

# Nooksack Indian Tribe Natural Resources Climate Change Vulnerability Assessment



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## Introduction

The climate of the Nooksack River watershed is changing, and is projected to continue to change throughout the 21<sup>st</sup> century. In addition to rising temperatures and exaggerated patterns of seasonal precipitation, the watershed is likely to experience greater wildfire risk, more severe winter flooding, rising sea levels, and increasing ocean acidification. These changes will have profound impacts on the watershed's plants, animals, and ecosystems, including changes in species distributions, abundances, and productivity; shifts in the timing of life cycle events such as flowering, breeding, and migration; and changes in the distribution and composition of ecological communities. Understanding which species and habitats are expected to be vulnerable to climate change, and why, is a critical first step toward identifying strategies and actions for maintaining priority species and habitats in the face of change.

The University of Washington Climate Impacts Group worked collaboratively with the Nooksack Indian Tribe's Natural Resource Department to evaluate the climate change vulnerability of priority species and habitats for the Tribe. This report describes the approach taken to assess vulnerability and summarizes key findings from the assessment's results. The report also includes an appendix of fact sheets describing individual assessment details for each of the species and habitat types evaluated (Appendix 3); these fact sheets highlight each species' key climate sensitivities as well as data gaps of importance for understanding their vulnerability. Together, the information provided in this assessment offers a rigorous foundation for future climate adaptation efforts aimed at addressing climate risks to the Nooksack Tribe's priority species and habitats.

## Assessment Approach

### Approach Overview

The Nooksack Indian Tribe's Natural Resource Department worked together with Tribal members, other Tribal departments, and the UW Climate Impacts Group to collaboratively develop a list of priority species and habitats of importance to the Tribe for inclusion in the vulnerability assessment. For species with sufficient natural history information and GIS range data, we assessed climate change vulnerability quantitatively using NatureServe's Climate Change Vulnerability Index (CCVI).<sup>1</sup> For species with insufficient natural history information or range data, and for all priority habitat types, we assessed climate change vulnerability qualitatively.

NatureServe's CCVI combines information on a species' projected exposure to climate change, sensitivity to climate change, and adaptive capacity (Figure 1), to generate a relative ranking of vulnerability to climate change. We chose to use the CCVI for this analysis because it is an open-source tool that is frequently used and offers a relatively high degree of transparency compared with other available tools. The widespread adoption of this tool facilitates result comparison with other assessments based on the CCVI. The CCVI's transparency enables users to easily make updates to an assessment, such as adding additional species or incorporating newly available information. Most importantly, the CCVI evaluates a comprehensive suite of





sensitivity and adaptive capacity factors that may contribute to a species' climate vulnerability, offering valuable information for guiding future climate change adaptation planning.

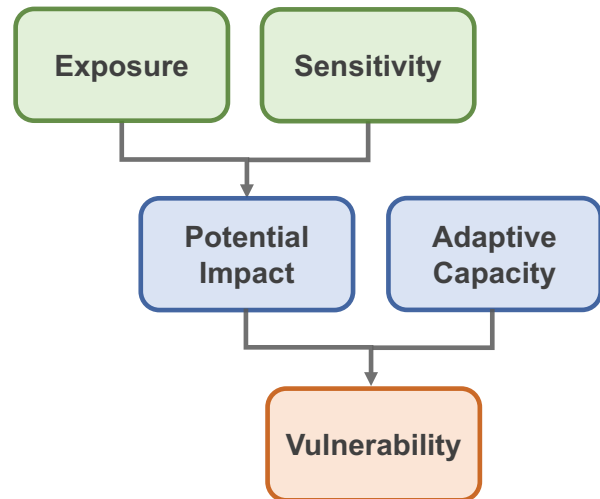
In this assessment, we evaluated sensitivity and adaptive capacity using the primary literature as well as existing databases of species natural history characteristics and other relevant information. We also incorporated the local knowledge and expertise of the Tribe's Natural Resources and Cultural Resources staff. A detailed description of methodology and data sources is provided below.

### Species and Habitat Selection

Through consultation with Tribal members, the Nooksack Indian Tribe Natural Resources Department (NNR) compiled an initial list of species and habitats to be considered in the vulnerability analysis. Due to the limited financial and temporal scope of the project, the assessment's initial proposed list of priority species and habitat types was drawn largely from a previous vulnerability assessment prepared by the UW Climate Impacts Group for the Stillaguamish Tribe of Indians.<sup>4</sup> The Stillaguamish and Nooksack watersheds are located approximately ~50 miles (~80 kilometers) apart, in western Washington State (Figure 2). These watersheds have comparable geographies and are similar in both habitat and species composition, which enabled us to use sensitivity and adaptive capacity factor rankings from the Stillaguamish assessment for the Nooksack assessment.

The Climate Impacts Group and the Nooksack Indian Tribe's Natural Resource staff worked together with Tribal members to refine the initial list to reach a final list of species for assessment. In Workshop 1, held on August 29<sup>th</sup>, 2017, participants received a tentative list of 28 species (drawn partially from a subset of species evaluated in the Stillaguamish Tribe's vulnerability assessment) to be included in the assessment (Table 1). Out of this initial list, 15 species were categorized by Tribal members and staff as cultural or economic priorities for the Tribe (Table 1). Workshop participants chose to keep these 15 species, and added an additional 15 species to the list based on cultural or economic priorities (Table 2). This resulted in a list of 30 species identified as Tribal priorities for assessment.

Because 30 species was beyond the scope of the assessment, the Climate Impacts Group and the Nooksack Natural Resource Department further refined the list to include a total of 23 species: 17 species had been evaluated previously in the Stillaguamish assessment (as budget



**Figure 1.** Components of vulnerability. The climate change vulnerability of a species or habitat is generally understood as being a product of (1) its exposure to climate change (i.e., how much climate change it will experience), (2) its sensitivity to climate change (i.e., how much a given change in climate will affect it), and (3) its adaptive capacity (i.e., its ability to undergo changes that would decrease its exposure or sensitivity). Figure modified from Glick et al 2011.<sup>3</sup>



and time constraints required leveraging of its results), and six species (American pika, beaked hazelnut, black bear, wetland wapato, shot shrimp, and the red sea urchin; Table 3) had not been analyzed previously. It was determined that four of the species that were not analyzed in the Stillaguamish Vulnerability assessment (beaked hazelnut, wetland wapato, red sea urchin, and sport shrimp) would be assessed only if time permitted. Time constraints ultimately prevented the analysis of the wetland wapato and insufficient information prevented the analysis of the red sea urchin, king crab, and the spot shrimp. Therefore, a total of 19 priority species were evaluated in this assessment (Table 4).

A complete list of species and habitat types evaluated in the assessment can be found in Table 4 and Table 5, respectively. The detailed account provided of the species selection process may be useful if future resources allow assessment of additional species or habitats.

**Table 1.** The 28 species initially presented to Workshop 1 participants. Species with an asterisk (\*) were noted as cultural or economic priorities for the Nooksack Tribe.

Initial List of Species Considered at Workshop 1		
American Pika*	Oregon Spotted Frog	Evergreen Huckleberry*
American Beaver	Pileated Woodpecker	Hazelnut*
Bald Eagle	Swainson’s Thrush	Labrador Tea
Black-tailed Deer*	Trumpeter Swan*	Red Elderberry
Canada Lynx	Wolverine	Wetland Wapato
Great Blue Heron*	Alaska Cedar*	Dyer’s Woad
Grizzly Bear	Bivalves*	Smooth Cordgrass
Marbled Murrelet	Bog Cranberry*	Japanese Knotweed
Mountain Goat*	Broadleaf Cattail*	
Mountain Lion*	Elk*	

**Table 2.** The 15 priority species added by Workshop 1 participants.

Species Added by Workshop 1 Participants		
Grouse	Geese	Crab
Western Redcedar	Longfin Smelt	Wild Carrot
Black Bear	Sea Urchin	Brachen Fern
Devils Club	Sea Cucumber	Geoduck
Ducks	Shrimp	Blueberries



**Table 3.** The final list of 23 priority species for the Nooksack Indian Tribe’s Climate Change Vulnerability Assessment. This table includes species that were not assessed due to time and information availability limitations. Species with an asterisk (\*) were evaluated previously in the Stillaguamish Vulnerability Assessment.<sup>4</sup>

Final List of Priority Species for the Nooksack Indian Tribe				
American Pika	Trumpeter Swan*	Northern Pintail*	Broadleaf Cattail*	Wetland Wapato
Black-tailed Deer*	Elk*	Sooty Grouse*	Evergreen Huckleberry*	Red Sea Urchin
Great Blue Heron*	Black Bear	Western Redcedar*	Beaked Hazelnut*	Spot Shrimp (prawn)
Mountain Goat*	Bufflehead*	Bog Cranberry*	Bivalves*	
Mountain Lion*	Alaska Cedar*	Alaska Blueberry*	King Crab	

**Table 4.** The 19 species ultimately assessed in the Nooksack Indian Tribe's vulnerability assessment. All species but bilvalves (+) were assessed quantitatively using NatureServe’s CCVI.

Species Assessed in Nooksack Vulnerability Assessment			
American Pika	Trumpeter Swan	Northern Pintail	Broadleaf Cattail
Black-tailed Deer	Elk	Sooty Grouse	Evergreen Huckleberry
Great Blue Heron	Black Bear	Western Redcedar	Beaked Hazelnut
Mountain Goat	Bufflehead	Bog Cranberry	Bivalves†
Mountain Lion	Alaska cedar	Alaska Blueberry	

**Table 5.** The six habitat types assessed in the Nooksack Indian Tribe's vulnerability assessment. All habitats were assessed qualitatively.

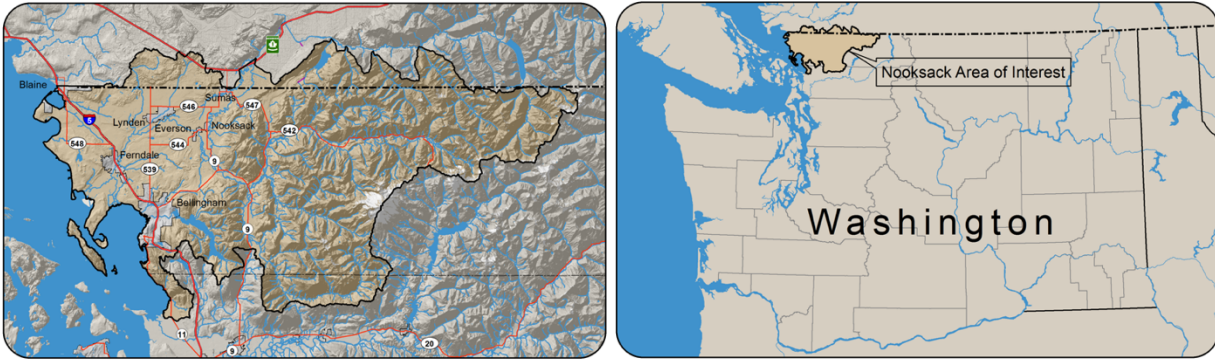
Habitat Types Assessed in Nooksack Vulnerability Assessment
Forest
Wetland: Forested Wetland
Marine: Nearshore, Gravel Beaches
Estuary: Salt Marsh, Eelgrass, Mud Flat
Riparian
Montane: Alpine, Subalpine, Meadow, Talus

### Assessment Area

The Nooksack Tribe Natural Resource staff selected the Nooksack River watershed as the appropriate geographic scale for this assessment. To be in accordance with the State’s watershed planning act and to align with previous reports, the geographic extent was extended to include all of Water Resource Area #1 (WRIA 1), which includes some watersheds that do not drain into the Nooksack River but discharge into the Salish Sea in areas of importance to the Tribe. The extent of the assessment area, WRIA 1, was based on a GIS layer developed by the Washington Department of Ecology (Figure 2). Though the Tribe’s Usual and Accustomed Area extends well beyond the WRIA 1 area, the smaller WRIA 1 area was determined to be a more appropriate scale given the time and budgetary constraints of this assessment.







**Figure 2.** Assessment area. Species and habitats were assessed at the scale of the Nooksack watershed (left), located in Washington State and British Columbia (right). Figure: Robert Norheim.

## Quantitative Climate Change Vulnerability Assessment

### The NatureServe Climate Change Vulnerability Index (CCVI)

We used NatureServe’s Climate Change Vulnerability Index (CCVI)<sup>i</sup> to quantitatively assess species’ relative vulnerability to climate change within the Nooksack River watershed. The CCVI integrates information on a species’ exposure to climate change (i.e., how much climate change it will experience), its sensitivity to climate change (i.e., how much a given change in climate will affect it), and its adaptive capacity (i.e., its ability to undergo changes that could decrease its exposure or sensitivity) to generate a relative ranking of vulnerability to climate change. Descriptions of the components of a species’ vulnerability measured by the CCVI are provided below:

- **Exposure to climate change.** The CCVI uses projected changes in air temperature, moisture availability, sea level rise, and current species range data to estimate a species’ *exposure* to climate change across the species range within the Nooksack River watershed.
  - **Direct exposure** to climate change was assessed by calculating the percent of each species’ range within the Nooksack River watershed that is exposed to different magnitudes of projected change in air temperature and moisture availability.
  - **Indirect exposure** to climate change was assessed by evaluating how projected sea level rise, anthropogenic barriers, natural barriers, and climate change mitigation efforts may affect species evaluated in this assessment.
- **Sensitivity to climate change.** A species’ *sensitivity* to climate change was assessed by scoring a species against a suite of 14 factors (Table 6). Examples of sensitivity factors include a species’ dietary versatility, dependence on ice or snow, and sensitivity to competition.

<sup>i</sup> Release 3.0.<sup>1</sup>



- **Adaptive capacity to withstand climate change.** A species' *adaptive capacity* was assessed by scoring the species against a suite of six factors (Table 6). Examples of adaptive capacity factors include genetic variation within a population, phenological responses to climate change, and dispersal or movement capabilities.

**Table 6.** Indirect climate exposure and species-specific sensitivity and adaptive capacity factors.

Factor	Description
<b>Indirect Climate Exposure Factors</b>	
Sea Level Rise	Effects of sea level rise on species habitat
Natural Barriers	Geographic features of the landscape that may restrict a species from naturally dispersing to new areas
Anthropogenic Barriers	Features of human-altered landscapes (urban or agricultural areas, roads, dams, culverts) that may hinder dispersal for terrestrial and aquatic species
Climate Change Mitigation	Effects of land use changes resulting from human responses to climate change (seawall development, wind farm, biofuel production)
<b>Species Sensitivity and Adaptive Capacity Factors</b>	
Dispersal / Movement	Ability of species to disperse or migrate across the landscape to new locations as conditions change over time
Historical Thermal Niche	Exposure to temperature variation over the past 30 years
Physiological Thermal Niche	Dependence on cool or cold habitats within the assessment area
Historical Hydrological Niche	Exposure to precipitation variation over the past 30 years
Physiological Hydrological Niche	Dependence on a specific precipitation or hydrologic regime
Disturbance	Dependence on a specific disturbance regime likely to be impacted by climate change
Dependence on Ice / Snow	Dependence on ice, ice-edge, or snow-cover habitats
Restriction to Uncommon Geologic Features	Dependence on specific substrates, soils, or physical features such as caves, cliffs, or sand dunes
Habitat Creation	Dependence on another species to generate habitat
Dietary Versatility	Breadth of food types consumed; dietary specialists vs. generalists (animals only)
Pollinator Versatility	Number of pollinator species (plants only)
Propagule Dispersal	Dependence on other species for propagule dispersal
Sensitivity to Pathogens or Natural Enemies	Pathogens and natural enemies (e.g., predators, parasitoids, herbivores, and parasite vectors) that can increase or become more pathogenic due to climate change
Sensitivity to competition from native or non-native species	Species may suffer when competitors are favored by changing climates
Interspecific Interactions	Other interspecific interactions not including diet, pollination, and habitat creation
Genetic Variation	Measured genetic variation (high, medium, low)
Genetic Bottlenecks	Occurrence of bottlenecks in recent evolutionary history
Reproductive System	A plant's reproductive system may serve as a proxy for a species' genetic variation or capacity to adapt to novel climatic conditions (plants only)
Phenological Response	A documented phenological response to changing seasonal temperature and precipitation dynamics.
Documented Response	This factor pertains to the degree to which a species is known to have responded to recent climate change (e.g., range contraction, phenology).



The suite of sensitivity and adaptive capacity factors (Table 6) were evaluated independently for each species and were assigned a categorical ranking classification defined by NatureServe’s CCVI guidelines (Young et al. 2015).<sup>1</sup> The five categorical ranking classifications include:

1. **Greatly Increase Vulnerability**
2. **Increase Vulnerability**
3. **Somewhat Increase Vulnerability**
4. **Neutral**
5. **Unknown**

More than one of these categorical ranking classifications can be selected to indicate intermediate classification or to capture uncertainty surrounding a species’ indirect exposure, sensitivity, or adaptive capacity. In addition, not all sensitivity and adaptive capacity factors are able to receive the full range of categorical responses, as they do not all equally affect overall species vulnerability. For example, scores for the adaptive capacity factor “Genetic Variation” range only from *Neutral* to *Increase Vulnerability*, and do not include the *Greatly Increase Vulnerability* classification.

The CCVI combines a species’ direct exposure to climate change, indirect exposure to climate change, and species-specific sensitivity and adaptive capacity rankings to generate a numerical sum quantifying a species’ relative vulnerability to climate change (Figure 3).<sup>1</sup> This numerical sum is then translated to one of five possible overall vulnerability rankings:

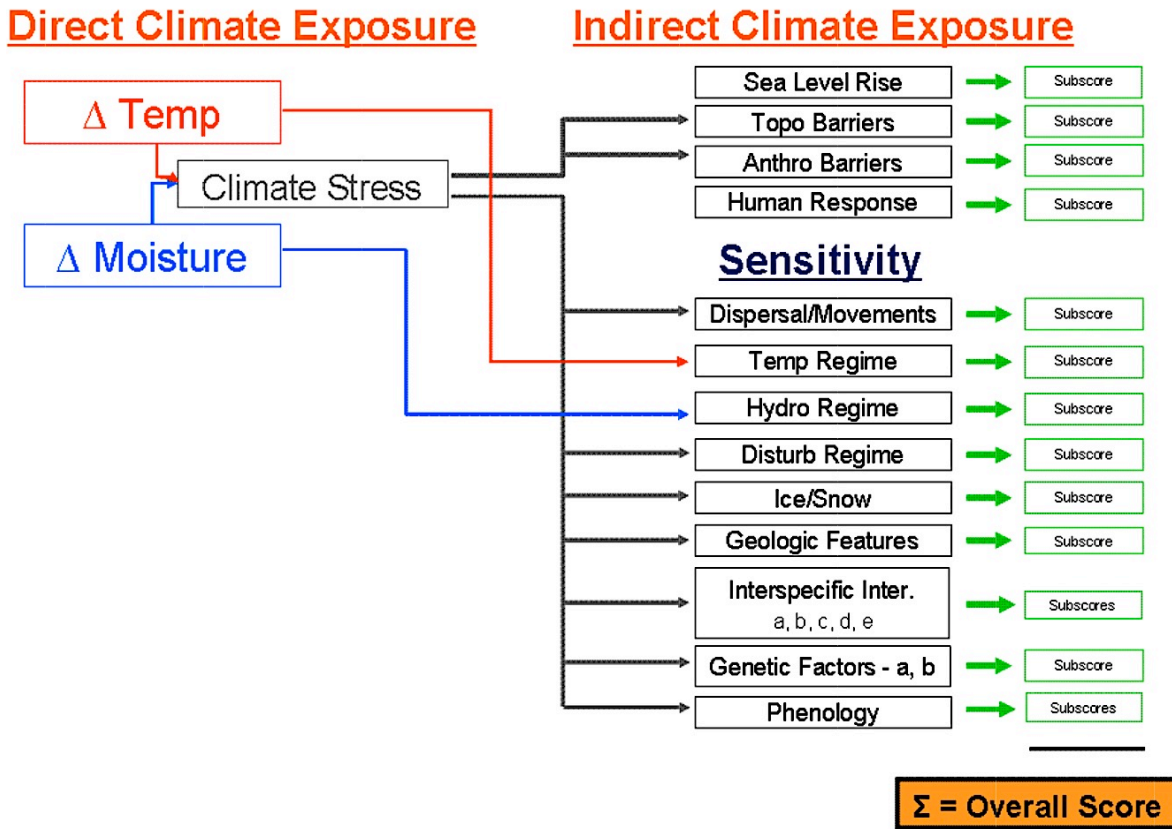
1. **Extremely Vulnerable:** Abundance and/or range extent within geographical area assessed extremely likely to substantially decrease or disappear by 2050 or 2080.
2. **Highly Vulnerable:** Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050 or 2080.
3. **Moderately Vulnerable:** Abundance and/or range extent within geographical area assessed likely to decrease significantly by 2050 or 2080.
4. **Less Vulnerable:** Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change (increase/decrease) substantially by 2050 or 2080.
5. **Insufficient Evidence:** Information entered about a species’ vulnerability is inadequate to calculate an overall vulnerability ranking.<sup>ii</sup>

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<sup>ii</sup> The index will calculate a species’ score with a little as 13 responses to the sensitivity and adaptive capacity factors.<sup>1</sup>







**Figure 3.** Components of the NatureServe Climate Change Vulnerability Index (CCVI). The CCVI measures climate change vulnerability based on direct exposure to local climate change (e.g., changes in temperature and moisture), indirect climate exposure (e.g., sea level rise), and species sensitivity factors (e.g., dispersal capacity). The products of exposure and sensitivities generate subscores, which are summed to generate a species’ overall vulnerability score. Figure reproduced from Young et al. 2015.<sup>1</sup>

#### Data Sources and Climate Data

To generate estimates of a species’ direct climate exposure, indirect climate exposure, sensitivity, and adaptive capacity, the CCVI requires several data inputs including species range data and life history information; observed climate data; and projected changes in temperature, moisture availability, and sea level (Table 7). While species-specific life history information was largely derived from databases, the primary literature, and “gray literature” (e.g., theses, dissertations, agency reports), the Nooksack Tribe’s Natural Resource staff also provided local information specific to the Nooksack River watershed via personal communication during project workshops. This information from Tribal staff increased the accuracy of the assessment by reflecting local observations and expertise from within the Nooksack River watershed.



**Table 7.** Primary data types and sources used in CCVI analysis.

Data Type	Source
Temperature Projections	MACA
Moisture Projections	MACA
Historic Temperature	MACA
Historic Moisture	MACA
Sea Level Rise	Surging Seas Risk Zone Map ( <a href="https://ss2.climatecentral.org/#12/40.7298/-74.0070?show=satellite&amp;projections=0-RCP85-SLR&amp;level=5&amp;unit=feet&amp;pois=hide">https://ss2.climatecentral.org/#12/40.7298/-74.0070?show=satellite&amp;projections=0-RCP85-SLR&amp;level=5&amp;unit=feet&amp;pois=hide</a> )
Species Distributions	IUCN ( <a href="http://www.iucnredlist.org/technical-documents/spatial-data">http://www.iucnredlist.org/technical-documents/spatial-data</a> ); GECSC: Tree Species Distribution Map for North America ( <a href="http://gec.cr.usgs.gov/data/little/">http://gec.cr.usgs.gov/data/little/</a> )
Species Life History	NatureServe Explorer ( <a href="http://explorer.natureserve.org/">http://explorer.natureserve.org/</a> ); Sensitivity Database ( <a href="http://climatechangesensitivity.org/">http://climatechangesensitivity.org/</a> ); The Birds of North America Online ( <a href="http://bna.birds.cornell.edu/bna/species">http://bna.birds.cornell.edu/bna/species</a> ); USDA Forest Service ( <a href="https://www.feis-crs.org/feis/">https://www.feis-crs.org/feis/</a> ); Primary literature (peer-reviewed journals); Gray literature (e.g., theses, dissertations, agency reports); Nooksack Tribe staff/member ( <i>personal communication</i> )

We calculated CCVI scores for two time horizons: the 2050s (2040-2069) and the 2080s (2070-2099). We used temperature and moisture datasets from the Multivariate Adaptive Constructed Analogs (MACA) project, which are drawn from a statistically downscaled global climate model (GCM) from the Coupled Model Intercomparison Project 5 (CMIP5).<sup>5</sup> Projections were generated for the 2050s and the 2080s using a low [Representative Concentration Pathway (RCP) 4.5] and a high (RCP 8.5) greenhouse gas scenario.

The Climate Impacts Group calculated projected changes in moisture availability using an AET:PET moisture metric. The moisture metric is a ratio between projected actual evapotranspiration (AET) and potential evapotranspiration (PET). PET was calculated based on the output for a Variable Infiltration Capacity (VIC) model.<sup>6</sup> Projected changes in the moisture metric were generated for the 2050s and the 2080s under both a low (RCP 4.5) and high (8.5) greenhouse gas scenario.

For the CCVI analysis we used ten different climate datasets. These include two observed data sets and eight data sets for projected changes in climate.



Projected changes in annual temperature (relative to 1970-1999) were categorized using a categorical binning structure defined in the NatureServe Guidelines.<sup>1</sup> There are six categorical temperature bins:

1. >6.0° F (>3.3° C)
2. 5.5-6.0° F (3.1-3.3° C) warmer
3. 5.1-5.5° F (2.8-3.1° C) warmer
4. 4.5-5.0° F (2.5-2.7° C) warmer
5. 3.9-4.4° F (2.2-2.4° C) warmer
6. < 3.9° F (2.2° C) warmer

Projected changes in the annual moisture metric were classified using a categorical binning structure. Lower negative values denote more net drying. There are six categorical moisture metric bins:

1. < -0.119
2. -0.097 - (-0.119)
3. -0.074 - (-0.096)
4. -0.051 - (-0.073)
5. -0.028 - (-0.050)
6. >-0.028

#### Data Processing

We first classified each of the eight exposure layers (e.g., annual temperature and annual HMM) into the respective categorical binning systems defined above.<sup>1</sup> Next, we clipped each of these eight exposure layers (now overlaid with NatureServe's defined binning system) to the Nooksack River watershed using a map developed by the Washington Department of Ecology. This step ensured that we solely considered the exposure data (i.e., projected change in temperature and moisture availability) within the assessment area boundary. The next step was to clip the eight exposure layers bounded at the Nooksack River watershed scale with each species distribution range. This step ensured that we solely examined exposure data across the range of a specific species within the Nooksack River watershed.

It should be noted that the Tribe has recently conducted climate change studies and forecasting for the Nooksack watershed in partnership with the University of Washington and Western Washington University for the application of the Distributed Hydrology Soils Vegetation Model (DHSVM).<sup>7,8</sup> Although the modeled results for watershed hydrology, stream temperature, and sediment are highly relevant to understanding climate impacts on species and habitats, such data is not considered by the CCVI.

#### Qualitative Climate Change Vulnerability Assessment

##### Species

Bivalves were the only group of species not analyzed using the CCVI. This was due to a lack of bivalve range data and because the CCVI is not currently designed to assess the vulnerability of





marine species to climate change.<sup>1</sup> We evaluated bivalves' indirect climate exposure, sensitivity factors, and adaptive capacity factors within the Nooksack River watershed using the suite of CCVI factors, however, direct climate exposure could not be evaluated due to the absence of species range data.

### Habitats

The CCVI was not used to assess the climate change vulnerability of priority habitats included in this assessment (Table 5). Habitat vulnerability was estimated using a coarse *low*, *moderate*, or *high* vulnerability ranking scale based on a habitat's estimated climate change sensitivity and the magnitude of projected climate change within the Nooksack River watershed. Sensitivity scores were taken from the Climate Change Sensitivity Database ([climatechangesensitivity.org](http://climatechangesensitivity.org)), an online, open-source database that captures information from the primary literature and expert opinion.

Climate Change Sensitivity Database scores were derived from expert surveys, in which experts estimated the sensitivities of various habitats to climate change by working through a series of questions regarding climate change sensitivity factors (i.e., temperature sensitivity, precipitation sensitivity, and sensitivity to indirect factors; further details are can be found in the database<sup>iii</sup>). For each climate change sensitivity factor, experts estimated a numeric sensitivity score ranging from one (low sensitivity) to seven (high sensitivity) and a confidence score ranging from one (low confidence) to five (high confidence).

To qualitatively assess habitat vulnerability to climate change, we used these sensitivity scores in combination with the exposure of habitats to climate change within the Nooksack River watershed. Exposure was estimated using the temperature and moisture data used in the CCVI analysis. Specifically, we considered temperature and moisture metric projections for the 2050s under the high (RCP 8.5) greenhouse gas scenario.

### Additional Climate Variables Not Included in the CCVI

The CCVI does not consider all of the climate change impacts likely to affect species' vulnerability to climate change in the Nooksack River watershed. Therefore, we developed a supplemental Physical Drivers report that highlights projected changes in a range of climate-relevant variables selected by the Nooksack Tribe's Natural Resource staff.<sup>9</sup> Variables considered included:

- Average temperature (seasonal)
- Maximum temperature (seasonal)
- Minimum temperature (seasonal)
- Precipitation (seasonal)
- Seasonal runoff
- Snowpack (April and May)
- Water deficit

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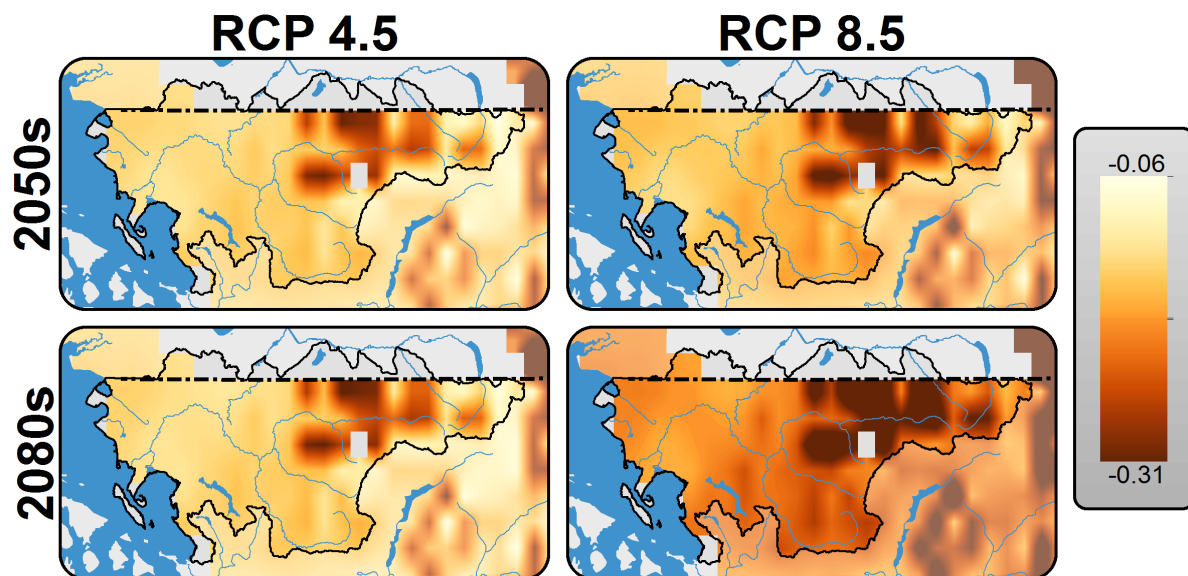
<sup>iii</sup> [climatechangesensitivity.org](http://climatechangesensitivity.org)



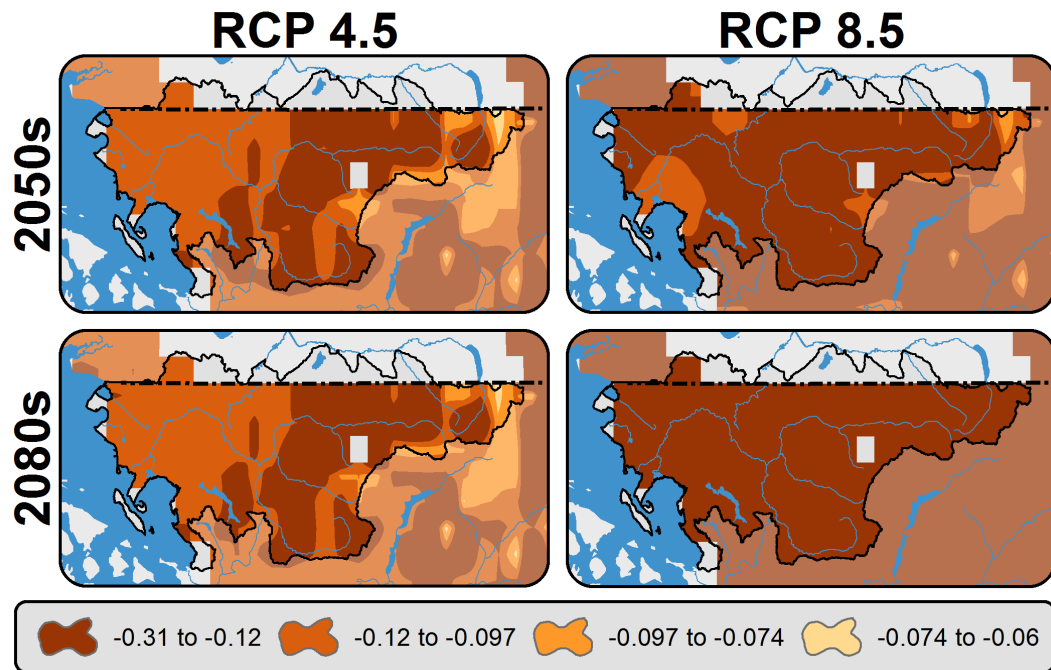
## Results

### Moisture Metric and Temperature Projections

We generated four projections of mean annual moisture, calculated for the 2050s (2040-2069) and 2080s (2070-2099) under a low (RCP 4.5) and a high (RCP 8.5) greenhouse gas scenario. Projected changes in the moisture metric, which integrates projected changes in both temperature and precipitation through an evapotranspiration ratio, suggest that moisture availability will decline across the Nooksack River watershed throughout the 21<sup>st</sup> century (Figure 4; Figure 5). Largest declines are projected to occur in the high elevations of the North Cascades.

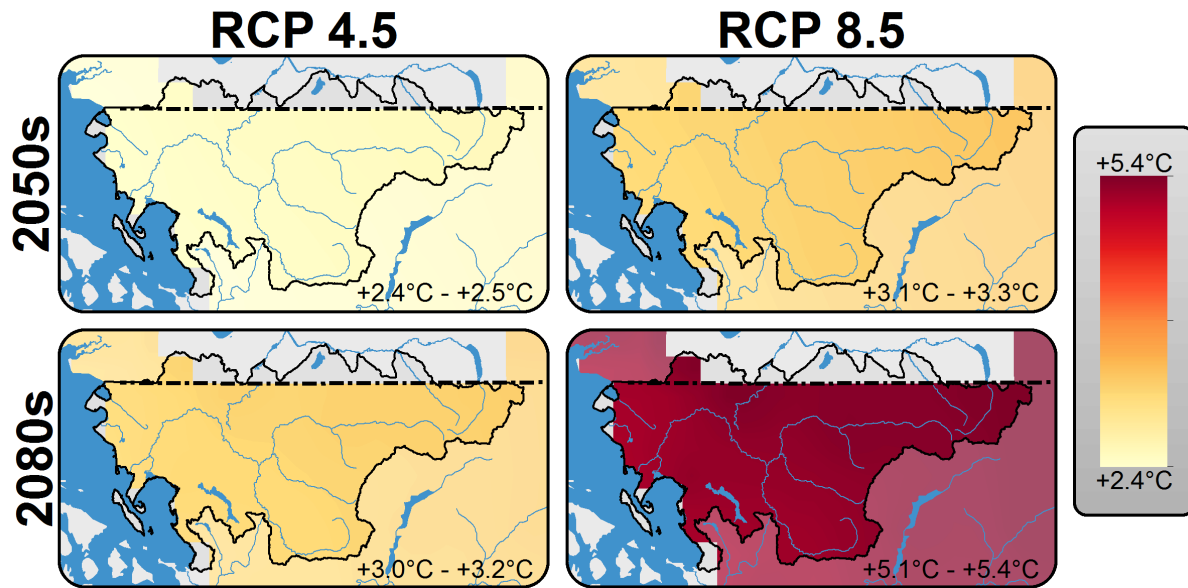


**Figure 1.** Projected change in mean annual moisture for the Nooksack River watershed, generated for the 2050s and 2080s under a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario. Negative values indicate net drying. Figure: Robert Norheim, Climate Impacts Group.

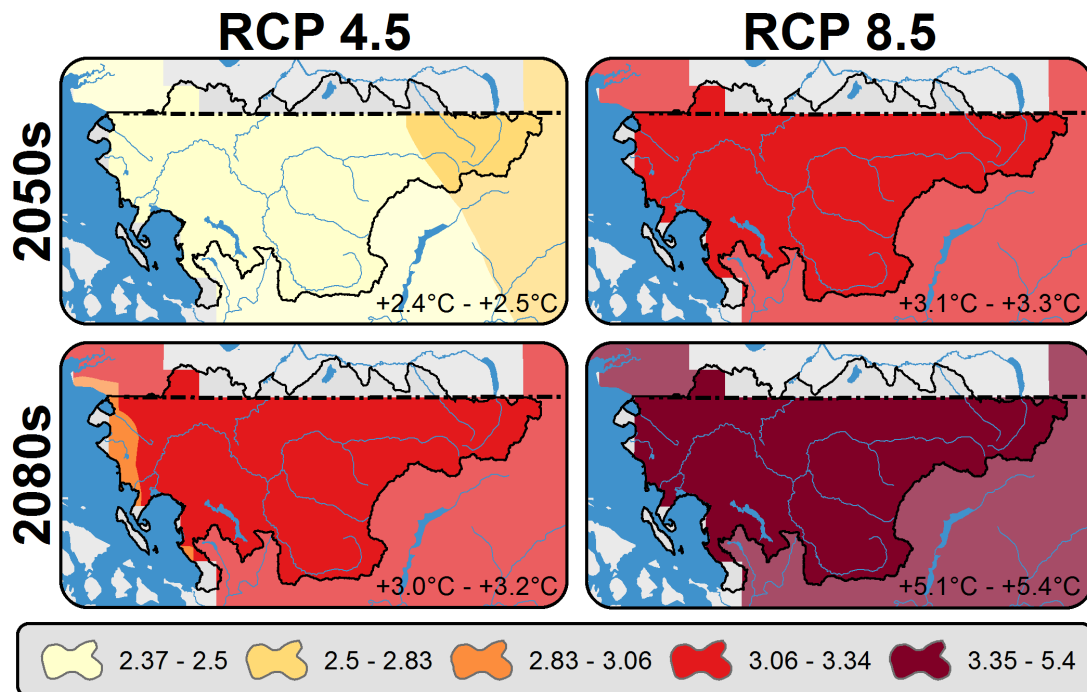


**Figure 5.** Projected change in mean annual moisture for the Nooksack River watershed categorized using the binning structure defined in the NatureServe Guidelines.<sup>1</sup> Projections were generated for the 2050s and 2080s under a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario. Negative values indicate net drying. Figure: Robert Norheim, Climate Impacts Group.

Projections for mean annual temperature were generated for the 2050s (2040-2069) and the 2080s (2070-2099) under both a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario (Figure 6). Within the Nooksack River watershed, significant difference is seen between temperature projections under the low and high greenhouse gas scenarios for the 2050s (2.4-2.5 °C and 3.1-3.3 °C, respectively; Figure 6; Figure 7).



**Figure 6.** Projected change in mean annual temperature for the Nooksack River watershed, generated for the 2050s and 2080s under a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario. Figure: Robert Norheim, Climate Impacts Group.



**Figure 7.** Projected change in mean annual temperature for the Nooksack River watershed categorized using the binning structure defined in the NatureServe Guidelines.<sup>1</sup> Projections were generated for the 2050s and 2080s under a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario. Figure: Robert Norheim, Climate Impacts Group.

## CCVI Analysis Results

Here we provide a summary of results for the 18 species analyzed with NatureServe’s CCVI (Table 8). Detailed results for each species can be found in Appendix 3, which includes quick reference fact sheets for each species that describe their CCVI results, primary sensitivities, and key information gaps. Appendix 2 summarizes the information gaps for all species. See the *Future Research Needs* section, below, for a more in-depth discussion of information gaps encountered in this assessment.

Six species analyzed using the CCVI (western redcedar, bog cranberry, Alaska blueberry, broadleaf cattail, evergreen huckleberry, and beaked hazelnut) do not currently have available GIS data layers for the species ranges. For these species, we assumed that their ranges span the entire Nooksack River watershed – an assumption supported by Nooksack Tribal staff – and used this as their CCVI range layer.

**Table 8.** CCVI rankings for species assessed using NatureServe’s CCVI. CCVI rankings: LV = Less Vulnerable, MV = Moderately Vulnerable, HV = Highly Vulnerable, EV = Extremely Vulnerable.

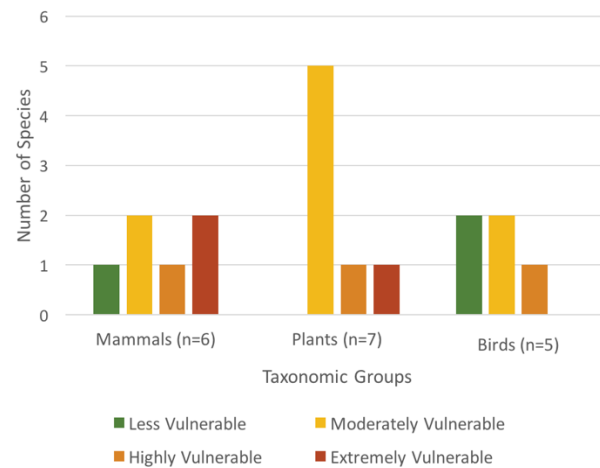
English Name	Species	Taxonomic Group	2050 LOW	2050 HIGH	2080 LOW	2080 HIGH
American pika	<i>Ochotona princeps</i>	Mammal	EV	EV	EV	EV
Black-tailed deer	<i>Odocoileus hemionus</i>	Mammal	MV	EV	EV	EV
Great blue heron	<i>Ardea herodias</i>	Bird	MV	HV	HV	HV
Mountain goat	<i>Oreamnos americanus</i>	Mammal	EV	EV	EV	EV
Mountain lion	<i>Puma concolor</i>	Mammal	LV	MV	MV	MV
Trumpeter swan	<i>Cygnus buccinator</i>	Bird	HV	EV	EV	EV
Elk	<i>Cervus canadensis</i>	Mammal	HV	EV	EV	EV
Black Bear	<i>Ursus americanus</i>	Mammal	MV	EV	EV	EV
Bufflehead	<i>Bucephala albeola</i>	Bird	MV	EV	EV	EV
Alaska cedar	<i>Callitropsis nootkatensis</i>	Plant	EV	EV	EV	EV
Northern pintail	<i>Anas acuta</i>	Bird	LV	MV	MV	MV
Sooty Grouse	<i>Dendragapus fuliginosus</i>	Bird	LV	MV	MV	MV
Western Redcedar	<i>Thuja plicata</i>	Plant	HV	EV	EV	EV
Bog Cranberry	<i>Vaccinium oxycoccos</i>	Plant	MV	HV	HV	EV
Alaska Blueberry	<i>Vaccinium alaskaense</i>	Plant	MV	HV	HV	EV
Broadleaf Cattail	<i>Typha latifolia</i>	Plant	MV	EV	EV	EV
Evergreen huckleberry	<i>Vaccinium ovatum</i>	Plant	MV	EV	EV	EV
Beaked Hazelnut	<i>Corylus cornuta</i>	Plant	MV	HV	HV	EV





## Results for the 2050s under a Low Greenhouse Gas Scenario (RCP 4.5)

Most species assessed using the CCVI received climate change vulnerability rankings of *Moderately Vulnerable* by 2050 under a low greenhouse gas scenario (RCP 4.5) (Figure 8; Figure 9). However, several species received rankings of *Extremely Vulnerable* (e.g., American pika, mountain goat, and Alaska cedar), *Highly Vulnerable* (e.g., elk, trumpeter swan, and western redcedar), and *Less Vulnerable* (e.g., mountain lion, sooty grouse, and northern pintail).

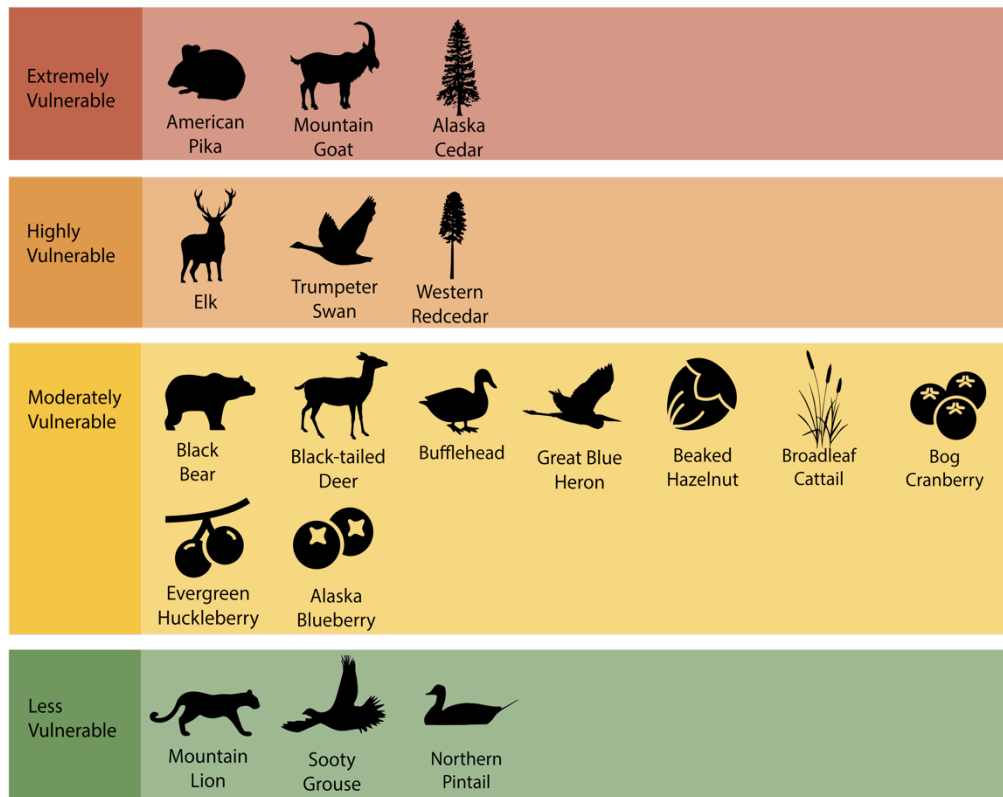


**Figure 8.** CCVI vulnerability rankings for the 2050s using a low greenhouse gas scenario (RCP 4.5), by taxonomic group.

The three species expected to be *Extremely Vulnerable* by the 2050s under a low greenhouse gas scenario all received rankings for the Physiological Thermal Niche factor (Table 6) that increased their overall climate change vulnerability rankings. The American pika and mountain goat received *Greatly Increase Vulnerability* rankings for this factor due to their extreme sensitivities to warm temperatures and association with cool or cold alpine habitats. The American pika and mountain goat also received rankings of *Somewhat Increase Vulnerability* for the *Restriction to Uncommon Geologic Features* factor (Table 6). The mountain goat's association with escape terrain (e.g., steep rocky ledges and cliffs) and the pika's dependence on rocky talus slopes may limit their ability to adapt to habitat loss from climate change, relative to species that are not dependent on uncommon geologic features.

Of the nine species expected to be *Moderately Vulnerable* to climate change by the 2050s under a low greenhouse gas scenario, six received rankings for the *Anthropogenic Barriers* factor that increased their overall vulnerability ranking. Anthropogenic barriers (e.g., highways, agricultural fields, urban areas) may limit a species' ability to effectively shift its geographic range in response to changing climate conditions. The remaining three species (bufflehead, great blue heron, and broadleaf cattail) received rankings for the *Physiological Hydrological Niche* factor (Table 6) that increased their overall vulnerability ranking. These species are reliant on small bodies of water that may dry out during summer months or are susceptible to projected increases in winter flood risk.

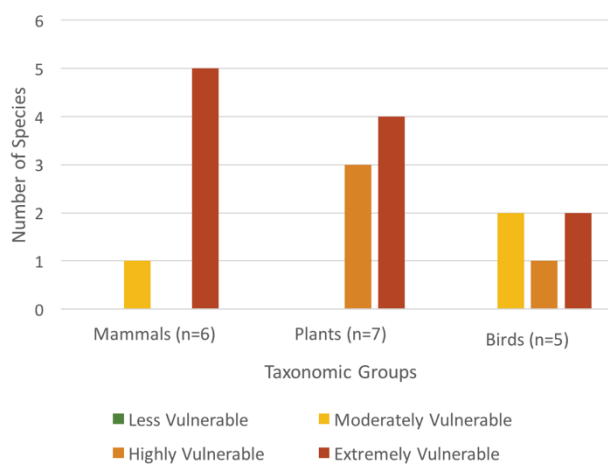




**Figure 9.** CCVI rankings for the 2050s under a low greenhouse gas scenario. CCVI ranking for the indicated species within their ranges in the Nooksack watershed by the 2050s under a low greenhouse gas scenario (RCP 4.5). Species fell into one of four categories: Less Vulnerable (green), Moderately Vulnerable (yellow), Highly Vulnerable (orange), Extremely Vulnerable (red). Image credit for species silhouettes available on page 34 of report.

### Results for the 2050s under a High Greenhouse Gas Scenario (RCP 8.5)

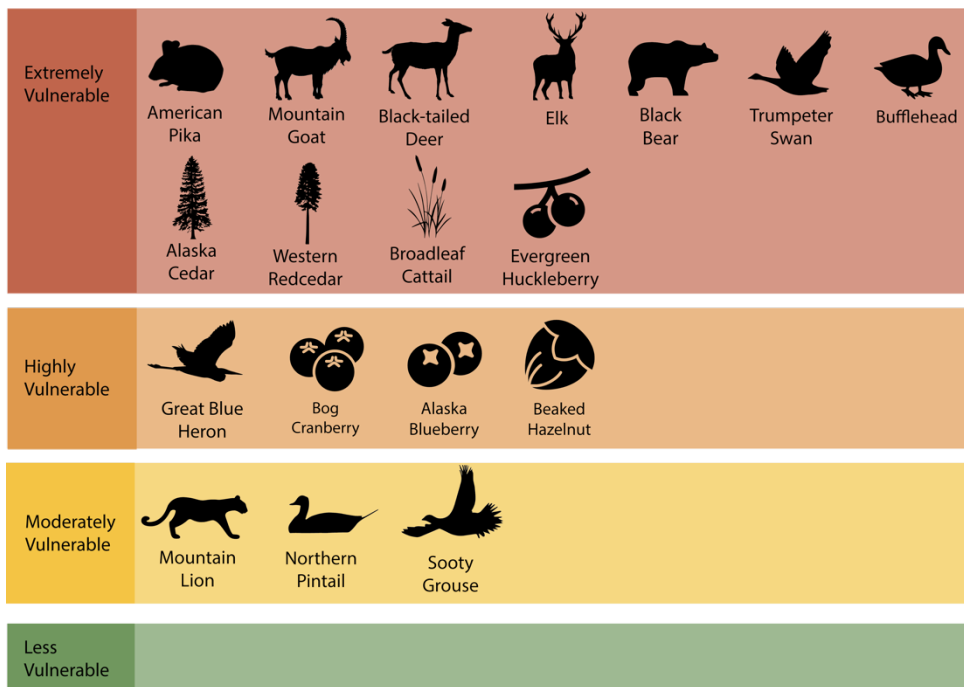
Most species assessed using the CCVI received overall vulnerability rankings of *Extremely Vulnerable* by the 2050s under a high (RCP 8.5) greenhouse gas scenario (Figure 10; Figure 11). With the exception of the American pika, mountain goat, and Alaska cedar, all species' overall vulnerability rankings increased under the high greenhouse gas scenario (relative to low greenhouse scenario vulnerability rankings). Four of the species that were categorized as *Moderately Vulnerable* to climate change by the 2050s under a low greenhouse gas scenario increased to *Highly Vulnerable* under a high greenhouse gas scenario, and five species increased to *Extremely Vulnerable* under a high greenhouse gas scenario (Figure 10; Figure



**Figure 10.** CCVI vulnerability rankings for the 2050s using a high greenhouse gas scenario (RCP 8.5) and for the 2080s using a low greenhouse gas scenario (RCP 4.5), by taxonomic group.

11). All three species expected to be *Less Vulnerable* in the 2050s under a low greenhouse gas scenario (mountain lion, sooty grouse, and northern pintail) experienced increases in overall vulnerability rankings under the high greenhouse gas scenario.

Changes in species' overall vulnerability rankings between the low and high greenhouse gas scenarios in the 2050s are exclusively due to the greater climate exposure under the high scenario. Sensitivity and adaptive capacity factor rankings are static across time horizons and greenhouse gas scenarios. The CCVI treats exposure as a modifier of a species' sensitivity and adaptive capacity. Therefore, increases in exposure (e.g., warmer temperatures or lower moisture availability) will magnify the influence of a sensitivity or adaptive capacity factor on a species' overall vulnerability score.<sup>1</sup>



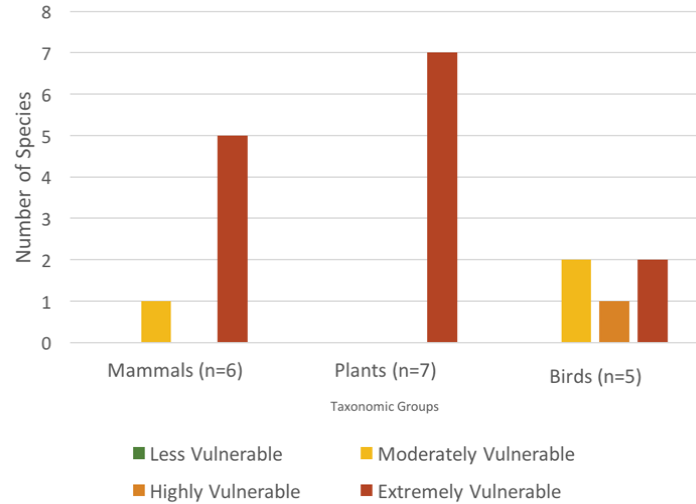
**Figure 11.** CCVI rankings for the 2050s under a high greenhouse gas scenario (RCP 8.5) and the 2080s under a low greenhouse gas scenario (RCP 4.5). CCVI results are identical for the 2050s under a high greenhouse gas scenario and the 2080s under a low greenhouse gas scenario. Species fell into one of four categories: Less Vulnerable (green), Moderately Vulnerable (yellow), Highly Vulnerable (orange), Extremely Vulnerable (red). Image credit for species silhouettes available on page 34 of report.

### Results for the 2080s under a Low Greenhouse Gas Scenario (RCP 4.5)

CCVI results for the 2080s under a low greenhouse gas scenario (Figure 10; Figure 11) are identical to CCVI results for the 2050s under a high greenhouse gas scenario. This is because projected temperature changes are almost identical for the 2050s under a high greenhouse gas scenario and 2080s under a low GHG scenario (Figure 6; Figure 7).

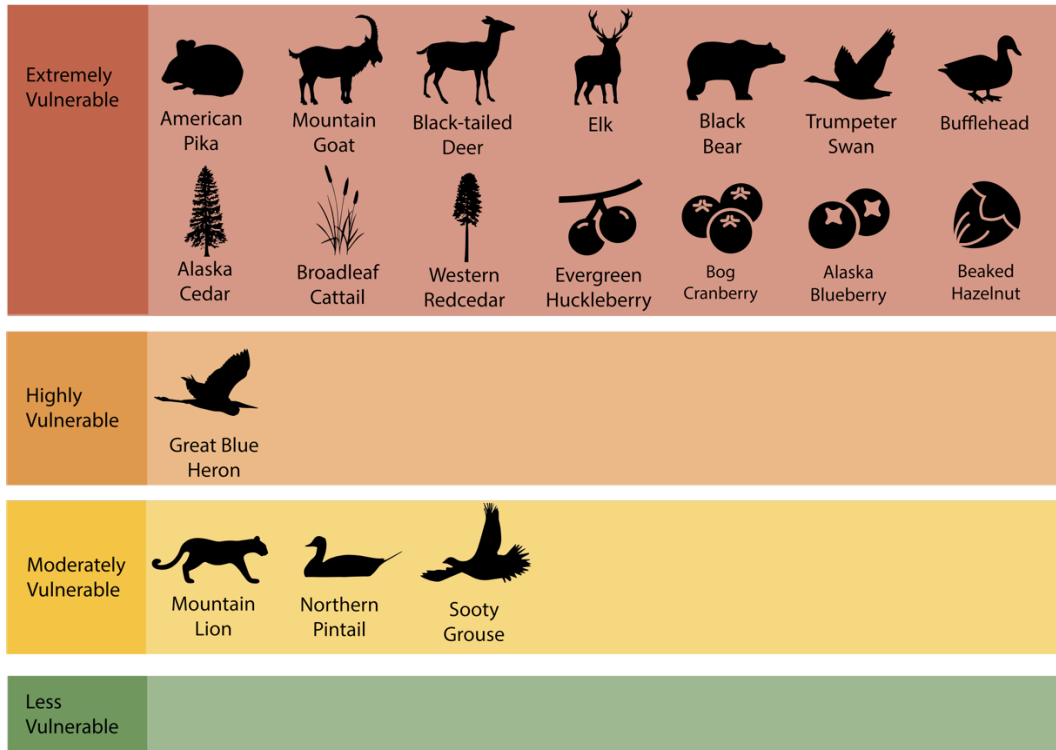
### Results for the 2080s under a High Greenhouse Gas Scenario (RCP 8.5)

Most species assessed using the CCVI received climate change vulnerability rankings of *Extremely Vulnerable* for the 2080s under a high (RCP 8.5) greenhouse gas scenario (Figure 12; Figure 13). Most species' overall vulnerability rankings did not change between the low and the high greenhouse gas scenario, but three of the four species that received a *Highly Vulnerable* ranking under the low scenario (bog cranberry, Alaska blueberry, beaked hazelnut) received an *Extremely Vulnerable* ranking under the high scenario. This was due to these species receiving *Somewhat Increase* rankings for the *Reproductive System* factor (Table 6) because they are capable of vegetative reproduction, which is often associated with low levels of genetic variation (Young et al. 2015). The ranking thus reflects the species' potential for low genetic variation and thus reduced capacity to adapt to novel climatic conditions.



**Figure 12.** CCVI vulnerability rankings for the 2080s using a high greenhouse gas scenario (RCP 8.5), by taxonomic group.





**Figure 13.** CCVI rankings for the 2080s under a high greenhouse gas scenario. CCVI ranking for the indicated species within their ranges in the Nooksack River watershed by the 2080s under a high greenhouse gas scenario (RCP 8.5). Species fell into one of four categories: Less Vulnerable (green), Moderately Vulnerable (yellow), Highly Vulnerable (orange), Extremely Vulnerable (red). Citations for species silhouettes available on page 34 of report.

### Incorporation of Nooksack Staff Feedback into CCVI Rankings

The CCVI results described above reflect incorporation of feedback provided by Nooksack tribal staff. At a second workshop with Tribal members and natural resource staff on October 14<sup>th</sup>, 2017, draft CCVI results were presented, and species sensitivity and adaptive capacity factor scores were modified, as needed, based on participants’ local knowledge of the Nooksack River watershed. Subsequent modifications resulted in changes to overall vulnerability rankings for great blue heron, elk, black bear, bufflehead, sooty grouse, and broadleaf cattail. Specifically:



**Great blue heron:** *Physiological Hydrological Niche* changed from *Somewhat Increase Vulnerability* to *Increase Vulnerability*. This resulted in an increase in the species’ overall vulnerability ranking from *Less Vulnerable* to *Moderately Vulnerable* for the 2050s under a low greenhouse gas scenario, and *Moderately Vulnerable* to *Highly Vulnerable* for the 2050s under a high greenhouse gas scenario. This also resulted in an increase in its overall vulnerability ranking from *Moderately Vulnerable* to *Highly Vulnerable* for the 2080s under both a low and high greenhouse gas scenario.



**Elk:** *Anthropogenic Barriers* changed from *Somewhat Increase Vulnerability* to *Increase Vulnerability*. This resulted in an increase in the elk’s overall vulnerability ranking from *Moderately Vulnerable* to *Highly Vulnerable* for the 2050s under a low greenhouse gas scenario and *Highly Vulnerable* to *Extremely Vulnerable* for the 2050s under a high greenhouse gas scenario. This also resulted in an increase in the elk’s overall



vulnerability ranking from *Highly Vulnerable* to *Extremely Vulnerable* for the 2080s under both a low and high greenhouse gas scenario.



**Black bear:** *Anthropogenic Barriers* changed from *Somewhat Increase Vulnerability* to *Increase Vulnerability*. *Disturbance* changed from *Somewhat Increase Vulnerability* to *Neutral/Somewhat Increase Vulnerability*. These changes resulted in an increase in the black bear's overall vulnerability ranking from *Highly Vulnerable* to *Extremely Vulnerable* for the 2050s under a high greenhouse gas scenario. These changes did not affect the overall vulnerability ranking for the 2050s under a low greenhouse gas scenario. These changes also resulted in an increase in the black bear's overall vulnerability ranking from *Highly Vulnerable* to *Extremely Vulnerable* for the 2080s under a low greenhouse gas scenario, but did not affect its overall vulnerability ranking for the 2080s under a high greenhouse gas scenario.



**Bufflehead:** *Sea Level Rise* changed from *Neutral* to *Somewhat Increase Vulnerability*. This change resulted in an increase the bufflehead's overall vulnerability ranking from *Highly Vulnerable* to *Extremely Vulnerable* for the 2050s under a high greenhouse gas scenario. This change did not affect its overall vulnerability ranking for the 2050s under a low greenhouse gas scenario. This change also resulted in an increase in the bufflehead's overall vulnerability ranking from *Highly Vulnerable* to *Extremely Vulnerable* for the 2080s under a low greenhouse gas scenario, but did not affect its overall vulnerability ranking for the 2080s under a high greenhouse gas scenario.



**Sooty grouse:** *Anthropogenic Barriers* changed from *Neutral/Somewhat Increase Vulnerability* to *Somewhat Increase Vulnerability*. This change resulted in an increase in the sooty grouse's overall vulnerability ranking from *Less Vulnerable* to *Moderately Vulnerable* for the 2050s under a high greenhouse gas scenario. This changes did not affect the overall vulnerability ranking for the 2050s under a low greenhouse gas scenario. This change also resulted in an increase in the sooty grouse's overall vulnerability ranking from *Less Vulnerable* to *Moderately Vulnerable* for the 2080s under a high greenhouse gas scenario, but did not affect the overall vulnerability ranking for the 2080s under a high greenhouse gas scenario.



**Broadleaf cattail:** *Physiological Hydrological Niche* changed from *Neutral* to *Somewhat Increase Vulnerability*. This change resulted in an increase in the cattail's overall vulnerability ranking from *Highly Vulnerable* to *Extremely Vulnerable* for the 2050s under a high greenhouse gas scenario. This change did not affect the overall vulnerability ranking for the 2050s under a low greenhouse gas scenario. This change also resulted in an increase in the cattail's overall vulnerability ranking from *Highly Vulnerable* to *Extremely Vulnerable* for the 2080s under a low greenhouse gas scenario, but did not affect the overall vulnerability ranking for the 2080s under a high greenhouse gas scenario.



## Results of Qualitative Vulnerability Assessment

### Species

Bivalves were the only species assessed qualitatively in this assessment. We assessed bivalves' natural history characteristics using the same suite of climate sensitivity and adaptive capacity factors included in the CCVI, but did not calculate an overall CCVI vulnerability ranking. Detailed descriptions of the bivalves' sensitivities are provided in their fact sheet (Appendix 3).

### Habitats

Six priority habitat types were assessed qualitatively based on sensitivity scores (to changes in temperature, precipitation, and indirect factors) and projected exposure for the 2050s. Each habitat received an estimated vulnerability ranking (low, moderate, or high; Table 9). Similar to species results, habitat sensitivities scores varied by habitat type, resulting in a range of overall vulnerability scores. A summary of key sensitivities for each habitat is provided below; additional details can be found in the habitat fact sheets (Appendix 3).

**Table 9.** Qualitative Assessment Results for Habitats. Habitats identified by the Tribe as a high priority for assessment are shown in bold. Possible vulnerability rankings included Low, Moderate, and High.

Habitat Type	Qualitative Vulnerability Ranking
<b>Forest / Old Growth Forest</b>	Moderate to High
<b>Wetland: Forested Wetland</b>	High
<b>Marine: Nearshore, Gravel Beaches</b>	Moderate
<b>Estuary: Salt Marsh, Eelgrass, Mud Flat</b>	Moderate to High
<b>Riparian</b>	Moderate to High
<b>Montane: Alpine, Subalpine, Meadow, Talus</b>	High

### Forest

Projected increases in air temperature will likely lengthen the growing season in western Washington forests, and drive shifts in species composition. Warmer temperatures may also expedite the spread of invasive species, forest pests, pathogens, and diseases. Increases in precipitation during fall, winter, and spring may result in increased growth rates. Additionally, projected increases in cool season precipitation may increase productivity in water-limited forests located in dry, higher elevation regions. Conversely, declining precipitation during the growing season may lead to reduced growth rates across forests in the region. Warming temperatures and declining moisture availability during the growing season will also likely result in increased fire frequency and intensity. Many species included in this assessment are associated with forest habitats, including elk, deer, black bear, mountain goat, mountain lion, sooty grouse, Alaska blueberry, evergreen huckleberry, western redcedar, and Alaska cedar.

### Wetland

Projected increases in air temperature may accelerate wetland drying, leading to mismatches between when species require wetlands seasonally for reproduction or metamorphosis and when the wetlands are wet. Declining precipitation during summer months may also contribute to earlier wetland drying and a longer dry period. Assessed species that are dependent on



forested wetlands include great blue heron (during the breeding season), northern pintail, bufflehead, trumpeter swan, and broadleaf cattail.

#### Marine: Nearshore, Gravel Beaches

Projected warming is expected to affect species composition of the nearshore marine environment. Warming temperatures also increase the likelihood of non-native species invasion into nearshore marine habitats, by facilitating the spread of species previously excluded by cold water temperatures. There is a relatively high degree of uncertainty regarding how the nearshore marine environment will respond to projected changes in precipitation.

Precipitation, especially extreme precipitation events, could alter sediment transport in the marine environment via scour and deposition in the nearshore. Ocean acidification and sea level rise are two indirect factors expected to have significant impacts on the nearshore marine ecosystem.

#### Estuary

Projected increases in air temperature and a longer dry season may result in more frequent drying of low-tide habits. For example, warming temperatures may increase the frequency of eel grass desiccation. However, estuaries may be less sensitive to such changes due to their tolerance to relatively high degrees of variability (e.g., daily tidal variation). Projected changes in precipitation are important for freshwater inflow into estuaries. In addition, ocean acidification, sea level rise, and coastal flooding are three indirect factors expected to have significant impacts on the nearshore estuaries.

#### Riparian

Riparian areas within the Nooksack River watershed are found beside rivers and adjacent to bodies of water. Riparian areas tend to have cooler micro-climates than surrounding habitat. Warming temperatures and declining snowpack may lower river water levels during summer months and could dry out small creeks and lower water table levels in adjacent floodplains. Drying of these water sources may negatively affect the species composition and structure of bordering riparian habitats. Projected increases in winter streamflow volume and timing will also affect water tables and soil moisture levels within riparian habitats. Winter flood risk is also projected to increase. Riparian and floodplain areas may thus become wetter and inundated more frequently in winter under future climate scenarios. Due to the importance of soil moisture levels to riparian species structure and composition, this habitat type is also sensitive to changes in precipitation. In addition to temperature and precipitation sensitivity, riparian habitats are also sensitive to disturbance from competition from non-native species.

#### Montane: Alpine, Subalpine, Meadow, Talus

Projected increases in air temperature are expected to increase vegetation growth and productivity in high-elevation zones that have historically been energy-limited by cold temperatures and deep and expansive snowpack. Warming temperatures are also expected to facilitate tree establishment in meadows and other suitable alpine areas, where trees have previously been excluded by cold temperatures, deep snowpack, and harsh conditions. Declines



in winter snowpack are also likely to extend the growing season, but will negatively affect snow dependent species. Declines in summer precipitation could lead to reductions in biomass production and increased likelihood of fire. Assessed species dependent on montane habitats include mountain goat, elk, and American pika.

## Key Findings

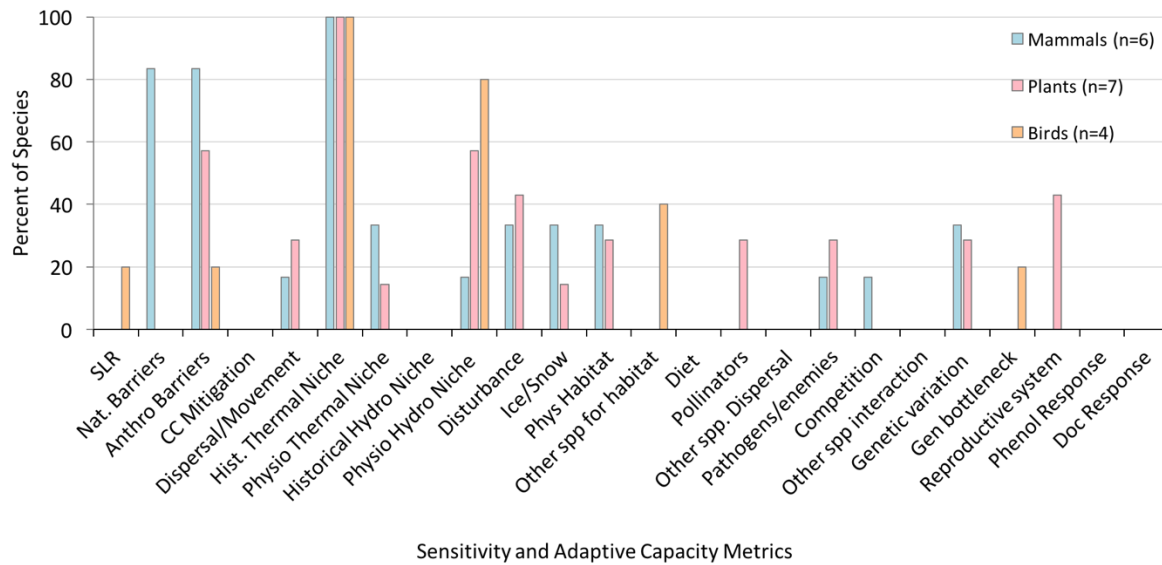
Here, we discuss key findings of our quantitative and qualitative analyses, highlighting the primary sensitivities contributing to vulnerability for each taxonomic group (mammals, birds, and plants). We also discuss findings of our qualitative assessment of priority habitat types.

### CCVI for the 2050s and 2080s

Overall vulnerability scores ranged widely, from *Less Vulnerable* to *Extremely Vulnerable*, but the majority of species ranked as *Moderately Vulnerable* for the 2050s under a low greenhouse gas scenario (Figure 9) and *Extremely Vulnerable* for the 2050s under a high greenhouse gas scenario (Figure 11). Most species also ranked as *Extremely Vulnerable* for the 2080s under both low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenarios (Figure 11; Figure 13).

Two sensitivity factors, *Historical Thermal Niche* and *Anthropogenic Barriers*, are expected to increase vulnerability for almost all species analyzed with the CCVI (Figure 14; Appendix 1). Because species within the Nooksack River watershed have experienced a relatively narrow range of temperature variation over the past thirty years, they are expected to have relatively low thermal tolerances to large changes in temperature. In addition, anthropogenic barriers (e.g., highways, dams, and developed areas) in the watershed are expected to increase species' vulnerability to climate change by impeding their ability to disperse across the landscape to track shifting areas of climate suitability.





**Figure 14.** Climate sensitivities, adaptive capacity factors, and indirect climatic exposures contributing to CCVI rankings by taxonomic group. Only sensitivities that increase vulnerability are shown (see Table 6 for full descriptions of sensitivity factors).

### Mammals

Mammal species exhibited a wide range of overall vulnerability rankings in this assessment, from *Less Vulnerable* to *Extremely Vulnerable*. *Natural Barriers*, *Anthropogenic Barriers*, and *Historical Thermal Niche* (Figure 14) were the factors most responsible for increasing mammals' vulnerability to climate change. Barriers within the watershed include high mountain ranges, large lakes, highways, urban centers, and agricultural fields, all of which can limit a mammal's ability to track shifting climate conditions.

*Physiological Thermal Niche*, *Disturbance Regime*, *Dependence on Ice/Snow*, and *Restriction to Uncommon Geologic Features* also increased some mammals' estimated vulnerability to climate change (Figure 14). *Physiological Thermal Niche*, *Dependence on Ice/Snow*, and *Uncommon Geologic Features* all increase vulnerability for the American pika and mountain goat, because of their association with cold, snowy subalpine and alpine habitats. In addition, dependence on a specific disturbance regime influenced the overall vulnerability rankings of the black bear and the mountain goat.

The mountain lion is the only mammal estimated to be *Less Vulnerable* to climate change by the 2050s under a low greenhouse gas scenario (Figure 9). The mountain lion is a habitat generalist with a diverse diet (Appendix 3), and will likely be able to adapt to shifting climate conditions assuming barriers do not inhibit its ability to track shifting climate conditions.

### Birds

Overall vulnerability rankings for birds also ranged from *Less Vulnerable* to *Extremely Vulnerable* (Figure 8; Figure 10; Figure 12). *Historical Thermal Niche*, *Physiological Hydrological Niche*, and *Dependence on Other Species for Habitat Generation* are the factors most responsible for increasing birds' overall vulnerability rankings (Table 6; Figure 14).





*Physiological Hydrological Niche*, which evaluates a species' dependence on a specific precipitation or hydrologic regime, influenced the overall vulnerability rankings of the great blue heron, trumpeter swan, bufflehead, and the northern pintail (Appendix 1). For example, projected increases in winter flood risk may negatively affect trumpeter swan fledgling survival due to declines in nesting habitat suitability.<sup>11</sup> *Dependence on Other Species for Habitat Generation* increased the overall vulnerability score for the trumpeter swan and the bufflehead. For example, the bufflehead exclusively nests in tree cavities constructed by the northern flicker and the pileated woodpecker.<sup>12</sup> Species that rely on a small number of species for habitat or nesting sites are likely to be more vulnerable to climate change than species with more generalized habitat requirements.

## Plants

Overall vulnerability rankings of plant species included in this assessment range from *Moderately Vulnerable* to *Extremely Vulnerable* (Figure 11, Figure 12, Figure 13). *Historical Thermal Niche*, *Anthropogenic Barriers*, *Physiological Hydrological Niche*, and *Reproductive System* were the factors most responsible for increasing plants' overall vulnerability rankings (Figure 14).

*Physiological Hydrological Niche*, which evaluates a species' dependence on a specific precipitation or hydrologic regime, influenced the overall vulnerability rankings of the Alaska cedar, bog cranberry, and broadleaf cattail. For example, bog cranberry grows in bogs and fens that are saturated for the majority of the year.<sup>13</sup> The *Reproductive System* factor influenced the overall vulnerability ranking of the Alaska blueberry, evergreen huckleberry, and beaked hazelnut. These species received *Somewhat Increase* rankings for the *Reproductive System* factor because they are capable of vegetative reproduction, which is often associated with low levels of genetic variation.<sup>1</sup> Species with low levels of genetic variation are expected to be less able to adapt to changing climate conditions than populations with average to high levels of genetic diversity.

## Key Findings for Habitats

All six habitat types evaluated in this assessment are estimated to be at least *Moderately Vulnerable* to climate change (Table 9) and two habitat types are estimated to be *Highly Vulnerable*, including wetlands and montane regions. Each of these habitats is expected to be highly vulnerable due to their relatively high climate sensitivity and projected exposure to future changes in both temperature and precipitation.

## Discussion

Priority species for the Nooksack Tribe are largely expected to be *Extremely Vulnerable* to climate change under both time horizons (2050s and 2080s) and greenhouse gas scenarios (low and high) evaluated in this assessment. The one exception to this trend is the overall vulnerability scores for the 2050s under a low greenhouse gas scenario, where the majority of species receive overall climate change vulnerability rankings of *Moderately Vulnerable*.



While mammal, bird, and plant species are all expected to be vulnerable to climate change to some degree, assumptions in the CCVI methodology likely resulted in lower relative vulnerability scores for the bird species evaluated in this assessment. Specifically, the CCVI assumes there are no anthropogenic or natural barriers for temperate bird species, as they are expected to be able to fly over or around these barriers.<sup>1</sup> Alternatively, overall vulnerability rankings for the mammal and plant species assessed range from *Less Vulnerable* to *Extremely Vulnerable* depending on the time horizon and greenhouse gas scenario considered. *Anthropogenic Dispersal Barriers* and *Sensitivity to a Disturbance Regime* increased the vulnerabilities of most mammal and plant species assessed (Figure 14).

### Comparing Results with other Assessments

As discussed earlier, species and habitats evaluated in this assessment were primarily drawn from an earlier vulnerability assessment prepared by the Climate Impacts Group for the Stillaguamish Tribe of Indians.<sup>4</sup> Overall, species' vulnerability rankings in the Stillaguamish assessment were significantly lower than the vulnerability rankings in the Nooksack assessment. We identified two primary methodological differences between the two assessments that could explain this discrepancy: (1) the version of the CCVI used in each assessment, and (2) the climate datasets used to evaluate exposure to projected changes in temperature and moisture availability.

The Stillaguamish assessment was conducted using an older version of the CCVI (version 2.1); the newer version (version 3.0) incorporates numerous updates, including – most notably – the elimination of the *Somewhat Decrease Vulnerability* and *Decrease Vulnerability* ranking scores for sensitivity and adaptive capacity factors. Version 3.0 also eliminates the overall vulnerability ranking of *Less Vulnerable*. To assess whether the removal of the *Somewhat Decrease Vulnerability* and *Decrease Vulnerability* scores affected overall vulnerability rankings, we re-ran several species included in the Stillaguamish assessment and changed those sensitivity factors previously scored as *Somewhat Decrease* or *Decrease* to *Neutral*. Changing these scores to *Neutral* significantly increased the overall vulnerability scores for the species tested. Differences between the two CCVI versions is thus the most likely explanation for the higher vulnerability rankings seen in the Nooksack assessment.

The Stillaguamish assessment also used the CMIP3 multi-model climate dataset, rather than the more recent CMIP5 multi-model dataset used in the Nooksack assessment. However, projected warming under CMIP3 and CMIP5 is similar for comparable greenhouse gas emissions.<sup>14</sup> Thus, differences between the climate datasets used are unlikely to have contributed to differences in results between the Stillaguamish and Nooksack vulnerability assessments.

### Limitations of the assessment

While NatureServe's CCVI is a useful tool for rapidly assessing species' relative vulnerability to climate change, it has several limitations. For example, the CCVI does not use climate sensitivity and adaptive capacity factors to directly assess population dynamics, or examine the effect of climate change on population vital rates (e.g., fecundity, survival). If population-level



information and results are a key management interest, demographic models will likely be better able to provide these results. A broader limitation of the CCVI is the limited degree to which uncertainty is reflected in its results. The CCVI does capture uncertainty in indirect climate exposure, sensitivity, and adaptive capacity factors by allowing users to select more than one categorical ranking classification for each factor. However, climate model uncertainty (i.e., direct exposure to climate change) is not reflected in CCVI results. To help address uncertainty around future carbon emissions scenarios, we performed the CCVI analysis under both a low (RCP 4.5) and high (RCP 8.5) greenhouse gas scenario. Perhaps more of a concern is that projected changes in direct climate exposure are developed using annual averages, when seasonal changes (e.g., reduced moisture availability in summer) may prove more important for species' climate change vulnerability.

The most important caveat for appropriately interpreting and applying results from this assessment – both quantitative and qualitative – is that vulnerability rankings have been shown to differ depending on the assessment approach or tool used.<sup>15</sup> That is, had we used a different tool or assessment approach, it is likely that resulting rankings would be at least somewhat different from those found in this assessment. Results from this assessment should thus be seen as useful hypotheses of species' and habitats' relative climate change vulnerability, but not as conclusive measures of absolute vulnerability. We therefore suggest that the most valuable and robust application of these results will come from considering why a given ranking was given (i.e., considering specific exposure, sensitivity, and adaptive capacity rankings), rather than focusing on overall vulnerability rankings. Understanding these underlying drivers of species' and habitats' vulnerabilities will also be most useful in identifying future adaptation responses aimed at maximizing climate change resilience.

## Future Research Needs

Most of the species and habitats evaluated in this assessment had adequate data for assessing their vulnerability to climate change. However, there are areas where additional research would improve our understanding of the climate exposures and sensitivities underlying the climate vulnerability of the species and habitats assessed (Appendix 2). For example, seven species considered in this assessment lacked GIS range data, a critical input for vulnerability assessments and adaptation planning. For six of these species, we made the assumption that their geographic range includes the entire Nooksack River watershed, thereby allowing their inclusion in the CCVI analysis. Having explicit range data for these species would increase the accuracy of their overall CCVI results, as it would more precisely reflect the magnitude of their projected climate exposure within the assessment area. Most species also lacked information regarding their phenological responses to climate change, sensitivity to pathogens or natural enemies, and documented response to climate change (Appendix 2). As these information gaps are addressed, vulnerability rankings and adaptation strategies should be re-visited.



## Next Steps

The *Nooksack Indian Tribe Natural Resource Climate Change Vulnerability Assessment* represents an important first step in the Tribe's ability to assess climate risks and prepare for future climate impacts on priority species and habitats. Results of this assessment suggest that while vulnerability is likely to vary across species and habitats, many of the Tribe's priority species and habitats may be highly or extremely vulnerable to climate change by the end of the century. In addition to identifying which species and habitats are expected to be vulnerable to climate change, this assessment highlights the specific climate sensitivity and adaptive capacity factors that underlie this vulnerability. This knowledge of *why* a species or habitat is vulnerable to climate change, and what information gaps remain in our understanding of its vulnerability, may be particularly useful in identifying activities that may help to reduce vulnerability. Developing a climate change adaptation plan that identifies specific strategies and actions for reducing climate risks may thus be a powerful next step toward increasing the resilience of priority species and habitats for the Nooksack Tribe.

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## Appendix 1

### NatureServe Climate Change Vulnerability Index (CCVI): Overall Rankings and Indirect Climate Exposure, Sensitivity, and Adaptive Capacity Sub-Scores.

Detailed description of sensitivity factors is provided in Table 6 (pg. 9).

#### Sensitivity Scores:

- (1) **Greatly Increase Vulnerability:** GI
- (2) **Increase Vulnerability:** Inc
- (3) **Somewhat Increase Vulnerability:** SI
- (4) **Neutral:** N
- (5) **Unknown**

#### Vulnerability Rankings:

- (1) **Extremely Vulnerable:** EV
- (2) **Highly Vulnerable:** HV
- (3) **Moderately Vulnerable:** MV
- (4) **Less Vulnerable:** LV



**Table A1-1.** Sensitivity factor rankings and CCVI rankings for species assessed using NatureServe's CCVI. Sensitivity rankings: U=Unknown, N=Neutral, SI=Somewhat Increase Vulnerability, Inc=Increase Vulnerability, GI=Greatly Increase Vulnerability. CCVI rankings: LV = Less Vulnerable, MV = Moderately Vulnerable, HV = Highly Vulnerable, EV = Extremely Vulnerable.

English Name	Species	Taxonomic Group	Sea level rise	Natl barriers	Anth barriers	CC mitigation	Dispersal/Movement	Hist. thermal niche	Physiol. thermal niche	Hist. hydrol. niche	Physiol. hydrol. niche	Disturbance	Ice/snow	Phys habitat	Other spp for habitat	Diet	Pollinators	Other spp. dispersal	Pathogens/enemies	Competition	Other spp interaction	Genetic variation	Gen bottleneck	Reproductive system	Phenol response	Doc response	2050 LOW	2050 HIGH	2080 LOW	2080 HIGH
			B1	B2a	B2b	B3	C1	C2ai	C2aii	C2bi	C2bii	C2c	C2d	C3	C4a	C4b	C4c	C4d	C4e	C5a	C5b	C6	D1	D2	D3	D4				
American pika	<i>Ochotona princeps</i>	Mammal	N	Inc	N/SI	N	SI	Inc	GI	N	N	N	SI	SI	N	N	N/A	N	U	U	N	SI	N/A	N/A	N	U	EV	EV	EV	EV
Black-tailed deer	<i>Odocoileus hemionus</i>	Mammal	N	SI	SI	N	N	Inc	N	N	N	N	N	N	N	N	N/A	N	SI	SI	N	N	N/A	N/A	U	U	MV	EV	EV	EV
Great blue heron	<i>Ardea herodias</i>	Bird	N	N	N	N	N	Inc	N	N	Inc	N	N	N	N	N/A	N	U	U	N	N	N	N/A	N/A	U	U	MV	HV	HV	HV
Mountain goat	<i>Oreamnos americanus</i>	Mammal	N	SI	SI	N	N	SI	GI	N	N	N/SI	N/SI	SI	N	N/A	N	U	U	N	Inc	N/A	N/A	U	U	EV	EV	EV	EV	
Mountain lion	<i>Puma concolor</i>	Mammal	N	N	SI	N	N	Inc	N	N	N	N	N	N	N	N/A	N	U	N	N	N	N/A	N/A	U	U	LV	MV	MV	MV	
Trumpeter swan	<i>Cygnus buccinator</i>	Bird	N	N	N	N	N	Inc	N	N	Inc	N	N	N	N/SI	N	N/A	N	U	U	U	U	Inc	N/A	U	U	HV	EV	EV	EV
Elk	<i>Cervus canadensis</i>	Mammal	N	SI	Inc	N	N	Inc	N	N	N/SI	N	N	N	N	N/A	N	U	U	N	N	N/A	N/A	U	U	HV	EV	EV	EV	
Black Bear	<i>Ursus americanus</i>	Mammal	N	SI	Inc	N	N	Inc	N	N	N	N/SI	N	N	N	N/A	N	U	N	N	N	N/A	N/A	U	U	MV	EV	EV	EV	
Bufflehead	<i>Bucephala albeola</i>	Bird	SI	N	N	N	N	Inc	N	N	SI	N	N	INC	N	N/A	N	U	N	N	N	N/A	N/A	U	U	MV	EV	EV	EV	
Alaska cedar	<i>Callitropsis nootkatensis</i>	Plant	N	N	SI	N	SI	Inc	SI	N	SI	N	INC	N	N/A	N	N	N/SI	N	N	U	U	N	U	U	EV	EV	EV	EV	
Northern pintail	<i>Anas acuta</i>	Bird	N	N	N	N	N	SI	N	N	Inc	N	N	N	N	N/A	N	U	N	N	N	N/A	N/A	U	U	LV	MV	MV	MV	
Sooty Grouse	<i>Dendragapus fuliginosus</i>	Bird	N	N	SI	N	N	Inc	N	N	N	N	N	N	N	N/A	N	U	N	N	N	N/A	N/A	U	U	LV	MV	MV	MV	
Western Redcedar	<i>Thuja plicata</i>	Plant	N	N	N/SI	N	SI	Inc	N	N	N/SI	N/SI	N	N	N	N/A	N	N	SI	N	Inc	N/A	N/A	U	U	HV	EV	EV	EV	
Bog Cranberry	<i>Vaccinium oxycoccos</i>	Plant	N	N	SI	N	N	Inc	N	N	SI	N	N	SI	N	N/A	N	U	N	N	N	N/A	N/A	U	U	MV	HV	HV	EV	
Alaska Blueberry	<i>Vaccinium alaskaense</i>	Plant	N	N	SI	N	N	Inc	N	N	N	N	N	N	N/A	SI	N	U	N	N	N	U	U	SI	U	MV	HV	HV	EV	
Broadleaf Cattail	<i>Typha latifolia</i>	Plant	N	N	N	N	N	Inc	N	N	SI	N/SI	N	N	N/A	N	N	U	U	N	Inc	N/A	N/A	U	U	MV	EV	EV	EV	
Evergreen huckleberry	<i>Vaccinium ovatum</i>	Plant	N	N	SI	N	N	Inc	N	N	N	N	N	SI	N	N/A	SI	N	U	N	N	U	U	SI	N	U	MV	EV	EV	EV
Beaked Hazelnut	<i>Corylus comuta</i>	Plant	N	N	N/SI	N	N	Inc	N	N	N	SI	N	N	N/A	N	N	U	U	N	U	U	SI	U	U	MV	HV	HV	EV	
Bivalves	<i>Bivalvia</i>	Mollusc	GI	N	SI	N	N	U	U	U	N	N	N	N	N	N/A	N	U	U	N	U	U	N/A	U	U					



## Appendix 2

### Information Gaps for Assessed Species

#### Information Status:

(1) **Information Available:** 

(2) **Non-applicable:** 

(3) **Unknown:** 

*Information Available* indicates sufficient data to evaluate a species for a CCVI factor; *Non-Applicable* indicates a CCVI factor that is non-applicable for a given species (e.g., “number of pollinators” for a mammal). *Unknown* indicates an information gap.



**Table A2-1.** Information gaps for species assessed in this assessment. Green=information available for this sensitivity factor, Orange=sensitivity factor is not applicable for the species, Gray=Sensitivity factors that are currently unknown.

English Name	Species	Taxonomic Group	Sea level rise	Natl barriers	Anth barriers	CC mitigation	Dispersal/Movement	Hist. thermal niche	Physiol. thermal niche	Hist. hydrol. niche	Physiol. hydrol. niche	Disturbance	Ice/snow	Phys habitat	Other spp for habitat	Diet	Pollinators	Other spp. dispersal	Pathogens/enemies	Competition	Other spp interaction	Genetic variation	Gen bottleneck	Reproductive system	Phenol response	Doc response
			B1	B2a	B2b	B3	C1	C2ai	C2aii	C2bi	C2bii	C2c	C2d	C3	C4a	C4b	C4c	C4d	C4e	C5a	C5b	C6	D1	D2	D3	D4
American pika	<i>Ochotona princeps</i>	Mammal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Black-tailed deer	<i>Odocoileus hemionus</i>	Mammal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Green	Green	Green	Green	Orange	Orange	Green	Green
Great blue heron	<i>Ardea herodias</i>	Bird	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Mountain goat	<i>Oreamnos americanus</i>	Mammal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Mountain lion	<i>Puma concolor</i>	Mammal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Trumpeter swan	<i>Cygnus buccinator</i>	Bird	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Green	Orange	Green	Green
Elk	<i>Cervus canadensis</i>	Mammal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Black Bear	<i>Ursus americanus</i>	Mammal	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Bufflehead	<i>Bucephala albeola</i>	Bird	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Alaska cedar	<i>Callitropsis nootkatensis</i>	Plant	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Green	Green	Green	Green	Gray	Green	Green	Green	Green
Northern pintail	<i>Anas acuta</i>	Bird	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Sooty Grouse	<i>Dendragapus fuliginosus</i>	Bird	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Western Redcedar	<i>Thuja plicata</i>	Plant	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Green	Green	Green	Green	Orange	Orange	Green	Green
Bog Cranberry	<i>Vaccinium oxycoccos</i>	Plant	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Alaska Blueberry	<i>Vaccinium alaskaense</i>	Plant	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Broadleaf Cattail	<i>Typha latifolia</i>	Plant	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Evergreen huckleberry	<i>Vaccinium ovatum</i>	Plant	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Beaked Hazelnut	<i>Corylus cornuta</i>	Plant	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green
Bivalves	<i>Bivalvia</i>	Mollusc	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Green	Orange	Green	Gray	Gray	Green	Green	Orange	Orange	Green	Green



## Appendix 3

### Species and Habitats Fact Sheets

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Black bear	Pg. 53
Bufflehead	Pg. 55
Alaska cedar	Pg. 57
Northern pintail	Pg. 69
Sooty grouse	Pg. 61
Western redcedar	Pg. 63
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Alaska blueberry	Pg. 67
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## **American pika (*Ochotona princeps*)**

**2050s, Low Greenhouse Gas Scenario (RCP 4.5):** Extremely Vulnerable

**2050s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

**2080s, Low Greenhouse Gas Scenario (RCP 4.5):** Extremely Vulnerable

**2080s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

### **Sea Level Rise | Neutral**

The American pika does not inhabit coastal regions and is thus unlikely to be affected by sea level rise.

### **Natural Barriers | Increase Vulnerability**

Non-mountainous areas have been identified as natural dispersal barriers for the American pika.<sup>16</sup> More than 50% of the pika's current distribution in the Nooksack watershed is surrounded by low-elevation forest, which may serve as a dispersal barrier.<sup>17</sup> Natural barriers may decrease the ability of the American pika to adjust its range, both altitudinally and latitudinally, in response to changing climate conditions.

### **Anthropogenic Barriers | Neutral/Somewhat Increase Vulnerability**

While roads have been shown to negatively affect American pika habitat,<sup>18</sup> road density in pika habitat within the Nooksack watershed is noted as being relatively low; most suitable habitat is in areas designated as wilderness. However, where roads do exist, these barriers to migration may limit the pika's ability to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are not likely to affect American pika habitat, which include high elevation rocky, talus slopes and lower elevation grasslands.<sup>19</sup>

### **Dispersal and Movement Ability | Somewhat Increase Vulnerability**

American pika have small home ranges (reported home ranges span 0.3 - 0.5 hectares), and are not local or long-distance migrants. The American pika's poor dispersal ability decreases the likelihood that the species will be able to adjust its range to keep pace with shifting climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Greatly Increase Vulnerability**

The American pika is extremely sensitive to warm temperatures. Projected increases in air temperature are likely to negatively affect the American pika, which is dependent on cool temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral**

The American pika is not dependent on a specific hydrologic niche. It is unlikely that climate change will alter the hydrologic suitability of American pika habitat.

### **Dependence on Disturbance Events | Neutral**

Fire is considered an important disturbance event for maintaining meadow habitats by limiting tree encroachment.<sup>18</sup> Projected increases in annual area burned<sup>20</sup> are thus unlikely to negatively affect the pika.





### **Dependence on Ice or Snow | Somewhat Increase Vulnerability**

Extended snow cover (e.g., longer than two weeks) may increase the likelihood of pika occupancy within otherwise suitable habitat.<sup>18</sup> Projected declines in winter snowpack<sup>14</sup> may thus negatively affect American pika habitat.

### **Physical Habitat Features | Somewhat Increase Vulnerability**

The American pika exclusively inhabits rocky talus slopes between the talus-meadow interface.<sup>19</sup> Its association with a specific geologic feature is expected to limit the pika's ability to adapt to habitat loss from climate change.

### **Dependence on Other Species for Habitat | Neutral**

The American pika is not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

### **Dietary Versatility | Neutral**

The American pika is an herbivore with a diet largely consisting of grasses, forbes, sedges, and occasionally woody vegetation.<sup>19</sup> Species that can readily switch between different food sources are less likely to be negatively affected by climate change.

### **Pollinators | N/A**

### **Other Species for Propagule Dispersal | Neutral**

American pika are not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

### **Sensitivity to Pathogens/Natural Enemies | Unknown**

Coyotes, weasels, martens, raptors, and corvids are all predators of the American pika. It is unknown whether some of these species will fare better than the American pika under a changing climate.

### **Competition from Natives or Non-Natives | Unknown**

The American pika and livestock will occasionally forage for similar vegetation, depending on location.<sup>18</sup> It is unknown whether livestock will fare better than the American pika under climate change.

### **Forms Part of an Interspecific Interaction | Neutral**

The American pika is not dependent on interspecific interactions. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

### **Genetic Variation | Somewhat Increase Vulnerability**

American pika have been observed to have low levels of genetic diversity in populations at the northern end of its range. Species with low levels of genetic variation are expected to be less able to adapt to changing climatic conditions.

### **Phenology | Neutral**

Pika habitat in the Nooksack watershed has been becoming snow free earlier in the year over the past five to six years, and pika vocalizations have been observed earlier in years with earlier snow melt.<sup>17</sup>



## **Black-Tailed Deer/Mule Deer (*Odocoileus hemionus*)**

**2050s, Low Greenhouse Gas Scenario (RCP 4.5):** Moderately Vulnerable

**2050s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

**2080s, Low Greenhouse Gas Scenario (RCP 4.5):** Extremely Vulnerable

**2080s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the mule deer's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Somewhat Increase Vulnerability**

While mule deer are good dispersers, rugged mountain terrain can act as barriers to movement.<sup>21</sup> In addition, post-fire deadfall accumulation can impede dispersal.<sup>22</sup> Natural barriers may decrease the ability of the mule deer to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Somewhat Increase Vulnerability**

Fences are a major barrier to mule deer movement in the western U.S. Urban, suburban, or rural housing developments can also obstruct mule deer movement.<sup>23</sup> These dispersal barriers may limit the mule deer's ability to adjust its range response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect mule deer habitat within the assessment area.

### **Dispersal and Movement Ability | Neutral**

Mule deer have excellent dispersal abilities. Research suggests that longer mule deer dispersal events may be more common in patchy environments with greater distances between suitable habitat areas.<sup>24</sup> The mule deer's high dispersal capacity increases the likelihood that it will be able to adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

Mule deer distribution is not significantly affected by thermal characteristics of the environment in the assessment area.<sup>24</sup> Mule deer are a wide-ranging species that inhabit areas with varying temperature regimes.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral**

Mule deer are not dependent on a specific hydrologic niche. It is unlikely that climate change will alter the hydrologic suitability of mule deer habitat.

### **Dependence on Disturbance Events | Neutral**

Mule deer are known to graze on early successional vegetation that re-colonizes after disturbance events.<sup>22</sup> Mule deer are also associated with fire-dependent and fire-adapted plant species and communities. Projected increases in annual area burned<sup>20</sup> are thus unlikely to negatively affect mule deer habitat.



**Dependence on Ice or Snow | Neutral**

The mule deer is not dependent on ice or snow associated habitats. Therefore, projected declines in winter snowpack are unlikely to negatively affect mule deer.

**Physical Habitat Features | Neutral**

Mule deer habitat is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the mule deer's ability to adapt to habitat loss from climate change.

**Dependence on Other Species for Habitat | Neutral**

The mule deer is a habitat generalist and does not depend on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

**Dietary Versatility | Neutral**

Mule deer consume a wide variety of grasses, forbs, and browse. Species that can readily switch between different food sources are less likely to be negatively affected by climate change.

**Pollinators | N/A****Other Species for Propagule Dispersal | Neutral**

Mule deer are not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

**Sensitivity to Pathogens/Natural Enemies | Somewhat Increase Vulnerability**

There are many bacterial diseases and parasites that negatively affect mule deer, some of which may become more prevalent or severe under climate change. For example, increasing incidence of drought and warming temperatures may benefit biting gnat populations, which transmit blue tongue virus to mule deer. Sensitivity to pathogens may thus increase mule deer's vulnerability to climate change.

**Competition from Natives or Non-Natives | Somewhat Increase Vulnerability**

Mule deer habitat use may be indirectly affected by other wildlife species that may benefit from climate change. For example, mule deer habitat selection has been shown to be strongly influenced by avoidance of areas inhabited by elk. Elk can eat a greater variety of forage than mule deer, which may give elk a competitive advantage under climate change.

**Forms Part of an Interspecific Interaction | Neutral**

The mule deer is not dependent on interspecific interactions. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

**Genetic Variation | Neutral**

Mule deer have been shown to have high levels of genetic diversity throughout its range. Species with average to high levels of genetic variation are expected to be better able to adapt to changing climatic conditions.

**Phenological Response | Unknown**

## Great Blue Heron (*Ardea herodias*)

**2050s, Low Greenhouse Gas Scenario (RCP 4.5):** Moderately Vulnerable

**2050s, High Greenhouse Gas Scenario (RCP 8.5):** Highly Vulnerable

**2080s, Low Greenhouse Gas Scenario (RCP 4.5):** Highly Vulnerable

**2080s, High Greenhouse Gas Scenario (RCP 8.5):** Highly Vulnerable

### Sea Level Rise | Neutral

Less than 10% of the great blue heron's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### Natural Barriers | Neutral

There are no significant natural barriers to great blue heron migration. It is unlikely that natural barriers will decrease the ability of the great blue heron to adjust its range in response to changing climate conditions.

### Anthropogenic Barriers | Neutral

There are no significant anthropogenic barriers to great blue heron migration. It is unlikely that anthropogenic barriers will decrease the ability of the great blue heron to adjust its range in response to changing climate conditions.

### Climate Change Mitigation Actions | Neutral

Climate change mitigation actions are not likely to affect great blue heron habitat, which include freshwater wet meadows and marshes, brackish marshes, lakes, and rivers.<sup>25</sup>

### Dispersal and Movement Ability | Neutral

The great blue heron is a local migrant.<sup>25</sup> The great blue heron's excellent dispersal ability increases the likelihood that it will be able to adjust its range in response to changing climate conditions.

### Historical Thermal Niche | Increase Vulnerability

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### Physiological Thermal Niche | Neutral

Great blue herons are adapted to a wide range of temperature regimes and are therefore unlikely to be directly negatively affected by warming temperatures.

### Historical Hydrologic Niche | Neutral

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### Physiological Hydrologic Niche | Increase Vulnerability

The great blue heron inhabits coastal lowlands, wetlands, marshes, wet meadows, vernal pools, stream channels (natural, irrigation, and drainage channels), and springs.<sup>17,26</sup> Each of these habitats may be affected by projected increases in winter flood risk and declines in summer low flows. The great blue heron is also expected to be negatively affected if wetlands dry out in summer months, diminishing its prey base.<sup>17</sup>

### Dependence on Disturbance Events | Neutral

The great blue heron is not thought to be sensitive to disturbance regimes that may be altered by climate change.

### Dependence on Ice or Snow | Neutral



The great blue heron is not dependent on ice or snow associated habitats. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect great blue heron habitat.

#### **Physical Habitat Features | Neutral**

Great blue heron habitat (e.g., freshwater and brackish marshes, lakes, and rivers) is not restricted to uncommon geological features.<sup>25</sup> Association with a specific geologic feature is thus not expected to limit the great blue heron's ability to adapt to habitat loss from climate change.

#### **Dependence on Other Species for Habitat | Neutral**

The great blue heron is an aquatic habitat generalist, and is not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

#### **Dietary Versatility | Neutral**

The great blue heron has a broad diet, including fish, insects, crustaceans, amphibians, reptiles, and small mammals.<sup>25</sup> Species that can readily switch between different food sources are less likely to be negatively affected by climate change

#### **Pollinators | N/A**

#### **Other Species for Propagule Dispersal | Neutral**

The great blue heron is not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

#### **Sensitivity to Pathogens/Natural Enemies | Unknown**

Bald eagles are the primary predator of the great blue heron. Crows and ravens have also been observed preying upon great blue heron eggs and hatchlings.<sup>27</sup> It is unknown if bald eagles, crows, or ravens will fare better than the great blue heron under a changing climate.

#### **Competition from Natives or Non-Natives | Unknown**

Double-crested cormorants and other herons compete with the great blue heron for limited nesting habitat.<sup>27</sup> It is unknown how these species will fare under climate change.

#### **Forms Part of an Interspecific Interaction | Neutral**

The great blue heron is not dependent on interspecific interactions. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

#### **Genetic Variation | Neutral**

It is estimated that dispersal among the four, large great blue heron colonies in Puget Sound contributes to the relatively high level of genetic diversity within the region's heron populations.<sup>28</sup> Species with average to high levels of genetic variation are expected to be better able to adapt to changing climatic conditions.

#### **Phenological Response | Unknown**



## **Mountain goat (*Oreamnos americanus*)**

**2050s, Low Greenhouse Gas Scenario (RCP 4.5):** Extremely Vulnerable

**2050s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

**2080s, Low Greenhouse Gas Scenario (RCP 4.5):** Extremely Vulnerable

**2080s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the mountain goat's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Somewhat Increase Vulnerability**

The mountain goat is a capable disperser but very high and very low elevations as well as bodies of water serve as barriers to movement.<sup>29</sup> Natural barriers may decrease the ability of the mountain goat to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Somewhat Increase Vulnerability**

While highways, urban areas, and agricultural fields have been identified as anthropogenic barriers to mountain goat dispersal,<sup>29</sup> such barriers are rare in and near mountain goat habitat within the Nooksack watershed. Additionally, the majority of mountain goat habitat in the Nooksack watershed is designated as wilderness, and is therefore unlikely to see future road and/or trail construction.<sup>17</sup> However, even at low densities, the presence of such barriers may limit the ability of the mountain goat to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

The mountain goat inhabits alpine and subalpine habitats. These habitat types are not likely to be used for climate change mitigation actions within the assessment area.

### **Dispersal and Movement Ability | Neutral**

In some areas, mountain goats will travel between summer and winter ranges. Mountain goats may also travel to salt licks during the summer months.<sup>30</sup> The good dispersal ability of the mountain goat increases the likelihood that it will be able to adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Somewhat Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Greatly Increase Vulnerability**

The mountain goat is adapted to cold alpine and subalpine habitats,<sup>31</sup> which are sensitive to climate change.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral**

Mountain goats are not dependent on a specific hydrologic niche. It is unlikely that climate change will alter the hydrologic suitability of mountain goat habitat.

### **Dependence on Disturbance Events | Neutral/Somewhat Increase**

Fire, windthrow, pests and disease can all negatively affect subalpine mountain goat habitat. Climate change is projected to increase the frequency and intensity of fire in western Washington.<sup>20</sup> In addition, warmer





and drier summers will stress forests, which may increase the susceptibility of forests to pests and disease. However, the winter range of the mountain goat within the Nooksack watershed is largely dominated by barren south facing, low elevation slopes.<sup>17</sup> It is thus possible that winter mountain goat habitat may initially maintain or expand due to projected increases in annual area burned.<sup>17</sup>

#### **Dependence on Ice or Snow | Neutral/ Somewhat Increase Vulnerability**

Mountain goats are often associated with snow in subalpine and alpine habitats during the winter months. Deep snowpack can impede mountain goat movement, but is also an important source of summer moisture for supporting vegetation for forage. While projected declines in snowpack may enhance mountain goat movement during winter, subsequent reductions in summer water availability may negatively affect mountain goat habitat. In addition, projected declines in snowpack may promote forest encroachment into subalpine and alpine zones, reducing mountain goat habitat.<sup>17</sup>

#### **Physical Habitat Features | Somewhat Increase Vulnerability**

The mountain goat inhabits open subalpine and alpine areas with close proximity to escape terrain (e.g., steep, rocky ledges and cliffs).<sup>31</sup> Because mountain goats are associated with steep rocky outcroppings and cliffs, they are less likely to be able to adapt to habitat loss from climate change, compared to species that are not dependent on uncommon geologic features.

#### **Dependence on Other Species for Habitat | Neutral**

Mountain goats are not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

#### **Dietary Versatility | Neutral**

The mountain goat has a generalist diet, largely composed of grasses, and shrubs.<sup>31</sup> Species that can readily switch among available food sources are less likely to be negatively affected by climate change.

#### **Pollinators | N/A**

#### **Other Species for Propagule Dispersal | Neutral**

Mountain goats are not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

#### **Sensitivity to Pathogens/Natural Enemies | Unknown**

Mountain goats are frequently infested by ticks, tapeworms, and nematodes.<sup>31</sup> While these parasites are ubiquitous in mountain goat populations, it is unknown if these infestations negatively affect population dynamics and or if these parasites will be affected by climate change.

#### **Competition from Natives or Non-Natives | Unknown**

Mountain goats and bighorn sheep occupy similar habitats, principally subalpine and alpine regions. They also have relatively similar diets composed of grasses, forbs, and shrubs.<sup>32</sup> However, it is unknown how bighorn sheep populations will be affected by climate change.

#### **Forms Part of an Interspecific Interaction | Neutral**

The mountain goat does not require interspecific interactions. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

#### **Genetic Variation | Increase Vulnerability**

Low genetic variation has been observed in mountain goat populations inhabiting the Cascade Range in Washington.<sup>33</sup> Species with low levels of genetic variation are expected to be less able to adapt to changing climate conditions than populations with average to high levels of genetic diversity.

#### **Phenological Response | Unknown**



## **Mountain Lion (*Puma concolor*)**

**2050s, Low Greenhouse Gas Scenario (RCP 4.5):** Less Vulnerable

**2050s, High Greenhouse Gas Scenario (RCP 8.5):** Moderately Vulnerable

**2080s, Low Greenhouse Gas Scenario (RCP 4.5):** Moderately Vulnerable

**2080s, High Greenhouse Gas Scenario (RCP 8.5):** Moderately Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the mountain lion's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Neutral**

Mountain lions are capable dispersers but large expanses of non-forested habitat may act as dispersal barriers. Narrow riparian corridors may allow dispersal through otherwise non-forested habitat.<sup>34</sup> It is unlikely that natural barriers will decrease the ability of the mountain lion to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Somewhat Increase Vulnerability**

Major highways as well as urban, agricultural, and industrial areas have all been identified as anthropogenic barriers to mountain lion dispersal.<sup>34</sup> These barriers may limit the ability of the mountain lion to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Mountain lions have the widest distribution of any native mammal in the western hemisphere, and inhabit a wide range of habitat types.<sup>35</sup> These habitat types are not likely to be used for climate change mitigation actions within the assessment area.

### **Dispersal and Movement Ability | Neutral**

Mountain lions are a wide-ranging species capable of long distance dispersal (the largest documented movements have exceeded 2000 km).<sup>34</sup> The excellent dispersal abilities of the mountain lion increase the likelihood that it will be able to adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

Mountain lions are adapted to a wide range of temperature regimes and are therefore unlikely to be directly negatively affected by warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral**

Mountain lions are adapted to habitats that span a wide range of hydrologic niches. It is unlikely that shifting precipitation regimes under climate change will alter the suitability of mountain lion habitat.

### **Dependence on Disturbance Events | Neutral**

Mountain lions are not thought to be sensitive to disturbance regimes that may be altered by climate change.



### **Dependence on Ice or Snow | Neutral**

Mountain lion habitat suitability is not dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect the mountain lion.

### **Physical Habitat Features | Neutral**

Mountain lion habitat is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the mountain lion's ability to adapt to habitat loss from climate change.

### **Dependence on Other Species for Habitat | Neutral**

Mountain lions are habitat generalists, and are not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

### **Dietary Versatility | Neutral**

The diet of mountain lions is primarily deer, but this species is highly opportunistic and eats various large and small mammals, including bighorn sheep, livestock, coyote, squirrels, rabbits, and mice.<sup>36</sup> Species that can readily switch among different food types are less likely to be negatively affected by climate change.

### **Pollinators | N/A**

### **Other Species for Propagule Dispersal | Neutral**

Mountain lions are not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

### **Sensitivity to Pathogens/Natural Enemies | Unknown**

While mountain lions are susceptible to some diseases, it is unclear whether the intensity, rate of transmission, and severity of these diseases will be affected by climate change.

### **Competition from Natives or Non-Natives | Neutral**

The mountain lion is not currently sensitive to competition from native or non-native species, and there is no indication that climate change will cause a species to become a competitor in the future.

### **Forms Part of an Interspecific Interaction | Neutral**

The mountain lion does not require interspecific interactions. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

### **Genetic Variation | Neutral**

In western North America, genetic variation of mountain lion populations is frequently observed to be high, due to large, stable populations and high rates of dispersal.<sup>37</sup> Species with average to high levels of genetic variation are expected to be better able to adapt to changing climate conditions.

### **Phenological Response | Unknown**



## **Trumpeter swan (*Cygnus buccinators*)**

**2050s, Low Greenhouse Gas Scenario (RCP 4.5):** Highly Vulnerable

**2050s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

**2080s, Low Greenhouse Gas Scenario (RCP 4.5):** Extremely Vulnerable

**2080s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the trumpeter's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Neutral**

There are no significant natural barriers to trumpeter swan migration. It is unlikely that natural barriers will decrease the ability of the trumpeter swan to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Neutral**

There are no significant anthropogenic barriers to trumpeter swan migration. It is unlikely that anthropogenic barriers will decrease the ability of the trumpeter swan to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect trumpeter swan habitat, which includes agricultural fields, wet meadows, shallow marshes and lakes, and river oxbows.<sup>17,38</sup>

### **Dispersal and Movement Ability | Neutral**

The trumpeter swan is an excellent disperser, capable of long-distance migration.<sup>39</sup> Its excellent dispersal ability increases the likelihood that it will be able to adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

Trumpeter swans are adapted to a broad range of temperature regimes and are therefore unlikely to be directly negatively affected by warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Increase Vulnerability**

Juvenile swan survival is tightly linked with stable water levels at nesting sites.<sup>38</sup> Projected increases in winter flood risk in western Washington<sup>14</sup> may negatively affect nesting habitat and fledgling survival.

### **Dependence on Disturbance Events | Neutral**

Trumpeter swans are not thought to be sensitive to disturbance regimes that may be altered by climate change. An exception to this is flooding, which is captured under Physiological Hydrologic Niche.



### **Dependence on Ice or Snow | Neutral**

Trumpeter swan habitat suitability is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect trumpeter swan habitat.

### **Physical Habitat Features | Neutral**

Trumpeter swan habitat is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the trumpeter swan's ability to adapt to habitat loss from climate change.

### **Dependence on Other Species for Habitat | Neutral/Somewhat Increase Vulnerability**

Preferred trumpeter swan nesting and loafing sites often include muskrat houses or beaver dams. However, swans may also construct nests on small natural islands.<sup>38</sup> Species that rely on a small number of species for habitat or nesting sites are likely to be more vulnerable to climate change than species with more generalized habitat requirements.<sup>1</sup>

### **Dietary Versatility | Neutral**

Trumpeter swans have a broad diet including roots and leaves of aquatic vegetation, water milfoil, waterweed, and yellow pond lily seeds.<sup>38</sup> Species that can readily switch between different food sources are less likely to be negatively affected by climate change.

### **Pollinators | N/A**

### **Other Species for Propagule Dispersal | Neutral**

Trumpeter swans are not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

### **Sensitivity to Pathogens/Natural Enemies | Unknown**

Predators are not a major concern for the trumpeter swan, but may increase mortality rates of juvenile swans.<sup>38</sup> River otters, coyotes, minks, and golden eagles have all been observed preying upon young swans. It is unknown if these predators will fare better than the trumpeter swan under a changing climate.

### **Competition from Natives or Non-Natives | Unknown**

There is currently no empirical evidence indicating that trumpeter swans compete with other species, though they are frequently observed foraging alongside other waterbirds, including the northern pintail, goldeneye, and mallard.

### **Forms Part of an Interspecific Interaction | Unknown**

The trumpeter swan does not require a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

### **Genetic Variation | Unknown**

Unknown

### **Genetic Bottleneck | Increase Vulnerability**

The trumpeter swan underwent a population bottleneck in the early part of the 20th century. By the year 1932, the largest known population of trumpeter swans consisted of 57 swans found within Yellowstone National Park.<sup>40</sup> Evidence of genetic bottlenecks can be used to infer reductions in species-level genetic variation that could potentially impede a species' ability to adapt to climate change.

### **Phenological Response | Unknown**



## **Elk (*Cervus canadensis*)**

**2050s, Low Greenhouse Gas Scenario (RCP 4.5):** Highly Vulnerable

**2050s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

**2080s, Low Greenhouse Gas Scenario (RCP 4.5):** Extremely Vulnerable

**2080s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the elk's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Somewhat Increase Vulnerability**

While elk are capable dispersers, high terraces, steep terrain, and gullies can act as natural dispersal barriers.<sup>41</sup> Presence of natural barriers may decrease the ability of elk to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Increase Vulnerability**

Human disturbances, including road construction and logging, can serve as anthropogenic barriers to elk dispersal.<sup>41</sup> A significant percentage of elk habitat in the Nooksack watershed is located in active forest areas.<sup>17</sup> These barriers may limit the ability of the elk to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Elk are habitat generalists, occurring across numerous habitats.<sup>41</sup> It is currently unknown if climate change mitigation activities will negatively affect elk populations within the Nooksack watershed.

### **Dispersal and Movement Ability | Neutral**

Elk are very capable dispersers and are estimated to disperse 25-50 km.<sup>42</sup> The species' excellent dispersal abilities increase the likelihood that the elk will be able to adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

Elk are a widely-distributed species, implying broad tolerance for various temperature regimes.<sup>41</sup> Therefore, the elk is less likely to be negatively affected by warming temperatures, compared to species restricted to cold climates.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral/Somewhat Increase Vulnerability**

Elk are often associated with wetland habitats within the Nooksack watershed (Nooksack Tribe staff, personal communication).<sup>17</sup> It is therefore expected to be sensitive to projected declines in moisture availability, which may increase its vulnerability to climate change.

### **Dependence on Disturbance Events | Neutral**

Elk are considered a disturbance tolerant species, often inhabiting sites disturbed by logging and fire, as well as other early-successional habitats.<sup>41</sup> The elk is also considered to be fire-dependent or fire-adapted to some extent, due to their positive response to food availability following wildfire. Projected increases in annual area burned<sup>20</sup> are thus unlikely to negatively affect elk.





**Dependence on Ice or Snow | Neutral**

Elk habitat suitability is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect elk habitat.

**Physical Habitat Features | Neutral**

Elk habitat is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the elk's ability to adapt to habitat loss from climate change.

**Dependence on Other Species for Habitat | Neutral**

The elk is a forest habitat generalist, and is not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

**Dietary Versatility | Neutral**

Elk have a very broad diet, consuming forbs, willow, aspen, cottonwood, grasses, and mushrooms.<sup>43</sup> Species that can readily switch between different food sources are less likely to be negatively affected by climate change.

**Pollinators | N/A****Other Species for Propagule Dispersal | Neutral**

Elk are not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

**Sensitivity to Pathogens/Natural Enemies | Unknown**

Gray wolves and mountain lions are noted as predators of elk.<sup>17,41</sup> It is unknown if elk will fare better than wolves or mountain lions under a changing climate.

**Competition from Natives or Non-Natives | Unknown**

Elk compete with livestock when forage availability is limited. It is unknown whether elk or livestock will fare better under climate change.

**Forms Part of an Interspecific Interaction | Neutral**

Elk do not require a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

**Genetic Variation | Neutral**

Elk have been shown to have relatively high levels of genetic variation.<sup>44</sup> Species with average to high levels of genetic diversity are expected to be better able to adapt to changing climate conditions.

**Phenological Response | Unknown**

## **Black Bear (*Ursus americanus*)**

**2050s, Low Greenhouse Gas Scenario (RCP 4.5):** Moderately Vulnerable

**2050s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

**2080s, Low Greenhouse Gas Scenario (RCP 4.5):** Extremely Vulnerable

**2080s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the black bear's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Somewhat Increase Vulnerability**

While black bears are capable dispersers, dry low-elevation habitat types and rivers may act as natural barriers to bear dispersal.<sup>29</sup> Natural barriers may decrease the ability of the black bear to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Increase Vulnerability**

Highways, roads, and urban areas have been identified as anthropogenic barriers to black bear dispersal.<sup>29,45</sup> Human population growth and expanded development will likely increase the number of anthropogenic barriers encountered by black bears. These barriers may limit the ability of the black bear to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect black bear habitat, which includes forest, wet meadows, riparian areas, and edge habitat.<sup>45</sup>

### **Dispersal and Movement Ability | Neutral**

Black bears are extremely capable dispersers. Natal dispersal of sub-adult male black bears has been documented to range 8-136 miles. The black bear's excellent dispersal abilities increase the likelihood that it will be able to adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

Black bears are adapted to a broad range of temperature regimes and are therefore unlikely to be directly negatively affected by warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral**

Black bears are not dependent on a specific hydrologic niche. It is unlikely that climate change will alter the hydrologic suitability of black bear habitat.

### **Dependence on Disturbance Events | Neutral/Somewhat Increase Vulnerability**

Climate change may affect the quality of black bear habitat by increasing both the frequency and intensity of wildfire. While increases in annual area burned may initially facilitate berry establishment, increasing black bear



forage, longer-term increases in area burn are likely to reduce suitable black bear habitat (Nooksack Tribe staff, personal communication).<sup>17</sup>

### **Dependence on Ice or Snow | Neutral**

Black bear habitat suitability is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect black bear habitat.

### **Physical Habitat Features | Neutral**

Black bear habitat is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the black bear's ability to adapt to habitat loss from climate change.

### **Dependence on Other Species for Habitat | Neutral**

Black bears are a forest habitat generalist and not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

### **Dietary Versatility | Neutral**

Black bears are opportunistic omnivores, generally consuming grasses and forbs in spring, berries and insects in summer, and acorns and nuts during fall. The species also eats carrion.<sup>45</sup> Species that can readily switch between different food sources are less likely to be negatively affected by climate change.

### **Pollinators | N/A**

### **Other Species for Propagule Dispersal | Neutral**

Black bears are not dependent on other species for propagule dispersal. This reduces the vulnerability of the black bear to climate change as they are not dependent on another species, which may be vulnerable to climate change, to ensure the next generation survives.

### **Sensitivity to Pathogens/Natural Enemies | Unknown**

Grizzly bears, mountain lions, and gray wolves are all predators of the black bear.<sup>45</sup> It is unknown if these predators will fare better than the black bear under a changing climate. While black bears are also susceptible to diseases, it is unknown how their virulence and spread will be affected by climate change.

### **Competition from Natives or Non-Natives | Neutral**

The black bear is not currently sensitive to competition from native or non-native species, and there is no indication that climate change will cause a species to become a competitor in the future.

### **Forms Part of an Interspecific Interaction | Neutral**

The black bear does not require a specific interspecific interaction. Because responses to climate change will be species-specific, those dependent on other species may be more vulnerable to climate change than species without interspecific interactions.

### **Genetic Variation | Neutral**

Black bears in Alberta have been shown to have relatively high levels of genetic diversity.<sup>46</sup> Species with average to high levels of genetic diversity are expected to be better able to adapt to changing climate conditions.

### **Phenological Response | Unknown**



## **Bufflehead (*Bucephala albeola*)**

**2050s, Low Greenhouse Gas Scenario (RCP 4.5):** Moderately Vulnerable

**2050s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

**2080s, Low Greenhouse Gas Scenario (RCP 4.5):** Extremely Vulnerable

**2080s, High Greenhouse Gas Scenario (RCP 8.5):** Extremely Vulnerable

### **Sea Level Rise | Somewhat Increase Vulnerability**

Washington is part of the bufflehead's winter range, which consists primarily of saltwater areas (beaches, estuaries, and harbors).<sup>47</sup> Bufflehead within the Nooksack watershed are thus likely to be affected by sea level rise.

### **Natural Barriers | Neutral**

There are no significant natural barriers to bufflehead dispersal. It is unlikely that natural barriers will decrease the ability of the bufflehead to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Neutral**

There are no significant anthropogenic barriers to bufflehead migration. It is unlikely that anthropogenic barriers will decrease the ability of the bufflehead to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect bufflehead habitat, which includes freshwater permanent ponds in its breeding range, and sheltered saltwater coves and estuaries within its winter range.<sup>47</sup>

### **Dispersal and Movement Ability | Neutral**

Buffleheads are excellent dispersers, capable of long-distance migration.<sup>47</sup> The bufflehead's excellent dispersal ability increases the likelihood that it will be able to adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

Bufflehead are adapted to a broad range of temperature regimes and is therefore unlikely to be negatively affected directly by warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Somewhat Increase Vulnerability**

Buffleheads are dependent on small permanent ponds in its breeding range.<sup>47</sup> These habitats may be sensitive to projected increases winter flood risk and declining summer low-flows.<sup>14</sup>

### **Dependence on Disturbance Events | Neutral**

The bufflehead is not thought to be sensitive to disturbance regimes that may be altered by climate change. An exception to this is flooding, which is discussed under Physiological Hydrologic Niche.

### **Dependence on Ice or Snow | Neutral**

Bufflehead habitat suitability is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect bufflehead habitat.



### **Physical Habitat Features | Neutral**

Bufflehead habitat is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the bufflehead's ability to adapt to habitat loss from climate change.

### **Dependence on Other Species for Habitat | Increase Vulnerability**

The bufflehead nests exclusively in tree cavities constructed by the northern flicker, and less frequently by the pileated woodpecker.<sup>47</sup> Species that rely on a small number of species for habitat or nesting sites are likely to be more vulnerable to climate change than species that have more generalized habitat requirements.

### **Dietary Versatility | Neutral**

The diet of the bufflehead varies seasonally and by the habitat type occupied (freshwater versus saltwater). Buffleheads are diving ducks that consume insects, crustaceans, mollusks, and plants.<sup>47</sup> Species that can readily switch between different food sources are less likely to be negatively affected by climate change.

### **Pollinators | N/A**

### **Other Species for Propagule Dispersal | Neutral**

Buffleheads are not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

### **Sensitivity to Pathogens/Natural Enemies | Unknown**

Peregrine falcon, snowy owl, bald eagle, Cooper's hawk, and the great horned owl are all predators of the bufflehead.<sup>47</sup> It is unknown if these predators will fare better than the bufflehead under a changing climate.

### **Competition from Natives or Non-Natives | Neutral**

The bufflehead is not currently sensitive to competition from native or non-native species, and there is no indication that climate change will cause a species to become a competitor in the future.

### **Forms Part of an Interspecific Interaction | Neutral**

The bufflehead does not require a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

### **Genetic Variation | Neutral**

The bufflehead has been shown to have relatively low levels of population differentiation compared to other cave-nesting sea-ducks.<sup>48</sup> Species with average to high levels of genetic diversity are expected to be better able to adapt to changing climate conditions.

### **Phenological Response | Unknown**



## **Alaska Cedar (*Callitropsis nootkatensis*)**

**2050s, Low GHG Scenario:** Extremely Vulnerable

**2050s, High GHG Scenario:** Extremely Vulnerable

**2080s, Low GHG Scenario:** Extremely Vulnerable

**2080s, High GHG Scenario:** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the Alaska cedar's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Neutral**

Alaska cedar seeds are dispersed by wind.<sup>49</sup> It is unlikely that natural barriers will decrease the ability of the Alaska cedar to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Somewhat Increase Vulnerability**

The region north of the Nooksack watershed is largely bordered by developed agricultural land, which may decrease the ability of the Alaska cedar to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to result in the removal of Alaska cedar from suitable habitat, which includes the Cascade Range.<sup>50</sup>

### **Dispersal and Movement Ability | Somewhat Increase Vulnerability**

Direct information on seed dispersal distance is not available for the Alaska cedar. However, it is noted that Alaska cedar seeds are heavier than Port-Orford-cedar seeds and are therefore unlikely to be dispersed more than 120 meters from the source.<sup>50</sup> The relatively poor dispersal abilities of Alaska cedar seeds may decrease the ability of the Alaska cedar to adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Somewhat Increase Vulnerability**

The Alaska cedar is restricted to relatively cool/cold regions within Washington's Cascade Range. The species is found between 600 - 2,300 m.<sup>49</sup> This dependence on cool, higher elevation habitats increases the species vulnerability to climate change, as these areas are thought to be more prone to habitat loss or reduction with warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Somewhat Increase Vulnerability**

The Alaska cedar is known to grow on bog and semi-bog.<sup>50</sup> Projected increases in temperatures and declines in summer precipitation<sup>14</sup> may reduce moisture availability in these habitats, potentially reducing the habitat suitability of some areas for the Alaska cedar.

### **Dependence on Disturbance Events | Neutral**

Alaska cedar is not reliant on a disturbance regimes that is projected to be altered by climate change.





### **Dependence on Ice or Snow | Increase Vulnerability**

Alaska cedar, also referred to as yellow-cedar, has experienced wide spread decline in Alaska and British Columbia. This widespread decline has not been linked with a biotic fungi, nematode, insect, or virus; and is therefore thought to be associated with an abiotic process. Specifically, declining snowpack is thought to expose the roots of the Alaska cedar to freezing damage during the winter months. Therefore, declining snowpack may negatively affect Alaska cedar.<sup>51</sup>

### **Physical Habitat Features | Neutral**

The Alaska cedar is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the Alaska cedar's ability to adapt to climate change.

### **Dependence on Other Species for Habitat | Neutral**

The Alaska cedar is not dependent on other species to generate habitat. Species that are not reliant on others to create habitat are more likely to adapt to shifting environmental conditions due to climate change.

### **Dietary Versatility | N/A**

### **Pollinators | Neutral**

Alaska cedar is wind pollinated. Species that are reliant on a limited number of pollinators are potentially more vulnerable to environmental changes resulting from climate change.

### **Other Species for Propagule Dispersal | Neutral**

Alaska cedar does not serve as a major form of browse for livestock or wildlife. It has been documented as a source of brose only when local densities of black-tailed deer in the region are high.<sup>49</sup> This reduces the vulnerability of Alaska cedar to climate change as they are not dependent on another species, which may be vulnerable to climate change, to ensure the next generation survives.

### **Sensitivity to Pathogens/Natural Enemies | Neutral/ Somewhat Increase Vulnerability**

Alaska cedar is susceptible to numerous insects, pathogens, and pests. It is challenging to make generalizations of the responses of diseases and pests to climate change because the responses will largely be species specific. Some diseases/pests may become more widespread while others may not.

### **Competition from Natives or Non-Natives | Neutral**

Alaska cedar generally is not damaged by insects. There are no known defoliators of this species currently.

### **Forms Part of an Interspecific Interaction | Neutral**

The Alaska cedar does not require interspecific interactions. Because responses to climate change will be species-specific, those dependent on other species may be more vulnerable to climate change than species without interspecific interactions.

### **Genetic Variation | Unknown**

### **Genetic Bottleneck | Unknown**

### **Reproductive System (plants only) | Neutral**

The Alaska cedar is monoecious and an outcrosser, reliant on wind for pollen dispersal.<sup>52</sup> In plants, genetic variation is linked to reproductive system. Species that are outcrossers may be more likely to adapt to changing climate conditions.<sup>1</sup>

### **Phenological Response | Unknown**



## **Northern Pintail (*Anas acuta*)**

**2050s, Low Greenhouse Gas Scenario:** Less Vulnerable

**2050s, High Greenhouse Gas Scenario:** Moderately Vulnerable

**2080s, Low Greenhouse Gas Scenario:** Moderately Vulnerable

**2080s, High Greenhouse Gas Scenario:** Moderately Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the northern pintail's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Neutral**

There are no significant natural barriers to northern pintail dispersal. It is unlikely that natural barriers will decrease the ability of the northern pintail to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Neutral**

There are no significant anthropogenic barriers to northern pintail migration. It is unlikely that anthropogenic barriers will decrease the ability of the northern pintail to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect northern pintail habitat, which includes freshwater seasonal, shallow wetland and shallow marshes.<sup>53</sup>

### **Dispersal and Movement Ability | Neutral**

Northern pintails are excellent dispersers, capable of long-distance migration.<sup>53</sup> Its excellent dispersal ability increases the likelihood that the northern pintail will be able to adjust its range with changing climate conditions.

### **Historical Thermal Niche | Somewhat Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

The northern pintail is adapted to a broad range of temperature regimes and is therefore unlikely to be directly negatively affected by warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Increase Vulnerability**

Northern pintails are dependent on small, shallow, semi-permanent wetlands and marshes.<sup>53</sup> These semi-permanent habitats may be susceptible to declining summer precipitation and increased risk of summer low flows.<sup>14</sup> These changes may increase the likelihood of premature drying of these wetlands and marshes, which would negatively affect the northern pintail.

### **Dependence on Disturbance Events | Neutral**

The northern pintail is not thought to be sensitive to disturbance regimes that may be altered by climate change. The one exception is drought and summer low flows, which are captured in the Physiological Hydrologic Niche factor.



### **Dependence on Ice or Snow | Neutral**

Northern pintail habitat suitability is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to negatively affect northern pintail habitat.

### **Physical Habitat Features | Neutral**

Northern pintail habitat is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the northern pintail's ability to adapt to climate change.

### **Dependence on Other Species for Habitat | Neutral**

The northern pintail is not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.<sup>1</sup>

### **Dietary Versatility | Neutral**

The northern pintail has a diverse diet consisting of insects, grains, grasses, aquatic vegetation, invertebrates, and seeds.<sup>53</sup> Species that can readily switch between different food sources are less likely to be negatively affected by climate change.

### **Pollinators | N/A**

### **Other Species for Propagule Dispersal | Neutral**

The northern pintail is not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

### **Sensitivity to Pathogens/Natural Enemies | Unknown**

The red fox, mink, Swainson's hawk, great horned owl, large raptors, and the coyote have all been documented as predators of adult pintails. Minks, raccoons, skinks, foxes, and several birds also prey upon northern pintail eggs.<sup>53</sup> It is unknown if these predators will fare better than the northern pintail under a changing climate.

### **Competition from Natives or Non-Natives | Neutral**

The northern pintail is not currently sensitive to competition from native or non-native species, and there is no indication that climate change will cause a species to become a competitor in the future.

### **Forms Part of an Interspecific Interaction | Neutral**

The northern pintail is not dependent on a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

### **Genetic Variation | Neutral**

Northern pintail have been observed to have little genetic structuring across three different wintering sites, indicating high levels of gene flow and average levels of genetic variation across the entire migrating population.<sup>54,55</sup> Species with average to high levels of genetic diversity are expected to be better able to adapt to changing climate conditions.

### **Phenological Response | Unknown**



## **Sooty Grouse (*Dendragapus fuliginosus*)**

**2050s, Low Greenhouse Gas Scenario:** Less Vulnerable

**2050s, High Greenhouse Gas Scenario:** Moderately Vulnerable

**2080s, Low Greenhouse Gas Scenario:** Moderately Vulnerable

**2080s, High Greenhouse Gas Scenario:** Moderately Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the sooty grouse's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones)

### **Natural Barriers | Neutral**

There are no significant natural barriers to sooty grouse dispersal. It is unlikely that natural barriers will decrease the ability of the sooty grouse to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Somewhat Increase Vulnerability**

Roads, urban areas, industrial areas, agricultural lands, and logging roads have all been identified as anthropogenic barriers to sooty grouse dispersal.<sup>17,56</sup> The sooty grouse may have difficulty flying over many of these barriers due to its limited dispersal abilities. These barriers may thus slightly decrease the ability of the sooty grouse to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect sooty grouse habitat, which includes open montane forest from sea level to the tree line in the subalpine/alpine zone.<sup>57</sup>

### **Dispersal and Movement Ability | Neutral**

The sooty grouse is a short-distance migrant, typically dispersing from low-elevation breeding areas to higher elevation forested habitat. Though its longest documented dispersal distance is 50 km, distances of ~8 km have been more commonly observed.<sup>57</sup> The dispersal abilities of the sooty grouse increase the likelihood that it will be able adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

Sooty grouse are exposed to both very warm and very cold temperatures, and are therefore unlikely to be negatively affected by warming temperatures, compared to species restricted to cool habitats.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral**

Sooty grouse are not dependent on a specific hydrological niche. It is unlikely that climate change will alter the hydrologic suitability of sooty grouse habitat.

### **Dependence on Disturbance Events | Neutral**

Windthrow, fire, and logging all create gaps in forest understory areas that are quickly inhabited by grouse.<sup>57</sup> Projected increases in area burned<sup>20</sup> may initially provide additional habitat for the sooty grouse, however, it is



unclear if increases in area burned will continue to be beneficial for grouse throughout the 21st century.

#### **Dependence on Ice or Snow | Neutral**

Sooty grouse habitat suitability is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect sooty grouse habitat.

#### **Physical Habitat Features | Neutral**

Sooty grouse habitat is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the sooty grouse's ability to adapt to climate change.

#### **Dependence on Other Species for Habitat | Neutral**

Sooty grouse are not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

#### **Dietary Versatility | Neutral**

Adult sooty grouse are reliant on a range of vegetative matter. Flowers, leaves, and berries are consumed in summer, and conifer needles and cones are consumed in the fall and winter.<sup>57</sup> Species that can readily switch between different food sources are less likely to be negatively affected by climate change.

#### **Pollinators | N/A**

#### **Other Species for Propagule Dispersal | Neutral**

The sooty grouse is not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

#### **Sensitivity to Pathogens/Natural Enemies | Unknown**

There are many diseases and parasites that can affect the fitness of the sooty grouse. Examples include fowl pox, avian malaria, and helminths.<sup>57</sup> It is unknown if these diseases and parasites will become more widespread or virulent with climate change.

#### **Competition from Natives or Non-Natives | Neutral**

The sooty grouse is not currently sensitive to competition from native or non-native species, and there is no indication that climate change will cause a species to become a competitor in the future.

#### **Forms Part of an Interspecific Interaction | Neutral**

The sooty grouse is not dependent on a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

#### **Genetic Variation | Neutral**

Genetic studies by the Washington Department of Fish and Wildlife have found relatively high genetic variation in sooty grouse populations.<sup>58</sup> Species with average to high levels of genetic diversity are expected to be better able to adapt to changing climate conditions.

#### **Phenological Response | Unknown**



## **Western Redcedar (*Thuja plicata*)**

**2050s, Low Greenhouse Gas Scenario:** Highly Vulnerable

**2050s, High Greenhouse Gas Scenario:** Extremely Vulnerable

**2080s, Low Greenhouse Gas Scenario:** Extremely Vulnerable

**2080s, High Greenhouse Gas Scenario:** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the western redcedar's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Neutral**

Western redcedar seeds are dispersed by wind.<sup>59</sup> It is unlikely that natural barriers will decrease the ability of the western redcedar to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Neutral/Somewhat Increase Vulnerability**

Alaska redcedar is a relatively hardy species, often found in the Nooksack watershed along the edges of agricultural fields and human modified sites.<sup>17</sup> Therefore, barriers presented by agriculture fields and developed areas within the Nooksack River watershed are unlikely to decrease the ability of the western redcedar to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect western redcedar habitat, which includes open forest from sea level to the tree line in the subalpine/alpine zone.<sup>59</sup>

### **Dispersal and Movement Ability | Somewhat Increase Vulnerability**

Western redcedar seeds are wind dispersed. However, the seed's small wings limit its dispersal distance to ~120 meters.<sup>59</sup> The relatively poor dispersal abilities of the western redcedar may decrease its ability to adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

The western redcedar is adapted to a broad range of temperature regimes and is therefore unlikely to be significantly negatively affected by warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral/Somewhat Increase Vulnerability**

The western redcedar frequently grows in wetland habitat (more than 50% of the time) within the Nooksack watershed.<sup>17</sup> Projected declines in moisture availability may result in declining moisture availability in these wetland habitats. Thus, climate-driven shifts in the hydrologic regime may negatively affect the western redcedar.

### **Dependence on Disturbance Events | Neutral/Somewhat Increase Vulnerability**

Western redcedars growing on wet sites are susceptible to windthrow, but climate models do not project a change in wind strength or speed in the Nooksack watershed. Western red cedar is also commonly killed by fire.<sup>59</sup> Annual



area burned is projected to increase with climate change,<sup>20</sup> which may negatively affect western redcedar.

#### **Dependence on Ice or Snow | Neutral**

The western redcedar is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect western redcedar.

#### **Physical Habitat Features | Neutral**

The western redcedar is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the western redcedar's ability to adapt to climate change.

#### **Dependence on Other Species for Habitat | Neutral**

The western redcedar is not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

#### **Dietary Versatility | N/A**

#### **Pollinators | Neutral**

The western redcedar is wind pollinated. Species that are reliant on a limited number of pollinators are potentially more vulnerable to environmental changes resulting from climate change.

#### **Other Species for Propagule Dispersal | Neutral**

Western redcedar is not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

#### **Sensitivity to Pathogens/Natural Enemies | Somewhat Increase Vulnerability**

The western redcedar is susceptible to numerous insects, pathogens, and pests. It is challenging to make generalizations of the responses of diseases and pests to climate change because the responses will largely be species specific. Some diseases/pests may become more widespread while others may not. For example, western redcedar is susceptible to armellaria root disease. If climate change results in a warmer and drier climate armellaria impact is projected to increase. Conversely, if climate change results in a warmer and wetter climate, the impact of armellaria is projected to remain the same.<sup>60</sup>

#### **Competition from Natives or Non-Natives | Neutral**

The western redcedar is not currently sensitive to competition from native or non-native species, and there is no indication that climate change will cause a species to become a competitor in the future.

#### **Forms Part of an Interspecific Interaction | Neutral**

The western redcedar is not dependent on a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

#### **Genetic Variation | Increase Vulnerability**

The western redcedar has one of the lowest levels of genetic diversity among conifers.<sup>61</sup> Species with low levels of genetic diversity are expected to be less able to adapt to changing climate conditions.

#### **Phenological Response | Unknown**





## **Bog Cranberry (*Vaccinium oxycoccos*)**

**2050s, Low Greenhouse Gas Scenario:** Moderately Vulnerable

**2050s, High Greenhouse Gas Scenario:** Highly Vulnerable

**2080s, Low Greenhouse Gas Scenario:** Highly Vulnerable

**2080s, High Greenhouse Gas Scenario:** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the bog cranberry's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Neutral**

Bog cranberry seeds are dispersed by numerous bird and mammal species.<sup>62</sup> Birds are able to fly over most natural barriers.

### **Anthropogenic Barriers | Somewhat Increase Vulnerability**

The region north of the Nooksack watershed is largely bordered by developed agricultural land, which may limit to ability of the bog cranberry to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect bog cranberry habitat, which includes freshwater bogs and fens.<sup>62</sup>

### **Dispersal and Movement Ability | Neutral**

Bog cranberry seeds are dispersed by numerous bird and mammal species.<sup>62</sup> Seeds are likely to be regurgitated or defecated at least 1km from the parent bog cranberry plant. A species that is able to disperse long distances is more likely to be able to adjust its range in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

Bog cranberry is adapted to a broad range of temperature regimes and is therefore unlikely to be significantly negatively affected by warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Somewhat Increase Vulnerability**

Bog cranberry grows in bogs and fens occurring in wet coastal and boreal forests. These sites are poorly drained with a high-water table. In these areas, the ground is saturated for most of the year.<sup>62</sup> Rising temperatures and projected declines in summer precipitation and summer streamflows may dry out these bog and fen sites, negatively affecting bog cranberry.

### **Dependence on Disturbance Events | Neutral**

The bog cranberry regenerates from rhizomes, and is therefore able to survive low- to moderate-severity fires.<sup>62</sup> Low-severity fires have also been shown to stimulate berry production and to limit trees and shrubs from encroaching into bog and fen habitat.<sup>63</sup> Projected increases in annual area burned are unlikely to negatively affect



the bog cranberry due to its ability to regenerate, and its presence in wet bog environments.

#### **Dependence on Ice or Snow | Neutral**

The bog cranberry is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect bog cranberry.

#### **Physical Habitat Features | Somewhat Increase Vulnerability**

The bog cranberry is restricted to acidic conditions, thriving in soils with pH between 2.9-4.7.<sup>62</sup> Species that are dependent on uncommon geologic features are less likely to be able to adapt to climate change.

#### **Dependence on Other Species for Habitat | Neutral**

The bog cranberry is not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

#### **Dietary Versatility | N/A**

#### **Pollinators | Neutral**

The bog cranberry is self-pollinating. However, bee pollination can occur, and typically results in increased seed production.<sup>63</sup> Species that are not dependent on a specific pollinator are likely to be less vulnerable to the effects of climate change.

#### **Other Species for Propagule Dispersal | Neutral**

Bog cranberry seeds are dispersed by numerous bird and animal species.<sup>62</sup> Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

#### **Sensitivity to Pathogens/Natural Enemies | Unknown**

The bog cranberry is susceptible to numerous fungal diseases.<sup>63</sup> It is hard to make generalizations about how these fungal diseases will respond to climate change. It is unknown if these will fungal diseases will become more widespread with climate change.

#### **Competition from Natives or Non-Natives | Neutral**

The bog cranberry is not currently sensitive to competition from native or non-native species, and there is no indication that climate change will cause a species to become a competitor in the future.

#### **Forms Part of an Interspecific Interaction | Neutral**

The bog cranberry is not dependent on a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

#### **Genetic Variation | Neutral**

The bog cranberry has been shown to be genetically diverse and to have higher levels of genetic diversity than its relative, the small cranberry (*V. macrocarpon*).<sup>64</sup> Species with average to high levels of genetic diversity are expected to be better able to adapt to changing climate conditions.

#### **Phenological Response | Unknown**



## **Alaska Blueberry (*Vaccinium alaskaense*)**

**2050s, Low Greenhouse Gas Scenario:** Moderately Vulnerable

**2050s, High Greenhouse Gas Scenario:** Highly Vulnerable

**2080s, Low Greenhouse Gas Scenario:** Highly Vulnerable

**2080s, High Greenhouse Gas Scenario:** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the Alaska blueberry's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Neutral**

Alaska blueberry seeds are dispersed by numerous bird and mammal species.<sup>65</sup> Birds are largely able to fly over most natural barriers.

### **Anthropogenic Barriers | Somewhat Increase Vulnerability**

The region north of the Nooksack watershed is largely bordered by developed agricultural land, which may limit to ability of the Alaska blueberry to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect Alaska blueberry habitat, which most commonly includes cool, moist forests.<sup>65</sup>

### **Dispersal and Movement Ability | Neutral**

Alaska blueberry seeds are dispersed by numerous bird and mammal species.<sup>65</sup> Seeds are likely to be regurgitated or defecated at least 1 km from the parent Alaska blueberry plant. Species that are able to disperse long distances are more likely to be able to adjust their ranges in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

Alaska blueberry are adapted to a broad range of temperature regimes and are therefore unlikely to be significantly negatively affected by warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral**

The Alaska blueberry is not dependent on a specific hydrological niche; it is able to grow on both well-drained and poorly drained sites.<sup>65</sup> It is unlikely that climate change will alter the hydrologic suitability of Alaska blueberry habitat.

### **Dependence on Disturbance Events | Neutral**

The Alaska blueberry frequently colonizes disturbed sites following windthrow or fire events, however climate models do not project a change in wind strength or speed in the Nooksack watershed.<sup>14</sup> Models do project an increase in total area burned in Washington state.<sup>20</sup> Low-severity fires may facilitate Alaska blueberry establishment, while moderate- to high-severity fires may kill vegetative portions of the blueberry beneath the soil



surface, limiting re-growth.<sup>65</sup>

### **Dependence on Ice or Snow | Neutral**

The Alaska blueberry is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect Alaska blueberry.

### **Physical Habitat Features | Neutral**

The Alaska blueberry is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the Alaska blueberry's ability to adapt to climate change.

### **Dependence on Other Species for Habitat | Neutral**

The Alaska blueberry is not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

### **Dietary Versatility | N/A**

### **Pollinators | Somewhat Increase Vulnerability**

Alaska blueberry flowers are pollinated by bumble bees. Common bumble bee species in western Washington include the black-tailed bumble bee, yellow bumble bee, fuzzy horned bumble bee, and the yellow faced bumble bee. Species that are reliant on a limited number of pollinators are potentially more vulnerable to environmental changes resulting from climate change.

### **Other Species for Propagule Dispersal | Neutral**

Alaska blueberry seeds are dispersed by numerous bird and animal species.<sup>65</sup> Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

### **Sensitivity to Pathogens/Natural Enemies | Unknown**

While the Alaska blueberry is susceptible to some fungal diseases<sup>66</sup>, it is unclear whether the intensity, rate of transmission, and severity of these diseases will be affected by climate change.

### **Competition from Natives or Non-Natives | Neutral**

The Alaska blueberry is not currently sensitive to competition from native or non-native species, and there is no indication that climate change will cause a species to become a competitor in the future.

### **Forms Part of an Interspecific Interaction | Neutral**

The Alaska blueberry is not dependent on a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

### **Genetic Variation | Unknown**

### **Genetic Bottleneck | Unknown**

### **Reproductive System (plants only) | Somewhat Increase Vulnerability**

The Alaska blueberry is able to reproduce both vegetatively and via seed production. Vegetative reproduction has been noted to be of particular importance to western *Vaccinium* species.<sup>65</sup> Species that rely on vegetative reproduction are assumed to have lower levels of genetic variation and therefore, may be more vulnerable to changing climate conditions.

### **Phenological Response | Unknown**



## **Broadleaf Cattail (*Typha latifolia*)**

**2050s, Low Greenhouse Gas Scenario:** Moderately Vulnerable

**2050s, High Greenhouse Gas Scenario:** Extremely Vulnerable

**2080s, Low Greenhouse Gas Scenario:** Extremely Vulnerable

**2080s, High Greenhouse Gas Scenario:** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the broadleaf cattail's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Neutral**

Broadleaf cattail seeds are dispersed by wind, water, birds, and transported sediment.<sup>17,67</sup> It is unlikely that natural barriers will pose an issue for broadleaf cattail dispersal and thus its ability to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Neutral**

While the region north of the Nooksack watershed is largely bordered by developed agricultural land, the broadleaf cattail is often found to be abundant in disturbed agricultural sites.<sup>67</sup> It is thus unlikely that anthropogenic barriers will limit the broadleaf cattail's ability to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to adversely affect broadleaf cattail habitat, which most commonly includes slow rivers, ponds, ditches, lakes, and brackish marshes.<sup>67</sup>

### **Dispersal and Movement Ability | Neutral**

Broadleaf cattail seeds are dispersed by wind, water, and substrate. Achenes contain long hairs that facilitate dispersal.<sup>67</sup> Seeds are likely to be transported at least 1 km from the parent plant. Species that are able to disperse long distances are more likely to be able to adjust their ranges in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

The broadleaf cattail is a widely distributed species, suggesting broad tolerance for a variety of temperature regimes.<sup>67</sup> The broadleaf cattail is thus less likely to be negatively affected by warming temperatures, compared to species restricted to cold climates.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral/Somewhat Increase Vulnerability**

The broadleaf cattail is an aquatic/semiaquatic species that is reliant on a seasonal hydrologic regime that varies throughout the year.<sup>17</sup> The hydrologic regime within the Nooksack watershed is projected to be affected by climate change via increases in winter flooding and declines in summer flow,<sup>14</sup> which may negatively affect broadleaf cattail.

### **Dependence on Disturbance Events | Neutral/Somewhat Increase Vulnerability**

Broadleaf cattails are able to regenerate from low- to moderate-severity top-kill fires. Cattails are able to



regenerate from subsurface roots or rhizomes. While the broadleaf cattail is considered an aquatic/semiaquatic species, it has been noted that fires are not a rare occurrence in broadleaf cattail habitat. While the broadleaf cattail is noted as being tolerant of fluctuating water levels and *some* flooding, death and colony failure has been observed with relatively low flood levels (e.g., 25 inches).<sup>67</sup> Projected increases in winter flood risk for western Washington<sup>14</sup> may thus negatively affect broadleaf cattail populations in the region.

#### **Dependence on Ice or Snow | Neutral**

The broadleaf cattail is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect broadleaf cattail.

#### **Physical Habitat Features | Neutral**

The broadleaf cattail is not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the mule deer's ability to adapt to climate change.

#### **Dependence on Other Species for Habitat | Neutral**

The broadleaf cattail is not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

#### **Dietary Versatility | N/A**

#### **Pollinators | Neutral**

The broadleaf cattail is self-pollinating. Species that are not dependent on a specific pollinator are likely to be less vulnerable to the effects of climate change.

#### **Other Species for Propagule Dispersal | Neutral**

Broadleaf cattail seeds are predominantly wind-dispersed.<sup>67</sup> Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

#### **Sensitivity to Pathogens/Natural Enemies | Unknown**

It is unknown whether the broadleaf cattail is susceptible to pathogens or diseases.

#### **Competition from Natives or Non-Natives | Unknown**

Purple loosestrife (*Lythrum salicaria*) has been noted as a wetland invasive species that may negatively impact the broadleaf cattail.<sup>67</sup> It is unknown which of these species will fare better under climate change.

#### **Forms Part of an Interspecific Interaction | Neutral**

The broadleaf cattail is not dependent on a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

#### **Genetic Variation | Increase Vulnerability**

Genetic variation in the broadleaf cattail has been reported as "extremely low." It is hypothesized that self-pollination and clonal growth are the primary drivers of these low levels of genetic variation.<sup>67</sup> Species with low levels of genetic diversity are expected to be less able to adapt to changing climate conditions.

#### **Phenological Response | Unknown**



## **Evergreen Huckleberry (*Vaccinium ovatum*)**

**2050s, Low Greenhouse Gas Scenario:** Moderately Vulnerable

**2050s, High Greenhouse Gas Scenario:** Extremely Vulnerable

**2080s, Low Greenhouse Gas Scenario:** Extremely Vulnerable

**2080s, High Greenhouse Gas Scenario:** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the evergreen huckleberry's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Neutral**

Evergreen huckleberry seeds are dispersed by numerous bird and mammal species.<sup>68</sup> Birds are largely able to fly over most natural barriers, which may increase the ability of the evergreen huckleberry to adjust its range in response to changing climate conditions.

### **Anthropogenic Barriers | Somewhat Increase Vulnerability**

The region north of the Nooksack watershed is largely bordered by developed agricultural land, which may limit the ability of the evergreen huckleberry to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect evergreen huckleberry habitat, which most commonly includes cool, moist forests.<sup>68</sup>

### **Dispersal and Movement Ability | Neutral**

Evergreen huckleberry seeds are dispersed by numerous bird and mammal species.<sup>68</sup> Seeds are likely to be regurgitated or defecated at least 1km from the parent Alaska blueberry plant. Species that are able to disperse long distances are more likely to be able to adjust their ranges in response to changing climate conditions..

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

The evergreen huckleberry is adapted to a broad range of temperature regimes and is therefore unlikely to be significantly negatively affected by warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral**

The evergreen huckleberry is adapted to a broad range of moisture regimes<sup>68</sup>, and is therefore unlikely to be significantly negatively affected by shifts in moisture availability.

### **Dependence on Disturbance Events | Neutral**

The evergreen huckleberry regenerates vegetatively from roots and rhizomes, and is therefore able to survive low-to moderate-severity fires. Low-severity fires have also been shown to stimulate berry production.<sup>68</sup> Projected increases in annual area burned are thus unlikely to negatively affect the evergreen huckleberry due to its ability to regenerate after fire, and its presence in wet bog environments.





### **Dependence on Ice or Snow | Neutral**

The evergreen huckleberry is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect evergreen huckleberry.

### **Physical Habitat Features | Somewhat Increase Vulnerability**

The evergreen huckleberry is restricted to acidic conditions, thriving in soils with pH between 4.3-5.2.<sup>68</sup> Association with a specific geologic feature is expected to limit the evergreen huckleberry's ability to adapt to climate change.

### **Dependence on Other Species for Habitat | Neutral**

The evergreen huckleberry is not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

### **Dietary Versatility | N/A**

### **Pollinators | Somewhat Increase Vulnerability**

Evergreen huckleberry flowers are pollinated by long-tongued bees (i.e., bumble bees).<sup>68</sup> Common bumble bee species in western Washington include the black-tailed bumble bee, yellow bumble bee, fuzzy horned bumble bee, and the yellow faced bumble bee. Species that are reliant on a limited number of pollinators are potentially more vulnerable to environmental changes resulting from climate change.

### **Other Species for Propagule Dispersal | Neutral**

Evergreen huckleberry seeds are dispersed by numerous bird and animal species, including thrushes, ptarmigans, towhees, ring-neck pheasant, and grouse.<sup>68</sup> Dependence on a single other species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

### **Sensitivity to Pathogens/Natural Enemies | Unknown**

It is unknown whether the evergreen huckleberry is susceptible to pathogens or diseases.

### **Competition from Natives or Non-Natives | Neutral**

The evergreen huckleberry is not currently sensitive to competition from native or non-native species, and there is no indication that climate change will cause a species to become a competitor in the future.

### **Forms Part of an Interspecific Interaction | Neutral**

The evergreen huckleberry is not dependent on a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

### **Genetic Variation | Unknown**

### **Genetic Bottleneck | Unknown**

### **Reproductive System (plants only) | Somewhat Increase Vulnerability**

The evergreen huckleberry is able to reproduce vegetatively and also via seed production. Vegetative reproduction has been noted of particular importance to western *Vaccinium* species.<sup>68</sup> Species that primarily reproduce vegetatively are assumed to have lower levels of genetic variation and therefore may be more vulnerable to changing climate conditions.

### **Phenological Response | Neutral**

The Puyallup Climate Change Impact Assessment noted observations of huckleberries ripening two weeks earlier in 2015, compared to previous years.<sup>69</sup> This suggests that regional berry species responded adaptively to the warmer-than-average temperatures of 2015, and may thus be able to adjust their phenology in response to climate change.



## **Beaked Hazelnut (*Corylus cornuta*)**

**2050s, Low Greenhouse Gas Scenario:** Moderately Vulnerable

**2050s, High Greenhouse Gas Scenario:** Highly Vulnerable

**2080s, Low Greenhouse Gas Scenario:** Highly Vulnerable

**2080s, High Greenhouse Gas Scenario:** Extremely Vulnerable

### **Sea Level Rise | Neutral**

Less than 10% of the beaked hazelnut's range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

### **Natural Barriers | Neutral**

Beaked hazelnuts are dispersed by numerous bird and mammal species.<sup>70</sup> Jays are known to carry hazelnuts over long-distances<sup>70</sup>, and are largely able to fly over natural dispersal barriers.

### **Anthropogenic Barriers | Neutral/Somewhat Increase Vulnerability**

Agricultural sites and urban areas within and around the Nooksack watershed are likely to serve as breaks in suitable habitat for the beaked hazelnut.<sup>17</sup> These anthropogenic barriers may decrease the ability of the beaked hazelnut to adjust its range in response to changing climate conditions.

### **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect beaked hazelnut habitat, which most commonly includes newly burned sites and clear cuts.<sup>70</sup>

### **Dispersal and Movement Ability | Neutral**

Beaked hazelnuts are dispersed long-distances by numerous bird and mammal species.<sup>70</sup> Species that are able to disperse long distances are more likely to be able to adjust their ranges in response to changing climate conditions.

### **Historical Thermal Niche | Increase Vulnerability**

This factor measures the range of mean seasonal temperatures (the difference between the highest mean monthly maximum temperature and lowest mean monthly minimum temperature) observed for a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced a narrower range of historical temperatures are expected to be more sensitive to future warming.

### **Physiological Thermal Niche | Neutral**

The beaked hazelnut occurs continuously from British Columbia to southern California. Therefore, it is adapted to a broad range of temperature regimes and is unlikely to be significantly negatively affected by warming temperatures.

### **Historical Hydrologic Niche | Neutral**

This factor measures the range of mean annual precipitation (the wettest cell minus the driest cell) observed across a species' distribution within the assessment area in recent historical times (1970-1999). Species that have experienced less variation in precipitation are expected to be more sensitive to future changes in precipitation.

### **Physiological Hydrologic Niche | Neutral**

The beaked hazelnut is adapted to a broad range of moisture regimes<sup>70</sup>, and is therefore less likely to be significantly negatively affected by shifts in moisture availability.

### **Dependence on Disturbance Events | Somewhat Increase Vulnerability**

While many disturbance events – including fire, insects, and disease – may increase the frequency of hazelnut presence, flooding has been shown to negatively affect the beaked hazelnut.<sup>70</sup> Projected increases in winter flood risk may thus negatively affect beaked hazelnut habitat.



### **Dependence on Ice or Snow | Neutral**

The beaked hazelnut is not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect beaked hazelnut habitat. In fact, suitable beaked hazelnut habitat may expand if projected declines in snowpack allow tree encroachment into subalpine and alpine zones.<sup>17</sup>

### **Physical Habitat Features | Neutral**

The beaked hazelnut is not restricted to uncommon geological features.<sup>70</sup> Association with a specific geologic feature is thus not expected to limit the mule deer's ability to adapt to climate change.

### **Dependence on Other Species for Habitat | Neutral**

The beaked hazelnut is not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.

### **Dietary Versatility | N/A**

### **Pollinators | Neutral**

The beaked hazelnut is wind pollinated.<sup>70</sup> Species that are not dependent on a specific pollinator are likely to be less vulnerable to the effects of climate change.

### **Other Species for Propagule Dispersal | Neutral**

Beaked hazelnuts are dispersed by numerous bird and animal species. Examples include blue jays, scrub jays, and rodents.<sup>70</sup> Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

### **Sensitivity to Pathogens/Natural Enemies | Unknown**

It is unknown whether beaked hazelnuts are susceptible to pathogens or diseases.

### **Competition from Natives or Non-Natives | Unknown**

The beaked hazelnut is vulnerable to invasion from the non-native Siberian peashrub (*Caragana arborescens*).<sup>70</sup> It is unknown whether the Siberian peashrub will fare better than the beaked hazelnut under climate change.

### **Forms Part of an Interspecific Interaction | Neutral**

Beaked hazelnut is not dependent on a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

### **Genetic Variation | Unknown**

### **Genetic Bottleneck | Unknown**

### **Reproductive System (plants only) | Somewhat Increase Vulnerability**

While the beaked hazelnut is capable of both sexual and vegetative reproduction, vegetative means of reproduction are more common.<sup>70</sup> Species that primarily reproduce vegetatively are assumed to have lower levels of genetic variation and therefore may be more vulnerable to changing climatic conditions.

### **Phenological Response | Unknown**



# Bivalves

## **Sea Level Rise | Greatly Increase Vulnerability**

More than 90% of bivalves range within the Nooksack watershed is subject to sea level rise (i.e., low-lying islands or within the coastal zones).

## **Natural Barriers | Neutral**

There are no known natural barriers to bivalve dispersal, which may increase the ability of bivalves to adjust their ranges in response to changing climate conditions.

## **Anthropogenic Barriers | Neutral/Somewhat Increase Vulnerability**

Shorelines and the presence of bulkheads may present a barrier to inland migration of bivalves as sea levels rise.<sup>17</sup> These anthropogenic barriers may thus decrease the ability of bivalves to adjust their ranges in response to changing climatic conditions and associated sea level rise.

## **Climate Change Mitigation Actions | Neutral**

Climate change mitigation actions are unlikely to affect bivalve habitat, which includes coastal marine habitat.

## **Dispersal and Movement Ability | Neutral**

Larval bivalves drift in the water for a significant amount of time and distance (i.e., several miles) prior to stopping and burrowing beneath the sand or sediment surface.<sup>71</sup> Species that are able to move long distances are more likely to be able to adjust their ranges in response to changing climate conditions.

## **Historical Thermal Niche | Unknown**

## **Physiological Thermal Niche | Unknown**

Some bivalve species are extremely hardy and are able to tolerate large swings in water temperature (e.g., the Pacific oyster and the Kumamoto). Conversely, some bivalves are sensitive to slight changes in temperature (e.g., the Olympia oyster and the European flat or Belon Oyster).<sup>72</sup> Bivalve species that are sensitive to changes in temperature are likely to be more vulnerable to warming ocean temperatures due to climate change.

## **Historical Hydrologic Niche | Unknown**

## **Physiological Hydrologic Niche | Neutral**

Bivalves are not dependent on a specific hydrological niche. It is unlikely that climate change will alter the hydrologic suitability of bivalve habitat.

## **Dependence on Disturbance Events | Neutral**

Bivalves are not reliant on a disturbance regime that is projected to be altered by climate change.

## **Dependence on Ice or Snow | Neutral**

Bivalves are not directly dependent on the presence of snow or ice. Therefore, projected declines in winter snowpack are unlikely to directly negatively affect bivalves.

## **Physical Habitat Features | Neutral**

Bivalves are not restricted to uncommon geological features. Association with a specific geologic feature is thus not expected to limit the mule deer's ability to adapt to climate change.

## **Dependence on Other Species for Habitat | Neutral**

Bivalves are not dependent on other species to generate habitat. Dependence on another species, which may be vulnerable to climate change, for habitat generation is expected to increase a species' vulnerability to climate change.



**Dietary Versatility | Neutral**

Bivalves are filter feeders and consume a range of phytoplankton and zooplankton species.<sup>71</sup> Species that can readily switch between different food sources are less likely to be negatively affected by climate change.

**Pollinators | N/A****Other Species for Propagule Dispersal | Neutral**

Bivalves are not dependent on other species for propagule dispersal. Dependence on another species, which may be vulnerable to climate change, for dispersal is expected to increase a species' vulnerability to climate change.

**Sensitivity to Pathogens/Natural Enemies | Unknown**

Oyster drills (marine snails), numerous sea star species, dungeness crab, redrock crab, graceful crab, mud shrimp, and the flatworm are all noted as predators of oysters and other bivalves.<sup>72</sup> It is unknown if these predators will fare better than bivalves under climate change.

**Competition from Natives or Non-Natives | Unknown**

It is unknown whether bivalves are sensitive to competition from native or non-native species.

**Forms Part of an Interspecific Interaction | Neutral**

Bivalves are not dependent on a specific interspecific interaction. Dependence on an interaction with another species, which may be vulnerable to climate change, is expected to increase a species' vulnerability to climate change.

**Genetic Variation | Unknown****Genetic Bottleneck | Unknown****Phenological Response | Unknown**

**Habitat:** Estuary - Salt marsh, eelgrass, mud flat

**Estimated Climate Change Vulnerability<sup>iv</sup>:** Moderate to High

**Summary:** This habitat is estimated to have moderate to high vulnerability due to its moderate sensitivity<sup>v</sup> and high projected exposure to temperature and precipitation changes in the Nooksack watershed<sup>iv</sup>.

### **Key Sensitivities<sup>v</sup>:**

- **Temperature changes: 4 (out of 7)**

Projected increases in air temperature may lead to increases in drying, specifically in low-tide systems (e.g., eel grass habitat). Tidal zone marshes (i.e., low marshes) are much more sensitive to projected net drying than these habitats, while tidal marshes above the mean high water mark (i.e., high marshes) are less sensitive. While estuaries are generally able to tolerate a high degree of temperature variability, some species that inhabit estuaries may be extirpated as a result of warming temperatures. Nevertheless, the complexity of these systems is expected to increase the resilience of estuary habitat to increases in air temperature.

- **Precipitation changes: 6 (out of 7)**

The influence of projected changes in precipitation for estuary systems are uncertain. Fluctuations in freshwater inflow due to changes in seasonal or annual precipitation will be particularly influential for salinity levels within estuaries. However, because many of these nearshore habitats have been separated from freshwater inflows due to land use changes and river modifications, they may be buffered, to some degree, from these future changes. Shifts in nearshore salinity may also have implications for invasive species, including reed canary grass, due to increased salinity in summer.

- **Indirect factors: 4 (out of 7)**

Water chemistry in the nearshore may change due to increasing sea surface temperatures and may increase acidification. Sea level rise is expected to significantly affect nearshore habitats. Some level of inundation may be offset or magnified by seasonal changes in streamflow and sediment delivery in some regions. Sea level rise may create estuary habitat in coastal areas by flooding undeveloped, low-lying shorelines. Local geomorphology is also important in determining how sea level rise may affect a specific site. For example, mud flats that are exposed may be more vulnerable compared to flats with some form of natural barrier that may limit inundation. Diseases and parasites of species inhabiting estuaries are also linked to shifts in climate. For example, eelgrass wasting disease is affected by both water temperature and salinity. Projected shifts in surface temperature and salinity are expected stress nearshore species, increasing susceptibility to infection.

### **Research Needs**

While estuaries are generally adapted to a high degree of climatic variability, changes in seasonal precipitation and the corresponding timing of flood events may lead to unknown changes. Mapping estuary habitat and identifying sites that may expand or contract may help prioritize future restoration and development.

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<sup>iv</sup> Vulnerability was estimated by considering both sensitivity<sup>ix</sup> and exposure (i.e., projected warming of 2.5–4.0°C for the Nooksack watershed by the 2050s under RCP 8.5).

<sup>v</sup> Sensitivity rankings are from the Climate Change Sensitivity Database ([climatechangesensitivity.org](http://climatechangesensitivity.org)), a publically available on-line database that summarizes information from both peer-reviewed literature and expert knowledge of species and habitats. It does not incorporate projections of climate change (i.e., exposure).



**Habitat:** Forest (including old-growth)

**Estimated Climate Change Vulnerability<sup>vi</sup>:** Moderate to **High**

**Summary:** This habitat is estimated to have moderate to high vulnerability to climate change due to moderate climate sensitivity and high projected exposure to temperature and precipitation changes within the Nooksack watershed<sup>iv</sup>.

**Key Sensitivities<sup>vii</sup>:**

- **Temperature changes: 4 (out of 7)**

Patterns of forest distribution and growth are largely determined by regional patterns in temperature and precipitation. Air temperature influences photosynthesis and respiration rates, frost tolerances, and phenology.<sup>73</sup> Projected increases in temperature are expected to alter the species composition and growth rates (especially in energy-limited forests) of western Washington forests. However, warming temperatures may also facilitate the introduction and spread of forest insects and pathogens (CCSD).<sup>74</sup> Temperature influences the rate of insect growth and development, and winter temperatures influence winter mortality in forest pests.<sup>73</sup> Additionally, projected increases in temperature and associated declines in summer moisture availability are expected to stress forests, increasing their susceptibility to insect and pest infestation.

- **Precipitation changes: 4.5 (out of 7)**

In some Washington forests, tree productivity is currently limited more by precipitation, or water availability, than temperature (i.e., water-limited forests).<sup>73</sup> While these seasonally water-limited forests can be found throughout Washington<sup>73</sup>, they typically occur in drier locations and at high elevations. Increases in winter precipitation at the highest elevations could lead to decreased tree growth due to a deeper snowpack. Projected declines in snowpack may facilitate forest encroachment into sub-alpine and alpine habitats.<sup>17</sup> Many forests are currently considered energy-limited and therefore many not respond to precipitation changes.

- **Indirect factors: 5 (out of 7)**

Forests are sensitive to indirect factors associated with climate change, such as fire, disease, pests, and wind disturbances. Increases in temperature and declines in moisture availability are projected to increase the annual area burned by fire in western Washington.<sup>20</sup> This may alter the species composition of wet, lowland-forests from stands of western hemlock and red alder to those dominated stands to Douglas-fir. Projected increases in temperature may also lead to increases of pests, especially when combined with blowdown events.

**Research Needs**

Forests in western Washington vary in species composition, structure, age, and expected response to climate change. Additional research is needed to improve our understanding of how climatic changes in temperature, precipitation, and shifts in disturbance regimes (e.g., fire) may affect forests.

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<sup>vi</sup> Vulnerability was estimated by considering both sensitivity<sup>ix</sup> and exposure (i.e., projected warming of 2.5–4.0°C for the Nooksack watershed by the 2050s under RCP 8.5).

<sup>vii</sup> Sensitivity rankings are from the Climate Change Sensitivity Database ([climatechangesensitivity.org](http://climatechangesensitivity.org)), a publically available on-line database that summarizes information from both peer-reviewed literature and expert knowledge of species and habitats. It does not incorporate projections of climate change (i.e., exposure).





**Habitat:** Montane: alpine, subalpine, meadow, talus

**Estimated Climate Change Vulnerability<sup>viii</sup>:** High

**Summary:** Given this system's high climate sensitivity<sup>ix</sup> and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed<sup>iv</sup>, we estimate that its climate change vulnerability within the Nooksack watershed will be relatively high.

#### **Key Sensitivities<sup>ix</sup>:**

- **Temperature changes: 7 (out of 7)**

Projected increases in air temperature may increase growth and productivity of high-elevation montane habitats that are currently energy limited. Warming temperatures are also expected to facilitate the spread and encroachment of trees into meadows habitat. Warming temperatures may adversely impact montane species that have a narrow thermal tolerance and are unable to persist in warm climates, such as the American pika.

- **Precipitation changes: 6 (out of 7)**

Projected changes in precipitation are expected to significantly affect montane habitats and associated vegetation. Increases in winter precipitation at the highest elevations could lead to decreased tree growth due to a deeper snowpack. Projected declines in summer precipitation may result in decreased growth due to water limitation. Additionally, projected increases in temperature and projected declines in summer precipitation are expected to increase annual area burned in western Washington.<sup>20</sup> Declining snowpack could result in a longer growing season and an associated increased growth, but may also expose some plant roots to frost and wind disturbances during harsh winter weather (where these were previously protected by snowpack).

- **Indirect factors: 6 (out of 7)**

Montane habitats are considered extremely sensitive to disturbances, including fire, wind, disease, and pests. Climate change is expected to increase the frequency and intensity of some of these indirect factors. Alpine areas and meadows are generally considered more sensitive than subalpine areas to these indirect factors. Major disturbance events (e.g., fire, wind, disease) may result in the most significant changes in species composition if existing species cannot re-establish due to competition from species moving up from lower elevations.

#### **Research Needs**

Montane areas are diverse and consist of many ecosystems, such as alpine, subalpine, meadow, and talus. More research on identifying individual climate change sensitivity rankings for each of these ecosystems is needed.

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<sup>viii</sup> Vulnerability was estimated by considering both sensitivity<sup>ix</sup> and exposure (i.e., projected warming of 2.5–4.0°C for the Nooksack watershed by the 2050s under RCP 8.5).

<sup>ix</sup> Sensitivity rankings are from the Climate Change Sensitivity Database ([climatechangesensitivity.org](http://climatechangesensitivity.org)), a publically available on-line database that summarizes information from both peer-reviewed literature and expert knowledge of species and habitats. It does not incorporate projections of climate change (i.e., exposure).



**Habitat:** Marine – Nearshore / gravel beaches

**Estimated Climate Change Vulnerability<sup>x</sup>:** Moderate

**Summary:** This habitat is estimated to have relatively *moderate vulnerability* due to its low to moderate sensitivity<sup>xi</sup> and high projected exposure to temperature and precipitation changes in the Nooksack watershed<sup>iv</sup>.

**Key Sensitivities<sup>xi</sup>:**

- **Temperature changes: 4 (out of 7)**

Gravel beaches are identified as being somewhat sensitive to temperature change. Projected increases in temperature may result in changes to species composition and abundance. Additionally, warming temperatures are expected to facilitate the spread of invasive species into regions that may have historically been too cold for them. Projected increases in temperature may also reduce populations of forage fish species in nearshore habitats and accelerate rates of organic matter decay.

- **Precipitation changes: 3 (out of 7)**

Nearshore and gravel beach habitats were categorized as being less sensitive to projected changes in precipitation than to those in temperature. However, there is a high level of uncertainty as to how these nearshore and gravel beach habitats will respond to shifts in precipitation. Projected changes in precipitation, specifically extreme precipitation events, may alter erosion and sediment transport, which could lead to flooding and scouring.

- **Indirect factors: 5 (out of 7)**

Water chemistry in the nearshore may change due to increasing sea surface temperatures and may increase acidification. Ocean acidification has significant implications for shellfish inhabiting nearshore environments. Additionally, coastal flooding may negatively affect biota and lead to changes in erosion and sediment transport. Sea level rise has the potential to significantly influence these nearshore systems, but similar to estuaries, may be partially offset or intensified locally by shifts in river discharge and sediment deposition. Sea level rise may create new nearshore habitat by flooding undeveloped, low-lying shorelines. Some non-climate stressors increase the climate sensitivity of the nearshore and gravel beaches. For example, pollution, shellfish harvest, and shoreline modifications such as development and armoring are all major threats to the nearshore and gravel beaches.

**Research Needs**

There is a high level of uncertainty surrounding climate change impacts to nearshore habitats and gravel beaches. Shifts in flooding, erosion, and sediment deposition are expected to significantly change the dynamics and species composition of these habitats. Mapping marine nearshore and gravel beach habitat and identifying sites that may expand or contract may help prioritize future restoration and development. Non-climate stressors that may increase the climate sensitivity of these habitats also require further research.

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<sup>x</sup> Vulnerability was estimated by considering both sensitivity<sup>ix</sup> and exposure (i.e., projected warming of 2.5–4.0°C for the Nooksack watershed by the 2050s under RCP 8.5).

<sup>xi</sup> Sensitivity rankings are from the Climate Change Sensitivity Database ([climatechangesensitivity.org](http://climatechangesensitivity.org)), a publically available on-line database that summarizes information from both peer-reviewed literature and expert knowledge of species and habitats. It does not incorporate projections of climate change (i.e., exposure).



**Habitat:** Riparian

**Estimated Climate Change Vulnerability<sup>xii</sup>:** **Moderate to High**

**Summary:** Given this system’s moderate climate sensitivity<sup>ix</sup> and high projected exposure to temperature and precipitation changes in the Nooksack watershed<sup>iv</sup>, we estimate that its climate change vulnerability will be relatively moderate to high.

**Key Sensitivities<sup>xiii</sup>:**

- **Temperature changes: 4 (out of 7)**

Riparian habitats in western Washington are found adjacent to rivers and in close proximity to bodies of water. Many riparian areas occur within the relatively cool, moist maritime climate. As a result, riparian habitats are considered to be moderately sensitive to projected increases in temperature. Projected increases in temperature may dry up some small creeks and groundwater springs or shorten the period of the year with flowing water. Declines in streamflow or dry streambeds would negatively affect the species composition and structure of riparian habitats. Significant warming could cause some of these systems to disappear altogether.

- **Precipitation changes: 2 (out of 7)**

While riparian habitats were identified as less sensitive to projected changes in precipitation than to warming temperatures, riparian areas will still be affected by shifts in precipitation. Species composition and structure in riparian habitat is tightly associated with soil moisture, which is influenced by both precipitation and evapotranspiration. Riparian habitats often include hardwood tree species, which are relatively sensitive to declining soil moisture.

- **Indirect factors: 6 (out of 7)**

Riparian habitats are extremely sensitive to indirect effects of climate change. Specifically, riparian habitats are sensitive to changes in summer low flows, warming water temperatures, and winter flooding events. Projected declines in summer low flows and increases in stream temperatures will negatively affect key species, including salmon. Projected increases in winter flooding may lead to changes in species composition by favoring smaller hardwoods species. Shifts in the seasonality and volume of streamflows will also influence local water table levels and soil moisture.

**Research Needs**

Monitoring riparian habitats, particularly after disturbances, is critical for understanding how climate change may affect riparian processes. For example, vulnerability mapping of riparian habitats based on projected changes in seasonal streamflow could be developed to highlight priority restoration areas.

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<sup>xii</sup> Vulnerability was estimated by considering both sensitivity<sup>ix</sup> and exposure (i.e., projected warming of 2.5–4.0°C for the Nooksack watershed by the 2050s under RCP 8.5).

<sup>xiii</sup> Sensitivity rankings are from the Climate Change Sensitivity Database ([climatechangesensitivity.org](http://climatechangesensitivity.org)), a publically available on-line database that summarizes information from both peer-reviewed literature and expert knowledge of species and habitats. It does not incorporate projections of climate change (i.e., exposure).



**Habitat:** Wetland: Forested Wetland

**Estimated Climate Change Vulnerability<sup>xiv</sup>:** High

**Summary:** Given this system's high climate sensitivity<sup>ix</sup> and high projected exposure to temperature and precipitation changes in the Nooksack watershed<sup>iv</sup>, we estimate that its climate change vulnerability will be relatively high.

**Key Sensitivities<sup>xv</sup>:**

- **Temperature changes: 6 (out of 7)**

Forested wetlands are reliant on groundwater and surface runoff for water supply. Shallow wetlands are extremely sensitive to projected increases in temperature. The degree of a wetland's response to warming will depend on the form and size of the habitat. For example, some wetlands may be better able to store water during the winter months, which may buffer them against earlier snowmelt and declining summer precipitation. Warming can also lead to changes in evaporation rates, which could shorten the wetland's wet season. This may result in mismatches between when species require these wetlands for life-cycle events (e.g., reproduction, metamorphosis) and when a wetland is wet.

- **Precipitation changes: 6 (out of 7)**

Projected declines in summer precipitation could result in earlier wetland drying and a shorter wet season. Shading in forested wetlands will likely buffer these habitats from water loss driven by decreasing summer precipitation and warming temperatures. Shading in forested wetlands may also lead to longer snowpack retention than non-forested wetlands due to temperature regulation. Locally, this may limit the degree to which spring peak streamflows shift earlier in the season.

- **Indirect factors: 4 (out of 7)**

Warming temperatures and declining summer moisture availability are expected to increase the risk of wildfire and beetle infestation in forested wetlands. Losses of forest cover due to disturbance (e.g., fire, pests) could significantly alter water balances in these wetlands. Projected declines in snowpack will impact the wet season of forested vernal pools and wet meadows in western Washington.

**Research Needs**

More research is needed to evaluate how wetland function and process will shift under different time horizons and climate scenarios. The degree to which different wetland plant species may affect riparian system functioning has also not been studied.

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<sup>xiv</sup> Vulnerability was estimated by considering both sensitivity<sup>ix</sup> and exposure (i.e., projected warming of 2.5–4.0°C for the Nooksack watershed by the 2050s under RCP 8.5).

<sup>xv</sup> Sensitivity rankings are from the Climate Change Sensitivity Database ([climatechangesensitivity.org](http://climatechangesensitivity.org)), a publically available on-line database that summarizes information from both peer-reviewed literature and expert knowledge of species and habitats. It does not incorporate projections of climate change (i.e., exposure).



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## Appendix 4

### Summary Report of Workshops and Webinars

The following Appendix summarizes the work completed by the Climate Impacts Group (CIG) and the Nooksack Indian Tribe to assess the vulnerability of key species and habitats for the Nooksack Tribe.

#### **Workshop 1 | Project Kickoff & Selecting target species and habitats**

On August 29th, 2017 the CIG met with Tribal staff at the Nooksack Natural Resources Department to discuss and finalize the list of target species and habitats to be included in the vulnerability assessment (Table 1 for attendance list). Tribal staff were asked to highlight the priority species and habitat types. The primary consideration for ranking was importance to the Nooksack Tribe. In many cases that importance was based on present-day use by the Tribe. In other cases, that importance was based historic and/or anticipated future use of the species or habitat for economic or cultural reasons. Data availability and perceived adaptive capacity were not factored into this ranking evaluation.

Table 1. Attendance for Workshop 1.

<b>Name</b>	<b>Organization</b>
Meade Krosby	UW Climate Impacts Group
Harriet Morgan	UW Climate Impacts Group
Richard Auguston	Nooksack Natural Resources Department
Jezra Beaulieu	Nooksack Natural Resources Department
Tom Cline	Nooksack Natural Resources Department
Treva Coe	Nooksack Natural Resources Department
Ned Currence	Nooksack Natural Resources Department
Trevor Delgado	Nooksack Cultural Resources Department
Lindsie Fratus-Thomas	Nooksack Natural Resources Department
Oliver Grah	Nooksack Natural Resources Department
Gary MacWilliams	Nooksack Natural Resources Department
Eric Stover	Nooksack Natural Resources Department
George Swanaset	Nooksack Cultural Resources Department
Holly O'Neil	Evergreen Land Trust

#### **Workshop 2 | Draft Result Presentation & Incorporating Local Knowledge**

On October 14<sup>th</sup>, 2017, the CIG facilitated a second workshop with Tribal members and natural resource staff to present draft CCVI results and provide workshop participants with an opportunity to modify the species sensitivity and adaptive capacity factor scores based on local knowledge of the Nooksack watershed. These modifications of the sensitivity and adaptive capacity factors resulted in changes for the overall vulnerability rankings for twelve species included in the assessment.



Table 2. Attendance for Workshop 2.

Name	Organization
Harriet Morgan	UW Climate Impacts Group
Meade Krosby	UW Climate Impacts Group
Richard Auguston	Nooksack Natural Resources Department
Jezra Beaulieu	Nooksack Natural Resources Department
Tom Cline	Nooksack Natural Resources Department
Treva Coe	Nooksack Natural Resources Department
Oliver Grah	Nooksack Natural Resources Department
Holly O'Neil	Evergreen Land Trust

**Webinar 1 | Review Workshop 2 Edits & Highlight Final CCVI Results**

An hour-long webinar was hosted by the CIG to (1) review what edits were made to the sensitivity and adaptive capacity factors in Workshop 1, and (2) present the final CCVI results after incorporation of Natural Resource Staff changes from Workshop 2.

Table 3. Attendance for webinar.

Name	Organization
Harriet Morgan	UW Climate Impacts Group
Meade Krosby	UW Climate Impacts Group
Jezra Beaulieu	Nooksack Natural Resources Department
Lindsie Fratus-Thomas	Nooksack Natural Resources Department
Oliver Grah	Nooksack Natural Resources Department

**Workshop 3 | Final Workshop & Final Report Presentation**

On December 12, 2017, the CIG facilitated the third and final workshop with Tribal members and natural resource staff. During this workshop the CIG presented the final results of the Nooksack Tribe’s Natural Resource Climate Change Vulnerability Assessment. This workshop focused on the results, caveats of the CCVI tool, and strategies for how to use and apply these CCVI results.

Table 4. Attendance for Workshop 3.

Name	Organization
Harriet Morgan	UW Climate Impacts Group
Meade Krosby	UW Climate Impacts Group
Richard Auguston	Nooksack Natural Resources Department
Jezra Beaulieu	Nooksack Natural Resources Department
Tom Cline	Nooksack Natural Resources Department
Lindsie Fratus-Thomas	Nooksack Natural Resources Department
Oliver Grah	Nooksack Natural Resources Department
Eric Stover	Nooksack Natural Resources Department

