Chapter 5

Climate Change Vulnerability of Species and Habitats in Washington

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5.0 Introduction and Overview

This chapter describes the approach and methodology used to integrate the risks of climate change into the State Wildlife Action Plan (SWAP) Update, and also presents a summary of key findings. Additional detail is available in Appendix C. The Washington Department of Fish and Wildlife (WDFW) has been working for several years to better understand how the risks posed by climate change will affect the fish and wildlife resources of our state. Working in partnership with other organizations, the agency has conducted studies and contributed to research aimed at assessing the nature and degree of the climate change threat to our conservation efforts. More recently, climate change efforts at the agency have focused on understanding how policies and procedures might be modified to create greater resilience or facilitate adaptive response to the impacts of climate change.

The effort to integrate climate change into the SWAP Update represents a step in this direction. One goal of the project was to evaluate the relative importance of climate change not as a stand-alone threat, but in the context of existing stressors. From a management perspective, this increases our ability to determine which stressors or actions will leverage the greatest long term conservation benefit for the species or habitat under consideration. Future work will include additional analysis of the conservation needs for those species determined to be at highest risk. Developing our understanding regarding how and when climate may exacerbate existing stressors can inform priorities, research needs and other conservation actions.

Figure 5-1: Explanation of terms

Defining Terms

Sensitivity: A measure of whether and how a resource is likely to be affected by a given change in climatic factors (Glick et al. 2011).

Exposure: A measure of how much of a change in climate or climate-driven factors a resource is likely to experience (Glick et al. 2011).

Vulnerability: The degree to which a habitat or species is susceptible to, and unable to cope with adverse impacts of climate change (Schneider et al. 2007).

Confidence: For the purposes of this study, confidence reflects the sureness assessors had in a given sensitivity or exposure ranking.

5.1 Approach and Methodology

We began by assessing the relative vulnerability of all of the Species and Habitats of Greatest Conservation Need, using existing resources and tools, and a consistent methodology. See Figure 1 for an explanation of terms used in this section.

Vulnerability Assessment Methodology

To determine the vulnerability to climate change, we evaluated sensitivity and exposure for each species or habitat, assessed confidence for each sensitivity and exposure evaluation, and scored overall vulnerability and confidence for a species or habitat. Note that the SWAP uses ecological systems to describe habitat types, and ecological systems of concern indicate those systems most imperiled. The terms habitats and ecological systems are used interchangeably in this chapter. Please see the introduction of Chapter 4 for more description about these terms.

Each evaluation of sensitivity includes assigned rankings as well as short summaries describing key information from the scientific literature. The aim of the summaries that accompany rankings is to make the rationales and assumptions underlying the rankings and confidences assigned transparent. Each evaluation of exposure includes assigned rankings as well as a bulleted list of the key climate exposure factors for a given species or habitat. This list of exposure factors, along with the spatial location of a resource, was used to guide the literature review for future climate projections in order to assign rankings.

Based on the literature review, one of five rankings (High-5, Moderate-High-4, Moderate-3, Low-Moderate-2, or Low-1) was assigned each to sensitivity and exposure for a given species or habitat. Assigned rankings for sensitivity and exposure were then averaged to generate an overall vulnerability score for that particular species or habitat:

Vulnerability = (Climate Exposure Rank + Sensitivity Rank) ÷ by two.

Sensitivity and exposure evaluations were also assigned one of three confidence rankings (High-3, Moderate-2, or Low-1); confidence reflects the sureness assessors had in a given sensitivity or exposure ranking and was based on the extent and quality of reference material. Confidence rankings for sensitivity and exposure were also averaged (mean) to generate an overall confidence score.

Species Sensitivity

Species sensitivity to climatic factors may be direct (e.g., physiological) or indirect (e.g., ecological relationships). Sensitivity to climatic factors includes consideration of direct climate (i.e., temperature, precipitation) or climate-driven changes (e.g., pH, oxygen) or disturbance regimes (e.g., fire, flooding, extreme events). Physiological sensitivity refers to a species' physiological ability to tolerate changes that are higher or lower than the range of variability that they currently experience. Species that are able to tolerate a wide range of climatic factors may be considered less sensitive (Glick et al. 2011). The sensitivity of a species also depends on the sensitivity of its ecological relationships (e.g., habitat needs, diseases, predator-prey dynamics, foraging, pollination, competition). More generalist species (e.g., few to no dependencies on specific habitats, prey or forage species, etc.) are likely less sensitive to climate change effects, whereas specialist species that are dependent on specific habitats, prey or forage are likely more sensitive, particularly if those relationships are likely to be affected by climate change. For example, climate-driven changes in Clark's Nutcracker distribution or behavior could have a significant impact on whitebark pine regeneration, as this species is dependent on the Clark's Nutcracker for seed dispersal (Tomback 2007; Lorenz et al. 2008). Ecological relationships significantly affected by small changes in climatic factors likely confer a higher sensitivity to a species.

Evaluations of sensitivity for species considered the following factors:

- Physiology (e.g., limits to heat tolerance)
- Phenology dependencies (the timing of ecological events e.g., the availability of prey or forage species relative to migration timing)
- Other ecological relationships (e.g., competition, predator-prey dynamics)

Species sensitivity rankings were assigned as follows:

- **Low:** Unlikely to be affected by a given change in climatic factors. The species exhibits little to no physiological or phenological sensitivity to climatic factors. The species is more of a generalist with few to no dependencies (e.g., on specific habitat types, prey or forage species). For those dependencies that do exist, they are unlikely to be sensitive to climate change.

- **Low-Moderate:** May be somewhat affected by a given change in climatic factors but to a low degree. The species may exhibit some slight sensitivity to climatic factors in terms of physiology, phenology, and/or ecological relationships (e.g., habitat needs, forage or prey).
- **Moderate:** Likely to be noticeably but not significantly affected by a given change in climatic factors. The species exhibits a fair amount of sensitivity to climatic factors in terms of physiology, phenology, and/or ecological relationships.
- **Moderate-High:** Likely to be significantly affected by a given change in climatic factors. The species exhibits more significant sensitivity to climatic factors in terms of physiology, phenology, and/or ecological relationships.
- **High:** Likely to be substantially affected by a given change in climatic factors, with major implications for species long-term persistence. The species exhibits substantial physiological sensitivity to climatic factors **AND/OR** the species is more of a specialist with critical dependencies (e.g., on specific habitat types, prey or forage species) that are likely to be significantly affected by climate change.

Habitat Sensitivity

Habitat sensitivity to climatic factors includes consideration of whether the habitat occurs in a relatively narrow climatic zone, and/or whether it experiences large changes in structure or composition in response to relatively small changes in climatic factors. Sensitivity to climatic factors includes consideration of direct climate (i.e., temperature, precipitation) or climate-driven changes (e.g., pH, snowpack) or disturbance regimes (e.g., fire, flooding, insect and disease outbreaks, wind). More sensitive habitats are likely those that occur within a narrow climatic zone and/or experience large changes in composition or structure in response to small changes in climatic factors (Lawler 2010). Similarly, habitats may be at greater risk of decline, or elimination even, in response to small alterations in disturbance regimes (Lawler 2010). For example, altered fire regimes in grassland habitats may increase invasion rates and abundance of non-native annual grasses and weed species that out-compete native grasses.

Habitat sensitivity rankings were assigned as follows:

- **Low:** Unlikely to be affected by a given change in climatic factors. The habitat exhibits little to no change in structure or composition in response to changes in climatic factors or disturbance regimes, and/or does not occur in a relatively narrow climatic zone.
- **Low-Moderate:** May be somewhat affected by a given change in climatic factors but to a low degree. The habitat may exhibit some slight sensitivity to climatic factors in terms of changes in structure or composition.
- **Moderate:** Likely to be noticeably but not significantly affected by a given change in climatic factors. The habitat exhibits a fair amount of sensitivity to climatic factors in terms of changes in structure or composition, and/or may inhabit a somewhat narrow climatic zone, increasing its potential susceptibility to climate changes.
- **Moderate-High:** Likely to be significantly affected by a given change in climatic factors. The habitat exhibits more significant sensitivity to climatic factors in terms of changes in structure or composition, and/or occurs in a narrow climatic zone likely to be significantly affected by climate change.
- **High:** Likely to be substantially affected by a given change in climatic factors, with major implications for long-term persistence. The habitat exhibits substantial change in structure or composition in response to changes in climatic factors or disturbance regimes, and/or occurs in a narrow climatic zone likely to be eliminated or experience substantial declines due to climate change.

Assessing Exposure - Species and Habitat

An exposure evaluation for habitats or species includes considering exposure to climate changes (e.g., temperature and precipitation) as well as climate-driven changes and disturbance regimes (e.g., water chemistry, altered fire regimes, altered flow regimes). In particular, to what degree is the habitat or species likely to be exposed to and affected by a given change? As part of this evaluation, it is important to consider both the magnitude and rate of projected future change. In general, exposure for a given species or habitat was evaluated using downscaled climate projections (tables, narratives, figures) from the following resources (see full citations at the end of this chapter):

- Appendix C: A summary and overview of climate impacts affecting natural systems in Washington – prepared to support the SWAP Update
- Washington State Integrated Climate Change Response Strategy, 2012
    - Projected future changes in marine and coastal ecosystems, forests, freshwater/aquatic ecosystems, and aridlands.
- Washington Climate Change Impacts Assessment (Climate Impacts Group, 2009)
    - Temperature, precipitation, April 1 snow-water equivalent, shifts from snow to rain, extreme precipitation, flood risk, heat waves.
- Wade et al. 2013
    - Water temperature, high and low flows.
- Tillman and Siemann 2011
    - Projected future changes in marine ecosystems.
- Littell et al, 2010
    - Fire and insect outbreaks.
- Michalak et al. 2014
    - Vegetation projections, temperature, precipitation, and invasive species spread for the Columbia Plateau ecoregion.

Exposure rankings were assigned as follows:

- **Low:** Unlikely to be exposed to and affected by a given change in climatic factors.
- **Low-Moderate:** May be somewhat exposed to and affected by a given change in climatic factors but to a low degree.
- **Moderate:** Likely to be noticeably but not significantly exposed to and affected by a given change in climatic factors.
- **Moderate-High:** Likely to be significantly exposed to and affected by a given change in climatic factors.
- **High:** Likely to be substantially exposed to and affected by a given change in climatic factors, with major implications for long-term persistence.

Overall Vulnerability

In this particular context, vulnerability was evaluated by considering the sensitivity and exposure of the habitat or species to climatic factors. Vulnerability rankings were assigned as follows:

- **Low:** A combination of low or low-moderate sensitivity and exposure to climate change. Score range: 1-1.8
- **Low-Moderate:** A combination of low to moderate sensitivity and exposure to climate change. Score range: 1.81-2.6
- **Moderate:** Moderate sensitivity and exposure to climate change or some combination of high and low sensitivity and exposure. Score range: 2.61-3.4
- **Moderate-High:** A combination of moderate to high sensitivity and exposure to climate change. Score range: 3.41-4.2

- **High:** A combination of moderate-high or high sensitivity and exposure to climate change. Score range: 4.21-5

Assessing Confidence
Confidence can be defined as "the subjective assessment that any ranking will prove correct" (Schneider et al. 2007). Sensitivity and exposure evaluations were assigned one of three confidence rankings (High-3, Moderate-2, or Low-1). These approximate confidence levels were based on Manomet Center for Conservation Sciences (2012), which collapsed the 5-category scale developed by Moss and Schneider (2000) for the IPCC Third Assessment Report into a 3-category scale to avoid implying a greater level of certainty precision. Confidence rankings for sensitivity and exposure were averaged (mean) to generate an overall confidence score.

Confidence rankings were assigned as follows:
- **Low:** Little to no information exists in the scientific literature and/or information is characterized by high uncertainty.
- **Moderate:** Some (e.g., 1-3 scientific or gray literature reports or papers) exist for the sensitivity or exposure factors identified although there may be some uncertainty and/or conflicting information.
- **High:** Multiple (>3) scientific or gray literature sources exist for each sensitivity or exposure factor identified with less uncertainty.

5.2 Summary of Climate Impacts in Washington State

Climate in the Pacific Northwest has been changing significantly over the past century as a result of natural climate variability and greenhouse gas emissions, resulting in warmer air temperatures and variable precipitation patterns. Air temperatures are projected to continue increasing over the next century, while precipitation will remain variable but largely exhibit summer declines. These changes are projected to lead to a future with significantly altered snowpack, streamflow patterns, water availability, wildfire risk, ocean pH, and sea levels, with various impacts on terrestrial, aquatic, and marine and coastal habitats and their associated species in Washington State.

The following section summarizes current understanding of the historical and observed climate changes in Washington State, as well as projected future changes. Please refer to Appendix C for a more comprehensive summary of climate impacts and what they mean for habitats and species of Washington.

5.2.1 Historical and Observed Changes

Terrestrial Ecosystems
- Average annual air temperatures in the Pacific Northwest have been increasing over the past century, including increases in all seasons and in both maximum and minimum air temperatures.
- No significant trend in precipitation over the past century has been observed.
- Snowpack declined significantly (average 25 percent) and snowmelt occurred 0 to 30 days earlier (depending on location) in the Cascade Mountains during the latter half of the 20th century.
- Over the past half-century, snow-dominated watersheds have experienced earlier snowmelt runoff and reduced snowmelt contributions.
- Soil moisture recharge has been occurring earlier in the Pacific Northwest over the past half century. Over the same time period, July 1 soil moisture trends have been variable, and warmer areas (e.g., the Washington coast) have experienced declines.
- Warmer temperatures have contributed to increasing wildfire frequency and extent in the Pacific Northwest since the 1970s.

Freshwater Ecosystems

- Stream temperatures in the northwest United States experienced a net increase from 1980-2009 largely as a result of increasing air temperatures, with rates of summer warming of 0.40°F per decade.
- 20th century warming caused no change in flood risk for rain-dominant basins, reduced flood risk in snow-dominant basins (due to reduced snowpack), and highly variable but generally elevated flood risk in transient basins.
- All watersheds are experiencing reduced summer flows.

Marine and Coastal Ecosystems

- Global sea surface temperatures have increased 1.1°F since 1950, but no significant ocean warming offshore of North America was observed between 1900 to 2008, except in localized areas (e.g., west of Vancouver Island).
- Global sea levels rose 1.8 (+/- .5) mm/year from 1961 to 2003, with rates accelerating to 3.1 (+/- 0.7) mm/year in the last decade of observation. In the Pacific Northwest, sea levels are largely increasing, although some areas are experiencing decreases.
- The coastal waters of Washington State have been experiencing seasonal hypoxic conditions since at least 1950, and feature the lowest recorded dissolved oxygen (DO) levels of the California Current System.
- Global ocean surface pH has declined 0.1 units since 1750, with rates of -0.02 units/year in the past two decades. Since 1800, outer coastal water acidity in Washington State has increased 10 to 40 percent, translating to a pH decline of -0.05 to -0.15.

5.2.2 Projected Future Changes

Terrestrial Ecosystems

- Air temperatures are projected to continue increasing in all seasons through the end of this century at rates from 0.2 to 1.0°F per decade.
    - Summer temperatures are projected to warm more rapidly than winter temperatures' and the interior of Washington is projected to experience slightly greater warming than coastal areas.
    - The number, mean duration, and maximum duration of extreme heat events are expected to increase, particularly in south central Washington and lowlands in western Washington.
- Precipitation projections are highly variable, and may include either increases or decreases in annual precipitation over the next century.
    - By the end of the century, winters will likely be wetter and summers will likely be drier.
    - Precipitation intensity may also rise, particularly in the North Cascades and NE Washington.
- April 1st snowpack is projected to continue decreasing significantly throughout this century (-53 percent to -65 percent by 2080); snowpack losses are likely to be greatest at lower elevations and more modest at higher elevations.
- Snowmelt is projected to occur increasingly earlier by 2050, potentially three to four weeks earlier than the 20th century average.
- Warmer temperatures will likely drive shifts from snow-dominant to transient or rain-dominant basins, with streamflow timing likely occurring earlier in snow-dominant and transient basins.
- Flood risk and erosion is projected to increase in transient basins while snowmelt and rain-dominant basins will see minimal or slight increases.
- July 1 soil moisture is largely projected to decline across Washington State (-15 to -18 percent by 2080).
- Increased lightning activity and projected temperature increases over the next century may contribute to increased fire frequency, severity, intensity, and total area burned in the Pacific Northwest.
    - Forested ecosystems in the Pacific Northwest are projected to experience a larger relative increase in area burned than non-forested vegetation.

Freshwater Ecosystems

- Spring and summer stream temperatures are projected to continue increasing across the state, including increases in the frequency and duration of unfavorable temperature events (periods with water temperatures greater than 70°F).
    - Increasing stream temperature trends will be particularly pronounced in the Yakima River, the Columba River (near Bonneville Dam), the Lower Snake River, and in western Washington, the Stillaguamish River, Lake Washington and Lake Union.

Marine and Coastal Ecosystems

- Northwest ocean temperatures are projected to increase 2.2°F by the 2040s.
- Rates of sea level rise are projected to continue increasing globally over the next century, and Washington State could experience increases of +4 to +56 inches by 2100 (relative to 2000).
    - Puget Sound is projected to keep pace with global sea level rise and experience the most sea level rise by the end of the century.
    - The northwest Olympic Peninsula, which is experiencing significant uplift (greater than2 mm/year), will see much lower increases and/or declines in sea level by 2100.
    - The central and southern coasts, which may be experiencing moderate uplift (0-2 mm/year), will likely experience sea level increases with magnitudes in between the other two regions during the same time period.
- Coastal hypoxia episodes may increase as a result of climate change due to warmer sea surface temperatures, which affect oxygen solubility, and intensified upwelling as a result of shifting wind patterns.
- Global ocean surface pH, as well as pH in the North Pacific, is projected to decline an additional -0.2 to -0.3 units by 2100, translating to a 100 to 150 percent increase in ocean acidity.

5.2.3 How will climate change affect habitats and species?

The implications for species and habitats will vary based on location and the specific vulnerabilities of the target resource, but in general will include the following:

- Shifts in habitat amount, extent, and quality.
- Shifts in species composition, distribution and biodiversity, as well as shifts in species interactions.
- Impaired biological, ecological, and biogeochemical processes.
- Declines in certain vegetation types and expansions in others as suitable habitat ranges shift.
- Shifts in phenology, affecting plant reproduction and/or productivity and animal life histories, survival, reproduction, and growth.
- Increases in forest disease susceptibility due to moisture stress.
- Altered aquatic organism behavior, health, growth, reproductive success, and survival.
- Increased sensitivity to pollutants and contaminants.
- Increased risk of invasive species spread and/or establishment.

5.3 Results: Vulnerability Rankings for Species of Greatest Conservation Need

The following section highlights those Species of Greatest Conservation Need evaluated as having moderate-high or high vulnerability to climate change. Table 5-1 below highlights those species with moderate-high or high vulnerability *and* high confidence[1] -- 10 mammals, two birds, three amphibians, 16 fishes, and four invertebrates.

Species that received moderate-high or high vulnerability rankings but low or moderate confidence evaluations are not listed in this table, as more research, data, and/or expert consultation is required to improve confidence. Table 5-1 should be considered a dynamic as opposed to a static list. As new information becomes available for the sensitivity or exposure of a given species, it can be incorporated into the table and used to reevaluate vulnerability.

Summaries of the results for all species are summarized below, by taxa. Each of the taxa summaries includes a figure that represents relative vulnerability in ways that may help to identify appropriate management options. For example, figure 5-2, below shows the 44 mammals placed according to their vulnerability and the confidence in that evaluation. Feasible adaptation approaches for these animals vary depending on location within the figure, as described below.

Low Vulnerability
Focus on reducing current stressors as these likely represent a greater threat to these species. For species with low confidence, managers could consider gathering and integrating additional data to refine vulnerability information and improve confidence.

Moderate Vulnerability
Focus on identifying possible interactions between climate and non-climate stressors, as non-climate stressors may have the potential to exacerbate climate impacts. Other options include reducing current stressors, enhancing knowledge to refine vulnerability information and improve confidence evaluation (e.g., for low or moderate confidence), or increasing or enhancing monitoring to include evaluation of climate stressors.

High Vulnerability
Focus on reducing climate stressors as these likely represent a significant threat to these habitats. Additionally, those habitats with low or moderate confidence could be prioritized for monitoring to determine if and when impacts occur. High vulnerability and high confidence habitats may also provide an opportunity to review and modify actions for reducing non-climate stressors so that they help to ameliorate the effects of climate change.

For more discussion on adaptation approaches, see section 6.0 – Management Considerations. For full descriptions of the vulnerability rankings for all 268 SGCN see Appendix C, which includes narrative descriptions of sensitivity and summaries of the key exposure factors.

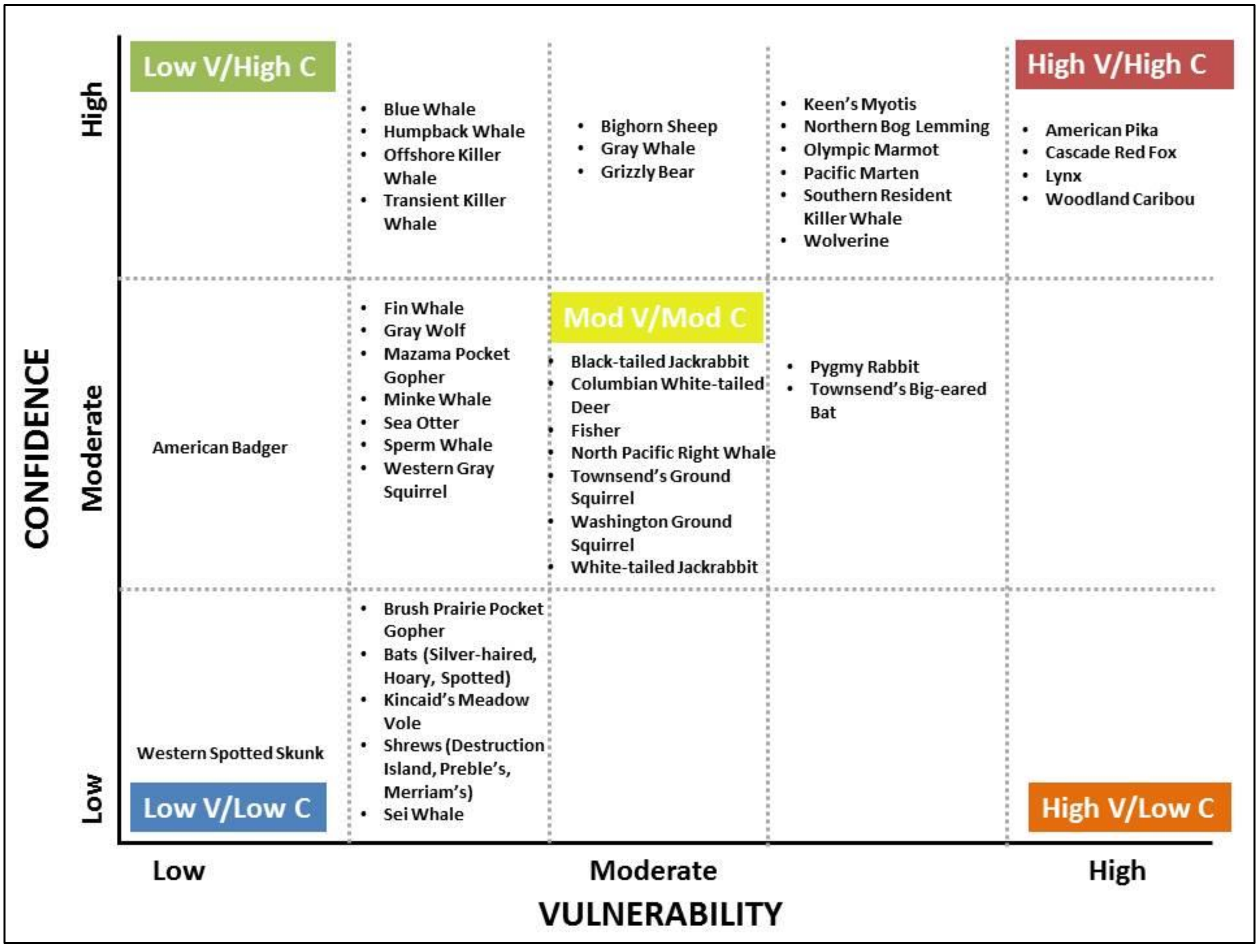
[1] Confidence reflects the average sureness assessors had in a vulnerability ranking.

5.3.1 Summary of key findings from each of the species taxa

Mammals

- Species such as American Pika, Olympic Marmot, Wolverine, Lynx, Cascade Red Fox, and Pacific Marten occupying higher elevation habitats such as alpine and subalpine forests, meadows, and parklands have higher vulnerability, in particular, to warming temperatures and reduced snowpack
- Many marine mammals including Blue, Fin, Humpback, Sperm, Minke, and Sei Whales; Transient/Offshore Killer Whales, and Sea Otters were evaluated as having low-moderate overall vulnerability.
    - Sensitivity for many of these marine mammals was primarily driven by prey availability, although many species (e.g., Sea Otters, Sei, Minke, Fin Whales) are able to switch prey species, lowering overall sensitivity.
- Species evaluated with moderate-high or high vulnerability but only moderate confidence included Pygmy Rabbit and Townsend's Big-eared Bat.
- Hoary, Spotted, and Silver-haired Bats occupy a range of habitats and/or exhibit a generalist diet, leading to a lower overall vulnerability ranking.
- A number of small mammal species had little to no information on climate sensitivity including the Brush Prairie Pocket Gopher, Destruction Island Shrew, Kincaid's Meadow Vole, Mazama Pocket Gopher, Preble's Shrew, and Western Spotted Skunk.

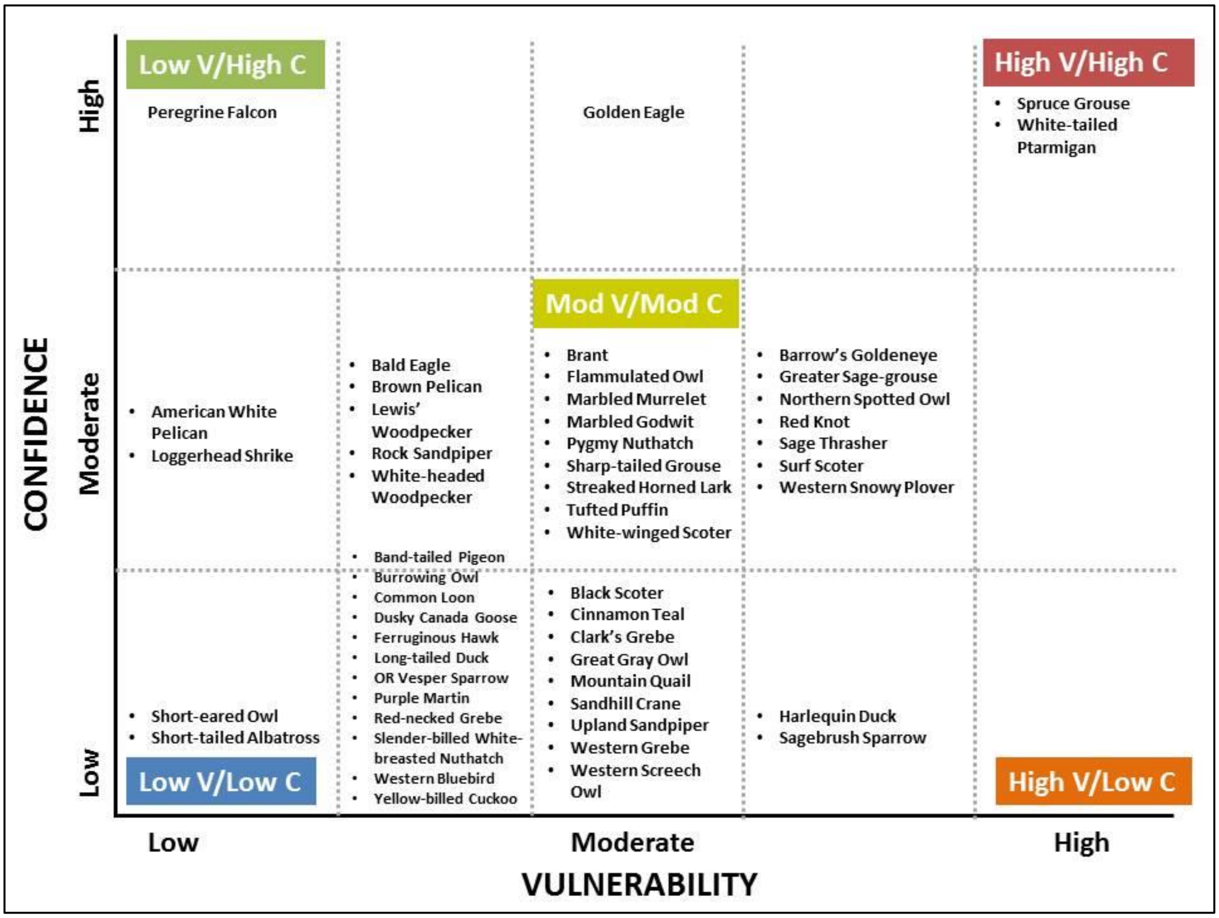
Figure 5-2: Mammals - Vulnerability (V) and Confidence (C)



Birds

- Species evaluated with moderate-high or high vulnerability but low or moderate confidence included Barrow's Goldeneye, Harlequin Duck, Greater Sage-grouse, Northern Spotted owl, Red Knot, Sage Thrasher, Sagebrush Sparrow, Surf Scoter, and Western Snowy Plover.
- Birds utilizing higher elevation habitats (e.g., White-tailed Ptarmigan and Spruce Grouse) as well as sagebrush-obligate species such as Greater Sage-grouse, Sage Thrasher, and Sagebrush Sparrow exhibit high sensitivity due to potential climate impacts on habitats (e.g., higher elevation habitats have higher vulnerability to warming temperatures and reduced snowpack while sagebrush habitats have higher vulnerability to altered fire regimes and invasive weeds). The sagebrush-obligates are not on the climate watch list because of a lower confidence level in exposure - the rate and timing of climate changes to the species range.
- Coastal species such as Red Knot, Surf Scoter, and Western Snowy Plover exhibit high vulnerability due to sea level rise impacts on nesting and/or foraging habitat, as well as climate-driven changes in phenology resulting in timing mismatches with prey availability.
- Many species evaluated as having low or low-moderate overall vulnerability are considered generalist species or are highly adaptable (e.g., occur within a range of habitats, including human-altered landscapes); e.g., Bald Eagle, American White and Brown Pelicans, Dusky Canada Goose, Loggerhead Shrike, and Peregrine Falcon.

Figure 5-3: Birds - Vulnerability (V) and Confidence (C)



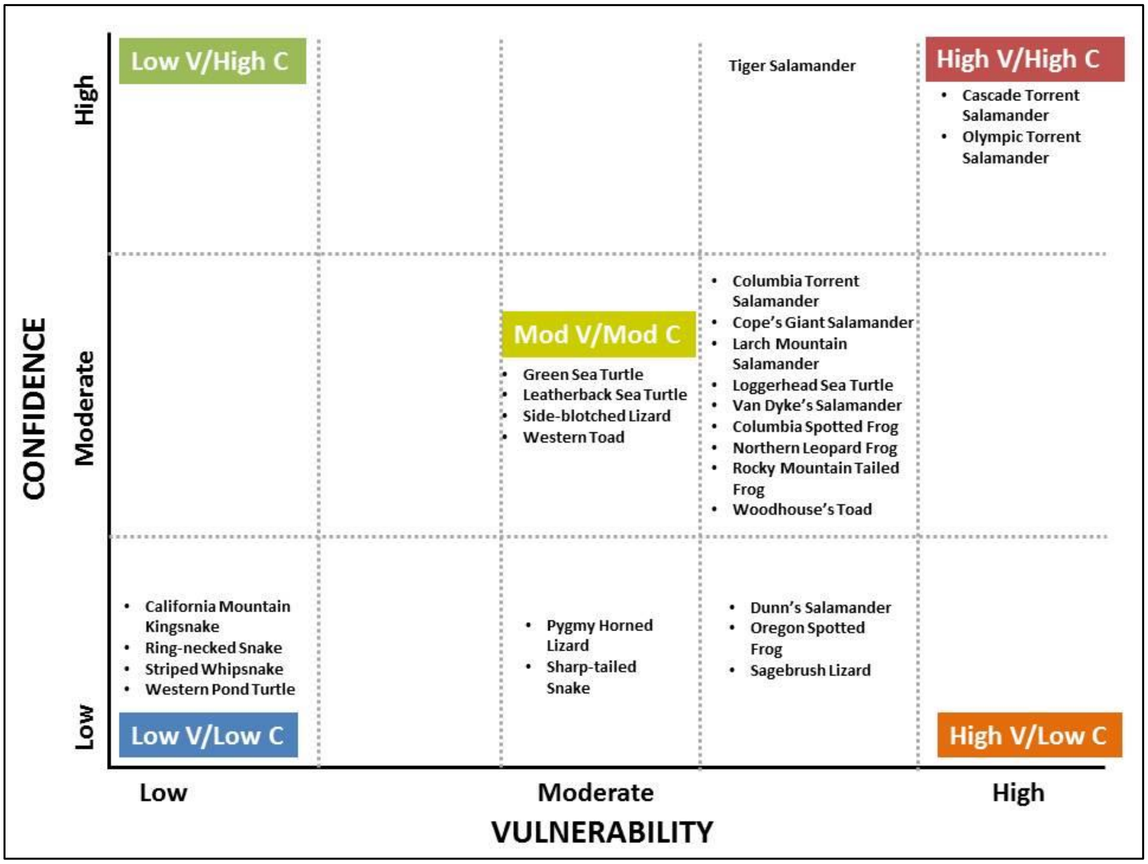
Reptiles

- No reptiles were evaluated as having moderate-high or high vulnerability *and* high confidence
- Species evaluated with moderate-high or high vulnerability but low or moderate confidence included: Loggerhead Sea Turtle and Sagebrush Lizard.
- The Green Sea Turtle, Loggerhead Sea Turtle, and Leatherback Sea Turtle exhibit moderate or moderate-high sensitivity to climate change (e.g., increased ocean temperatures, declines in pH) however, exposure is thought to be moderate in this region.
- Overall, there is a lack of information regarding sensitivity of all snake species evaluated, which led to low or moderate vulnerability rankings.
- Side-blotched and Pygmy Horned Lizard both exhibit moderate vulnerability primarily due to their association with shrub-steppe habitats that are sensitive to altered fire regimes and invasive weeds that degrade or eliminate habitat.

Amphibians

- All salamanders were evaluated as having moderate-high or high sensitivity to climate change due to physiological sensitivity to heat and desiccation and/or their dependence on specific habitats that are sensitive to changes in water supply (e.g., decreased precipitation or snowpack) that dry or reduce available habitat and/or shifts from snow to rain that lead to erosion and scouring of habitats. Cascade Torrent, Columbia Torrent, Olympic Torrent and Cope's Giant Salamanders exhibit greater vulnerability due to their association with headwater habitats that are sensitive to rain-on-snow events.
- Species evaluated with moderate-high or high vulnerability but low or moderate confidence included: Columbia Spotted Frog, Columbia Torrent Salamander, Cope's Giant Salamander, Dunn's Salamander, Larch Mountain Salamander, Northern Leopard Frog, Oregon Spotted Frog, Rocky Mountain Tailed Frog, Van Dyke's Salamander, Western Toad, and Woodhouse's Toad. The low confidence ranking was largely due to lack of information.
- Columbia Spotted, Northern Leopard, Oregon Spotted, and Rocky Mountain Tailed frogs exhibit moderate-high vulnerability to climate change primarily due to warmer temperatures and altered hydrologic regimes that lead to declines in available habitat.
- Sensitivity of the Western Toad and Woodhouse's Toad is primarily driven by their dependence on aquatic habitats for breeding and/or migration routes.

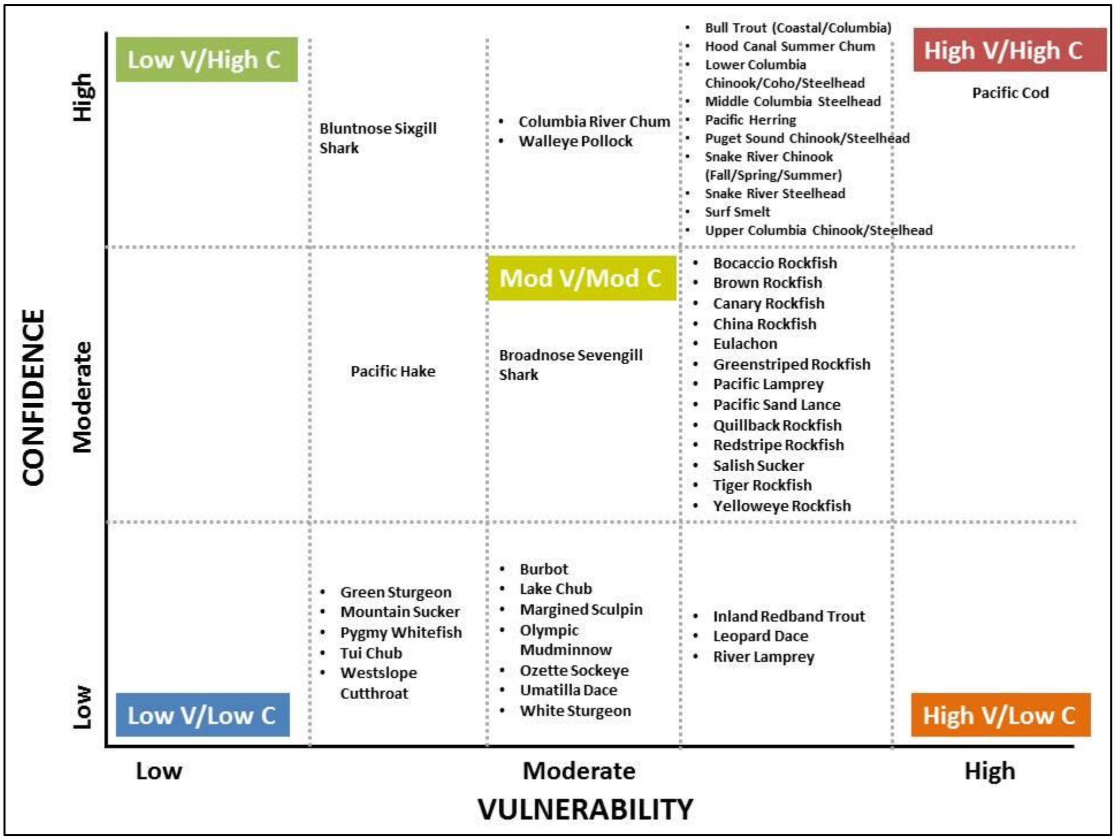
Figure 5-4: Amphibians and Reptiles - Vulnerability (V) and Confidence (C)



Fishes

- Pacific Cod, Pacific Herring, and Surf Smelt received moderate-high or high vulnerability and high confidence scores – Pacific Cod and Pacific Herring primarily because of warming sea surface or ocean temperatures that can affect prey availability and/or spawning and recruitment, and Surf Smelt because of potential reductions in beach spawning habitat due to sea level rise.
- Species evaluated with moderate-high or high vulnerability but low or moderate confidence included: Bocaccio, Brown, Canary, China, Copper, Greenstriped, Quillback, Redstripe, Tiger and Yelloweye Rockfishes; Eulachon; Inland Redband Trout; Leopard Dace; Pacific Lamprey; Pacific Sand Lance; River Lamprey; and Salish Sucker.
- In general, rockfish species were evaluated as having moderate sensitivity to climate change due to potential impacts to their prey base and habitat requirements. Key exposure factors for Washington including increased ocean temperatures, declines in pH, sea level rise, and decreased oxygen contributed to an overall moderate-high vulnerability evaluation.
- While Bull Trout (Coastal and Mid-Columbia) received moderate-high vulnerability rankings, some of the literature suggests that future exposure to warmer temperatures, lower flows, and higher flows may be moderate within current distributions.
- Chinook, Coho, and Steelhead of the Lower and Upper Columbia and Snake River received moderate-high vulnerability rankings due to higher sensitivities and projected future exposure to warmer water temperatures and lower low flows.
- Puget Sound Chinook and Steelhead received moderate-high vulnerability rankings due to moderate future exposure to warmer water temperatures and lower summer flows but higher exposure to increased high flow events.

Figure 5-5: Fishes - Vulnerability (V) and Confidence (C)



Invertebrates

- Species evaluated with moderate-high or high vulnerability but low or moderate confidence included: Beller's Ground Beetle, Butterflies (see list below), Caddisflies (Limnephilus flavastellus, Psychoglypha browni), Northern Abalone, Sand-verbena Moth, Subarctic Bluet, Wenatchee Forestfly, Western Bumblebee, and White-belted Ringtail.
- Butterfly species such as Chinquapin and Johhson's Hairstreak, Island Marble, Mardon Skipper, and Taylor's Checkerspot exhibit both direct (e.g., activity and emergence are influenced by temperature) and indirect sensitivity to climate (i.e., due to habitat specialization).
- Similar to butterflies, dragonfly species exhibit moderate-high to high direct and indirect sensitivity to climate change; temperature is known to influence the phenology, development, and behavior of dragonflies while altered flow regimes and reduced water supply may degrade aquatic habitat.
- Several species of caddisflies including Allomyia acanthis, Goereilla baumanni, Limnephilus flavastellus, and Psychoglypha browni received moderate-high vulnerability rankings, primarily due to climate impacts on specialized habitat requirements (e.g., cold water streams).
- Marine invertebrate species including the Northern Abalone and Olympia Oyster received moderate-high or high vulnerability rankings due to high sensitivity and exposure to declines in pH.
- All snail species were evaluated as having low or low-moderate sensitivity to climate change, primarily driven by a lack of information.
- A number of invertebrate species had little to no information on climate sensitivity including Cryptomastix mullani hemphilli, Leschi's Millipede, Mission Creek Oregonian, Nimapuna tigersnail, and the Salmon River Pebblesnail.

Figure 5-6: Invertebrates part I, Vulnerability (V) and Confidence (C)

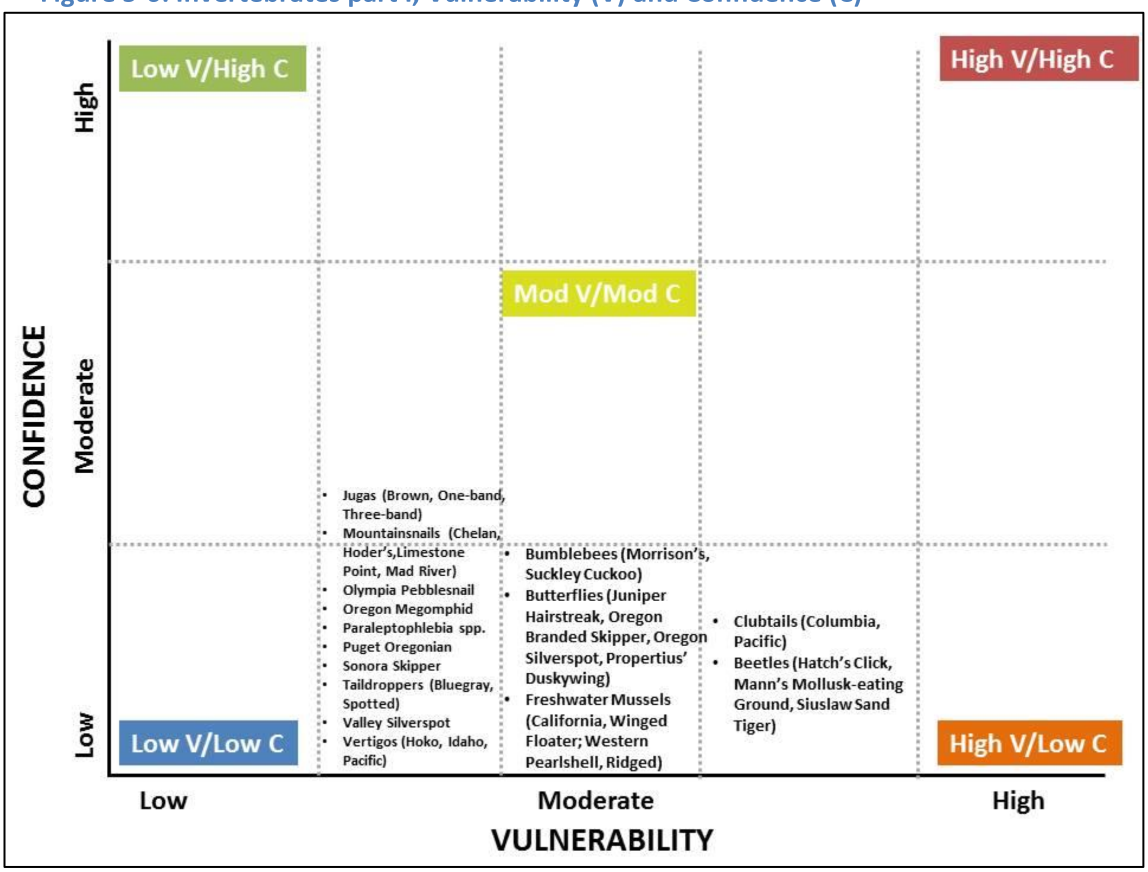
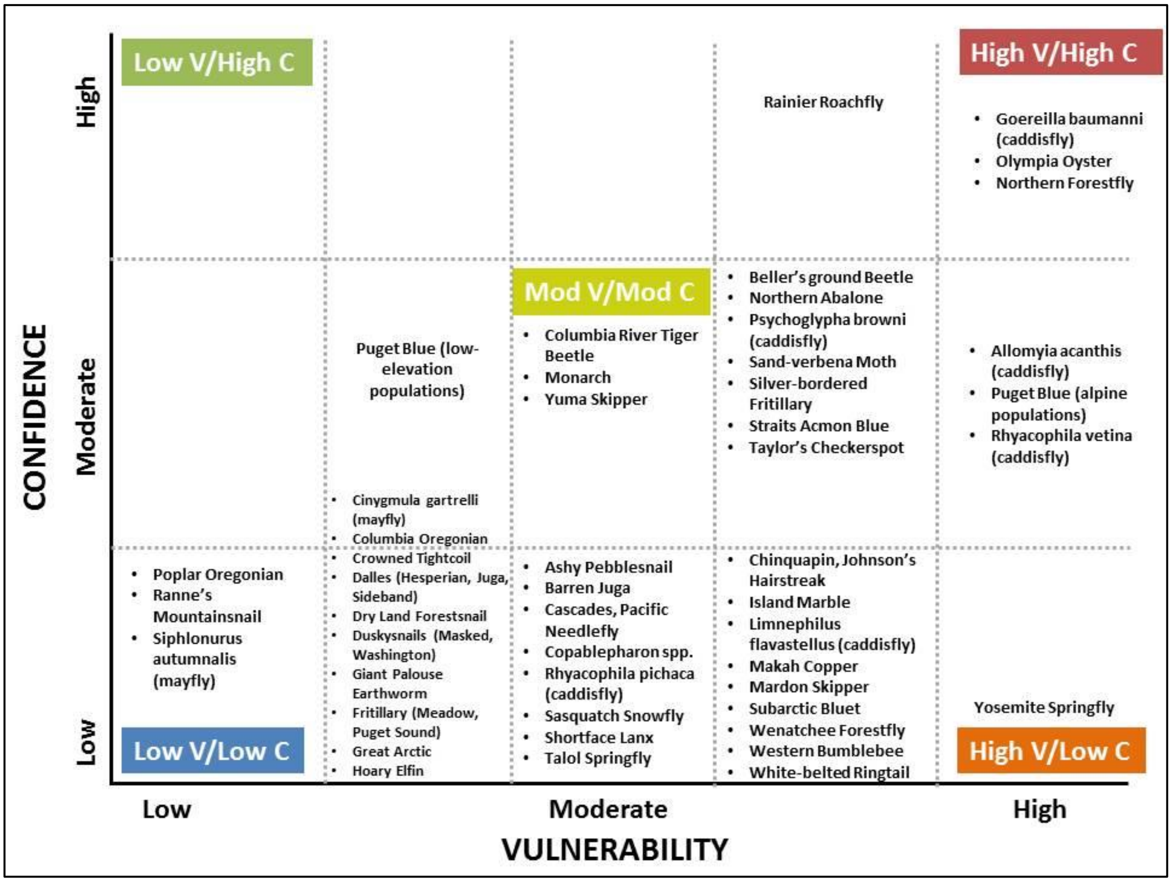


Figure 5-7: Invertebrates part 2, Vulnerability (V) and Confidence (C)



5.3.2 Climate Watch Species

The following table lists those SGCN which ranked highest in the overall vulnerability ranking (moderate-high or high) *and* for which we had a high confidence, based on the available literature. This list should be considered preliminary, as research on the impacts of climate change on species and habitats is growing rapidly and over time the confidence and/or vulnerability score for several species is expected to change.

Table 5-1: SGCN – Preliminary Climate Watch List – SGCN with moderate-high or high vulnerability and high confidence

MAMMALS	American Pika Cascade Red Fox Keen's Myotis Killer Whale Lynx Northern Bog Lemming Olympic Marmot Pacific Marten Wolverine Woodland Caribou
BIRDS	Spruce Grouse White-tailed Ptarmigan
AMPHIBIANS	Cascade Torrent Salamander Olympic Torrent Salamander Tiger Salamander
FISHES	Bull Trout Coastal Recovery Unit Bull Trout Mid-Columbia Recovery Unit Hood Canal Summer Chum ESU Lower Columbia Chinook ESU Lower Columbia Coho ESU Lower Columbia Steelhead DPS Middle Columbia Steelhead DPS Pacific Cod (Salish Sea Population) Pacific Herring Puget Sound Chinook ESU Puget Sound Steelhead DPS Snake River Chinook – Spring/summer ESU Snake River Basin Steelhead DPS Surf Smelt Upper Columbia Spring Chinook ESU Upper Columbia Steelhead DPS
INVERTEBRATES	Caddisfly ((Goereilla baumanni) Northern Forestfly Rainier Roachfly Olympia Oyster

Table 5-2: SGCN Preliminary Climate Watch List Descriptions

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
MAMMALS	American Pika	High	High	The American Pika displays high sensitivity because of its preferred habitat type and condition, very low reproductive rate, and limited dispersal ability. The Pika requires a moderate amount of snowpack in order to provide insulation during the winter months; decreasing snowpack because of rising temperatures and shifting precipitation patterns with more rain than snow will negatively impact this species. Pikas have high energetic demands, partly because they do not hibernate; increasing temperatures and extreme heat events may affect the Pika's ability to forage during the day. In addition, climate change will likely alter the composition of vegetation in montane habitats; this shift may be to plant species less suited to the Pika's nutritional needs.	• Increased temperatures • Reduced snowpack • Shifts from snow to rain
	Cascade Red Fox	High	High	The Cascade Red Fox is presumably adapted to colder climates, and is restricted to alpine and subalpine ecosystems and high elevation meadows. The overall sensitivity of this species to climate change is likely driven by their dependence on these colder, high elevation habitats. Warmer temperatures and reduced snowpack may negatively impact this species by further contracting suitable habitat ranges and/or facilitating movement of coyotes (potential competitor and predator) into the range of Cascade Red Foxes. Altered fire regimes that degrade or eliminate alpine and subalpine habitat are also likely to negatively impact this species.	• Increased temperatures • Reduced snowpack • Altered fire regimes
	Keen's Myotis	Moderate-High	High	Keen's Myotis has a specialist's diet and its sensitivity is therefore tightly linked to both the timing and abundance of its prey. This species does not migrate, which makes it very sensitive to changes in microclimate, especially during winter hibernation; changes in temperature that drive the timing and length of winter hibernation could result in a mismatch in timing of insect prey availability and emergence from hibernation. It has a small geographic distribution; however, field identification of this species is difficult because of strong similarities with the Western Long-eared Myotis, making statements about distribution, population size, and trends less certain. Cooler temperatures may energetically stress this species.	• Increased temperatures

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
MAMMALS	Southern Resident Killer Whale	Moderate-High	High	Some Killer Whale populations occupy a wide temperature range; thus these are unlikely to experience physiological sensitivity to increasing ocean temperatures. However, their overall climate sensitivity is much higher due to potential declines in prey abundance. For the Southern Resident populations in particular, since they feed primarily on Chinook salmon, declines in Chinook abundance – which could stem from a number of climate factors, such as increases in sea surface and fresh water temperature or higher levels of precipitation and runoff – could lead to decreases in survival and fecundity of Southern Resident whales.	• Increased ocean and fresh water temperatures • Increased precipitation • Increased runoff • Declines in pH
	Lynx	High	High	Lynx exhibit sensitivity to warming temperatures, decreased snowpack and earlier snowmelt, and altered fire regimes. Lynx are reliant on consistent snowpack during winter months for hunting, which provides them a competitive advantage over other predators. Lynx are usually considered hare specialists; increasingly variable timing of the arrival and melting periods of snowpack may lead to local extirpations of Snowshoe Hares, potentially affecting Lynx survivorship and recruitment. However, Lynx have been known to switch prey items when hares are limiting. Altered fire regimes and insect and disease outbreaks that reduce mature stands, early seral-stage coniferous stands and/or dense understory cover further increases the sensitivity of this species.	• Increased temperatures • Reduced snowpack • Earlier snowmelt • Altered fire regimes • Increased insect and disease outbreaks
	Northern Bog Lemming	Moderate-High	High	The Northern Bog Lemming's physiological sensitivity to climate is likely moderate-high, as Lemming populations may have historically been reduced in size and number when the climate was warmer and the Lemming is moderately restricted to relatively cool or cold environments in most of its range. Additionally, Washington is at the very southern edge of the species' geographic range, which may increase sensitivity to warming temperatures. The overall sensitivity of this species is likely driven by their dependence on cold, moist habitats such as peat lands and sphagnum moss, which are sensitive to changes in temperature and precipitation that lead to reduced moisture. Altered fire regimes that degrade or eliminate habitat may also impact this species.	• Increased temperatures • Changes in precipitation • Drought • Altered fire regimes

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
MAMMALS	Olympic Marmot	Moderate-High	High	Olympic Marmots' sensitivity to climate is likely driven by their association with subalpine meadows that are vulnerable to increasing temperatures and reduced snowpack that result in habitat alterations (e.g., increased forest encroachment into meadows). Altered fire regimes may benefit subalpine meadows by preventing conifer encroachment. Olympic Marmots are also indirectly sensitive to climate change through effects on their primary predator, coyotes. Warmer winters and lower snowpack are thought to allow coyotes to persist at higher elevations than they could otherwise, increasing their predation on Olympic Marmots. Some evidence suggests that Olympic Marmots may also be directly sensitive to changes in snowpack; prolonged spring snow cover may be detrimental to survival and reproduction while sparse winter snow cover increases winter mortality.	• Increased temperatures • Reduced snowpack • Altered fire regimes
	Pacific Marten	Moderate-High	High	Sensitivity of the Marten to climate change will likely be driven by its habitat specificity and reliance on deep snowpack. Altered fire regimes and/or drought that result in reductions in the distribution and connectivity of important habitat features (e.g., large diameter tree stands with high canopy cover) may negatively impact this species. Martens rely on deep and persistent snowpack to exclude predators, provide high-quality hunting conditions, and provide winter resting and denning sites. Future reductions in snowpack may affect both Marten and its prey species due to creation of more thermally variable subnivean space, and may alter Marten spatial distributions and/or competition with fisher.	• Reduced snowpack • Altered fire regimes • Drought
	Wolverine	Moderate-High	High	Wolverines exhibit sensitivity to temperature and declines in snowpack. Wolverines are obligatorily associated with persistent spring snow cover, which provides critical thermal advantages such as predator refugia for denning females and young, preventing competition with other scavengers, and important prey caching/refrigeration areas. Temperature appears to play a role in fine-scale habitat selection, and may affect prey-caching success. Warming temperatures and declines in snowpack could lead to decreased habitat patch size, quality, and connectivity; reduced success of caching/refrigeration of carrion prey with subsequent impacts on survivorship and recruitment; limited den sites and/or loss of thermal refugia important for juvenile survival; and/or increased dispersal costs.	• Increased temperatures • Reduced snowpack

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
MAMMALS	Woodland Caribou	High	High	Woodland Caribou occupy higher elevations and rely on old-growth Engelmann spruce/subalpine fir and western red-cedar/western hemlock forests that support arboreal lichens, which constitute a large portion of the Woodland Caribou diet. In combination with fire, warmer temperatures, precipitation changes, climate-driven increases in forest disease and insect mortality, and reduced snowpack and earlier snowmelt are likely to alter suitable habitat and predation risk for Woodland Caribou. Fire creates younger-age stands and edge habitat that attract deer, elk, and moose; higher ungulate densities increases associated predator density, and these predators (e.g., Bears, Wolves, Cougars) prey opportunistically on Caribou. Woodland Caribou require deep, consolidated snow for movement at higher elevations during winter. Reduced snowpack and earlier snowmelt will affect the seasonal movements of Woodland Caribou and other ungulates, likely increasing predation risk by extending the length of time Caribou share habitat with other ungulates.	• Increased temperatures • Changes in precipitation • Altered fire regimes • Reduced snowpack • Earlier snowmelt • Increased insect and disease outbreaks
BIRDS	Spruce Grouse	High	High	Sensitivity of Spruce Grouse appears to be driven by their dependence on high elevation conifer forests. Spruce Grouse prefer relatively young successional stands of dense conifers, and populations appear to fluctuate over time in response to the degree of maturation of post-fire regrowth. Altered fire regimes and insect and disease outbreaks that lead to habitat degradation increase the sensitivity of Spruce Grouse to climate change.	• Altered fire regimes • Increased insect and disease outbreaks
	White-tailed Ptarmigan	High	High	Physiological sensitivity of White-tailed Ptarmigan is likely low-moderate as this species is well-adapted to high altitude climatic variation and harsh conditions, although it has been shown that high winter minimum temperatures can retard population growth rates. The sensitivity of this species will primarily be driven by its dependence on high elevation habitats likely to be affected by or shrink in response to climate change, as well as its dependence on willow for foraging.	• Increases in winter minimum temperatures • Increased temperatures overall • Reduced snowpack
AMPHIBIANS	Cascade Torrent Salamander	High	High	Cascade Torrent Salamanders are likely highly sensitive to climate change due to their inability to tolerate desiccation and specialized habitat requirements. Declines in water availability and timing (e.g., due to reduced snowpack and earlier snow melt), as well as increased sedimentation (e.g., due to shifts from snow to rain), could decrease suitable headwater habitat for this species. This species may also be physiologically limited by high temperatures.	• Increased temperatureswater) • Changes in precip • Reduced snowpack • Shifts from snow to rain • Earlier snowmelt

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
AMPHIBIANS	Olympic Torrent Salamander	High	High	Overall sensitivity of this species is likely high due to high physiological sensitivity and specific habitat requirements (e.g., associated with permanent, high elevation cold water sources with steep gradients and silt-free). Increasing water temperatures and moisture loss will negatively impact this species as it is desiccation-intolerant and cannot survive where water temperatures are too high. Reduced snowpack and shifts from snow to rain that lead to high flow events, erosion and scouring could reduce headwater riparian habitat for the Olympic Torrent Salamander.	• Increased temperatures (air and water) • Changes in precipitation • Reduced snowpack • Shifts from snow to rain
	Tiger Salamander	Moderate-High	High	This species likely exhibits sensitivity to warmer and drier conditions that reduce aquatic breeding habitat, lead to desiccation, and/or result in an inability to move. Warmer temperatures and a decrease in total annual precipitation (including snow), as well as an increase in drought, has led to wetland desiccation and significant population declines in Yellowstone National Park. Timing of reproduction may also be affected by increasing temperatures.	• Increased temperatures • Changes in precipitation and/or reduced snowpack • Drought
FISHES	Bull Trout - Coastal Recovery Unit and Mid-Columbia Recovery Unit	Moderate-High	High	Sensitivity of Bull Trout is primarily driven by water temperature. Bull Trout are the southern-most species of Western North American Char and have lower thermal tolerance than other salmonids they co-occur with. Indeed the geographic distribution of Bull Trout, and the persistence of populations during contemporary warming has been most strongly related to maximum water temperature. The ability of Bull Trout to persist in sub-optimally warm temperatures likely depends on food abundance. As temperature increases metabolic costs, the extent to which Bull Trout can maintain positive energy balance depends on its ability to find food. Bull Trout historically relied heavily on salmon as a food resource and may be less resilient to temperatures in areas where foraging opportunities of salmon eggs and juveniles have declined. Invasive chars (Brook and Lake Trout) now reside in many headwater streams and lakes, and may exclude Bull Trout from these potential cold water refuges, increasing their sensitivity to warming. Bull Trout sensitivity to flows is likely to occur during two critical periods: (1) direct effects of altered runoff timing and magnitude on emerging fry in late winter/spring, and (2) indirect effects of low summer flows on all life phases by mediating the duration and magnitude of thermal stress events.	• Increased water temperatures • Altered runoff timing • Increased winter/spring flood events • Lower summer flows
	Chinook – Lower Columbia	Moderate-High	High	In general, Chinook Salmon are sensitive to warmer water temperatures, low flows, and high flows. Warmer water temperatures can affect physiological performance and energy budgets, as well as developmental rates and the timing of key life-cycle	• Increased freshwater temperatures • Lower summer flows

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
	ESU, Puget Sound ESU, Snake River Spring/ Summer ESU, and Upper Columbia Spring ESU			transitions (i.e., phenology). Lower stream flows have been linked to mass mortality events of Chinook Salmon. Extreme high flows can reduce the likelihood of egg survival during incubation, and both low and high flows can affect adult migration. Temperature: Chinook Salmon appear sensitive to elevated freshwater temperatures both as juveniles rearing in tributary streams and as adults migrating up river networks to spawn. Elevated water temperature reduces the amount of time a spawning adult can persist in freshwater and decreases the total distance a fish can migrate on a given level of energy stores. Also, temperatures in excess of ~63˚F begin to thermally stress individuals, making them more vulnerable to pathogens and other health issues. Puget Sound Chinook Salmon may be more sensitive to warmer summer temperatures and lower flows, as their spawning migration encounters the warmest part of the watershed (the downstream portion) during the warmer part of the year (later summer and early fall). Cool tributaries may provide refuge from heat stress for migratory Chinook Salmon, and may reduce the sensitivity of this species to warming temperatures. Warming temperatures in the streams where Chinook salmon rear can have negative effects even when temperatures are not near the thermal maxima of the species. For example, warming temperatures decrease the carrying capacity of streams for rearing juvenile salmonids. Because Puget Sound Chinook Salmon rear in streams for up to one year, they may be vulnerable to heat stress during low flow periods of late summer and fall. However, the life-history diversity of this species (particularly the diversity in age-at-maturity) likely enhances resilience to mortality events such as extreme flows or temperatures. Flow regimes: Low flows during the summer and fall may be stressful for migrating adults. Mass mortality events in both fall and spring-run Chinook Salmon have been linked to high temperatures due to low flows. Some Salmon populations may also depend on high flows to allow passage to upstream spawning areas. Increased severity of winter floods has been linked to decreased egg-to-fry survival in Washington. Snowmelt and the resulting runoff in spring may be important for aiding the seaward migration of Salmon Smolts. The reduced stream velocities increase the travel time required for Smolts to reach the ocean – this in turn increases the time of exposure to predators.	• Increased winter/spring flood events

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
				Marine: Increases in ocean and estuarine temperature, increased stratification of the water column, and/or changes in the intensity and timing of coastal upwelling may alter primary and secondary productivity, with potential impacts on growth, productivity, survival, and migrations of salmonids.	
	Hood Canal summer chum	Moderate-High	High	Washington State is near the southern extent of the geographic range for Chum Salmon, which suggests they may be sensitive to increases in water temperature (freshwater and ocean). Chum Salmon incubate embryos in freshwater, but juveniles migrate to estuaries as age-zeros, typically during the spring; the spawning migrations of adult fish typically occur in early fall. Thus Chum Salmon may be sensitive to lower summer flows during adult migration to spawning areas. Altered freshwater thermal regimes could affect chum salmon by altering their phenology and potentially creating mismatch between arrival in estuaries and the timing of ideal ecological conditions in estuarine habitats. Chum Salmon will likely be most sensitive to changes in marine thermal regimes. In general, Pacific Salmon survival is positively related to sea surface temperatures (SST) at the northern extent of their distribution, and negatively related at the southern extent. However, recent evidence suggests that Chum Salmon may be less sensitive to SST at the southern extent of their range compared with Pink and Sockeye. Chum Salmon embryos are vulnerable to flood events that can scour redds or bury them in silt. Chum may be vulnerable to altered flow regimes that include increased flood severity, particularly in watersheds where land use has enhanced stream flashiness.	• Increased water temperatures (freshwater and sea surface) • Increased winter/spring flood events • Lower summer flows
FISHES	Lower Columbia Coho	Moderate-High	High	In general, Coho Salmon likely exhibit sensitivity to warmer water temperatures (freshwater and ocean) and lower summer flows. Freshwater temperature and flow regimes: Central California represents the southern extent of the range for Coho Salmon, suggesting that they may be less sensitive to increases in water temperature than other species of Pacific Salmon (i.e. Pink, Chum, and Sockeye). However, due to their reliance on streams for freshwater rearing, Coho are likely sensitive to both altered flow and thermal regimes. Juveniles prefer low-velocity habitat often in off-channel areas; reduced summer flows may increase the likelihood that such off-channel habitats become inaccessible, thermally stressful, or hypoxic. Early run timing individuals might be more sensitive to fall flood events, which are	• Increased water temperatures (freshwater and sea surface) • Lower summer flows

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
				projected to increase in Washington, and may also be more sensitive to warmer water temperatures and lower flows during peak migration timing (i.e., mid-August to September). Later run timing individuals should be less sensitive because they migrate as adults during cooler periods of the year and their embryos are not yet buried in the gravel during late fall flooding. However, late run individuals may be more likely to have embryos or recently emerged fry threatened by spring flooding that is predicted to increase in severity and frequency. In general, Coho Salmon populations may be less resilient to episodic mortality events caused by climate stressors, because they exhibit only moderate levels of life history diversity and do not have as much variation in age-at maturity as do Sockeye Salmon and Chinook Salmon. Marine: Increases in ocean and estuarine temperature, increased stratification of the water column, and/or changes in the intensity and timing of coastal upwelling may alter primary and secondary productivity, with potential impacts on growth, productivity, survival, and migrations of salmonids. For example, cool Pacific-Decadal Oscillation (PDO) years have historically coincided with high returns of coho salmon, while warm PDO cycles coincided with declines in Salmon numbers. Cooler SSTs during the winter prior to and after smolt migration have also been linked to higher Coho survival. In general, changes in coastal ocean habitat quality and productivity could negatively impact Coho Salmon.	
FISHES	Pacific cod (Salish Sea population)	Moderate-High	High	Though limited information is available regarding the sensitivity of the Salish Sea population of Pacific Cod to climate change, their main sensitivity will be due to potential increases in sea surface temperature. Pacific Cod recruitment is strongly linked to temperature, with colder water supporting larger hatch size and maximizing growth performance. Cooler waters also support higher abundance of zooplankton prey (e.g., copepods), which is thought to be linked to increased recruitment. Temperature over 45°F appears to be associated with poor spawning success and limited recruitment. For Atlantic Cod, declines in recruitment with increasing temperature were particularly high for Cod at the limits of their distribution. Pacific Cod in Washington are already at the upper end of their thermal preference, which is likely to increase their sensitivity to any increases in temperature and could lead to northward population shifts.	• Increased ocean temperatures
	Pacific Herring	Moderate-High	High	A main way in which Pacific Herring will be sensitive to climate change is through change in their prey availability and the distribution of appropriate spawning	• Increased ocean temperatures

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
				habitat. Primary and secondary productivity are strongly linked to juvenile abundance, as juveniles tend to prey on zooplankton (e.g., copepods). Predicted increases in sea surface temperature and changes in upwelling, such as delayed and shorter upwelling seasons, could affect the timing and abundance of available prey for juveniles, though the magnitude of these effects is uncertain. In Washington, Herring populations have already shown northward movement for spawning and smaller juvenile cohorts, and these patterns could increase with predicted increases in sea surface temperature. Increased temperatures could also lead to northward shifts and increased abundance of Pacific Hake, which prey upon Herring and could thus lead to population declines through increased predation. Herring will also be sensitive to potential changes in nearshore and estuarine spawning habitat, such as increased salinity due to sea level rise and saltwater intrusion in estuaries, which could create suboptimal conditions for spawning and larval growth. Additionally, the suite of vegetative species used by Herring as spawning substrate could change with long-term variation in water temperature and acidity. The prevalence and composition of this algal mat could result in degradation of spawning habitat to a degree that ultimately reduces incubation success.	• Altered upwelling patterns • Changes in salinity • Saltwater intrusion in estuarine habitat
	Steelhead – Lower Columbia DPS, Middle Columbia DPS, Puget Sound DPS, Snake River Basin DPS, and Upper Columbia DPS	Moderate-High	High	In general, Steelhead appear sensitive to warmer water temperatures, low flows, and high flows. Warmer water temperatures can affect physiological performance and energy budgets, as well as developmental rates and the timing of key lifecycle transitions (i.e., phenology). Lower stream flows (particularly summer and early fall) can reduce the probability of survival in rearing juveniles. Extreme high flows can reduce the likelihood of egg survival during incubation, and both low and high flows can affect adult migration. Steelhead may be able to shift the timing of a life stage transition to reduce the probability of exposure to changes in temperature or flow through phenotypic plasticity. Similar to Chinook Salmon, Steelhead exhibit alternative life histories in regards to run-timing, which confer different sensitivities to climate. Summer-run Steelhead migrate higher in river networks, entering freshwater between late spring and fall, and overwinter before spawning the following spring. In contrast, winter-run Steelhead migrate during winter or early spring and spawn immediately. Because they spend more time in freshwater, summer-run populations of Steelhead may be more sensitive to changes in flow and temperature regimes across river networks. For example, higher temperatures will increase the metabolic costs accrued by	• Altered spring runoff timing and amount/magnitude • Increased water temperatures

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
				summer-run Steelhead during the several months that they hold in streams prior to spawning. The existence of a resident life history form likely buffers O. mykiss from environmental stochasticity and may make populations less vulnerable to extirpation. For example, anadromous individuals can survive ephemeral periods of unsuitability in their natal streams while they are away at the ocean, whereas residents can survive in years where conditions are poor along migratory routes. Temperature: Steelhead may exhibit some sensitivity to warming water temperatures. Direct measures of Oncorhynchus mykiss thermal physiology suggest many parameters do not differ significantly from those of other salmonids (except in locally adapted populations of Redband Rainbow Trout in desert streams). In addition, contemporary temperature regimes in the Columbia River cause Steelhead and Chinook Salmon to use the same thermal refuges during spawning migrations. Similar to Chinook Salmon, Steelhead are vulnerable to high angling pressure when seeking refuge in cold refugia such as tributary junctions; thus warmer temperatures can have indirect effects on mortality. However, the geographic distribution of Steelhead suggests they may be less sensitive to warm temperatures than other anadromous salmonids—Steelhead occur in Southern California, farther south than any Pacific Salmon. Further, the resident life history form of O. mykiss can persist in desert streams that often exceed 68˚F through what appears to be local adaptation. Whether Steelhead populations from warmer streams exhibit higher thermal tolerance is poorly understood, as is the potential rate of evolution in attributes of thermal physiology. Flow regimes: The survival of Steelhead embryos or recently emerged fry may be sensitive to the timing and magnitude of spring runoff rather than the fall and winter aspects of flow regimes. For example, high winter flows that threaten the egg-to-fry survival of fall-spawning salmonids are not predicted to negatively affect Steelhead. Marine: Increases in ocean and estuarine temperature, increased stratification of the water column, and/or changes in the intensity and timing of coastal upwelling may alter primary and secondary productivity, with potential impacts on growth, productivity, survival, and migrations of salmonids.	

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
	Surf Smelt	Moderate-High	High	Surf Smelt may experience some physiological sensitivity to climate change since warmer and drier beach conditions have been shown to lead to higher levels of smelt egg mortality. Surf Smelt sensitivity will be increased by potential changes in zooplankton prey availability. Predicted delayed and shorter upwelling systems could affect the timing and abundance of prey and lead to declines in prey availability, particularly for juveniles, though the magnitude of these impacts is uncertain. Additionally, since Washington Surf Smelt tend to use a small number of beaches for spawning, changes in beach habitat due to sea level rise and stronger and increased storms could lead to declines in available spawning area.	• Increased air temperatures • Altered upwelling patterns • Sea level rise • Increased storminess
INVERTEBRATES	Caddisfly (*Goereilla baumanni)*	High	High	*Goereilla baumanni* is a species of Caddisfly found only in few sites and always in very low numbers in Washington, Idaho, and Montana. They are restricted to headwater springs and seepage in high-elevation forested areas during their larval and pupae stages, and within this habitat are associated with the surrounding muck comprised of decomposing organic materials. Sensitivity for this species is likely tied primarily to their specialized habitat, which is particularly vulnerable to warming air and water temperatures, low summer flows, sedimentation from upstream erosion, and habitat fragmentation from nearby human activity (i.e. forestry practices and road construction). The close association of *Goereilla baumanni* to organic muck may make this species particularly sensitive to high temperatures, drought, and precipitation changes which may make these areas more likely to dry out. Caddisflies in general are often considered an indicator of high-quality streams, suggesting that they are particularly vulnerable to changes in their habitat.	• Increased air and water temperatures • Drought and/or changes in precipitation • Low summer flows • Increased sedimentation and erosion
	Northern Forestfly	High	High	The Northern Forestfly is a species of stonefly with only one currently known location in the northern Cascades. It is associated with a high-elevation spring and stream which flows into an alpine lake, and in fact all three species in the *Lednia* genus are restricted to alpine or subalpine springs and glacial streams (the proposed name for the genus is "Meltwater Stoneflies"). This species is extremely sensitive to climate change because of its dependence on coldwater habitats, which are likely to warm significantly along with disappearing glaciers.	• Increased water temperatures • Reduced glacier size and increased glacier melting
	Olympia Oyster	High	High	Olympia Oysters are likely to be sensitive to a number of climate factors, including declines in salinity, oxygen, and pH. Olympia Oysters are sensitive to low salinity	• Declines in salinity

Taxa	Common Name	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
				levels, and potential increased precipitation (particularly during winter and spring) can lead to lower salinity levels and potential juvenile mortality, as juveniles have a more sensitive salinity threshold. Additionally, increases in extent of hypoxic conditions could limit oyster growth. Predicted declines in ocean pH in Washington are also likely to lead to decreases in growth, weight, and metamorphic success of oyster larvae, which could also trigger increased mortality at later life stages. The effects of acidification on Oyster larvae could be more severe if low pH conditions are coupled with decreases in phytoplankton food availability.	• Decreased oxygen and pH
	Rainier Roachfly	Moderate-High	High	The Rainier Roachfly has only been documented within Mt. Rainier National Park (mostly on the west side). It is found in seeps, springs, and small spring-fed streams. Climate sensitivity for this species is tied to melting glaciers and an associated rise in stream temperatures. Relatively little is known about this species, but Stoneflies as a whole are sensitive to drought or precipitation changes that may affect seep moisture, springs, and stream flow. Decreased water quality, habitat fragmentation and nearby development also alter the quality of suitable habitat.	• Increased water temperatures • Reduced glacier size and increased melting • Changes in precipitation • Altered flow regimes

5.4 Results: Vulnerability Rankings for Habitats of Greatest Conservation Need

The following section highlights climate change vulnerability rankings for Washington State habitats of greatest conservation need. As discussed in Chapter 4, the SWAP Update uses vegetation formations (representing coarse scale or landscape level habitats) and ecological systems (representing fine scale habitats) as the basis for understanding and identifying habitats of greatest conservation need. Both vegetative formations and ecological systems are collectively referred to as habitats in this chapter. Please refer to Chapter 4 for maps and further information about vegetation formations and ecological systems. Table 5-2 summarizes climate change vulnerability information for the 12 Washington vegetation formations, while Table 5-3 highlights those ecological systems of concern with moderate-high or high vulnerability and high confidence[2]. Habitats that received moderate-high or high vulnerability rankings but low or moderate confidence evaluations are not listed in this table, as more research, data, and/or expert consultation is required to improve confidence.

It is important to note that our initial assessment did not review all ecological systems in Washington, but focused on those already known to be imperiled from existing stressors (these are referred to as Ecological Systems of Concern in the SWAP). In this context Table 5-3 represents an incomplete picture of climate risk to ecological systems across Washington – it focuses exclusively on those already known to be imperiled. Table 5-4 represents a work in progress that will be updated as more of the ecological systems in Washington are assessed for climate

[2] Confidence reflects the average sureness assessors had in a vulnerability ranking.

vulnerability. These vulnerability assessments are updatable so that as new information becomes available on sensitivity or exposure for a given habitat, it can be incorporated into the table and used to re-evaluate vulnerability.

A few themes emerged in evaluating habitats for climate vulnerability:

- Vulnerable habitats can generally be grouped into two primary categories: (1) those that are vulnerable to changes in precipitation type, timing, and amount leading to reduced water supply and soil moisture (e.g., Bog & Fen, Flooded & Swamp Forest), and (2) those that are vulnerable to altered fire regimes and drought/reduced soil moisture (Semi-Desert Scrub and Grassland, Temperate Forest).
- In general, habitats in the East Cascades and Rocky Mountains appear more sensitive to climate change, and received overall moderate-high vulnerability rankings.
- Moisture-dependent habitats in the North Pacific such as Bog & Fen, Lowland Riparian Forest and Shrubland, and Hypermaritime Western Red-cedar-Western Hemlock Forest also received higher sensitivity and vulnerability rankings.

5.4.1 Climate Vulnerability for Vegetation Formations

Table 5-3: Climate Change Vulnerability Summaries for Washington Vegetation Formations

FORMATION	DESCRIPTION OF VULNERABILITY
Alpine Scrub, Meadow & Grassland	Climate change, which may result in reduced snowpack and encroachment by trees and shrubs is considered a major stressor.
Barren	Climate change is a significant stressor for the Alpine Ice Field ecological system (decline of glaciers and reduction in snowpack) and unconsolidated shore in coastal areas (sea level rise, shoreline armoring limiting the flow of sediment).
Bog & Fen	Climate changes such as decreased precipitation, reduced snowpack, or prolonged drought that reduce water availability and recharge may lead to range contraction and/or habitat conversion, increased invasion of dry-adapted species, or tree encroachment in bog and fen habitats. Shifts from snow to rain that enhances winter/spring flood risk may increase erosion of moist peat and topsoil, reduce opportunities for recharge, and/or lead to drying of habitats.
Cliff, Scree & Rock Vegetation	Climate change could alter species composition of this system possibly by allowing more vascular plant species to establish as well as a shift in species composition. Inter-mountain basins active and stabilized dune habitats are highly dynamic by nature, with varying vulnerabilities to climate changes such as increased temperatures and moisture stress. High moisture years enhance dune stabilization by limiting sand movement and/or favoring invasive vegetation establishment (e.g., cheatgrass) and dominance, whereas warmer, drier years enhance dune erosion and movement, facilitating habitat diversity and/or the establishment of new habitat areas.
Flooded & Swamp Forest	Flooded and swamp forests are generally adapted to high moisture levels, making them vulnerable to projected climate changes in hydrology and fluvial processes from precipitation shifts, reduced snowpack and earlier snowmelt, drought, and altered flow regimes. Declining summer and spring stream flows, particularly when combined with drought, could reduce available water for riparian communities, affecting seedling germination and adult survival and potentially contributing to shifts to more xeric and drought-adapted vegetation. Increasing winter flood frequency and volume may also affect vegetation composition, potentially selecting for hardwoods, smaller trees, and younger age classes. Alteration of seasonal and annual flooding regimes will likely alter vegetation establishment, succession, and composition. Drought periods may exacerbate fire risk.
Freshwater Aquatic Vegetation, Wet Meadow & Marsh	Climate changes such as drought, increasing temperatures, and changes in precipitation type, timing, and amount that alter hydrologic regimes and rates of evaporation and recharge may have significant impacts in wetland habitats. For example, these climate changes could lead to wetland drying, shifts in species assemblages (native and non-native), habitat conversion, and/or decreased quality and quantity of habitat available for aquatic biota. Changes in winter precipitation type and timing, as well as earlier runoff, could positively (e.g., create side channels or additional habitat) or negatively (e.g., reduced opportunities for water storage and recharge, increased erosion) impact these habitats. Intertidal freshwater wetlands are also vulnerable to rising sea levels and intrusion of brackish water that can lead to vegetation changes, increased eutrophication, and expansion of invasive plant species.

FORMATION	DESCRIPTION OF VULNERABILITY
Grassland, Meadow & Shrubland	In general, prairies and grasslands are well-adapted to warm and dry conditions and periodic soil drought, and projected future increases in temperature and/or drought for the region are unlikely to disadvantage (and may benefit) these systems. Grasslands may be somewhat sensitive to altered wildfire regimes, particularly increased fire frequency or severity that could limit native species regeneration or increase invasion rates and abundance of non-native annual grasses and weeds. However, increases in wildfire may also benefit grasslands and savannas by preventing conifer encroachment. Conifer encroachment associated with warmer temperatures likely represents the greatest stressor for alpine and subalpine meadows, shrublands, and grasslands.
Open Water	Climate changes such as reduced glacial and snowpack runoff as well as more frequent, intense, and longer-lasting droughts may affect replenishment of open water systems. Increased water temperatures and changes in precipitation type, timing, and amount that lead to altered flow regimes and/or shifts in water supply represent important climatic stressors for open water. Warming water temperatures may cause shifts in species distribution, phenology, and life histories. Changes in precipitation type, timing, and amount may affect habitat complexity, quality, and quantity; reduce connectivity of aquatic habitats; modify food web structure or productivity; or cause range contraction and/or loss of local species.
Salt Marsh	Climate changes that lead to changes in water levels may impact inter-mountain basin playa, alkaline closed depressions and greasewood flats. Changes in precipitation may lead to fluctuations in salinity levels (e.g., increased salinity with decreased precipitation), which could lead to shifts in vegetation composition. Increases in runoff that increase nutrient levels in basin playas and alkaline closed depressions could also threaten vegetation. Projected sea level rise represents a key climate stressor for tidal salt and brackish marshes, as it could lead to submergence of habitats and declines in vegetation unless they are able to migrate inwards through sediment accretion.
Scrub & Herb Coastal Vegetation	Sea level rise, increased coastal erosion, and increased storminess and wave action represent significant climate stressors. Projected sea level rise could cause erosion and/or landward shift of dunes and cliffs. Similarly, greater wave and wind action from storms could cause increased disturbance and erosion of cliffs, dunes, and dune vegetation. Climate induced-changes or declines in dune vegetation that help stabilize and protect dunes could make dune habitat more vulnerable to disturbances from increased erosion, waves, and winds.
Semi-Desert Scrub & Grassland	Climate changes including shifts in precipitation, drought, and altered fire regimes may affect plant composition, density, and distribution in semi-desert scrub and grassland habitats. Precipitation likely influences plant composition, growth, and recruitment, and drought negatively affects seedling survival in sagebrush systems, reduces shrub cover, and elevates herbaceous diversity and cover. Increasing fire frequencies and/or intensities will likely negatively affect sagebrush and shrub habitats, and may favor grassland expansion. However, fire also favors cheatgrass and other non-native annual establishment, which can alter ecosystem function.
Temperate Forest	Increasing temperatures, decreased moisture availability, and altered fire regimes represent the most significant climate stressors to temperate forests. Altered fire regimes appear to be the greatest threat, particularly given fire suppression practices of the past century that have led to the invasion of shade-tolerant and fire-intolerant species and/or altered forest structure and composition (i.e., increased stand density, smaller diameter trees. Warmer temperatures and decreased moisture availability may increase insect outbreaks in some temperate forests. In general, North Pacific temperate forests likely exhibit less vulnerability to climate change than temperate forests of the East Cascades and Rocky Mountains.

5.4.2 Ecological Systems of Concern at highest risk from climate change

Figure 8 summarizes the vulnerability and confidence ranks for all of the ecological systems of concern – the symbols indicate the formation in which the ecological system is found. Table 5-4, following, lists and describes those systems which were evaluated as having moderate-high or high vulnerability *and* high confidence. As noted previously, WDFW plans to evaluate all ecological systems for climate vulnerability – the list below represents only a partial list of the ecological systems of concern currently found in Washington.

Figure 5-8: Ecological Systems of Concern – Vulnerability and Confidence

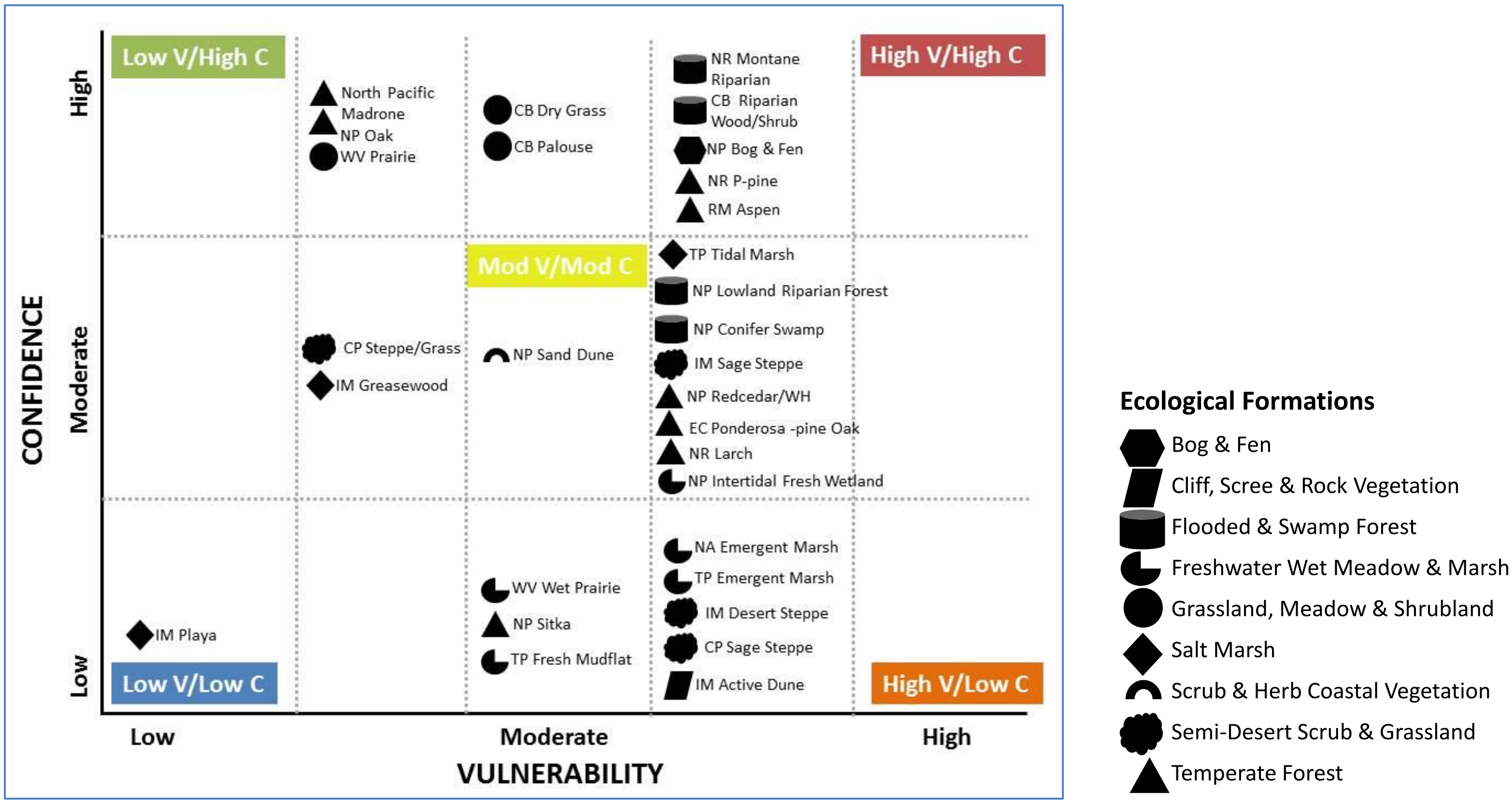


Table 5-4: Ecological Systems of Concern evaluated as having moderate-high or high vulnerability and high confidence

Forma-tion	Ecological System of Concern	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
BOG & FEN	North Pacific Bog and Fen	Moderate-High	High	Bog and fen habitats, particularly those that depend on surface water, are sensitive to drier climate conditions (i.e., decreased precipitation, reduced snowpack, shifts from snow to rain) that can lead to range contraction and/or habitat conversion, increased invasion of dry-adapted species, or tree encroachment. Groundwater-dependent bog and fen habitats may be more resilient to climate changes, but also exhibit sensitivity to prolonged drought as well as reduced snowpack and the subsequent impacts to groundwater recharge. Bog and fen habitats are also sensitive to shifts from snow to rain that lead to increased winter/spring flood risk, as this may increase erosion of moist peat and topsoil, reduce opportunities for recharge, and/or lead to drying of habitats.	• Changes in precipitation • Decreased snowpack • Shifts from snow to rain • Prolonged drought
FLOODED & SWAMP FOREST	Columbia Basin Foothill Riparian Woodland and Shrubland	Moderate-High	High	Columbia Basin Foothill Riparian Woodlands and Shrublands are adapted to high moisture levels and depend upon spring and late-winter floods for re-establishment, and are likely sensitive to changes in hydrology and fluvial processes resulting from precipitation shifts, reduced snowpack and earlier snowmelt, drought, and altered flow regimes. Declining summer and spring streamflows, particularly when combined with drought, will likely reduce available water for riparian communities, affecting seedling germination and adult survival and potentially contributing to shifts to more xeric and drought-adapted vegetation. Habitats along intermittent or ephemeral streams may be particularly vulnerable. Shifts in flood timing in magnitude (i.e., larger winter floods, lower spring floods) will likely affect riparian succession, age classes, and ecological composition, as many flood-adapted riparian species exhibit phenology (e.g., seed dispersal) timed with historic streamflow patterns. Drought periods may also exacerbate fire risk. Young foothill riparian woodlands and shrublands are fairly sensitive to fire, while mature riparian stands may be more resilient to low-intensity surface fires. In general, these riparian habitats experience infrequent fire; they can re-colonize after disturbance (including fire), but regeneration of many species post-fire is dependent on soil moisture.	• Changes in precipitation • Decreased snowpack • Shifts in runoff timing • Drought • Altered flow regimes (high and low) • Altered fire regimes

Forma-tion	Ecological System of Concern	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
FLOODED & SWAMP FOREST	Northern Rocky Mountain Lower Montane Riparian Woodland and Shrubland	Moderate-High	High	Sensitivity of this system is likely driven by soil moisture changes, altered hydrological and fluvial processes, and fire. This habitat is dependent on abundant soil moisture and adapted to seasonal flood regimes, both of which can be affected by temperature increases, precipitation shifts, reduced snowpack and earlier snowmelt, drought, and altered stream flow regimes. Soil moisture declines can affect germination and growth of component species. Alteration of seasonal and annual flooding regimes will likely alter vegetation establishment, succession, and composition. For example, declining summer and spring stream flows, particularly when combined with drought, will likely reduce available water for riparian plant communities, affecting seedling germination and adult survival and potentially contributing to shifts to more xeric and drought-adapted vegetation and associated losses in disturbance-adapted vegetation. Increasing winter flood frequency may facilitate shifts to younger overall age classes and annual species. This habitat occasionally experiences fire, and component species (e.g., deciduous trees) are able to recover fairly quickly. However, increasingly xeric conditions, increasing temperatures, and drought may increase fire frequencies, which will affect riparian age classes and vegetation composition.	• Reduced soil moisture • Altered flow regimes (high and low) • Altered fire regimes
TEMPERATE FOREST	Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	Moderate-High	High	This ecosystem exhibits sensitivity to reduced soil moisture and drought as well as wildfire. Seasonal precipitation and drought influence the establishment of ponderosa pine and Douglas fir, and soil moisture deficits can increase old growth ponderosa pine mortality due to heightened competition with dense stands of young trees. This system is also sensitive to insect outbreaks, which may increase due to warmer temperatures and/or increased environmental stress (e.g., decreased soil moisture) that make tree species more susceptible to infestation. Wildfire is likely the most significant sensitivity for this system. In general, low severity, high frequency fires maintained and expanded this ecosystem, and even severe, large crown fires may be beneficial by helping cultivate an open forest structure (i.e., by restoring to initial stand establishment phase). However, wildfires that re-burn a previous severe-burn area may limit forest establishment due to lost seed source, reduced soil moisture, and high surface soil temperature. Additionally, much of this system features altered structure and composition (i.e., increased stand density, smaller diameter trees), which increases sensitivity to altered fire regimes that may limit regeneration potential of this ecosystem.	• Reduced soil moisture • Drought • Altered fire regimes • Increased insect outbreaks

Forma-tion	Ecological System of Concern	Vulnerability Ranking	Vulnerability Confidence	Description of Sensitivity	Description of Exposure
	Rocky Mountain Aspen Forest and Woodland	Moderate-High	High	This ecosystem exhibits sensitivity to increasing temperatures, decreased moisture availability, and altered fire regimes. In general, aspen is a water-limited, drought-intolerant species, and warmer, drier conditions can affect aspen mortality, growth, and regeneration. Prolonged drought can lead to significant aspen die-offs, and recent declines in aspen extent may be partially explained by warmer temperatures and reduced moisture over the last several decades. Aspen sensitivity to climate change may be moderated by its tolerance of fire and other disturbances (e.g., wind, floods); interactions between multiple disturbance factors may favor aspen expansion because they negatively impact competitor species (i.e., conifers). However, severe fire and reburns may eliminate some stands in hotter and drier areas.	• Increased temperatures • Reduced soil moisture • Drought • Altered fire regimes

5.4.3 Other Ecological Systems of Concern with high vulnerability but less than high confidence

Other habitats evaluated with moderate-high or high vulnerability but low or moderate confidence included those listed in Table 5-5. As more research or information becomes available, some of these ecological systems could move to those in the high risk category. Descriptions of the specific impacts considered for each of these systems is available in Appendix C.

Table 5-5: Ecological systems of Concern evaluated with moderate-high or high vulnerability but low or moderate confidence

FORMATION	ECOLOGICAL SYSTEM
Cliff, Scree & Rock Vegetation	Inter-Mountain Basins Active and Stabilized Dune
Flooded & Swamp Forest	North Pacific Hardwood-Conifer Swamp
	North Pacific Lowland Riparian Forest and Shrubland
Freshwater Wet Meadow & Marsh	North American Arid West Emergent Marsh
	North Pacific Intertidal Freshwater Wetland
	Temperate Pacific Freshwater Emergent Marsh
Salt Marsh	Temperate Pacific Tidal Salt and Brackish Marsh
Semi-Desert Scrub & Grassland	Columbia Plateau Low Sagebrush Steppe
	Inter-Mountain Basins Big Sagebrush Steppe
	Inter-Mountain Basins Semi-Desert Shrub Steppe
Temperate Forest	East Cascades Oak-Ponderosa Pine Forest and Woodland
	North Pacific Hypermaritime Western Red-cedar-Western Hemlock Forest
	Northern Rocky Mountain Western Larch Savanna

5.4.4 Additional Ecological Systems likely to be at high risk

Although not covered in Table 5-4 or Table 5-5 above, preliminary research suggests the following ecological systems are also likely to be at least moderately sensitive to climate change:

- North Pacific Dry and Mesic Alpine Dwarf-Shrubland, Fell-field and Meadow
- Rocky Mountain Alpine Tundra/Fell-field/Dwarf-shrub
- Unconsolidated Shore
- North American Alpine Ice Field
- Rocky Mountain Subalpine-Montane Fen
- North Pacific Montane Riparian Woodland and Shrubland
- North Pacific Shrub Swamp
- Northern Rocky Mountain Conifer
- Rocky Mountain Lower Montane Woodland and Shrubland
- Rocky Mountain Subalpine-Montane Riparian Woodland
- Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland

- Inter-Mountain Basins Montane Riparian Systems
- Columbia Plateau Vernal Pool
- Rocky Mountain Alpine-Montane Wet Meadow
- Temperate Pacific Montane Wet Meadow
- Rocky Mountain Subalpine-Montane Riparian Shrubland
- Rocky Mountain Subalpine-Montane Mesic Meadow
- North Pacific Maritime Eelgrass Bed
- Temperate Pacific Intertidal Mudflat
- Open Water
- North Pacific Coastal Cliff and Bluff
- Inter-Mountain Basins Big Sagebrush Shrubland
- Inter-Mountain Basins Semi-Desert Grassland
- Inter-Mountain Basins Montane Sagebrush Steppe
- East Cascades Mesic Montane Mixed-Conifer Forest and Woodland
- North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest
- North Pacific Mesic Western Hemlock-Silver Fir Forest
- North Pacific Mountain Hemlock Forest
- Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest
- Northern Rocky Mountain Mesic Montane Mixed Conifer Forest
- Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
- Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland

Additional work is underway to fully assess the vulnerability of these habitats to climate change.

5.5 Management Considerations

This section discusses important considerations in applying the climate change vulnerability information for species and habitats, and provides a general overview of adaptation approaches.

5.5.1 Important Considerations

Non-climate stressors

Non-climate stressors have the potential to exacerbate the effects of climate change on species and habitats, or vice versa, although they may also have independent or antagonistic effects. For example, elevated abundance of cheatgrass may contribute to altered fire regimes due to higher fuel densities and shorter fire return intervals. Habitats or species that have to endure multiple non-climate stressors may be more sensitive to climate changes. For example, the overall vulnerability of Columbia Basin Palouse Prairie habitats to climate change may be greater due to a current stressor of invasive species that can outcompete native vegetation for soil moisture and/or increase fire intensity, even if this habitat is currently evaluated as having moderate vulnerability (Figure 5-1). Managers are encouraged to consider climate vulnerabilities for all resources, not just the target species under consideration, as they have the potential to interact with non-climate stressors in unanticipated ways and may lead to significant impacts on species or habitats.

Expert consultation

Information used in the species and habitats vulnerability assessment came primarily from the scientific and unpublished (gray) literature. An important component of this process is expert consultation, which helps to better characterize uncertainty and fill in data gaps where traditional scientific research or data are not yet available. WDFW anticipates updating and refining these vulnerability assessments and rankings over time with additional expert review.

5.5.2 Adaptation Approaches

Adaptation refers to efforts to avoid or ameliorate climate change effects that are already being or are expected to be experienced. In the context of vulnerability, adaptation refers to actions that reduce exposure or sensitivity to climatic changes. Examples of reducing exposure include protecting resources and infrastructure from flood damage or sea level rise, planting riparian vegetation buffers that enhance water quality, or restoring wetlands to limit flooding. Examples of reducing sensitivity include replanting with a mix of species that can cope with a range of climatic conditions, reducing or limiting levels of pollutants, or preventing or removing invasive species.

In general, there are five approaches to facilitating adaptation:

1. **Enhance Resistance**
   Resistance strategies help prevent the effects of climate change from reaching or affecting a resource. Examples of resistance adaptation options include limiting non-climate stressors, preventing invasive species establishment after disturbances, reducing non-natives, reducing the impacts of disease and fire, protecting vulnerable areas from sea level rise, or reducing erosion, among others.

2. **Promote Resilience**
   Resilience strategies help weather the impacts of climate change by avoiding or recovering from the effects. Examples of resilience strategies include employing a risk diversification approach to forest management and silvicultural practices, promoting native genotypes and adapted genotypes of

native species, requiring setbacks or buffers for future coastal developments, or upgrading culverts, bridges, and stream crossings to deal with higher peak flows, among others.

3. **Facilitate Transition**
   Transitional or response strategies involve taking a new course or path because the effects of climate change are unlikely to be dealt with in a current location or given current conditions. Examples of transitional or response strategies include facilitating change to desired assemblages, promoting connected landscapes to facilitate forest species migration along climatic gradients, or identifying and protecting projected future refugia, among others.

4. **Increase Knowledge**
   Increasing knowledge will help to fill data and information gaps to make better climate-informed decisions. Examples of increasing knowledge strategies include increasing or enhancing monitoring, continuing to gather and integrate data for refinement of vulnerability information, or improving understanding of patterns, characteristics, and rates of change in species distributions, among others.

5. **Management Coordination**
   Management coordination will better align values and efforts to improve conservation success in light of climate change. Examples of coordination strategies include aligning budgets and priorities for climate-focused work, establishing regional monitoring networks, or increasing communication and collaboration among local, regional, and state entities, among others.

No single adaptation strategy or individual management action will be appropriate to all situations or in all places. As with all management actions, adaptation strategies need to be tailored to particular resource locations and management contexts.

5.5.3 Next Steps

The following possible next steps have been identified. Please note that this list is not comprehensive; additional steps may be considered at a later date.

1. Complete vulnerability assessments for all ecological systems in Washington.
2. Convene workshops for expert review and refinement of vulnerability assessment summaries for species and ecological systems.
3. Evaluate existing non-climate stressors for climate watch species and assess priority in the context of added climate risk.
4. Explore the feasibility of additional adaptation actions for climate watch species.
5. Consider climate risk in other agency action prioritization.

5.6 References

Climate Impacts Overview

The information in the climate impacts overview was compiled from various synthesis reports on climate change projections and impacts for the Pacific Northwest region. Specific citations for information not derived from these reports can be found in-text. Otherwise, primary literature sources can be found within the following synthesis reports:

Climate Impacts Group. 2009. The Washington Climate Change Impacts Assessment, M. McGuire Elsner, J. Littell, and L. Whitely Binder (eds). Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle, Washington.

Doney, S., A. A. Rosenberg, M. Alexander, F. Chavez, C. D. Harvell, G. Hofmann, M. Orbach, and M. Ruckelshaus. 2014. Ch. 24: Oceans and Marine Resources. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 557-578. doi:10.7930/J0RF5RZW.

Gregg, R. M., K. M. Feifel, J.M. Kershner, and J.L. Hitt. 2012. The State of Climate Change Adaptation in the Great Lakes Region. EcoAdapt, Bainbridge Island, WA.

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Mote, P., A. K. Snover, S. Capalbo, S. D. Eigenbrode, P. Glick, J. Littell, R. Raymondi, and S. Reeder. 2014. Ch. 21: Northwest. Climate Change Impacts in the United States: The Third National Climate Assessment, J. M. Melillo, Terese (T .C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 487-513. doi:10.7930/J04Q7RWX.

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State of Washington Department of Ecology (WDOE). 2012. Preparing for a Changing Climate: Washington States Integrated Climate Response Strategy. Publication No. 12-01-004. Olympia, WA.

Tillman, P. and P. Glick. 2013. Climate Change Effects and Adaptation Approaches for Terrestrial Ecosystems, Habitats, and Species: A Compilation of the Scientific Literature for the North Pacific Landscape Conservation Cooperative Region. National Wildlife Federation. Available at: http://www.nwf.org/~/media/PDFs/Global-Warming/2014/Terrestrial-Report/CC-and-Terrestrial-Systems_Final-Report_NPLCC-NWF_online-size.pdf

Tillman, P. and D. Siemann. 2011. Climate Change Effects and Adaptation Approaches in Freshwater Aquatic and Riparian Ecosystems in the North Pacific Landscape Conservation Cooperative Region: A Compilation of Scientific Literature. National Wildlife Federation. Available at: http://www.nwf.org/~/media/PDFs/Global-Warming/2014/Freshwater-Report/NPLCC_Freshwater_Climate-Effects_Final.pdf

Tillman, P. and D. Siemann. 2011. Climate Change Effects and Adaptation Approaches in Marine and Coastal Ecosystems of the North Pacific Landscape Conservation Cooperative Region: A Compilation of Scientific Literature. National Wildlife Federation. Available at: http://www.nwf.org/~/media/PDFs/Global-Warming/2014/Marine-Report/NPLCC_Marine_Climate-Effects_Final.pdf

Washington Wildlife Habitat Connectivity Working Group (WHCWG). 2010. Washington Connected Landscapes Project: Statewide Analysis. Washington Departments of Fish and Wildlife, and Transportation

Species and Habitat Vulnerability

Information sources used to assess the climate vulnerability of species, ecological systems and formations can be found in Appendix C – Supporting Information for Climate Change, and also in Appendix F - Master Bibliography.