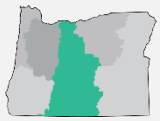


CENTRAL OR.

# REGION 4

## Observed & Projected Climate Changes

## Air & Water Temperature

### Observed

**Annual Air**
- Mean annual temperature in south-central Oregon has increased by 0.05°C (0.09°F) per decade between 1895-2012.

**Extreme Heat**
- Increasing number of days >90°F (32°C) (e.g., 65 days/yr in 2021-2022 compared with 39.4 days/yr from 1951-2020 in The Dalles).
- Increasing number of extremely warm nights (i.e., ≥65°F/18°C).

**Streams**
- August stream temperatures averaged 14.4°C (58°F) and ranged from 3.5°C (38.3°F) to 27.5°C (81.5°F) (1970-1999).

### Projected by 2100

**Annual Air**
- Mean annual temperature is projected to increase by 4.6-4.7°C (8.3-8.5°F).

**Seasonal Air**
- Warming is projected in all seasons, with the most warming in summer.

**Extreme Heat**
- Longer, more frequent, and more intense extreme heat events.
- Increase in the annual number of days ≥90°F (32°C) by mid-century (+10 to +24 days) compared to 1971-2000.
  - Bend: 12 days in 2020s; 26 days by 2050s.
- Increased frequency and magnitude of days with an extreme heat index (temperature + humidit
  - +22 to +36 days with a heat index of ≥90°F (32°C) relative to 1971-2000.

**Streams**
- Summer temperatures are projected to increase by an average of 1.3°C (2.3°F) in the 2040s and 2.2°C (4°F) in the 2080s.
- Larger than average increases are projected to occur in the warmest streams at low elevations; smaller than average increases are projected for the coldest streams.

## Precipitation & Drought

### Observed

**Annual**
- Annual precipitation has not changed since 1895, and interannual variability in precipitation is high.

**Snowpack**
- Annual peak SWE (snow-water equivalent; a measure of snow depth) has decreased significantly since 1980, with a concomitant increase in rain-on-snow events throughout the Cascades.
- No significant decrease in April 1 SWE since 1980; Cascade Range snowpack during the past 40 years has been stable despite recent regional warming.
- Snowmelt season is occurring 1-3 weeks earlier across the western US.
- In the low-elevation eastern portions of the region, snow is already absent or ephemeral.

**Drought**
- Persistent and severe droughts have occurred in Oregon since 2000.

### Projected by 2100

**Annual**
- Models project minimal increase in precipitation (~6%) or no significant change.

**Seasonal**
- Models project an increase in seasonal amplitude of precipitation, with more precipitation in winter (Dec-Mar) and less during the growing season (Apr-Oct).

**Extreme Precipitation**

- Increase in frequency and intensity of floods due to stronger storms and a shift from snow to rain
- Increased intensity of atmospheric rivers and possible penetration further inland.

**Snowpack**

- In the low-elevation eastern portions of the region, warming temperatures will change average snow residence times (i.e., duration of snow) to a small degree, as snow is already absent or ephemeral.
- At higher elevations in the southwestern portion of the region, the average residence time of snow projected to decline on the order of 3 to 4 weeks.
- At higher elevations (i.e., crest and peaks of the Cascades) in the northwestern portion of the region, the average residence time of snow projected to decline on the order of 8 to 10 weeks.
- At lower elevations (<2000 m/6500 ft) in the Oregon Cascades, snow residence time is expected to decrease by 7-8 weeks, with minimal snow remaining by April 1 at many sites.
- Three to 4 times as much SWE loss in the Cascades as farther east in the region.
- Annual mean snowfall in Deschutes County projected to decline from 7.4 ft (2.3 m) in 1981-2010 to 5.4 ft (1.6 m) in 2025-2049.

**Drought**

- Increased severity and duration of droughts.
- Increased annual number of dry days in Bend: 186 in 1990s; 192 by 2050.
- Under a high-emissions scenario, climatic water deficit (CWD; a measure of drought stress) is projected to double at most elevations.

## Hydrology

### Observed

**Streamflows**

- Spring, early summer, and late summer flows have been decreasing, and more annual flow has been occurring earlier in the water year.

### Projected by 2100

**Streamflows**

- Small decreases in low flows are expected in areas where snow is not a large contributor to streamflow.
- The largest reductions in summer streamflows are projected for the eastern slopes of the High Cascades, where earlier snowmelt timing will potentially result in summer streamflow losses of 40-60% by 2040 and 60-80% by 2080.
- Reduced summer streamflow is also projected in the uplands of the Fremont-Winema National Forest, with projected reductions of 20-30% by the 2040s and 40-50% by the 2080s.
- Summer streamflow is more likely to decrease 10-20% over the next 50 years in the Ochoco Mountains and Crooked River National Grassland.
- Common floods are expected to increase in magnitude and extreme hydrologic events (e.g., those currently rated as having 100-year recurrence intervals) may become more frequent.
- The eastern slopes of the Cascades are projected to have peak-flow increases of 20-40% by mid-century, with progressively more areas showing increased peak flows by 2080.
- By 2080, other areas, including Fremont-Winema and Ochoco National Forests are projected to have increased peak flows of 20-30%.
- Runoff timing is projected to occur 8-18 days earlier in the year relative to the 1980s baseline period.
- Slight increase in the number of winter high-flow days (1-4 days).
- Lake Abert, Middle Deschutes, Sprague, Summer Lake, Upper Crooked, and Upper Klamath Lake subbasins will likely experience substantial changes in bankfull flow (>30 percent increase in magnitude) by 2080.

## Disturbances

**Observed**

**Wildfire**

- Fire season has increased significantly since the 1980s.
- The intensity and severity of fires in the last 3-4 decades has increased in shrub steppe and low- to mid-elevation dry forests and woodlands.

**Projected by 2100**

**Wildfire**

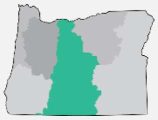
- Projected temperature increases will likely extend the length of the fire season.
- Increased frequency and extent of wildfire.
- Slight increases in fire suitability in higher-elevation forests along the Cascade Crest.
- Increased number of high fire danger days in summer and fall in Bend: 11 in 2020s; 15 by 2050s.
- Large increases in the number of summer days with high fire danger in the Cascade Range and Klamath Mountains.
- Increased average size of fires on the east slope of the Cascade Range.
- Increased proportion of forests in which conditions are consistent with large wildfires (>100 acres/40 ha); largest projected increases in Klamath Mountains and eastern Cascade Range.

**Insects & Pathogens**

- Increased frequency and extent of insect and disease outbreaks.

**Information from the following references and the citations therein:**


1. Halofsky, J.E., D.L. Peterson, and R.A. Gravenmier, eds. 2022. Climate change vulnerability and adaptation in the Columbia River Gorge National Scenic Area, Mount Hood National Forest, and Willamette National Forest. Gen. Tech. Rep. PNW-GTR-1001. U.S. Dept of Ag., Forest Service, Pacific Northwest Research Station. 469 p.
2. Halofsky, J.E., D.L. Peterson, and J.J. Ho, eds. 2019. Climate change vulnerability and adaptation in south-central Oregon. Gen. Tech. Rep. PNW-GTR-974. U.S. Dept of Ag., Forest Service, Pacific Northwest Research Station. 473 p.
3. Dalton, M. and E. Fleishman, eds. 2021. Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University. 183 p.
4. Fleishman, E., ed. 2023. Sixth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University. 248 p.
5. Department of Land Conservation and Development. 2023. Climate Change Vulnerability Assessment Workshops, Regional Climate Change Projections Fact Sheets. https://www.oregon.gov/lcd/CL/Pages/Vulnerability-Assessment.aspx



CENTRAL OR.

# REGION 4 Observed & Projected Changes for Habitats & Fish Species

## Habitats

### Cold Forests / Subalpine

Credit: Linda Repplinger

- Likely that cold forests will be more sensitive to warming at their lower elevation limits as moist-forest species may expand into these places.
- As snowpack decreases, cold-forest species may be able to establish at treeline (assuming sufficient soil is available).
- Soil moisture stress will reduce overall vigor and growth of subalpine tree species.
- Increased frequency and extent of wildfire could not only kill subalpine species across large landscapes but make regeneration difficult.
- Increased frequency and extent of wildfire and insects would have a significant negative effect on most species, especially whitebark pine.

### Woodlands

credit: Joan Amero

- Tree establishment and growth in woodlands are limited by precipitation and soil moisture; lower precipitation could decrease tree establishment and possibly increase tree mortality.
- Higher temperatures in spring and summer may increase mortality in some woodlands, particularly at lower elevations.
- Higher precipitation could facilitate further juniper expansion.
- Increased fire frequency could reduce conifer encroachment, favoring the development of open woodlands.
- In general, expansion of woodland types is likely with hotter and drier future conditions; expansion is likely at the expense of dry forest.

### Mesic Forests

credit: OWEB

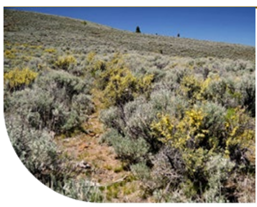
- Higher temperatures may increase growth and productivity in some locations, especially if precipitation increases; drought stress could limit the expansion of mesic forests and favor species that tolerate low soil moisture/adapted to drier conditions (e.g., ponderosa pine, lodgepole pine).
- Pumice soils could limit expansion in some areas.
- Severe wildfires are possible in areas with high fuel loading.

## Dry Forests

credit: OWEB

- Dry forests are less sensitive to warming than other forest types; species may be able to expand into more suitable habitat (e.g., higher elevation).
- Dry forests are sensitive to the duration and severity of summer drought stress at lower elevations; shifts from dry forest to woodlands or shrublands may occur in the driest portions of the current dry forest range, especially if drought and frequent fire limit regeneration.
- Establishment and growth will be affected by water availability; growth of dry forest species is projected to decrease.
- Increased frequency and extent of wildfire will tend to favor dominant species in these forests except where fuel loads are high.
- Increasing the frequency of short-interval, high-severity reburns could result in conversion to shrubland.
- Increased precipitation could lead to the expansion of dry forest.
- Tree mortality may also increase in some locations because of interactions among drought, disturbance, and insects.
- Ponderosa pine may shift to higher elevations and become more dominant relative to Douglas-fir.

## Shrub & Grasslands



credit: OWEB

- Shrublands are limited by snowpack, soil moisture, and winter temperatures; grassland composition and extent are controlled by soil moisture and winter temperatures.
- Continued loss of snowpack may accelerate the loss of some shrublands, especially big sagebrush; drought-tolerant species may replace big sagebrush in some locations.
- Shrublands are sensitive to altered wildfire frequency and severity; increased fire frequency and extent would reduce the distribution of sagebrush and some other shrub species.
- Decreased winter or spring precipitation may shift the composition and abundance of grasslands to more drought-tolerant or invasive species whereas increased winter or spring precipitation may increase woody vegetation in areas currently dominated by grasslands.
- Relatively little change projected for cool-season grasslands.

## Wetlands, Riparian, & Groundwater-Dependent Ecosystems (GDE)

credit: OWEB

- Sensitive to drought, higher evapotranspiration, and lower summer streamflows, which can decrease habitat extent and alter plant community composition.
- In wetlands and GDEs, less water during summer would reduce the duration and depth of standing water and increase water temperature; this could affect local distribution and abundance of plant species and aquatic fauna.
- Some GDEs may decrease in size or completely dry out in summer due to reduced snowpack and resulting declines in the length of time that aquifer recharge can occur.
- Some ephemeral montane wetlands may disappear, and intermediate montane wetlands may become ephemeral.
- Drier conditions and more frequent fire in riparian areas may favor conifers over species typically associated with riparian areas (e.g., deciduous hardwoods).
- Increased flooding as a result of lower snowpack and increased intensity of winter precipitation events would affect erosion and sedimentation, resulting in changes to channel form and fluvial dynamics.

# Fish Species

## Steelhead Trout

credit: Greg Shields, cc

- Increased peak flows may affect rearing fish, particularly in streams that lack low-velocity habitat.
- Based on projections of stream temperature, steelhead streams with optimal mean August temperatures are projected to decrease from 58% (current) to 31% (2080).
- Lower flows and warmer temperatures place additional stress on steelhead, which could increase pre-spawn mortality rates, impair spawning ability, or reduce viability of eggs and embryos.
- Summer steelhead populations in the Middle Columbia are projected to experience warmer temperatures and lower flows while in freshwater, and consequently, find fewer cold-water refugia.

## Redband Trout

credit: Jonny Armstrong OSU

- Headwater habitat loss during summer will be most pronounced in the Goose Lake, Chewaucan, and Upper Klamath basin species management units.
- Higher winter peak flows may affect rearing fish, particularly in streams that lack low-velocity habitat.
- Based on projections of stream temperature, redband streams with optimal mean August temperatures are projected to decrease from 67% (current) to 40% (2080).

## Bull Trout

credit: Aubree Benson USFS

- Increasing water temperatures can affect spawning distribution and abundance and early rearing.
- Higher winter peak flows may affect bull trout redds and incubating eggs; rearing fish, especially in streams that lack low-velocity habitat may also be at risk.
- Bull trout streams within the optimal temperature range are projected to decrease 31% by the 2040s and 52% by the 2080s.
- The Columbia River-Hood core area retains a greater amount of streams within the optimal August temperature than the other Columbia River core areas.
- Populations exposed to high temperatures and frequent winter flooding may have lower genetic diversity.

## Pacific Lamprey

credit: USFWS

- Increased risk of mortality for embryonic and newly-hatched Pacific lamprey due to water temperatures exceeding 20°C (68°F) in summer.
- Increases in water temperature can also affect the survival of larval rearing fishes and timing or number of individuals as they metamorphose into ocean-going life stage, or lead to premature migration of juvenile lamprey (which could expose them to saltwater before they have made necessary physiological changes).

## Lost River & Shortnose Suckers

credit: USGS

- Nearly 80% of current stream habitats used by suckers will have summer temperatures higher than 20°C (68°F) by 2080.
- These species will also be affected by low summer flows and declining water quality (e.g., if declining flows in important spawning tributaries result in habitat fragmentation).

## Coho Salmon

credit: USGS

- Areas inhabited by coho salmon from the Hood population are projected to have more stream length experiencing high-flow conditions.
- Warming water temperatures can accelerate egg incubation rates in winter or spring and potentially desynchronize the developmental phenology of juveniles from the temporal availability of seasonal habitats.

## Chinook Salmon

credit: Greg Morgan, BLM

- Highly variable flow and temperature regimes in April and May can affect smolt migration (e.g., high flows and water temperatures can narrow the migration window while cool temperatures and minimal flows can delay migration).
- Holding adults are vulnerable to higher summer water temperatures.
- Reduced availability of cold-water refuges in late summer and early fall.
- Altered behavior, physiology, and growth due to warmer water temperatures.

**Information from the following references and the citations therein:**

1. Halofsky, J.E., D.L. Peterson, and R.A. Gravenmier, eds. 2022. Climate change vulnerability and adaptation in the Columbia River Gorge National Scenic Area, Mount Hood National Forest, and Willamette National Forest. Gen. Tech. Rep. PNW-GTR-1001. U.S. Dept of Ag., Forest Service, Pacific Northwest Research Station. 469 p.
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