climate change

The implications of global warming for water and salmon in the Pacific Northwest

Projected human-caused changes in 21st century climate are expected to have important implications for Pacific Northwest water resources and salmon. Understanding these impacts and incorporating projected impacts into management applications may help the region adapt to these changes.

Greenhouse gases and global warming

The "greenhouse" gases (most notably water vapor, carbon dioxide, and methane) play a critical role in keeping the planet warm enough to sustain life. Since the start of the Industrial Age (1750), humans have enhanced the natural greenhouse effect by increasing the quantities of key greenhouse gases through fossil fuel burning, deforestation, and agriculture (Figure 1). From a long-term perspective, these changes are enormous.

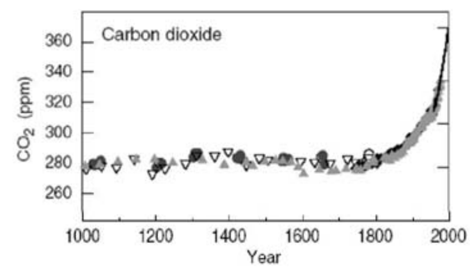

Figure 1. Atmospheric concentration of carbon dioxide since 1,000 AD. Historic data collected from ice cores and snow from sites in Antarctica and Greenland.

Average global temperature has increased about 1.1°F (0.6°C) since the late 19th century. Evidence of this change is found throughout the physical environment: mountain glaciers are in widespread retreat, snow and ice cover has decreased, global average sea level has increased, and plant and animal ranges are shifting towards the poles and higher elevations.

In 2001, the Intergovernmental Panel on Climate Change (IPCC) concluded that "There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities." Furthermore, the IPCC found that human influences will continue to change atmospheric composition through the 21st century. In other words, global warming will not be reversed quickly.

The IPCC projects that global average temperature will increase 2.7 to 10.4°F (1.5 to 5.8°C) by 2100 (compared to 1990). Precipitation changes are also expected, and these are seasonally and regionally specific. These projections are based on assumptions about (1) future greenhouse gas and aerosol emissions, and (2) modeled sensitivity to those changes. Both are imperfectly known, but the scenarios that result provide valuable insights into likely future climate conditions.

Global warming and Pacific Northwest climate

Global warming presents both challenges and opportunities for the Pacific Northwest (PNW).

Research conducted by the Climate Impacts Group (CIG) finds that regional temperatures increased 1.5°F (0.8°C) on average during the 20th century, a rate slightly higher than the global average. This warming, which is consistent across urban and rural landscapes, coincides with a region-wide decline in mid-elevation April 1 snowpack and a shift in the timing of spring snowmelt earlier into the season (Figure 2).

Is this due to global warming? Although natural climate variability plays a role in some of the observed trends, these changes cannot be totally explained by climate variability. Furthermore, the observed trends are consistent with model projections of 21st century global warming. While it is premature to assume that human-caused global warming is driving these trends, it is clear is that regional climate has been changing and is likely to continue doing so.

CIG's evaluation of seven 21st century climate scenarios finds increases in average annual temperature on the order of 2.5°F (1.4°C) by the 2020s and 3.8°F (2.1°C) by the 2040s. Changes in annual precipitation are more variable between scenarios, though most models project warmer, wetter winters and warmer, drier summers for the PNW.

Impacts on water resources

The projected changes in PNW climate have significant implications for the region's water resources. In most PNW river basins, especially in Washington and Oregon, the dominant form of water storage is mountain snowpack rather than man-made reservoirs. Mountain snowpack stores

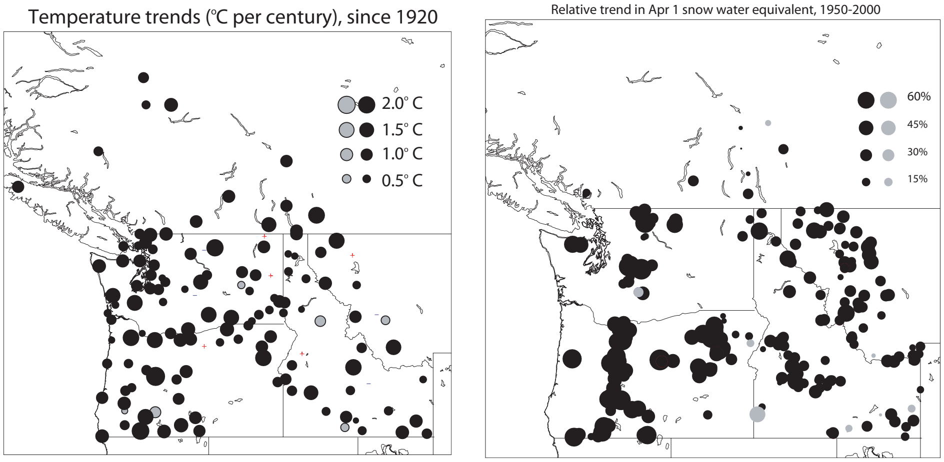

Figure 2. Twentieth century trends in (a) average annual PNW temperature (1920–2000) and (b) April 1 snow water equivalent at mid-elevation stations (1950–2000). These figures show widespread increases in average annual temperature and decreases in April 1 snow water equivalent, an important indicator for forecasting summer water supplies. The size of the dot corresponds to the magnitude of change.

water from the winter, when most precipitation falls, and releases it in spring and summer as runoff when economic, environmental, and recreational demands for water throughout the region are greatest.

Climatic changes that influence spring snowpack have major impacts on water availability in the PNW. Warmer temperatures result in more winter precipitation falling as rain rather than snow throughout much of the PNW, particularly in mid-elevation basins where average winter temperatures are near freezing. Simply put, warmer winter temperatures cause less winter snow accumulation, higher winter streamflows, earlier spring snowmelt, earlier peak spring streamflow, and lower summer streamflows in the PNW's snow-dependent rivers (Figure 3).

Substantial reductions in summer streamflow adversely affect many water users, including farmers who rely on irrigation, resident and anadromous fish, and summertime hydropower production. Because greenhouse gas concentrations are likely to continue rising, these changes are likely to become more prevalent in the coming decades. Global warming, along with increases in regional population, is likely to increase existing conflicts among competing water users.

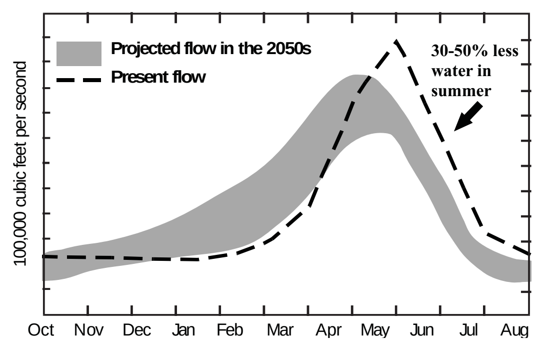

Figure3. Naturalized Columbia River streamflow at The Dalles today (dashed) and in the 2050s as simulated by several climate models. The grey band indicates the upper and lower bounds of projected average streamflow in the 2050s. The effects of the Columbia River dams on streamflow have been removed.

Global warming and salmon

Salmon productivity in the PNW is clearly sensitive to climate-related changes in stream, estuary, and ocean conditions. In the past century, most PNW salmon populations have fared best in periods having high precipitation, deep mountain snowpack, cool air and water temperatures, cool coastal ocean temperatures, and abundant north-to-south "upwelling" winds in spring and summer.

Global warming's expected impact on PNW climate includes many negatives for PNW salmon. Increased winter flooding and decreased summer and fall streamflows, and elevated warm season stream and estuary temperatures will clearly degrade in-stream and estuarine salmon habitat in the PNW. These changes will likely cause severe problems for the salmon stocks that are already stressed from already degraded freshwater and estuarine habitat.

It is unclear how PNW coastal ocean conditions will respond to global warming. Warmer temperatures are likely to increase ocean stratification, yet possible increases in winds may counter that in ways that mitigate or even increase the wind-driven upwelling of nutrients that fuel a productive food web.

From the global warming scenarios the CIG has examined, the likelihood for many positive impacts on PNW salmon is low. Where winter temperatures are now cooler than optimal for juvenile salmon and/or incubating eggs, warming may improve stream productivity. However, such conditions are now limited to a very small number of inland, high elevation salmon bearing streams.

Will PNW salmon be able to adapt to a rapidly changing chain of habitats in the coming decades? Pacific salmon populations have shown an amazing capacity for adaptation. Management activities that enhance this capacity to adapt will play a vital role in determining the answer to this key question.

Climate Impacts Group

The Water Center

University of Washington ◆ Box 352100 ◆ Seattle, Washington 98195-2100
206.543.6920 ◆ cwws@u.washington.edu ◆ http://depts.washington.edu/cwws