

## SECTION 8

# How Will Climate Change Affect Plants and Animals in Washington?

*Climate change is expected to cause significant changes in plant and animal distributions and communities, and may threaten some of the region's iconic species.<sup>[A]</sup> The timing of biological events, such as spring budburst and migration, will shift for many species. Sea level rise is projected to displace coastal habitats and the species that depend on them. Ocean acidification will negatively impact marine species and ecosystems, particularly shellfish. Recent studies have provided projections specific to Pacific Northwest species and ecosystems, and significantly more detail on the impacts of ocean acidification on Washington's marine species.*

- 1. The spatial distributions of suitable climate for many species of plants and animals are projected to change considerably by the end of the 21<sup>st</sup> century.** Many species may be unable to move fast enough to keep up with shifting areas of climatic suitability, which may result in local extirpations. Both range shifts and local extirpations are likely to lead to changes in the composition of Washington's biological communities.<sup>[1]</sup>
  - *Areas of suitable climate for alpine and subalpine species are projected to significantly decline.* Suitable climate for alpine tundra and subalpine vegetation in Washington is projected to decline substantially in area or disappear by the end of the century under a high greenhouse gas scenario.<sup>[B][C][2]</sup> These reductions may negatively affect associated wildlife species, such as American pika.<sup>[3]</sup> Areas of contiguous habitat for Pacific Northwest populations of wolverine<sup>[D][4]</sup> and American marten<sup>[E][5]</sup> are projected to significantly decrease by the late 21<sup>st</sup> century under a medium greenhouse gas scenario.
  - *Areas of suitable climate for several Washington tree species are projected to decline.* For example, climate is projected to become unfavorable for Douglas-fir over 32% of its

<sup>A</sup> Impacts on specific species and ecosystems described in this document represent examples rather than an exhaustive list of potential regional impacts. In describing potential impacts, we have used the term “projected” where future impacts have been estimated quantitatively (e.g., using models or experiments) and explicitly incorporate climate models and greenhouse gas scenarios (which we report in associated footnotes), and the term “may” where future impacts have been inferred from available biological information and projected climatic changes.

<sup>B</sup> Changes from historical (1971–2000) to future (2070–2099) modeled using MC1 vegetation model projections based on CSIRO-Mk3, Hadley CM3, and MIROC 3.2 medres global climate models under the SRES-A2 greenhouse gas scenario.

<sup>C</sup> Greenhouse gas scenarios were developed by climate modeling centers for use in modeling global and regional climate impacts. These are described in the text as follows: “very low” refers to the RCP 2.6 scenario; “low” refers to RCP 4.5 or SRES B1; “medium” refers to RCP 6.0 or SRES A1B; and “high” refers to RCP 8.5, SRES A2, or SRES A1FI – descriptors are based on cumulative emissions by 2100 for each scenario. See Section 3 for more details.

<sup>D</sup> Models of future (2070-2099) wolverine connectivity based on projected late spring snow cover under 10 global climate models and the A1B greenhouse gas scenario.

<sup>E</sup> Models of future marten connectivity based on upward shifts of current temperatures by approximately 325, 650, 985, 1310, and 1640 ft from the current optimum elevation of 4920 ft, which correspond to a low to medium increase in temperature by 2081-2100, relative to 1950-1999.

current range in Washington by the 2060s relative to 1961-1990, under a medium greenhouse gas scenario.<sup>[F][6]</sup> Only 15% of the area currently suitable for three pine species in Washington (ponderosa pine, lodgepole pine, and whitebark pine) is projected to remain suitable for all three by the 2060s relative to 1961-1990, under a medium greenhouse gas scenario, while 85% of their current range is projected to become climatically unsuitable for one or more of the three species.<sup>[F][6]</sup>

- *Area of suitable climate for sagebrush-steppe vegetation is projected to decline.* Sagebrush-steppe ecosystems in eastern Washington are projected to decline in extent by the 2080s (2070-2099), relative to 1970-1999, under a high greenhouse gas scenario.<sup>[B][2]</sup> This has negative implications for associated wildlife, such as greater sage grouse and pygmy rabbit.
- *Climate change may lead to reductions in the extent of wetlands and ponds.* Reduced snowpack and altered runoff timing may contribute to the drying of many ponds and wetland habitats across the Pacific Northwest.<sup>[7]</sup>
- *Climate change may result in the expansion of prairies.* Projected increases in summer drought may result in an expansion of Pacific Northwest prairies. Projected increases in winter precipitation may lead to the expansion of wetland prairies on poorly drained soils in areas such as the South Puget Sound.<sup>[8]</sup> However, high levels of human land use in future areas of climatic suitability may limit opportunities for expansion.

- 2. Timing of critical biological events, such as spring bud burst, emergence from overwintering, and the start of migrations, will continue to shift, leading to significant impacts on species and habitats.**<sup>[1]</sup> For example, some migratory birds now arrive too late for the peak of food resources at breeding grounds because temperatures at wintering grounds are changing more slowly than at spring breeding grounds.<sup>[9]</sup> There are currently few studies on such impacts specific to the Pacific Northwest.
- 3. Climate change will affect biodiversity through major ecosystem disturbances, including fire, drought, and flooding.**<sup>[1]</sup> For example, climate change may increase the risk of severe, stand-replacing fires, which may negatively impact species associated with old-growth forest, such as marbled murrelets and northern spotted owls. Species that thrive in conditions after severe fires, such as the northern flicker and hairy woodpecker, may benefit under an altered fire regime.<sup>[1]</sup>
- 4. Climate change may promote the spread of invasive species.**<sup>[1]</sup> This will include both native invasive species (e.g., western juniper) moving beyond their historical ranges, and non-native species (e.g., cheat grass) increasing due to improved conditions. Moreover, responses of invasive species to climate change will vary, so that some may benefit while others will not.<sup>[1]</sup>

<sup>F</sup> Using results from the HadCM3GGa1 and CGCM2 global climate models (GCMs) under a scenario that assumes a 1%/year increase in greenhouse gas emissions. This scenario closely resembles the RCP 6.0 scenario, with the exception that late 21<sup>st</sup> century emissions are higher.

- *Some invasive species are projected to benefit from climate change.* For example, changes in salinity due to sea level rise may facilitate invasion by non-native species better adapted to salinity variations, such as the invasive New Zealand mud snail, which has been found in the Columbia River estuary.<sup>[G][10]</sup>
- *Some invasive species may not benefit from climate change.* For example, suitable habitat for cheatgrass is projected to increase in some areas of the Pacific Northwest and decrease in others by 2100, relative to 1971-2000, under a medium greenhouse gas scenario; its future distribution will be strongly influenced by future changes in precipitation.<sup>[H][11]</sup>

## 5. Changes in the timing and quantity of streamflows, together with increasing stream temperatures, are projected to cause significant changes in freshwater aquatic species and ecosystems.<sup>[7]</sup>

- *Suitable stream temperatures for aquatic species may shift upstream.* Suitable stream temperatures for many aquatic species across the Pacific Northwest could shift a few to nearly one hundred miles upstream, with smaller changes seen along steep streams, and larger changes along relatively flat streams.<sup>[I][12]</sup>
- *Rising stream temperatures and altered streamflows will likely reduce the reproductive success of many Washington salmon populations, though impacts will vary by location.* Relative to 20<sup>th</sup> century conditions, under a low-warming scenario, juvenile salmon growth rates by mid-21<sup>st</sup> century are projected to be lower in the Columbia Basin, but unchanged or greater in coastal and mountain streams.<sup>[J][13]</sup> By the 2080s (2070-2099, relative to 1970-1999), for a medium emissions scenario, the duration of summertime stream temperatures that cause thermal stress and migration barriers to salmon is projected to at least double for many areas in eastern Washington and along the lower Columbia River.<sup>[K][14]</sup> Earlier spring runoff may alter migration timing and survival rates for salmon smolts in snowmelt-dominated streams.<sup>[14]</sup>
- *Steelhead vulnerability to climate change varies across the region.* Steelhead vulnerability to streamflow change at mid-century (2030-2059) relative to 1970-1999 under a medium greenhouse gas scenario is projected to be high in northeastern Washington and Cascade Mountain rivers (both east and west side), and lowest in coastal rivers. Vulnerability to stream temperature change is projected to be high in eastern and

<sup>G</sup> Based on experiment demonstrating increased salinity tolerance of New Zealand mud snails from the Columbia River estuary compared to those found in a freshwater lake.

<sup>H</sup> Based on bioclimatic envelope models under the SRES A1B greenhouse gas scenario and 10 general circulation models for 2100.

<sup>I</sup> Assuming a warming of 3.6°F, which is near the average projected warming for mid-century in the Pacific Northwest, under a low greenhouse gas scenario.

<sup>J</sup> Fish growth from winter to summer was projected with temperature-dependent models of egg development and juvenile growth using empirical temperature data from 115 sites.

<sup>K</sup> Based on the average of 10 climate models run under the A1B emissions scenario.

southwest Washington, but low in most Cascade Mountain rivers.<sup>[L][15][16]</sup>

**6. Rising sea levels are projected to displace many coastal habitats and the species that depend on them.** Most of the region’s important coastal habitats have already been damaged or destroyed by extensive dredging, coastal modifications, pollution, and other development. Natural barriers and coastal modifications such as dikes and seawalls may significantly impede the ability of habitats to migrate inland to accommodate sea-level rise.<sup>[17]</sup>

- *Sea level rise is projected to cause reductions in the extents of many coastal habitats.* By 2100, under a medium greenhouse gas scenario, sea level rise in Washington and Oregon is projected to result in the loss of as much as 44% of tidal flat, 13% of inland freshwater marsh, 25% of tidal fresh marsh, 61% of tidal swamp, and 65% of estuarine beaches.<sup>[M][17]</sup>
- *Sea level rise is projected to change the composition of many existing coastal habitats.* By 2100 in Washington and Oregon, under a medium greenhouse gas scenario, 52% of brackish marsh is projected to be converted to tidal flats, transitional marsh and saltmarsh; 11% of inland swamp is projected to be inundated with salt water; and 2% of undeveloped land is projected to be inundated or eroded to form other habitat types.<sup>[M][17]</sup>

**7. Ocean acidification is expected to threaten coastal and marine species and ecosystems.**

- *Ocean acidification is likely to reduce shellfish populations.* By the end of the century, ocean acidification is projected to result in a 40% reduction, globally, in the rate at which mollusks (e.g., mussels and oysters) form shells, as well as a 17% decline in growth, and a 34% decline in survival.<sup>[N][18]</sup>
- *Ocean acidification may negatively impact some fish species.* By 2028, ocean acidification impacts on shellfish and plankton are projected to result in a 10–80% decline in the abundance of commercially important groundfish on the US west coast, including English sole, arrowtooth flounder, and yellowtail rockfish, owing to the loss of shelled prey items from their diet.<sup>[O][19]</sup>

<sup>L</sup> Based on Elsner et al.’s (2010)<sup>[16]</sup> historical and future hydrologic projections, which stem from an average of 20 global climate models and the A1B greenhouse gas scenario.

<sup>M</sup> Based on a 27.3-inch global sea-level rise by 2100 relative to 1980-1999 (projected under a medium greenhouse gas scenario) and the Sea Level Affecting Marshes Model (SLAMM) applied to 11 coastal sites in Puget Sound and along the Pacific Coast in southwestern Washington and northwestern Oregon. Projected changes in habitat are relative to total habitat amounts in 2007.

<sup>N</sup> Based on statistical synthesis of results from 228 experimental assessments of responses of marine organisms to acidification, with end-of-century projections based on 0.5 unit reduction in global average ocean surface pH relative to current pH. This is higher than the change projected for 2100 by the IPCC (0.30 to 0.32 unit reduction under the high RCP 8.5 scenario, for 2081-2100 relative to 1986-2005) and also higher than the projections of Feely et al. 2009 (0.4 to 0.48 unit reduction, under a high (A2) greenhouse gas scenario, for 2095 relative to pre-industrial (1875) levels).

<sup>O</sup> Relative to 2009 (with baseline conditions established 1995-2005), and based on a 20-year model run of the Atlantis ecosystem model, using four scenarios treating acidification as a range of additional mortality rates on shelled plankton and benthos groups.

- *Ocean acidification may benefit some species.* For example, seagrasses may experience increased growth rates with elevated ocean carbon dioxide levels.<sup>[20]</sup>

**8. Increasing sea surface temperatures may alter the ranges, types, and abundances of Pacific Northwest marine species.** However, projections specific to waters off of Washington and the Pacific Northwest are currently limited relative to terrestrial and freshwater studies.<sup>[21]</sup>

**9. As a result of recent research, scientific understanding of the biological impacts of anthropogenic climate change in Washington State has advanced and the specificity of projections has increased.**

- *Ocean acidification has become a primary area of study and concern.* Ocean acidification has only recently been widely recognized as a concern, and there has been a tremendous increase in studies documenting projected impacts.
- *Changes in suitable climate have been projected for several species and habitat types.* However, many of these are for economically important species such as Douglas-fir and salmon, and projected climate impacts on most Washington species and ecosystems remain understudied.

**10. Various Washington communities, government agencies, and organizations are preparing for the impacts of climate change on plants and animals.**<sup>[22]</sup> Examples include:

- *The Pacific Northwest Vulnerability Assessment* is a collaboration among researchers, managers, and planners from Pacific Northwest universities, agencies, and non-government organizations. It will soon be releasing products indicating the potential effects of future climate change on regional species and habitats. More information is available at: [Climatevulnerability.org](http://Climatevulnerability.org)
- *The Washington Wildlife Habitat Connectivity Working Group* (WHCWG) is a large collaborative effort to identify opportunities for maintaining and restoring landscape connectivity in Washington. Increasing connectivity is a key recommendation of the *Washington State Integrated Climate Change Response Strategy*.<sup>[P]</sup> WHCWG products offer tools for implementing this recommendation. More information is available at: [waconnected.org](http://waconnected.org).
- The new *Washington Ocean Acidification Center* at the University of Washington (funded by the State Legislature in summer 2013) will coordinate scientific research, monitoring and data-sharing related to ocean acidification, and work with partners in state and federal agencies, tribes, industries, and academic institutions to link ocean-acidification science with decision-making.

---

<sup>P</sup> Available at: [http://www.ecy.wa.gov/climatechange/ipa\\_responsestrategy.htm](http://www.ecy.wa.gov/climatechange/ipa_responsestrategy.htm)

- The Washington Department of Fish & Wildlife (WDFW) is developing a *Climate Adaptation Handbook* designed to provide practical, hands on guidance for integrating climate considerations into WDFW activities.

- 
- [1] Groffman, P. M. et al. (In review). Ecosystems, Biodiversity, and Ecosystem Services. Chapter 8 in the *Third U.S. National Climate Assessment*, scheduled for release in early 2014, January 2013 review draft. Available at: <http://ncadac.globalchange.gov/download/NCAJan11-2013-publicreviewdraft-chap8-ecosystems.pdf>
- [2] Rogers, B.M. et al. 2011. Impacts of climate change on fire regimes and carbon stocks of the U.S. Pacific Northwest, *Journal of Geophysical Research* 116: G03037.
- [3] Beever, E.A. et al. 2010. Testing alternative models of climate-mediated extirpations. *Ecological Applications* 20:164–178.
- [4] Mckelvey, K.S. et al. 2011. Climate change predicted to shift wolverine distributions, connectivity, and dispersal corridors. *Ecological Applications* 21:2882–2897.
- [5] Wasserman, T. N. et al. 2012. Simulating the effects of climate change on population connectivity of American marten (*Martes americana*) in the northern Rocky Mountains, USA. *Landscape Ecology* 27:211-225.
- [6] Littell, J.S. et al. 2010. Forest ecosystems, disturbance, and climatic change in Washington State, USA. *Climatic Change* 102:129-158.
- [7] Raymondi, R. R. et al. 2013. Water Resources: Implications of changes in temperature and precipitation. Chapter 6 in M.M. Dalton, P.W. Mote, and A.K. Snover (eds.) *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities*, Washington D.C.: Island Press.
- [8] Bachelet, D. et al. 2011. Climate Change Impacts on Western Pacific Northwest Prairies and Savannas. *Northwest Science* 85:411-429.
- [9] Jones, T. and W. Cresswell. 2010. The phenology mismatch hypothesis: Are declines of migrant birds linked to uneven global change? *Journal of Animal Ecology* 79:98-108.
- [10] Hoy, M. et al. 2012. Salinity adaptation of the invasive New Zealand mud snail (*Potamopyrgus antipodarum*) in the Columbia River estuary (Pacific Northwest, USA): Physiological and molecular studies. *Aquatic Ecology* 46:249–260.
- [11] Bradley, B. A. 2009. Regional analysis of the impacts of climate change on cheatgrass invasion shows potential risk and opportunity. *Global Change Biology* 15:196-208.
- [12] Isaak, D. J., and B. E. Rieman. 2013. Stream isotherm shifts from climate change and implications for distributions of ectothermic organisms. *Global Change Biology* 19: 742–751.
- [13] Beer, W. N., and J. J. Anderson. 2013. Sensitivity of salmonid freshwater life history in western US streams to future climate conditions. *Global Change Biology* 19: 2547–2556.
- [14] Mantua, N. et al. 2010. Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. *Climatic Change* 102:187–223.
- [15] Wade, A. et al. 2013. Steelhead vulnerability to climate change in the Pacific Northwest. *Journal of Applied Ecology* 50:1093-1104.
- [16] Elsner, M.M. et al., 2010. Implications of 21st century climate change for the hydrology of Washington State. *Climatic Change* 102(1-2): 225-260.
- [17] Glick, P. et al. 2007. *Sea-level Rise and Coastal Habitats in the Pacific Northwest: An Analysis for Puget Sound, Southwestern Washington, and Northwestern Oregon* (Reston, VA: National Wildlife Federation).
- [18] Kroeker, K.J. et al. 2013. Impacts of ocean acidification on marine organisms: quantifying sensitivities and interaction with warming. *Global Change Biology* 19:1884-1896.
- [19] Kaplan, I.C. et al. 2010. Fishing catch shares in the face of global change: a framework for integrating cumulative impacts and single species management. *Canadian Journal of Fisheries and Aquatic Sciences* 67:1968-1982.
- [20] Koch, M. et al. 2013. Climate change and ocean acidification effects on seagrasses and marine macroalgae. *Global Change Biology* 19:103-132.

- <sup>[21]</sup> Tillmann, 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*. Phase 1 Draft Final Report. National Wildlife Federation – Pacific Region, Seattle, WA.
- <sup>[22]</sup> Glick, P. et al. 2013. *Safeguarding Washington’s Fish and Wildlife in an Era of Climate Change: A Case Study of Partnerships in Action*, National Wildlife Federation, Seattle, WA.