Stillaguamish Tribe Natural Resources Climate Change Vulnerability Assessment

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Prepared by the

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1. INTRODUCTION

Future changes in climate are expected to significantly impact regional species and ecosystems, via changes in species distributions and abundances; the productivity, composition, and distribution of vegetation communities; and the timing of biological events (e.g., flowering, breeding, and migration). Understanding which species and ecosystems are most likely to be vulnerable to the effects of climate change, and why, is a critical first step in addressing potential negative effects and maintaining healthy ecosystems.

This report describes an assessment of the climate change vulnerability of priority species and habitats for the Stillaguamish Tribe of Indians. In addition to describing our approach and resulting sensitivity scores and vulnerability rankings, we provide an appendix of quick-reference fact sheets for each of the assessed species and habitat types, highlighting their primary climate sensitivities and research needs. These estimates of climate vulnerability, underlying climate sensitivities, and key information gaps should help lay the foundation for the Tribe's future climate adaptation and research efforts.

2. METHODS

2.1 Overview of Assessment Approach

We worked with the Stillaguamish Tribe's Natural Resources Department to develop a list of priority species and habitat types, and specify their level of priority for assessment. We assessed as many of these species and habitats as possible, according to their level of priority, data availability, and the time available for the assessment. For species for which adequate data were available, we completed a quantitative assessment of climate vulnerability using NatureServe's Climate Change Vulnerability Index (CCVI). For habitats and species lacking sufficient data for a CCVI analysis, we completed a qualitative assessment of climate vulnerability.

We chose the CCVI for our assessment because it is freely available, relatively transparent and replicable, and widely used. These qualities should help facilitate future updates of the assessment as additional information becomes available, as well as comparison of results to other assessments based on the CCVI. The CCVI also highlights the species sensitivities that contribute to vulnerability, offering critical information to guide future adaptation efforts.

To maximize efficiency and allow assessment of as many species as possible, we relied heavily on existing databases of species characteristics and climate sensitivities, rather than gathering information from the primary literature, and drew from a few primary sources (e.g., NatureServe Explorer, Climate Change Sensitivity Database). Detailed methods and data sources are described below.

2.2 Species and Habitats Selection

We worked with the Stillaguamish Tribe's Natural Resources Department to specify the level of priority for assessment of species and habitats (i.e., high, medium, or low) based on their importance to the Tribe. Assigned priorities were based on current, historic, and/or anticipated future use of species and habitats by the Tribe, and reflected both economic and cultural values. Data availability and perceived adaptive capacity of species or habitats were not factored into this evaluation.

The final list of priority species and habitats targeted for assessment included 96 individual species and 10 habitat types. A full list of species and habitats and the type of assessment provided for each can be found in the Results (Section 3.1).

2.3 Assessment Areas

Based on the information needs of the Tribe, we analyzed species and habitats at one of two scales. For the majority of species and habitats, we assessed climate change vulnerability at the scale of the Stillaguamish Watershed. We defined the watershed extent based on a GIS layer provided by the Washington Department of Ecology (Figure 1a).

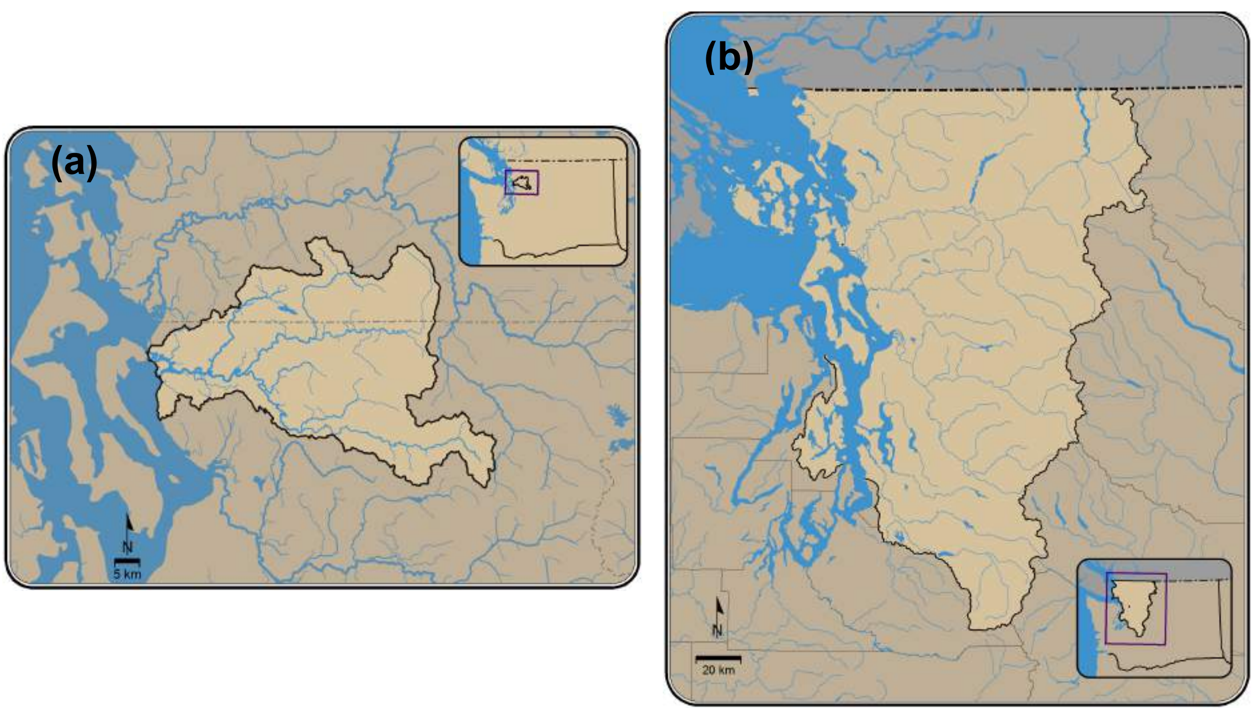

Figure 1. Assessment Areas. Species and habitats were assessed at one of two scales: a) the Stillaguamish watershed, and b) the Tribe's ceded area.

We assessed four species at the larger scale of the Tribe's ceded area. We defined the ceded area extent based on a GIS layer provided by the Washington Department of Fish and Wildlife (Figure 1b).

2.4 Quantitative Climate Change Vulnerability Assessment

i. NatureServe CCVI

We used the NatureServe Climate Change Vulnerability Index (CCVI)[1] to quantitatively assess climate change vulnerability for those species and habitats for which adequate data were available. The CCVI tool uses projected temperature and moisture data, species range data, and species life history information to estimate species' direct and indirect climate exposure and climate sensitivity, ultimately producing a numerical sum quantifying a species' vulnerability to projected climate change (Young et al. 2011; Figure 2).

Direct climate exposure was evaluated by calculating the proportion of each species range that is subject to different levels of projected change in temperature and moisture. Indirect climate exposure and species sensitivity were evaluated using a suite of 16 variables (Table 2).[2] Each variable was evaluated autonomously and given a categorical ranking classification defined by NatureServe (Young et al. 2011). The 7 categories include:

(1) **Greatly Increase Vulnerability**

(2) **Increase Vulnerability**

(3) **Somewhat Increase Vulnerability**

(4) **Neutral**

(5) **Somewhat Decrease Vulnerability**

(6) **Decrease Vulnerability**

(7) **Unknown**

More than one categorical ranking can be selected to capture uncertainty regarding a species sensitivity or indirect climate exposure.

Direct and indirect climate exposure and species sensitivities are used to calculate an index score, which is then converted to one of six possible vulnerability categories, based on threshold values (Young et al. 2011):

(1) **Extremely Vulnerable**: Abundance and/or range extent within geographical area assessed is extremely likely to substantially decrease or disappear.

[1] Release 2.1

[2] Though the CCVI includes 20 factors, we did not include 4 factors falling under the heading of "Documented response to climate change" due to lack of readily available data.

(2) **Highly Vulnerable**: Abundance and/or range extent within geographical area assessed is likely to decrease significantly.

(3) **Moderately Vulnerable**: Abundance and/or range extent within geographical area assessed is likely to decrease.

(4) **Not Vulnerable / Presumed Stable**: Available evidence does not suggest that abundance and/or range extent within the geographical area assessed will change substantially, actual range boundaries may change.

(5) **Not Vulnerable / Increase Likely**: Available evidence suggests that abundance and/or range extent within geographical area assessed is likely to increase.

(6) **Insufficient Evidence**

Finally, following each species' vulnerability classification, the tool uses a Monte Carlo simulation to determine how uncertainty in scoring individual factors might affect confidence in species information. Confidence estimates for vulnerability classifications range from low to very high.

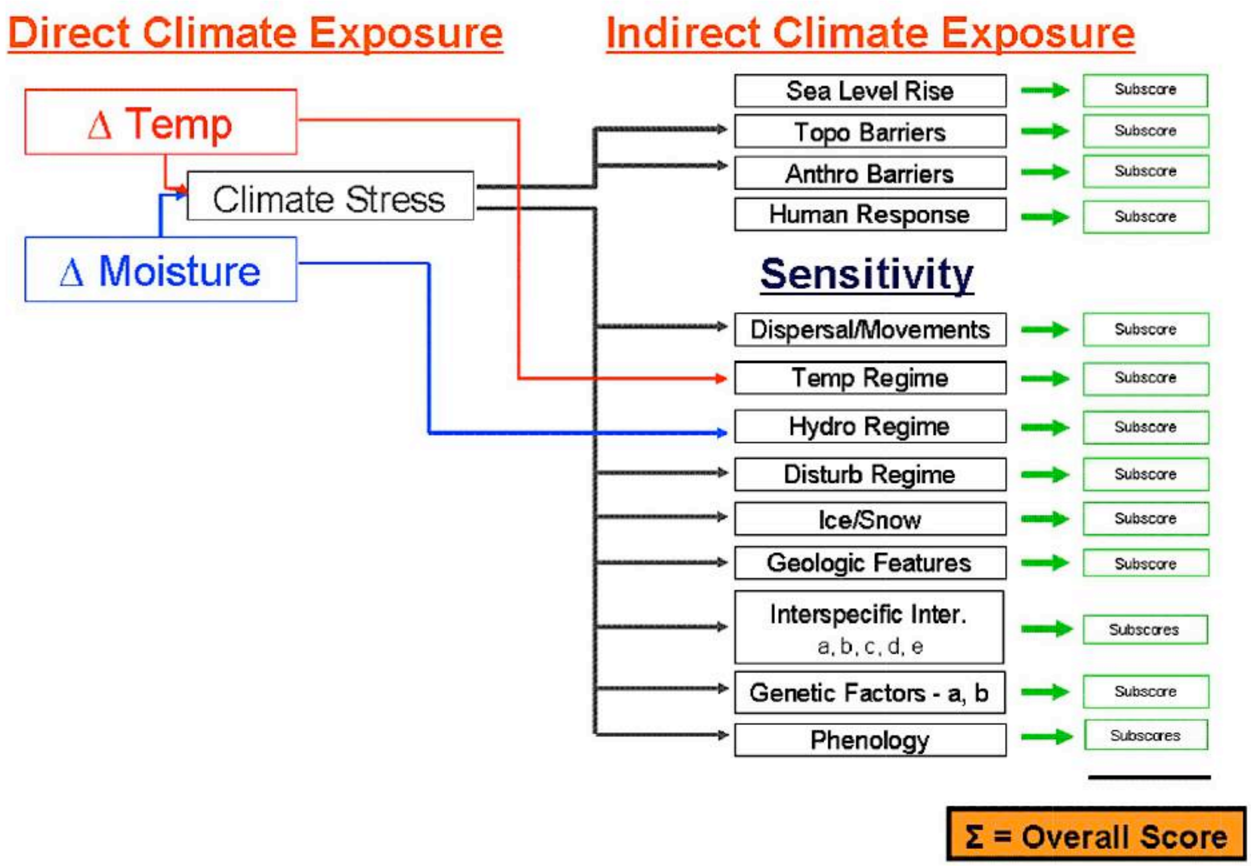

Figure 2. Inputs to the NatureServe Climate Change Vulnerability Index (CCVI) (from Young et al. 2011)**.** The CCVI measures climate change vulnerability based on direct exposure to local climate change (e.g., changes in temperature and moisture), indirect climate exposure (e.g., sea level rise), and 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.

ii. Data Sources and Climate Scenarios

CCVI assessment requires historic and projected future temperature and precipitation data for the study areas; spatial data layers of the projected sea level rise, species distributions, and the wildland-urban interface; and information on species life histories (Table 1). In addition, the Stillaguamish Tribe's Natural Resources staff provided local information from the Stillaguamish watershed and the Tribe's ceded area to supplement available life history information.

Table 1. Primary data types used in CCVI analysis.

Data Type	Source
Temperature Projections	ClimateWizard (ClimateWizard.org)
Moisture Projections	ClimateWizard (ClimateWizard.org)
Historic Temperature	ClimateWizard (ClimateWizard.org/NatureServe)
Historic Moisture	ClimateWizard (ClimateWizard.org/NatureServe)
Sea Level Rise	NOAA (http://coast.noaa.gov/slrdata/)
Wildland-Urban Interface	The Wildland Urban Interface http://silvis.forest.wisc.edu/maps/wui_main
Species Distributions	IUCN (http://www.iucnredlist.org/technical-documents/spatial-data); StreamNet (http://www.streamnet.org/data/interactive-maps-and-gis-data/); Encyclopedia of Puget Sound (http://www.eopugetsound.org/maps)
Species Life History	NatureServe Explorer (http://explorer.natureserve.org/); Sensitivity Database (http://climatechangesensitivity.org/); The Birds of North America Online (http://bna.birds.cornell.edu/bna/species); USDA Forest Service (http://www.fs.fed.us/database/feis/plants/); AmphibiaWeb (http://amphibiaweb.org/search/index.html); Stillaguamish Tribe Natural Resource Staff (*personal communication*)

We calculated CCVI scores for two time horizons: the 2050s (2040-2069) and the 2080s (2070-2099). We used Climate Wizard (Girvetz et al. 2009) to generate downscaled predicted temperature and moisture changes for both time horizons (relative to the historical 1961-1990 baseline average) across the Stillaguamish watershed and the Tribe's ceded area. We generated projections for each time horizon using two greenhouse gas scenarios from the IPCC Fourth Assessment: A1B and A2 (Nakicenovic et al. 2000).[3] Greenhouse gas scenarios were developed by climate modeling centers for use in modeling global and regional climate impacts. The A1B scenario is a medium emissions scenario, while A2 assumes that emissions remain high and continue to increase through the 21st century. Climate Wizard uses the previous archive of global model projections, described in the 2007 IPCC report (IPCC 2007). The projections used in the more recent 2013 IPCC report (IPCC 2013), which make use of the newer greenhouse gas scenarios ("Representative Concentration Pathways," or RCPs), have not yet been integrated into the tool. A discussion of how the A1B and A2 scenarios compare to RCPs scenarios can be found in the accompanying Climate Drivers Report (Climate Impacts Group 2015).

[3] Using a 16-model ensemble average.

We calculated projected changes in moisture using the Hamon AET:PET moisture metric (Hamon 1961), which incorporates temperature and precipitation information through a ratio of actual evapotranspiration (AET) and potential evapotranspiration (PET). This metric takes total daylight hours and saturated vapor pressure into consideration. However, it does not account for water-holding capacity, effect of snowpack on water availability, or vegetation type (Young et al. 2011). For all CCVI calculations, we used a single estimate of future moisture provided by Climate Wizard, which projects Hamon AET:PET annually for 2040 to 2069, using the A1B scenario (projections using the A2 scenario are not available).[4]

Climate projections were classified using a continuous binning structure defined by NatureServe (Young et al. 2011). The 5 temperature bins include:

(1) **>5.5° F (3.1° C) warmer**

(2) **5.1-5.5° F (2.8-3.1° C) warmer**

(3) **4.5-5.0° F (2.5-2.7° C) warmer**

(4) **3.9-4.4° F (2.2-2.4° C) warmer**

(5) **< 3.9° F (2.2° C) warmer**

Moisture bins represent the predicted annual change in Hamon AET:PET moisture metric, 2040-2069 (based on medium emissions scenario A1B[3]). They express a percent change, with negative values indicating net drying. Moisture bins include:

(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**

iii. Data Preparation

We performed a bilinear re-interpolation of the climate data used in this assessment, to reduce their resolution from 4km and 12km (for historical and projected climate data, respectively) to 1km.[5] This allowed for better alignment of the data with the study area, and a more appropriate resolution for watershed-scale analysis.

We also clipped range-wide species distribution layers to the Stillaguamish watershed using a map developed by the Washington Department of Ecology, or to the Tribe's ceded area using a

[4] IPCC 4th Assessment medium emissions scenario A1B, 16-model ensemble average.

[5] Re-interpolation completed for temperature projections, moisture projections, historic thermal data, and historic hydrological data,

map developed by the Washington Department of Fish and Wildlife. This ensured that the vulnerability assessment was conducted only for the portion of the species' range that occurs within the watershed or ceded area. Relevant data layers were overlaid on clipped range maps to determine the level of exposure to direct and indirect effects of climate change within the watershed or ceded area (Table 2).

2.5 Qualitative Climate Change Vulnerability Assessment

i. Species

Several species could not be quantitatively assessed with the CCVI due to lack of species range data. For these species, we qualitatively assessed their climate sensitivity within the Stillaguamish watershed using sensitivity factors included in the CCVI, and highlighted those factors expected to have a strong influence on their vulnerability.

ii. Habitats

We did not use the CCVI to assess the climate change vulnerability of habitats. Instead, we estimated the relative climate change vulnerability (low, moderate, or high) of habitats based on their climate change sensitivity and projected exposure to climate change within the Stillaguamish watershed. Sensitivity values were taken from the Climate Change Sensitivity Database (climatechangesensitivity.org), a publically available, on-line database that summarizes information from peer-reviewed literature and expert knowledge.

Climate Change Sensitivity rankings in the database were determined by habitat experts engaged through regional workshops and/or and independent work. This included approximately 300 experts with a diversity of backgrounds, expertise, and affiliations[6]; all held advanced graduate degrees in ecology, forestry, or biology. All species and habitat profiles were completed between 2009 and 2012.

Through a series of expert workshops and individual assessments, experts identified the sensitivities of species and habitats to climate change by answering a series of questions related to numerous climate change sensitivity factors, details of which can be found online.[7] For each of the sensitivity factors, experts provided both a sensitivity score ranging from one (low sensitivity) to seven (high sensitivity) and a confidence score ranging from one (low confidence) to five (high confidence). Confidence scores represent experts' certainty about their sensitivity score. Individual scores were averaged when more than one expert assessed the sensitivity of a

[6] U.S. Forest Service, U.S. National Park Service, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, Washington Department of Natural Resources, Washington Department of Fish and Wildlife, Oregon Department of Fish and Wildlife, Idaho Department of Fish and Game, University of Washington, University of Idaho, Idaho Cooperative Fish and Wildlife Research Unit, Washington Natural Heritage Program, Canadian Forest Service, Parks Canada, The Nature Conservancy, National Wildlife Federation, and a number of Tribes and First Nations.
[7] climatechangesensitivity.org

Table 2. Indirect climate exposure and species sensitivity factors.

Variable	Description
i. Indirect Climate Exposure Factors	
Sea Level Rise	Effects of sea level rise
Natural Barriers	Geographical features of the landscape that may restrict a species from naturally dispersing to new areas
Anthropogenic Barriers	Features of anthropogenically 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)
ii. Species Sensitivity Factors	
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 50 years
Physiological Thermal Niche	Dependence on cool or cold habitats within the assessment area
Historical Hydrological Niche	Exposure to precipitation variation over the past 50 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 other species to generate habitat
Dietary Versatility	(Animals Only) Breadth of food types consumed; dietary specialists vs. generalists
Pollinator Versatility	(Plants Only) Number of pollinator species
Propagule Dispersal	Dependence on other species for propagule dispersal
Interspecific Interactions	Other interspecific interactions not including diet, pollination, and habitat creation
Genetic Variation[8]	Measured genetic variation (high, medium, low)
Genetic Bottlenecks[9]	Occurrence of bottlenecks in recent evolutionary history
Phenological Response	Phenological response to changing seasonal temperature and precipitation dynamics

[8] The genetic variation metric was excluded from our analysis due to the challenges and uncertainties associated with categorizing this factor in a categorical framework of high, medium, and low.

[9] Given the lack of information on genetic variation, species known to have experienced a genetic bottleneck (population reduction and subsequent rebound) were categorized as Somewhat Increase or Increase Vulnerability.

species or habitat. Experts also provided more detailed comments and citations when they were available. To qualitatively estimate habitat vulnerability, we also considered the exposure of habitats to climate change within the Stillaguamish watershed, using the same temperature and moisture data used in the CCVI analysis. Specifically, we used temperature projections for the 2050s under the A2 emissions scenario, and the Hamon AET:PET Moisture metric (Hamon 1961).

2.6 Assessing Impacts of Additional Projected Climatic Changes

NatureServe's CCVI does not consider all of the direct and indirect climatic changes likely to influence the vulnerability of species within the Stillaguamish watershed and ceded area. We therefore included for both CCVI and qualitatively assessed species an additional, brief assessment of how they might be impacted by relevant projected changes in physical conditions that are not considered in the CCVI. These changes are described in detail in the climatic drivers assessment that accompanies this report,[10] and include:

- Longer freeze-free period
- Increase in the number of days above 90°F
- Decrease in the number of nights below 10°F
- Increase in the frequency and intensity of heavy rainfall events
- Decline in the average snowpack depth (and snow water equivalent)
- Earlier timing of peak spring snowmelt
- Increases in proportion of winter precipitation falling as rain instead of snow
- Changes in spring, summer, and winter streamflows
- Increases in winter flood risk
- Increases in freshwater and marine water temperatures
- Increased risks of landslides
- Increased sedimentation in the marine environment
- Increased area burned from wildfires
- Increased exposure to pests and diseases
- Increased coastal flooding
- Ocean acidification

We did not include a separate section on additional climatic factors in our assessments of habitats, as their climate sensitivity rankings[7] considered a broader range of factors than those considered by the CCVI, including many of those listed above.

[10] Primary Climatic Drivers of Change in Natural Resources for the Stillaguamish Tribe in the Puget Sound. 2015. Climate Impacts Group, University of Washington.

3. RESULTS

3.1 Species and Habitats Assessed

We were able to acquire sufficient data to analyze 40 species using NatureServe's CCVI (Table 3). Another 17 species or groups of species (e.g., bivalves, forage fish) had insufficient range data to support a complete quantitative analysis using the CCVI and were assessed qualitatively using sensitivity information available in the literature (Table 4). We were unable to complete either a quantitative or qualitative assessment for another three priority species due to lack of information in the literature (Table 5). Time constraints also prevented quantitative or qualitative analysis for an additional 19 lower priority species (Table 6). We completed qualitative assessments for all 10 habitats (Table 7).

3.2 Temperature and Moisture Projections

We generated a single projection of future mean annual moisture, the Hamon AET:PET moisture metric, which was calculated for 2040 to 2069, using the A1B scenario. Future projections of the moisture metric suggest a relatively uniform decrease in annual moisture for the Stillaguamish watershed by mid-century (Fig. 3a). The Tribe's ceded area exhibits greater spatial variability in changes in mean annual moisture (Fig. 3b), with little change seen at higher elevations in the Cascade Range (particularly the North Cascades), and declines seen in many lowland areas.

Temperature projections were generated for the 2050s and 2080s for both A1B and A2 scenarios. In the Stillaguamish watershed, little difference is seen between temperature projections under the A1B and A2 scenarios for the 2050s (3.7-3.9 °F and 3.3-3.5 °F, respectively; Fig. 4). Indeed, projected temperature changes for the 2050s for the two emissions scenarios analyzed fell within the same CCVI bin for temperature exposure (the lowest bin: < 3.9° F (2.2° C) warmer). For the Stillaguamish watershed in the 2080s, greater difference is seen between the A1B and A2 scenarios (5.5-5.7 °F and 6.4-6.7 °F, respectively; Fig. 4). However, these still fall into the same CCVI bin for temperature exposure (the highest bin: >5.5° F (3.1° C) warmer).

For the Tribe's ceded area, greater differences in temperature projections for the 2050s are observed for the A1B and A2 scenarios (3.5-4.1 °F and 3.2-3.7 °F, respectively; Fig. 4). These differences resulted in the projected changes for the A1B scenario falling into the two lowest CCVI bins for temperature exposure (< 3.9° F (2.2° C) warmer and 3.9-4.4° F (2.2-2.4° C) warmer), while changes for the A2 scenario fell into only the lowest bin (< 3.9° F (2.2° C) warmer). For the Tribe's ceded area in the 2080s, even greater difference is seen between the A1B and A2 scenarios (5.2-5.8 °F and 5.9-6.8 °F, respectively; Fig. 4). Changes for the A1B scenario for the 2080s fell into the two highest CCVI bins for temperature exposure (5.1-5.5° F (2.8-3.1° C) and >5.5° F (3.1° C) warmer), while changes for the A2 scenario fell into only the highest bin (>5.5° F (3.1° C) warmer).

Table 3. Species assessed using NatureServe's CCVI. Bold names indicate species that were identified by the Tribe as a high priority for assessment. Names with an asterisk were assessed at the scale of the Tribe's ceded areas; all other species were assessed at the scale of the Stillaguamish watershed.

Common Name	Latin Name	Common Name	Latin Name
American Beaver	***Castor canadensis***	Mountain Lion	*Puma concolor*
American Pipit	*Anthus rubescens*	Northern Flying Squirrel	*Glaucomys sabrinus*
Bald Eagle	*Haliaeetus leucocephalus*	Northern Goshawk	*Accipiter gentilis*
Black Bellied Plover	*Pluvialis squatarola*	**Northern Pintail***	***Anas acuta***
Black-Tailed Deer	*Odocoileus hemionus columbianus*	Olive Sided Flycatcher	*Contopus cooperi*
Brant	*Branta bernicla*	**Oregon Spotted Frog**	***Rana pretiosa***
Bufflehead	*Bucephala albeola*	Pigeon Guillemont	*Cepphus columba*
Bull Trout	***Salvelinus confluentus***	Pileated Woodpecker	*Dryocopus pileatus*
Canada Goose	*Branta canadensis*	Red-Breasted Sapsucker	*Sphyrapicus ruber*
Canada Lynx*	*Lynx canadensis*	Rhinoceros Auklet	*Cerorhinca monocerata*
Cassin's Finch	*Haemorhous cassinii*	Sooty Grouse	*Dendragapus fuliginosus*
Chinook Salmon	***Oncorhynchus tshawytscha***	Spotted Owl	*Strix occidentalis caurina*
Coho Salmon	***Oncorhynchus kisutch***	**Steelhead**	***Oncorhynchus mykiss***
Common Goldeneye	*Bucephala clangula*	Swainson's Thrush	*Catharus ustulatus*
Gray-Crowned Rosy-Finch	*Leucosticte tephrocotis*	Trumpeter Swan	*Cygnus buccinator*
Great Blue Heron	*Ardea herodias*	**Western Grebe**	***Aechmophorus occidentalis***
Greater Scaup	*Aythya marila*	**Western Pond Turtle***	***Actinemys marmorata***
Grizzly Bear	*Ursus arctos horribilis*	Western Sandpiper	*Calidris mauri*
Marbled Murrelet	***Brachyramphus marmoratus***	Wilson's Warbler	*Cardellina pusilla*
Mountain Goat*	***Oreamnos americanus***	**Wolverine**	***Gulo gulo***

Table 4. Species qualitatively assessed due to inadequate data for CCVI analysis. Bold names indicate species that were identified by the Tribe as a high priority for assessment.

Common Name	Latin Name	Common Name	Latin Name
Alaska Blueberry	*Vaccinium alaskaense*	Green Sturgeon	*Acipenser medirostris*
Alaska Cedar	*Cupressus nootkatensis / Chamaecyparis nootkatensis*	Northern Shoveler	*Anas clypeata*
Bivalves[11]	***Bivalvia***	Pacific Jumping Mouse	*Zapus trinotatus*
Bog Cranberry	*Vaccinium oxycoccos*	Pacific Lamprey	*Lampetra tridentata*
Black Oystercatcher	*Haematopus bachmani*	Purple Martin	*Progne subis*
Cattail	*Typha latifolia*	Red Huckleberry	*Vaccinium parvifolium*
Elk	*Cervus elaphus*	Western Redcedar	*Thuja plicata*
Evergreen Huckleberry	*Vaccinium ovatum*	Western Toad	*Anaxyrus boreas*
Forage Fish[12]	**-**	White Sturgeon	*Acipenser transmontanus*

Table 5. Species for which neither CCVI nor qualitative assessment was completed due to lack of data. None of these species was identified by the Tribe as a high priority for assessment.

Common Name	Latin Name	Common Name	Latin Name
Coastal Cutthroat	*Oncorhynchus clarki clarki*	Dungeness Crab	*Cancer magister*
Crayfish	*Pacifasticus leniusculus,*		

[11] The group "bivalves" includes eastern softshell clam, oysters/mussels, geoduck, pacific oyster, manila clams, butter clams, foolish mussel, purple varnish clam, native littlenecks, cockles, Olympic oyster, Macoma clams, horse clams, and freshwater mussels.
[12] The group "forage fish" includes lance, surf smelt, and pacific herring

Table 6. Species for which no assessment was completed due to lack of time. None of these species was identified by the Tribe as a high priority for assessment.

Common Name	Latin Name	Common Name	Latin Name
Aquatic Insects	-	Mallard	*Anas platyrhynchos*
Bitter Root	*Lewisia rediviva*	Mason Bee	*Osmia*
Bulb Plants	-	Pink Salmon	*Oncorhynchus gorbuscha*
Bumble Bee	*Bombus*	Red Elderberry	*Sambucus racemosa*
Chum Salmon	*Oncorhynchus keta*	Red Rock Crab	*Cancer productus*
Gadwall	*Mareca strepera*	River Lamprey	*Lampetra ayresii*
Hazel nut	*Corylus avellana*	Sockeye Salmon	*Oncorhynchus nerka*
Labrador Tea	*Ledum glandulosum*	Townsend’s Warbler	*Setophaga townsendi*
Lesser Scaup	*Aythya affinis*	Western Fence Lizard	Sceloporus occidentalis
Long-Billed Dowitcher	*Limnodromus scolopaceus*	Wetland Wapato	Sagittaria latifolia

Table 7. Habitats qualitatively assessed based on available climate sensitivity data. Bold names indicate habitats that were identified by the Tribe as a high priority for assessment.

Habitat Type	Habitat Type
Marine: Open Water	**Riparian**
Marine: Nearshore, Gravel Beaches	Open Meadow
Estuary: Salt Marsh, Eelgrass, Mud Flat	**Forest**
Freshwater Aquatic	Old Growth Forest
Wetland: Forested Wetland	**Montane: Alpine, Subalpine, Meadow, Talus**

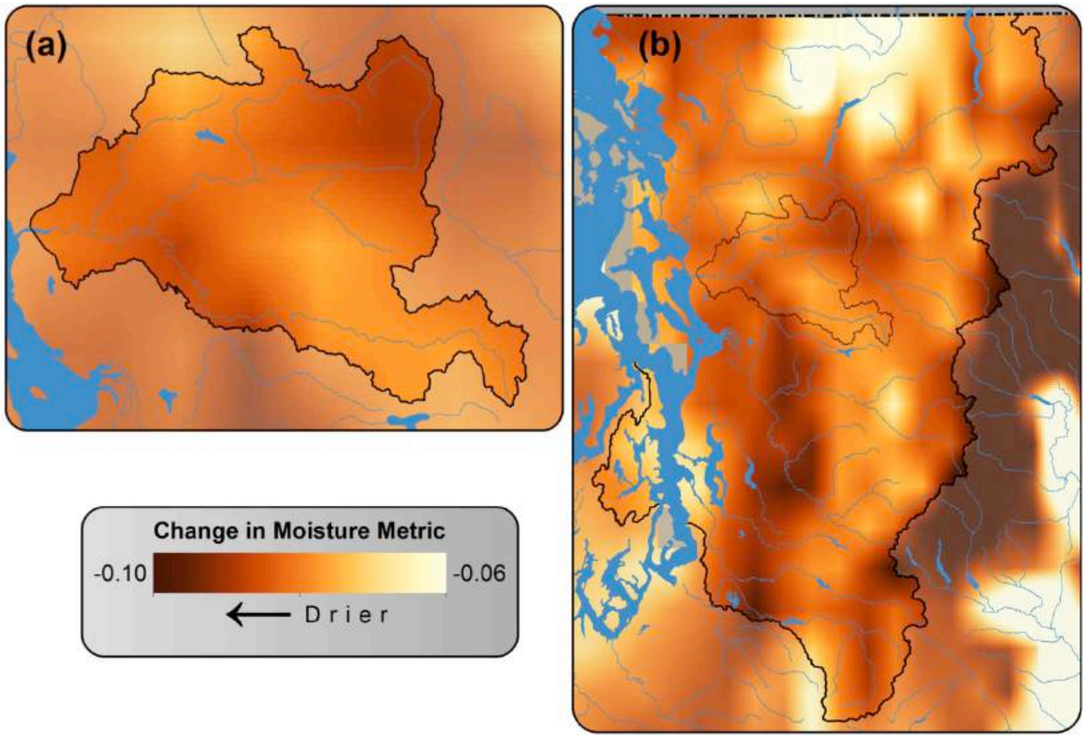

Figure 3. Projected changes in mean annual moisture by mid-century, for a) the Stillaguamish watershed and b) ceded area. For all CCVI calculations, we used a single projection of future moisture: the Hamon AET:PET moisture metric calculated for 2040 to 2069, using the A1B scenario and a 16 model ensemble.

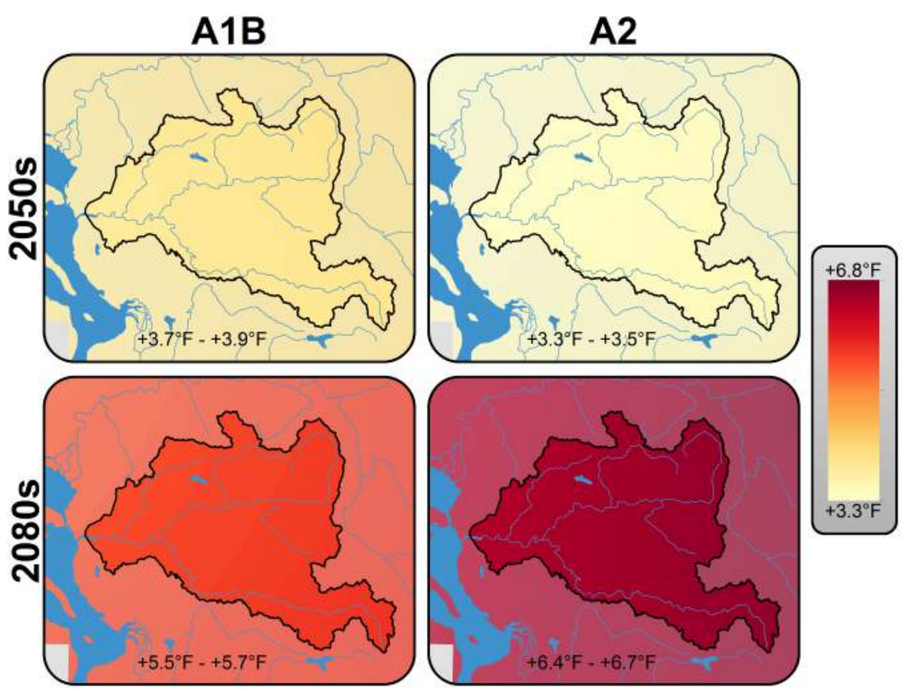

Figure 4. Projected changes in mean annual temperature for the Stillaguamish watershed. Generated for the 2050s and 2080s under the A1B and A2 greenhouse gas scenarios, using an ensemble of 16 global climate models.

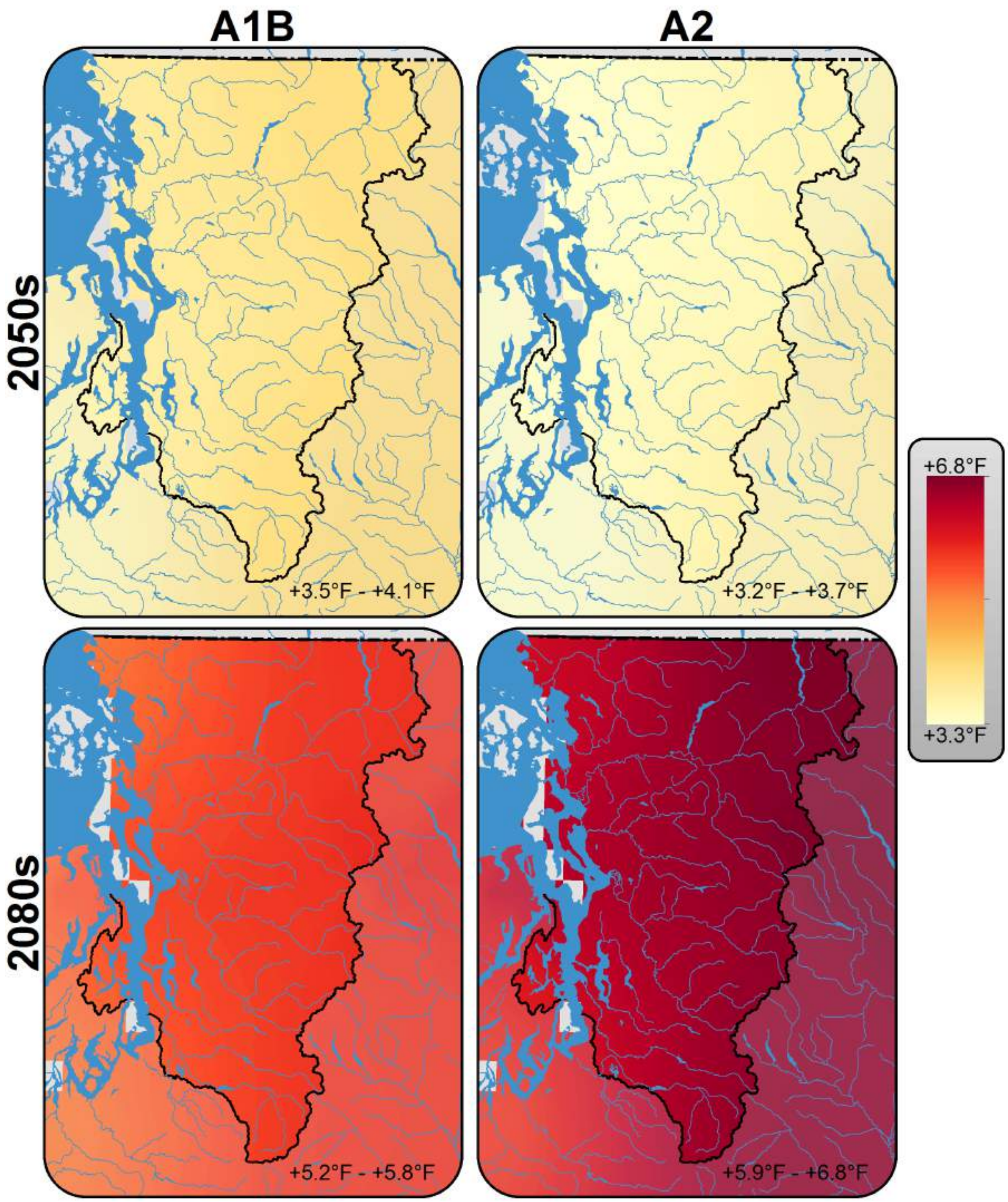

Figure 5. Projected changes in mean annual temperature for the Tribe's ceded area. Generated for the 2050s and 2080s under the A1B and A2 greenhouse gas scenarios, using an ensemble of 16 global climate models.

3.3 CCVI Analysis Results

In this section, we provide a summary of analysis results for the 40 species analyzed using the CCVI (Table 8). Detailed results for each species can be found in Appendices 1, 2, and 3. Appendix 1 includes CCVI index scores and sensitivity sub-scores for each species. Appendix 2 lists the information gaps encountered for each species. Appendix 3 includes quick reference fact sheets for each species describing their CCVI results, primary climate sensitivities, a brief assessment of potential additional impacts from climatic changes not considered by the CCVI, and key information gaps.

i. CCVI results for 2050s

CCVI results suggest that most species are presumed stable by the 2050s, with some bird species expected to see increases (Table 8, Fig. 6 & 7). However, several species are expected to be moderately vulnerable (e.g., salmonids, western grebe) or highly vulnerable (e.g., Canada lynx) by the 2050s. Underlying climatic sensitivities vary by taxonomic group (Fig. 8).

Because projected temperature changes for the 2050s within the Stillaguamish watershed fell within the same CCVI bin for temperature exposure (< 3.9° F (2.2° C) warmer) under both the A1B and A2 scenarios, species analyzed at the watershed scale received identical CCVI scores for both scenarios (Table 8). However, at the scale of the Tribe's ceded area, Canada lynx is expected to be highly vulnerable under the A1B scenario but moderately vulnerable under the A2 scenario (Table 8), while mountain goat and western pond turtle are expected to be moderately vulnerable under the A1B scenario but stable under the A2 scenario (Table 8). This is because slightly warmer temperature projections under A1B resulted in portions of the Tribe's ceded area falling into the higher CCVI bin for temperature exposure.

Incorporation of local knowledge from Tribal Natural Resources staff resulted in several changes to the 2050s sensitivity scores for the marbled murrelet, pigeon guillemot, spotted owl, and wolverine. These changes included: diet sensitivity changed from *somewhat increase vulnerability* to *increase vulnerability* for the marbled murrelet; diet sensitivity changed from *neutral* to *somewhat increase vulnerability* for the pigeon guillemot; diet sensitivity changed from *neutral* to *somewhat increase vulnerability*, and disturbance regime shifted from *somewhat increase vulnerability* to *increase vulnerability* for the spotted owl; and anthropogenic barriers changed from *neutral* to *somewhat increase vulnerability* for wolverine. Ultimately, none of these changes resulted in changes to the final CCVI scores for these species.

ii. CCVI results for 2080s

CCVI results suggest that many species may become highly or extremely vulnerable by 2080 (Table 8, Fig. 9); this includes all of the amphibians, reptiles, and aquatic species assessed. However, many birds are estimated to remain stable or see increases. For species that experience increased vulnerability by the 2080s, underlying sensitivities remain largely unchanged from those seen in the 2050s (Fig. 10), with the exception of sea level rise, which becomes a contributing factor to vulnerability for several bird species (Fig. 10).

Because projected temperature changes for the 2080s within the Stillaguamish watershed again fell within the same CCVI bin for temperature exposure (>5.5° F (3.1° C) warmer) under both the A1B and A2 scenarios, species analyzed at the watershed scale again received identical CCVI scores for both scenarios. Because the ranges of species analyzed at the scale of the ceded area fell within a single bin (>5.5° F (3.1° C) warmer) for the 2080s under both the A1B and A2 scenarios, they, too, received identical CCVI scores for both scenarios.

For the 2080s, incorporation of local knowledge from Tribal Natural Resources staff again resulted in changes to sensitivity scores for marbled murrelet, pigeon guillemot, spotted owl, and wolverine. Unlike the 2050s, these resulted in changes to final 2080s CCVI scores for the spotted owl and the marbled murrelet. For the spotted owl, diet sensitivity changed from *neutral* to *somewhat increase vulnerability,* and disturbance regime changed from *somewhat increase vulnerability* to *increase vulnerability*. This resulted in an increase in the spotted owl's final CCVI score from moderately vulnerable to highly vulnerable. For the marbled murrelet, diet sensitivity changed from *somewhat increase vulnerability* to *increase vulnerability*. This resulted in an increase in the marbled murrelet's final CCVI score from moderately vulnerable to highly vulnerable.

3.4 Incorporating Additional Relevant Information

Almost all species were considered likely to be affected by climatic factors not included in the CCVI. While we did not adjust vulnerability rankings to reflect this, these factors should be considered along with the CCVI rankings to better understand species' vulnerability. In some cases, these additional factors may present the most important impacts on species, and will thus be critical to guiding adaptation efforts to address potential negative effects. These additional factors are described for each species in the fact sheets provided in Appendix 3.

Table 8. CCVI rankings for species assessed using NatureServe's CCVI. Bold names indicate species that were identified by the Tribe as a high priority for assessment. Names with an asterisk indicate species that were analyzed at the scale of the Tribe's ceded area; all other species were analyzed at the scale of the Stillaguamish watershed. CCVI Results Key:
IL Increase Likely, PS Presumed Stable, MV Moderately Vulnerable, HV Highly Vulnerable, EV Extremely Vulnerable.

Common Name	Scientific Name	Taxon	2050s A1B	2050s A2	2080s A1B	2080s A2	Confidence
American Beaver	***Castor canadensis***	Mammal	PS	PS	PS	PS	VH
American Pipit	*Anthus rubescens*	Bird	PS	PS	PS	PS	VH
Bald Eagle	*Haliaeetus leucocephalus*	Bird	PS	PS	PS	PS	VH
Black Bellied Plover	*Pluvialis squatarola*	Bird	PS	PS	PS	PS	VH
Black-Tailed Deer	*Odocoileus hemionus columbianus*	Mammal	PS	PS	MV	MV	VH
Brant	Branta bernicla	Bird	PS	PS	PS	PS	VH
Bufflehead	*Bucephala albeola*	Bird	PS	PS	PS	PS	VH
Bull Trout	***Salvelinus confluentus***	Fish	MV	MV	EV	EV	VH
Canada Goose	*Branta canadensis*	Bird	PS	PS	PS	PS	VH
Canada Lynx*	*Lynx canadensis**	Mammal	HV	MV	EV	EV	VH
Cassin's Finch	*Haemorhous cassinii*	Bird	IL	IL	PS	PS	VH
Chinook Salmon	***Oncorhynchus tshawytscha***	Fish	MV	MV	EV	EV	VH
Coho Salmon	***Oncorhynchus kisutch***	Fish	MV	MV	EV	EV	VH
Common Goldeneye	*Bucephala clangula*	Bird	IL	IL	IL	IL	VH
Gray-Crowned Rosy-Finch	*Leucosticte tephrocotis*	Bird	PS	PS	MV	MV	VH
Great Blue Heron	*Ardea herodias*	Bird	PS	PS	PS	PS	VH
Greater Scaup	*Aythya marila*	Bird	PS	PS	PS	PS	VH
Grizzly Bear	*Ursus arctos horribilis*	Mammal	PS	PS	MV	MV	VH
Marbled Murrelet	***Brachyramphus marmoratus***	Bird	PS	PS	HV	HV	VH
Mountain Goat*	***Oreamnos americanus****	Mammal	MV	PS	EV	EV	VH
Mountain Lion	*Puma concolor*	Mammal	PS	PS	PS	PS	VH
Northern Flying Squirrel	*Glaucomys sabrinus*	Mammal	PS	PS	HV	HV	VH
Northern Goshawk	*Accipiter gentilis*	Bird	IL	IL	IL	IL	VH
Northern Pintail*	***Anas acuta***	Bird	PS	PS	PS	PS	VH

Common Name	Scientific Name	Taxon	2050s A1B	2050s A2	2080s A1B	2080s A2	Confidence
Olive Sided Flycatcher	*Contopus cooperi*	Bird	IL	IL	IL	IL	VH
Oregon Spotted Frog	***Rana pretiosa***	Amphibian	PS	PS	HV	HV	VH
Pigeon Guillemont	*Cepphus columba*	Bird	PS	PS	IL	IL	VH
Pileated Woodpecker	*Dryocopus pileatus*	Bird	PS	PS	PS	PS	VH
Red-Breasted Sapsucker	*Sphyrapicus ruber*	Bird	IL	IL	IL	IL	VH
Rhinoceros Auklet	*Cerorhinca monocerata*	Bird	PS	PS	PS	PS	VH
Sooty Grouse	*Dendragapus fuliginosus*	Bird	IL	IL	IL	IL	VH
Spotted Owl	*Strix occidentalis caurina*	Bird	PS	PS	HV	HV	VH
Steelhead	***Oncorhynchus mykiss***	Fish	MV	MV	EV	EV	VH
Swainson's Thrush	*Catharus ustulatus*	Bird	IL	IL	IL	IL	VH
Trumpeter Swan	*Cygnus buccinator*	Bird	PS	PS	PS	PS	VH
Western Grebe	***Aechmophorus occidentalis***	Bird	MV	MV	HV	HV	VH
Western Pond Turtle*	***Actinemys marmorata****	Reptile	MV	PS	EV	EV	VH
Western Sandpiper	*Calidris mauri*	Bird	IL	IL	IL	IL	VH
Wilson's Warbler	*Cardellina pusilla*	Bird	IL	IL	IL	IL	VH
Wolverine	***Gulo gulo***	Mammal	PS	PS	EV	EV	VH

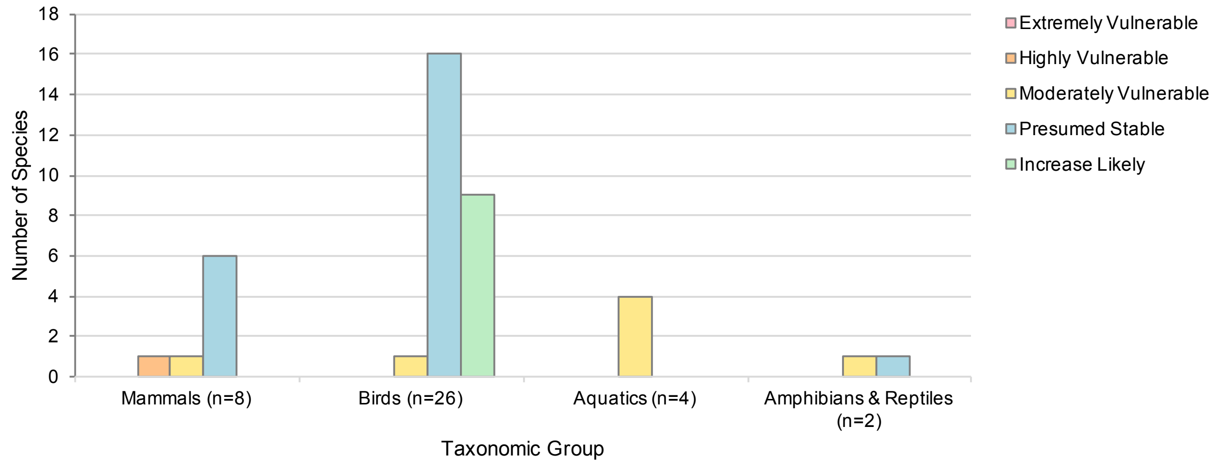

Figure 6. CCVI vulnerability rankings for the 2050s using a medium emissions scenario (A1B), by taxonomic group.

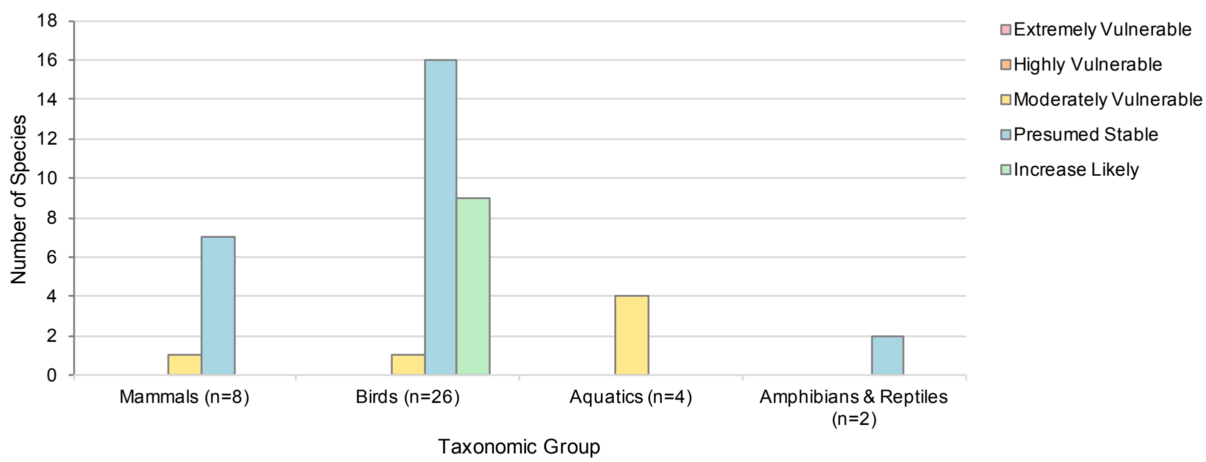

Figure 7. CCVI vulnerability rankings for the 2050s using a high emissions scenario (A2), by taxonomic group.

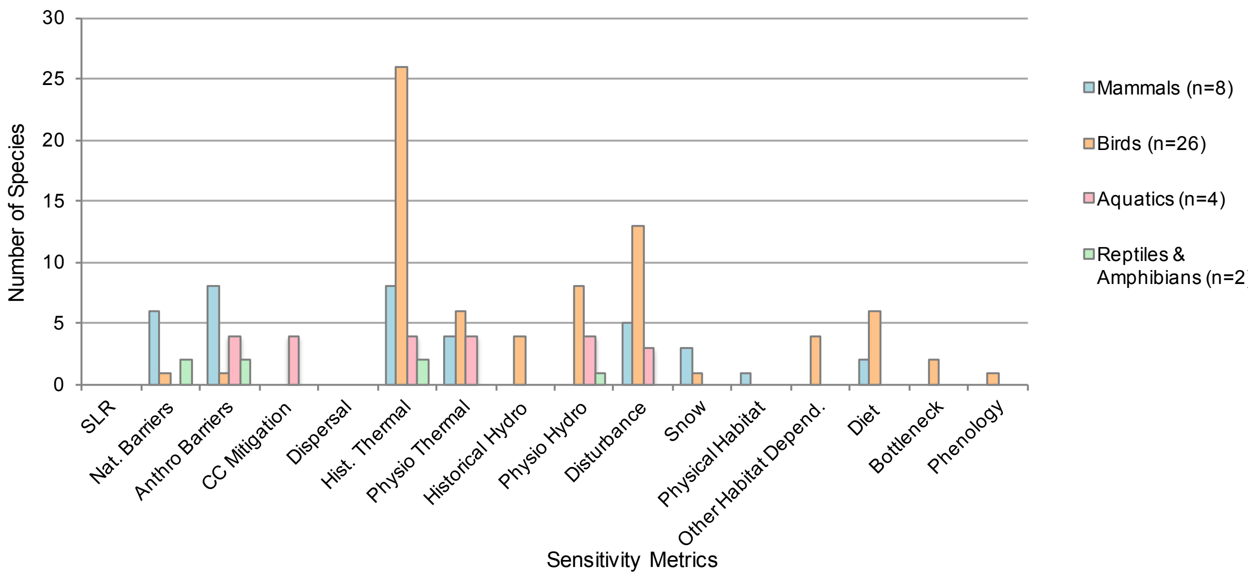

Figure 8. Climate sensitivities and indirect climatic exposures contributing to CCVI rankings for the 2050s, by taxonomic group. Only sensitivities that increase vulnerability are shown (see Table 2 for full descriptions of sensitivity factors).

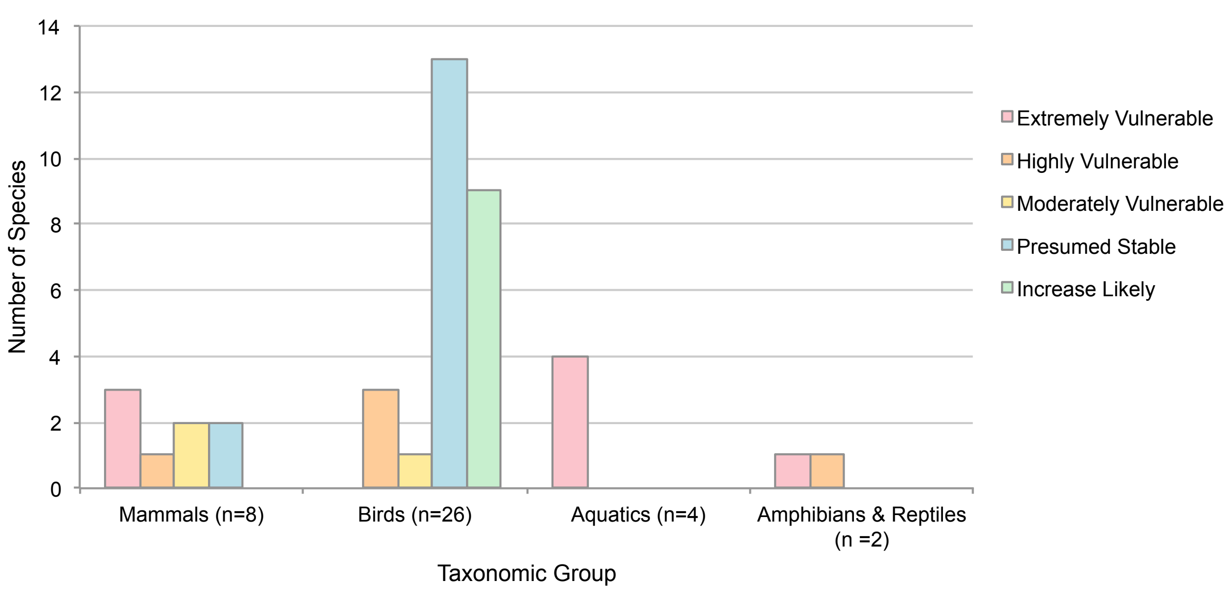

Figure 9. CCVI vulnerability rankings for the 2080s, by taxonomic group. Results are identical for both the medium (A1B) and high (A2) emissions scenarios.

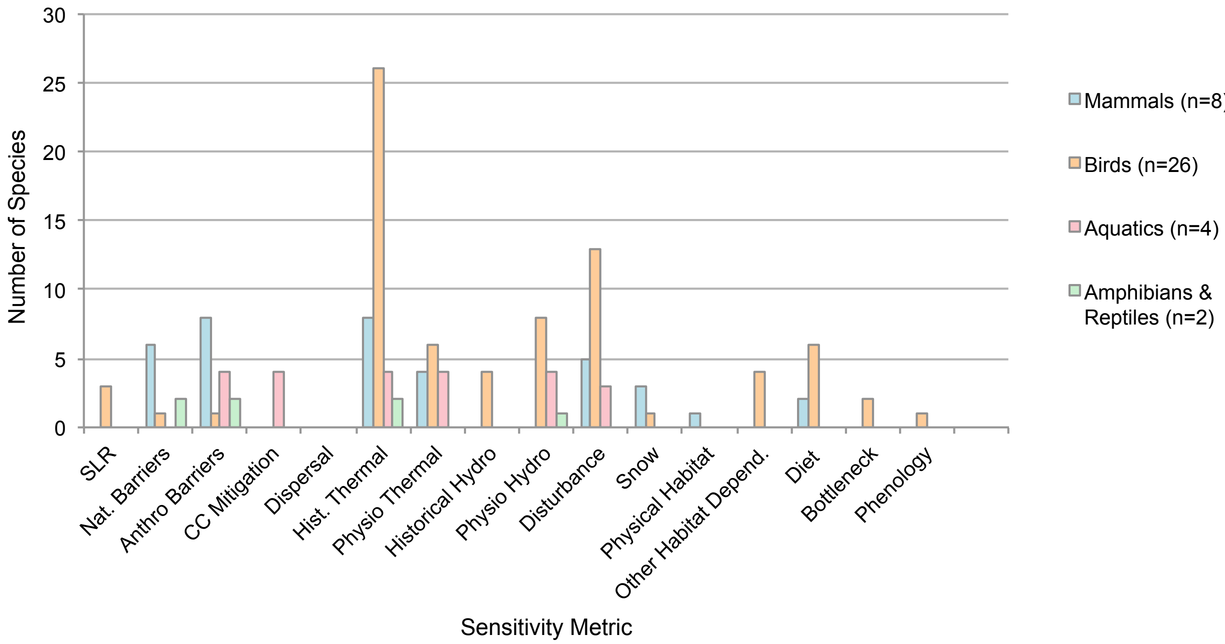

Figure 10. Climate sensitivities and indirect climatic exposures contributing to CCVI rankings for the 2080s, by taxonomic group. Only sensitivities that increase vulnerability are shown (see Table 2 for full descriptions of sensitivity factors).

3.5 Results of Qualitative Vulnerability Assessment

i. Species

Qualitatively assessed species (Table 4) did not receive a vulnerability ranking, but rather were assessed for climatic sensitivities that may influence their vulnerability to future climatic changes. As with species assessed using the CCVI, climatic sensitivities for qualitatively assessed species varied individualistically; details for each species, including primary climatic sensitivities and potential impacts from additional factors not considered in the CCVI, can be found in the fact sheets provided in Appendix 3. Particularly for marine species (e.g., bivalves, forage fish), factors not considered in the CCVI (e.g., increasing ocean temperatures and acidification) may be the greatest contributors to vulnerability.

ii. Habitats

All habitats were assessed qualitatively based on their sensitivity scores[7] and projected climate exposure for the 2050s, and given estimated vulnerability rankings (low, moderate, or high; Table 9). Similar to species results, habitats varied in which sensitivities contributed to their vulnerability; details for each habitat can be found in the fact sheets provided in Appendix 3. Unlike assessed species, no habitats were estimated to experience increases or to be presumed stable; rather, all were estimated to be moderately to highly vulnerable.

Table 9. Qualitative Assessment Results for Habitats. Bold names indicate habitats that were identified by the Tribe as a high priority for assessment. Ranking categories: **Low**, **Moderate**, **High**.

Habitat Type	Qualitative Vulnerability Ranking
Estuary: Salt Marsh, Eelgrass, Mud Flat	**Moderate** *to* **High**
Forest	**High**
Freshwater Aquatic	**High**
Marine: Nearshore, Gravel Beaches	**Moderate**
Marine: Open Water	**Moderate**
Montane: Alpine, Subalpine, Meadow, Talus	**High**
Old Growth Forest	**Moderate**
Open Meadow	**High**
Riparian	**Moderate** *to* **High**
Wetland: Forested Wetland	**High**

4. KEY FINDINGS

Here, we discuss the main findings of our analysis. We first review key CCVI findings for the 2050s and 2080s, highlighting the primary sensitivities contributing to vulnerability for each taxonomic group (mammals, birds, aquatic species, and amphibians and reptiles). We then discuss key findings of our qualitative habitat assessment.

4.1 Key CCVI Findings for the 2050s

Vulnerability index scores for the 2050s ranged from likely to expand to highly vulnerable, with the majority of species classified as stable or likely to expand by the 2050s (Fig. 6, Fig. 7). Two sensitivity factors, historical thermal niche and presence of anthropogenic barriers, are expected to increase vulnerability across all taxonomic groups (Fig. 8, Appendix 1a). Because species within the Stillaguamish watershed and the Tribe's ceded area have experienced relatively stable climatic conditions over the past fifty years, they are expected to have relatively low thermal tolerances to future temperature increases. Significant anthropogenic barriers (e.g., highways, dams, and urban areas) in the assessment area are expected to increase species' vulnerability by impeding their ability to move across the landscape to track shifting areas of climatic suitability. Physiological thermal niche, physiologic hydrologic niche, disturbance, and natural barriers are also expected to increase vulnerability across most taxonomic groups (Fig. 8, Appendix 1a).

i. Mammals

The majority of mammal species assessed are estimated to remain stable by the 2050s, with two exceptions. Canada lynx is estimated to be highly vulnerable to climate change by mid-century under an A1B emissions scenario (Fig. 6).[13] Canada lynx is physiologically adapted to cold alpine and subalpine habitats (physiological thermal niche, Fig. 8, Appendix 1a), and also dependent on persistent snowpack levels (dependence on snow cover habitats, Fig. 8, Appendix 1a), which are expected to decline as temperatures increase. Mountain goat is also expected to be moderately vulnerable to climate change by mid-century under an A1B emissions scenario (Fig. 6).[14] This is because mountain goat is physiologically adapted to cold alpine and subalpine zones (physiological thermal niche, Fig. 8, Appendix 1a), and thus is sensitive to slight increases in air temperature.

ii. Birds

Birds are the sole taxonomic group for which species (35% of the birds assessed) are estimated to expand by the 2050s. This is largely due to birds' relative insensitivity to natural and anthropogenic barriers (Fig. 8, Appendix 1a), which may help them to shift their ranges to new areas of climatic suitability. Despite this, western grebe is expected to be moderately vulnerable to climate change by the 2050s. This is because of the western grebe's specific nesting habitat requirements (physiological hydrologic niche, Fig. 8, Appendix 1a) and sensitivity to fluctuating water levels (disturbance regime, Fig. 8, Appendix 1a).

iii. Aquatic Species

All four fish species assessed (chinook salmon, coho salmon, bull trout, and steelhead) are expected to be moderately vulnerable to climate change by the 2050s. This is due to salmonids' narrow thermal tolerance (physiological thermal niche, Fig. 8, Appendix 1a) and sensitivity to disturbance (disturbance regime, Fig. 8, Appendix 1a). Rising stream temperatures are expected to more frequently exceed thermal tolerances of adult salmonids, which will result in increased stress levels and the formation of thermal migration barriers. Furthermore, flooding events can scour streambeds and remove and/or crush salmonid eggs, while low flow events can reduce salmonid mobility, health, survival, and habitat area.

iv. Amphibians and Reptiles

While the Oregon spotted frog is expected to be stable under both the A1B and A2 emissions scenarios, the western pond turtle is expected to be stable under the A2 emissions scenario but moderately vulnerable under the A1B emissions scenario. This is because the western pond turtle is somewhat dependent on seasonal hydrologic regimes (physiological hydrological niche, Fig. 8, Appendix 1b), which are sensitive to shifts in temperature and precipitation, and is sensitive to anthropogenic barriers such as roads (anthropogenic barriers, Fig. 8, Appendix 1b) that may limit its dispersal to newly climatically suitable areas.

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[13] This ranking is calculated using temperature projections for the 2050s under the A1B emissions scenario (Fig. 6). Note that this species is ranked as moderately vulnerable under the A2 emissions scenario.

[14] This ranking is calculated using temperature projections for the 2050s under the A1B emissions scenario (Fig. 6). Note that this species is ranked as presumed stable under the A2 emissions scenario.

4.2 Key CCVI Findings for the 2080s

By the 2080s many assessed species are expected to become highly or extremely vulnerable to climate change, including all amphibians and reptiles, and all aquatic species (Fig. 9). Historical thermal niche, presence of anthropogenic barriers, and physiological thermal niche again contributed to increases in climate vulnerability for most taxonomic groups (Fig. 10, Appendix 1b), with sea level rise additionally contributing to the vulnerability of several bird species (Fig. 10, Appendix 1b).

i. Mammals

By the 2080s, the northern flying squirrel is expected to be highly vulnerable to climate change, and three additional mammal species – Canada lynx, mountain goat, and wolverine – are expected to be extremely vulnerable. Each of the extremely vulnerable species is physiologically adapted to cold alpine and subalpine zones (physiological thermal niche, Fig. 10, Appendix 1b), and thus extremely sensitive to increases in air temperature. In addition, both Canada lynx and wolverine are strongly dependent on persistent snowpack (dependence on snow, Fig. 10, Appendix 1b), which is projected to decline as temperatures increase.

Within Washington State, NatureServe classifies Canada lynx and wolverine as critically imperiled, and mountain goat as vulnerable. Their conservation status and high climate vulnerabilities suggest that these species should be high priorities for climate adaptation planning.

ii. Birds

As in the 2050s, most bird species are expected to remain stable or increase by the 2080s. However, marbled murrelet, spotted owl, and western grebe are all expected to be highly vulnerable. Each of these species is vulnerable to shifts in disturbance regimes (disturbance regimes, Fig. 10, Appendix 1b) such as fires and floods, which can negatively affect spotted owl and marbled murrelet habitat, and reduce the reproductive success of western grebe. The specialized diets (diet, Fig. 10, Appendix 1b) of these three species are also expected to increase their vulnerability. Marbled murrelet is highly dependent on forage fish, and is known to defer breeding during food shortages. The primary food source of the spotted owl is the northern flying squirrel, which is currently experiencing population declines as a result of forest thinning throughout the Pacific Northwest, and is also estimated in this assessment to become highly vulnerable by the 2080s. The western grebe consumes a variety of fishes, but these food sources must be in close proximity to breeding ponds, as this species rarely flies outside of migration.

Within Washington State, NatureServe classifies spotted owl as critically imperiled, and marbled murrelet and western grebe as vulnerable. Their conservation status and high climate vulnerabilities suggest that these species should be high priorities for adaptation planning.

iii. Aquatic Species

All four of the aquatic species evaluated – chinook salmon, coho salmon, steelhead, and bull trout – are expected to be extremely vulnerable by the 2080s (Fig. 9). The underlying causes of their vulnerability are largely unchanged from the 2050s, with the two main drivers being narrow thermal tolerances (physiological thermal niche, Fig. 10, Appendix 1b) and sensitivity to disturbances (e.g., extreme high and low flows) (disturbance regime, Fig. 10, Appendix 1b).

iv. Amphibians and Reptiles

By the 2080s, Oregon spotted frog is estimated to be highly vulnerable and western pond turtle to be extremely vulnerable. As in the 2050s, the two main drivers of vulnerability for western pond turtle remain dependence on seasonal hydrologic regimes (physiological hydrological niche, Fig. 10, Appendix 1b) and anthropogenic barriers such as roads (anthropogenic barriers, Fig. 10, Appendix 1b).

4.3 Key Findings for Habitats

All ten habitat types evaluated in this assessment are estimated to be at least moderately vulnerable to climate change (Table 9) and five are estimated to be highly vulnerable, including forest, freshwater aquatic, wetland (forested wetland), montane, and open meadow habitats. Each of these is expected to be highly vulnerable due to their relatively high climate sensitivities and projected exposures to future changes in temperature and precipitation.

i. Forest

Increasing temperatures are expected to extend the length of the growing season for western Washington forests, and lead to changes in forest species composition. Warmer temperatures may also facilitate the spread of invasive species, insects, and diseases (including those not previously found in this region). Increases in precipitation could lead to increased growth rates and productivity in drier, higher elevation forests that are currently water-limited, while decreases in precipitation during the growing season could lead to decreased growth rates across most forests. Increases in temperature and dryness during the growing season will likely result in increased fire risk. Numerous assessed species are dependent of forest habitats, including Canada lynx, grizzly bear, mountain goat, mountain lion, northern flying squirrel, Pacific jumping mouse, pileated woodpecker, northern goshawk, marbled murrelet, purple martin, sooty grouse, spotted owl, swainson's thrush, red huckleberry, Alaska cedar, and western red cedar.

ii. Freshwater Aquatic

Increasing stream temperatures are expected to negatively affect species adapted to cool freshwater habitats. Freshwater aquatic habitats are also expected to experience increased flooding as a result of increased precipitation during the wet season, and a greater proportion of that precipitation falling as rain instead of snow. Climate-driven changes in fire regimes, insects, and disease could indirectly impact freshwater habitats by affecting neighboring vegetation. Assessed species that are dependent on freshwater aquatic habitats include chinook salmon, coho salmon, steelhead, bull trout, green sturgeon, white sturgeon, and Pacific lamprey.

iii. Montane: Alpine, Subalpine, Meadow, Talus

Warmer temperatures are expected to increase growth and productivity in high-elevation habitats that are currently limited by cold temperatures, and to facilitate tree encroachment into meadows and other suitable alpine areas. Changes in summer precipitation could alternatively lead to increases in biomass production and biodiversity rates (if precipitation increases), or decreased growth and higher likelihood of fire (if precipitation decreases). Less snow in winter could lead to a longer growing season but negatively affect snow dependent species. Numerous assessed species are dependent on montane habitats, including purple martin, gray-crowned rosy-finch, wolverine, Canada lynx, grizzly bear, mountain goat, elk, and Pacific jumping mouse.

iv. Open Meadow

Warming temperatures will affect different types of meadows differently: wet and cool meadows may see biomass increases but also tree encroachment, while hot and dry meadows may see declines in biomass production and overall biodiversity. Meadows will be especially sensitive to changes in precipitation, with effects varying by meadow type and location. Because of their relatively small size, meadow habitats may be especially sensitive to indirect effects of climate change (e.g., fire, flooding, wind, disease, pests). Assessed species that are dependent on open meadow habitats include American pipit, elk, mountain goat, and Pacific jumping mouse.

v. Wetland: Forested Wetland

Increasing temperatures may result in accelerated drying for some wetlands, and may lead to mismatches between when species require these wetlands seasonally (e.g., timing of reproduction or metamorphosis) and earlier drying. Declining precipitation during the dry season could also lead to earlier wetland drying and a shorter wet season. Assessed species that are dependent on forested wetlands include Oregon spotted frog, western pond turtle, great blue heron, greater scaup, northern pintail, northern shoveler, bufflehead, and common goldeneye.

5. LIMITATIONS OF THE CCVI

While NatureServe's CCVI is a widely used and useful tool, it has several limitations. First, there are several climate sensitivities known to influence vulnerability that are not accounted for by this index. For example, assessment of migratory bird species considered only their summer ranges; though we were able to assess their vulnerability within the Stillaguamish watershed (where many received a score of "Not Vulnerable / Increase Likely"), considering impacts and sensitivities in their wintering ranges could result in changes to their overall score. In addition, no sensitivity factors addressed species sensitivity to pathogens and/or diseases, though climate change could result in changes to virulence or spread to previously unaffected areas. Furthermore, sensitivity to competition with native or non-native species was not addressed in the CCVI, but climate change is expected to influence competitive interactions.

NatureServe released an update to the CCVI, CCVI 3.0, after we had already initiated our analysis using CCVI 2.1. Due to time constraints, we were unable to repeat the analysis using the newer version. However, CCVI 3.0 addresses many of the limitations described above. For example, CCVI 3.0 incorporates a climate change exposure index for South America, improving evaluation of long distance migrants with winter ranges outside the assessment area.[15] In addition, CCVI 3.0 incorporates a "sensitivity to pathogens or natural enemies" factor that addresses potential sensitivities due to pathogens or enemies.

It is also important to note that CCVI 3.0 has eliminated both the *somewhat decrease vulnerability* and *decrease vulnerability* ranking classifications for indirect climate exposure and climate sensitivity. Furthermore, the new version has eliminated the *Increase Likely* vulnerability ranking, which was removed "because increases are hard to predict, especially in the context of a fixed assessment area" (Young et al. 2015). This change has significant implications for our results, because 35% of the bird species we evaluated were estimated to expand by mid-century. Therefore, we recommend interpreting vulnerability rankings that suggest future expansion within the Stillaguamish watershed or Tribe's ceded area as *presumed stable*.

Another important consideration is that the CCVI does not incorporate species conservation status in its ranking. Rather, conservation status should be evaluated in concert with CCVI scores when developing climate adaptation actions and priorities.

Finally, the CCVI is one of several available approaches for assessing species' vulnerability to climate change, and vulnerability rankings have been shown to vary with the approach taken (Lankford et al. 2014). The rankings we report here also reflect current knowledge derived from a limited set of data sources, and should be expected to change with the provision of new information and additional sources. We would thus encourage interpretation of the CCVI and resulting rankings as a useful, but not final, means of systematically considering the climate exposures and sensitivities contributing to species' vulnerabilities within the Stillaguamish watershed and the Tribe's ceded area. While those species identified as highly vulnerable in this assessment in fact agree well with those identified as such in other regional assessments (e.g., Case et al. 2015), the most useful and robust application of these CCVI results is likely to come from considering why a ranking was given, rather than focusing on the ranking itself.

[15] This climate change exposure index uses a continuous numerical scale from 0 to 14 that compares projections of annual climate moisture deficit and mean annual temperature for the 2050s using an A1B emissions scenario (relative to the 1961-1990 average).

6. FUTURE RESEARCH NEEDS

While there were in most cases sufficient data to conduct an informative assessment for the Tribe's priority species and habitats, there are many places where additional research would greatly increase our understanding of the climatic exposures and sensitivities underlying vulnerability (Appendix 2). For example, many species lacked GIS range data, a fundamental tool for assessment and adaptation. For the majority of the species evaluated qualitatively in this assessment, missing GIS range data was the sole information gap preventing quantitative analysis using the CCVI. Furthermore, information gaps regarding species' phonological responses to climate change, and dependence on disturbance regimes influenced by climate change were present for the majority of species evaluated in this assessment. Vulnerability rankings and adaptation strategies should thus be re-assessed as these information gaps are filled, ideally within the context of an adaptive management framework.

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Appendix 1

NatureServe Climate Change Vulnerability Index (CCVI) Rankings, Confidence Scores, and Sensitivity Sub-Scores

Detailed description of sensitivity factors is provided in Table 2.

Sensitivity Scores:

(1) **Greatly Increase Vulnerability:** GI

(2) **Increase Vulnerability**: Inc

(3) **Somewhat Increase Vulnerability:** SI

(4) **Neutral**: N

(5) **Somewhat Decrease Vulnerability:** SD

6) **Decrease Vulnerability**: Dec

(7) **Unknown**

CCVI Rankings (Index):

(1) **Extremely Vulnerable:** EV

(2) **Highly Vulnerable:** HV

(3) **Moderately Vulnerable:** MV

(4) **Not Vulnerable/Presumed Stable:** PS

(5) **Not Vulnerable /Increase Likely:** IL

Confidence:

(1) **Very High:** VH

(2) **High:** H

(3) **Moderate:** M

(4) **Low:** L

Appendix 1a. 2050s

English Name	Species	Taxonomic Group	Sea Level Rise B1	Natural Barriers B2a	Anthropogenic Barriers B2b	Climate Change Mitigation B3	Dispersal/Movement C1	Historical Thermal Niche C2ai	Physiological Thermal Niche C2aii	Historical Hydrological Niche C2bi	Physiological Hydrological Niche C2bii	Disturbance C2c	Ice/Snow C2d	Physical Habitat C3	Depend on Others for Habitat C4a	Diet C4b	Pollinators C4c	Dependent on Others for Dispersal C4d	Other Spp. Interaction C4e	Genetic Variation C5a	Genetic Bottleneck C5b	Phenological Response C6	Documented Response D1	Modeled Change D2	Modeled Overlap D3	Protected Areas D4	Index	Confidence
Stillaguamish Watershed (A1B and A2 Scenarios)																												
American Beaver	*Castor canadensis*	Mammal	N	Inc	SI	N	Dec	Inc	N	SD	SI	N	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
American Pipit	*Anthus rubescens*	Bird	N	N	N	N	Dec	Inc	U	SD	SI	SI	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Bald Eagle	*Haliaeetus leucocephalus*	Bird	N	N	N	N	Dec	Inc	N	SD	N	SI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Black Bellied Plover	*Pluvialis squatarola*	Bird	N	N	N	N	Dec	SI	Inc	SD	SI	SI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Black-Tailed Deer	*Odocoileus hemionus*	Mammal	N	SI	Inc	N	Dec	Inc	N	SD	N	SI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Brant	Branta bernicla	Bird	N	N	N	N	Dec	Inc	N	SI	N	N	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Bufflehead	*Bucephala albeola*	Bird	N	N	N	N	Dec	Inc	N	SD	SI	SI	N	SD	Inc	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Bull Trout	*Salvelinus confluentus*	Fish	N	N	Inc	Inc	Dec	Inc	GI	SD	GI	Inc-SI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Canada Goose	*Branta canadensis*	Bird	N	N	N	N	Dec	Inc	N	SD	SI	SI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Cassin's Finch	*Haemorhous cassinii*	Bird	N	N	N	N	Dec	Inc	Inc	SD	N	N	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Chinook Salmon	*Oncorhynchus tshawytscha*	Fish	N	N	Inc	Inc	Dec	Inc	GI	SD	GI	GI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Coho Salmon	*Oncorhynchus kisutch*	Fish	N	N	Inc	Inc	Dec	Inc	GI	SD	GI	U	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Common Goldeneye	*Bucephala clangula*	Bird	N	N	N	N	Dec	Inc	N	SD	N	U	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Gray-Crowned Rosy-Finch	*Leucosticte tephrocotis*	Bird	N	N	N	N	Dec	SI	GI	SD	N	U	Inc	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Great Blue Heron	*Ardea herodias*	Bird	N	N	N	N	Dec	Inc	N	SD	SI	N	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Greater Scaup	*Aythya marila*	Bird	N	N	N	N	Dec	Inc	N	Inc	SI	U	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Grizzly Bear	*Ursus arctos*	Mammal	N	N	Inc	N	Dec	Inc	Inc	SD	N	SI	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Marbled Murrelet	*Brachyramphus marmoratus*	Bird	N	SI	N	N	Dec	Inc	N	SD	N	SI	N	SD	SI	Inc	N/A	N	N	U	N	SI	U	U	U	U	PS	VH
Mountain Lion	*Puma concolor*	Mammal	N	N	Inc	N	Dec	Inc	N	SD	N	U	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Northern Flying Squirrel	*Glaucomys sabrinus*	Mammal	N	SI	Inc	N	Dec	Inc	N	SD	N	SI	N	SD	N	Inc	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Northern Goshawk	*Accipiter gentilis*	Bird	N	N	N	N	Dec	Inc	N	SD	N	SI	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Olive Sided Flycatcher	*Contopus cooperi*	Bird	N	N	N	N	Dec	Inc	SI	SD	N	SD	N	N	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Oregon Spotted Frog	*Rana pretiosa*	Amphibian	N	SI	Inc	N	N	Inc	U	SD	Inc	U	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Pigeon Guillemont	*Cepphus columba*	Bird	N	N	N	N	Dec	SI	N	SI	N	U	N	SD	N	SI	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Pileated Woodpecker	*Dryocopus pileatus*	Bird	N	N	N	N	Dec	Inc	N	SD	N	SI	N	SD	N	Inc	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Red-Breasted Sapsucker	*Sphyrapicus ruber*	Bird	N	N	N	N	Dec	Inc	N	SD	N	U	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Rhinoceros Auklet	*Cerorhinca monocerata*	Bird	N	N	N	N	Dec	Inc	N	Inc	N	SI	N	SD	N	SI	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Sooty Grouse	*Dendragapus fuliginosus*	Bird	N	N	SI	N	Dec	SI	N	SD	N	SD	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Spotted Owl	*Strix occidentalis caurina*	Bird	N	N	N	N	Dec	Inc	Inc	SD	N	Inc	N	SD	SI	SI	N/A	N	N	U	SI	U	U	U	U	U	PS	VH
Steelhead	*Oncorhynchus mykiss*	Fish	N	N	Inc	Inc	Dec	Inc	GI	SD	GI	Inc	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Swainson's Thrush	*Catharus ustulatus*	Bird	N	N	N	N	Dec	Inc	SI	SD	N	U	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Trumpeter Swan	*Cygnus buccinator*	Bird	N	N	N	N	Dec	SI	N	SD	N	SI	N	SD	N	SD	N/A	N	N	U	Inc	U	U	U	U	U	PS	VH
Western Grebe	*Aechmophorus occidentalis*	Bird	N	N	N	N	Dec	Inc	N	SD	GI	Inc	N	SD	SI	SI	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Western Sandpiper	*Calidris mauri*	Bird	N	N	N	N	Dec	Inc	N	SD	N	N	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Wilson's Warbler	*Cardellina pusilla*	Bird	N	N	N	N	Dec	Inc	N	SD	N	U	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Wolverine	*Gulo gulo*	Mammal	N	Inc	SI	N	Dec	Inc	GI	SD	N	N	GI	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Ceded Area (A1B Scenario)																												
Canada Lynx	Lynx canadensis	Mammal	N	SI	SI	N	Dec	Inc-SI	Inc	SD	N	Inc	GI	SD	N	Inc	N/A	N	N	U	N	U	U	U	U	U	HV	VH
Mountain Goat	*Oreamnos americanus*	Mammal	N	SI	SI	N	Dec	Inc-SI	GI	SD	N	SI	SI	SI	N	N	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Northern Pintail	Anas acuta	Bird	N	N	N	N	Dec	Inc	N	SD	Inc	SI	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Western Pond Turtle	Actinemys marmorata	Reptile	N	SI	GI-In	N	N	Inc	N	SD	SI	U	N	N	N	N	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Ceded Area (A2 Scenario)																												
Canada Lynx	Lynx canadensis	Mammal	N	SI	SI	N	Dec	Inc-SI	Inc	SD	N	Inc	GI	SD	N	Inc	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Mountain Goat	*Oreamnos americanus*	Mammal	N	SI	SI	N	Dec	Inc-SI	GI	SD	N	SI	SI	SI	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Northern Pintail	Anas acuta	Bird	N	N	N	N	Dec	Inc	N	SD	Inc	SI	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Western Pond Turtle	Actinemys marmorata	Reptile	SI	SI	GI - Inc	N	N	Inc	N	SD	SI	U	N	N	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH

Appendix 1b. 2080s

English Name	Species	Taxonomic Group	B1 Sea Level Rise	B2a Natural Barriers	B2b Anthropogenic Barriers	B3 Climate Change Mitigation	C1 Dispersal/Movement	C2ai Historical Thermal Niche	C2aii Physiological Thermal Niche	C2bi Historical Hydrological Niche	C2bii Physiological Hydrological Niche	C2c Disturbance	C2d Ice/Snow	C3 Physical Habitat	C4a Depend on Others for Habitat	C4b Diet	C4c Pollinators	C4d Dependent on Others for Dispersal	C4e Other Spp. Interaction	C5a Genetic Variation	C5b Genetic Bottleneck	C6 Phenological Response	D1 Documented Response	D2 Modeled Change	D3 Modeled Overlap	D4 Protected Areas	Index	Confidence
Stillaguamish Watershed (A1B and A2 Scenarios)																												
American Beaver	*Castor canadensis*	Mammal	N	Inc	SI	N	Dec	Inc	N	SD	SI	N	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
American Pipit	*Anthus rubescens*	Bird	N	N	N	N	Dec	Inc	U	SD	SI	SI	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Bald Eagle	*Haliaeetus leucocephalus*	Bird	N	N	N	N	Dec	Inc	N	SD	N	SI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Black Bellied Plover	*Pluvialis squatarola*	Bird	N	N	N	N	Dec	SI	Inc	SD	SI	SI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Black-Tailed Deer	*Odocoileus hemionus*	Mammal	N	SI	Inc	N	Dec	Inc	N	SD	N	SI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Brant	Branta bernicla	Bird	N	N	N	N	Dec	Inc	N	SI	N	N	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Bufflehead	*Bucephala albeola*	Bird	N	N	N	N	Dec	Inc	N	SD	SI	SI	N	SD	Inc	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Bull Trout	*Salvelinus confluentus*	Fish	N	N	Inc	Inc	Dec	Inc	GI	SD	GI	Inc - SI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	EV	VH
Canada Goose	*Branta canadensis*	Bird	N	N	N	N	Dec	Inc	N	SD	SI	SI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Cassin's Finch	*Haemorhous cassinii*	Bird	N	N	N	N	Dec	Inc	Inc	SD	N	N	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Chinook Salmon	*Oncorhynchus tshawytscha*	Fish	N	N	Inc	Inc	Dec	Inc	GI	SD	GI	GI	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	EV	VH
Coho Salmon	*Oncorhynchus kisutch*	Fish	N	N	Inc	Inc	Dec	Inc	GI	SD	GI	U	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	EV	VH
Common Goldeneye	*Bucephala clangula*	Bird	N	N	N	N	Dec	Inc	N	SD	N	U	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Gray-Crowned Rosy-Finch	*Leucosticte tephrocotis*	Bird	N	N	N	N	Dec	SI	GI	SD	N	U	Inc	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Great Blue Heron	*Ardea herodias*	Bird	N	N	N	N	Dec	Inc	N	SD	SI	N	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Greater Scaup	*Aythya marila*	Bird	SI	N	N	N	Dec	Inc	N	Inc	SI	U	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Grizzly Bear	*Ursus arctos*	Mammal	N	N	Inc	N	Dec	Inc	Inc	SD	N	SI	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	MV	VH
Marbled Murrelet	*Brachyramphus marmoratus*	Bird	N	SI	N	N	Dec	Inc	N	SD	N	SI	N	SD	SI	Inc	N/A	N	N	U	N	SI	U	U	U	U	HV	VH
Mountain Lion	*Puma concolor*	Mammal	N	N	Inc	N	Dec	Inc	N	SD	N	U	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Northern Flying Squirrel	*Glaucomys sabrinus*	Mammal	N	SI	Inc	N	Dec	Inc	N	SD	N	SI	N	SD	N	Inc	N/A	N	N	U	N	U	U	U	U	U	HV	VH
Northern Goshawk	*Accipiter gentilis*	Bird	N	N	N	N	Dec	Inc	N	SD	N	SI	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Olive Sided Flycatcher	*Contopus cooperi*	Bird	N	N	N	N	Dec	Inc	SI	SD	N	SD	N	N	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Oregon Spotted Frog	*Rana pretiosa*	Amphibian	N	SI	Inc	N	N	Inc	U	SD	Inc	U	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	HV	VH
Pigeon Guillemont	*Cepphus columba*	Bird	N	N	N	N	Dec	SI	N	SI	N	U	N	SD	N	SI	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Pileated Woodpecker	*Dryocopus pileatus*	Bird	N	N	N	N	Dec	Inc	N	SD	N	SI	N	SD	N	Inc	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Red-Breasted Sapsucker	*Sphyrapicus ruber*	Bird	N	N	N	N	Dec	Inc	N	SD	N	U	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Rhinoceros Auklet	*Cerorhinca monocerata*	Bird	SI	N	N	N	Dec	Inc	N	Inc	N	SI	N	SD	N	SI	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Sooty Grouse	*Dendragapus fuliginosus*	Bird	N	N	SI	N	Dec	SI	N	SD	N	SD	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Spotted Owl	*Strix occidentalis caurina*	Bird	N	N	N	N	Dec	Inc	Inc	SD	N	Inc	N	SD	SI	SI	N/A	N	N	U	SI	U	U	U	U	U	HV	VH
Steelhead	*Oncorhynchus mykiss*	Fish	N	N	Inc	Inc	Dec	Inc	GI	SD	GI	Inc	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	EV	VH
Swainson's Thrush	*Catharus ustulatus*	Bird	N	N	N	N	Dec	Inc	SI	SD	N	U	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Trumpeter Swan	*Cygnus buccinator*	Bird	N	N	N	N	Dec	SI	N	SD	N	SI	N	SD	N	SD	N/A	N	N	U	Inc	U	U	U	U	U	PS	VH
Western Grebe	*Aechmophorus occidentalis*	Bird	N	N	N	N	Dec	Inc	N	SD	GI	Inc	N	SD	SI	SI	N/A	N	N	U	N	U	U	U	U	U	HV	VH
Western Sandpiper	*Calidris mauri*	Bird	N	N	N	N	Dec	Inc	N	SD	N	N	N	SD	N	N	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Wilson's Warbler	*Cardellina pusilla*	Bird	N	N	N	N	Dec	Inc	N	SD	N	U	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	IL	VH
Wolverine	*Gulo gulo*	Mammal	N	Inc	SI	N	Dec	Inc	GI	SD	N	N	GI	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	EV	VH
Ceded Area (A1B and A2 Scenarios)																												
Canada Lynx	Lynx canadensis	Mammal	N	SI	SI	N	Dec	Inc - SI	Inc	SD	N	Inc	GI	SD	N	Inc	N/A	N	N	U	N	U	U	U	U	U	EV	VH
Mountain Goat	*Oreamnos americanus*	Mammal	N	SI	SI	N	Dec	Inc-SI	GI	SD	N	SI	SI	SI	N	N	N/A	N	N	U	N	U	U	U	U	U	EV	VH
Northern Pintail	Anas acuta	Bird	SI	N	N	N	Dec	Inc	N	SD	Inc	SI	N	SD	N	SD	N/A	N	N	U	N	U	U	U	U	U	PS	VH
Western Pond Turtle	Actinemys marmorata	Reptile	N	SI	GI - Inc	N	N	Inc	N	SD	SI	U	N	N	N	N	N/A	N	N	U	N	U	U	U	U	U	EV	VH

Appendix 2

Information Gaps for Assessed Species

Information Status:

(1) **No Information Available:**

(2) **Information Available:**

(3) **Non-applicable:**

(4) **Unknown:**

No Information Available indicates an information gap for a CCVI factor; *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 CCVI factors that fell under the heading of "Documented Response to Climate Change," which were not included in our assessment due to lack of readily available data.

Appendix 2a. Information Status for Quantitatively Assessed Species

English Name	Species	Taxonomic Group	GIS Range Data	Sea Level Rise B1	Natural Barriers B2a	Anthropogenic Barriers B2b	Climate Change Mitigation B3	Dispersal / Movement C1	Historical Thermal Niche C2ai	Physiological Thermal Niche C2aii	Historical Hydrological Niche C2bi	Physiological Hydrological Niche C2bii	Disturbance C2c	Ice/snow C2d	Physical Habitat C3	Depend on Others for Habitat C4a	Diet C4b	Pollinators C4c	Dependent on Others for Dispersal C4d	Other Species Interaction C4e	Genetic Variation C5a	Genetic Bottleneck C5b	Phenological Response C6	Documented Response D1	Modeled Change D2	Modeled Overlap D3	Protected Areas D4
Stillaguamish Watershed																												
American Beaver	*Castor canadensis*	Mammal																										
American Pipit	*Anthus rubescens*	Bird																										
Bald Eagle	*Haliaeetus leucocephalus*	Bird																										
Black Bellied Plover	*Pluvialis squatarola*	Bird																										
Black-Tailed Deer	*Odocoileus hemionus*	Mammal																										
Brant	*Branta bernicla*	Bird																										
Bufflehead	*Bucephala albeola*	Bird																										
Bull Trout	*Salvelinus confluentus*	Fish																										
Canada Goose	*Branta canadensis*	Bird																										
Cassin's Finch	*Haemorhous cassinii*	Bird																										
Chinook Salmon	*Oncorhynchus tshawytscha*	Fish																										
Coho Salmon	*Oncorhynchus kisutch*	Fish																										
Common Goldeneye	*Bucephala clangula*	Bird																										
Gray-Crowned Rosy-Finch	*Leucosticte tephrocotis*	Bird																										
Great Blue Heron	*Ardea herodias*	Bird																										
Greater Scaup	*Aythya marila*	Bird																										
Grizzly Bear	*Ursus arctos*	Mammal																										
Marbled Murrelet	*Brachyramphus marmoratus*	Bird																										
Mountain Lion	*Puma concolor*	Mammal																										
Northern Flying Squirrel	*Glaucomys sabrinus*	Mammal																										
Northern Goshawk	*Accipiter gentilis*	Bird																										
Olive Sided Flycatcher	*Contopus cooperi*	Bird																										
Oregon Spotted Frog	*Rana pretiosa*	Amphibian																										
Pigeon Guillemont	*Cepphus columba*	Bird																										
Pileated Woodpecker	*Dryocopus pileatus*	Bird																										
Red-Breasted Sapsucker	*Sphyrapicus ruber*	Bird																										
Rhinoceros Auklet	*Cerorhinca monocerata*	Bird																										
Sooty Grouse	*Dendragapus fuliginosus*	Bird																										
Spotted Owl	*Strix occidentalis caurina*	Bird																										
Steelhead	*Oncorhynchus mykiss*	Fish																										
Swainson's Thrush	*Catharus ustulatus*	Bird																										
Trumpeter Swan	*Cygnus buccinator*	Bird																										
Western Grebe	*Aechmophorus occidentalis*	Bird																										
Western Sandpiper	*Calidris mauri*	Bird																										
Wilson's Warbler	*Cardellina pusilla*	Bird																										
Wolverine	*Gulo gulo*	Mammal																										
Point Elliot Treaty Area																												
Canada Lynx	*Lynx canadensis*	Mammal																										
Mountain Goat	*Oreamnos americanus*	Mammal																										
Northern Pintail	*Anas acuta*	Bird																										
Western Pond Turtle	*Actinemys marmorata*	Reptile																										

Appendix 2b. Information Status for Qualitatively Assessed Species

English Name	Species	Taxonomic Group	GIS Range Data	Sea Level Rise B1	Natural Barriers B2a	Anthropogenic Barriers B2b	Climate Change Mitigation B3	Dispersal / Movement C1	Historical Thermal Niche C2ai	Physiological Thermal Niche C2aii	Historical Hydrological Niche C2bi	Physiological Hydrological Niche C2bii	Disturbance C2c	Ice/snow C2d	Physical Habitat C3	Depend on Others for Habitat C4a	Diet C4b	Pollinators C4c	Dependent on Others for Dispersal C4d	Other Species Interaction C4e	Genetic Variation C5a	Genetic Bottleneck C5b	Phenological Response C6	Documented Response D1	Modeled Change D2	Modeled Overlap D3	Protected Areas D4
Stillaguamish Watershed																												
Alaska Blueberry	*Vaccinium alaskaense*	Shrub																										
Alaska Cedar	*Cupressus nootkatensis / Chamaecyparis*	Tree																										
Bivalves	*Bivalvia*	Molluscs																										
Bog Cranberry	*Vaccinium oxycoccos*	Shrub																										
Black Oystercatcher	*Haematopus bachmani*	Bird																										
Cattail	*Typha latifolia*	Plant																										
Elk	*Cervus elaphus*	Mammal																										
Evergreen Huckleberry	*Vaccinium ovatum*	Shrub																										
Forage Fish		Fish																										
Green Sturgeon	*Acipenser medirostris*	Fish																										
Pacific Jumping Mouse	*Zapus trinotatus*	Mammal																										
Pacific Lamprey	*Lampetra tridentata*	Jawless Fishes																										
Purple Martin	*Progne subis*	Bird																										
Red Huckleberry	*Vaccinium parvifolium*	Shrub																										
Western Toad	*Anaxyrus boreas*	Amphibian																										
White Sturgeon	*Acipenser transmotanus*	Fish																										

Appendix 3

Species and Habitats Fact Sheets

Species

Habitats

Common Name: Alaska Blueberry
Scientific Name: *Vaccinium alaskaense*

The Alaska blueberry is sensitive to fire, which can delay berry production. Huckleberries (*Vaccinium spp.*) are sensitive to soil pH, and will only thrive in acidic conditions. This acidic soil requirement could make migration to new locations more challenging.

Key Sensitivities

- **Disturbance** – Somewhat Increase Vulnerability
  Berry production in Alaska blueberry is generally delayed for at least 5 years after a fire. On some sites, production may be reduced for 20 years or longer.[1]

- **Dependence on others for propagule dispersal** – Somewhat Decrease Vulnerability
  Alaska blueberry seeds are dispersed by a wide variety of birds and mammals.[1]

- **Uncommon Geologic Feature** – Somewhat Increase Vulnerability
  Huckleberries (*Vaccinium spp*.) require acidic conditions and can thrive where pH ranges from 4.3 to 5.2. These shrubs require relatively small amounts of many essential elements and are capable of growing on many relatively infertile soils. Alaska blueberry commonly occurs on nitrogen-poor soils. It grows on well-drained sandy and gravelly soils, and on silty loam, but generally reaches greatest abundance on sandy soils.[1]

Additional Factors Not Reflected in the CCVI

An increase in the area burned may negatively impact plant reproduction and berry production. Declines in snowpack and a longer summer drought period may reduce soil moisture and limit growth and reproduction in the future.

Future Research Needs

GIS distribution maps are needed for this species. The pollinator versatility of the Alaska blueberry is unknown.

[1] Forest Service Database http://www.fs.fed.us/database/feis/plants/shrub/vacala/all.html

Common Name: Alaska Cedar
Scientific Name: *Chamaecyparis nootkatensis*

The Alaska cedar grows in the relatively cool, mid-elevation region of the Cascade range in Washington, and is therefore likely to be at a greater risk from climate change.

Key Sensitivities

- **Dispersal / Movement – Neutral**
  Seeds of Alaska cedar are heavier than seeds of the closely related Port Orford cedar and probably are not disseminated beyond 120 m (400 ft). Information is not available on the distance seeds are disseminated by the wind.[1]

- **Physiological Thermal Niche – Increase Vulnerability**
  Alaska cedar grows at elevations from 600 to 2,300 m (2,000 to 7,500 ft) in the Cascade Range in Washington. It is restricted to relatively cool or cold regions within the Stillaguamish watershed, and is therefore at greater risk from climate change.[1,2]

- **Physiological Hydrological Niche – Neutral**
  Alaska cedar is notable within the cypress family for its tolerance of cool and wet conditions. The climate of its natural range is cool and humid. This species is not dependent on a narrowly defined precipitation or hydrologic regime.[1,2]

- **Uncommon Geologic Feature – Somewhat Decrease Vulnerability**
  Best growth and development are on slopes with deep, well-drained soils. However, because of competition with faster growing associates, the species is more frequently found on thin organic soils over bedrock and is able to survive and grow on soils that are deficient in nutrients.[1]

Additional Factors Not Reflected in the CCVI

Potential declines in summer precipitation could negatively affect the growth and competitive advantage of this species. An increase in the number of growing degree days and a decrease in the length of the freeze-free period also threaten Alaska cedar's competitive advantage in some sites.

Future Research Needs

GIS range maps are needed for the Alaska cedar. It is unknown if Alaska cedar is affected by a specific disturbance regime, and it is unknown whether the species is dependent on other species for propagule dispersal.

[1] Griffith, R.S (1992)
[2] Young et al. (2011)

Common Name: American Beaver
Scientific Name: *Castor canadensis*


Photo: Jim Jenkins

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The American beaver received a CCVI ranking of *presumed stable* for both time horizons evaluated (2050s and 2080s).

Key Sensitivities

- **Historical Thermal Niche** – **Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the American beaver has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]

- **Physiological Hydrological Niche** – **Somewhat Increase Vulnerability**
  Water bodies with greatly fluctuating flow or water levels are generally considered poor habitat for the American beaver.[2]

- **Natural Barriers** – **Increase Vulnerability**
  Impassable uplands (cliffs, etc.) that require more than a 10 km route to circumvent act as natural barriers to dispersal. Additionally, if tributaries dry up dispersal from higher elevation lakes, ponds, or wetlands will be impacted.[2]

- **Anthropogenic Barriers** – **Increase Vulnerability**
  Roads (highway and arterial) and arid lands can act as barriers to dispersal.[3]

Additional Factors Not Reflected in the CCVI

Warmer winter temperatures and increased precipitation could contribute to higher streamflows and an increased flood risk, which would negatively affect this species. Declining summer precipitation could result in poor habitat for beavers.

Future Research Needs

It is unknown if the American beaver is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.

[2] Young et al. (2011)

[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/castor-canadensis-0

Common Name: American Pipit
Scientific Name: *Anthus rubescens*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The American pipit received a CCVI ranking of *presumed stable* for both time horizons evaluated (2050s and 2080s). This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche – Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the American pipit has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]

- **Physiological Hydrological Niche – Somewhat Increase Vulnerability**
  The American pipit depends on wetlands and vernal pools, which are sensitive to climate change.[3]

- **Diet – Somewhat Decrease Vulnerability**
  The American pipit feeds on several kinds of arthropods (mostly insects) in summer and also plant seeds in autumn and winter.[3] The species is also known to feed on mollusks, crustaceans, and aquatic worms.[2]

- **Disturbance – Somewhat Increase Vulnerability**
  Increased frequency of wind events could lead to nesting failure as the American pipit nests on the ground in wet and dry meadows, tussocks, or erosion banks, usually partly protected by overhanging vegetation, sod, or rock.[4]

Additional Factors Not Reflected in the CCVI

An earlier shift in the timing of peak spring streamflow could affect some of the wetlands and vernal pools that this species relies on. Declining snowpack may also adversely affect wetlands and vernal pools. An increase in the acidity of marine waters may affect the food source for this species. Storm events and sedimentation may affect food sources for this species.

Future Research Needs

It is unknown if the American pipit is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1]Results incorporate projected temperature change (compared to the baseline average between 1961 and 1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.

[2] Young et al. (2011)

[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/anthus-rubescens

[4] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/095/articles/introduction


Photo: Kenneth Cole Schneider

Common Name: Bald Eagle
Scientific Name: *Haliaeetus leucocephalus*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The bald eagle received a CCVI ranking of *presumed stable* for both time horizons evaluated (2050s and 2080s). This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche – Increase Vulnerability**
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the bald eagle has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]

- **Disturbance – Somewhat Increase Vulnerability**
  Eagles are sensitive to fire, wind, urbanization, and pollution. Fire, wind, and frequent flooding can be destructive at nest sites – destroying large nest trees. [3]

- **Diet – Neutral**
  The bald eagle is classified as a carnivore, piscivore, and an opportunistic forager consuming a range of species depending upon availability. Eagles primarily consume fish where possible and available, but also carrion (particularly in winter).[3]

Additional Factors Not Reflected in the CCVI

An increase in the number of days above 90°F and a decrease in the nights below 10°F may negatively impact this species and lead to changes in its distribution. An increase in the length of the freeze-free period may also facilitate the spread of cold-limited diseases. An increase in the area burned may also negatively impact available habitat.

Future Research Needs

It is unknown whether the bald eagle is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/haliaeetus-leucocephalus-0

Common Name: Bivalve Mollusk (clams, oysters, mussels, scallops)
Scientific Class: Bivalvia

Bivalves have a relatively flexible diet and reside in coastal and estuarine habitats. Sea level rise could inundate coastal habitat areas important for bivalve reproduction and survival.

Key Sensitivities:

- **Dietary Versatility –** Neutral
  Bivalves are filter feeders and consume phytoplankton and zooplankton species.[1]

- **Restriction to Uncommon Geological Features or Derivatives – Somewhat Increase Vulnerability**
  Once bivalve larvae have developed into the mature life stage they attach to gravel, shell, or sand grains, and burrow below the sediment surface.[1]

- **Dispersal / Movement – Somewhat Decrease Vulnerability**
  Larval clams spend a significant amount of time drifting in the water before settling and burrowing beneath the sediment surface. Therefore, larvae may disperse several miles from the parental origins.[1]

Additional Climatic Factors That May Influence Vulnerability:
An increase in ocean temperatures and an increase in the acidity of marine waters will likely affect this species. The chemistry of the ocean along the Washington coast has changed due to the absorption of excess CO_2 from the atmosphere. Local conditions are also affected by variations and trends in upwelling of deeper Pacific Ocean water that is low in pH and high in nutrients, deliveries of nutrients and organic carbon from land, and absorption of other important acidifying atmospheric gases.[2][3] By the end of the century, ocean acidification is projected to result in a 40% reduction, globally, in the rate at which mollusks (e.g., mussels and oysters) form shells, as well as a 17% decline in growth, and a 34% decline in survival.[4] Additionally, an increase in sedimentation from freshwater flooding and scouring will likely have adverse effects.

Data Needs
There is a significant need for natural history information relating to specific families and genera within the large and diverse *Bivalvia* class. These data are necessary to address the specific vulnerabilities of clam, oyster, mussel, and scallop species in coastal Washington.

[1] Washington Department of Fish and Wildlife - Clams
[2] Reeder et al. 2013
[3] Feely et al. 2010
[4] Kroeker et al. 2013

Common Name: Black-bellied Plover
Scientific Name: *Pluvialis squatarola*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The black-bellied plover received a CCVI ranking of *presumed stable* for both time horizons (2050s and 2080s). This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – Somewhat Increase Vulnerability
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the black-bellied plover has experienced slightly lower than average (47.1 - 57° F/26.3 - 31.8° C) temperature variation in the past 50 years.[2]

- **Physiological Thermal Niche** – Increase Vulnerability
  The black-bellied plover is physiologically sensitive to high temperatures. Its body is poorly insulated from heat, and there are high costs associated with its thermoregulation and basal metabolic rate.[3]

- **Physiological Hydrological Niche** – Somewhat Increase Vulnerability
  Precipitation is expected to affect the predatory/prey relationships and the habitat hydrology of the black-bellied plover.[3]

- **Disturbance** – Somewhat Increase Vulnerability
  It is likely to be sensitive to flooding as well as storm frequency and intensity.[3]

Additional Factors Not Reflected in the CCVI

Warming ocean temperatures and an increase in the acidity of marine waters may affect the food source for this species. Coastal flooding and sea-level rise may affect habitat.

Future Research Needs

It is unknown if the black-bellied plover is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/pluvialis-squatarola

Common Name: Black Oystercatcher
Scientific Name: *Haematopus bachmani*


Photo: Ingrid Taylar

The black oystercatcher is a shorebird that is dependent on marine shoreline for all food and nesting habitat.[1 2] This species has excellent movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Diet** – Somewhat Increase Vulnerability
  The diet of the black oystercatcher is mainly composed of Intertidal marine invertebrates, particularly bivalves and other molluscs (limpets, whelks, and chitons); also crabs, sea urchins, isopods, and barnacles. Contrary to the species' common name, oysters are an unimportant component of the species' diet.[2] The flexible diet of the black oystercatcher enables the species to respond to climate mediated shifts in prey abundance and availability. However, many of the species that make up the diet of the black oystercatcher are currently being impacted by ocean acidification. [4]

- **Dispersal / Movement** – Decrease Vulnerability
  The maximum annual dispersal distance of the black oystercatcher is estimated to be greater than 100 km.[3]

- **Disturbance** – Somewhat Increase Vulnerability
  The black oystercatcher is affected by landslides during winter storm events, which lead to increases in sedimentation. [4]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures and an increase in the acidity of marine waters will likely affect the food resources of this species. Additionally, coastal flooding and an increase in sedimentation could have adverse effects on its ability to forage.

Future Research Needs

GIS range maps are needed for the black oystercatcher. It is unknown if the black oystercatcher is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] NatureServe Explorer http://bit.ly/1CqhcFe
[2] The Birds of North America Online http://bit.ly/1JVkUqj
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/node/571
[4] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Black-tailed Deer
Scientific Name: *Odocoileus hemionus columbianus*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Moderately Vulnerable

The black-tailed deer received a CCVI ranking of *presumed stable* for the 2050s, and *moderately vulnerable* for the 2080s. The moderately vulnerable ranking is a result of the species' sensitivity to disturbance regimes and the presence of anthropogenic barriers within the watershed, which hinder the species' ability to move to new locations as conditions change over time.

Key Sensitivities

- **Natural Barriers** – **Somewhat Increase Vulnerability**
  Rugged mountain terrain acts a barrier to dispersal.[2]

- **Anthropogenic Barriers** – **Increase Vulnerability**
  Roads and urban centers act as barriers to dispersal.[2]

- **Historical Thermal Niche** – **Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the black-tailed deer has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[3]

- **Disturbance** – **Somewhat Increase Vulnerability**
  The black-tailed deer is not tightly linked to particular disturbance regimes, although fire could negatively affect habitat quality.[2]

Additional Factors Not Reflected in the CCVI

Declining summer precipitation and a longer dry season could reduce food resources and lead to population declines. An increase in the length of the freeze-free period may facilitate the spread of diseases that were previously limited by cold temperatures. An increase in the area burned may also reduce foraging habitat.

Future Research Needs

It is unknown if the black-tailed deer is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/odocoileus-hemionus-0
[3] Young et al. (2011)

Common Name: Bog Cranberry
Scientific Name: *Vaccinium oxycoccos*

The bog cranberry is sensitive to severe fires, which can delay berry production. The bog cranberry is sensitive to soil pH, and will only thrive in acidic conditions. This acidic soil requirement could make migration to new locations more challenging.

Key Sensitivities

- **Disturbance** – Somewhat Increase Vulnerability
  Members of the family *Ericaceae* easily regenerate from rhizomes following fire. Bog cranberry is able to survive low- to moderate-severity fires because rhizomes are found well below the surface of the bog. Bog cranberry can utilize ash nutrients for rapid growth, preventing additional nutrient loss from the burn site. Wildfires are infrequent in the wet or saturated habitats that bog cranberry generally occupies. However, it is important to note that severe fires that remove the underlying sphagnum layer generally kill underground reproductive organs.[1]

- **Physiological Hydrological Niche** – Somewhat Increase Vulnerability
  Bog cranberry is found in ombrotrophic sphagnum bogs and minerotrophic fens in moist coastal and boreal forests. Bog cranberry grows on peat in these poorly drained, subhygric to hygric sites that have a very high water table. The ground may be saturated for most or part of the year. The bog sites derive water from precipitation only and are generally nutrient-poor and low in productivity.[1]

- **Dependence on others for propagule dispersal** – Somewhat Decrease Vulnerability
  Seeds are dispersed by birds and animals that consume the fruits of the bog cranberry.[1]

- **Uncommon Geologic Feature** - Somewhat Increase Vulnerability
  Bog cranberry is found in ombrotrophic sphagnum bogs and minerotrophic fens in moist coastal and boreal forests. The bog sites derive water from precipitation only and are generally nutrient-poor and low in productivity. The soil is very acidic and pH ranges from about 2.9 to 4.7. Since fen water is derived from ground water as well as precipitation, the fen sites are more ion-rich, and therefore, more alkaline. The soil pH ranges from about 6.0 to 7.5.[1]

Additional Factors Not Reflected in the CCVI

An increase in the area burned may impact plant reproduction and berry production, with low intensity fires potentially promoting bog cranberries and high intensity fires destroying them. Declines in snowpack and a longer summer drought period will reduce soil moisture, dry habitats, and limit growth and reproduction.

Future Research Needs

GIS distribution maps are needed for this species.

[1] Forest Service Database http://www.fs.fed.us/database/feis/plants/shrub/vacoxy/all.html

Common Name: Brant
Scientific Name: *Branta bernicla*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

Brant received a CCVI ranking of *presumed stable* for both time horizons evaluated (2050s and 2080s). This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – Increase Vulnerability
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the brant has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]

- **Diet** – Somewhat Decrease Vulnerability
  Brants feed mainly on eelgrass, green algae, and saltmarsh plants during the nonbreeding season. Recent declines in eelgrass abundance have led to greater dependence on alternative foods. [3]

- **Dispersal / Movement** – Decrease Vulnerability
  The maximum annual dispersal of the brant is estimated to be greater than 100 km.[4]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures will likely affect the food resources of this species. Additionally, coastal flooding and an increase in sedimentation could have adverse effects on its ability to forage.

Future Research Needs

It is unknown if the brant is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics. More research is needed to determine how marsh and eelgrass habitat will respond to climate change.

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[1] Results incorporate projected temperature change (compared to the baseline average between 1961 and 1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/337/articles/introduction
[4] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/branta-bernicla-0

Common Name: Bufflehead
Scientific Name: *Bucephala albeola*


Photo: Tyler Ingram

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The bufflehead received a CCVI ranking of *presumed stable* for both time horizons evaluated (2050s and 2080s). This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – **Increase Vulnerability**
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the bufflehead has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]

- **Physiological Hydrological Niche** – **Somewhat Increase Vulnerability**
  The bufflehead is physiologically sensitive to the pH of the waters it resides in. Though usually moderately alkaline (about pH 8), ponds used range from slightly acidic to highly alkaline.[3] [4]

- **Disturbance** – **Somewhat Increase Vulnerability**
  Flooding may affect the characteristics of ponds used by the bufflehead.[3]

- **Dependence on Other Species for Habitat** – **Increase Vulnerability**
  The Bufflehead is an obligate cavity nester. Buffleheads use cavities excavated by northern flicker (*Colaptes auratus*) and, occasionally, pileated woodpecker (*Dryocopus pileatus*), and avoid cavities with broken tops. pH variation may affect the ability of the species to find suitable ponds to live.[4]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures and the acidity of both marine and freshwater bodies could negatively affect its food resources, such as aquatic invertebrates, crustaceans, and mollusks. Coastal flooding and sedimentation may also adversely impact habitat along the shoreline. An increase in the area burned could impact nesting sites.

Future Research Needs

It is unknown if the bufflehead is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to the baseline average between 1961 and 1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/bucephala-albeola
[4] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/067/articles/introduction

Common Name: Bull Trout
Scientific Name: *Salvelinus confluentus*

CCVI[1] Ranking 2050s: **Moderately Vulnerable**
CCVI Ranking 2080s: **Extremely Vulnerable**

The bull trout received a CCVI ranking of *moderately vulnerable* for the 2050s and *extremely vulnerable* for the 2080s. These vulnerability rankings are a result of the species' sensitivity to water temperatures and disturbance regimes.

Key Exposures and Sensitivities

- **Climate Change Mitigation** – **Increase Vulnerability**
  Sea wall development, which primarily affects the nearshore areas that juvenile salmonids rely on in their critical early marine life stage. Sea wall development could also impede bull trout movement and migration.[2]
- **Anthropogenic Barriers** – **Increase Vulnerability**
  There are no large hydroelectric or flood control dams within the Stillaguamish watershed. However, small diversion structures such as the Cook Slough weir and the Granite Falls fishway pose some fish passage problems. Culverts and tide gates can also act as fish passage barriers.
- **Physiological Thermal Niche** – **Greatly Increase Vulnerability**
  Bull trout require extremely cold water temperatures, from 7.2-10°C.[3] Optimum temperatures for incubation are about 2-4°C.
- **Physiological Hydrological Niche** – **Greatly Increase Vulnerability**
  Spawning usually occurs in gravel riffles of small tributary streams, including lake inlet streams, and is often associated with springs. Areas with large woody debris and rubble substrate are important as juvenile rearing habitat. Habitat includes the bottom of deep pools in cold rivers and large tributary streams, often in moderate to fast currents and large cold-water lakes and reservoirs.[3]
- **Disturbance** – **Greatly Increase Vulnerability**
  Bull trout in the North Fork of the Stillaguamish River select spawning areas that are associated with the gravel riffles of small tributary streams, including lake inlet streams, and are often associated with springs. These spawning locations are at high risk for impacts from late fall and winter flooding. Low flows in the summer impact the amount of water available for adult migration and spawning. Excessive sediment can smother fish eggs, and flooding can destroy redds.[4]

Additional Factors Not Reflected in the CCVI

Warming stream temperatures and declining snowpack will affect the ability of this species to survive in some streams. An earlier shift in the timing of peak spring streamflow could scour streams, lowering reproductive success. An increase in ocean temperatures and ocean acidification could reduce food resources.

Future Research Needs

It is unknown if the bull trout is exhibiting phenological responses to changing temperature or precipitation dynamics. There is very limited baseline data on bull trout within the Stillaguamish watershed. Current species population status is unknown.

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[1] Results incorporate projected temperature change (compared to the baseline average between 1961 and 1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Final Environmental Impact Statement, Elliott Bay Seawall (2013)
[3] NatureServe Explorer http://bit.ly/1HO0rGs
[4] SIRC (2005)

Common Name: Canada Goose
Scientific Name: *Branta canadensis*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The Canada goose received a CCVI ranking of *presumed stable* for both time horizons evaluated (2050s and 2080s). This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche – Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the Canada goose has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]
- **Physiological Hydrological Niche – Somewhat Increase Vulnerability**
  During breeding and wintering the Canada goose inhabits coastal areas: mudflats, shallow tidal waters, and salt-water marshes with extensive beds of bulrush and cord grass near or adjacent to agricultural fields of grain or cover crops. Climate change may affect the suitability of this habitat.[3 4]
- **Disturbance – Somewhat Increase Vulnerability**
  It is not linked to particular disturbance regimes, although changes in flood frequency and/or intensity could negatively affect habitat quality for the Canada goose.[4]
- **Diet – Neutral**
  The species is primarily dependent upon grasses, sedges, and other monocots during summer and spring. In fall and winter, grains, berries, and seeds are increasingly important for high carbohydrate content.[4]

Additional Factors Not Reflected in the CCVI

An increase in the number of days above 90°F and a decrease in the nights below 10°F may negatively impact this species, especially during the breeding season. An increase in the length of the freeze-free period may also facilitate the spread of cold-limited diseases.

Future Research Needs

It is unknown if Canada geese are exhibiting phenological response to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to the baseline average between 1961 and 1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/682/articles/introduction
[4] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/branta-canadensis

Common Name: Canada Lynx
Scientific Name: *Lynx Canadensis*


Photo: Keith Williams

CCVI[1] Ranking 2050s A1B: Highly Vulnerable
CCVI Ranking 2050s A2: Moderately Vulnerable
CCVI Ranking 2080s A1B: Extremely Vulnerable
CCVI Ranking 2080s A2: Extremely Vulnerable

The Canada lynx received a CCVI ranking of *moderately/highly vulnerable* for the 2050s, and *extremely vulnerable* for the 2080s. These high vulnerability rankings are the result of the species' preference for cool habitats in subalpine and alpine regions, as well as the species' dependence on snow.

Key Exposures and Sensitivities

- **Natural Barriers** – **Somewhat Increase Vulnerability**
  Unlikely to venture outside of the alpine / subalpine ecosystems within the Stillaguamish watershed. Primarily resides in the alpine / subalpine region.[2]

- **Anthropogenic Barriers** – **Somewhat Increase Vulnerability**
  Roads, and industrial or urban development can act as barriers to dispersal.[2]

- **Physiological Thermal Niche** – **Increase Vulnerability**
  The Canada lynx is mostly found in alpine and subalpine mountain forests, which are sensitive to climate change.[2]

- **Disturbance** – **Increase Vulnerability**
  Fire and wind have the potential to negatively affect alpine and subalpine mountain forests, a key habitat type for the Canada lynx in the Stillaguamish watershed.[2]

- **Dependence on Ice/Snow** – **Greatly Increase Vulnerability**
  Snowfall and habitat structure may influence lynx distribution at coarse and fine scales. Various features of the snow may influence lynx interaction with its main prey species, the snowshoe hare.[2]

Additional Factors Not Reflected in the CCVI

A decrease in the snowpack, an increase in the number of days above 90°F, and a decrease in the number of nights below 10°F will all negatively impact this species. An increase in the length of the freeze-free period may also facilitate the spread of cold-limited diseases and affect food resources. An increase in the area burned may also negatively impact available habitat during the summer.

Future Research Needs

It is unknown if the Canada lynx is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to the baseline average between 1961 and 1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B).
[2] Climate Change Sensitivity Database http://bit.ly/1NPmFGg

Common Name: Cassin's Finch
Scientific Name: *Haemorhous cassinii*


Photo: Maggie Smith

CCVI[1] Ranking 2050s: **Not Vulnerable / Increase Likely**
CCVI Ranking 2080s: **Presumed Stable**

The Cassin's finch received a CCVI ranking of *presumed stable / increase likely* for the 2050s, and *presumed stable* for the 2080s. This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – **Increase Vulnerability**
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the Cassin's finch has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]
- **Physiological Thermal Niche** – **Increase Vulnerability**
  The Cassin's finch is physiologically sensitive to high temperatures, and has a preference for higher elevations when breeding. Unlike Purple and House finches, both of which increase oxygen consumption at higher temperatures in dry air, Cassin's Finch appears to regulate body temperature only by continuing to depress metabolism as temperature increases.[3]
- **Dispersal / Movement** – **Decrease Vulnerability**
  Though dispersal has not been well studied, Cassin's Finch appears to be both an altitudinal and latitudinal migrant throughout its range. Birds move to lower elevations in fall, but some individuals can be found in breeding areas in fall and winter, indicating that some birds may not migrate at all.[4]
- **Diet** – **Somewhat Decrease Vulnerability**
  The diet of the Cassin's finch is mainly comprised of vegetable matter, particularly buds, berries, and other fruits, seeds, some insects. Forages mostly on ground; removes seeds from open cones, and insects from conifer foliage.[4]

Additional Factors Not Reflected in the CCVI

An increase in the number of days above 90°F and a decrease in the nights below 10°F will negatively impact this heat-intolerant species. An increase in the length of the freeze-free period may also facilitate the spread of cold-limited diseases and affect food resources. An increase in the area burned may also negatively impact available habitat.

Future Research Needs

It is unknown if the Cassin's finch is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/carpodacus-cassinii
[4] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/240/articles/introduction

Common Name: Broadleaf Cattail
Scientific Name: *Typha latifolia*


Photo: Michael Pierce

The broadleaf cattail is able to germinate in a wide variety environmental conditions, making the species somewhat resilient to environmental perturbations stemming from climate change. While the species is tolerant of fluctuating water levels, documented cases of plant mortality have been reported for certain flood levels.

Key Sensitivities

- **Dispersal / Movement – Neutral**
  Broadleaf cattail seeds are transported by wind, water, and substrate movement. Achenes have numerous long slender hairs at the base that allow fruits to float on water and blow in the wind. Seeds are also dispersed through soil movement when mud clings to animals or people. Broadleaf cattail produces abundant seeds.[1]

- **Disturbance – Somewhat Increase Vulnerability**
  Broadleaf cattail is tolerant of fluctuating water levels and some flooding (stands have been documented growing in 3 feet of water (1 meter)); however, death or colonization failure has occurred at flood levels as low as 25 inches (63 cm). The species is described as fairly drought tolerant.[1]

- **Uncommon Geologic Feature – Somewhat Decrease Vulnerability**
  Broadleaf cattail seeds germinate best in warm temperatures and high light conditions. Seeds germinate in acid, basic, or neutral pH conditions, and ash extracts have increased broadleaf cattail germination. Reduced oxygen levels through the manipulation of gases in the air or through submersion have also increased broadleaf cattail germination success.[1]

Additional Climatic Factors That May Influence Vulnerability

Although this species is somewhat tolerant of flooding, **earlier spring snowmelt** and potentially **higher winter streamflow** could adversely affect cattail reproduction and survival. **Low summer sreamflows** could also negatively impact this species in watersheds fed at least in part by snowmelt.

Future Research Needs

GIS distribution maps are needed for this species.

[1] Forest Service Database http://www.fs.fed.us/database/feis/plants/graminoid/typlat/all.html

Common Name: Chinook Salmon
Scientific Name: *Oncorhynchus tshawytscha*

CCVI[1] Ranking 2050s: Moderately Vulnerable
CCVI Ranking 2080s: Extremely Vulnerable

Chinook salmon received a CCVI ranking of *moderately vulnerable* for the 2050s, and *extremely vulnerable* for the 2080s. These high vulnerability rankings are the result of the species' sensitivity to water temperatures and disturbance regimes.

Key Sensitivities and Exposures

- **Climate Change Mitigation** – **Increase Vulnerability**
  Sea wall development, which primarily affects the nearshore areas that juvenile salmonids rely on in their critical early marine life stage, could impede Chinook salmon movement and migration.[2]
- **Anthropogenic Barriers** – **Increase Vulnerability**
  There are no large hydroelectric or flood control dams within the Stillaguamish watershed. However, small diversion structures such as the Cook Slough weir and the Granite Falls fishway pose some fish passage problems. Culverts and tide gates can also act as fish passage barriers.
- **Physiological Thermal Niche** – **Greatly Increase Vulnerability**
  Chinook salmon require large, deep cold pools for holding prior to spawning.[3] Constant water temperatures above 9-10 °C may reduce survival of Chinook embryos and alevins.[4] Migration blockages can occur when water temperatures exceed 21°C. Migration blockages or delays can contribute to reproductive failure. [5]
- **Physiological Hydrological Niche** – **Greatly Increase Vulnerability**
  Successful adult upstream migration requires adequate water quality and suitable streamflow velocity, temperature, cover and depth. Chinook salmon also require large, deep, cold pools for holding prior to spawning. Substrate composition is also an import habitat requirement for salmon during spawning.[6]
- **Disturbance** – **Greatly Increase Vulnerability**
  Chinook salmon in the North Fork of the Stillaguamish River select spawning areas associated with tail outs, riffles, and bars in deeper portions of the low-flow channel area. These locations are vulnerable to the effects of late fall and winter flooding; excessive sediment can smother eggs and flooding can destroy redds.[6] Low flows in summer impact water availability for adult migration and spawning.

Additional Factors Not Reflected in the CCVI

Warming stream temperatures and declining snowpack will affect the ability of this species to survive in some streams. An earlier shift in the timing of peak spring streamflow could scour streams, lowering reproductive success. An increase in ocean temperatures and sedimentation could reduce food resources.

Future Research Needs

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[1] Results incorporate projected temperature change (compared to the baseline average between 1961 and 1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Final Environmental Impact Statement, Elliott Bay Seawall (2013)
[3] NatureServe Explorer http://bit.ly/1TmvYBd
[4] Richter, A., Kolmes, S. 2003. Appendix L: Maximum Temperature: Upper optimal temperature limits for salmonids in the Willamette and lower Columbia Rivers. http://www.nwfsc.noaa.gov/trt/wlc/viability_criteria.cfm
[5] McCullough, D.A. 1999. A review and synthesis of effects of alterations of the water temperature regime on freshwater life stages of salmonids, with special reference to chinook salmon. USEPA Report 910-R-99-010. 279 p.
[6] SIRC (2005)

It is unknown if Chinook salmon are exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

Common Name: Coho Salmon
Scientific Name: *Oncorhynchus kisutch*

CCVI[1] Ranking 2050s: Moderately Vulnerable
CCVI Ranking 2080s: Extremely Vulnerable


Photo: Oregon BLM

Coho salmon received a CCVI ranking of *moderately vulnerable* for the 2050s and *extremely vulnerable* for the 2080s. This high vulnerability ranking is a result of the species' dependence on cold water temperatures and sufficient stream flow levels for migration.

Key Sensitivities and Exposures

- **Climate Change Mitigation** – **Increase Vulnerability**
  Sea wall development, which primarily affects the nearshore areas that juvenile salmonids rely on in their critical early marine life stage, could also impede Coho salmon movement and migration.[2]

- **Anthropogenic Barriers** – **Increase Vulnerability**
  There are no large hydroelectric or flood control dams within the Stillaguamish watershed. However, small diversion structures such as the Cook Slough weir and the Granite Falls fishway pose some fish passage problems. Culverts and tide gates can also act as fish passage barriers.[3]

- **Physiological Thermal Niche** – **Greatly Increase Vulnerability**
  Coho salmon require cold tributaries, between 6 to 12 °C.[4]

- **Physiological Hydrological Niche** – **Greatly Increase Vulnerability**
  Adult Coho migrate up streams typically in late summer and fall when heavy fall rains result in flows strong enough to allow spawning in the smaller tributaries. The salmon spawn in streams, generally in forested areas, in loose coarse gravel at heads of riffles in rounded troughs excavated by females where water is 10 to 54 cm deep.[4]

Additional Factors Not Reflected in the CCVI

An earlier shift in the timing of peak spring streamflow could scour streams and lead to lower reproductive success. Warming stream temperatures and declining snowpack may also affect the ability of the species to survive in some streams. An increase in ocean temperatures could reduce food resources.

Future Research Needs

It is unknown if Coho salmon are dependent on a disturbance regime that is likely to be impacted by climate change.

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[1] Results incorporate projected temperature change (compared to the baseline average between 1961 and 1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Final Environmental Impact Statement, Elliott Bay Seawall (2013)
[3] Salmon Habitat Limiting Factors Final Report
[4] NatureServe Explorer http://bit.ly/1HinaDW

Common Name: Common Goldeneye
Scientific Name: *Bucephala clangula*

CCVI[1] Ranking 2050s: Not Vulnerable / Increase Likely
CCVI Ranking 2080s: Not Vulnerable / Increase Likely

The common goldeneye received a CCVI ranking of *presumed stable / increase likely* for both time horizons evaluated (2050s and 2080s). This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche – Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the common goldeneye has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]
- **Physiological Hydrological Niche – Neutral**
  The common goldeneye relies on primarily marine habitats throughout the winter range. Mainly occurs in shallow coastal bays, estuaries of Atlantic and Pacific coasts, wherever adequate food is found. Because winter diet is largely mollusks and crustaceans, it prefers foraging over sandy, gravel, rocky, or boulder substrates in relatively shallow waters where such prey are concentrated.[3] (Cornell Ornithology). Species has little or no dependence on a strongly seasonal hydrologic regime and/or a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change.[2]
- **Dispersal / Movements – Decrease Vulnerability**
  All populations migrate, generally short to intermediate distances. A broad-front migrant over most of its range, but major rivers, lake chains, and coastlines provide a focus for movements.[3]
- **Diet – Neutral**
  During winter, foraging habitat on salt water includes rocky shorelines, mussel beds, mudflats, and estuaries. Winter diet is largely mollusks and crustaceans.[3]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures and the acidity of marine waters could negatively affect food resources, such as mollusks and crustaceans. Coastal flooding and sedimentation may also adversely impact wintering habitat along the shoreline.

Future Research Needs

It is unknown if the common goldeneye is dependent on a disturbance regime that is likely to be impacted by climate change.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/170/articles/introduction

Common Name: Elk
Scientific Name: *Cervus canadensis*


Photo: Grand Canyon National Park

Elk have a flexible diet and excellent movement capabilities, which enable them to migrate to new locations as conditions change over time. Elk are not restricted to a narrow thermal niche, and could potentially tolerate increases in temperature better than a species that is confined to a narrow thermal niche.

Key Sensitivities

- **Diet – Neutral**
  There is significant variation in the elk diet. The species is primarily a grazer, but also consumes forbs (in summer) and may browse on willow, aspen, oak, where grasses are unavailable. Elk also commonly feeds on mushrooms, especially in late summer and fall.[1]

- **Dispersal / Movement – Decrease Vulnerability**
  The maximum annual dispersal distance of elk is estimated to be between 25 and 50 km.[2]

- **Physiological Thermal Niche – Neutral**
  In mountainous regions, elk will summer in alpine meadows, and winters in valleys. On more level terrain, the species seeks wooded hillsides in summer, open grasslands in winter. Pacific coast populations are more sedentary than are those elsewhere.[1] It is evident that the species distribution is not significantly affected by thermal characteristics within the assessment area.[3]

Additional Factors Not Reflected in the CCVI

Declining summer precipitation and a longer dry season could reduce food resources and lead to population declines. An increase in the length of the freeze-free period may facilitate the spread of diseases that were previously limited by cold temperatures. An increase in the area burned may also affect foraging habitat.

Future Research Needs

GIS range maps are needed for elk. It is unknown if elk are exhibiting phenological responses to changing seasonal temperature or precipitation dynamics. It is unknown if this species is dependent on a disturbance regime that is likely to be impacted by climate change.

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[1] NatureServe Explorer http://bit.ly/1KQcCTv
[2] Climate Change Sensitivity Database http://climatechangesensitivity.org/node/518
[3] Young et al. (2011)

Common Name: Evergreen Huckleberry
Scientific Name: *Vaccinium ovatum*


Photo: James Gaither

The evergreen huckleberry is sensitive to fire, which can delay berry production. Huckleberries (*Vaccinium spp.*) are sensitive to soil pH, and will only thrive in acidic conditions. This acidic soil requirement could make migration to new locations more challenging.

Key Sensitivities

- **Disturbance** – **Somewhat Increase Vulnerability**
  Berry production in most evergreen huckleberries is generally delayed for at least 5 years after a fire. On some sites production may be reduced for 20 years or longer.[1]

- **Pollinator Versatility** – **Somewhat Increase Vulnerability**
  Evergreen huckleberry flowers are borne at the leaf axils in clusters of 3 to 10 and are primarily pollinated by long-tongued bees such as bumblebees.[1] Pollinators are also susceptible to the effects of climate change. Mismatches between pollinator activity and plant flowering can reduce the effectiveness of pollination. [2]

- **Dependence on others for propagule dispersal** – **Somewhat Decrease Vulnerability**
  Evergreen huckleberry seeds are dispersed by a wide variety of birds and mammals. Bird dispersers include thrushes, ptarmigans, towhees, ring-neck pheasant, and spruce, riffed, blue, and sharp-tailed grouse.. Mammal dispersers include the black bear, chipmunks, red fox, squirrels, gray fox, and skunks.[1]

- **Uncommon Geologic Feature** – **Somewhat Increase Vulnerability**
  Huckleberries (*Vaccinium spp*.) require acidic conditions and can thrive where pH ranges from 4.3 to 5.2. These shrubs require relatively small amounts of many essential elements and are capable of growing on many relatively infertile soils. Evergreen huckleberry commonly occurs on nitrogen-poor soils. It grows on well-drained sandy and gravelly soils, and on silty loam, but generally reaches greatest abundance on sandy soils.[1]

Additional Factors Not Reflected in the CCVI

An increase in the area burned may negatively impact plant reproduction and berry production. A longer summer drought period would reduce soil moisture and also limit growth and reproduction in the future. Coastal flooding could also affect shoreline populations.

Future Research Needs

GIS distribution maps are needed for this species.

[1] Forest Service Database http://www.fs.fed.us/database/feis/plants/shrub/vacova/all.html
[2] Stillaguamish Tribal Staff – Personal Communication

Common Name: Forage Fish (Pacific Sand Lance, Surf Smelt, Pacific Herring)
Scientific Name: *Ammodytes hexapterus, Hypomesus pretiosus, Clupea pallasii*

Forage fish school in bays and inlets of marine waters, and spawn on beaches in shallow water during high tide. Juveniles, who reside in nearshore waters, may be vulnerable to climate change mitigation efforts (seawalls), which can negatively impact fish movement.

Key Sensitivities

- **Dietary Versatility - Neutral**
  Surf smelt consume crustaceans, copepods, amphipods, crabs, larvae, and euphausiids.[3] The flexible diet of forage fish enable the species to respond to climate mediated shifts in prey abundance and availability. Many of the species that make up the diet of forage fish are currently being impacted by ocean acidification. [4]

- **Physiological Hydrological Niche** – **Somewhat Increase Vulnerability**
  Pacific herring live in coastal waters and often occur offshore. Adults move toward shore and enter bays and estuaries prior to spawning. Eggs are sticky and adhere to eelgrass, kelp, and other objects. Juveniles congregate in bays, inlets, and channels in summer.[5] Surf smelt are a near-shore species that occurs in marine, sometimes brackish waters. This species spawns on sand and gravel beaches in light to moderate surf, during incoming or high tide.[3]

- **Climate Change Mitigation** – **Increase Vulnerability**
  The modifications resulting from seawall development primarily occur along the near shore area that forage fish rely on. Sea wall development could impede forage fish movement.[6]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures and acidity could adversely affect the food resources of forage fish, such as insects and crustaceans. Coastal flooding and sedimentation would likely impact their habitat.

Future Research Needs

GIS range data are needed for these species. It is unknown if forage fish are dependent on a disturbance regime that is likely to be impacted by climate change. It is also unknown if forage fish are exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

[3] NatureServe Explorer http://bit.ly/1LWPouh
[4] Stillaguamish Tribe's Natural Resources Staff – Personal Communication
[5] NatureServe Explorer http://bit.ly/1JZRHKO
[6] Final Environmental Impact Statement, Elliott Bay Seawall (2013)

Common Name: Gray-crowned Rosy-Finch
Scientific Name: *Leucosticte tephrocotis*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Moderately Vulnerable

The gray-crowned rosy-finch received a CCVI ranking of *presumed stable* for the 2050s, and *moderately vulnerable* for the 2080s. This moderately vulnerable ranking for the 2080s is a result of the species' preference for cool or cold alpine habitats.

Key Sensitivities

- **Historical Thermal Niche** – **Somewhat Increase Vulnerability**
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the gray-crowned rosy-finch has experienced slightly lower than average (47.1 - 57° F/26.3 - 31.8° C) temperature variation in the past 50 years.[2]

- **Physiological Thermal Niche** – **Greatly Increase Vulnerability**
  The gray-crowned rosy-finch is mostly found in alpine areas, usually near snowfields or glaciers, talus, rock piles, and cliffs. It is typically found at or above the timberline (Cornell Ornithology). The gray-crowned rosy-finch is possibly the highest-altitude breeding bird in North America.[3]

- **Dependence on Ice / Snow** – **Increase Vulnerability**
  The gray-crowned rosy-finch forages on open ground, among rocks on talus, and on open snowfields and glaciers. It often forages along the edge of receding snow on cutworms and germinating seeds. The species has been observed eating snow crystals.[3 4]

Additional Factors Not Reflected in the CCVI

Gray-crowned rosy-finches use alpine habitats for wintering and a change in the snowpack and/ or a change in the length of the freeze-free period may affect this species. Warming temperatures may also affect their current distribution.

Future Research Needs

It is unknown if the gray-crowned rosy-finch is dependent on a disturbance regime that is likely to be impacted by climate change. It is unknown if the gray-crowned rosy-finch is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/559/articles/introduction
[4] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/leucosticte-tephrocotis-tephrocotis

Common Name: Great Blue Heron
Scientific Name: *Ardea Herodias*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The great blue heron received a CCVI ranking of *presumed stable* for both time horizons evaluated (2050s and 2080s). This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – Increase Vulnerability
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the great blue heron has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]

- **Physiological Hydrological Niche** – Somewhat Increase Vulnerability
  The great blue heron depends on coastal lowlands, marshes, estuaries, vernal pools, and springs, all of which are sensitive to climate change. Precipitation could affect key habitat characteristics of the great blue heron.[3]

- **Diet** – **Neutral**
  The great blue heron eats fishes, insects, crustaceans, amphibians, reptiles, mice, shrews, and other animals. Herons forage mostly while standing in water, but also in fields and sometimes dropping from air or perch into water.[4]

Additional Factors Not Reflected in the CCVI
An increase in ocean temperatures and the acidity of marine waters could negatively affect some food resources, such as fish and crustaceans. Coastal flooding and sedimentation may also adversely impact foraging habitat along the shoreline, particularly rookeries. Declining summer precipitation and a longer dry season could reduce inland habitat and food resources.

Future Research Needs
It is unknown if the great blue heron is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/ardea-herodias
[4] NatureServe Explorer http://bit.ly/1LXsHqX

Common Name: Greater Scaup
Scientific Name: *Aythya marila*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The greater scaup received a CCVI ranking of *presumed stable* for both time horizons evaluated (2050s and 2080s). This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Exposures and Sensitivities

- **Sea Level Rise** – **Somewhat Increase Vulnerability**
  Projected levels of sea level rise by the 2080s for the Stillaguamish watershed show that 10-49% of the greater scaup range occurs in area subject to sea level rise (in the coastal zone).[2 3]
- **Historical Thermal Niche** – **Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the greater scaup has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[2]
- **Diet** – **Somewhat Decrease Vulnerability**
  The greater scaup feeds on aquatic plants and animals. In coastal regions mollusks (clams, scallops, mussels, etc.) comprise a significant portion of the diet of the greater scaup. In other areas it eats seeds, leaves, and stems of plants (sedges, pondweeds, muskgrass, wild celery, etc.).[4]
- **Dispersal / Movement** – **Decrease Vulnerability**
  The greater scaup is a migratory bird and is characterized by excellent movement capability.[2 5]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures and an increase in the acidity of marine waters will likely affect the food resources of this species. Additionally, coastal flooding and an increase in sedimentation could have adverse effects on its ability to forage.

Future Research Needs

It is unknown if the greater scaup is dependent on a disturbance regime that is likely to be impacted by climate change. It is unknown if the greater scaup is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] NOAA Sea Level Rise Viewer http://coast.noaa.gov/digitalcoast/tools/slr
[4] NatureServe Explorer http://bit.ly/1G8bAdO
[5] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/650/articles/introduction

Common Name: Green Sturgeon
Scientific Name: *Acipenser medirostris*

The green sturgeon spends most of its life in coastal marine waters, ascending to rivers to spawn. Climate change mitigation efforts, such as sea wall developments, have the potential to negatively affect the dispersal/migration abilities of the species.

Key Sensitivities

- **Climate Change Mitigation** – **Increase Vulnerability**
  The modifications resulting from seawall development primarily occur along the nearshore area that green sturgeon rely on in their critical marine life stage. Sea wall development could impede green sturgeon movement and migration during specific life-stages.[1]

- **Anthropogenic Barriers** – **Increase Vulnerability**
  There are no large hydroelectric or flood control dams within the Stillaguamish watershed. The Cook Slough weir is likely too high in the watershed to pose passage problems for the green sturgeon. Culverts and tide gates can also act as fish passage barriers. [2]

- **Physiological Thermal Niche** – **Unknown**
  Green sturgeon spend most of their lives in coastal marine waters, estuaries, and the lower reaches of large rivers. They ascend rivers to spawn, but specific spawning and rearing habitats are poorly known.[3] The lower flows in the Stillaguamish have led to shallower distributary channels and the shallow water and increased water temperatures may be affecting sturgeon. [4]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures and acidity could adversely affect food resources. Coastal flooding and sedimentation may impact habitat for juveniles. An earlier shift in the timing of peak spring streamflow could scour streams and lead to less reproductive success.

Future Research Needs

GIS range maps are needed for this species. While very little is known about habitats requirements and life history characteristics for the green sturgeon,[3] it is likely that they are similar to those of the white sturgeon. [4]

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[1] Final Environmental Impact Statement, Elliott Bay Seawall (2013)
[2] Salmon Habitat Limiting Factors Final Report
[3] NatureServe Explorer http://bit.ly/1D2bF2I
[4] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Grizzly Bear
Scientific Name: *Ursus arctos horribilis*


Photo: Terry Tollefsbol - USFWS

CCVI[1] Ranking 2050s: **Presumed Stable**
CCVI Ranking: 2080s: **Moderately Vulnerable**

The grizzly bear received a CCVI ranking of *presumed stable* for the 2050s, and *moderately vulnerable* for the 2080s. The higher vulnerability ranking is a result of the species occurrence in cool alpine and subalpine forests, which are sensitive to climate change, and the species' sensitivity to fire.

Key Exposures and Sensitivities

- **Anthropogenic Barriers** – **Increase Vulnerability**
  Roads, industrial or urban development, suburban or rural residential development can act as barriers to dispersal.[2]
- **Historical Thermal Niche** – **Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the grizzly bear has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[3]
- **Physiological Thermal Niche** – **Increase Vulnerability**
  The grizzly bear is mostly found in alpine and subalpine mountain forests, which are sensitive to climate change.[2]
- **Disturbance** – **Somewhat Increase Vulnerability**
  Fire has the potential to affect subalpine mountain forests, a key habitat type for the grizzly bear in the Stillaguamish watershed.[2] Insect infestations may also create forest fragments that could impact habitat. [4]

Additional Factors Not Reflected in the CCVI

An increase in the number of days above 90°F, and a decrease in the nights below 10°F will negatively impact the grizzly bear. An increase in the length of the freeze-free period may also facilitate the spread of cold-limited diseases and potentially shorten its hibernation. An increase in the area burned may also negatively impact available habitat during the summer.

Future Research Needs

It is unknown if the grizzly bear is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

[1] Results incorporate projected temperature change (compared to the baseline average between 1961 and 1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Climate Change Sensitivity Database http://climatechangesensitivity.org/node/68
[3] Young et al. (2011)
[4] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Marbled Murrelet
Scientific Name: *Brachyramphus marmoratus*

CCVI Ranking 2050s: Presumed Stable
CCVI[1] Ranking 2080s: Highly Vulnerable

The marbled murrelet received a CCVI ranking of *presumed stable* for the 2050s, and *highly vulnerable* for the 2080s. The higher vulnerability ranking is a result of the species' dependence on limited tree species in old-growth forests to provide nesting platforms, as well as the species' sensitivity to fire and wind disturbance.

Key Sensitivities

- **Historical Thermal Niche** - Increase Vulnerability
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the marbled murrelet has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[2]
- **Disturbance** – Somewhat Increase Vulnerability
  Marbled murrelet nesting habitat is sensitive to fire, wind, disease, and pest disturbance. High intensity wind can blow down nesting trees. Fires in old growth forests will reduce the amount of nesting habitat.[3]
- **Dependence on other species to generate habitat** – Somewhat Increase Vulnerability
  The required breeding habitat for the marbled murrelet is primarily generated by a few species of large trees in old growth forests to provide suitable nesting platforms. Nests often are in mature/old growth coniferous forest near the coast: on large mossy horizontal branch, mistletoe infection, witches broom, or other structure providing a platform high in mature conifer[4].
- **Diet** – Increase Vulnerability
  Murrelets are tightly linked to offshore distribution of suitable prey (forage fish)[3]. The species has also been documented eating crustaceans (*mysids*, *euphausiids*), and mollusks[4]. Lack of food availability is having a significant impact on the marbled murrelet. The species will defer breeding during food shortages[5].

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures and the acidification of marine waters could negatively affect food resources, such as fish and some crustaceans. An increase in the area burned may negatively impact breeding and nesting habitats.

Future Research Needs

Fog is an important factor shaping marbled murrelet nesting habitat, because it favors growth of mosses on horizontal branches that murrelets prefer as nest sites. Little is known about how future changes in climate will affect coastal fog patterns, and how this may impact murrelet nesting habitat suitability. It is unknown if there is a cost-benefit relationship associated with travel distance between a food source and nesting site for the marbled murrelet. Evidence suggests that murrelets may attempt to shorten feeding travel distance, and therefore select nesting platforms in younger forests closer to food sources, thereby avoiding older forests located further inland in the Stillaguamish watershed.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/node/555
[4] NatureServe Explorer http://bit.ly/1eHBAXt
[5] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Mountain Goat
Scientific Name: *Oreamnos americanus*

CCVI[1] Ranking 2050s A1B: Moderately Vulnerable
CCVI Ranking 2050s A2: Presumed Stable
CCVI Ranking 2080s A1B: Extremely Vulnerable
CCVI Ranking 2080s A2: Extremely Vulnerable

The mountain goat received a CCVI ranking of *moderately vulnerable* and *presumed stable* for the 2050s, and *extremely vulnerable* for the 2080s. These high vulnerability rankings are a result of the species' preference for cool alpine and subalpine mountain forests, as well as the species' sensitivity to fire, which has the potential to negatively affect the species' habitat.

Key Sensitivities

- **Natural Barriers** – Somewhat Increase Vulnerability
  Low elevation river valleys of the Frasier and Okanagan act as partial barriers to movement that increase isolation between the Cascade Range and habitat to the north in British Columbia.
- **Anthropogenic Barriers** – Somewhat Increase Vulnerability
  Roads, industrial or urban development, suburban or rural residential development, and agriculture act as barriers to dispersal.[2] Interstate 90, and, increasingly, State Highway 2, present significant dispersal barriers.
- **Physiological Thermal Niche** – Greatly Increase Vulnerability
  The mountain goat is physiologically adapted to cold alpine and subalpine habitats, which are sensitive to climate change. Survival has been negatively correlated with warm summer temperatures.
- **Disturbance** – Somewhat Increase Vulnerability
  Fire, windthrow, disease, and pests have the potential to reduce the area of subalpine mountain forests, a key winter habitat type for the mountain goat in the Stillaguamish watershed.
- **Physical Habitat** – Somewhat Increase Vulnerability
  The mountain goat depends on steep terrain to avoid predators.[3,4]

Additional Factors Not Reflected in the CCVI

An increase in the length of the freeze-free period may facilitate the spread of cold-limited diseases and affect food resources, such as high-elevation plants. An increase in the area burned may negatively impact available winter habitat. Treeline encroachment on alpine and subalpine meadows may reduce summer foraging opportunities. Aerial surveys in the Stillaguamish watershed detected goats at lower elevations. If this retreat to lower elevations becomes more frequent, there will be in an increase in the risk of cougar predation.[5]

Future Research Needs

It is unknown if the mountain goat is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B).
[2] Climate Change Sensitivity Database http://climatechangesensitivity.org/node/102
[3] Nature Serve Explorer http://bit.ly/1Hfkwjg
[4] Young et al. (2013)
[5] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Mountain Lion
Scientific Name: *Puma concolor*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The mountain lion received a CCVI ranking of *presumed stable* for both time horizons evaluated (2050s and 2080s). This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to move to new locations as conditions change over time.

Key Exposures and Sensitivities

- **Anthropogenic Barriers** – Increase Vulnerability
  Roads, industrial or urban development, suburban or rural residential development can act as barriers to dispersal.[2]
- **Historical Thermal Niche** – Increase Vulnerability
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the mountain lion has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[3]
- **Dispersal / Movement** – Decrease Vulnerability
  The mountain lion's maximum annual dispersal is estimated to be greater than 100 km.[2][4] Dispersal may be affected by loss of travel corridors if forests become fragmented by fire or disease.[5]
- **Diet – Neutral**
  The mountain lion is a highly opportunistic feeder, consuming a wide variety of vertebrate prey. Their primary food is deer in many areas.[2]

Additional Factors Not Reflected in the CCVI

Declining summer precipitation and a longer dry season could reduce food resources and lead to population declines. An increase in the length of the freeze-free period may facilitate the spread of diseases that were previously limited by cold temperatures. An increase in the area burned may also reduce availability of prey and habitat.

Future Research Needs

It is unknown if the mountain lion is dependent on a disturbance regime that is likely to be impacted by climate change. It is unknown if the mountain lion is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.

[2] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/puma-concolor

[3] Young et al. (2011)

[4] Territoriality of the mountain lion is not taken into consideration when discussing dispersal/movement.

[5] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Northern Flying Squirrel
Scientific Name: *Glaucomys sabrinus*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Highly Vulnerable

The northern flying squirrel received a CCVI ranking of *presumed stable* for the 2050s, and *highly vulnerable* for the 2080s. The high vulnerability ranking at the end of the century is a result of the species' specific diet, and the narrow thermal niche that the species has occupied over the past 50 years.

Key Exposures and Sensitivities

- **Natural Barriers** – Somewhat Increase Vulnerability
  Rivers and areas that are lacking or devoid of trees are barriers to dispersal.[2,3]

- **Anthropogenic Barriers** –Increase Vulnerability
  Roads and agriculture act as barriers to dispersal.[2]

- **Historical Thermal Niche** – Increase Vulnerability
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the northern flying squirrel has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[4]

- **Disturbance** – Somewhat Increase Vulnerability
  Somewhat sensitive to fire, wind, and drought. Summer drought can result in lower fungal production. Fire and wind have the potential to affect northern flying squirrel forest habitat.[2]

- **Diet** – Increase Vulnerability
  Foraging dependency makes this species more of a specialist. The northern flying squirrel specializes in ectomycorrhizal fungi and lichens.[2]

Additional Factors Not Reflected in the CCVI

An increase in the number of days above 90°F and a decrease in the nights below 10°F may negatively impact this species. An increase in the length of the freeze-free period may also facilitate the spread of cold-limited diseases and affect food resources. An increase in the area burned may also negatively impact available habitat.

Future Research Needs

It is unknown if the northern flying squirrel is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics. It is unknown if declines in spotted owls (a predator of the northern flying squirrel) will have an impact on northern flying squirrel populations.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/glaucomys-sabrinus
[3] NatureServe Explorer http://bit.ly/1eX1mqK
[4] Young et al. (2011)

Common Name: Northern Goshawk
Scientific Name: *Accipiter gentilis*

CCVI[1] Ranking 2050s: Not Vulnerable / Increase Likely
CCVI Ranking 2080s: Not Vulnerable / Increase Likely

The northern goshawk received a CCVI ranking of *presumed stable / increase likely* for the 2050s and the 2080s. This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche – Increase Vulnerability**
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the northern goshawk has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]
- **Physiological Hydrological Niche – Neutral**
  Forest ponds or small, ephemeral streams to a major river or large lake-are often present near nest sites, but are not a habitat requirement. Goshawks bathe or wade in water, but the benefit, if any, is unknown.[3] The species has little or no dependence on a strongly seasonal hydrologic regime and/or a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change. Hydrological requirements are not likely to be significantly disrupted in major portion of the range.[2]
- **Disturbance – Somewhat Increase Vulnerability**
  The northern goshawk is not linked to particular disturbance regimes, although changes in fire frequency could negatively affect habitat quality for the northern goshawk.[4]
- **Diet – Somewhat Decrease Vulnerability**
  The northern goshawk is an opportunistic hunter and kills a wide diversity of prey. Main foods include ground and tree squirrels, rabbits and hares, large passerines, woodpeckers, game birds, and corvids; occasionally reptiles and insects.[4 5]

Additional Factors Not Reflected in the CCVI
An increase in the number of hot days and warm nights may affect the ability of this species to forage. An increase in the area burned may also affect its available habitat.

Future Research Needs
It is unknown if the northern goshawk is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/298/articles/introduction
[4] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/accipiter-gentilis-0
[5] NatureServe Explorer http://bit.ly/1eJSMLU

Common Name: Northern Pintail
Scientific Name: *Anas acuta*

CCVI[1] Ranking 2050s A1B: Presumed Stable
CCVI Ranking 2050s A2: Presumed Stable
CCVI Ranking 2080s A1B: Presumed Stable
CCVI Ranking 2080s A2: Presumed Stable

The northern pintail received a CCVI ranking of *presumed stable* for both emissions scenarios evaluated in the 2050s and 2080s. This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Exposures and Sensitivities

- **Sea Level Rise** – Somewhat Increase Vulnerability
  Projected sea level rise for the Stillaguamish watershed by the 2080s show that 10-49% of the northern pintail range occurs in area subject to sea level rise (in the coastal zone).[2]

- **Historical Thermal Niche** – Increase Vulnerability
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the northern pintail has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]

- **Physiological Hydrological Niche** – Increase Vulnerability
  The northern pintail nests in open country with shallow, seasonal, or intermittent wetlands and low vegetation. Northern pintail are also dependent on wetlands and vernal pools, which are sensitive to climate change.[3]

- **Disturbance** – Somewhat Increase Vulnerability
  Flooding and wind have the potential to negatively affect northern pintail habitat. Annual nest success and productivity vary with water conditions, predation, and weather.[3]

Additional Factors Not Reflected in the CCVI

Warming ocean temperatures and an increase in the acidity of marine waters may impact food resources, such as insects, crustaceans, and snails. Coastal flooding and sedimentation may also affect its ability to forage for food. Declining summer precipitation and a longer dry season could reduce inland habitat and food resources.

Future Research Needs

It is unknown if the northern pintail is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B).
[2] Young et al. (2013)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/anas-acuta

Common Name: Northern Shoveler
Scientific Name: *Anas clypeata*

The northern shoveler has a flexible diet and excellent movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Diet** – Somewhat Increase Vulnerability
  The northern shoveler is classified as an opportunistic feeder. The diet is mainly comprised of invertebrates and seeds. [1] [2] Invertebrate communities may be impacted by climate change. [3]

- **Dispersal / Movement** – Decrease Vulnerability
  The northern shoveler is classified as an annual migrant throughout most of its range, and has excellent dispersal capabilities. However, the northern shoveler is a year-round resident within the Stillaguamish Watershed.

- **Uncommon Geological Features** – Decrease Vulnerability
  The northern shoveler occupies both freshwater and brackish habitats. It has been observed in a variety of wetland habitats including prairie potholes, saline wetlands, and coastal marshes.

Additional Factors Not Reflected in the CCVI
An increase in ocean temperatures will likely affect the food resources of this species. Additionally, coastal flooding and an increase in sedimentation could have adverse effects on its ability to forage.

Future Research Needs
GIS distribution maps are needed for this species. It is unknown if the northern shoveler is dependent on a disturbance regime that is likely to be impacted by climate change. It is unknown if the northern shoveler is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

[1] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/217/articles/introduction
[2] NatureServe Explorer http://bit.ly/1f8lQwC
[3] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Olive-sided Flycatcher
Scientific Name: *Contopus cooperi*


Photo: Jon Nelson

CCVI[1] Ranking 2050s: Not Vulnerable / Increase Likely
CCVI Ranking 2080s: Not Vulnerable / Increase Likely

The olive-sided flycatcher received a CCVI ranking of *presumed stable / increase likely* for the 2050s and the 2080s. This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – Increase Vulnerability
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the olive-sided flycatcher has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[2]

- **Disturbance** – Somewhat Decrease Vulnerability
  The species may prefer habitat recently burned by medium to high severity fires due to the creation of openings and remnant snags that may serve as perches for singing and hunting.[3]

- **Diet** – Somewhat Decrease Vulnerability
  Almost exclusively consumes flying insects.[4]

- **Dispersal / Movements** – Decrease Vulnerability
  Long-distance, complete migrant between its North American breeding grounds and Central and South American wintering grounds; longest migration route of any flycatcher breeding in North America. [4] No noted barriers to dispersal.[3] Extreme storm events during migration increase the vulnerability of the olive-sided flycatcher during periods of fall out. [5]

Additional Factors Not Reflected in the CCVI

Warming temperatures may affect their current distribution, food resources, and lead to more diseases. An increase in area burned may improve habitat in some areas.

Future Research Needs

It is unknown if the olive-sided flycatcher is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2013)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/node/560
[4] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/502/articles/introduction
[5] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Oregon Spotted Frog
Scientific Name: *Rana pretiosa*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Highly Vulnerable

The Oregon spotted frog received a CCVI ranking of *presumed stable* for the 2050s, and *highly vulnerable* for the 2080s. The high vulnerability ranking at the end of the century can be attributed to natural barriers in landscape that prevent or hinder species movement as conditions change over time, and the specific aquatic habitat requirements of the species.

Key Exposures and Sensitivities

- **Natural Barriers** – **Somewhat Increase Vulnerability**
  Upland habitat devoid or nearly devoid of wetlands, streams, ponds or lakes; and wide streams serve as barriers to dispersal for the Oregon spotted frog.[2]
- **Anthropogenic Barriers** – **Increase Vulnerability**
  Major highways and urban developments serve as barriers to dispersal for the Oregon spotted frog.[2]
- **Historical Thermal Niche** – **Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the Oregon spotted frog has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years.[3]
- **Physiological Hydrological Niche** – **Increase Vulnerability**
  The Oregon spotted frog is a highly aquatic species that generally avoids dry uplands. Breeding usually occurs in shallow water in pools, ponds, or other quiet waters, among moderate or dense herbaceous vegetation. Climate change is likely to negatively affect the aquatic habitat of the Oregon spotted frog.[2,3]

Additional Factors Not Reflected in the CCVI

An earlier shift in the timing of peak spring streamflow and declining snowpack could affect some of the wetlands and vernal pools that this species relies on. Warming temperatures may impact water temperature of breeding habitats and lead to an increase in diseases.

Future Research Needs

The physiological thermal niche is unknown for the Oregon spotted frog. It is also unknown if the species is dependent on a disturbance regime that is likely to be impacted by climate change.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] NatureServe Explorer http://bit.ly/1NWzuPQ
[3] Young et al. (2011)

Common Name: Pacific Jumping Mouse
Scientific Name: *Zapus trinotatus*

Photo: US Forest Service

The Pacific jumping mouse resides in alpine and meadow habitats that are typically close to a water source. An increase in drought frequency may negatively affect the most, riparian habitats this species depends on.

Key Sensitivities

- **Diet** – **Somewhat Decrease Vulnerability**
  Feeds primarily on seeds (e.g., grasses, dock, and skunk cabbage). Also eats berries, insects, and some mosses and fungi. Rarely may consume bird eggs.[1]

- **Dispersal / Movements** – **Neutral**
  Dispersal behavior is unknown, but it is likely that some individuals periodically move or disperse at least several hundred meters from one location to another.[1]

- **Physiological Thermal Niche** – **Somewhat Increase Vulnerability**
  The Pacific jumping mouse occurs in alder and skunk cabbage riparian communities in redwood and Douglas-fir forests, alpine and other moist meadows, marshy thickets, brushy successional stages of coniferous and mixed forests; and to a lesser extent in lodgepole pine and Sitka spruce communities, and headland scrub and prairie. The Pacific jumping mouse also nests underground or concealed in vegetation on surface. [1]

- **Disturbance** – **Somewhat Increase Vulnerability**
  The Pacific jumping mouse is likely to be sensitive to drought due to its dependence on moist, riparian habitats.[1]

- **Phenological Response**– **Somewhat Increase Vulnerability**
  Deposition of fat reserves depends on availability of plant seeds. A shift in the maturation of seeds relative to hibernation for the Pacific jumping mouse could result in a phenological resource mismatch.[1]

Additional Factors Not Reflected in the CCVI

Warming temperatures, particularly very hot days and nights, may limit their current range. Declining snowpack and an increase in the length of the drought period may negatively affect their habitat. Warming winter temperatures may interfere with hibernation.

Future Research Needs

GIS range data are needed for the Pacific jumping mouse. It is unknown whether this mouse is dependent on other species to generate habitat. It is unknown if the Pacific jumping mouse is exhibiting phonological responses to changing seasonal temperature or precipitation dynamics.

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[1] NatureServe Explorer http://bit.ly/1QHceXu

Common Name: Pacific Lamprey
Scientific Name: *Lampetra tridentata*

The Pacific lamprey spawns in cold freshwater streams, which are projected to warm as a result of climate change. The lamprey is also vulnerable to anthropogenic barriers, such as seawalls and culverts, which can prevent passage to and from spawning sites.

Key Exposures and Sensitivities

- **Climate Change Mitigation** – Increase Vulnerability
  The modifications resulting from seawall development primarily occur along the near shore area that Pacific lamprey rely on for migration to spawning sites. Sea wall development could impede lamprey movement and migration during specific life-stages.[1]

- **Anthropogenic Barriers** – Increase Vulnerability
  There are no large hydroelectric or flood control dams within the Stillaguamish watershed. However, small diversion structures such as the Cook Slough weir and the Granite Falls fishway pose some passage problems for lamprey. Culverts and tide gates can also act as passage barriers.

- **Physiological Hydrological Niche** – Increase Vulnerability
  Ammocoetes (lamprey larvae) inhabit shallow backwater and eddy areas along edges of streams in mud, silt and sand. Adults spawn in runs and riffles in rock-, sand-, or gravel-bottomed clear streams, in small, shallow depressions, or crude nests, at the heads of riffles. Water depth at spawning sites often is 30-150 cm.[2]

- **Physiological Thermal Niche** – Increase Vulnerability
  While the Pacific lamprey is noted as being less temperature dependent than salmonids,[3] water temperature is still documented as playing a role in the species' physiological sensitivity.[3]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures and acidity could adversely affect this species. Coastal flooding and sedimentation may impact habitat for larvae and juveniles. An earlier shift in the timing of peak spring streamflow could scour streams where they breed and lead to less reproductive success.

Future Research Needs

GIS range maps are needed for the Pacific lamprey. It is unknown if the Pacific lamprey is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

[1] Final Environmental Impact Statement, Elliott Bay Seawall (2013)
[2] NatureServe Explorer http://bit.ly/1fpk633
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/lampetra-tridentata

Common Name: Pigeon Guillemot
Scientific Name: *Cepphus columba*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Not Vulnerable / Increase Likely

The pigeon guillemot received a CCVI ranking of *presumed stable* for the 2050s, and *presumed stable / increase likely* for the 2080s. This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – **Somewhat Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the pigeon guillemot has experienced slightly lower than average (47.1 - 57° F/26.3 - 31.8° C) temperature variation in the past 50 years.[2]

- **Dispersal / Movements** – **Decrease Vulnerability**
  Dispersal is greater for pigeon guillemots from California and Oregon colonies, compared with Washington and British Columbia. Most Californian immatures move north in first winter (median distance 50 km, maximum 850 km), at least 30% to Washington and British Columbia. Elsewhere, median dispersal in the first year only 33 km, range 0–180 km. Adults disperse slightly shorter distances, (median 30 km, range 0–180 km).[3]

- **Diet** – **Somewhat Increase Vulnerability**
  Its diet is mainly comprised of small fishes (e.g., blennies, sculpins, sand lance, smelt, etc.); generally inshore benthic species; also includes mollusks, crustaceans, and marine worms. The pigeon guillemot forages underwater.[4] This species diet is sensitive to declines in forage fish populations. [5]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures and an increase in the acidity of marine waters will likely affect the food resources of this species. Additionally, coastal flooding and an increase in sedimentation could have adverse effects on its ability to forage. Nest sites might be disturbed or destroyed with storm surges or coastal storm events.

Future Research Needs

It is unknown if the pigeon guillemot is dependent on a disturbance regime that is likely to be impacted by climate change. It is also unknown if the species is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] The Birds of North America Onlinehttp://bna.birds.cornell.edu/bna/species/049/articles/introduction
[4] NatureServe Explorer http://bit.ly/1LYOrTc
[5] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Pileated Woodpecker
Scientific Name: *Dryocopus pileatus*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable


Photo: Robin Horn

The pileated woodpecker received a CCVI ranking of *presumed stable* for the 2050s and 2080s. This stable ranking is a result of the species' broad thermal niche, which enables the species to tolerate greater variation in temperature, and the species' movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – **Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the pileated woodpecker has experienced minimal (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[2]
- **Disturbance** – **Somewhat Increase Vulnerability**
  It is not linked to particular disturbance regimes, although changes in fire frequency could negatively affect habitat quality for the pileated woodpecker.[3] The pileated woodpecker may benefit from insect infestations in forest areas because they are a primary cavity nester. [4]
- **Diet** – **Increase Vulnerability**
  The foraging dependency makes this species more of a specialist. The pileated woodpecker's diet is mainly comprised of carpenter ants (*Camponotus spp.*) and wood-boring beetle larvae.[3]
- **Dispersal / Movement** – **Decrease Vulnerability**
  The maximum annual dispersal of the pileated woodpecker is estimated to be between 25 and 50 km.[3]

Additional Factors Not Reflected in the CCVI

An increase in the length of the freeze-free period may increase food resources, but may also facilitate the spread of cold-limited diseases. An increase in the area burned may also negatively impact nesting trees.

Future Research Needs

It is unknown if the pileated woodpecker is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/node/563
[4] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Purple Martin
Scientific Name: *Progne subis*


Photo: Wiki Commons

We estimate that the purple martin is likely to have a stable vulnerability ranking due to the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Diet – Neutral**
  The diet of the purple martin consists mainly of flying insects. Examples include beetles, dragonflies, damselflies, butterflies, moths, grasshoppers, and crickets.[1,2]

- **Dispersal / Movements – Decrease Vulnerability**
  The purple martin is a long-distance migrant. The maximum annual dispersal distance of the species is greater than 100 km. [2,3]

- **Dependence on others to generate habitat – Somewhat Increase Vulnerability**
  Purple martins in the western United States inhabit montane forest or Pacific lowlands, and are restricted to areas with dead snags containing woodpecker holes.[2]

- **Disturbance – Somewhat Increase Vulnerability**
  Drought may negatively affect the abundance of prey species that are consumed by the purple martin.[3]

Additional Factors Not Reflected in the CCVI
Declining summer precipitation and a longer dry season could reduce food resources and lead to population declines. An increase in the area burned may also reduce foraging and nesting habitats.

Future Research Needs
GIS range data is needed for the purple martin. It is unknown if the purple martin is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

[1] NatureServe Explorer http://bit.ly/1HfN78e
[2] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/287/articles/introduction
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/node/587

Common Name: Red-Breasted Sapsucker
Scientific Name: *Sphyrapicus ruber*

CCVI[1] Ranking 2050s: Not Vulnerable / Increase Likely
CCVI Ranking 2080s: Not Vulnerable / Increase Likely

The red-breasted sapsucker received a CCVI ranking of *presumed stable / increase likely* for the 2050s and the 2080s. This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche – Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the red-breasted sapsucker has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[2]

- **Physiological Thermal Niche – Neutral**
  The red-breasted sapsucker is not likely to be physiologically sensitive to changes in temperature, although there is little information on this assumption.[3]

- **Diet – Somewhat Increase Vulnerability**
  The diet of the red-breasted sapsucker is mainly comprised of sap, fruits, and arthropods. It forages in old-growth forests, as opposed to mature or young forests, when available. Sapsuckers are specialized for sipping sap; their tongues are shorter and less extensible than those of other woodpeckers, and tipped with stiff hairs to allow sap to adhere.[3] Forest fires could negatively affect food availability. [4]

Additional Factors Not Reflected in the CCVI

An increase in the length of the freeze-free period may increase insects, the primary food resource, but warming may also affect the timing of insect reproduction. An increase in the length of the freeze-free period may facilitate the spread of cold-limited diseases. An increase in the area burned may also negatively impact nesting trees.

Future Research Needs

It is unknown if the red-breasted sapsucker is dependent on a disturbance regime that is likely to be impacted by climate change. It is also unknown if the species is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/663a/articles/introduction
[4] Stillaguamish Tribe's Natural Resources Staff – Personal Communication

Common Name: Red Huckleberry
Scientific Name: *Vaccinium parvifolium*

The red huckleberry is sensitive to fire, which can delay berry production. Huckleberries (*Vaccinium spp.*) are sensitive to soil pH, and will only thrive in acidic conditions. This acidic soil requirement could make migration to new locations more challenging.

Key Sensitivities

- **Disturbance** – Somewhat Increase Vulnerability
  Berry production in most western huckleberries is generally delayed for at least 5 years after a fire. On some sites, production may be reduced for 20 years or longer. However, it is noted that the importance of fire in many long-lived coastal forests, of which red huckleberry is a component, is poorly understood.[1]

- **Dependence on others for propagule dispersal** – Somewhat Decrease Vulnerability
  Red huckleberry seeds are dispersed by a wide variety of birds and mammals. Bird dispersers include: thrushes, catbird, band-tailed pigeon, bluebirds, ptarmigans, towhees, ring-necked pheasant, and grouse. Mammal dispersers include: black bear, deer mice, white-footed mouse, raccoon, pika, ground squirrels, chipmunks, red fox, squirrels, gray fox, and skunks.[1]

- **Uncommon Geologic Feature** - Somewhat Increase Vulnerability
  Huckleberries (*Vaccinium spp*.) require acidic conditions and can thrive where pH ranges from 4.3 to 5.2. These shrubs require relatively small amounts of many essential elements and are capable of growing on many relatively infertile soils. Red huckleberry commonly occurs on nitrogen-poor soils. It grows on well-drained sandy and gravelly soils, and on silty loam, but generally reaches greatest abundance on sandy soils.[1]

Additional Factors Not Reflected in the CCVI

An increase in the area burned may negatively impact plant reproduction and berry production. A longer summer drought period would reduce soil moisture and also limit growth and reproduction in the future.

Future Research Needs

GIS distribution maps are needed for this species.

[1] Forest Service Database http://www.fs.fed.us/database/feis/plants/shrub/vacpar/all.html

Common Name: Rhinoceros Auklet
Scientific Name: *Cerorhinca monocerata*

Photo: Cathie Barron

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The rhinoceros auklet received a CCVI ranking of *presumed stable* for the 2050s and the 2080s. This stable vulnerability ranking is a result of the species' broad thermal niche, which enables the species to tolerate greater variation in temperature, and the species' movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Sea Level Rise** – **Somewhat Increase Vulnerability**
  By the 2050s, sea level rise will flood nest burrows and take over nesting sites used by the rhinoceros auklet. [2]

- **Historical Thermal Niche** – **Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the rhinoceros auklet has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[3]

- **Disturbance** – **Increase Vulnerability**
  The rhinoceros auklet is sensitive to landslides, which may affect burrowing colonies. This effect has been seen in other burrowing sea birds.[4]

- **Diet** – **Somewhat Increase Vulnerability**
  Foraging dependency makes this species more of a specialist, and therefore more vulnerable to climate change (Sensitivity Database). During the breeding season the rhinoceros auklet's diet includes sand lance (*Ammodytes hexapterus*) and other small schooling fishes.[5]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures could affect food resources, specifically the availability of small fish. Coastal flooding and increased landslides may adversely impact nesting colonies.

Future Research Needs

It is unknown if the rhinoceros auklet is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Stillaguamish Tribal Staff – Personal Communication
[3] Young et al. (2011)
[4] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/cerorhinca-monocerata
[5] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/212/articles/introduction

Common Name: Sooty Grouse
Scientific Name: *Dendragapus fuliginosus*

CCVI[1] Ranking 2050s: Not Vulnerable / Increase Likely
CCVI Ranking 2080s: Not Vulnerable / Increase Likely

The sooty grouse received a CCVI ranking of *presumed stable / increase likely* for the 2050s and 2080s. This stable ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche - Somewhat Increase Vulnerability**
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the sooty grouse has experienced slightly lower than average (47.1 - 57° F/26.3 - 31.8° C) temperature variation in the past 50 years.[2]
- **Anthropogenic Barriers – Somewhat Increase Vulnerability**
  Roads, and industrial and urban development act as barriers for the sooty grouse.[3]
- **Disturbance – Somewhat Decrease Vulnerability**
  Windthrow may create gaps favoring understory to develop thus favoring occupancy by sooty grouse. Old-growth forest and early forest seres following logging and/or fire are both occupied.[4] Therefore, increased fire frequency could positively affect sooty grouse habitat quality.
- **Diet - Neutral**
  Vegetable matter comprises the majority of the sooty grouse diet throughout year. Small juveniles rely heavy on invertebrates. In some areas, grasshoppers (*Orthoptera*) may be taken heavily by juveniles and older grouse in mid summer to early autumn.[4]

Additional Factors Not Reflected in the CCVI

A longer summer drought period could lead to changes in food availability, namely insects. An earlier spring snowmelt may also lead to mismatches in prey availability and juvenile development. An increase in the area burned may have a positive impact on habitat quality.

Future Research Needs

It is unknown if the sooty grouse is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/dendragapus-fuliginosus
[4] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/015/articles/introduction

Common Name: Spotted Owl
Scientific Name: *Strix occidentalis*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Highly Vulnerable

The spotted owl received a CCVI ranking of *presumed stable* for the 2050s, and *highly vulnerable* for the 2080s. The high vulnerability ranking at the end of the century is a result of the species' sensitivity to fire, which has the potential to destroy suitable habitat in old-growth forests. The species is also sensitive to high temperatures, which are projected to increase.

Key Sensitivities

- **Diet** – **Somewhat Increase Vulnerability**
  Thinning of Douglas-fir forests in the Pacific Northwest has reduced flying squirrel populations in the region. Flying squirrels are a significant component of the diet of the spotted owl. [3]
- **Physiological Thermal Niche** – **Increase Vulnerability**
  The spotted owl is physiologically sensitive to high temperatures. It thermoregulates through choice of roost locations.[2]
- **Disturbance** – **Increase Vulnerability**
  Fire has the potential to destroy spotted owl suitable habitat in old-growth forests.[2] Insect infestations may impact nesting and dispersal habitat. [3]
- **Dependence on Other Species for Habitat** – **Somewhat Increase Vulnerability**
  The spotted owl is a habitat specialist dependent on old-growth forests. It tends to nest in standing snags, hollow trees, or uses nesting platforms provided by a few species of large trees in old-growth forests.[2,4]

Additional Factors Not Reflected in the CCVI

An increase in the number of days above 90°F and a decrease in the nights below 10°F may negatively impact this physiologically sensitive species. Warming temperatures may also facilitate the spread and dominance of the barred owl. An increase in the area burned may also negatively impact nesting sites.

Future Research Needs

It is unknown if the spotted owl is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Climate Change Sensitivity Database http://climatechangesensitivity.org/node/538
[3] Stillaguamish Tribe's Natural Resources Staff – Personal Communication
[4] NatureServe Explorer http://bit.ly/1eKwOsl

Common Name: Steelhead
Scientific Name: *Oncorhynchus mykiss*

CCVI[1] Ranking 2050s: Moderately Vulnerable
CCVI Ranking 2080s: Extremely Vulnerable

Steelhead received a CCVI ranking of *moderately vulnerable* for the 2050s and *extremely vulnerable* for the 2080s. This high vulnerability ranking is a result of the species' dependence on cold water and sufficient stream flow levels for migration.

Key Sensitivities and Exposures

- **Climate Change Mitigation** – **Increase Vulnerability**
  The modifications resulting from sea wall development primarily occur along the nearshore area that juvenile salmonids rely on in their critical early marine life stage. Sea wall development could impede steelhead movement and migration during specific life-stages.[2]
- **Anthropogenic Barriers** – **Increase Vulnerability**
  There are no large hydroelectric or flood control dams within the Stillaguamish watershed. However, small diversion structures such as the Cook Slough weir and the Granite Falls fishway pose some fish passage problems. Culverts and tide gates can also act as fish passage barriers.[3]
- **Physiological Thermal Niche** – **Greatly Increase Vulnerability**
  Steelhead are found in cool clear lakes and cool swift streams.
- **Physiological Hydrological Niche** – **Greatly Increase Vulnerability**
  The pools of small quiet streams and beaver ponds are important for the young fry, but as the fish grow in size they are able to use the higher energy stream environments.[4] Steelhead are often found in cool clear lakes and cool swift streams with silt-free substrate. In streams, deep low velocity pools are important wintering habitats.[5]
- **Disturbance** – **Increase Vulnerability**
  Steelhead spawning locations are at risk for impacts from late fall and winter flooding. Additionally, low flows in the summer impact the amount of water available for adult migration and spawning.[4]

Additional Factors Not Reflected in the CCVI

Warming stream temperatures and declining snowpack will affect the ability of this species to survive in some streams. An earlier shift in the timing of peak spring streamflow could scour streams and lead to less reproductive success. An increase in ocean temperatures and sedimentation could reduce food resources. Low summer streamflows would also negatively impact this species.

Future Research Needs

It is unknown if steelhead are dependent on a disturbance regime that is likely to be impacted by climate change.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.

[2] Final Environmental Impact Statement, Elliott Bay Seawall (2013)

[3] Salmon Habitat Limiting Factors Final Report

[4] SIRC (2005)

[5] NatureServe Explorer http://bit.ly/1ToDWK3

Common Name: Swainson's Thrush
Scientific Name: *Catharus ustulatus*

CCVI[1] Ranking 2050s: Not Vulnerable / Increase Likely
CCVI Ranking 2080s: Not Vulnerable / Increase Likely

Swainson's thrush received a CCVI ranking of *presumed stable / increase likely* for the 2050s and the 2080s. This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – Increase Vulnerability
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, Swainson's thrush has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[2]

- **Diet** – Somewhat Decrease Vulnerability
  The diet of the Swainson's thrush includes beetles, caterpillars, ants, flies, and fruits. Generally considered a near-ground forager, although less so than other thrushes. Forages on or near forest floor, where it gleans from ground and litter, and leaf-gleans on conifer and broadleaved foliage in low understory.[3 4]

- **Dispersal / Movements** – Decrease Vulnerability
  Swainson's thrush is a complete long-distance migrant. Migrates widely throughout North and Middle America, but migration routes differ between western and eastern populations.[3 4]

Additional Factors Not Reflected in the CCVI
Declining summer precipitation and a longer dry season could reduce food resources. An increase in the length of the freeze-free period may affect food resources such as insects. An increase in the area burned may also reduce foraging habitat.

Future Research Needs
It is unknown if Swainson's thrush is dependent on a disturbance regime that is likely to be impacted by climate change. It is also unknown if the species is exhibiting phonological responses to changing seasonal temperature or precipitation projections.

[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] NatureServe Explorer http://bit.ly/1UGGzZk
[4] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/540/articles/introduction

Common Name: Trumpeter Swan
Scientific Name: *Cygnus buccinators*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Presumed Stable

The trumpeter swan received a CCVI ranking of *presumed stable* for the 2050s and the 2080s. This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – **Somewhat Increase Vulnerability**
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the trumpeter swan has experienced slightly lower than average (47.1 - 57° F/26.3 - 31.8° C) temperature variation in the past 50 years.[2]

- **Disturbance** – **Somewhat Increase Vulnerability**
  It is likely to be sensitive to flooding, wind, and pollution.[3]

- **Genetic Bottleneck** – **Increase Vulnerability**
  The trumpeter swan underwent a population bottleneck in the early part of the 20th Century. By 1932, the largest known collection of adult trumpeter swans consisted of 57 individuals on a chain of thermal lakes in the vicinity of Yellowstone National Park.[4]

Additional Factors Not Reflected in the CCVI
Warmer winter temperatures and increased precipitation could contribute to higher streamflows and an increased flood risk which could impact freshwater breeding habitats. Declining summer precipitation and a longer dry season could reduce habitat and food resources.

Future Research Needs
It is unknown if the trumpeter swan is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/cygnus-buccinator
[4] Oyler-McCance et al. (2007)

Common Name: Western Grebe
Scientific Name: *Aechmophorus occidentalis*

CCVI[1] Index 2050s: Moderately Vulnerable
CCVI Index 2080s: Highly Vulnerable

The western grebe received a CCVI ranking of *moderately vulnerable* for the 2050s, and *highly vulnerable* for the 2080s. These rankings are a result of the species' dependence on a narrowly defined hydrologic niche, and sensitivity to flooding.

Key Sensitivities

- **Physiological Hydrologic Niche** – **Increase Vulnerability**
  The western grebe requires stable water levels, with little to no wave action. Rapid changes in water levels (either rising or falling) can negatively affect the reproductive success of the species.[2]
- **Historical Thermal Niche** – **Increase Vulnerability**
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the western grebe has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[3]
- **Disturbance** – **Increase Vulnerability**
  This species is highly sensitive to flooding, wind, and drought disturbance regimes. Cycles of flooding, wind, and/or drought can all result in reproductive failure. However, yearly water level fluctuations are needed to maintain the appropriate wetland vegetation structure this species requires for nesting.[2]
- **Dependence on Other Species for Habitat** – **Somewhat Increase Vulnerability**
  This species requires floating/submergent vegetation for building a floating nest mat. The nest is typically built up from the bottom or a submerged snag, or floating in up to 3m of water and anchored to emergent or floating plants.[2 4]
- **Diet** – **Somewhat Increase Vulnerability**
  This species is strictly piscivorous and requires access to fish prey that are directly connected to the water body of breeding sites, as it rarely flies outside of migration.[2] However, it consumes a wide variety of fish.[4]

Additional Factors Not Reflected in the CCVI

Warmer winter temperatures and increased precipitation could contribute to higher streamflows and an increased flood risk, which could impact breeding habitats. Declining summer precipitation and a longer dry season could reduce habitat and food resources. An increase in ocean temperatures and an increase in the acidity of marine waters will likely affect the food resources of this species. Additionally, coastal flooding and an increase in sedimentation could have adverse effects on its ability to forage.

Future Research Needs

It is unknown if the western grebe is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/aechmophorus-occidentalis
[3] Young et al. (2011)
[4] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/026a/articles/introduction

Common Name: Western Pond Turtle
Scientific Name: *Actinemys marmorata*

CCVI[1] Ranking 2050s A1B: Moderately Vulnerable
CCVI Ranking 2050s A2: Presumed Stable
CCVI Ranking 2080s A1B: Extremely Vulnerable
CCVI Ranking 2080s A2: Extremely Vulnerable

The western pond turtle received a CCVI ranking of *moderately vulnerable* and *presumed stable* for the 2050s, and *extremely vulnerable* for the 2080s. The high vulnerability rankings are a result of the species' poor dispersal ability around highways and other anthropogenic barriers. Additionally, climate change may negatively affect this species' hydrological niche.

Key Exposures and Sensitivities

- **Natural Barriers** – Somewhat Increase Vulnerability
  Areas lacking aquatic or wetland habitat, or regions with unsurpassable terrain (e.g. cliffs) act as barriers to dispersal for the western pond turtle.[2]

- **Anthropogenic Barriers** – Greatly Increase / Increase Vulnerability
  Busy highways or highways with obstructions serve as significant dispersal barriers for the western pond turtle.[2]

- **Historical Thermal Niche** – Increase Vulnerability
  Considering the mean seasonal temperature variation for occupied cells, the western pond turtle has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[3]

- **Physiological Hydrological Niche** – Somewhat Increase Vulnerability
  The western pond turtle resides in permanent and intermittent waters of rivers, creeks, small lakes and ponds, marshes, unlined irrigation canals, and reservoirs. These bodies of water are vulnerable to temperature and precipitation regimes that are sensitive to climate change.[3]

Additional Factors Not Reflected in the CCVI

Declining summer precipitation and a longer dry season could reduce habitat and food resources. An increase in the number of days above 90°F and a decrease in the nights below 10°F may exceed the thermal threshold for this species in some areas.

Future Research Needs

It is unknown if western pond turtles are dependent on a disturbance regime that is likely to be impacted by climate change. It is also unknown if the species is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B).
[2] NatureServe Explorer http://bit.ly/1dPbEZf
[3] Young et al. (2011)

Common Name: Western Redcedar
Scientific Name: *Thuja plicata*


Photo: Flicker Creative Commons

The western redcedar is able to grow in a wide variety of soil types, making the species somewhat resilient to environmental perturbations stemming from climate change. The species has a low to moderate resistance to fire, and is susceptible to fire damage.

Key Sensitivities

- **Dispersal / Movement – Neutral**
  Western redcedar seeds are small, and are dispersed primarily by wind. However, the seeds have small wings and are not carried more than 400 feet (122 m) from the parent tree.[1]

- **Disturbance – Somewhat Increase Vulnerability**
  The species has a low to moderate resistance to fire. Western redcedar's thin bark, shallow root system, low dense branching habit, and highly flammable foliage make it susceptible to fire damage. However, it often survives fire because of its large size. [1]

- **Uncommon Geologic Feature – Decrease Vulnerability**
  Western red cedar can tolerate a wide range of soil. It grows well on shallow soils over chalk and can tolerate both acid and alkaline soils conditions. It is able to survive and grow on soils that are low in nutrients and is found on such soils over much of its natural range. [1]

Additional Climatic Factors That May Influence Vulnerability

An increase in the area burned may negatively impact tree reproduction and growth. A longer summer drought period would reduce soil moisture and also limit growth and reproduction in the future.

Future Research Needs

GIS distribution maps are needed for this species.

[1] Forest Service Database http://www.fs.fed.us/database/feis/plants/tree/thupli/all.html

Common Name: Western Sandpiper
Scientific Name: *Calidris mauri*


Photo: Heather Paul

CCVI[1] Ranking 2050s: Not Vulnerable / Increase Likely
CCVI Ranking 2080s: Not Vulnerable / Increase Likely

The western sandpiper received a CCVI ranking of *presumed stable / increase likely* for the 2050s and 2080s. This stable vulnerability ranking is a result of the species' flexible diet and movement capabilities, whichenable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche – Increase Vulnerability**
  Considering the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the western sandpiper has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[2]

- **Physiological Thermal Niche - Neutral**
  Species distribution is not significantly affected by thermal characteristics of the environment in the assessment area, or species occupies habitats that are thought to be not vulnerable to projected climate change.[2]

- **Physiological Hydrologic Niche – Neutral**
  The western sandpiper has little or no dependence on a strongly seasonal hydrologic regime and/or a specific aquatic/wetland habitat or localized moisture regime that is highly vulnerable to loss or reduction with climate change.[2] At coastal stopover areas, western sandpipers frequent intertidal mud and sandflats, roosting during high tide on exposed tussocks in the saltmarsh, or if high tide occurs in broad daylight, flying over water in over-ocean flocking behavior.[3]

- **Dispersal / Movement – Decrease Vulnerability**
  Maximum annual dispersal for the western sandpiper is estimated to be between 1 and 5 km.[4]

Additional Factors Not Reflected in the CCVI
Coastal flooding and sea-level rise could affect roosting sites. Warming ocean temperatures, increased sedimentation, and increased acidity could also affect food resources.

Future Research Needs
It is unknown if the western sandpiper is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] Young et al. (2011)
[3] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/090/articles/introduction
[4] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/calidris-mauri

Common Name: Western Toad
Scientific Name: *Anaxyrus boreas*


Photo: J. N. Stuart

The western toad is vulnerable to the negative effects that drought will have on the species' aquatic habitat. Additionally, the species' dependence on gopher and ground squirrel holes may make it challenging for the species to move to new areas as conditions change.

Key Sensitivities

- **Physiological Hydrological Niche** – Increase Vulnerability
  Adults emerge from hibernation sites and migrate to breeding wetlands. Breeding sites are in still or barely moving water, typically ponds and small lakes, streams, rain pools, and ditches. (Adult Habitat) Historically, western toads were thought to be more terrestrial except when breeding, and tolerant of dry habitats.[1]

- **Dependence on other species for habitat** – Somewhat Increase Vulnerability
  During cold weather (temperatures below 3 ˚C), western toads will use gopher and ground squirrel holes as retreats. At higher elevations, western toads hibernate in rock-lined chambers near creeks, in ground squirrel burrows, in and under root systems of evergreen trees, and possibly in beaver dams.[1]

- **Dispersal / Movement** – Somewhat Decrease Vulnerability
  Maximum annual dispersal of the western toad is estimated to be between 1 and 5 km.[2]

- **Diet** – Neutral
  The diet of the western toad includes spiders, worms, ants, moths, beetles and other arthropods. Billbug weevils (*Sphenophorus* sp.) are also ingested frequently.[1]

- **Disturbance** – Somewhat Increase Vulnerability
  Drought can negatively affect habitat quality for the western toad.[2]

Additional Factors Not Reflected in the CCVI

Declining summer precipitation and a longer dry season could reduce habitat and food resources. An increase in the number of days above 90°F and a decrease in the nights below 10°F may exceed the thermal threshold for this species in some areas.

Future Research Needs

GIS range data is needed for the western toad. It is also unknown if the species is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

[1] AmphibiaWeb http://bit.ly/1HgaeiX
[2] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/anaxyrus-boreass

Common Name: White Sturgeon
Scientific Name: *Acipenser transmontanus*


Photo: Josh More

The white sturgeon spends most of its life in coastal marine waters, ascending to rivers to spawn. Climate change mitigation efforts, such as sea wall developments, have the potential to negatively affect the dispersal/migration abilities of the species.

Key Sensitivities

- **Climate Change Mitigation – Increase Vulnerability**
  The modifications resulting from seawall development primarily occur along the nearshore area that white sturgeon rely on in their critical marine life stage. Sea wall development could impede white sturgeon movement and migration during specific life-stages.[1]

- **Anthropogenic Barriers – Increase Vulnerability**
  There are no large hydroelectric or flood control dams within the Stillaguamish watershed. However, small diversion structures such as the Cook Slough weir and the Granite Falls fishway pose some fish passage problems. Culverts and tide gates can also act as fish passage barriers.[2]

- **Physiological Thermal Niche – Unknown**
  Some are anadromous and make extensive saltwater migrations. Many move more locally from estuaries to fresh water, or farther inland within fresh water, to spawn. Spawns probably either over deep gravel riffles or in deep holes with swift currents and rock bottoms.[3]

- **Diet – Neutral**
  The white sturgeon feeds mostly on the larvae of aquatic insects, crustaceans, and molluscs. A significant portion of the diet of larger sturgeon consists of fish.[3]

Additional Factors Not Reflected in the CCVI

An increase in ocean temperatures and acidity could adversely affect food resources, such as fish, insects, crustaceans, and mollusks. Coastal flooding and sedimentation may impact habitat for juveniles. An earlier shift in the timing of peak spring streamflow could scour streams and lead to less reproductive success. Warming stream temperatures and declining snowpack may also affect the ability of the species to survive in some rivers.

Future Research Needs

Need GIS range maps are needed for this species. More life history information is needed for the white sturgeon.

[1] Final Environmental Impact Statement, Elliott Bay Seawall (2013)
[2] Salmon Habitat Limiting Factors Final Report
[3] NatureServe Explorer http://bit.ly/1CsA0UL

Common Name: Wilson's Warbler
Scientific Name: *Cardellina pusilla*

CCVI[1] Ranking 2050s: Not Vulnerable / Increase Likely
CCVI Ranking 2080s: Not Vulnerable / Increase Likely

Wilson's warbler received a CCVI ranking of *presumed stable / increase likely* for the 2050s and 2080s. The stable vulnerable ranking is a result of the species' flexible diet and movement capabilities, which enable it to fly to new locations as conditions change over time.

Key Sensitivities

- **Historical Thermal Niche** – Increase Vulnerability
  Given the mean seasonal temperature variation for the species' range within the Stillaguamish watershed, the Wilson's warbler has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[2]

- **Diet – Neutral**
  The diet of the Wilson's warbler includes insects (wasps, ants, flies, beetles, caterpillars, etc.). Most food is obtained from leaves by gleaning while perched or flying.[3]

- **Dispersal / Movements** – Decrease Vulnerability
  The Wilson's warbler is a medium- to long-distance migrant, and winters primarily south of the United States border.[4]

Additional Factors Not Reflected in the CCVI

Earlier spring snowmelt and a longer summer dry period could adversely affect wetlands that the Wilson's warbler uses. Drier habitats will also likely affect food resources, such as insects. Warming temperatures may also affect their current distribution.

Future Research Needs

It is unknown if Wilson's warbler is dependent on a disturbance regime that is likely to be impacted by climate change. It is also unknown if the species is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.

[2] Young et al. (2011)

[3] NatureServe Explorer http://bit.ly/1JXGwSU

[4] The Birds of North America Online http://bna.birds.cornell.edu/bna/species/478/articles/introduction

Common Name: Wolverine
Scientific Name: *Gulo gulo*

CCVI[1] Ranking 2050s: Presumed Stable
CCVI Ranking 2080s: Extremely Vulnerable

The wolverine received a CCVI ranking of *presumed stable* for the 2050s, and *extremely vulnerable* for the 2080s. This high vulnerability ranking at the end of the century is a result of the species' physiological sensitivity to high temperatures, and dependence on persistent snow cover.

Key Sensitivities

- **Natural Barriers** – **Somewhat Increase Vulnerability**
  The wolverine typically resides in alpine and subalpine environments. Warm lowlands may act as a dispersal barrier for the wolverine.[2 3]
- **Anthropogenic Barriers** – **Somewhat Increase Vulnerability**
  The wolverine has been in lower elevations of the Stillaguamish watershed, and human disturbance has been noted as a major barrier for the species. [4]
- **Historical Thermal Niche** – **Increase Vulnerability**
  Considering the mean seasonal temperature variation for occupied cells, the wolverine has experienced small (37 - 47° F/20.8 - 26.3° C) temperature variation in the past 50 years within the Stillaguamish watershed.[3]
- **Physiological Thermal Niche** – **Greatly Increase Vulnerability**
  The wolverine is extremely physiologically sensitive to high temperatures. The estimated lower threshold of thermoneutrality for the wolverine may be as low as -40°C, and -8 to 5°C in the summer. This species is almost completely restricted to relatively cool or cold environments that may be lost or reduced in the Stillaguamish watershed as a result of climate change.[3 5]
- **Dependence on Ice / Snow** – **Greatly Increase Vulnerability**
  Snow is an important component of the wolverine's seasonal habitat requirements. Persistent spring snow cover is an obligate component of wolverine denning because it aids the survival of young by providing a thermal advantage and a refuge from predators. Ecological association with spring snow cover also extends to year-round locations throughout the species' range.[5 6]

Additional Factors Not Reflected in the CCVI

A decrease in the snowpack, an increase in the number of days above 90°F, and a decrease in the nights below 10°F will negatively impact the wolverine. An increase in the length of the freeze-free period may also facilitate the spread of cold-limited diseases. An increase in the area burned may also negatively impact available habitat during the summer.

Future Research Needs

It is unknown if the species is exhibiting phenological responses to changing seasonal temperature or precipitation dynamics.

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[1] Results incorporate projected temperature change (compared to baseline average 1961-1990) for the 2050s and 2080s for two separate emission scenarios from the IPCC 4th Assessment (high emissions scenario A2 and medium emissions scenario A1B). For the 2050s and 2080s, the temperature binning classification used by NatureServe puts the temperature projections for the two emission scenarios into the same temperature bin, thus leading to identical CCVI rankings. Since NatureServe does not distinguish between the two scenarios, we do not present separate results for each scenario, instead including just one scenario each for the 2050s and 2080s.
[2] NatureServe Explorer http://bit.ly/1J74U1A
[3] Young et al. (2011)
[4] Stillaguamish Tribe's Natural Resources Staff – Personal Communication
[5] Climate Change Sensitivity Database http://climatechangesensitivity.org/species/gulo-gulo
[6] Copeland et al. (2010)

Habitat: Estuary - Salt marsh, eelgrass, mud flat
Estimated Climate Change Vulnerability[1]: Moderate *to* **High**

Summary: This habitat is estimated to have relatively moderate to high vulnerability due to its moderate sensitivity [2] and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed[1].

Key Sensitivities[2]:

- **Temperature changes:** ***4 (out of 7)***

Increases in air temperature could cause more drying, especially in low tide systems (e.g. eel grass desiccation may increase). Low marshes are very sensitive while higher marshes are less so. Estuaries are generally adapted to a high degree of variability; however, some species may be displaced or become locally extinct due to temperature extremes. Nonetheless, because many of these systems are complex and are composed of large assemblages of species, the overall functionality of estuarine habitat is likely to be resilient to air temperature increase.

- **Precipitation changes:** ***6 (out of 7)***

Precipitation changes for these systems are uncertain and fresh water inflow will be particularly influential. However, since many of these systems have been cut off from their natural freshwater inflows due to land use/river alterations, they may already be more resilient to future changes. Furthermore, some systems might lose invasive species like reed canary grass due to increased salinity in summer.

- **Indirect factors:** ***4 (out of 7)***

Water chemistry may change in response to warming water temperatures and could increase acidification. Sea level rise (SLR) will greatly influence these systems, but may be partially offset or intensified by changes in river discharge and sediment delivery in some locations. It is likely that SLR may create an opportunity to add estuary habitat in some places by flooding low-lying shorelines where there is no current development. Geomorphology is also important - mud flats that are exposed may be more vulnerable compared to protected flats. Diseases and parasites are important for some systems – for example, eelgrass wasting disease is affected by temperature and salinity. Increased stress will also increase disease rates and susceptibility, while increased temperature will likely have a net increase in propensity for disease.

Research Needs

Estuaries are generally adapted to a high degree of variability; however changes in precipitation, particularly the seasonal timing of flood events could cause unknown changes. Shoreline mapping of potential areas of contraction and expansion of estuaries could help prioritize future development. Additional research into changes in diseases, pests, and invasive species is needed.

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[1] Vulnerability was estimated by considering both sensitivity[2] and exposure (i.e., projected warming of 3.3 – 3.5°C and a -0.087 to -0.094 decline in Hamon AET:PET metric for the Stillaguamish watershed by the 2050s).

[2] Sensitivity rankings are from the Climate Change Sensitivity Database (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
Estimated Climate Change Vulnerability[1]: High

Summary: This habitat is estimated to have relatively high vulnerability due to its moderate to high sensitivity[22] and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed[1].

Key Sensitivities[2]:

- **Temperature changes: *5 (out of 7)***

The extent and density of forests are largely determined by temperature and precipitation. Warming temperatures would likely affect the species composition of western Washington forests by extending the growing season. However, warmer temperatures may also facilitate the introduction of invasive species, pests, and disease not previously found in this area.

- **Precipitation changes: *6 (out of 7*)**

Some forest habitats of Washington State are more limited by precipitation than temperature. These forests are generally found in drier locations and at high elevations. An increase in precipitation could potentially lead to increase growth and productivity of some dry forests. By contrast, increased precipitation during the winter at high elevation may lead to decreased growth because of a deeper snowpack. However, warming temperatures may offset the snowpack depth and long term snowpack is projected to decline. Decreased precipitation during the growing season and in particular the already dry summer months would lead to decreased growth across most forests.

- **Indirect factors: *5 (out of 7)***

Forests are sensitive to indirect factors of climate change, such as fire, disease, pests, and wind disturbances. Although it is not known how wildfire risk will change in the 21st Century, increases in temperature and dryness will undoubtedly result in an increase in risk. This could change species composition, such as in wet lowland forests of western Washington, from western hemlock and red alder dominated stands to Douglas-fir. Warmer temperatures could lead to increases of pests, especially when combined with blowdown events.

Research Needs

Forested habitats in western Washington are diverse in species composition, structure, and potential response to climate change. In addition to better understanding how changes in temperature and precipitation might affect forests, more information on how disturbances may affect forests is also needed. Certain forestry techniques like thinning may help make some forests more resilient to climate change.

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[1] Vulnerability was estimated by considering both sensitivity[2] and exposure (i.e., projected warming of 3.3 – 3.5°C and a -0.087 to -0.094 decline in Hamon AET:PET metric for the Stillaguamish watershed by the 2050s).
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Habitat: Freshwater Aquatic
Estimated Climate Change Vulnerability[1]: High

Summary: Given this system's moderate to high climate sensitivity[2] and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed[1], we estimate that its climate change vulnerability will be relatively high.

Key Sensitivities[2]:

- **Temperature changes: 5 (out of 7)**

Changes in temperature will impact all freshwater habitats. For example, some sections of the Stillaguamish River already exceed the lethal temperature threshold for salmon during the summer months. Riparian areas and streams provide water storage for biotic refuge during dry seasons and are sensitive to even slight increases in water temperature. Warming temperatures can also raise biotic respiration rates and contribute to lower dissolved oxygen content, exacerbating stress on species.

- **Precipitation changes: 5 (out of 7)**

Increased precipitation, particularly during the already wet season, could lead to increased flooding, which could be detrimental if floods occur during spawning times. Increased precipitation (in combination with warming temperatures) could also lead to more rain on snow events. By contrast, decreasing rainfall (and warming temperatures) in summer could exacerbate water shortages – particularly in freshwater systems that are already water limited.

- **Indirect factors: 6 (out of 7)**

Freshwater aquatic habitats are sensitive to indirect factors such as fire, flooding, insects, and disease. There is an increase in the risk of wildfire and beetle infestation with warmer temperatures and longer dry seasons, which would affect the vegetation along freshwater bodies. Large fire and beetle infestation could also drastically change the water balance for some freshwater habitats. The risk of fish diseases increases with warmer water temperature. Dams, reservoirs, and armoring of rivers have drastically changed the hydrograph and predispose these systems to be more sensitive to climate change.

Research Needs

Freshwater aquatic habitats are diverse and their response to climate change will vary considerably. The location and type of these habitats is generally lacking. Research on how stream temperatures and flow might change under climate scenarios is also needed. Information on the effect of invasive species and disease/ pest outbreaks is generally lacking.

[1] Vulnerability was estimated by considering both sensitivity[2] and exposure (i.e., projected warming of 3.3 – 3.5°C and a -0.087 to -0.094 decline in Hamon AET:PET metric for the Stillaguamish watershed by the 2050s).

Habitat: Marine – Nearshore / gravel beaches
Estimated Climate Change Vulnerability[1]: Moderate

Summary: This habitat is estimated to have relatively *moderate vulnerability* due to its low to moderate sensitivity[2] and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed[1].

Key Sensitivities[2]:

- **Temperature changes:** ***4 (out of 7)***

Gravel beaches are identified as being somewhat sensitive to temperature change. Warming temperatures may lead to shifts in biota composition and density. Furthermore, temperature change could increase likelihood of invasive species moving in. This is possible for invasive species that are currently limited by cooler temperatures (i.e., they are frost sensitive). Warming temperatures may also lead to a loss of forage fish species in nearshore habitats and may accelerate the rate of organic matter decay.

- **Precipitation changes:** ***3 (out of 7)***

Although nearshore and gravel beach habitats were identified as being less sensitive to precipitation changes than temperature changes, there is still considerable uncertainty in how these systems may respond to increased or decreased precipitation. One way that precipitation changes may impact these habitats is through sediment production, especially during intense precipitation events, which could lead to flooding and scouring.

- **Indirect factors:** ***5 (out of 7)***

Warming temperatures will likely affect water chemistry and make it more acidic. This acidity would have major effects on shellfish in nearshore habitats. Flooding may adversely affect biota and change sediment production. Sea level rise (SLR) has the potential to greatly influence these systems, but similar to estuaries, may be partially offset or intensified by changes in river discharge and sediment delivery in some locations. It is likely that SLR may create an opportunity to add nearshore habitat in some places by flooding low-lying shorelines where there is no current development. Other non-climate related threats also predispose this habitat group to be more sensitive to climate change. For example, pollution, shellfish harvest, and land-use change – including development, armoring, and shoreline modification are all major threats to nearshore and rocky beaches.

Research Needs

Climate change impacts to nearshore habitats and gravel beaches are largely unknown. Flooding and sediment changes are o1bvious events that could drastically change the character and species composition of these habitats. Shoreline mapping of potential areas of contraction and expansion of marine nearshore and gravel beaches could help prioritize future development. The synergistic effect of land-use change and pollution could compound climate change and requires further research.

[1] Vulnerability was estimated by considering both sensitivity2 and exposure (i.e., projected warming of 3.3 – 3.5°C and a -0.087 to -0.094 decline in Hamon AET:PET metric for the Stillaguamish watershed by the 2050s).

[2] Sensitivity rankings are from the Climate Change Sensitivity Database (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 - Open water (photic zone)
Estimated Climate Change Vulnerability[1]: Moderate

Summary: Given this system's low to moderate climate sensitivity[2] and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed[1], we estimate that its climate change vulnerability will be relatively moderate.

Key Sensitivities[2]:

- **Temperature changes: 3 (out of 7)**

Warming air temperatures will significantly impact the photic zone by changing the temperature of the water and modifying ocean currents.

- **Precipitation changes: 4 (out of 7)**

Changes in precipitation will affect the salinity and consequently the density of the photic zone water, but freshwater inputs may offset some of these changes, depending on how close they are.

- **Indirect factors: 4 (out of 7)**

Warming temperatures and changes in carbon dioxide will likely affect water chemistry leading to more acidity. This acidity would have major effects on shellfish in nearshore habitats. Changes in solar radiation, wind speed and direction will impact the upwelling, down welling and mixing of the water. Freshwater flow and flooding may adversely affect biota and change sediment production. Other non-climate related threats also predispose this habitat group to be more sensitive to climate change. For example, pollution, shellfish harvest, and land-use change – including development, armoring, and shoreline modification are all major threats to nearshore and rocky beaches.

Research Needs

The marine photic zone will persist in the future but water chemistry will change and new species will likely move in. More research into how these changes will affect species and system functioning is needed. Identification as to which species might invade and how they might change the system is needed. New species will also likely bring new diseases, which could possibly affect other species.

[1] Vulnerability was estimated by considering both sensitivity[2] and exposure (i.e., projected warming of 3.3 – 3.5°C and a -0.087 to -0.094 decline in Hamon AET:PET metric for the Stillaguamish watershed by the 2050s).

[2] Sensitivity rankings are from the Climate Change Sensitivity Database (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[1]: High

Summary: Given this system's high climate sensitivity[2] and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed[1], we estimate that its climate change vulnerability will be relatively high.

Key Sensitivities[2]:

- **Temperature changes: 7 (out of 7)**

Warmer temperatures may promote increased growth and productivity of high-elevation habitats that are currently limited by cold temperatures. However, warmer temperatures will also facilitate the encroachment of trees into meadows and other suitable alpine areas and may also adversely impact species that are intolerant of hot temperatures, such as the American pika and cause them to locally disappear.

- **Precipitation changes: 6 (out of 7)**

Changes in precipitation will greatly affect montane habitats and their vegetation. More winter precipitation at the highest elevations could lead to decreased tree growth if temperatures are still cold. Increased summer precipitation could lead to increases in biomass production and a greater diversity of species, but at the cost of endemic species. Decreases in precipitation during the summer months could lead to decreased growth and a higher likelihood of fire. Less snow could lead to a longer growing season and increased growth, but may also expose some species to frost and wind disturbances during harsh winter weather.

- **Indirect factors: 6 (out of 7)**

Montane areas are generally very sensitive to disturbances such as fire, wind, diseases, and pests. It is likely that climate change will increase the frequency and possibly the intensity of some of these indirect factors. Alpine areas and meadows may be the most sensitive, but subalpine areas are also very sensitive. Some of the biggest changes will occur after a disturbance occurs if existing species cannot establish and new species appear. Invasive species, diseases, and pests are also a major concern in montane areas and could change the species composition and character of many of these habitats.

Research Needs

The montane habitat is diverse and consists of many ecosystems, including alpine, subalpine, meadow, talus, etc. It is difficult to identify one ranking for all of these ecosystems. Further research into identifying individual climate change sensitivity rankings for each ecosystem is needed.

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[1] Vulnerability was estimated by considering both sensitivity[2] and exposure (i.e., projected warming of 3.3 – 3.5°C and a -0.087 to -0.094 decline in Hamon AET:PET metric for the Stillaguamish watershed by the 2050s).

[2] Sensitivity rankings are from the Climate Change Sensitivity Database (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: Old growth forest
Estimated Climate Change Vulnerability[1]: Moderate

Summary: Given this system's low sensitivity[2] and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed[1], we estimate that this system's climate change vulnerability will be relatively moderate. However, indirect impacts from modified fire regimes could have substantial negative effects.

Key Sensitivities[2]:

- **Temperature changes: 3 (out of 7)**

Warming temperatures may cause some local tree populations to be stressed, especially during the dry summer months, however, many species are likely to persist. For example, on sites that warm considerably, western hemlock and western redcedar may decline in growth and dominance due to competition from other species. By contrast, species with a broad temperature tolerance, such as Douglas-fir may do better with warmer temperatures, assuming adequate soil moisture.

- **Precipitation changes: 3 (out of 7)**

Generally old-growth forests in western Washington are located in wet maritime areas. An increase in precipitation could potentially lead to increased growth and productivity of some species. However, many are currently energy-limited (light-limited) in the growing season and may not respond to changes in precipitation. Nevertheless, drying during the already dry summer could stress some species and lead to competitive changes.

- **Indirect factors: 4 (out of 7)**

Climate-change induced increased frequency of large, intense wildfires could have substantial impacts to the age, species composition, and structure of old-growth forests. Species that are able to regenerate after these events will be favored. Although some species, such as Douglas-fir are somewhat resilient to fire, large events will likely reset forest succession. Disease, pest outbreaks and wind storms may also have significant impacts to old growth forests of western Washington.

Research Needs

Although climate change is not expected to drastically affect old growth forests, it is largely unknown how changes in soil moisture (during the summer) and cloudiness may impact species, especially energy-limited trees. Many of the trees growing in old growth forests are long-lived and most research has short time frames.

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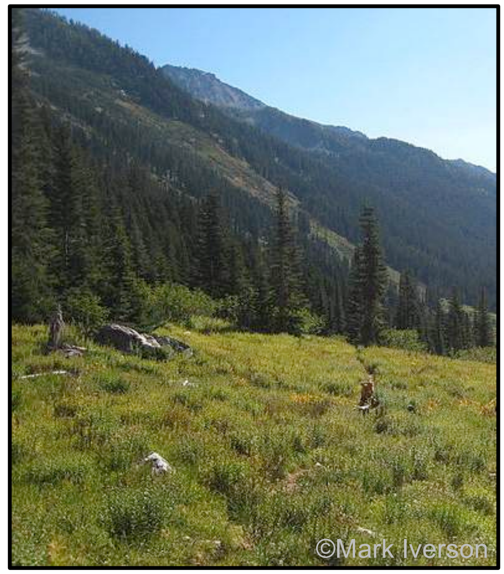
[1] Vulnerability was estimated by considering both sensitivity[2] and exposure (i.e., projected warming of 3.3 – 3.5°C and a -0.087 to -0.094 decline in Hamon AET:PET metric for the Stillaguamish watershed by the 2050s).

[2] Sensitivity rankings are from the Climate Change Sensitivity Database (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: Open meadow
Estimated Climate Change Vulnerability[1]: High



Summary: Given this system's high climate sensitivity[2] and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed[1], we estimate that its climate change vulnerability will be relatively high.

Key Sensitivities[2]:

- **Temperature changes: 5 (out of 7)**

Open meadows can be found in a variety of climates from wet and cool to dry and hot. Subsequently, changes in temperature will manifest in changes to species composition. Warmer temperatures may increase biomass production in wet and cool meadows, but also increase the likelihood of tree encroachment. Warming temperatures in dry and hot meadows may lead to decreased plant growth and potential loss of biodiversity.

- **Precipitation changes: 7 (out of 7)**

Shorter snow duration in meadows at high elevations could lead to increased growth and potentially a greater diversity of flora. However, soil moisture during the dry summer months will ultimately decide how much growth is possible. Additionally, an increase in rain during the dry season could also be beneficial for the growth and productivity of dry and hot meadows; however, as with alpine areas, tree encroachment is a potential. Decreases in precipitation will likely negatively affect all meadows, but the biggest impacts will probably be within dry and hot meadows.

- **Indirect factors: 6 (out of 7)**

Meadows are generally smaller in size than other habitat types and therefore are more sensitive to the indirect effects of climate change. Increases in fire, flooding, wind, diseases, and pests will be magnified within meadows due to their limited extent. Furthermore, the proximity of other nearby meadows will also affect species dispersal and seed regenerations following major disturbances. Meadows are also threatened by land-use change in some areas.

Research Needs

Open meadows are found in a variety of climates and sites and although it is expected that some species will persist under future climatic change, it is not known which ones. Further research into how these habitats function and what processes are important to maintaining meadows is needed. Further research into how disturbances will affect meadows is also needed.

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[1] Vulnerability was estimated by considering both sensitivity[2] and exposure (i.e., projected warming of 3.3 – 3.5°C and a -0.087 to -0.094 decline in Hamon AET:PET metric for the Stillaguamish watershed by the 2050s).

[2] Sensitivity rankings are from the Climate Change Sensitivity Database (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[1]:
Moderate *to* **High**

Summary: Given this system's moderate climate sensitivity[2] and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed[1], we estimate that its climate change vulnerability will be relatively moderate to high.

Key Sensitivities[2]:

- **Temperature changes:** ***4 (out of 7)***

Lowland riparian habitats in western Washington are found along rivers and near bodies of water. Many are within the relatively cool, moist maritime climate. Subsequently, riparian habitats are moderately sensitive to temperature changes. Warming temperatures could dry up some small creeks and groundwater springs or shorten the duration of their seasonal wetness. If this were to occur, the species composition and structure of riparian habitats could significantly change. If temperatures warm considerably some of these systems could disappear altogether.

- **Precipitation changes:** ***2 (out of 7)***

Although riparian habitats were identified as being less sensitive to changes in precipitation than to changes in temperature, they still are dependent on precipitation. Soil moisture in riparian habitats is particularly important to species composition and structure and is at least partially constrained by precipitation and evapo-transpiration. Generally, riparian habitats have a significant portion of hardwood tree species and these trees can be quite sensitive to decreasing water availability.

- **Indirect factors:** ***6 (out of 7)***

Riparian habitats are very sensitive to indirect factors of climate change and in particular, summer low flows, higher water temperatures, and flooding events. Summer low flows and higher water temperatures will negatively impacts key species, such as salmon. Increased frequency and intensity of flooding events could shift species towards hardwoods, with smaller trees and younger age classes. Shifts in the timing and levels of stream flows will also affect water tables and soil moisture levels.

Research Needs

Riparian habitats are complex with many processes and monitoring these habitats, particularly after disturbances, will be important to understanding how climate change may affect them. For instance, detailed mapping of vulnerability riparian habitats could be done given current projections of summer low flows and higher temperatures.

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[1] Vulnerability was estimated by considering both sensitivity[2] and exposure (i.e., projected warming of 3.3 – 3.5°C and a -0.087 to -0.094 decline in Hamon AET:PET metric for the Stillaguamish watershed by the 2050s).

[2] Sensitivity rankings are from the Climate Change Sensitivity Database (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[1]: High

Summary: Given this system's high climate sensitivity[2] and high projected exposure to temperature and precipitation changes in the Stillaguamish watershed[1], we estimate that its climate change vulnerability will be relatively high.

Key Sensitivities[2]:

- **Temperature changes:** ***6 (out of 7)***

Forested wetlands depend upon surface runoff of groundwater for water supply. Shallow wetlands will respond more quickly to increases in temperature. Depending on form and size, some wetlands may be able to store increasing winter runoff, buffering against summer drying. A small change in temperature could lead to significant changes in evaporation and therefore could mean earlier drying up of these wetlands. Additionally, there may be mismatches in the timing of when component species require these wetlands and earlier drying.

- **Precipitation changes: 6 (out of 7)**

Decreasing precipitation, especially during the already dry season could result in much earlier drying up and a shorter wet season. Heavily forested wetlands will be somewhat buffered from water loss from decreasing precipitation and increasing temperature because of shading. Forested wetlands may also help mitigate flooding from increasing rainfall in autumn and winter. Forested wetlands may retain snowpack longer than non-forested wetlands due to temperature regulation, thus decreasing the degree to which spring peak streamflows shift earlier in the season.

- **Indirect factors: 4 (out of 7)**

Forested wetlands have a higher risk of wildfire and beetle infestation due to warming temperatures and a longer dry season in western Washington. Water balances in forested wetlands could drastically change with such broad forest loss. Loss of snowpack will impact forested vernal pools and wet meadows in western Washington. Forested wetlands that are seasonal, shallow, and dependent on a limited water source are the most sensitive to climate change.

Research Needs

Forested wetlands are important to a number of species and provide ecosystem services; however, further research into how these systems might be affected by climate change is needed. Wetland function and processes have largely not been tested under climate scenarios. Different wetland plant species may also affect functioning and has not been studied.

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[1] Vulnerability was estimated by considering both sensitivity[2] and exposure (i.e., projected warming of 3.3 – 3.5°C and a -0.087 to -0.094 decline in Hamon AET:PET metric for the Stillaguamish watershed by the 2050s).

[2] Sensitivity rankings are from the Climate Change Sensitivity Database (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).