2021

PACIFIC NORTHWEST WATER YEAR

IMPACTS ASSESSMENT

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Supported by the NOAA National Drought Information System

ON THE COVER:
Field of lettuce near Kent, Washington.
Credit: Trong Nguyen.

EXECUTIVE SUMMARY

Regional Water Year Conditions at a Glance

- The 2021 water year in Washington, Oregon, and Idaho (the Pacific Northwest; PNW) tied as the 5th warmest and 17th driest since records began in 1895. Parts of western Washington and coastal Oregon were the exceptions, with near-normal water year temperatures and precipitation.
- The winter of 2020–2021 was characterized by La Niña, but a typical La Niña atmospheric pattern over the PNW did not emerge until February 2021, which was wetter than normal and critical in building mountain snowpack. By April 1, most of the basins in the PNW had normal to above normal snowpack, with notable exceptions throughout southern Idaho and in the southern Cascade Mountains of Oregon.
- Drought worsened region-wide throughout the water year and a record dry spring was a major contributor to deteriorating conditions. For the PNW, March–May precipitation was the 2nd driest (45% of the 1981–2010 normal) since 1895 and the driest since 1924.
- An exceptionally warm summer, including a record-breaking heat wave in late June, worsened drought conditions and caused high evaporative demand. Averaged throughout the PNW, June–August ranked as the warmest on record (+4.5°F above the 1981–2010 normal).
- The exceptionally dry spring and summer combined with the warm summer caused the 2021 PNW drought, and the persistence of drought conditions over at least the last 2 water years in parts of the region also contributed.

Impacts at a Glance

- The agriculture, forestry, drinking water, fisheries, and recreation sectors were affected by the abnormally dry conditions. Impacts included less surface water available for agriculture and fishes, water rights restrictions, reduced crop yields, plant stress, tree mortality, and voluntary water restrictions.
- Impacts were particularly widespread in central and southern Oregon, eastern Washington, and the Big Wood, Little Wood, Big Lost, and Little Lost River basins in Idaho.
- The June heat wave scalded and scorched crops, caused tree seedling mortality and mortality of shellfish in the intertidal, and damaged transportation infrastructure. Human health impacts from the heat, such as increased hospitalization and even death, were widespread.

Response Actions at a Glance

- Portions of Idaho, Oregon, and Washington issued State drought declarations as early as March 31 and as late as November 17, 2021. Burn bans were issued for parts of Washington, Oregon, and Idaho and the use of certain recreational areas was limited during the wildfire season.
- Organizations and individuals responded to the drought conditions in a variety of ways. Examples of these responses include water systems requesting voluntary water restrictions and agricultural operators changing cattle feeding routines and watering schedules.

Forecast Verification at a Glance

- A qualitative examination of two separate seasonal forecasts from the NOAA Climate Prediction Center, one for November 2020 through January 2021 and one for April through June 2021, showed that the region was drier than predicted. Seasonal forecasts indicated a drier than normal April–June for Oregon and southern Idaho, but both the magnitude of dry conditions and their extent into Washington and northern Idaho was unforeseen.

1 PURPOSE

For several years, researchers, practitioners, and organizations working across practitioner–research boundaries in Oregon and Washington have held a joint Water Year[1] Recap and Outlook meeting. A separate but similar meeting in Idaho is also held each year.

Two main objectives of the water year meetings are:

1. To summarize the climate conditions of the previous water year;
2. To review climate and weather-related impacts on various sectors, focusing on drought and other extremes.

In addition to these impact discussions, an Annual Pacific Northwest Water Year Impacts Survey is used to collect information on water year impacts for multiple sectors.

The purpose of this assessment is to summarize the water year conditions and sector impacts as a resource for future management of drought and other climate extremes.

The assessment primarily reflects the information from the meeting discussions, the survey, and author expertise. Drought and, to a lesser extent, the June 2021 heat wave and its impacts are the focus of this report.

1 A water year is defined as the 12 months beginning on October 1 and ending on September 30 of the following year (e.g., water year 2021: October 1, 2020-September 30, 2021).

2 LESSONS LEARNED

1. Lessons Learned Based On the Assessment of Water Year 2021 Conditions and Associated Impacts

Lesson 1.1: Rapid changes in the spring of 2021 demonstrated the importance of considering a broader set of potential conditions when planning for drought. The La Niña winter brought normal to above-normal snowpack on April 1 to much of the region, which generally means no worse than modest drought during the following summer. The exceptionally dry spring and warm summer combined with rapid snowmelt associated with an early warm spell in mid-April, accelerated development of drought and compounded its effects.

Lesson 1.2: The widespread impacts on multiple sectors associated with the unprecedented June heat wave demonstrates the importance of planning and preparing for short duration extreme temperatures, in addition to monthly and seasonal temperatures that are typically monitored for drought. Additionally, the timing of heat waves can influence natural resource impacts. For example, stream temperatures during the heat wave remained relatively cool despite high air temperatures because snow was still melting in many areas. This likely mitigated potential impacts on fisheries relative to a late season heat wave. In contrast, impacts in the forestry and agriculture sectors may have been more severe because the heat wave occurred before plants were acclimated to seasonal hot and dry conditions.

Lesson 1.3: Multiple-year impacts of drought are possible and warrant planning. The PNW, particularly Washington, rarely experiences multi-year drought because precipitation in fall and winter usually is sufficient for recovery. The 24-month precipitation deficits ending in September 2021 in some regions of the PNW are a reminder of the potential for multi-year impacts. The severity of the drought in the 2021 water year means that complete recovery is unlikely during the 2022 water year, setting up more of the region for a multi-year event.

2. Lessons Learned From Water Year 2021 For Improving Regional Drought Response

Lesson 2.1: Regular collaboration and coordinated drought status updates among key state and federal agencies throughout the water year are valuable opportunities to share information on evolving conditions and response measures. Ongoing collaboration enabled coordinated messaging and press releases that served as important communication tools for the drought response.

Lesson 2.2: Compounded impacts of climate change and variability are becoming more diverse and affecting natural resources, agriculture, and water supply. For example, during the 2020 water year, extensive impacts were associated with drought and widespread wildfires. During the 2021 water year, extensive impacts were associated with the June heat wave and extreme drought. In efforts to document impacts associated with abnormal climate combinations, it is undeniable that complex factors lead to consequences for natural resource managers, agricultural producers, and water providers. Interest in documenting sector-specific impacts is high, but the complexity involved with identifying the mechanisms behind each impact may warrant a different approach.

Lesson 2.3: Interests and needs for information related to the climate of the water year and its impacts are becoming more diverse. In the PNW, participants at annual water meetings now include members of sectors such as forestry and recreation, in addition to professionals in the water resource sectors. The audience has expanded to a wider range of agency programs beyond water management and hydrology, and now includes more interest from the general public. This suggests a need to expand the water year meeting discussions to include ecological drought and aspects of water supply beyond drinking water, hydropower, and irrigation. Content of the water year meetings is also shifting away from technical information on forecasting water supply to information that serves the needs of this more diverse audience.

Lesson 2.4: Water supply conditions were experienced differently by different types of agricultural producers depending on the source of their water supply, revealing a gap in the state drought response. During the 2021 water year, irrigation production was more resilient than dryland production in the areas with normal to above normal snowpack. Since state drought response is centered on facilitating emergency withdrawals for entities with water rights, state resources for dryland producers were limited. While dryland producers do have resources to mitigate drought impacts through the federal government (i.e., crop insurance and USDA agricultural disaster proclamations), the 2021 water year could be used as a catalyst for state governments to explore strategies that dryland producers may use to reduce their vulnerability to drought impacts.

3 WATER YEAR EVOLUTION

WATER YEAR 2021 AT A GLANCE*

4th warmest; +1.9°F

16th driest; −6.80 inches (79% of normal)

8th warmest; +1.7°F

45th driest; −3.08 inches (93% of normal)

8th warmest; +1.7°F

10th driest; −5.91 inches (75% of normal)

*Anomalies relative to 1981–2010 normal; records since 1895 (Source: NOAA NCEI 2021)

The 2021 water year was warmer and drier than normal for the PNW. For the PNW, the 2021 water year tied 2016 as the 5th warmest and tied 1915 as the 17th driest (83% of normal precipitation) on record (since 1895; NOAA NCEI).

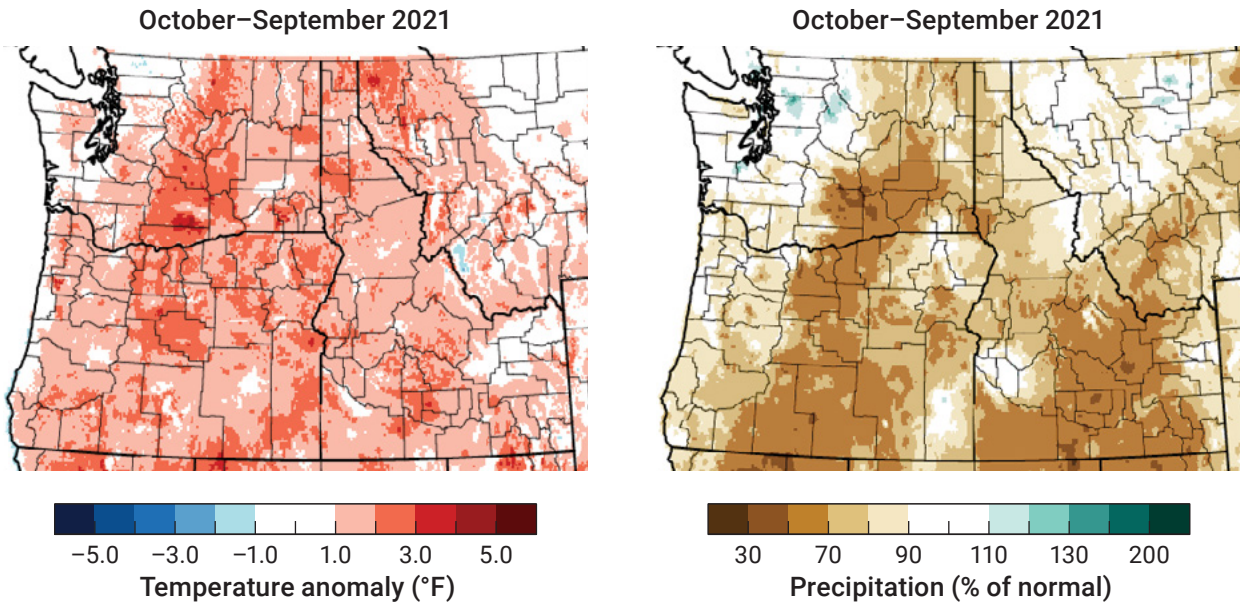


Figure 1: October 2020–September 2021 average temperature departures and precipitation percent of normal. The normal period is 1981–2010. Source: *WestWide Drought Tracker*.

Water year temperature and precipitation anomalies were spatially consistent throughout much of the PNW (*Figure 1*). Averaged over the 2021 water year, temperatures were above normal[2] throughout nearly the entire region and for each state. Drier than normal conditions were widespread in Oregon and Idaho, with more variability in Washington. Southern Idaho and the east slopes of the southern Cascade Mountains in Washington and Oregon were the driest locations, with 30 to 70% of normal precipitation. Most of western Washington had near-normal precipitation, with a few small areas above normal. Idaho was the driest of the three states relative to its normal.

At the start of the 2021 water year, there was significant variability in drought across the PNW as defined by the U.S. Drought Monitor (*Figure 2, next page*). Oregon had the most extensive drought coverage, with 66% of the state in either "severe" or "extreme" drought. Many of Oregon's reservoirs had much below average carryover from the 2020 water year, particularly in areas outside of northwest Oregon. Drought in Washington was limited to eastern Washington, with 17% of the state in "severe" or "extreme" drought as a result of below normal 2020 water year precipitation. Nevertheless, the reservoir storage at the start of the water year was adequate. For example, the Yakima Basin started the water year with above normal storage. Similarly, almost all reservoirs in Idaho began the water year with above average carryover. The Wood and Lost River basins, in the 4% of Idaho that was in "severe" or "extreme" drought, were the exceptions, with below normal reservoir volumes at the start of the water year.

Drought conditions worsened throughout the water year, however, and not necessarily

2 The period of 1981–2010 is used as the "normal" throughout this report unless stated otherwise.

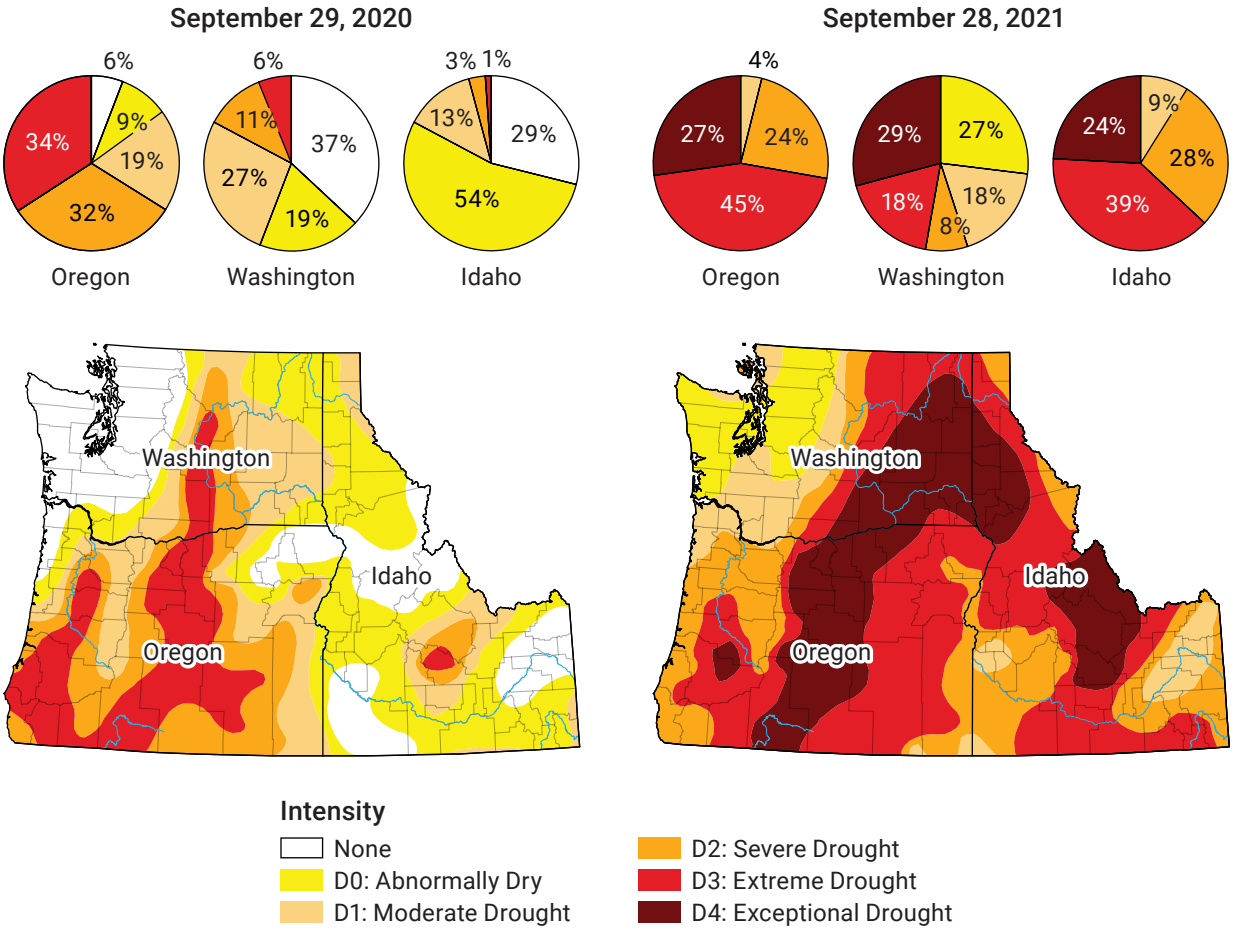


Figure 2: Pie charts and maps of drought conditions from the *U.S. Drought Monitor* on September 29, 2020 (*left*) and September 28, 2021 (*right*).

due to lack of snowpack. Worsening drought conditions were primarily caused by an exceptionally dry spring and warm and dry summer. By the end of the water year, about 25% of each state's area was in "exceptional drought," the worst drought category recognized by the U.S. Drought Monitor. About 39% of Idaho, 45% of Oregon, and 18% of Washington were in "extreme drought". The following section describes the weather conditions that led to drought expansion in more detail.

Seasonal Progression

The seasonal progression of temperature and precipitation characterizes the water year better than water year averages and totals. This fact is illustrated by the water year total precipitation percent of normal (*Figure 3, next page*). The Washington total water year precipitation is neutral relative to the historical rank because it is an average of wetter than normal conditions in the early part of the water year and drier than normal conditions during the spring and summer. By contrast, total water year precipitation for Oregon and Idaho rank in the moderately dry and severely dry categories, respectively.

Precipitation ranks for individual months clearly show the extent to which spring conditions were dry (*Figure 3*). In each state,

March, April, and May were moderately, severely, or extremely dry. There is more variability among the states during summer months. In June, Idaho was extremely dry whereas Oregon was abnormally dry and Washington June precipitation ranked as neutral. In contrast, August was abnormally wet in Idaho but neutral, although drier than normal, in Oregon and Washington. Washington's July precipitation rank was as low as in April, and was extremely dry compared to the historical record. Few months ranked amongst the wettest in the historical record. February, which finally looked like a typical winter month during La Niña, was abnormally wet for all three states. The water year ended moderately wet for Washington and Oregon, but September was still drier than normal for Idaho.

The relative dry and wet periods are also illustrated by the October 2020–September 2021 average streamflow for the PNW (*Figure 4, next page*). Streamflow was below normal in early December and March through mid-September, corresponding well with the drier periods of the water year. Streamflows in mid-October and late December through mid-January were above normal. The monthly and seasonal conditions are discussed in further detail in the next sections.

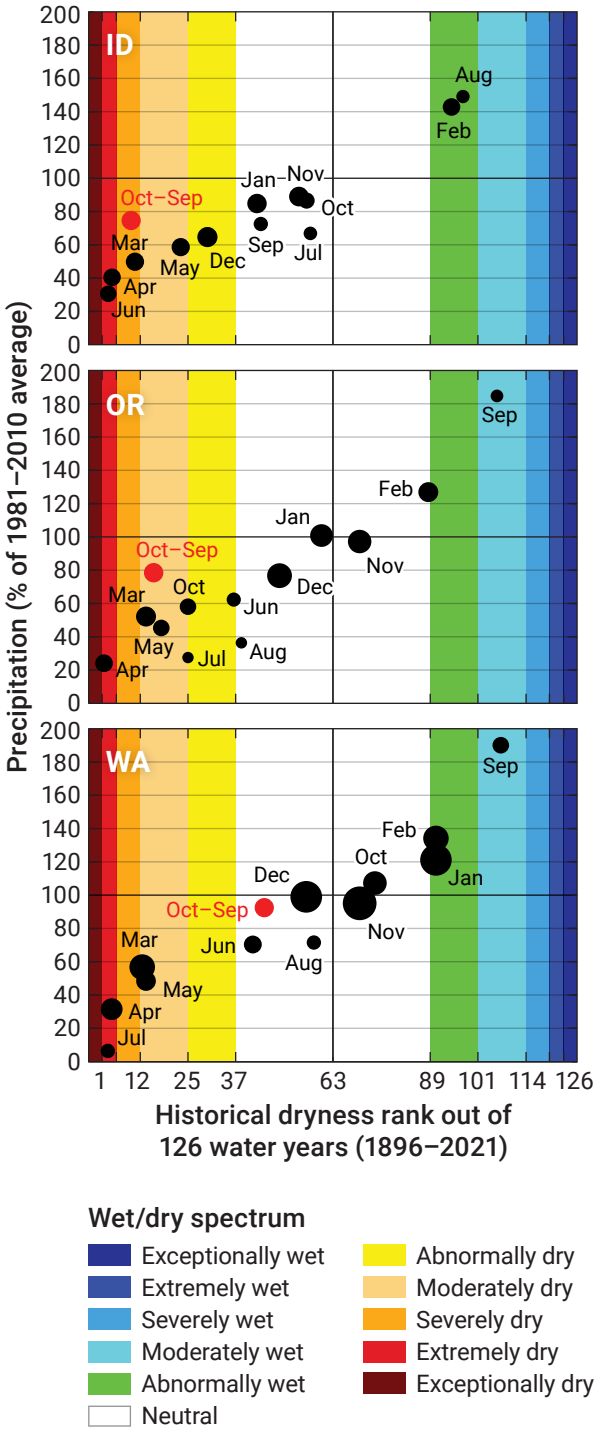


Figure 3: Monthly percent of normal (compared to 1981–2010 baseline) statewide precipitation as a function of the monthly precipitation rank during the last 126 water years for Idaho (*top*), Oregon (*middle*), and Washington (*bottom*). The water year 2021 total is shown as the red circle. The colors corresponding to dry conditions follow the U.S. Drought Monitor and those corresponding to wet conditions follow the *Climate Toolbox U.S. Water Watcher tool*. The sizes of the circles are scaled according to each month's relative average contribution to the water year total precipitation, from dry (*small*) to wet (*large*). NCEI nClimDiv data accessed on December 31, 2021; panels adapted from L. O'Neill.

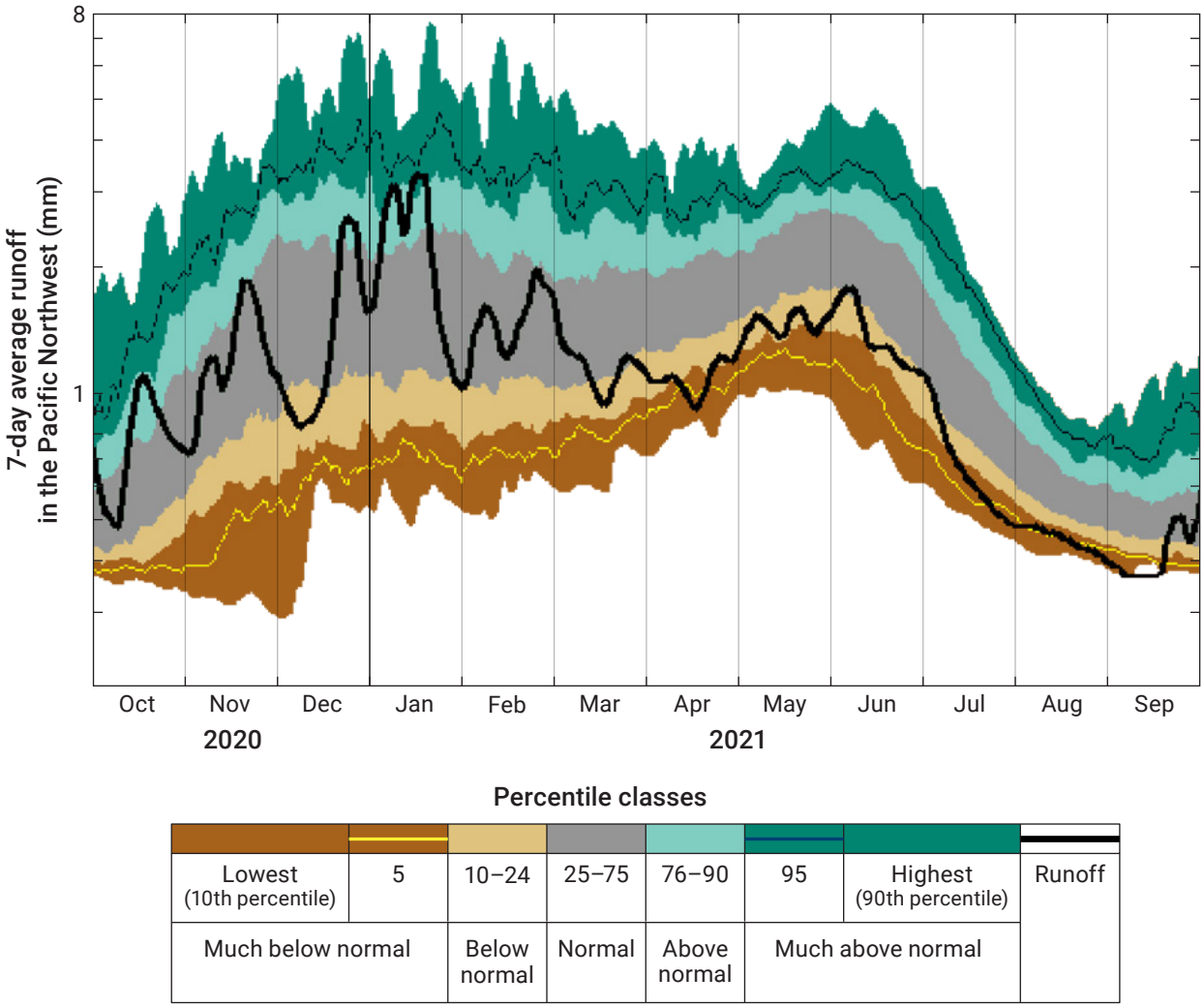


Figure 4: Seven-day average runoff over the PNW for water year 2021 (*top*) and the percentiles as the runoff relates to the historical record (*bottom*). Source: *USGS*.

October 2020–January 2021

Temperature

The 2021 water year began with near-normal to above normal October 2020 temperatures throughout the PNW. The majority of the region was warmer than normal through the next several months. Temperatures from October through January in Oregon, Washington, and Idaho ranked as the 9th, 11th, and 17th warmest, respectively, and temperature anomalies were between 1 and 5°F above normal (*Figure 5, next page*).

Precipitation

Precipitation from October–January was more spatially variable than temperature, and was below-normal across most of Oregon and central and southern Idaho, which is atypical during La Niña winters. The driest part of Idaho during this period were the basins along the southern border, which received 30–70% of their normal precipitation, and statewide it was the 25th driest on record. In Washington, the only area with below-normal October–January precipitation was the Lower Columbia

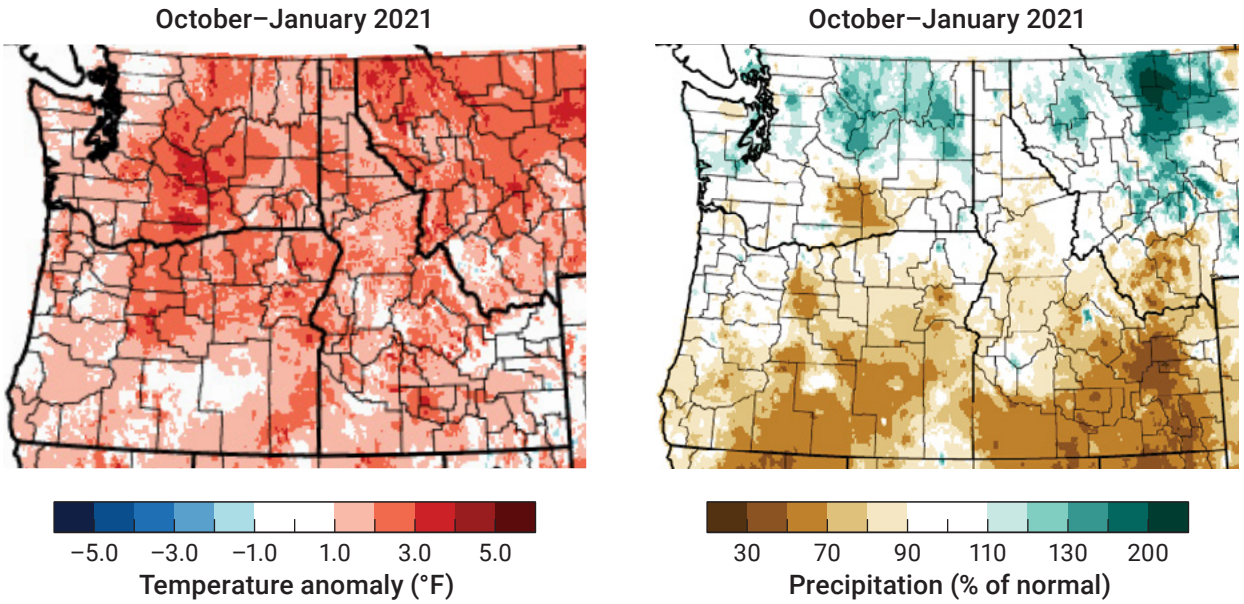
OCTOBER 2020–JANUARY 2021 STATISTICS*

9th warmest; +1.8°F
40th driest; –2.17", 87% of normal

11th warmest; +2.0°F
74th driest; +1.15", 105% of normal

17th warmest; +1.8°F
25th driest; –1.93", 81% of normal

*Anomalies relative to 1981–2010 normal; records since 1895. Source: NOAA NCEI 2021



Basin in eastern Washington, one of areas that was dry during the 2020 water year. Conversely, the rest of Washington and northern Idaho had normal to above-normal precipitation.

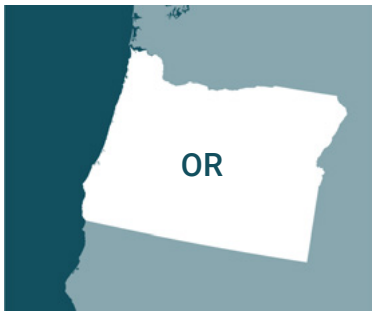
Figure 5: October 2020–January 2021 average temperature departures from normal (*left*) and precipitation percent of normal (*right*). Normal period is 1981–2010. Source: *WestWide Drought Tracker*, using provisional PRISM data.

Snowpack

Mountain snowpack accumulated early in the water year, with statewide percentages on December 1, 2020 at 148%

and 129% of median for Oregon and Washington, respectively. On December 1, average basin snowpack in Idaho was lagging behind at 73 and 89% of median for areas south of and north of the Salmon River, respectively. However, December was a particularly dry month throughout the PNW, except in the Puget Sound region of Washington. December–January combined was dry except in northern Washington, western Washington, and northwest Oregon, resulting in below normal snowpack for

DECEMBER 1, 2020 SNOW WATER EQUIVALENT*



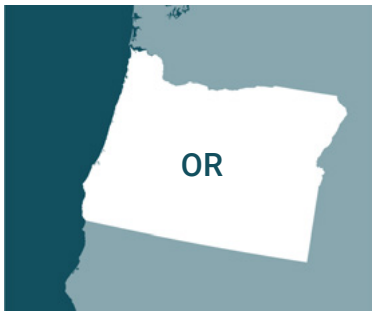
148% of median

129% of median

89% of median North of Salmon River

73% of median South of Salmon River

FEBRUARY 1, 2021 SNOW WATER EQUIVALENT*



78% of median

102% of median

82% of median North of Salmon River

79% of median South of Salmon River

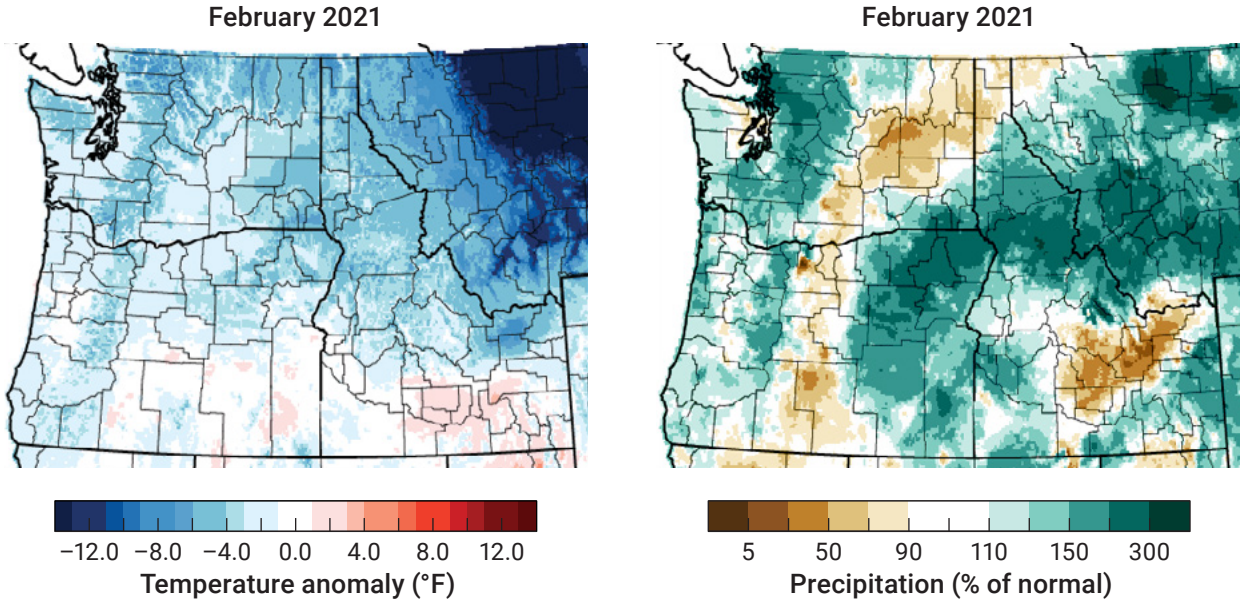
*Statewide on Dec 1, 2020; compared to 1981–2010 median. Source: National Resources Conservation Service

most basins in Oregon and Idaho. As a result, February 1, 2021, statewide average snow water equivalent was 78%, 102%, and 80% of normal for Oregon, Washington, Idaho, respectively.

February 2021

The atmospheric pattern shifted in February to one that is more typical during La Niña winters. Anomalous flow from

Figure 6: February 2021 average temperature departures from normal (*left*) and precipitation percent of normal (*right*). Normal period is 1981–2010. Source: *WestWide Drought Tracker*, using provisional PRISM data.



FEBRUARY 2021 STATISTICS*

53rd coldest; −1.8°F

39th wettest; +0.95”, 127% of normal

34th coldest; −3.2°F

37th wettest; +1.45”, 134% of normal

44th coldest; −2.1°F

33rd wettest; +0.92”, 143% of normal

*Anomalies relative to 1981–2010 normal; records since 1895. Source: NOAA NCEI 2021

the northwest brought cooler and wetter than normal conditions, greatly increasing snowpack in Washington, northeastern Oregon, and northern Idaho. The lee side of the Cascade Mountains in Oregon and Washington remained dry, as did south-central Idaho (*Figure 6, previous page*). Regionwide, February precipitation ranked as the 36th wettest for the PNW as a whole. Average February temperatures were below normal throughout the PNW, especially in Washington, where the month ranked as the 34th coldest February on record.

March–May 2021

Temperature

Average spring temperatures were near-normal throughout the PNW. In general, temperatures were relatively cool in March, warm in April, and near-normal in May.

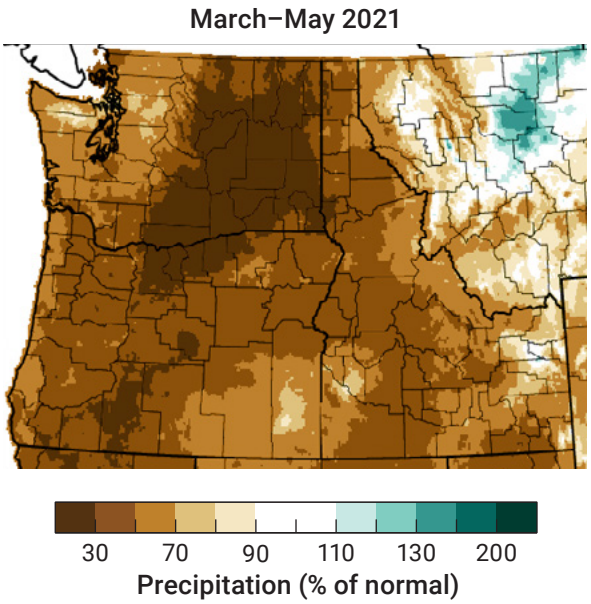
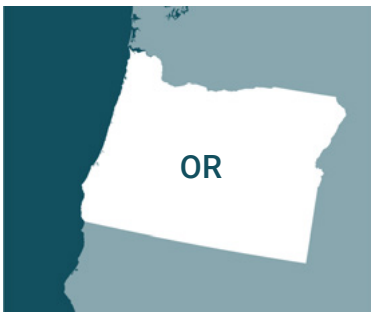


Figure 7: March–May 2021 precipitation percent of normal. Normal period is 1981–2010. Source: *West-Wide Drought Tracker*, using provisional PRISM data.

Precipitation

Regional precipitation was much below normal for spring as a whole, and for each individual month (*Figure 7*). March–May precipitation ranked as the 2nd driest for Oregon, Idaho, and Washington, separately, with individual statewide totals ranging from 41 to 50% of normal. Eastern Washington,

MARCH–MAY 2021 STATISTICS*



32nd warmest; +0.6°F

2nd driest; –5.07”, 41% of normal

34th warmest; +0.5°F

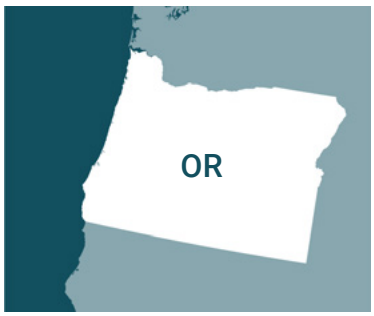
2nd driest; –5.37”, 46% of normal

40th warmest; +0.2°F

2nd driest; –3.43”, 50% of normal

*Anomalies relative to 1981–2010 normal; records since 1895. Source: NOAA NCEI 2021

APRIL 1, 2021 SNOW WATER EQUIVALENT*



113% of median

126% of median

99% of median North of Salmon River

87% of median South of Salmon River

*Statewide on Dec 1, 2020; compared to 1981–2010 median. Source: National Resources Conservation Service

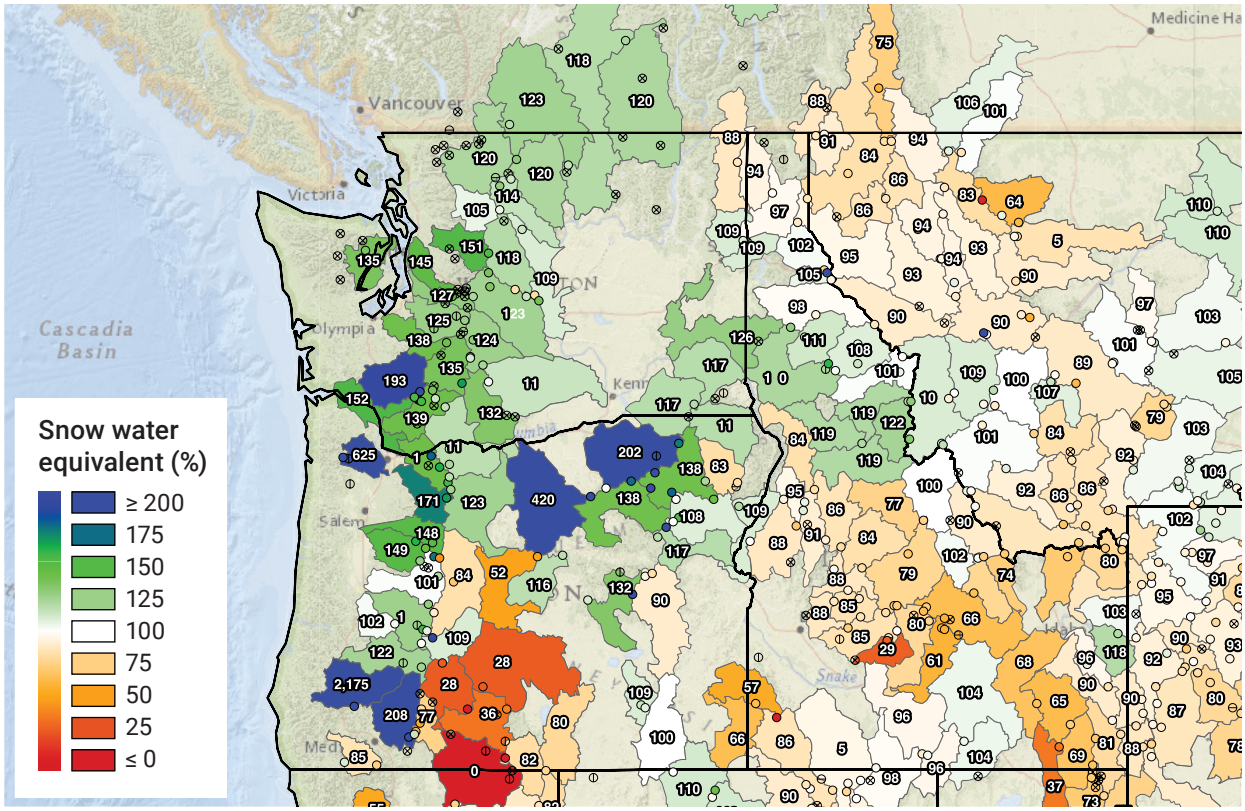


Figure 8: April 1, 2021 snow water equivalent (SWE) percent of 1981–2010 median. Source: *NRCS*.

the driest area relative to normal, received less than 30% of normal spring precipitation.

Snowpack

Despite the dry conditions, snow water equivalent (SWE) on April 1, 2021 was normal to above normal for most of Washington, Oregon, and northern Idaho (*Figure 8, previous page*). Average statewide snowpack, compared to normal, was 126% in Washington, 113% in Oregon, and 87% in Idaho. Snowpack in most basins south of the Salmon River in Idaho was below normal.

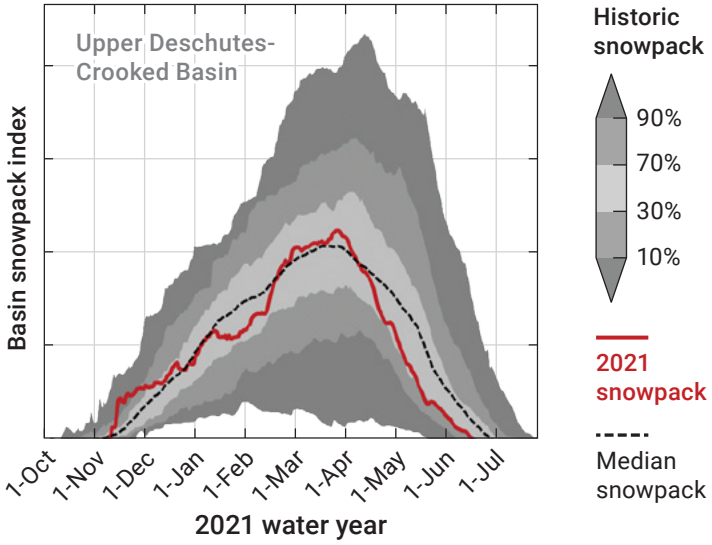


Figure 9: The Upper Deschutes-Crooked Basin, Oregon, water year 2021 snowpack trace (*red line*) compared to normal (*dashed line*), illustrating faster than usual melt-out even with above-normal snowpack by April 1. Source: Scott Oviatt USDA-NRCS.

At this point in the season, the severity of the forthcoming drought was unforeseen. While Idaho had the lowest snowpack of the three states, excellent carryover in the reservoir system promised to significantly mitigate the impacts of any potential drought. Based on the April 1 snowpack, the only areas where drought was expected to intensify were the Klamath basin of southern Oregon and the eastern portion of the mountains of central Idaho. A warm spell in mid-April, however, caused snowpack in Oregon and Idaho to melt faster than usual. Snowpack ultimately melted out 1–3 weeks early, even in basins with above-normal April 1 SWE (*Figure 9*). By April 15, the NOAA Seasonal Drought Outlook for April through July 2021 reflected the increasingly dry conditions and predicted drought development across the entire PNW except western Washington and northwest Oregon.

June–August 2021

Temperature

Summer temperatures were much above normal throughout the PNW. Average state temperatures from June–August were the warmest on record for Oregon and Idaho and the second warmest for Washington. Average June–August temperatures were between 2 and 6°F above normal regionally (*Figure 10, next page*), and there was an unprecedented heat wave at the end of June (see "The June 2021 Heat Wave," *page 22*) that sent temperatures soaring across the region. For a few days during that event, temperatures in the temperate coastal cities of Portland and Seattle exceeded those in Las Vegas.

Summer temperatures remained elevated beyond the duration of the extreme heat event, causing very high evaporative demand that increased drought severity. Values of the June–July–August Evaporative Demand

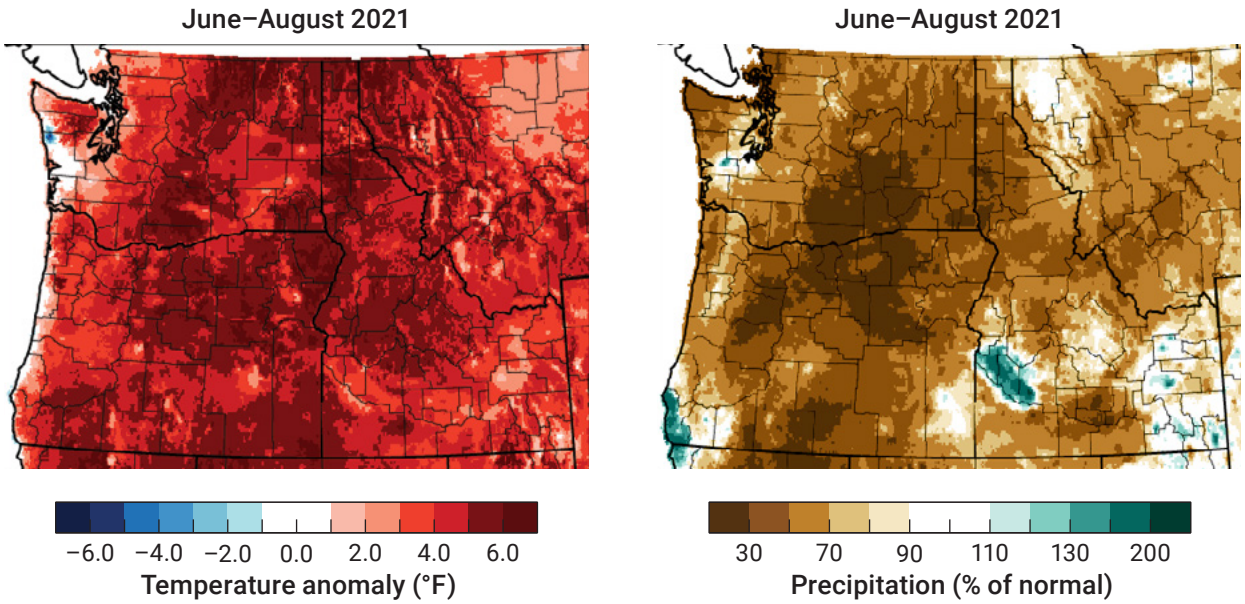


Figure 10: June–August 2021 average temperature departures from normal (*left*) and precipitation percent of normal (*right*). Normal period is 1981–2010. The small area of below-normal temperatures on the Washington coast is an artifact of unreliable data that were removed from the PRISM data during the quality control process but are still visible in the mapping application used here. Source: *WestWide Drought Tracker*, using provisional PRISM data.

JUNE–AUGUST 2021 STATISTICS*

OR	WA	ID
RECORD warmest; +4.8°F	2nd warmest; +4.2°F	RECORD warmest; +4.4°F
14th driest; –1.39”, 49% of normal	16th driest; –1.79”, 55% of normal	27th driest; –1.16”, 67% of normal

*Anomalies relative to 1981–2010 normal; records since 1895. Source: NOAA NCEI 2021

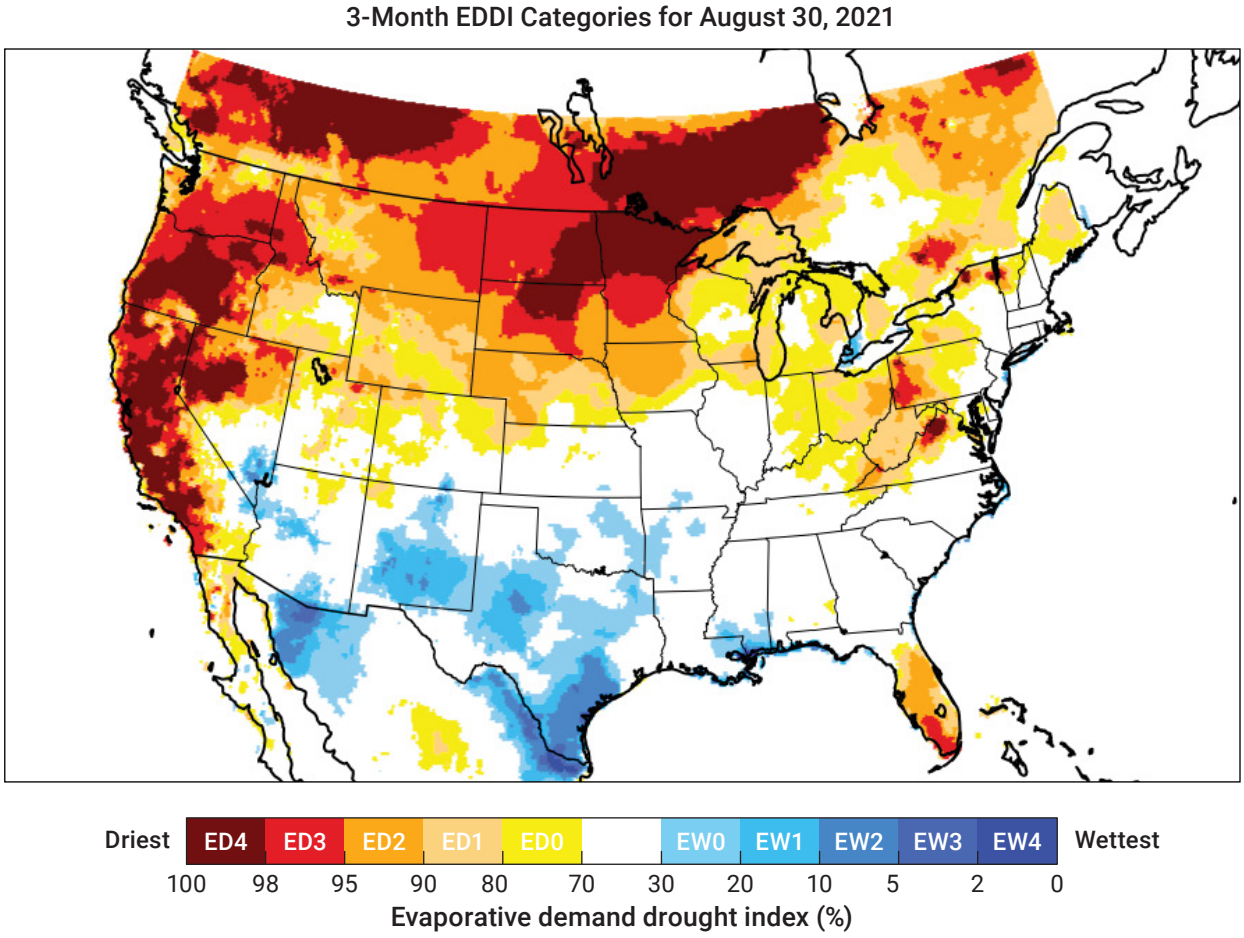


Figure 11: Evaporative Demand Drought Index (EDDI) for the 3-month period ending on August 30, 2021. Source: *PSL*.

Drought Index (EDDI) show extremely and exceptionally dry conditions throughout the PNW (*Figure 11, page 20*). The high evaporative demand meant that the little precipitation that fell was even less likely to meet water supply demands. Soils were also extremely dry throughout the summer with historically low soil moisture in the upper 1 meter of the surface as measured by the *NASA Grace satellite* (not shown).

Precipitation

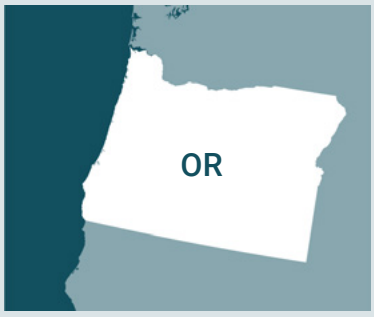
The dry spring conditions continued into summer, with a majority of the PNW receiving less than 70% of normal precipitation (*Figure 10, previous page*). For the PNW, June through August precipitation ranked as the 11th driest on record. Some of the dryness can be attributed to a lack of monsoonal rainfall that is mainly associated with thunderstorms. Parts of western and southern Idaho and far eastern Oregon, including the Owyhee and Wallowa Mountains, received well above normal precipitation during August 2021 (not shown). However, central Oregon, eastern Washington, and northern Idaho received below-normal precipitation during these months.

Vineyards in the Columbia River Gorge, Washington. Credit: Rigucci

March–August 2021 Conditions

The exceptionally dry spring and summer in combination with the warm summer drove drought development throughout the PNW. In parts of southern Oregon and southern Idaho, below normal winter snowpack also contributed to the drought severity and subsequent impacts. Averaged across the PNW, the March–August period was the second driest on record, with 49% of normal precipitation, and the driest March–August since 1924. PNW March–August average temperatures ranked as the 4th warmest on record, with an anomaly of 2.5°F. Although the individual state rankings are included for the March–May and June–August periods, separately, we are also highlighting those numbers for the March through August period as a whole since 2021 was anomalous even over the longer 6-month period.

MARCH–AUGUST 2021 STATISTICS*



3rd warmest; +2.7°F

2nd driest; –6.45”, 43% of normal

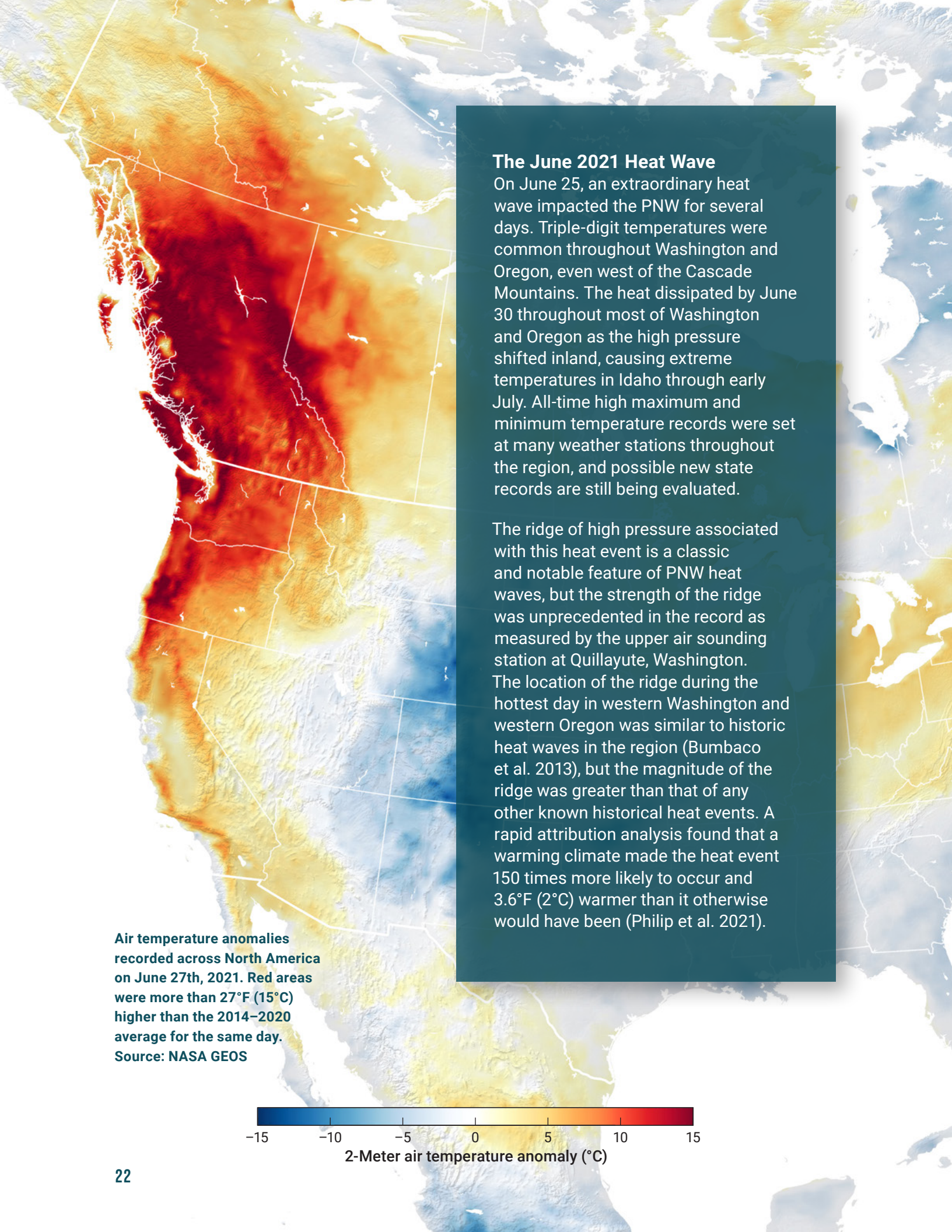
4th warmest; +2.3°F

2nd driest; –7.16”, 49% of normal

5th warmest; +2.3°F

3rd driest; –4.59”, 56% of normal

*Anomalies relative to 1981–2010 normal; records since 1895. Source: NOAA NCEI 2021



The June 2021 Heat Wave

On June 25, an extraordinary heat wave impacted the PNW for several days. Triple-digit temperatures were common throughout Washington and Oregon, even west of the Cascade Mountains. The heat dissipated by June 30 throughout most of Washington and Oregon as the high pressure shifted inland, causing extreme temperatures in Idaho through early July. All-time high maximum and minimum temperature records were set at many weather stations throughout the region, and possible new state records are still being evaluated.

The ridge of high pressure associated with this heat event is a classic and notable feature of PNW heat waves, but the strength of the ridge was unprecedented in the record as measured by the upper air sounding station at Quillayute, Washington. The location of the ridge during the hottest day in western Washington and western Oregon was similar to historic heat waves in the region (Bumbaco et al. 2013), but the magnitude of the ridge was greater than that of any other known historical heat events. A rapid attribution analysis found that a warming climate made the heat event 150 times more likely to occur and 3.6°F (2°C) warmer than it otherwise would have been (Philip et al. 2021).

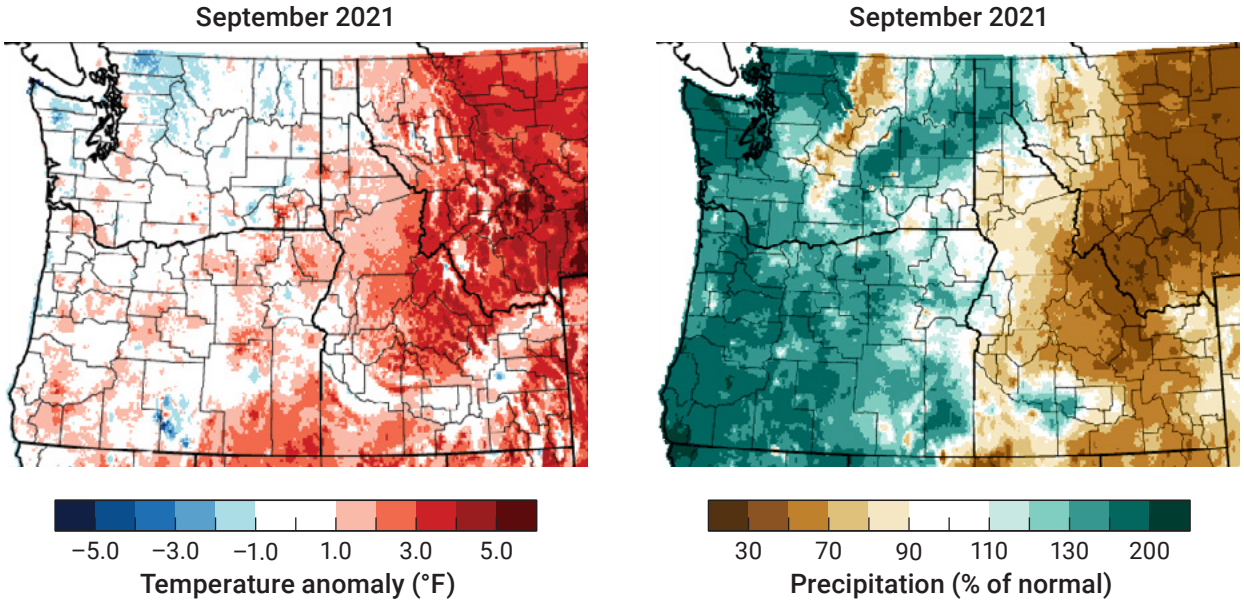
Air temperature anomalies recorded across North America on June 27th, 2021. Red areas were more than 27°F (15°C) higher than the 2014–2020 average for the same day. Source: NASA GEOS

September 2021

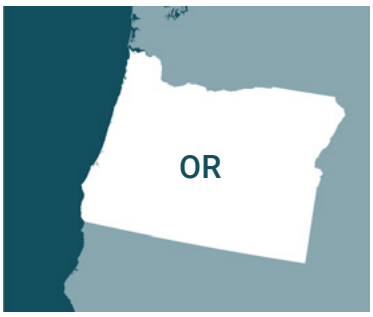
Temperature

Temperatures moderated in September, with monthly averages near normal for most of Washington and Oregon, except southeastern Oregon where temperatures were above normal (*Figure 12*). In Idaho, temperatures were 1–4°F above normal, and September ranked as the 23rd warmest on record.

Figure 12: September 2021 average temperature departures from normal and precipitation percent of normal. Normal period is 1981-2010. Source: *WestWide Drought Tracker*, using provisional PRISM data.



SEPTEMBER 2021 STATISTICS*



29th warmest; +1.0°F

22nd wettest; +0.87”, 184% of normal

43rd warmest; +0.2°F

20th wettest; +1.47”, 190% of normal

23rd warmest; +1.7°F

42nd driest; −0.31”, 73% of normal

*Anomalies relative to 1981–2010 normal; records since 1895. Source: NOAA NCEI 2021

Precipitation

An atmospheric river event began on September 17, ushering in fall and offering the first glimpse of relief from the dry conditions. Overall, September was much wetter than normal for Washington and Oregon, but drier than normal for Idaho, except in the northern panhandle. There was minor alleviation of drought conditions, mostly west of the Cascade Mountains, but much more precipitation was required to make a significant dent in the drought conditions. At the end of the water year, the U.S. Drought Monitor still classified nearly the entire PNW in "moderate drought" or worse (*Figure 2, page 10*).

Multi-Year Drought

The weather and seasonal climate conditions for water year 2021 are reviewed above, but there are longer-term precipitation deficits across much of the PNW when considering the previous *2020 water year*. The Standardized Precipitation Evapotranspiration Index (SPEI), a standardized index that has both a precipitation and temperature component, is shown for the 24 months ending September 2021 in *Figure 13*. Indices less than –1 typically signify the beginning of drought, and drought severity increases as the index becomes more negative. The 24-month SPEI shows drought throughout the PNW, with values less than –2.0 east of the Cascade Mountains in Oregon and Washington and in southern Idaho. The 24-month SPEI ending with the 2021 water year, averaged statewide and compared to all consecutive two water years on record, indicated the 2nd worst drought on record (since 1897) for Oregon (–1.66), the 5th worst for Idaho (–1.41), and the 14th worst for Washington (–0.97). Although the exceptionally dry spring and summer and warm summer

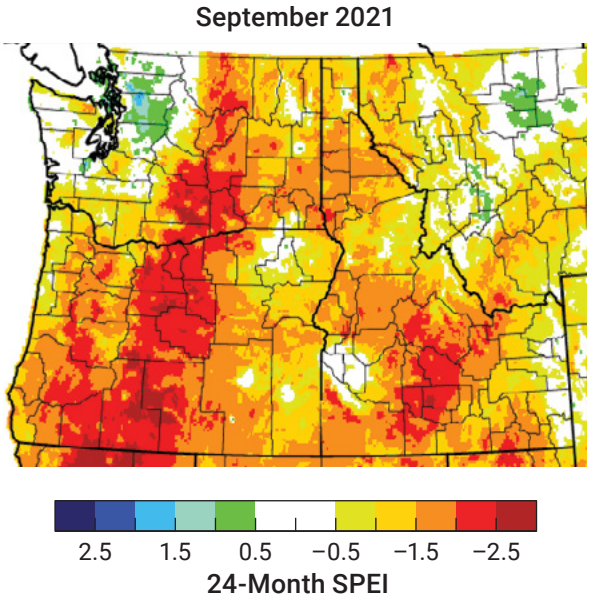


Figure 13: 24-month Standardized Precipitation Evapotranspiration Index (SPEI) for the period ending September 30, 2021. Source: *WestWide Drought Tracker*, using provisional PRISM data.

were likely the main drivers of the drought throughout much of the PNW, longer-term drought in the region also played a role.

At the time of this writing, the 2022 water year is underway, and exceptionally wet fall conditions have alleviated drought in some areas of the PNW. Western Washington in particular has greatly improved, in part because drought across most of that area had not persisted for multiple years. However, drought is persisting and is likely to continue in some of the areas that were the driest during the last two water years. As of early January 2022, the *NOAA Drought Termination and Amelioration tool* shows that about 200% of normal precipitation is needed for the driest areas (SPEI of –2.0 or less in *Figure 13*) to completely erase the drought conditions by April 2022, and the probability of that occurring is less than 1%.

4 WATER YEAR IMPACTS

Information on drought and other climate conditions are critical to connecting those conditions to their effects on local resources, people, and economies. Here we summarize impacts on multiple sectors in Oregon, Idaho, and Washington from three sources:

- The national Condition Monitoring Observer Reports (CMOR)
- The Annual Pacific Northwest Water Year Impacts Survey
- Presentations and discussions from the 2021 water year meetings

Information on impacts is collected throughout the water year and retrospectively at the end of the water year. CMOR, started in 2018, allows members of the public to submit drought impact reports for their specific location at any time of year. The Annual Pacific Northwest Water Year Impacts Survey is distributed at the end of the water year to natural resource managers and agency staff, as well as everyone who registers to attend the water year meetings. Information from presentations and discussions from the 2021 water year meetings detailed here highlights particularly compelling drought impacts and responses within the region. Neither these sources nor the impacts presented in this report are exhaustive.

Condition Monitoring Observer Reports (CMOR)

CMOR, organized by the National Drought Mitigation Center (NCMC) and the National Integrated Drought Information System (NIDIS), collects local observations of drought impacts to aid in drought monitoring and research. The observations inform the U.S. Drought Monitor process and agencies that make drought-related decisions. Observers submitted 94 reports for the PNW—50 from Oregon, 23 from Washington, and 11 from Idaho—to CMOR during the 2021 water year. An additional 316 reports were submitted on a supplemental CMOR survey that focused solely on forestry impacts. Specific results from CMOR can be found on *page 32*.

Annual Pacific Northwest Water Year Impacts Survey

The PNW survey is designed to collect information on impacts of abnormally dry or wet conditions on multiple sectors (drinking water, agriculture, forestry, fisheries, hydropower, recreation, and stormwater), and is distributed at the end of the water year. Characterization of abnormally dry or wet conditions is made by the survey respondents. Respondents are able to select impacts from a list or specify other impacts. Impacts due to abnormally wet conditions were omitted from this report due to the very few responses in the 2021 water year.

We distributed the 2021 water year survey in October 2021 via listservs of NIDIS, Office of the Washington State Climatologist (OWSC), Climate Impacts Group (CIG), and regional water associations. Fifty-two people responded; 47% were employees of local, state, and federal agencies, and others were affiliated with Tribes, nonprofit organizations, universities, irrigation districts, and power and water utilities. Most responses were from Oregon and Washington. We include responses from agencies, as well as resource producers, and in some cases responses may describe the same impacts. While the survey asked for impacts related to stormwater, no responses were recorded for the 2021 water year, so stormwater sector impacts are omitted. The sector-specific survey results depicted in the pie charts are from this survey, and do not include results from CMOR.

SECTOR-SPECIFIC WATER YEAR IMPACTS

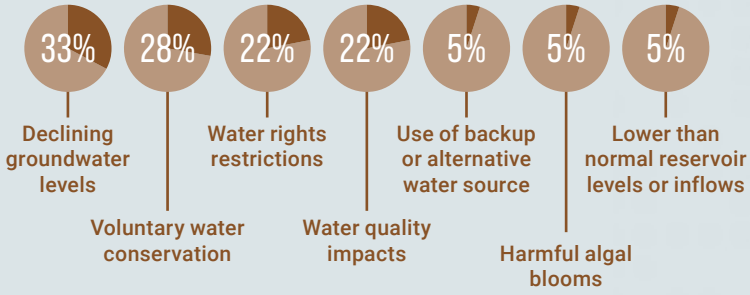
Drinking water

Impacts on the drinking water sector were mainly reported for watersheds in Oregon, including the Bull Run and Clackamas. Respondents indicated that the primary causes of these impacts were a combination of a lack of winter precipitation, low spring snowpack, and extreme summer heat. Of the 19 respondents, 18 (95%) reported impacts due to abnormally dry conditions and 1 (5%) reported impacts due to abnormally wet conditions.

DRINKING WATER IMPACTS SURVEY

Abnormally dry

18 responses



Dry bed of Emigrant Lake (near Ashford, Oregon) in October 2020. Emigrant Lake is associated with the Talent Irrigation District Credit: Julie Smitherman

Rogue Valley, Oregon Water Resources

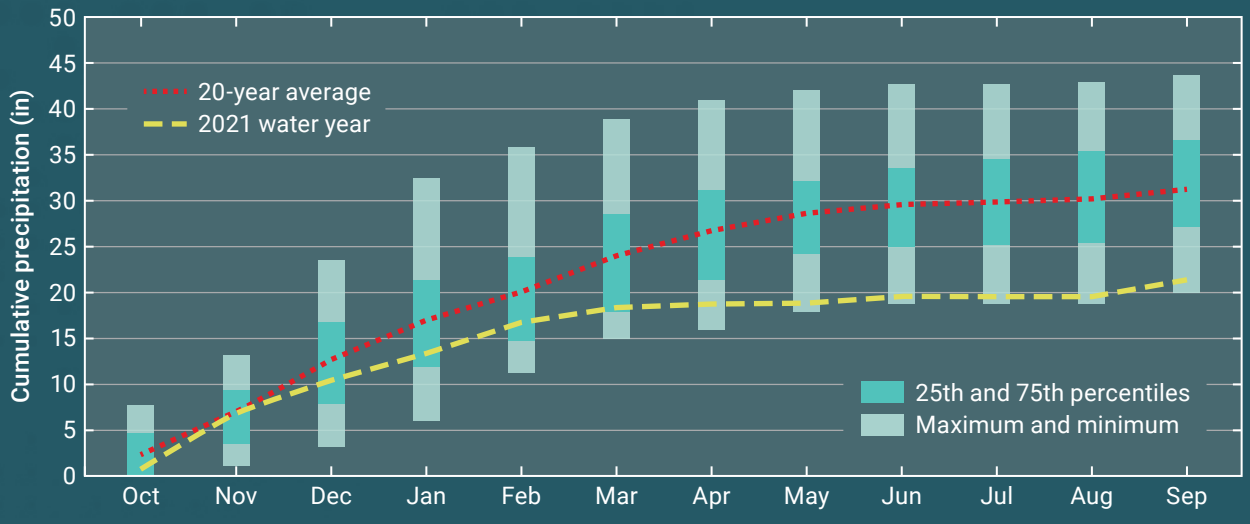
Drought conditions in water year 2021 and in previous years, caused by below-normal precipitation and snow accumulation, created challenges for water providers in southern Oregon. Medford Water, the largest municipal water provider in the area, serves water to approximately 140,000 customers across eight cities from their primary source, Big Butte Springs, and their secondary source, the Rogue River.

Streamflow values for Big Butte Springs throughout the year were considerably below average. Precipitation at Big Butte Springs from October 2020–May 2021 was about 70% of average, and snowpack on May 1 was about 52% of average. This led to spring flows at Big Butte Springs that were 20% less than average, and the lowest in the last 20 years.

Municipal supply was also restricted by record high demand earlier in the year. Flow limitations at Big Butte Springs required Medford Water to rely more heavily on the Rogue River. 2021 marked the earliest use of that secondary source, with the start-up of the Duff Water Treatment Plant on April 1.

Recognizing the growing concern over water supply in the Rogue Valley, Medford Water requested voluntary water reductions throughout the summer. Ultimately, Medford Water was able to supply sufficient water to meet customer demands thanks to a stable water supply and water conservation efforts.

Other water providers were not as fortunate. Some southern Oregon irrigation districts were highly impacted by the multiple-year drought, resulting in late irrigation start-ups, late rotations, and early shut-offs in mid-July through August 1, two months earlier than normal. In some cases, crops were not planted, yields were greatly reduced, or crop quality was poor, leaving many property owners looking for alternative water supplies.



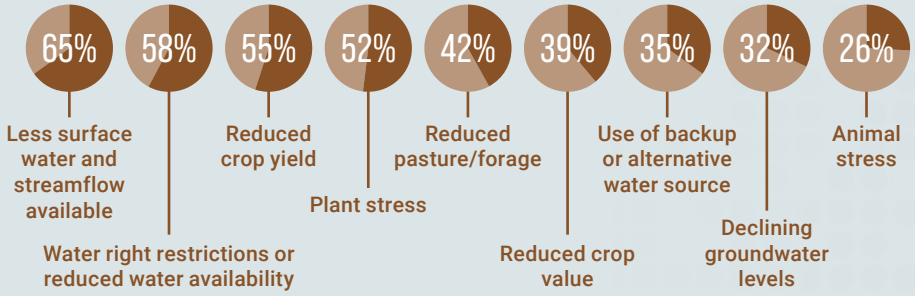
Cumulative precipitation at Big Butte Springs, Oregon for the 2021 water year (*yellow dashed line*) and the 20-year average (*red dotted line*). The dark blue bars represent the 25th and 75th percentiles and the light blue bars show the maximum and minimum cumulative precipitation in the 20-year record. Precipitation for the 2021 water year was less than previous water years, with only about 70% of the previous 20-year average. Source: Julie Smitherman, Medford Water.

Agriculture

Deschutes, Malheur, and Clackamas counties in Oregon and Yakima County in Washington had numerous impacts on agriculture due to abnormally dry conditions. Dry conditions in Oregon affected dryland and irrigated agriculture, as well as beef production through reduced forage and stressed cattle. Crop yields and values were reduced in Klamath and Deschutes counties, Oregon. Many respondents also reported reduced surface water availability and water right restrictions due to abnormally dry conditions. Reports of such impacts were prevalent throughout central and eastern Oregon into southern Washington. Thirty-one (31) survey respondents reported impacts on agriculture and all of these impacts were due to abnormally dry conditions.

AGRICULTURE IMPACTS SURVEY

Abnormally dry
31 responses

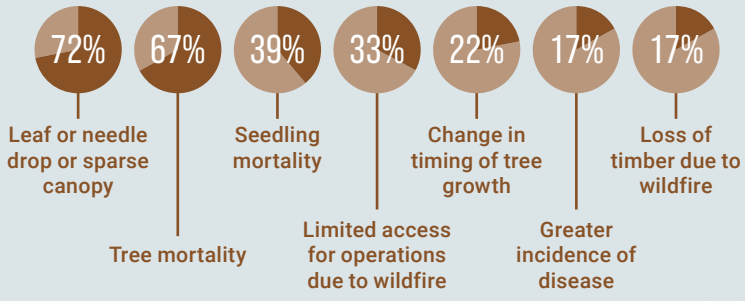


Forestry

Impacts on forestry were reported throughout Oregon and Washington, with specific impacts reported in Clackamas County in Oregon, and Okanogan and Skagit counties in Washington.

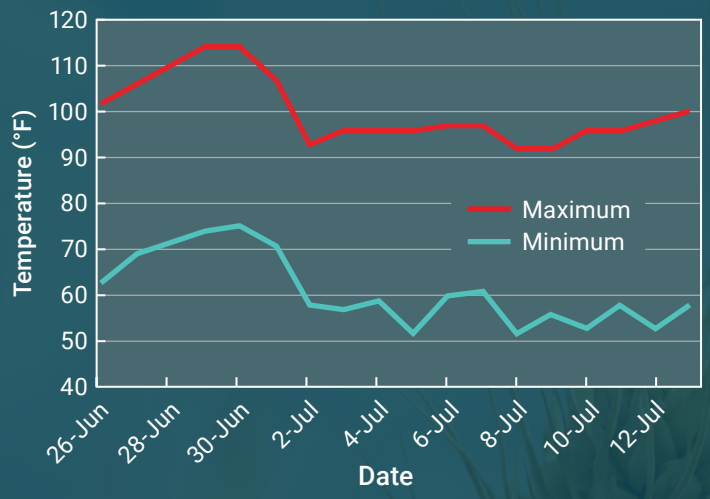
FORESTRY IMPACTS SURVEY

Abnormally dry
18 responses



Many of the impacts reported were related to the extreme heat event in June 2021. Nineteen (19) survey respondents reported impacts on forestry, 18 (95%) of which were due to abnormally dry conditions.

Dryland Wheat Impacts



Daily temperatures at Lind, Washington during the June and July 2021 heat wave. The daily maximum and minimum optima for wheat are 75˚F and 63˚F, respectively. The daily maximum and minimum temperatures at which wheat becomes heat stressed are 90˚F and 75˚F, respectively. The maximum temperatures were well above the temperatures at which heat stress occurs for wheat for this time period. Source: David Huggins, USDA.

Heat and drought stress led to a combined 40% reduction in winter and spring wheat yield for the PNW. Based on calculations from data compiled by the National Agricultural Statistics Service (NASS), the impact was most significant in southeast Washington and northern Idaho counties, where winter wheat yields (bushels/acre) were reduced by 46% and spring wheat yields were reduced by 52% for the 2021 calendar year from yields in 2020. The southeast Washington and northern Idaho yield reductions occurred over nearly 2.73 million acres of land planted in wheat, representing 83% of the wheatland in the PNW and a reduction of more than 98 million bushels from 2020.

The composition, weight, and quality of the wheat yield was also affected. The reduced wheat yield had a higher protein percentage (11.3% versus the 5-year average of 9.7%), lower test weight (59.3 lb/bu versus the 5-year average of 61.4 lb/bu), and overall quality (grade no. 2 rather than the usual grade, no. 1) (Idaho Wheat Commission, Oregon Wheat Commission, Washington Grain Commission, U.S. Wheat Associates, Wheat Marketing). Prices of wheat increased by over $2/bu from 2020 to 2021.

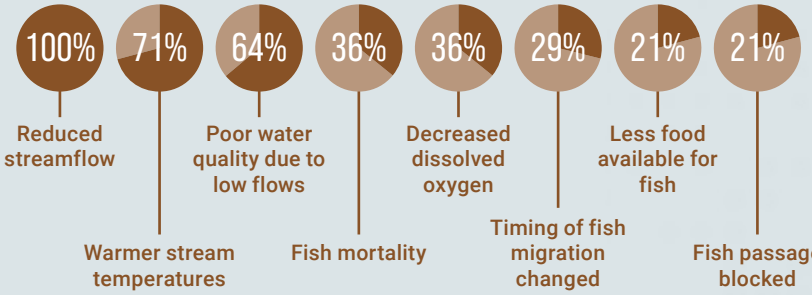
Conditions at the end of a given water year can affect the following year's crop because planting occurs in fall. Low soil water after annual fallow and a deficit of seed-zone water can inhibit the establishment and growth of wheat. High precipitation in some parts of the PNW during September–November 2021 aided in the establishment of winter wheat at the time of this writing. However, above-average winter precipitation is needed to promote soil water recharge and for wheat yield to return to normal.

Fisheries

Impacts on fisheries were reported for Oregon (statewide and in the upper Deschutes Basin), Washington (Yakima and Klickitat counties), and Idaho. Fourteen (14) survey respondents reported impacts on fisheries due to abnormally dry conditions.

FISHERIES IMPACTS SURVEY

Abnormally dry
14 responses

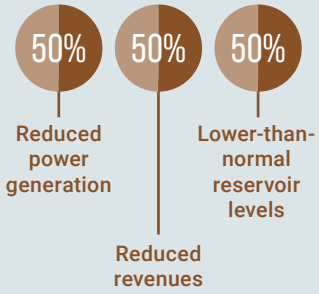


Hydropower

Primary impacts on hydropower associated with abnormally dry conditions were loss of hydropower generation due to lower streamflows across the PNW. Two respondents reported impacts on hydropower; both reported impacts due to abnormally dry conditions and one reported impacts due to abnormally wet conditions.

HYDROPOWER IMPACTS SURVEY

Abnormally dry
2 responses



CMOR on Drought Impacts

The main CMOR received 94 reports for the 2021 water year. Sixty of these reports referenced Oregon, especially western Oregon, although drought severity was worse in eastern Oregon during the 2021 water year. A large spike in reports occurred during late June and early to mid-July, which coincided with the major heat wave in the PNW.

Most of the main CMOR reports were associated with reduced crop and livestock production. Reports also identified impacts on public health, households, wildlife habitat, and municipal water supply, and impacts from wildfires. Observations in Malheur County and Baker County, Oregon, reflected the persistence of drought conditions through spring and summer, with severe impacts reported as early as April. The two reports shown below for Malheur County three months apart demonstrate the long lifetime and increasing severity of the drought.

> **"It is severely dry throughout all of Malheur County"** — 4/18/2021

> **"All of Malheur County is in an extreme drought."** — 7/15/2021

During the 2021 water year, the Oregon Department of Forestry developed a supplemental CMOR survey focused on forestry impacts in the US. Due to their *outreach efforts*, this survey had numerous reports (316 total) with the vast majority reported for locations in Oregon (293). Common impacts from these reports included discolored leaves, dead branch tips, dead trees, excess leaf/needle drop, and sparse canopy. Reports were steadily recorded throughout the summer of 2021, but spiked considerably on July 15 (20 reports), September 8 (35 reports), and September 9 (51 reports). Reports from the CMOR for these days were representative of many other forestry impacts reported through the summer of 2021, all of which implicated severe and ongoing drought conditions.

> **"Trees along the highway from Willapa Bay near Ilwaco, north to at least South Bend, WA were browned on many of the branch tips closest to the blacktop."** — 7/15/21 PACIFIC, WA

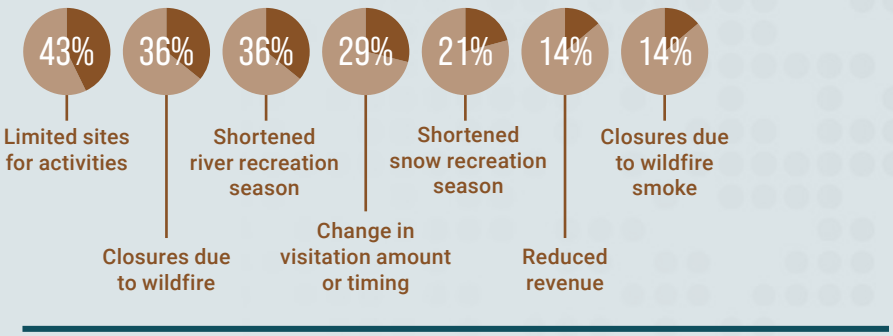
> **"The big leaf maples all around were hard hit by the heat wave and dry conditions. A lot of other landscaping has died, even with supplemental water, the heat was just too much for so many plants."** — 9/8/21 CLACKAMAS, OR

> **"Had to spend $2,000 to have more pipe added to well so I wouldn't run out of water. I live in [the] country and can see dying trees [that] I believe are [from] lack of water."** — 9/9/21 LINN, OR

Recreation

Impacts on recreation were reported for areas throughout Oregon, with many counties in north and south central Oregon highlighted. Impacts were also reported throughout Washington, including Klickitat and King counties. Fourteen respondents reported impacts on recreation. Of these, all fourteen (100%) reported impacts associated with abnormally dry conditions and 1 (7%) reported impacts associated with abnormally wet conditions.

A reduction in the number of sites for recreation activities was the most commonly reported impact. Other commonly reported impacts included a shortened river recreation season and closures of recreational lands due to wildfire and wildfire smoke. Respondents highlighted that water levels along the Willamette reservoir system, Upper Deschutes River, and Owyhee River were so low as to limit whitewater rafting.



Drought Impacts Discussed in the Idaho Water Supply Meeting

The exceptional spring drought in Idaho's central mountains resulted in significant shortages in surface water deliveries in the Big Wood, Little Wood, Big Lost, and Little Lost River basins. Water year 2021 was the second consecutive year of drought in these basins. Under normal conditions, water deliveries typically start on May 1 and end around September 15. In 2021, storage deliveries to members of the Big Wood Canal Company ceased on June 10, when Magic Reservoir ran out of storage water. As reported in the *Idaho Mountain Express* on June 23, "…growers across the state are already reporting devastating crop losses. That's especially true in south-central Idaho, where farmers and ranchers have been left reeling after Magic Reservoir was shut on June 10, just 26 days after the headgates opened. The dam usually isn't shut off until mid-to-late September; last year it shut off Sept. 1."

According to the Natural Resources Conservation Service (NRCS), inflow into Magic Reservoir during the water year was the lowest in the 103 record of reservoir inflows. Inflows in Mackay Reservoir were the second lowest in the 105 years of observed streamflow. Mackay Dam ran out of storage water on July 20. Preliminary streamflow data provided by the NRCS also indicate that new records in minimum water year streamflow volumes were set for the Little Wood River above High Five Creek (57 year period of record) and the Little Lost River below Wet Creek near Howe (63 year period of record). Similarly, the Salmon River Canal Company south of Twin Falls, Idaho, which diverts water from Salmon Falls Creek Dam near the Idaho-Nevada border, ceased deliveries on August 22.

In the larger, federally operated reservoir systems of the Boise, Snake, and Owyhee basins, lower than expected runoff and warmer than normal temperatures resulted in higher than expected demand for storage water. All three reservoir systems ended the season with minimal carryover storage for water year 2022.

The rainfed agricultural region in northern Idaho also was heavily impacted by drought. National Agricultural Statistics Service (NASS) estimates indicate that chickpea yields in Idaho dropped by 45%, lentils by 25%, and peas by 21%. An experiment on the timing of planting on crop yield found that winter peas yielded 380 lb per acre (normally 3,000 lb/acre), but spring peas failed because of heat stress during the flowering stage (Kurtis Schoder, University of Idaho, personal communication).

Spring wheat yield reductions were most severe in Lewis and Idaho Counties, where they dropped by 63% and 61%, respectively, in calendar year 2021 compared to 2020, based on calculations from NASS data. University of Idaho Extension reported that soft winter wheat yields in the towns of Genesee, Nez Perce, and Tammany dropped by 47%, 60%, and 45%, respectively. In some locations in northern Idaho, wheat farmers described losing entire fields of wheat. While a rise in crop prices helped offset some of the impact due to reduced yield, poor quality product reduced prices in many cases. For example, soft winter wheat grown without adequate soil moisture produces kernels with higher protein content. The Asian market for winter wheat prefers low-protein wheat. Farmers with high-protein wheat could not sell at the higher than normal prices being offered for low-protein wheat.

June 2021 Heat Wave Impacts

Impacts from the June 2021 heat wave were widespread, and in some ways, difficult to differentiate from drought impacts. Clearly tied to the heat wave were heat-related hospitalizations and deaths. According to the *Washington State Department of Health*, there were 100 heat-related deaths in Washington from June 26 to July 2. A preliminary report from the *Multnomah County Health Department,* which includes Portland, counted 54 hyperthermia deaths in Multnomah County alone. A rapid analysis from the *Centers for Disease Control and Prevention (CDC)* found that the number of heat-related emergency room visits in Oregon, Idaho, Washington, and Alaska was 69 times higher than during the same days in 2019 (Schramm et al. 2021). Adverse health outcomes from heat are typically underestimated; research on the broad health impacts and excess deaths from this record-breaking heat event is ongoing.

Other widespread impacts were reported in the media, such as sunburn on berry, cherry, and apple crops, roads buckling from the heat, and high mortality of intertidal shellfish and coastal invertebrate species.

The Annual Pacific Northwest Water Impacts survey asked respondents to elaborate on impacts of the June 2021 heat wave. Reported impacts included rapid mountain snow loss, plant damage, tree seedling mortality, and fish die-offs due to high stream temperatures. No sector seemingly was spared from impacts due to the heat wave. Respondents reported impacts on agriculture, forestry, drinking water, fisheries, and recreation. Additional impacts on infrastructure included pavement damage, weather station outages, and logging operation shutdowns due to increased fire hazard. Several utilities reported record water consumption during the heat wave.

The 2021 Pacific Northwest heat wave buckled pavement on Interstate 5 in Shoreline, Washington, requiring emergency repairs. Credit: SounderBruce

5 INDIVIDUAL, ORGANIZATION, & STATE-LEVEL RESPONSES

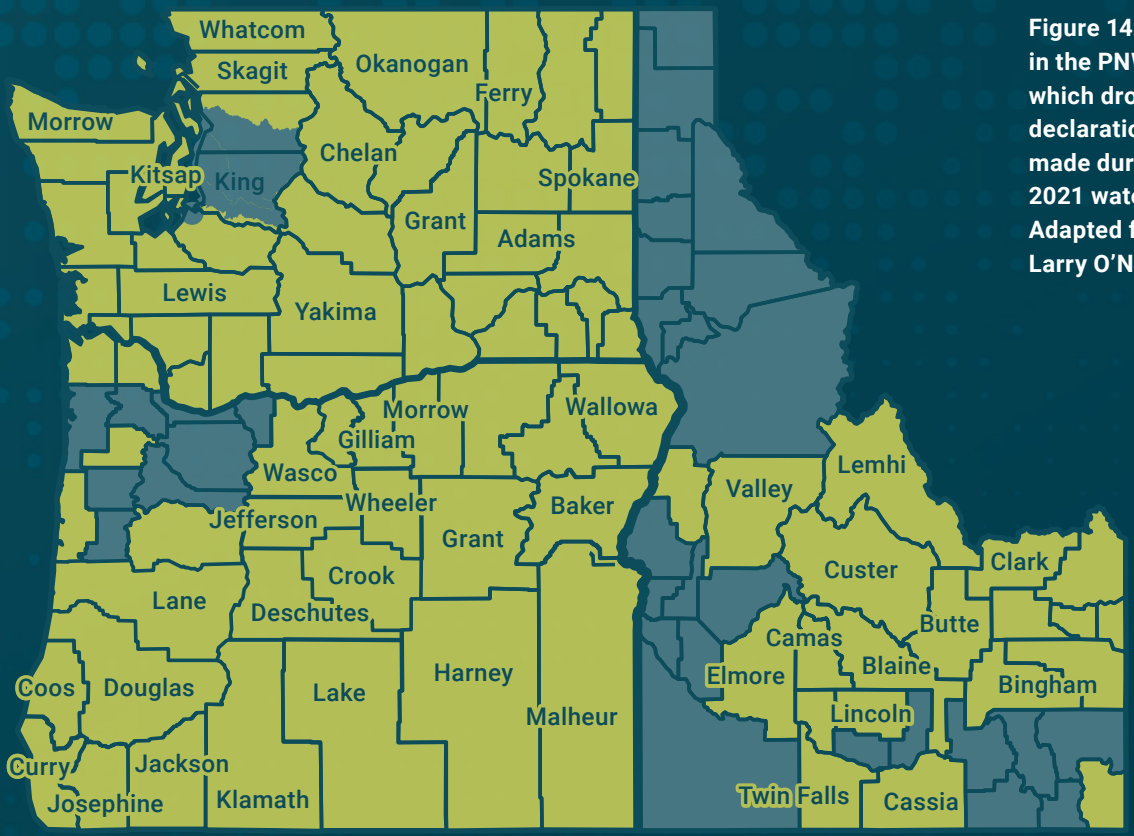


Figure 14: Counties in the PNW for which drought declarations were made during the 2021 water year. Adapted from Larry O'Neill.

Drought Declarations

Drought declarations (*Figure 14, previous page*) were made at varying times of the year for each state.

Oregon

In Oregon, 26 counties received state drought declarations through Executive Orders signed by Governor Brown. The first drought-related Executive Order was issued for Klamath County on March 31, while the final drought declaration for Curry County was issued on November 17, 2021. In drought-affected counties a suite of water rights tools are made available, including temporary transfers, instream leases, and emergency water use permits, that are intended to provide short-term solutions to water supply challenges.

Idaho

In Idaho, Governor Little approved 20 county drought declarations, starting in Butte and Custer counties on April 21 and ending with Adams County on August 4. In Idaho a drought declaration is an administrative tool to ease the temporary transfer of water rights. These drought declarations are aimed at irrigated agriculture, and are not necessarily an indication of drought in other sectors of the economy, including industrial, municipal, and rain-fed or dryland agriculture.

Washington

The Washington State Department of Ecology, with Governor Inslee's approval, issued the state's first-ever Drought Advisory for all counties east of the Cascade Mountain Divide, southwest Washington, and the coast on May 27. Drought advisories are meant to promote early awareness of drought conditions that may be developing. These advisories are a new capability of the Department following passage of drought preparedness and response legislation in March 2020. On July 14, the Department of Ecology and Governor Inslee declared a drought emergency for the entire state except the basins that supply water to Everett, Seattle, and Tacoma. Emergency funding became available on July 28 to alleviate hardship for farms, fishes, and public health. The Washington State Joint Legislative Committee on Water Supply during Drought convened on August 16, September 29 and November 30 to hear testimony regarding water supply conditions, drought impacts, and recommendations for changes to Washington's drought response and planning strategies.

Other State Responses

In addition to drought declarations, emergency proclamations were made in response to the weather and climate conditions.

Oregon

In Oregon, the water year began with an executive order to aid ongoing recovery from the wildfires at the end of water year 2020. On February 13, a state of emergency due to severe winter storms causing damage to transportation infrastructure and power outages was issued for Benton, Clackamas, Hood River, Linn, Marion, Multnomah, Polk, Washington, and Yamhill Counties. The Oregon Department of Forestry (ODF) declared the beginning of "Fire Season" for The Dalles and Prineville units of ODF's Central Oregon District on May 15, which was the earliest declaration in the district in more than forty years. On June 29, a state of emergency was declared to prepare state resources and the Oregon National Guard for the imminent threat of wildfires for the entire state of Oregon. Nine emergencies for individual fires were issued throughout the summer and burn bans were in effect

for much of the state beginning in early June and extending throughout the summer. On July 7, state agencies were directed to conserve water through a number of different measures, including forgoing landscaping projects requiring irrigation at state buildings and grounds. Finally, on both July 29 and August 10, state of emergencies were issued due to high temperatures threatening life, health, and infrastructure, first for 23 counties and then statewide.

Idaho
Governor Little issued an emergency declaration for wildfire on July 9 to mobilize the Idaho National Guard to assist firefighting efforts in northern Idaho. The declaration followed the first request by the Idaho Department of Lands for that area of the state. Shortly thereafter, most of Idaho entered Stage 1 or Stage 2 fire restrictions, which limited outdoor fires, operation of motorized off-road vehicles, and use of power tools with combustion engines for certain activities, among other restrictions, depending on the Stage.

Washington
On July 6, Washington's Governor Inslee declared a wildfire state of emergency and banned most outdoor burning statewide through the remainder of the water year. On July 16, Governor Inslee issued a state of emergency for 18 counties (and added one more county on September 1) due to transportation infrastructure damage from the June 2021 heat wave. In addition, two proclamations were made restricting summer use of state recreation lands due to the extremely dry conditions and high fire danger. The first, issued on July 20 and effective through October 1, closed Washington Department of Fish and Wildlife recreation lands in eastern Washington to overnight use. On July 23, the Washington Department of Natural Resources closed state-managed lands in eastern Washington, including conservation areas, trails, campgrounds, and recreational sites, through September 16.

At the request of the Washington State Legislature, in September 2021 the Washington Department of Health sent a survey to 4,831 water system managers across the state to better understand the drought response and identify needs to improve future infrastructure resilience. Of the 108 respondents, 57 requested voluntary water conservation and 3 requested mandatory conservation (47 did not request conservation and 1 did not respond). Several system managers noted that their billing structures encourage conservation. Nine respondents reported that they need to deepen their wells, and an additional 9 reported that they need new wells or an intertie. Other infrastructure needs to improve drought resilience included new water mains, well motors, pumps, and larger pressure tanks, in addition to increased reservoir storage.

Organizational or Individual Responses

The Annual Pacific Northwest Water Year Impacts Survey asked respondents if they modified operations in anticipation of or in response to abnormally dry or abnormally wet conditions during the water year.

Sector-Specific Water Year Changes
Respondents in all sectors indicated that they changed operations in response to abnormally dry conditions (responses to abnormally wet conditions were omitted because there were so few). Eighty-three percent of respondents from the agriculture sector, 78% of respondents from the drinking

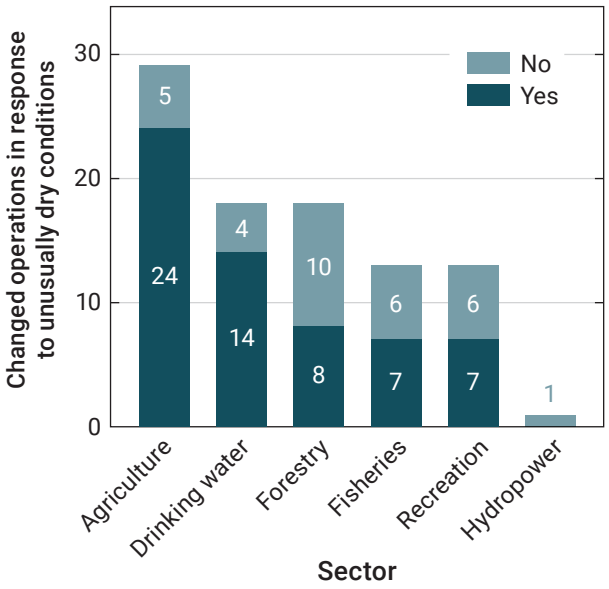


Figure 15: Annual PNW Water Year Impacts Survey responses to whether operations were changed in response to dry conditions for multiple sectors.

water sector, and about 50% of respondents from other sectors indicated that they changed operations (*Figure 15*).

Drinking Water:
Common operational changes in response to abnormally dry conditions included voluntary conservation measures, increased monitoring of supply, and use of secondary groundwater systems to augment primary surface-water sources. Fourteen respondents in the drinking water sector reported a change in operations as a result of abnormally dry conditions.

Agriculture:
Shifts in operations in response to abnormally dry conditions included changes to cattle feeding routines, watering crops more or less frequently, leaving crops unharvested, and supplemental pumping of water to combat higher evaporation rates due to heat stress. Twenty-four respondents in the agriculture sector reported a change in operation as a result of abnormally dry conditions.

Recreation:
Responses to the abnormally dry conditions included closing recreation areas due to wildfire risk and reducing the number of visitors due to reduced groundwater supply. Seven respondents from the recreation sector reported a change in operations as a result of abnormally dry conditions.

Changes in Operations Based on Forecast Conditions
Eighty-five percent of water providers and natural resource managers who responded to the Annual Pacific Northwest Water Year Impacts Survey indicated that they use seasonal forecasts throughout the year and take anticipatory action on the basis of the forecasts. The most commonly used forecast is the *NOAA Climate Prediction Center Seasonal Outlook*. In addition to monitoring forecasts more closely as drought developed and increasing their efforts to provide forecasts to users, respondents took the following actions in anticipation of abnormally dry conditions.

- Increasing outreach to local and tribal governments and coordinating with state agencies to prepare for and track limited water supply
- Requesting voluntary reduction of water consumption
- Planting crops as early as possible
- Shipping calves to other ranchers a month early
- Purchasing more alfalfa hay than usual
- Clearing brush and trees near roads
- Storing rainwater

Climate Smart Agriculture Project

Nez Perce Tribe Water Resources Division No-Till Project (credit: Nez Perce Tribe Water Resources Division).

The Nez Perce Tribe in northeastern Oregon, southeastern Washington, and northern Idaho has been working to improve Tribal resilience to drought and to climate change impacts such as increased wildfire risk, drier soils, and increased stream temperatures that place stress on salmon. The exceptional drought in 2021 allowed the Nez Perce Tribe to test the Climate Smart Agriculture Project.

The project aims to reduce barriers to adopting regenerative and conservation agriculture practices to adapt to changing climate conditions. The primary focus is to reduce barriers for the farmers on the Reservation transitioning to regenerative agriculture practices. The Tribe has been highly successful with an 80% adoption rate of these practices on the Reservation. The Tribe hopes to use the same model to help build economic and ecological resilience by working with local farmers to reduce barriers to adoption of practices that improve soil health such as cover cropping and other regenerative techniques. There are already farmers on the

Reservation and in the region that are early adopters of innovative technology and have shown that these techniques can make a difference.

For example, the Hasselstrom Farm transitioned to no-till practices long ago, which promotes soil carbon sequestration and limits soil moisture evaporation (Derpsch et al., 2010). In 2021, they added a carbon capture technology called Bio-Agtive (*https://bioagtive.com/*). Despite the historic drought that created incredible hardships and losses for farmers in the region, the Hasselstrom's experienced a better harvest. Their crop yields were significantly greater than those of neighboring farms, with 23 bushels of garbanzo beans compared to the neighboring 10 bushels. The Hasselstrom Farm's wheat grain protein percentage was below 10.5%, which was close to the 5-year PNW average of 9.7%. The Climate Smart Agriculture Project intends to reward farmers like the Hasselstroms who have taken risks and have proved that techniques like cover cropping, grazing management, carbon capture and injection technology work, and to help other farmers adopt similar practices that are suitable for them.

Testing new equipment on hay at Hasselstrom Farm (credit: Hasselstrom Farm Facebook).

6 FORECAST VERIFICATION

La Niña was predicted, and emerged, in the tropical equatorial Pacific Ocean during the winter of 2020–2021. Typically, La Niña conditions are associated with colder and wetter than normal winters in the PNW, with above normal snowpack by April 1, although there is some variability in the strength of that relationship throughout the PNW.

Empirical relationships based on past La Niña events along with other observed properties of the global system that have been found to provide predictability, in combination with projections from global atmosphere–ocean climate models, were used in producing the seasonal weather predictions made by NOAA's Climate Prediction Center (CPC) and other centers for long-term forecasts.

Over 75% of the survey respondents indicated their reliance on the CPC's seasonal forecasts.

The seasonal forecasts made during the 2021 water year were consistent with those typical La Niña relationships. Here, we qualitatively examine the accuracy of two example seasonal forecasts, one for November 2020 through January 2021 (NDJ) and one for April through June 2021 (AMJ).

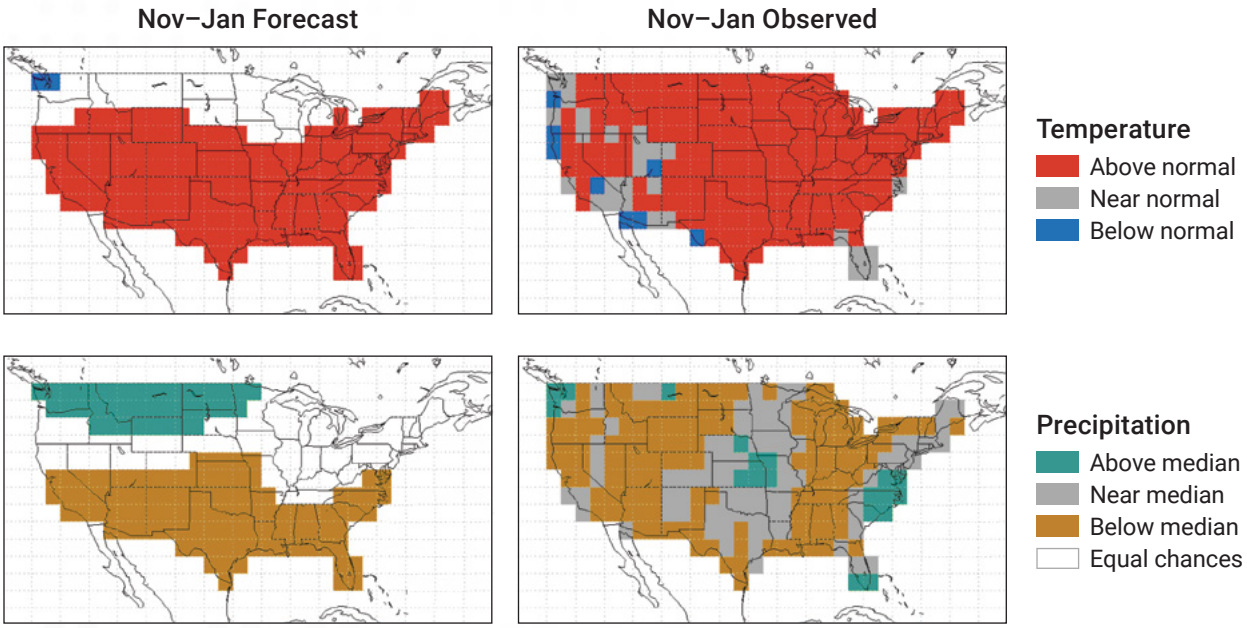


Figure 16: Categorical temperature and precipitation forecasts for November 2020–January 2021 (NDJ), issued in October 2020, compared to observations for those months (*Climate Prediction Center*).

November 2020–January 2021 Forecast and Verification

The CPC temperature forecast for NDJ issued in October 2020 (*Figure 16*) favored higher odds of below-normal temperatures for northwest Washington and higher odds of above-normal temperatures for southern Oregon and southern Idaho. The remaining areas had equal chances of below, near-normal, or above-normal temperatures, which as standard in the CPC forecasts means that there is an equal 33.3% chance of each outcome.

Temperatures in parts of southern Idaho and southern Oregon were above normal as forecast. However, much of the region, including eastern Washington and parts of western Oregon, had above normal temperatures that were not in the forecast. Coastal areas were forecasted either accurately or nearly so. For example, the odds indicated colder than normal temperatures in northwestern Washington, but realized temperatures were near-normal. Coastal southwestern Oregon was the exception, however, as the forecast was for above normal temperatures but below-normal temperatures were observed.

NOV–JAN 2021 FORECAST

As a whole, the region was warmer and drier than the forecast indicated.

The CPC NDJ precipitation forecast indicated above-median precipitation for most of Washington and Idaho, and equal chances of below, equal to, or above-median precipitation for most of Oregon. Precipitation in western Washington was above median as forecast, but precipitation elsewhere in Washington and across Idaho was near median or below median, representing a missed forecast. Oregon's precipitation also was generally below median.

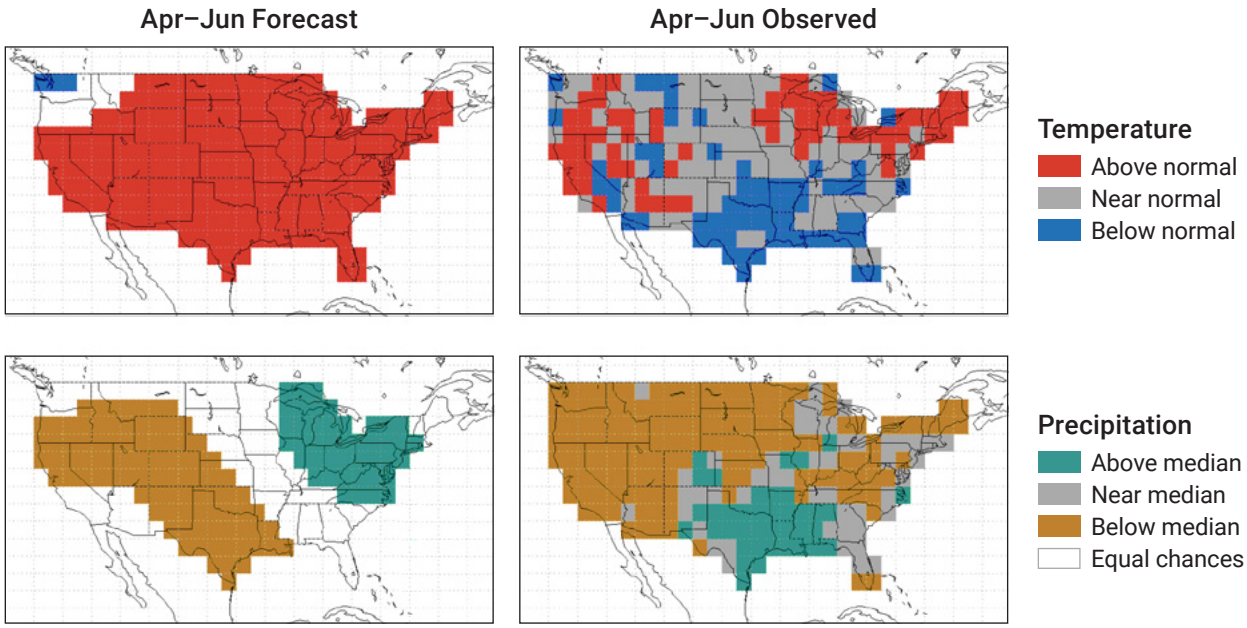


Figure 17: Categorical temperature and precipitation forecasts for April–June 2021, issued in March 2021, compared to observations for that period (*Climate Prediction Center*).

April–June 2021 Forecast and Verification

The CPC AMJ temperature forecast issued in March 2021 (*Figure 17*) included higher odds of below-normal temperatures for northern Washington, higher odds of above-normal temperatures for southern Oregon and southern Idaho, and equal odds of either outcome elsewhere in the PNW.

The CPC temperature forecast represented observed conditions fairly well, as temperatures everywhere except the coast were near-normal or above normal. The below-normal temperatures observed on the Oregon coast were not forecast and the below-normal temperatures in northern Washington weren't as widespread as forecast.

The CPC AMJ precipitation forecast of below-median precipitation throughout most of Oregon and Idaho was accurate, as AMJ observations were below median for the entire region. The below median precipitation in Washington and northern Idaho was not explicitly predicted in the AMJ outlook as equal chances of below, equal to, or above median precipitation was forecast for AMJ.

APR–JUN 2021 FORECAST

The forecast was mostly accurate throughout the PNW for both temperature and precipitation, though the below median AMJ precipitation was not in the forecast for Washington or northern Idaho.

These forecast verifications are merely recent examples, and should not be generalized. They do illustrate that observed seasonal temperature and precipitation anomalies tend to be patchier than the broad-scale distributions that are forecast. Although not necessarily the case during the 2020–2021 La Niña, the skill of the seasonal forecasts is generally greater during winter, when the effects of the El Niño–Southern Oscillation are fairly predictable, than during other seasons. For the 2021 water year, the April–June outlook appeared to be more skillful than the November–January outlook.

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2021

PACIFIC NORTHWEST WATER YEAR

IMPACTS ASSESSMENT

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