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Climate Change Effects and Adaptation Options for Riparian Areas and Wetlands in the Northwest

Authors: Jessica E. Halofsky (USDA Northwest Climate Hub), Steven M. Wondzell (U.S. Forest Service, Pacific Northwest Research Station), and Janelle Christensen (USDA Northwest Climate Hub)

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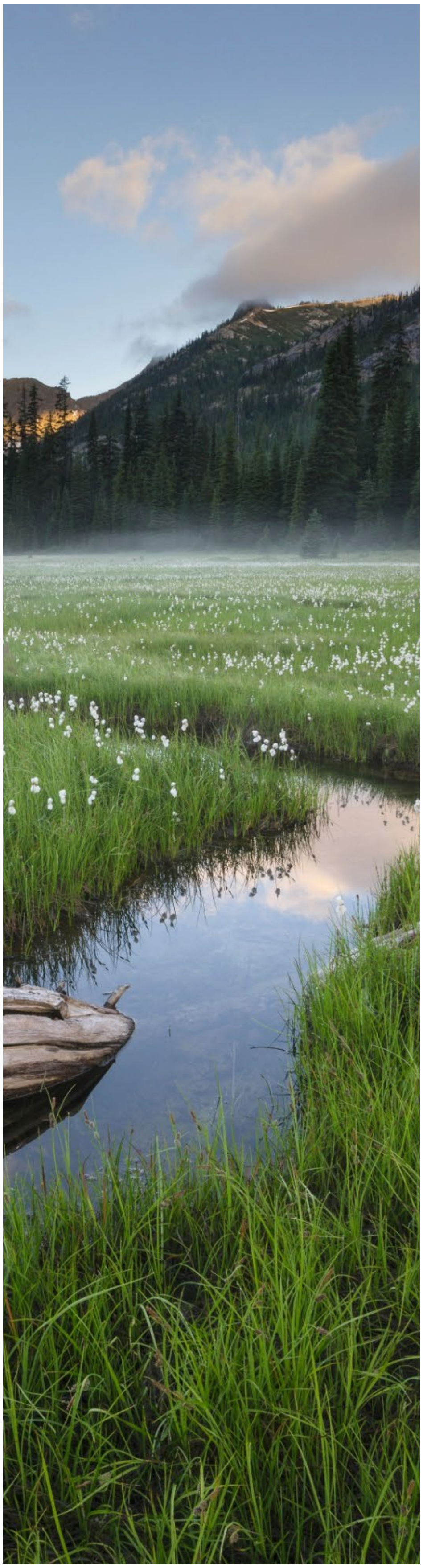

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Cover photo: Deschutes River in the Deschutes National Forest. Photo by US Forest Service Pacific Northwest Region.

Table of Contents photo: Wetland in Washington, North Cascades. Credit: Danita Delimont

Summary

Climatic changes

- Temperatures in the Northwest (Oregon, Washington, and Idaho) are projected to increase by 5.5 to 9.5 °F by the end of the century.
- Climate model projections suggest there will be slight increases in average annual precipitation in the future, with most increases occurring in winter.
- Intense rainfall events will likely occur more frequently in winter.
- With increasing temperatures, more precipitation will fall as rain rather than snow, and snowpack and persistence of snow will decline, especially at middle and lower elevations.

Effects of climate change on streamflow and riparian areas

- Peak stream flows will increase in frequency and magnitude, particularly in watersheds that shift from snow, and mixed rain and snow, to rain dominated. Thus, flood damage to riparian vegetation will likely increase in winter and spring.
- Low stream flows will likely decrease in summer. Decreases in low flows will most affect small intermittent streams, where reductions in water availability will likely affect riparian vegetation.
- Along large streams with wide floodplains, the effects of reduced stream flows on riparian zones will likely differ among floodplain systems because of the complex interactions between stream flow and the hydrology of floodplain aquifers. However, shifts in timing of stream flows and a longer summer draw-down period may limit riparian vegetation access to water and result in water stress. If water stress is severe and prolonged, mortality of riparian and wetland plants will likely occur, leading to long-term shifts in species composition.
- Along many streams, anthropogenic changes resulting from historical land use, including channel incision, channel modifications, water diversions, dams, and other flow alterations increased vulnerability of riparian vegetation to summer drying.

Effects of climate change on wetlands

- Wetlands will also be sensitive to increased temperatures and evapotranspiration, lower snowpack, lower summer low stream flows, and a longer summer draw-down period.
- Riverine wetlands may be affected by reduced minimum water levels, which could lead to water stress in wetland plants.
- Snow-dependent wetlands at higher elevations will likely be sensitive to climatic changes; some ephemeral montane wetlands may disappear, and some perennial wetlands, or those that historically dried in late summer during dry years, may become ephemeral.
- Some groundwater-dependent wetlands may decrease in size or dry out in summer under changing climate. However, large regional aquifers may be buffered from direct impacts

from changing recharge, making those wetlands less likely to be impacted by climate change.

- Wetland plant species are very sensitive to changes in water table elevation, and compositional shifts will likely occur where water tables decline.

Climate adaptation options for riparian areas and wetlands

- Avoiding removal of riparian vegetation and planting trees in riparian areas will help to increase shade over streams and minimize stream temperature increases, which will benefit aquatic organisms.
- In fire-prone ecosystems (e.g., dry forests east of the Cascade Mountains), reducing fuels in adjacent upland vegetation, and in some cases riparian areas, can help reduce the risk of high-severity fire across the treated landscapes, including riparian areas and wetlands.
- Implementing stream restoration techniques can improve stream channel stability and complexity, slow water movement, improve aquatic habitat, and increase resilience to both low and high flows.
- Reconnecting stream channels to floodplains and maintaining native plant species in riparian areas and wetlands can help to reduce flooding intensity.
- Reducing existing, non-climatic stressors in riparian areas and wetlands is likely to help them better withstand the effects of climate change. For example, managing use numbers and duration of use for both livestock and recreationists can help to minimize negative effects on riparian areas and wetlands.

1. Background

Climate change is likely to have significant effects on riparian areas and wetlands in the Northwest through warming, changes in snow and streamflow, and increasing length and severity of droughts. However, the services provided by these ecosystems will become even more important in the future with warming and changes in water availability. The objective of this guide is to review the potential effects of climate change on riparian areas and wetlands, and to explore potential adaptation options to reduce the negative effects of climate change on these critical ecosystems.

1.1. Riparian areas

Riparian areas, or riparian zones, are the areas adjacent to rivers, streams, lakes, and ponds. The Natural Resources Conservation Service (NRCS; NRCS 2010) defines riparian areas as "ecosystems that occur along watercourses and water bodies. They are distinctly different from the surrounding lands because of unique soil and vegetation characteristics that are strongly influenced by free or unbound water in the soil. Riparian ecosystems occupy the transitional area between the terrestrial and aquatic ecosystems." These areas have many benefits for humans and wildlife (Figure 1). Benefits and services provided by riparian areas include:

- Controlling nonpoint source pollution by filtering nutrients and pollutants
- Trapping sediment before and after it enters waterways
- Providing recreation and scenic values
- Supplying food, cover, habitat, and water for fish, wildlife, and pollinators
- Serving as wildlife migration routes
- Providing forage for livestock
- Growing dense vegetation that stabilizes streambanks and decreases erosion
- Reducing floodwater velocity, potentially reducing downstream flood peaks
- Supporting alluvial aquifers and extensive stream-groundwater exchange and shallow depths to the water table that supports high plant productivity, especially in drier regions
- Providing tall woody vegetation that shades streams and lowers or maintains water temperatures, as well as increasing carbon storage in plant biomass and riparian soils.

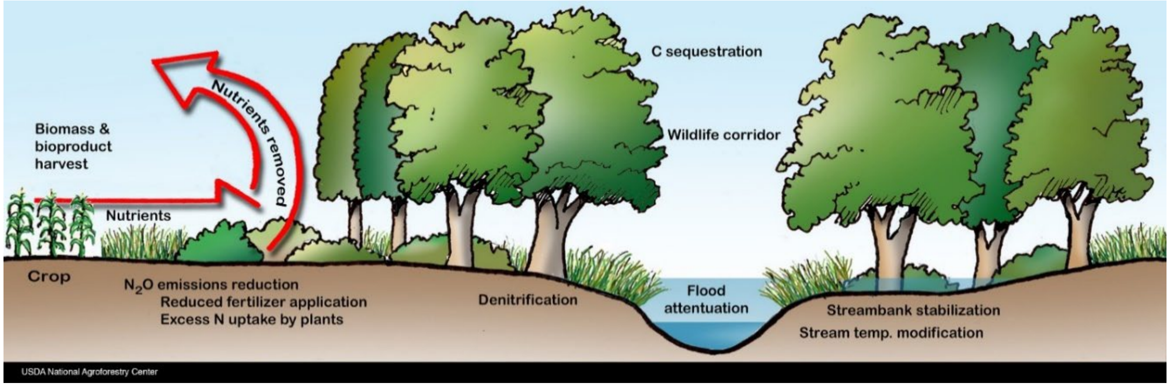

Figure 1 Image of a riparian area and some of the benefits riparian areas provide.
Credit: USDA National Agroforestry Center.

Vegetation composition in riparian areas in the Northwest varies by geographic region, stream size, and location. On many small streams (1st- or 2nd-order) with narrow valley floors in forested regions of the Northwest, the riparian forest canopy resembles the adjacent upland forest and is thus dominated by conifer species (e.g., Douglas-fir, grand fir, Engelmann spruce, and lodgepole pine). Along large streams, deciduous hardwood species (e.g., cottonwood, aspen, alders, willows, maples) become an increasingly important component of riparian vegetation and dominate many low-gradient reaches. Finally, in drier areas east of the Cascade Mountains, riparian areas are often dominated by shrubs (e.g., alders, currants, and common snowberry). There are also riparian areas dominated by herbaceous species, particularly in meadows at high elevations and in many riparian wetlands.

The condition of riparian areas has been affected by historical and current land uses and activities, including mining, forest harvest, road building, livestock grazing, beaver removal, conversion of floodplains to agriculture, and channel straightening. These activities can result in loss of stream-floodplain connectivity, bank erosion, and in some locations, channel entrenchment, along with reduced vegetation cover and shifted riparian species composition. Disturbed riparian zones are often open to invasion by non-native plant species. In drier areas east of the Cascade Mountains, many riparian areas previously dominated by woody native shrubs are now dominated by invasive grasses and forbs, and many previously wet meadows have been drained and planted to European pasture grasses for livestock forage. At lower elevations in western Oregon, Himalayan blackberry and Japanese knotweed are often problematic exotic invasives. Where present, these invasive species often outcompete native riparian species, leading to shifts in species composition and vegetation structure and function (e.g., the ability of plant roots to stabilize the streambank). In some cases, native species can respond in ways similar to exotic invasives, dominating riparian vegetation after disturbance (e.g., native salmon berry in Oregon’s Coast Range). The condition of riparian areas, as affected by historical land uses, is likely to affect their response to climate-related stressors. For example, extensive livestock grazing in a riparian area may hinder the ability of the vegetation community to withstand climate-related stressors such as drought.

1.2. Freshwater wetlands

Freshwater wetlands are often considered unique, and although they are often associated with riparian zones, they are commonly treated (or managed) independently of riparian zones. The 1985 Food Security Act wetland conservation provisions defined wetlands as land that:

- Has a predominance of hydric soils
- Is inundated or saturated by surface or groundwater at a frequency and duration sufficient to support a prevalence of hydrophytic vegetation typically adapted for life in saturated soil conditions
- Under normal circumstances does support a prevalence of such vegetation.

Similar to riparian areas, wetlands provide crucial ecosystem services (Figure 2), including:

- Providing protection from floods
- Improving water quality by processing excess nutrients such as nitrogen

- Reducing erosion
- Providing habitat for many species, including many endangered species
- Capturing and storing carbon
- Providing products such as shellfish or cranberries that benefit the economy
- Contributing to local and regional biodiversity

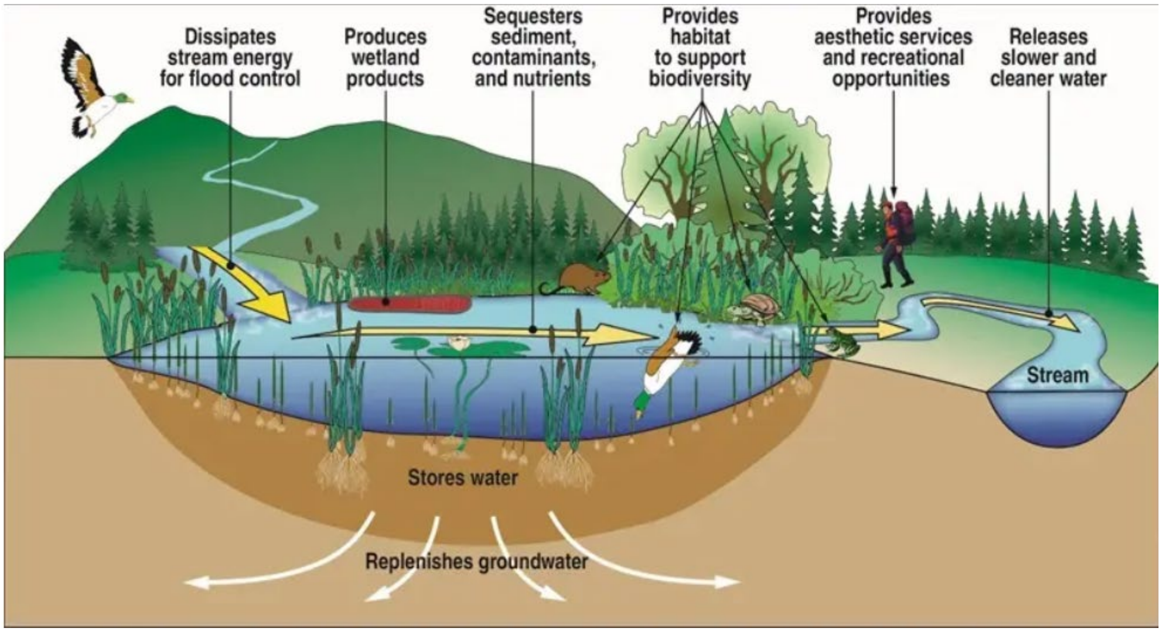

Figure 2. Wetlands provide many benefits. Figure credit: Ducks unlimited

Many wetlands have been degraded by human actions such as livestock grazing, groundwater withdrawal, building of drainage ditches or canals for agriculture, filling wetlands for development, and building roads, dikes, or levees that prevent natural water flows. Addressing effects of past and current land uses will help ensure that wetlands continue to provide valued ecosystem services in a warming climate.

2. Effects of climate change on streamflow and disturbance in the Northwest

Climate change in the Northwest will affect hydrological processes, especially the timing and amounts of streamflow, and these changes are likely to influence riparian areas and wetlands. First, climate change will affect the type of precipitation. Temperature is a critical control, determining where precipitation falls as snow or rain. Climate projections suggest that air temperatures in the Northwest will increase by 5.5 to 9.5 °F by the end of the century (Vose et al. 2017). Thus, many locations that currently receive snow during the winter will become rain dominated, or mid-winter thaws will become more common. Further, warmer temperatures also mean that where snowpacks are persistent over the winter, they will melt sooner in the spring. Snowpack, commonly measured as April 1 snow water equivalent (SWE), has decreased since the mid-20th century (Figure 3), and declines are projected to continue with warming. The largest declines in snowpack in the Pacific Northwest are expected at mid-elevation and wetter locations (Luce et al. 2014).

Changes in air temperatures and accompanying changes in snow accumulation will have predictable effects on streamflow. Catchments that are currently snow dominated, with spring and early summer peak flows due to snow melt, may experience more rain-on-snow peak flows during the winter or earlier snowmelt peaks in the spring. Earlier runoff and reduced snowpack volumes, and longer warmer summers, will combine to reduce late summer low flows (Safeeq et al. 2013). Summer streamflow is projected to decrease by as much as 50% in some parts of the region by 2040 (Figure 4). Overall, more headwater streams are likely to go dry during the summer (Ward et al. 2020), summer low flows will likely be reduced throughout the remainder of the stream network, and reservoir managers may face increasing uncertainty for refilling reservoirs in the spring (Fayaz et al. 2020).

Both the timing and amount of precipitation may also be affected by climate change. However, projections of future precipitation trends in the Pacific Northwest are more uncertain than those for temperature. Many global climate models project slight increases in average annual precipitation, with most increases occurring in the winter. Climate models also project more extreme precipitation events (such as atmospheric rivers), with longer periods without precipitation (Easterling et al. 2017). Extreme hydrologic events (e.g., those currently rated as having 100-year recurrence intervals) are projected to become more frequent with future increases in temperature, and potentially in amount and intensity of precipitation, in the winter months (Hamlet et al. 2013). For example, for southwest Washington, analyses indicate that the number of days with high streamflows in the winter could increase 20 to 45 percent, and the magnitude of peak flows could increase 10 to 23 percent (Safeeq et al. 2015).

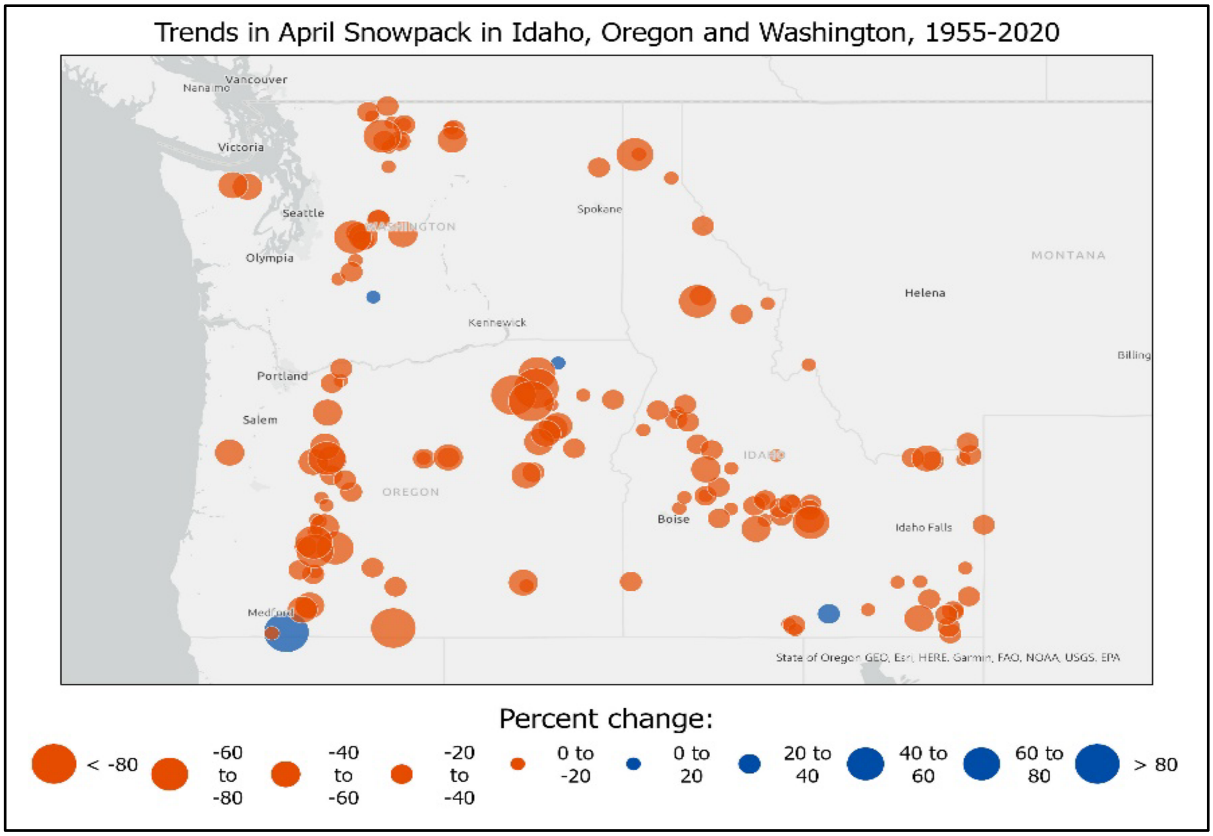

Figure 3. Map of percent change in April 1 snow water equivalent in Idaho, Oregon, and Washington between 1955 and 2020. Red dots indicate a decreasing trend and blue dots indicate an increasing trend. Larger dots indicate a stronger trend. Credit: USDA Natural Resources Conservation Service, 2020.

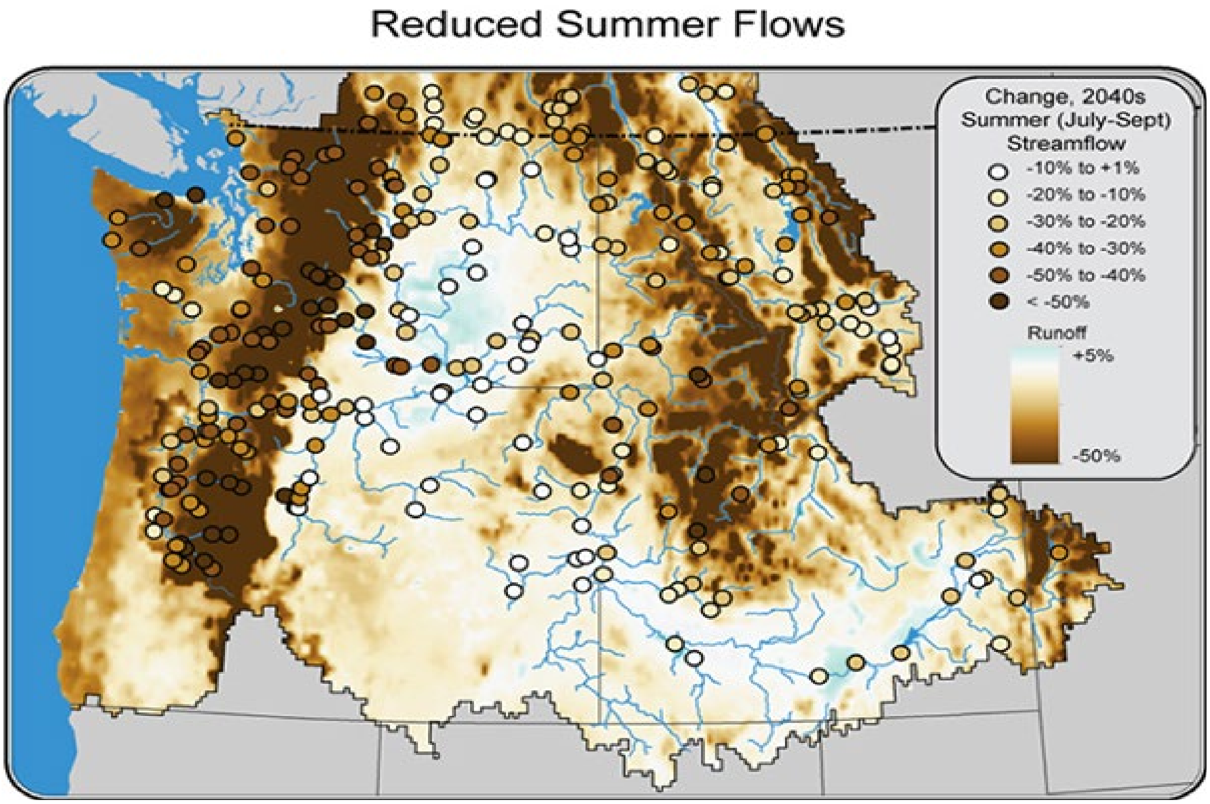

Figure 4. Map of percent change of summer flows in the Oregon, Washington, and Idaho. Credit: US Global Climate Change Research Program (USGCRP) 2014.

3. Climate change, changing stream flows, and riparian vegetation

DEFINITIONS

Groundwater: Water that is underground – usually referring to water in the saturated sediment of an aquifer.

Unconfined aquifer: An aquifer whose upper extent is not limited by an impermeable confining layer of rock or sediment. The water table is at atmospheric pressure because air can move through the pores of the overlying soil/sediment. Riparian zones are typically underlain by shallow, unconfined aquifers.

Water table: In unconfined aquifers, the boundary between the saturated zone and an overlying unsaturated zone. The elevation of the water table is the water surface in a well; the water table can be higher than the land surface, in which case water pools at the surface.

Head: In unconfined aquifers, this will be the difference in the water table elevation between two points as measured in wells or relative to the water surface elevation in the stream. Water flows from locations with high "head" to locations with lower "head".

Saturated hydraulic conductivity: A measure of how easily a soil or a sediment layer will transmit water. Sands and gravels have high conductivity; silts and clays have low conductivity.

Baseflow: The period of sustained stream flow between storm events. Base flow is frequently supported by groundwater entering (subsurface) from hillslopes or beneath the channel.

Baseflow recession: The gradual decrease in stream flow in the days, weeks, or months following peak flows.

Phreatic: Denoting water in the underground saturated area (groundwater)

Capillary fringe: Part of the unsaturated zone above the water table where phreatic water is present due to capillary action. Many riparian plants root into the capillary fringe and use water drawn from this zone

Peak or storm flow: The rapid increases in stream flow during storms. Storm flows typically recede rapidly, allowing return to baseflow conditions.

The effects of climate change on riparian zones will be highly variable because they will be mediated by future changes in streamflows, which will vary depending on the current climatic and hydrologic regime. For example, shifts from snow-dominated watersheds to rain-on-snow or rain-dominated watersheds will likely lead to more peak flows, especially winter peak flows. Some of these peak flows will likely be more extreme because storm intensities are expected to increase. Thus, streams in currently snow-dominated watersheds are at risk of increasing impacts from more and larger floods, which might increase channel and bank erosion, overbank deposition of sediment, and attendant changes on channel form and floodplain dynamics, including flood disturbance of riparian vegetation. Changes will likely be less severe in watersheds that are currently rain dominated because they will seldom experience rain-on-snow events and are already characterized by frequent winter peak flows. Even here, however, increases in the frequency of extreme storm events suggests that flood disturbance will increase in the future.

Projecting the effects of decreased late-summer low flows is also difficult. Riparian zones require the presence of water, but that water need not be perennial (or present at the surface year-round) to maintain many riparian attributes. Thus, decreases in low flows will not necessarily impact all riparian zones. Effects on riparian zones along small intermittent streams with narrow floodplains will likely differ from those along larger streams with wider floodplains.

3.1. Small streams with narrow floodplains

Climate change may lead to drier summer conditions, which could dry out headwater channels and reduce the extent of the perennial stream network. There will be exceptions, however. The headward extent of perennial flow in many streams is determined by the location of springs, and in these cases, climate change would have to drive changes in recharge to the aquifers supplying water to the springs before the springs would go dry. Thus, these aquifers could provide a buffer against climate-related changes, depending on the size of the aquifer and its recharge patterns. Elsewhere, we would expect that the intermittent (non-perennial) portion of the stream network would extend farther downstream. In places where perennial streams become intermittent, we might expect riparian vegetation to change so that in the future it will resemble the vegetation along stream reaches higher in the network that are currently intermittent.

Lower in the stream network where flows remain perennial, riparian ecosystems can have different sensitivities to changes in stream flows. If floodplains are narrow, water table elevations will tend to be in equilibrium with the water level in the stream. In small streams at summer baseflow, the water level in the stream may not be very sensitive to changes in flow. In part, this is because the water level is controlled by obstructions that form pools and influence the locations of riffles. Because of these obstructions, changes in velocity and wetted width under baseflow conditions often account for much of the change in streamflow, with little change in water level[1]. Consequently, the water table may not change appreciably, even with large changes in discharge. For example, water levels were measured in a small well network along a 2nd-order mountainous stream in the H.J. Andrews Experimental Forest during a small storm (flow [Q]=1.204 cfs) and again at extreme summer low flow (flow [Q]=0.029 cfs). Despite this very large change in discharge, water levels in the stream only declined by 4.8 inches and groundwater levels declined by only 4.6 inches (Wondzell, unpublished data). Thus, riparian vegetation can maintain access to phreatic water across a wide range of stream flows and may be little affected by future declines in flow.

Many streams in the interior Pacific Northwest have experienced channel incision because of historical land uses (e.g., Figure 5). Erosion and channel incision in these streams could affect riparian vegetation more than the impacts of climate change on summer low flows. Again, because the water table is in equilibrium with the water level in the stream channel, incision will immediately lower the water table. If these changes in the water table are large enough, riparian vegetation may lose access to phreatic water, leading to change in riparian vegetation. If changes in flow regimes, especially floods, further exacerbate channel incision (or reverse channel recovery), riparian condition could be further degraded. However, channel restoration that fills incised channels, especially in broad, low-gradient floodplains, can dramatically raise water

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[1] The flow in the channel, abbreviated "Q" (*cfs* or *ft*^{3}*/s*), is equal to the width (*ft*) * depth (*ft*) * velocity (*ft/s*) or Q=w*d*v. Thus, as flow changes during baseflow periods, it results in changes in both the wetted channel width and flow velocity, as well as the depth of water. The exact relationship among these variables is determined by the channel morphology – the channel's cross-sectional shape, longitudinal slope, and the streambed roughness.

tables, once again restoring riparian vegetation access to phreatic water, leading to large and persistent changes in that vegetation.

Figure 5. Eroded and incised channel that is disconnected from its floodplain. Riparian vegetation along incised channels will be more vulnerable to drying with climate change. Photo by Steve Wondzell, USFS Pacific Northwest Research Station.

3.2. Large streams with wide floodplains

The hydrology of wide floodplains along larger rivers can be much more complex than in the narrow stream valleys described above. One critical difference is the time it takes water to flow across a wide floodplain. Large river floodplains tend to be relatively flat so that the gradients in the water table elevation (commonly called "head") that drive subsurface flows are weak. Further, sediment deposited on floodplains tends to be fine textured, and thus has low hydraulic conductivity. This combination of shallow head gradients and low conductivity means that groundwater moves slowly. For example, in a typical wet meadow with a 1.0% longitudinal gradient, saturated hydraulic conductivity of a fine sand (~3 ft/day), and porosity of 30%, groundwater would flow only 0.1 ft/day. Put another way, it would take some 300 days for groundwater to flow 10 yards. These very slow flow velocities are what keep wet meadows wet; simply put, they drain slowly.

Because groundwater flows so slowly, only in areas immediately adjacent to the stream will the water table elevations be in equilibrium with the water level in the channel during baseflow periods. Farther into the floodplain, the water table elevation might be relatively independent of the water level in the channel, and other factors may have greater control on the depth to the water table. For example, over-bank flooding during the spring snow-melt pulse, and water flowing in secondary or back channels, might be important sources of recharge to the shallow floodplain aquifer. Similarly, both surface and subsurface flows from tributary channels, as well as subsurface drainage from adjacent hillslopes if sufficiently large, might also be important sources of water maintaining water tables along the hillslope margins of valley floors.

The water levels in large floodplain aquifers usually show large seasonal variations, because the amount of water recharging the aquifer varies seasonally. In the Northwest, recharge is greatest in the winter in rain-dominated locations, and during the snow-melt period in snow-dominated locations. In both cases, water levels tend to be high in late spring and early summer and decline over the dry summer season due to the combined effects of drainage to the channel and evapotranspiration from riparian vegetation. The exact patterns in any given floodplain are determined by a number of factors, including the prevailing climate, width of the floodplain and the texture of floodplain sediment (i.e., sands and gravels versus silts and clay), the location of the mainstem channel and its morphology, presence of secondary or back channels, tributary channels, the size and lithology of the adjacent hillslopes, and in some places, groundwater upwelling underneath the floodplain.

In wetter locations, we might expect the seasonal variations in water levels to be smallest adjacent to the channel and largest along the hillslope margin, because lateral recharge in winter or spring from adjacent hillslopes can be substantial. In drier locations, where lateral inputs from hillslopes and tributaries are minimal, then the stream peak flows will be the primary source of recharge, either through bank infiltration, or if peak flows are high enough, from over-bank flooding. However, if channels are incised, riparian zones can be more susceptible to summer drying. Depending on other sources of water to the floodplain, these effects might be restricted to areas close to the channel, with shallow depths to groundwater maintained farther away from the channel, especially along relict channels and other low-elevation areas. However, more severe changes also occur with channel incision, so that the water table drops far enough that no vegetation has access to phreatic water.

Depth to the water table also varies with the height of the floodplain surface above the river channel. Low areas from previous or relict channels, for example, may have shallow depths to groundwater, whereas the depth to groundwater might be quite deep under terraces, naturally formed dikes, and other high surfaces. These factors create substantial complexity in naturally occurring riparian vegetation, because depth to groundwater determines whether or not the roots of riparian vegetation can access phreatic water. Because of the complex interactions between stream flow and the hydrology of floodplain aquifers described above, the effects of reduced stream flows on riparian zones will tend to be unique in every floodplain system. Further, we would not expect a simple and predictable relationship between changes in streamflow and water table elevations.

One of the more likely impacts of climate change on riparian systems of rivers and streams with large floodplains may well come from changes in the timing of the recharge period. As described above, climate change is likely to shift the timing of peak flows earlier in the spring and increase summertime temperatures, thus creating a longer summer draw-down period and enhanced evapotranspiration demands. As the drawdown period lengthens, the water table and its capillary fringe may eventually fall below the rooting depth of riparian vegetation, limiting their access to water. This period of reduced water access will lengthen, and at the same time, increased temperatures will stress vegetation. If this period of increased stress is too long or severe, we would expect that large changes in riparian vegetation would occur, including die-back or death of mature trees or decreased seedling/sapling survival that limits regeneration of new age cohorts. These effects could be further exacerbated by more frequent droughts.

In most locations across the western USA, riparian locations with wide valley floors have experienced substantial changes over the past century, and these changes are usually human caused. In some cases, changes result from indirect responses to land-use-related disturbances, for example, severe channel incision from past decades of over grazing. In other cases, changes result from intentional modifications. Streams have been channelized, channels have been moved to the edges of valley floors, wet meadows have been drained, and locations with woody riparian vegetation have been cleared. Valley floors may be farmed or planted with European pasture grasses for either hay production or to increase forage availability for livestock, and streams may have been diverted to irrigate pastures and fields. These changes have had many impacts on riparian function, from direct impacts to vegetation, to indirect impacts where drainage and channelization have lowered water tables or conversely, where irrigation artificially elevates water tables, and in both cases changing the availability of water for riparian vegetation. Thus, expected future changes in climate will impact highly altered riparian ecosystems.

3.3. Interactions among climate change, disturbance, and riparian hydrology and vegetation

Riparian vegetation provides critical functions for many aquatic ecosystems. For example, the roots and rhizomes of sedges and grasses (or graminoids) and many shrubs help stabilize streambanks, limiting bank erosion, and help trap sediment from over-bank flows during floods. In addition, many species of fish, including salmon and trout, rely on cold, flowing water and are particularly vulnerable to warming stream temperatures and lower stream flow. Tall shrubs and trees are especially important in riparian areas because they provide shade, which can limit stream warming, and large wood, which contributes to habitat complexity. Shade has a much larger influence on maximum daily stream temperatures during the summer than do changes in discharge or air temperatures (Wondzell et al. 2019). Thus, maintaining tall shrubs and trees or restoring them where they are lacking will be important to limiting the near-term effects of a warming climate.

Successful tree and shrub establishment in riparian areas is often timed to coincide with specific periods of the annual water cycle. For example, seed germination for cottonwoods and some species of willows often occurs shortly after the peak of spring snowmelt, so that root elongation can follow water table drawdown, allowing seedlings access to phreatic water throughout the growing season. However, snowmelt is expected to occur earlier in the year due to warming. As the snowmelt moves earlier in the year, seed release may occur later than the peak of melt, and seeds may not have a favorable environment for germination and survival (Rood et al. 2008).

Historically, there is evidence that fires commonly burned with lower severity in riparian areas (Halofsky and Hibbs 2008), where vegetation is kept wetter than surrounding uplands because of access to phreatic water. Riparian fuels, especially those under dense canopies, can stay moist because the riparian microclimate has higher humidity and lower temperature than adjacent uplands. However, fire exclusion has resulted in denser forests in some riparian areas and adjacent uplands (Messier et al. 2012). Further, climate change is creating warmer and drier riparian microclimates, and combined with attendant changes in hydrology, may lead to drier fuels. As fire area burned increases with climate change, riparian areas may burn more frequently, and conditions will be more likely to favor root-sprouting hardwoods like red alder and shade-intolerant conifers.

Nonnative species may also become more competitive in riparian areas with increased opportunities for invasion after disturbance (Catford et al. 2013). For example, in the semi-arid and arid regions of the Great Basin in Oregon and Idaho, and the Columbia Plateau in Oregon, Idaho, and Washington, changes in streamflow are likely to favor invasive species such as tamarisk over desirable woody species, and annuals over other herbaceous species. This is largely because tamarisk and annuals are adapted to drought and intermittent flow, and they establish during periods of disturbance (Perry et al. 2012).

Overall, changes in riparian plant species composition and reduced riparian extent could result in direct losses to the quantity and quality of ecological contributions of riparian vegetation, such as wildlife habitat, shade over streams, and buffer capacity for maintenance of water quality (Dwire and Mellmann-Brown 2017).

4. Climate change effects on wetlands

Wetlands in the Northwest may be vulnerable to climate change with changes in snowpack, precipitation, and groundwater recharge and discharge (Waibel et al. 2013). As described above for riparian zones, the exact effects of these hydrological changes are likely to be complex and difficult to predict. However, both recent trends in temperature and projections from global climate models suggest that future temperatures will be warmer in all seasons (Mote et al. 2013), which will result in increased evapotranspiration and increased soil moisture stress in summer (Littell et al. 2013). These effects might result in a more rapid recession of stream flows over the summer, and earlier drawdown of groundwater levels from shallow, unconfined riparian aquifers, which could lead to reduced minimum water levels in riverine wetlands (Lee et al. 2015).

Snow-dependent wetlands at higher elevations will likely be sensitive to climatic changes; some ephemeral montane wetlands may disappear, and some perennial wetlands, or those that historically dried in late summer during dry years, may become ephemeral. Lee et al. (2015) projected that some perennial montane wetlands in Washington (Olympic Peninsula and Cascade Range) will become more ephemeral as wetland water levels decline. Wetlands at lower elevations will be vulnerable to increasing water demands, pressure for increased diversion or water development, and other watershed-scale land use effects (Dwire and Mellmann-Brown 2017).

Many wetlands are groundwater dependent. However, little is known about how groundwater recharge may change in a warming climate (Tague and Grant 2009), making it difficult to predict the hydrologic effects on groundwater-dependent wetlands. In many western USA mountainous regions, snowpack is the main source of groundwater recharge, and thus there are concerns that reduced snowpack will limit groundwater recharge and result in less groundwater to support groundwater-dependent wetlands. However, it is not known if a switch to winter rain or transient snow conditions will lead to less recharge than occurs during the relatively short snowmelt period (Dwire and Mellmann-Brown 2017). Certainly, some groundwater-dependent wetlands may decrease in size or dry out in summer under changing climate. However, large regional aquifers may be buffered from direct impacts from changing recharge, making those wetlands less likely to be impacted by climate change. Thus, effects will differ depending on hydrogeologic setting (Drexler et al. 2013).

Groundwater pumping may have a bigger impact on groundwater-dependent wetlands than will changes to recharge patterns resulting from climate change. Persistent drought across the western United States in recent years has limited supplies of surface water for irrigation, forcing many farmers to rely increasingly on wells to irrigate their fields. The current drought conditions may be considered a harbinger of climate change, representing a “new normal” under which supplies of surface water may be reduced relative to past decades. Groundwater pumping is poorly regulated, and in many places, water extraction exceeds annual recharge (House and Graves 2016). As a consequence, groundwater levels have dropped in many locations, threatening not only groundwater-dependent wetlands, but also cottonwood-dominated riparian forests (Dwire and Mellmann-Brown 2017) and water supplies for domestic users reliant on groundwater.

Wetland plant species are very sensitive to changes in water table elevation (Magee and Kentula 2005), and compositional shifts will likely occur where water tables decline. With lowered water tables and soil moisture declines in wetlands in summer, drought-tolerant species will likely become more competitive, rare and/or sensitive species may be lost, and cover of non-natives may increase (Dwire and Mellmann-Brown 2017).

5. Adaptation options

Adaptation, or an "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects" (McCarthy et al. 2001), can help to reduce negative effects of climate change or transition organisms and systems to new conditions under future climates. Adaptation actions may help riparian areas and wetlands be more resilient to stressors associated with climate change and help ensure they continue to provide valued ecosystem services. Priority adaptation actions for riparian areas and wetlands are described below and in Table 1.

5.1. Increasing stream shade

Preserving and increasing shade are likely to be the most effective ways to mitigate stream temperature increases. Managing riparian vegetation to help optimize shade to streams will help to minimize stream temperature increases and negative effects to aquatic biota. A primary way to increase shade over streams is to **plant trees in riparian areas** and/or **avoid removing native riparian vegetation**. When planting trees in riparian areas, it will be important to consider the future conditions these trees and/or shrubs will have to endure (e.g., increased temperatures and drought). Thus, it may be beneficial to plant species that have a broad range of moisture tolerances, particularly low moisture in summer. Plantings may require more monitoring and maintenance (e.g., watering in the summer) in the short term to help ensure survival. Many native shrubs are also highly palatable to domestic livestock, and both deer and elk. These species will likely need to be protected from browsing until they are well established. Alternatively, planting could be limited to less palatable species (e.g., ponderosa pine and thinleaf alder in eastern Oregon). Finally, restoring native hardwoods, like cottonwood, aspen, and willows, may require reversing channel incision to reconnect streams to their floodplain and raise water tables so phreatic water is available to the roots of these species.

Preventing high-severity fire in riparian areas and wetlands will also help to reduce loss of riparian and wetland vegetation and associated loss of shade. In fire-prone ecosystems (e.g., dry forests east of the Cascade Mountains), **reducing fuels in adjacent upland vegetation** can help reduce risk of high-severity fire in riparian areas and wetlands. Reducing fuels in some riparian areas (e.g., conifer-dominated riparian areas along small streams) may also be considered to help prevent high-severity fire. However, there are few studies on the effects of prescribed fire and mechanical treatments in riparian areas, and many factors (e.g., rare plant presence, invasive species presence, effects on wildlife) need to be considered before treatments are implemented (Dwire et al. 2016).

5.2. Restoring degraded streams and wetlands

Maintaining or restoring stream channel form, particularly in incised streams, helps to increase hydrologic function and store water, which is beneficial for riparian and wetland vegetation, water quality, and aquatic habitat (Luce et al. 2012). Implementing stream restoration techniques that improve floodplain hydrologic connectivity, increase water storage capacity, and add wood to streams can improve channel stability and complexity, slow water movement, improve aquatic habitat, and increase resilience to both low and high flows. Reintroducing or supporting populations of American beaver, or installing beaver dam analogs, may help to slow water movement and increase water storage in some locations (Pollock et al. 2014). However, some studies have shown that water temperatures within and downstream of beaver ponds may be elevated (Stevenson et al. 2022), and not all locations are appropriate for beaver introduction.

5.3. Mitigating flood effects

Decreasing snowpack and higher precipitation intensity will lead to increased flood risk in some locations. **Managing for highly functioning riparian areas and wetlands** might help mitigate effects of high flows, although likely not the effects of major floods (i.e., 50- and 100-year floods). For example, **reconnecting stream channels to floodplains** and **maintaining native plant species** in riparian areas and wetlands might help reduce the effects of high flows on riparian systems.

Flood damage to roads that are near streams may have negative effects on wetlands, riparian areas, and aquatic ecosystems through sedimentation. Thus, landowners and managers might consider **reducing the hydrological connectivity of roads to streams and wetlands** (e.g., by out-sloping and increasing rolling dips and cross culverts), which would have a dual benefit of decreasing flood damage to roads and reducing negative effects of flood-damaged roads on wetland, riparian, and aquatic ecosystems. In some cases, moving roads and other infrastructure out of riparian areas and floodplains may be necessary to avoid continued damage to infrastructure and ecosystems.

5.4. Reducing non-climatic stressors

Reducing existing, non-climatic stressors in riparian areas and wetlands could help them better withstand the effects of climate change. Examples of non-climatic stressors in riparian areas and wetlands include invasive plant species, high-intensity livestock grazing (e.g., Figure 6), and high recreation use. **Restoring and protecting riparian and wetland vegetation by managing livestock and recreation use** helps to protect riparian and wetland ecosystems, adjacent aquatic habitat, and water quality by increasing water storage and providing shade to streams. **Fencing around sensitive riparian vegetation and wetlands** can reduce damage by recreationists, native ungulates (deer and elk), and livestock. **Managing use numbers and duration of use for both livestock and recreationists** can also help to minimize negative effects on riparian areas and wetlands.

Where feasible, **invasive plant species can be eliminated** to reduce negative effects on riparian areas and wetlands, especially if invasive species are displacing dominant natives. Tactics to minimize establishment and spread of invasive species include **early detection, rapid response** for new invasions, implementing **weed-free policies, preventing invasive plant introductions** during projects, and **planting locally adapted, native species** to compete with invasives. **Monitoring and controlling invasive plants in flood-prone areas** could help ensure the functionality of riparian zones.

Figure 6. Cattle in a riparian area. Reducing existing stressors, such as undesired grazing effects by cattle, can help riparian areas better cope with stressors associated with climate change. The heavily trampled and eroded area in the foreground shows a small water access point for cattle in the pasture to the right of the fence line. The severe impacts of cattle grazing are limited to this small zone. Cattle management along the stream in the left-hand pasture (background) has been changed, allowing revegetation of eroded/incised stream banks.
Photo by Steve Wondzell, USFS, Pacific Northwest Research Station.

Table 1. Adaptation actions for riparian areas and wetlands (adapted from the Northwest Climate Hub Climate Risk-Management Practices). Natural Resource Conservation Service conservation practices associated with each group of adaptation actions are also listed with each adaptation section.

Climate risk management practice	**Adaptation actions**	**Associated NRCS conservation practices**
Increase shade over streams to minimize stream temperature increases	• Manage upland vegetation to reduce risk from large-scale, high-severity fire in riparian areas (e.g., with thinning and prescribed fire). • Plant native trees and shrubs in riparian areas.	• Riparian Forest Buffer • Tree/Shrub Establishment
Restore degraded streams and wetlands to promote key processes and functions	• Restore riparian and wetland obligate species. • Promote appropriate livestock grazing management and proper use standards. • Reconnect floodplains and side channels to improve hyporheic and baseflow conditions. • Maintain and improve soil function and health. • Address water loss at water diversions and ditches. • Consider float valves for watering troughs and disconnect diversions during off seasons. • Increase floodplain and channel water storage by managing for American beaver populations. • Plant shrubs in riparian areas for beaver use. • Trap and relocate beavers to selected watersheds; use valley form analysis to assess potential sites for beaver colonies and channel migrations. • Consider beaver dam analogues to improve habitat quality. • Work with appropriate agencies to reduce trapping rates in vulnerable watersheds.	• Stream Habitat Improvement and Management • Wetland Enhancement, Wetland Restoration • Tree/Shrub Establishment, Riparian Forest Buffer

Plan and prepare for more frequent and severe flood events	• Restore native plant species in riparian areas. • Control invasive plant species in flood-prone reaches. • Expand current restoration projects to mitigate increasing flood risk. • Use natural flood protection (e.g., vegetation or engineered logjams). • Disconnect roads from streams to reduce drainage efficiency.	• Tree/Shrub Establishment • Stream Habitat Improvement and Management • Wetland Enhancement • Wetland Restoration
Increase riparian and wetland plant resilience by reducing non-climatic threats	• Manage road, trail, and recreation impacts. • Maintain hydrology of critical habitats. • Increase habitat connectivity and heterogeneity. • Mitigate road impacts; eliminate unnecessary roads and impacts to wetlands and riparian areas. • Redesign road drainage to reduce runoff and increase water infiltration and retention. • Control invasive species; use early detection, rapid response. • Manage to adjust livestock season of use, use numbers, and duration of use. • Manage to adjust recreation season of use, use numbers, and duration of use.	• Stream Habitat Improvement and Management • Wetland Enhancement • Wetland Restoration

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