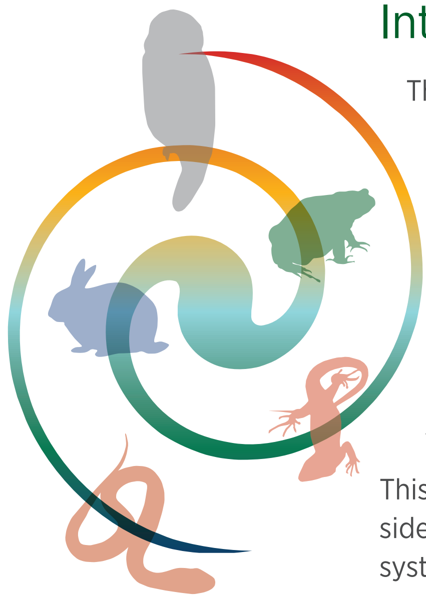
Washington Department of FISH and WILDLIFE

How Will Climate Change Affect West-side Forest Systems and Species in Washington?



Introduction

This summary represents an initial evaluation of climate change vulnerability for west-side forest systems and associated species based on expert input and information in the scientific literature. In this context, climate change vulnerability is a function of the sensitivity of a particular resource to climate changes and its exposure to those changes. The aim of this document is to summarize the climatic factors west-side forest systems and species are sensitive to, the projected changes for those factors, and potential impacts to systems and species. This document also provides an overview of management actions that could be implemented to help reduce vulnerabilities and impacts.

This initial evaluation focused on the terrestrial ecological systems within west-side forests, and did not include the fish species that use aquatic and riparian systems in the same geography.

Exposure: How much of a change in climate a system or species is likely to experience

Sensitivity: Whether and how a system or species is likely to be affected by a given change in climate

Vulnerability

V = E+S / 2

This assessment also included confidence rankings. Confidence reflects the sureness experts had in a given ranking and was based on the extent and quality of reference material and information.

West-side Forest System Description[1]

West-side forest systems occur throughout western Washington, including the west slopes of the Cascades and across the Olympic Mountains, Puget lowlands, and coastal areas. These forest systems are widespread, and are typically dominated by conifers and other evergreens. Natural disturbances (e.g., fire, insect outbreaks, and disease) and forest management practices create a mosaic of forest patches of varying successional stages, resulting in a heterogeneous landscape. Current non-climate stressors include some kinds of timber harvest, tree plantations, invasive plants, introduced diseases, and land use conversion to development or agriculture.

[1] Information in this section comes from: (1) Washington Department of Fish and Wildlife. 2015. Washington's State Wildlife Action Plan: 2015 Update. Washington Department of Fish and Wildlife, Olympia, Washington, USA; and (2) Rocchio, F.J. and R.C. Crawford. 2015. Ecological Systems of Washington State: A Guide to Identification. Washington State Department of Natural Resources. Report 2015-04. 397 pp.

Fact sheet developed by EcoAdapt.

This summary covers the following west-side forest systems:

North Pacific Dry Douglas-fir Forest and Woodland.

This system is found on dry soils west of the Cascade crest, and typically occurs in small to large patches with a heterogeneous structure that includes small openings and meadows. However, much of this system lies within the Puget lowlands, where disturbance regimes and forest structure, composition, and diversity have been heavily impacted by human activities such as development and land use conversion, timber harvest, fire suppression, tree plantations, and invasive species. Closely associated species include a number of butterflies, including the great arctic, hoary elfin, Puget Sound fritillary, Taylor's checkerspot, and valley silverspot.

North Pacific Maritime Mesic Subalpine Parkland.

This system is found at the forest/alpine transition zone throughout the Olympic and Cascade Mountains, and is comprised of tree islands or small patches of forest within larger areas of low shrublands and meadows. Plant associations are a mix of montane and subalpine tree, shrub, and meadow species. Although the majority of this system is intact, the system is being altered in some areas by encroaching trees; additionally, livestock, horse, and foot traffic can compact soils, and plants are unable to recover quickly due to slow growth. Closely associated species include the Mazama pocket gopher, Olympic marmot, mardon skipper, Puget blue, Puget Sound fritillary, valley silverspot, and western bumblebee.

North Pacific Maritime Mesic-Wet Douglas-fir Western Hemlock Forest.

This system is widespread throughout western Washington, occurring in lowland and low montane forests where soils are moist to wet. These forests can advance to late-successional stages due to infrequent disturbances (e.g., stand-replacing fires may only occur every few hundred years), and have thick understories with abundant moss and lichens. This system has been impacted by timber harvest and tree plantations, which reduce species and patch diversity, alter forest structure and composition, and reduce regeneration. Development and other human activity have also fragmented forest areas and altered natural disturbance regimes. Closely associated species include the Cascade torrent salamander, Dunn's salamander, ring-necked snake, bluegray taildropper, and Johnson's hairstreak.

North Pacific Dry-Mesic Silver Fir-Western Hemlock Douglas-fir Forest.

This widespread system occurs throughout the mid-montane zones of the Cascade and Olympic mountains, and has generally not been heavily impacted by human activity. However, logging, fire suppression, tree plantations, and introduced diseases have impacted some areas by reducing species diversity and tree regeneration, changing forest structure and composition, and altering natural disturbance regimes. Closely associated species include the Cascade torrent salamander, Chinquapin hairstreak, Taylor's checkerspot, and valley silverspot.

North Pacific Oak Woodland.

This system can typically be found on dry, low-elevation sites that historically experienced frequent, low-severity fires, primarily in the Puget Trough and Willamette Valley. Woodland extent and integrity have been increasingly limited by fire suppression and associated conifer encroachment, as well as invasions of other non-native grasses and shrubs. Development, agricultural conversion, and grazing have also contributed to habitat loss, fragmentation, and invasive species establishment. Closely associated species include the slender-billed white-breasted nuthatch, western pond turtle, Propertius' duskywing, Puget Sound fritillary, Taylor's checkerspot, and valley silverspot.

Most west-side forest systems have been impacted by logging and conversion to tree plantations, which reduce species and genetic diversity and alter forest structure, composition, and patch heterogeneity. Many west-side forests have also experienced increases in non-native species and introduced diseases and conversion to development or agriculture, which have reduced forest extent and integrity. Climate change is likely to exacerbate the impacts of these non-climate stressors on west-side forest systems, potentially leading to increased habitat degradation and loss of habitat diversity.

Key Climate Sensitivities and Impacts:
West-side Forest Systems[2]

Overall, west-side forest systems exhibit sensitivity to increased air temperatures, changes in precipitation, reduced snowpack, decreased soil moisture, altered wildfire regimes, and changes in storm frequency and severity. Increased air temperatures and reduced snowpack are likely to extend the length of the growing season, potentially increasing tree establishment in areas where growth is primarily limited by temperature rather than water. Reduced soil moisture may also contribute to shifts in species composition, favoring those adapted to periods of summer drought (e.g., Douglas-fir), and potentially limiting seedling recruitment in those that require moist growing conditions (e.g., oak [Quercus spp.]). Warmer, drier conditions are likely to contribute to more frequent and/or more severe fires that may lead to loss of forest area, limit forest regeneration and/or contribute to shifts in species composition, and facilitate the spread of invasive species (e.g., scotch broom [Cytisus scoparius]). However, altered fire regimes may benefit some systems by maintaining more open conditions. Finally, changes in the frequency and/or intensity of extreme precipitation events may increase blowdowns where soil is very saturated and/or in exposed areas, and may also increase damage from flooding, landslides, and erosion. Sensitivity rankings for west-side forest systems include:

North Pacific Dry Douglas-fir-Forest and Woodland	Mod-High Sensitivity	Mod Confidence
North Pacific Maritime Mesic Subalpine Parkland	Mod-High Sensitivity	High Confidence
North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest[3]	Mod Sensitivity	Mod Confidence
North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest	Mod-High Sensitivity	Mod Confidence
North Pacific Oak Woodland	Low-Mod Sensitivity	High Confidence

Key Climate Sensitivities and Impacts:
West-side Forest Associated Species

In west-side forest systems, reduced habitat and host/forage plant availability drive overall species sensitivity to climate change. Increased temperatures, changes in precipitation, reduced snowpack and soil moisture, and altered fire regimes that reduce the extent and quality of west-side forest habitats will likely have adverse impacts on species that are associated with these ecological systems. **For example:**

- Increased forest density and forest encroachment into higher elevation parkland, meadow and grassland areas could reduce optimal habitat for the **Cascade red fox**, **mardon skipper**, and **western bumblebee**.
- Decreased snowpack and earlier snowmelt may expose overwintering **Taylor's checkerspot** and **mardon skipper** larvae, and may also allow increased conifer encroachment into their open grassland habitats in the Cascades and in the Olympics.
- Warmer, drier (summer) conditions are likely to reduce suitable habitat for species that utilize moist microsites (e.g., **Cope's giant salamander**, **Dunn's salamander**) and aquatic and riparian habitats associated with forest systems (e.g., **Columbia spotted frog**, **Oregon spotted frog**, **Van Dyke's salamander**, **Cascades needlefly**, ***Psychoglypha***, **Rainier roachfly**, ***Rhyacophilia***).

[2] Sensitivity of west-side forest systems to climatic factors was assessed by evaluating whether each system 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 a given climate or climate-driven factor (e.g., temperature, drought).

[3] For those systems with moderate confidence evaluations, managers may want to target monitoring or data collection efforts that help increase understanding of potential impacts of climate. Higher confidence evaluations can provide greater clarity as to what management actions may be most effective in reducing vulnerabilities and increasing resilience of these systems.

- Flooding and associated scour/sedimentation may reduce breeding sites and/or suitable habitat for the **Cascade torrent salamander**, **Cope's giant salamander**, and **western toad**, and alter breeding and forage habitats for the **Harlequin duck**.
- Low stream flows may degrade and/or reduce available habitat for **Cope's giant salamander** and the **western toad**.
- Altered disturbance regimes (i.e. fire, insect and disease outbreaks) could decrease or degrade suitable habitat for the **western gray squirrel** and **northern spotted owl**, and reduce roosting and foraging opportunities for the **silver-haired bat** and **hoary bat**.
- More frequent wildfires may reduce conifer encroachment into open grasslands and create more forest and meadow edges preferred as habitat by invertebrates such as the **mardon skipper**, **Puget blue**, and **western bumblebee**, as well as other species that depend on open areas and/or edge habitat (e.g., **Olympic marmot**).
- Wildfire may extirpate existing populations of non-mobile species or those with limited distributions, such as the **western bumblebee**, **mardon skipper**, and **Chinquapin hairstreak**.
- Scotch broom and other invasive species can reduce habitat quality and/or outcompete host plants for the **Puget blue**.
- Warming temperatures and declines in snowpack could lead to reduced habitat availability and quality, prey caching success, and dispersal for the **wolverine**.

Other possible climate impacts on west-side forest associated species include:

- Warmer, drier conditions could affect insect availability and reduce drinking sources for the **hoary bat** and **silver-haired bat**, and limit the time periods for movement across terrestrial habitats for the **Columbia spotted frog**.
- Warmer, less severe winters may positively impact **Columbia spotted frog** by increasing survival and breeding probability.
- Warmer temperatures may increase disease risk for **western gray squirrels**, and have physiological impacts on **Dunn's salamanders** and **Van Dyke's salamanders**.
- Increased temperatures may alter behavior (e.g., mating, foraging), adult life span, and/or larval development in the **Taylor's checkerspot**, **mardon skipper**, **Johnson's hairstreak**, **Chinquapin hairstreak**, **Propertius duskywing**, **western bumblebee**, **Cascade torrent salamander**, and **Dunn's salamander**; warmer temperatures can also affect the phenological timing of invertebrate development and their host and forage plants, potentially leading to reduced fitness or starvation.
- The **Olympic marmot** may experience increased coyote predation as warmer temperatures and decreased snow cover allow coyotes to persist at higher elevations.
- Reduced snowpack and earlier snowmelt are likely to alter competition and prey dynamics for the **Cascade red fox**, while reduced snowpack and shifts from snow to rain are likely to negatively impact the **pika** as they require a moderate amount of snowpack for insulation during winter months.
- Earlier snowmelt could result in phenological mismatch with **harlequin duck** breeding ecology.
- Altered wildfire regimes may eliminate dwarf mistletoe in old-growth conifer forests, which is utilized as a larval host plant by the **Johnson's hairstreak**.

Sensitivity rankings for west-side forest species include[4]:

Mammals

Species	Sensitivity	Confidence
Cascade Red Fox *(Vulpes vulpes cascadensis)*	Mod-High Sensitivity	Mod Confidence
Hoary Bat *(Lasiurus cinereus)*	High Sensitivity	Mod Confidence
Olympic Marmot *(Marmota olympus)*	Mod-High Sensitivity	High Confidence
Pika *(Ochotona princips)*	High Sensitivity	High Confidence
Silver-haired Bat *(Lasionycteris noctivagans)*	High Sensitivity	High Confidence
Western Gray Squirrel *(Sciurus griseus)*	Mod-High Sensitivity	Mod Confidence
Wolverine *(Gulo gulo)*	High Sensitivity	High Confidence

[4] Sensitivities and impacts are described for closely associated species with moderate or higher sensitivity rankings and moderate-high to high sensitivity rankings for generally associated species. Closely associated species are used to describe those which are depending on these systems for one or more stages of their life cycle.

Birds

Species	Sensitivity	Confidence
Harlequin Duck *(Histrionicus histrionicus)*	Mod-High Sensitivity	Low Confidence
Northern Spotted Owl *(Strix occidentalis caurina)*	Mod-High Sensitivity	Mod Confidence

Amphibians & Reptiles

Species	Sensitivity	Confidence
Cascade Torrent Salamander *(Rhyacotriton cascadae)*	High Sensitivity	Mod Confidence
Columbia Spotted Frog *(Rana luteiventris)*	Mod-High Sensitivity	Mod Confidence
Cope's Giant Salamander *(Dicamptodon copei)*	Mod-High Sensitivity	Mod Confidence
Dunn's Salamander *(Plethodon dunni)*	Mod-High Sensitivity	Mod Confidence
Oregon Spotted Frog *(Rana pretiosa)*	Mod-High Sensitivity	Mod Confidence
Van Dyke's Salamander *(Plethodon vandykei)*	High Sensitivity	Mod Confidence
Western Toad *(Anaxyrus boreas)*	Mod-High Sensitivity	Mod Confidence

Vulnerability assessment methodology developed by EcoAdapt.

Invertebrates

Species	Sensitivity	Confidence
Caddisfly *(Psychoglypha browni)*	Mod-High Sensitivity	Mod Confidence
Caddisfly *(Rhyacophilia vetina)*	High Sensitivity	High Confidence
Cascades Needlefly *(Megaleuctra kincaidi)*	Mod-High Sensitivity	High Confidence
Chinquapin Hairstreak *(Habrodais grunus herri)*	Mod Sensitivity	Mod Confidence
Johnson's Hairstreak *(Callophrys johnsoni)*	Mod-High Sensitivity	Low Confidence
Mardon Skipper *(Polites mardon)*	Mod-High Sensitivity	Mod Confidence
Propertius Duskywing *(Erynnis propertius)*	Mod-High Sensitivity	Mod Confidence
Puget Blue[5] *(Icaricia icarioides blackmorei)*	Mod-High Sensitivity	Mod Confidence
Rainier Roachfly *(Soliperla fenderi)*	Mod-High Sensitivity	High Confidence
Taylor's Checkerspot *(Euphydryas editha taylori)*	Mod-High Sensitivity	High Confidence
Western Bumblebee *(Bombus occidentalis)*	Mod-High Sensitivity	Mod Confidence

Projected Future **Climate Exposure**[6]

Under projected future climate conditions, west-side forest habitats and species will likely be exposed to warmer temperatures, changes in precipitation and soil moisture, reduced snowpack, earlier snowmelt, increased wildfire risk and changes in storm patterns by the end of the century. Air temperature is projected to increase in all seasons, with summers experiencing the most rapid warming. Summer precipitation is also likely to decline, although total annual precipitation is highly variable and may increase in some areas; this change may be due, in large part, to more frequent and more intense extreme precipitation events, which significantly increase the risk of flooding. Snowpack is expected to decline significantly at all but the highest elevations, and the timing of snowmelt may advance by up to 3-4 weeks. Warmer, drier summer conditions are expected to contribute to decreased soil moisture in most areas, as well as increased drought risk, even with potential increases in winter precipitation. Increased wildfire frequency and total area burned are also projected for the region due to warmer temperatures; however, ongoing fire suppression practices in the region may reduce the magnitude of this change. By the end of the century under a high-emissions scenario, warmer, drier summer conditions within the Puget Lowlands may slow the typical transition from forests dominated by Douglas-fir (*Pseudotsuga menziesii*) to late-successional species such as western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*), resulting in reduced forest productivity.

[5] Alpine populations (i.e. Olympic Mountains) of Puget blue were evaluated as having High sensitivity due to their dependence on vulnerable alpine meadow habitats. Lower elevation prairie populations were evaluated as having Moderate sensitivity, primarily to fire.

[6] Information in this section comes from: (1) Laflower, D. M., M. D. Hurteau, G. W. Koch, M. P. North and B. A. Hungate. 2016. Climate-driven changes in forest succession and the influence of management on forest carbon dynamics in the Puget Lowlands of Washington State, USA. Forest Ecology and Management 362:194–204; (2) Littell, J. S., E. E. Oneil, D. McKenzie, J. A. Hicke, J. A. Lutz, R. A. Norheim, and M. M. Elsner. 2010. Forest ecosystems, disturbance, and climatic change in Washington State, USA. Climatic Change 102: 129-158; (3) Raymond, C. 2015. Seattle City Light Climate Change Vulnerability Assessment and Adaptation Plan. Seattle City Light, Seattle, WA; and (4) Washington Department of Fish and Wildlife. 2015. Washington's State Wildlife Action Plan: 2015 Update, Appendix C. Washington Department of Fish and Wildlife, Olympia, WA.

Climate Change
Vulnerability Assessment

Looking together at sensitivity and exposure, the west-side forest systems evaluated in this assessment exhibit overall moderate vulnerability (high confidence) to climate changes including increased air temperature, shifts in precipitation, reduced snowpack and soil moisture, changes in extreme precipitation events, and altered fire regimes. Shifts in precipitation and soil moisture will likely affect species composition within these systems, favoring drought-tolerant species. Increased temperatures and reduced snowpack are likely to increase the length of the growing season, allowing greater conifer encroachment into subalpine meadows and potentially causing type conversion to systems dominated by species such as Douglas-fir. Warmer, drier conditions and periods of summer drought will contribute to altered fire regimes (e.g., increased fire frequency and/or severity), which could shift composition away from fire-sensitive species and alter forest extent, distribution, and structure (e.g., creating more open understories and increasing invasive species cover). However, in oak woodlands, more frequent low-intensity fire may reduce conifer encroachment, benefitting this habitat type where soil moisture is sufficient to support oak regeneration. Many of the species closely associated with west-side forest systems are relatively specialized, and exhibit sensitivity to climatic factors that drive habitat quality and the availability of host and/or forage plants, as well as those that contribute to physiological changes (e.g., altered behavior) and shifts in phenology.

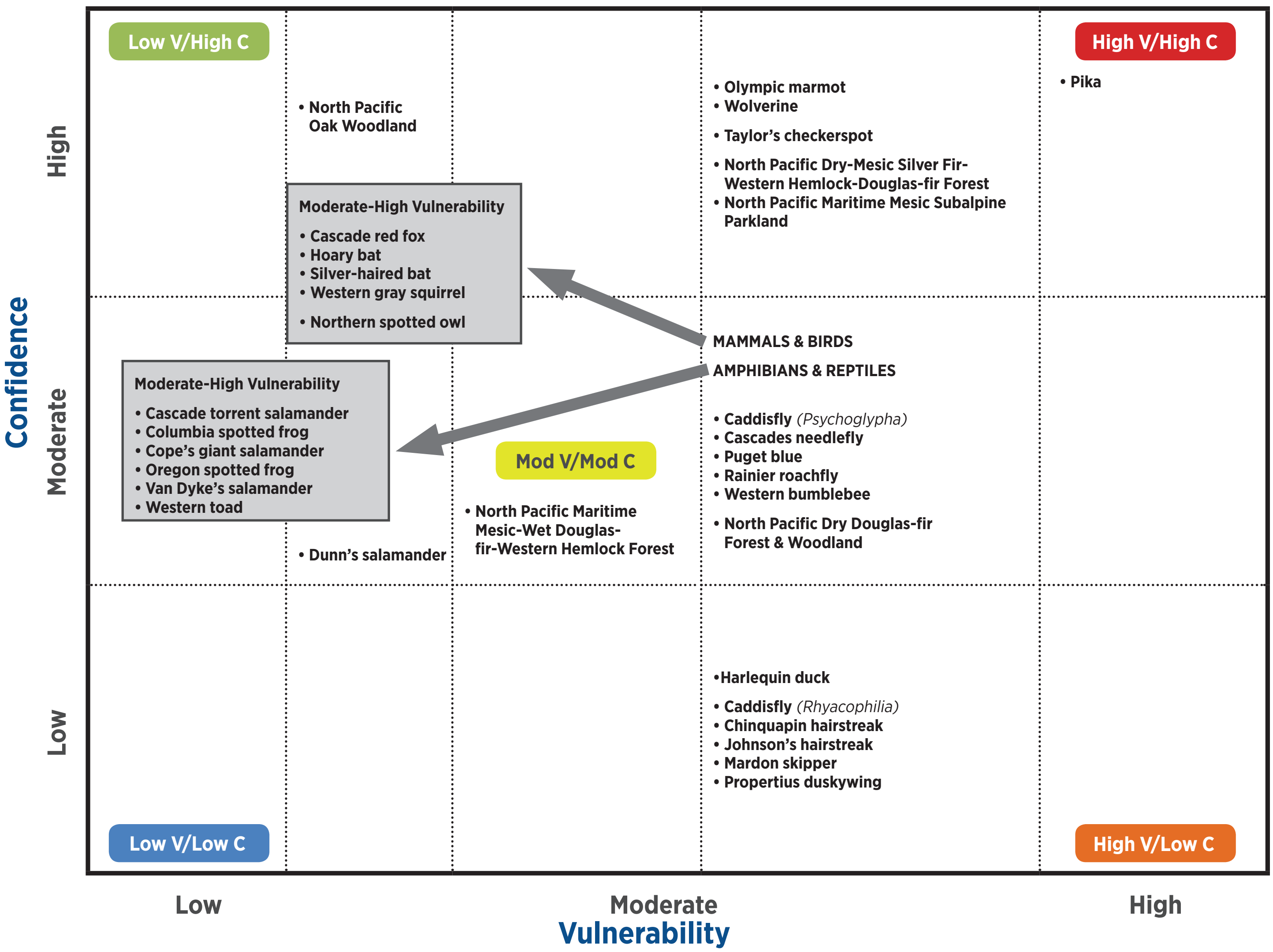
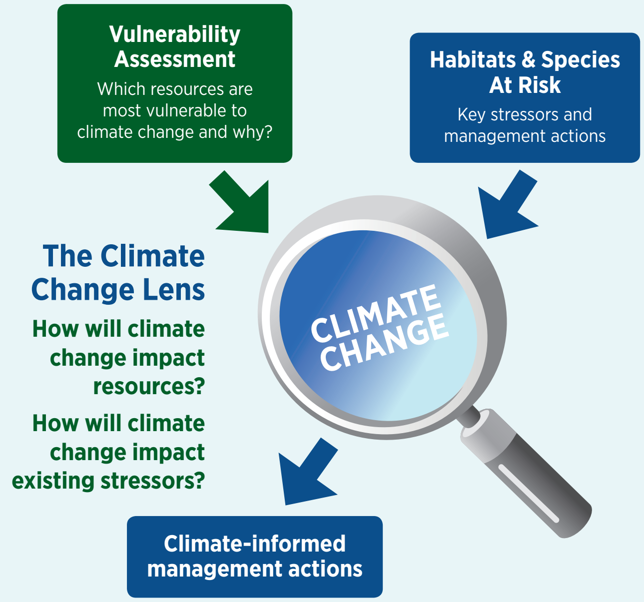


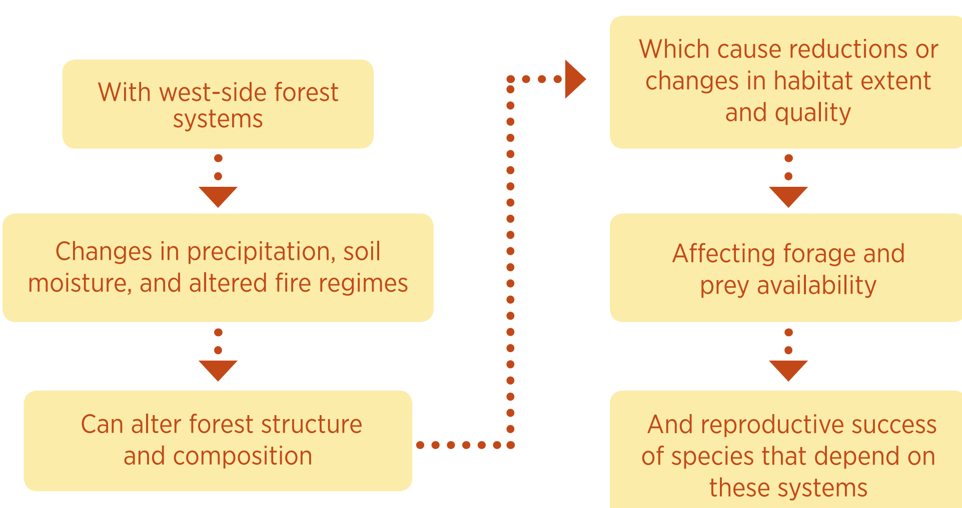
Figure 1. Vulnerability and confidence rankings plotted for west-side forest systems and species. Those systems and species with high vulnerability to climate change and high confidence are located in the upper right; those systems and species with low vulnerability to climate change and low confidence are located in the bottom left. Figure created by EcoAdapt.

Adapting to
Climate Change

Climate change adaptation strategies attempt to reduce the negative impacts of, or take advantage of opportunities presented by, climate change. To begin identifying adaptation options, it's helpful to consider the management actions proposed or currently underway and think about them in the context of climate change. For example, how may climate change affect the success of a given action (i.e., does it present a new or unexpected challenge)? Alternatively, does the action help to minimize climate vulnerabilities, making it a priority for implementation? Adding this climate 'lens' to what is already being done helps to mainstream adaptation into current decision-making frameworks.



There are five basic types of adaptation strategies; resistance, resilience, transition, knowledge, and collaboration. Managers can select adaptation strategies that best suit a given situation (e.g., long-term management plan vs. on-the-ground project), although they are encouraged to consider both near- or short-term options (e.g., resistance, resilience) as well as those more suitable in the long-term (e.g., transition). Additionally, managers can use the confidence evaluations from this vulnerability assessment to identify where more research or monitoring is needed. For example, the sensitivity of Dunn's salamander was evaluated as moderate-high, but the confidence in that ranking was low due to a lack of information on the life history and distribution of this species. A knowledge-gathering adaptation strategy to address this issue could be to survey and catalog nest sites, for which few have been described, to better identify site preferences of this species and determine possible sensitivity factors. The table below presents a suite of adaptation options that resource managers could consider implementing for west-side forest systems and species.



To sustain resources into the future, conservation actions and strategies must take into account future climatic conditions and consider multiple stressors and broad geographic scales.

What are the types of adaptation strategies?

Resistance strategies: Prevent the effects of climate change from affecting a resource.
Near-term approach

Resilience strategies: Buffer against climate change impacts by avoiding the effects of or recovering from changes.
Near- to mid-term approach

Transition strategies: Intentionally accommodate change and adaptively respond to variable conditions.
Long-term approach

Knowledge strategies: Gather information about climate impacts and/or management effectiveness in addressing climate change challenges.
Near- to long-term approach

Collaboration strategies: Coordinate efforts and capacity across landscapes and agencies.
Near- to long-term approach

Adaptation strategies for west-side forest systems and species[7]

ADAPTATION CATEGORY	ADAPTATION STRATEGIES
RESISTANCE	• Use thinning and/or prescribed burns to prevent stand-replacing wildfire in oak woodlands, dry Douglas-fir forests, and/or around high value resources • Minimize the impacts of recreation on forest systems • Protect rare, vulnerable, and/or endemic species from wildfire and post-fire impacts (e.g., landslides)
RESILIENCE	• Thin dense stands to increase tree vigor and reduce vulnerability to drought and disturbance events • Protect areas with high habitat heterogeneity, including structural diversity and stand-level species and genetic diversity • Design forest gaps that create opportunities for establishment
TRANSITION	• Maintain, create, and/or protect refugia • Enhance connectivity at multiple scales and elevational gradients to facilitate species migration
KNOWLEDGE	• Determine connectivity needs for different tree species and guilds to promote migration and dispersal • Use vegetation models to predict where species may best establish and persist under future conditions • Develop post-disturbance strategies for reforestation and monitoring that capture long-term changes
COLLABORATION	• Review and revise current reforestation strategies to prevent potential loss of genetic diversity • Improve education and communication about effective adaptation responses • Collaborate with other agencies and organizations to maintain seed collections that will help preserve genetic diversity and facilitate shifts in species assemblages as climate conditions change

For more information about this project or other WDFW climate change initiatives, please visit **wdfw.wa.gov/conservation/climate_change** or contact Lynn Helbrecht at **lynn.helbrecht@dfw.wa.gov** or **(360) 902-2238**

7 Adaptation strategies are drawn from: (1) Halofsky, J. E., D. L. Peterson, K. A. O'Halloran, C. Hawkins Hoffman. 2011. Adapting to climate change at Olympic National Forest and Olympic National Park. Gen. Tech. Rep. PNW-GTR-844. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR; and (2) Raymond, C. L., D. L. Peterson, R. M. Rochefort. 2014. Climate change vulnerability and adaptation in the North Cascades region, Washington. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, OR.

Fact sheet developed by EcoAdapt.