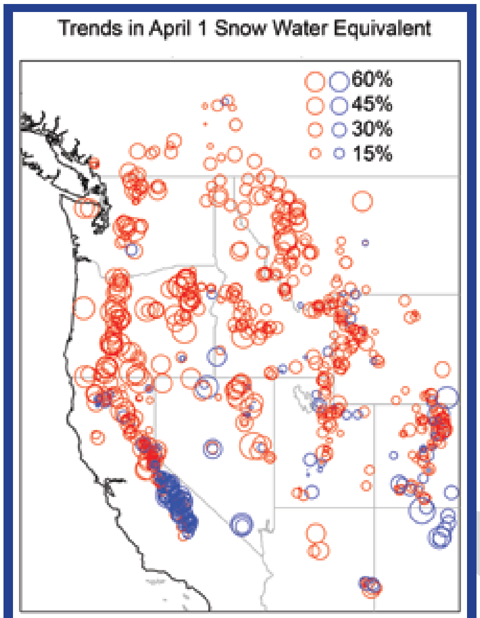
Northwest

The Northwest's rapidly growing population, as well as its forests, mountains, rivers, and coastlines, are already experiencing human-induced climate change and its impacts[1]. Regionally averaged temperature rose about 1.5°F over the past century[2] (with some areas experiencing increases up to 4°F), and is projected to increase another 3 to 10°F in this century[3], with higher emissions scenarios resulting in the upper end of this range. Increases in winter precipitation and decreases in summer precipitation are projected by many climate models, though these projections are less certain than those for temperature. Impacts related to changes in snowpack, streamflows, sea level, forests, and other important aspects of life in the Northwest are already underway, with more severe impacts expected in this century in response to continued and much more rapid warming.

Declining springtime snowpack leads to reduced summer streamflows, straining water supplies.

The Northwest is highly dependent on temperature-sensitive springtime snowpack to meet growing, and often competing, water demands such as: municipal and industrial uses, agricultural irrigation, hydropower production, navigation, recreation, and in-stream flows that protect aquatic ecosystems including threatened and endangered species. Higher cool season (October through March) temperatures cause more precipitation to fall as rain rather than snow, and contribute to earlier snowmelt. April 1 snowpack, a key indicator of natural water storage available for the warm season, has already declined substantially throughout the region. The average decline in the Cascade Mountains, for example, was about 25 percent over the past 50 years, with most of this due to the 2.5°F warming in cool season temperatures over that period. Increasing declines in Northwest snowpack are projected to accompany additional warming in this century, varying with latitude, elevation, and proximity to the coast. April 1 snowpack is projected to decline as much as 40 percent in the Cascades by the 2040s[4]. Throughout the region, earlier snowmelt will cause a reduction in the amount of water available during the warm season.



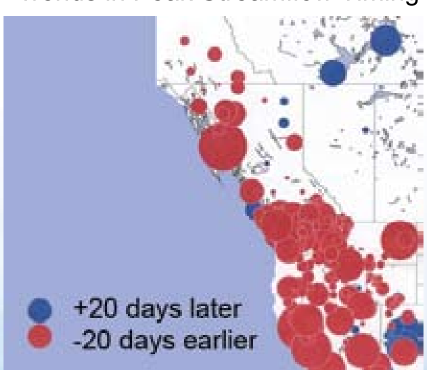
Trends in a common snowpack measurement, for the period 1950–1997. Decreasing trends are in red, increasing trends in blue[3]..

Placeholder for photos

In areas where it snows, a warmer climate means major changes in the timing of runoff: streamflow increases in winter and early spring, and decreases in late spring, summer, and fall. This shift in streamflow timing has already been observed over the past 50 years, with the peak of spring runoff shifting from a few days earlier in some places to as much as 25 or 30 days earlier in others[5].

Larger changes are expected due to increased warming, with runoff projected to shift 20 to 40 days earlier in this century[6]. Reductions in summer water availability will vary with midwinter temperatures experienced in different parts of the region. In relatively warm areas on the western slopes of the Cascade Mountains, for example, reductions in warm season (April through September) runoff of 30 percent or more are

Trends in Peak Streamflow Timing



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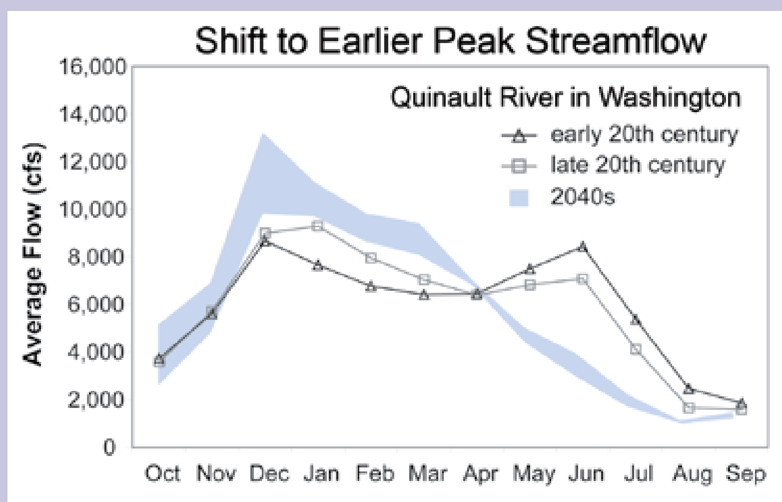


The blue swath represents the range of projected streamflow for 3.6°-5.4°F warming compared to 20th century streamflows[3].

projected by mid-century, whereas colder areas in the Rocky Mountains are expected to see reductions on the order of 10 percent. Areas dominated by rain rather than snow are not expected to see major shifts in the timing of runoff [7]. Extreme high and low streamflows are also expected to change with warming. Increasing winter rainfall (as opposed to snowfall) is expected to increase winter flooding in relatively warm watersheds west of the Cascades. The already low flows of late summer are projected to decrease further due to both earlier snowmelt and increased evaporation and water loss from plants. Projected decreases in summer precipitation would exacerbate these effects. Some sensitive watersheds are projected to experience both increased flood risk and increased drought risk due to warming.

The region's water supply infrastructure was built around the assumption that most of the water needed for summer uses would be stored naturally in snowpack. For example, the storage capacity in Columbia Basin reservoirs is only 30 percent of the annual runoff, and many small urban water supply systems west of the Cascades store less than ten percent of their annual flow[8]. Besides providing water supply and managing flows for hydropower, the region's reservoirs are operated for flood-protection purposes and as such, may have to release (rather than store) large amounts of runoff during the winter and early spring in order to maintain enough space for flood protection. Earlier flows would thus place more of the year's runoff into the category of hazard rather than resource. An advance in the timing of snowmelt runoff would also increase the length of the summer dry period, with important consequences for water supply, ecosystems, and wildfire management[9].

Placeholder for photos

One of the largest demands on water resources in the region is hydroelectric power production. About 70 percent of the Northwest's energy needs are provided by hydropower, far more than in any other region. Warmer summers will increase electricity demands for air conditioning and refrigeration at the same time of year that lower streamflows will decrease hydropower generation. At the same time, water is needed for irrigated agriculture, protecting fish species, reservoir and river recreation, and urban uses. Conflicts between all of these water uses are expected to increase, forcing complex trade-offs between competing objectives[10].

Placeholder for photos

Increased insect outbreaks, wildfires, and changing species composition in forests will pose challenges for unique ecosystems.

Higher summer temperatures and earlier spring snowmelt are expected to increase the risk of forest fires in the Northwest by increasing summer moisture deficits; this pattern has already been observed in recent decades. Drought stress and higher temperatures will decrease tree growth in most low and mid-elevation forests and also increase the frequency and intensity of mountain pine beetle and other insect attacks, further increasing fire risk and reducing timber production, an important part of the regional economy. The mountain pine beetle outbreak in British Columbia has destroyed 33 million acres of trees so far, and shows no signs of slowing (see *Natural Environment and Biodiversity sector* and *Complex Interactions*). Idaho's Sawtooth Mountains are now threatened by pine beetle infestation.

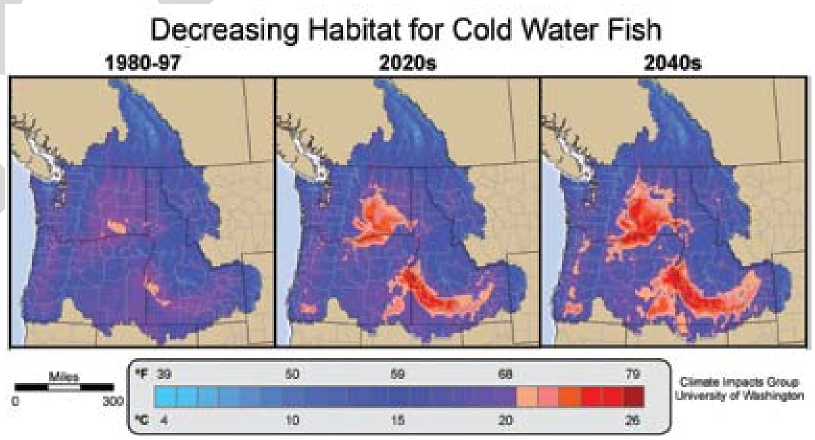
In the short term, high elevation forests west of the Cascade Mountains are expected to see increased growth. In the longer term, forest growth is expected to decrease as summertime soil moisture deficits limit forest productivity, with low-elevation forests experiencing these changes first. The extent and species composition of forests are also expected to change as tree species respond to climatic changes. There is also the potential for extinction of local populations and loss of biological diversity if environmental changes outpace species ability to shift their ranges and form successful new ecosystems.

Agriculture, especially production of tree fruit such as apples, is also an important part of the regional economy. Decreasing irrigation supplies and increased competition from weeds, pests, and disease are likely to have negative effects on agricultural production.

Salmon and other cold-water species experience additional stresses due to rising water temperatures and declining summer streamflows.

Northwest salmon populations are at historically low levels due to stresses imposed by a variety of human activities including dam building, logging, pollution, and over-fishing. Climate change affects salmon throughout their life stages and poses an additional stress. As more winter precipitation falls as rain rather than snow, higher winter streamflows scour the streambed, damaging spawning nests and washing away incubating eggs. Earlier peak streamflows flush young salmon from rivers to estuaries before they are physically mature enough for the transition, increasing a variety of stresses including the risk of being eaten by predators. Lower summer streamflows and warmer water temperatures create less favorable summer stream conditions for salmon and other cold-water fish species in many parts of the Northwest. And diseases and parasites that infect salmon tend to flourish in warmer water. Climate change also impacts the ocean environment, where salmon spend several years of their lives. Historically, warm periods in the coastal ocean have coincided with relatively low abundances of salmon, while cooler ocean periods have coincided with relatively high salmon numbers.

Wild Pacific salmon are mostly extinct or imperiled in 56 percent of their historic range in the Pacific Northwest and California[11], and populations are down more than 90 percent in the Columbia River system. Many species are listed as either threatened or endangered under the Federal Endangered Species Act. Studies suggest that about one-third of the current habitat for the Northwest's salmon and other cold-water fish will no longer be suitable for them by the end of this century as key temperature thresholds are exceeded. Because climate change impacts on their habitat are projected to be negative, climate change is expected to hamper efforts to recover depleted salmon populations.



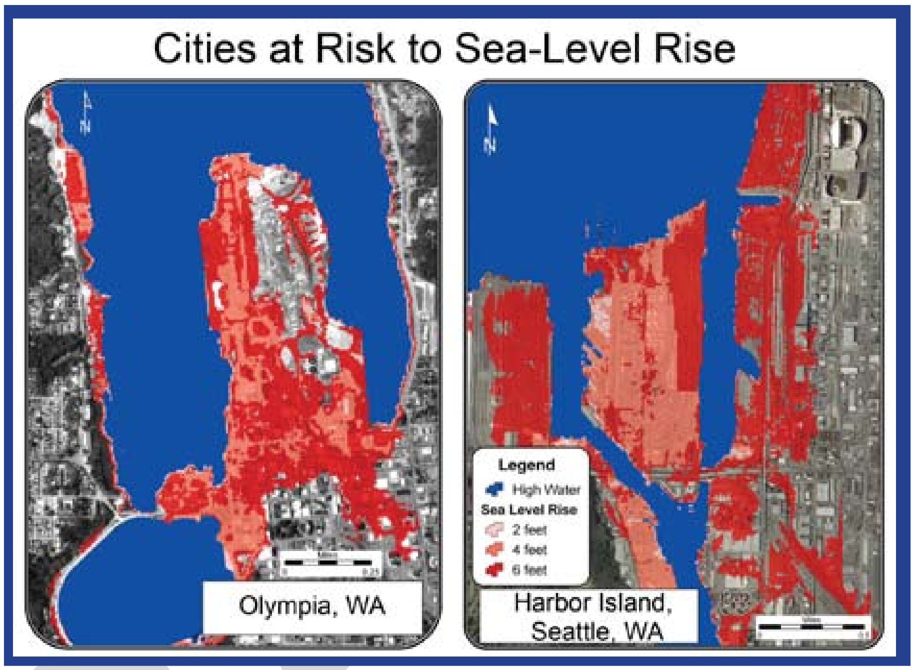
Salmon can be found where average air temperature is less than about 70°F, shown in blue. Projected average August surface air temperatures in the Columbia Basin under a modest warming scenario suggest that salmon are likely to be threatened by rising temperatures across much of their current habitat[3].

Sea-level rise will result in increased erosion along vulnerable coastlines.

Climate change is projected to exacerbate many of the stresses and hazards currently facing the coastal zone. Sea-level rise will increase erosion of the Pacific Northwest coast and cause the loss of beaches and significant coastal land areas. Among the most vulnerable parts of the coast are the heavily populated south Puget Sound region, which includes the cities of Olympia, Tacoma, Seattle, and Bellingham, Washington. Some climate models project changes in atmospheric pressure patterns that suggest a more southwesterly direction of future winter winds. Combined with higher sea levels, this would accelerate coastal erosion on the Pacific coast.

Sea-level rise in the Northwest (as elsewhere) is determined by global rates of sea-level rise, changes in coastal elevation associated with movement of the land locally, and atmospheric dynamics that influence wind-driven "pile up" of sea level along the coast. A medium estimate of sea-level rise for the Puget Sound basin is about 13 inches by 2100. However, higher levels, up to 50 inches by 2100 in more rapidly subsiding portions of the basin are also possible given the large uncertainties about accelerating rates of ice melt from Greenland and Antarctica in recent years[12].

An additional concern is landslides on coastal bluffs. The projected heavier winter rainfall suggests an increase in saturated soils and therefore more landslides. Increased frequency and/or severity of landslides is expected to be especially problematic in areas where there has been intensive development on unstable slopes. Within Puget Sound, the cycle of beach erosion and bluff landslides will be exacerbated by sea-level rise, increasing beach erosion and decreasing slope stability.



(end note 13)

Adaptation Strategies

States, counties, and cities in the Northwest are beginning to develop adaptation strategies to climate change. In 2007, Washington State convened stakeholders to develop adaptation strategies for water, agriculture, forests, coasts and infrastructure, and human health. Recommendations included improved drought planning, improved monitoring of diseases and pests, incorporating sea-level rise in coastal planning, and public education. An implementation strategy is under development.

In response to concerns about increasing flood risk, King County, Washington approved plans in 2007 to fund repairs to the county's aging levee system. The county will also replace more than 57 "short span" bridges with wider span structures that allow more debris and floodwater to pass underneath without raising river levels. The county has begun incorporating porous concrete and rain gardens into road projects to manage the effects of stormwater runoff during heavy rains, which are increasing due to climate change. King County has also published an adaptation guidebook that is becoming a model for other local governments to organize adaptation actions within municipal planning processes.

Concern about sea-level rise in Olympia, Washington, contributed to the city's decision to relocate its primary drinking water source from a low-lying surface water source to wells on higher ground. The city adjusted its plans for construction of a new City Hall to locate the building in an area less vulnerable to sea-level rise than the original proposed location. The building's foundation was also raised by one foot.