low	U/NA	U/NA
Enemies	U/NA	U/NA	High	High	U/NA	U/NA	U/NA	U/NA	U/NA	Moderate
Diet Breadth	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Diversity of Obligate Species	High	Moderate	High	High	High	High	U/NA	Moderate	Moderate	High
Seasonal Phenology	U/NA	High	U/NA	High	U/NA	U/NA	High	U/NA	U/NA	Moderate
Climate Niche Breadth	Low	Moderately Low	Moderately Low	Moderately Low	Moderately High	Moderately High	Moderately Low	Moderately Low	Moderately Low	Moderately Low
Physiological Tolerances	Low	Moderate	Moderate	Moderate	U/NA	Moderate	Moderate	U/NA	Moderate	Low
Behavioral Regulation of Physiology	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Disturbance Tolerances	Moderate	U/NA	Moderate	Moderate	U/NA	Moderate	Moderate	U/NA	Moderate	High
Reproductive Phenology	U/NA	High	High	High	U/NA	U/NA	High	U/NA	U/NA	U/NA
Reproductive Mode	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA

Factor	*Eriophorum angustifolium* ssp. *angustifolium*	*Caltha leptosepala*	*Carex aquatilis* var. *dives*	*Carex utriculata*	*Myrica gale*	*Sphagnum* spp.	*Empetrum nigrum*	*Kalmia microphylla*	*Ledum groenlandicum*	*Vaccinium oxycoccos*
Mating System (plant)	Low	U/NA	Moderate	Moderate	High	Low	High	High	High	Moderate
Fecundity	High	High	High	High	High	U/Na	High	High	High	High
Parity (plants)	High	High	High	High	High	High	High	High	High	High
Sex Ratio	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Sex Determination	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Parental Investment	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Life Span	U/NA	U/NA	Moderately High	U/NA	U/NA	U/NA	Low	Low	Low	U/NA
Generation Time	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Age of Sex Maturity	U/NA	U/NA	U/NA	high	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Age Structure	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA
Recruitment	U/NA	U/NA	U/NA	U/NA	U/NA	U/NA	Low	U/NA	U/NA	U/NA
Topographic Barriers to Movement	Somewhat Increase	Somewhat Increase	Neutral	Neutral	Unknown	Neutral	Neutral	Neutral	Neutral	Neutral
Anthropogenic Barriers to Movement	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
Land-use Change	Somewhat Increase	Somewhat Increase	Somewhat Increase	Somewhat Increase	Somewhat Increase	Somewhat Increase	Somewhat Increase	Somewhat Increase	Somewhat Increase	Somewhat Increase
Other Anthropogenic Threats	Unknown	Unknown	Unknown	Unknown	Neutral	Unknown	Neutral	Unknown	Unknown	Unknown
Other Biological Threats	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Documented Response to Recent Climate Change	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Somewhat Increase	Unknown	Somewhat Increase	Unknown
Modeled Future Change in Range or	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown

Factor	*Eriophorum angustifolium* ssp. *angustifolium*	*Caltha leptosepala*	*Carex aquatilis* var. *dives*	*Carex utriculata*	*Myrica gale*	*Sphagnum* spp.	*Empetrum nigrum*	*Kalmia microphylla*	*Ledum groenlandicum*	*Vaccinium oxycoccos*
Population Size										
Overlap of Modeled Future Range with Current Range	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Occurrence of Protected Areas in Modeled Future Distribution	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
Climate Exposure (RCP 8.5) Value	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63	0.63
Climate Exposure (RCP 8.5) Category	High	High	High	High	High	High	High	High	High	High
Adaptive Capacity Score	2.1	1.73	1.69	1.25	1.15	1.27	2.56	3.27	2.65	2.29
Adaptive Capacity Category	High	High	High	High	High	High	Moderately High	Moderately Low	Moderately High	High
CCVI Category (RCP 8.5)	Less Vulnerable	Less Vulnerable	Less Vulnerable	Less Vulnerable	Less Vulnerable	Less Vulnerable	Less Vulnerable	Moderately Vulnerable	Less Vulnerable	Less Vulnerable