

Climate Change Resources for Oregon Coast Coho Salmon

Global and U.S. Projections

The earth's climate and oceans are changing due to activities that emit greenhouse gases into the atmosphere. The Fourth National Climate Assessment (USGCRP, 2018) finds the following:



- The annual global average air temperature has increased by approximately 1.8°F over the last 115 years (1901–2016). This period is now the warmest in the history of modern civilization.
- The global atmospheric carbon dioxide (CO₂) concentration level has now passed a level that last occurred almost 3 million years ago (400 parts per million).
- In the United States, annual average temperatures are expected to rise by approximately 2.5°F over the next few decades (2021–2050), relative to the recent past (average from 1976–2005), under all plausible future climate scenarios.
- Global average sea levels are expected to continue to rise at least several inches in the next 15 years and by 1–4 feet by 2100, varying by geographic location.

Oregon Projections

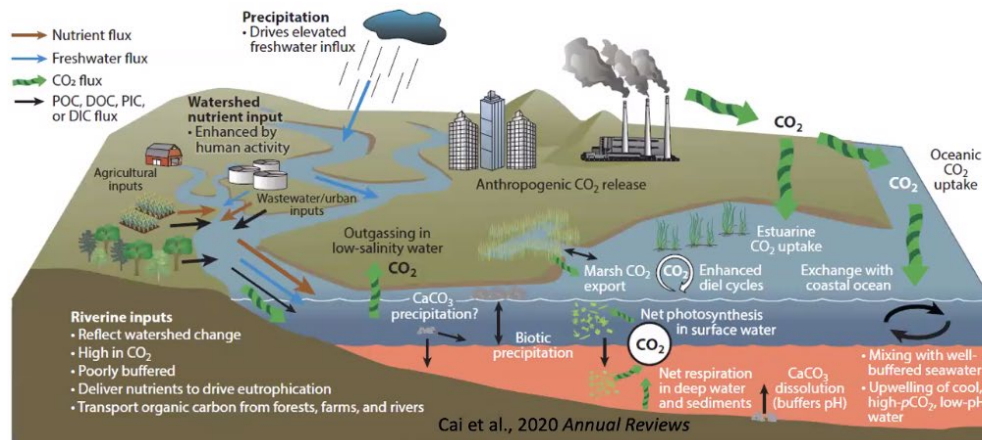
Oregon is already experiencing changes consistent with changes observed and projected globally, for example increased average air and water temperatures, disrupted precipitation patterns, and increased ocean acidification and hypoxia. If greenhouse gas emissions continue at current levels, the Fifth Oregon Climate Assessment (Dalton & Fleishman, 2021) finds the following:

- Oregon's air temperature is projected to increase on average by 5°F by the 2050s and 8.2°F by the 2080s, with the greatest seasonal increases in summer.
- Precipitation is projected to increase during winter and decrease during summer, with increasing intensity of heavy precipitation events in the winter throughout the twenty-first century. Precipitation falling as rain rather than snow is projected to increase, especially at lower to intermediate elevations in the Cascade Range.
- Runoff is expected to begin and peak earlier in the year, declining in summer, and increasing in winter while snowpack throughout Oregon is accumulating more slowly, and melting earlier. These trends are likely to continue, and may accelerate, as the temperature increases.

- The ocean surface temperature is projected to increase by approximately $5.0 \pm 1.1^\circ\text{F}$ by the year 2080. These changes may accelerate the rate of reduction in dissolved oxygen and increase the toxicity of harmful algal blooms. Ocean acidification is projected to change by roughly 100–150%, resulting in a drop in ocean pH from 8.1 to 7.8. Below is a depiction of the natural and human caused drivers of coastal acidification from Cai *et al* (2020).



Coastal acidification drivers

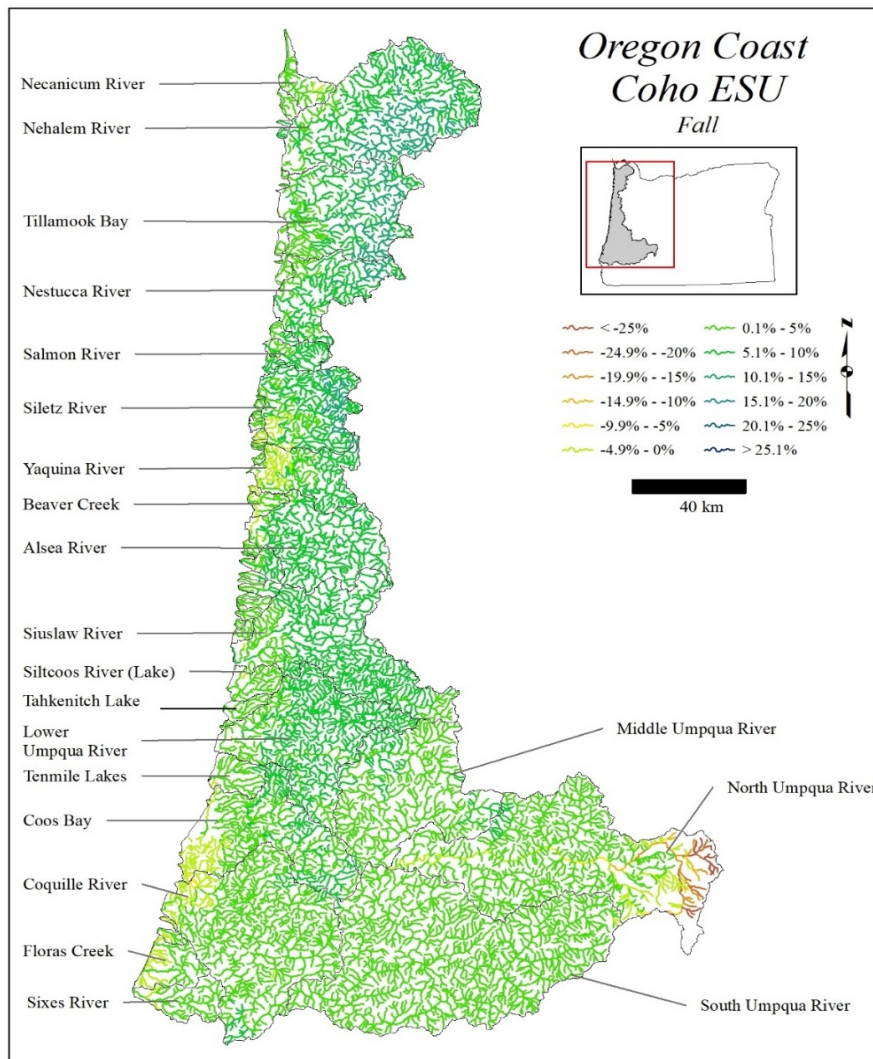


Natural and Anthropogenic drivers of coastal acidification dynamics

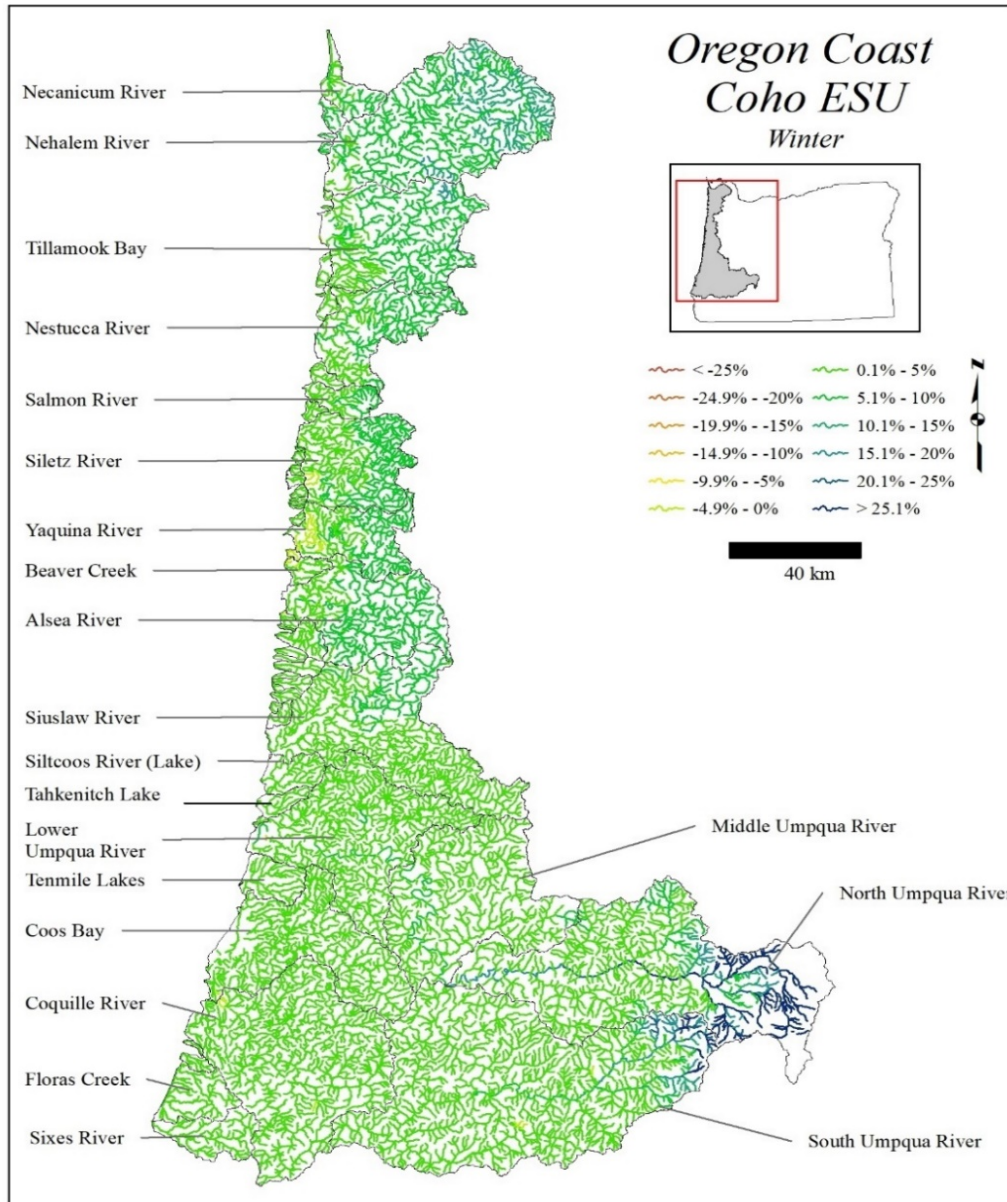
- River and coastal ocean mixing
- Biological metabolism
- Gas exchange
- CaCO_3 cycling
- Changing precipitation & ocean circulation patterns
- Altered riverine delivery of carbon, nutrients, alkalinity
- Enhanced organic matter production and respiration
- Anthropogenic CO_2 emissions uptake

The impact of climate change on stream flows is expected to vary within the OC Coho ESU and between seasons. Across all strata, late fall and winter flows are projected to increase, while spring, summer, and early fall flows are expected to decrease. Below are mapped projections for fall, winter, spring and summer median stream flows from the [OC Coho 2019 12-Year Assessment](#). The projections were developed using the VIC model (Liang et al. 1994; Hamman et al. 2018) based on the A1B emissions scenario.

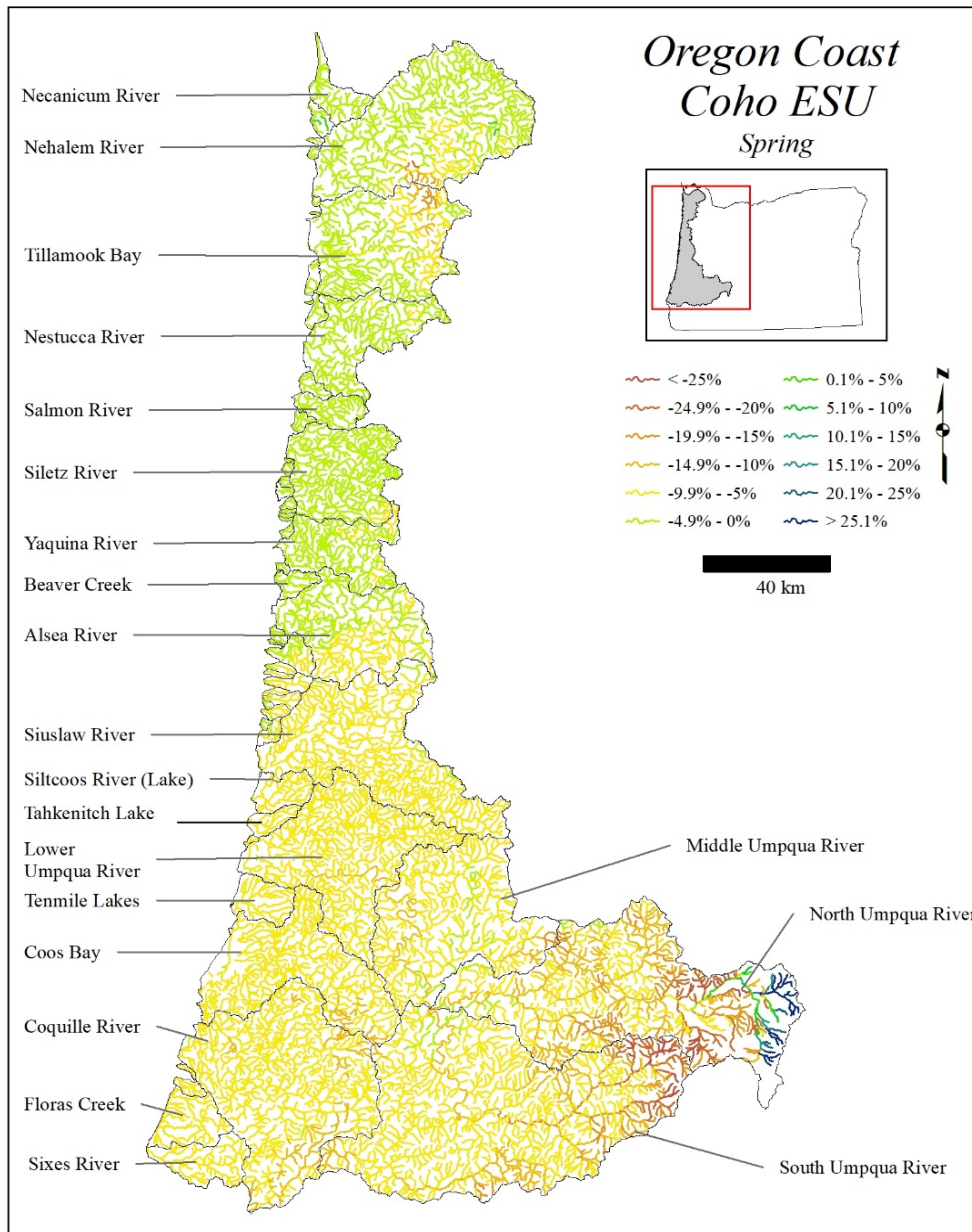
Fall Stream Flow- Median stream flow during fall (October–December) is projected to increase in most of the ESU due to increased precipitation. Projected increases are $\leq 10\%$ for most streams, but larger changes are expected in higher elevation areas in the northern portion of the ESU. Although fall flows are expected to increase overall, flows during early fall are expected to decrease along with late summer flows. This depiction represents projected percentage change in median fall stream flow in 2080 relative to the historical baseline (1915–2006) in the OC Coho ESU.



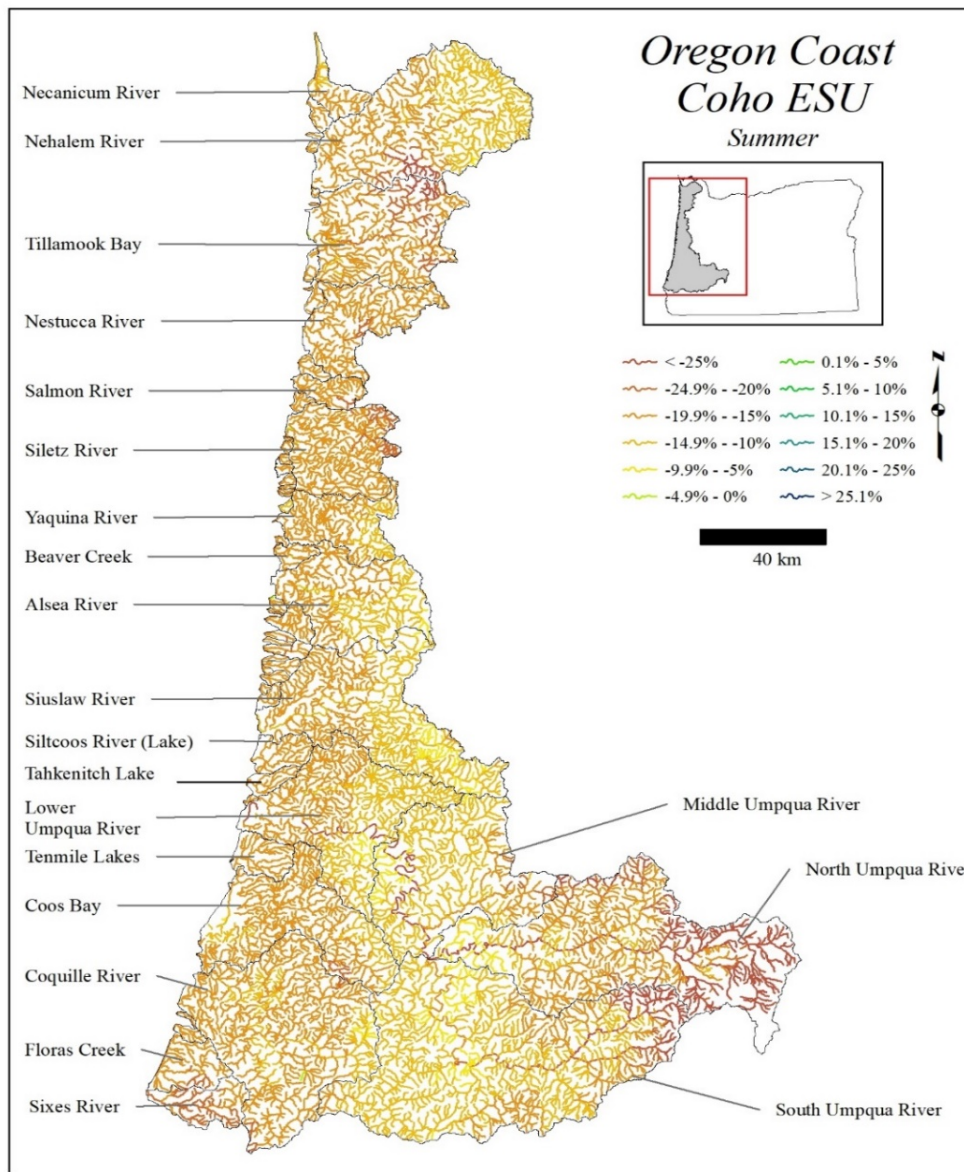
Winter Stream Flow- Winter (January-March) stream flow is projected to increase throughout most of the ESU due to increased precipitation. Projected increases are $\leq 10\%$ for most streams, with larger changes expected in the Upper Umpqua basin due to a shift in winter precipitation from snow to rain. In addition to overall increases in winter flow, the frequency of major storms and high flow events is expected to increase in the future. This depiction represents projected percentage change in median winter stream flow in 2080 relative to the historical baseline (1915–2006) in the OC Coho ESU.



Spring Stream Flow- Reduced spring flows (April-June) are projected for most of ESU, with the largest decreases projected for the southern half of the ESU. In the Upper Umpqua basin, a significant decrease in spring flow is projected for some mid-elevation streams due to reduced snowpack, while significant increases are projected for the highest elevation streams due to earlier snowmelt. This depiction represents projected percentage change in median spring stream flow in 2080 relative to the historical baseline (1915–2006) in the OC Coho ESU.



Summer Stream Flow- Summer stream (July- September) flow is projected to decrease throughout the ESU, with reductions ranging from 5–20% in most streams. Summer stream flow could also be affected by aspects of climate change that are not incorporated in the modeling presented below. For example, changes in vegetation due to increased wildfire or insect mortality may initially increase water yield by decreasing canopy interception and transpiration (Halofsky et al. 2020), but if such disturbances keep forests in earlier seral stages, an increase in transpiration may reduce low flows (Perry and Jones 2017). This depiction represents projected percentage change in median summer stream flow in 2080 relative to the historical baseline (1915–2006) in the OC Coho ESU.



Projected change in stream temperature from the historical (1993-2011) and future (2070-2099) time periods under the A1B emissions scenario. Reach specific estimates were obtained from NorWeST.

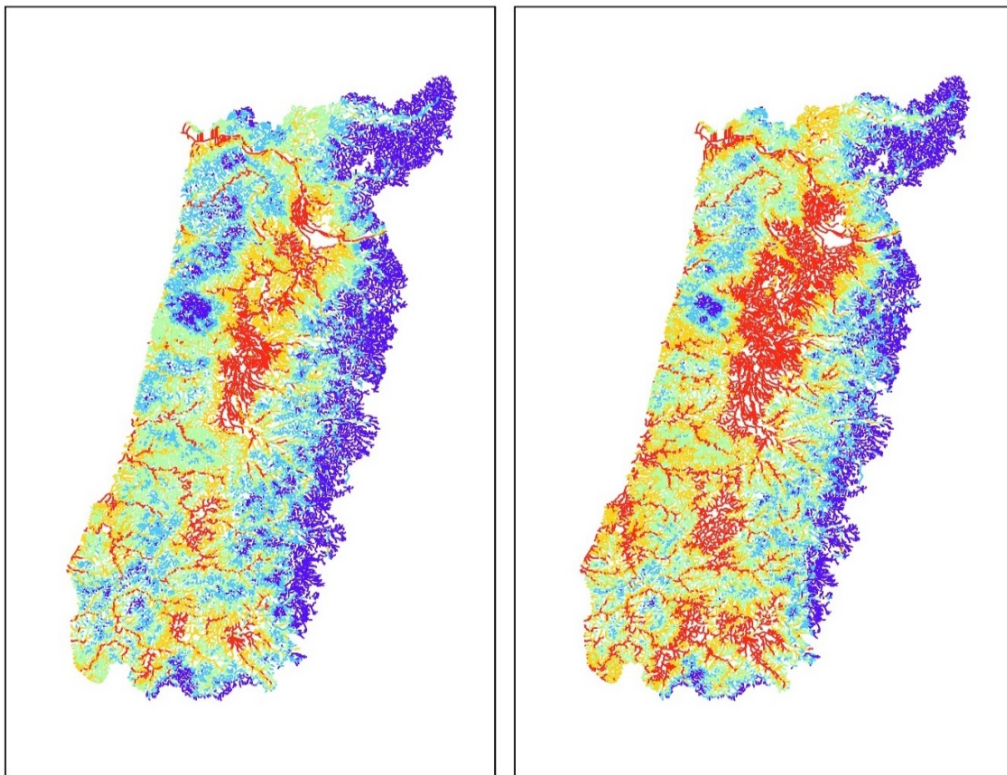
Projection Tools

To find a specific stream temperature projection, the NorWeST Stream Temperature Interactive Mapping tool is a publicly accessible resource for identifying future projected summer stream temperature scenarios. It was developed for all rivers and streams in the western U.S. from more than 20,000 stream sites in the database where mean August stream temperatures were recorded. <https://usfs.maps.arcgis.com/apps/webappviewer>

Below is an example product of the NorWeST Stream Temperature Interactive Mapping Tool, a comparison of the historic and projected mean summer stream temperatures for the Oregon Coast Coho Salmon evolutionary significant unit (ESU) geography using the NorWeST mapping tool.

Historic Mean August Stream Temperatures (1993-2011)

Projected Mean August Stream Temperatures (2040)



Temperature (c)

- ≤12
- ≤14
- ≤16
- ≤18
- ≤26

Source: NorWeST

What the Projections Mean to Oregon Coastal Coho Salmon

Coho salmon require four distinct habitats to support their life stages: 1) terrestrial forests, 2) freshwater rivers and lakes, 3) estuaries, and 4) the ocean. Each of these habitats is impacted by various aspects of climate change that collectively influence the future sustainability of the coho salmon populations (Wainwright and Weitkamp, 2013). The climate change projections for Oregon identified above are anticipated to have the following effects and subsequent ecological consequences for coastal coho salmon.

Table 1. Effects and ecological consequences to coastal coho salmon. Modified from Beechie *et al* (2013), Wainwright and Weitkamp (2013), and Reeves *et al.* (2018).

Projected Effects	Potential Ecological Consequences for Coho Salmon
Increased summer water temperature	<p>Reduced juvenile rearing habitat</p> <p>Reduced or increased juvenile growth rates depending on temperature and available food resources</p> <p>Increased susceptibility to disease</p> <p>Increased predation risk from non-native warmwater fish species</p>
Reduced summer flows	<p>Reduced juvenile rearing habitat</p> <p>Reduced juvenile growth rates</p>
Increased winter flows and major storm events	<p>Increased sediment input and transport</p> <p>Increased large wood recruitment and transport</p> <p>Increased redd scour and egg mortality</p> <p>Reduced juvenile overwinter survival</p>
Sea level rise	<p>Reduced tidal wetland habitat</p> <p>Altered estuarine food web</p> <p>Reduced or increased estuarine rearing habitat</p>
Increased sea surface temperature	<p>Altered marine food web</p> <p>Increased predation risk</p> <p>Increased thermal stress</p>

	Reduced marine growth and survival
Increased ocean acidification	Altered marine food web Sensory impacts Reduced marine growth and survival

Vulnerability Assessments

Oregon coast river basins differ in local climate, geomorphology, and spatial variation in physical forcing of coastal waters (Wainwright and Weitkamp, 2013), therefore, coho salmon populations are likely to be affected by climate change in different ways based on their vulnerability.

Vulnerability as described by the IPCC (2007) is a function of the *sensitivity* of a particular species or system to climate changes, its *exposure* to those changes, and its *capacity to adapt* to those changes. The more vulnerable a species or system is to climate change, the greater the impact.

Exposure: Extrinsic factors, focusing on the character, magnitude, and rate of change the species or system is likely to experience (Glick *et al.* 2011).

Sensitivity: species and systems innate characteristics of tolerance to changes in environmental conditions such as temperature, precipitation, fire regimes, or other key processes based on physiology, habitat requirements, life history, dispersal ability, location, population growth rates, effects to ecological climate and disturbance regimes (Glick *et al.* 2011). Sensitivity to climate change impacts can be directly influenced by the extent and existence of human-related stressors, for example habitat fragmentation due to roads. This can limit the species ability to shift its range in response to changing climate conditions and associated shifts in habitats or ecosystem processes important for the species life cycle. This may also be considered part of the adaptive capacity of a species or system.

Adaptive capacity: the ability of a species or system to accommodate or cope with climate change impacts with minimal disruption (Glick *et al.* 2011).

Climate change adaptation: initiatives or measures designed to reduce the vulnerability of a natural system to actual or expected climate change effects (Glick *et al.* 2011).

A climate change vulnerability assessment identifies factors contributing to climate-based vulnerability. They can identify which species or systems will be more affected by projected climate change and provide an understanding of why they are likely to be vulnerable. Those factors are then used to create initiatives and measures that can reduce the effects of climate vulnerability. Vulnerability assessments can provide information about the level and sources of vulnerability of a species or system to help in setting priorities, they do not direct what the priorities should be.

Four Key Steps for Conducting a Climate Change Vulnerability Assessment, modified from Glick *et al*, 2013.

Step 1. Determine the Objectives and Scope

- Identify audience, user requirements, and needed products
- Engage key stakeholders (internal and external)
- Establish and agree on goals and objectives
- Identify suitable assessment targets (species or system)
- Determine the appropriate spatial and temporal scales (population, strata, ESU, etc.)
- Select assessment approach based on targets, user needs, and available resources

Step 2. Gather Relevant Data and Expertise

- Conduct a literature review of assessment targets and climate change impacts
- Reach out to subject experts on target species or systems
- Obtain or develop climate projections, focusing on ecologically relevant variables and suitable spatial and temporal scales
- Obtain or develop ecological response projections

Step 3. Assess Components of Vulnerability

- Evaluate climate sensitivity of assessment targets
- Determine likely exposure of targets to climate/ecological change
- Consider adaptive capacity of targets that can moderate potential impacts
- Estimate overall vulnerability of targets
- Document level of confidence or uncertainty in assessments

Step 4. Apply Assessment Results in Adaptation Planning

- Explore why specific targets are vulnerable to inform possible adaptation responses
- Consider how targets might fare under various management and climate scenarios
- Share assessment results with stakeholders and decision makers

- Use results to advance development of adaptation strategies, plans, and actions.

Adaptation Strategies and Actions

The IPCC (2012) defines the adaptive capacity of the management response as “the combination of strengths, attributes, and resources available to an individual, community, society, or organization that can be used to prepare for and undertake actions to reduce adverse impacts, moderate harm, or exploit beneficial opportunities.” Adaptation concepts have evolved with the following approaches (Glick et al. 2011).

- Building **resistance** to climate change-related stressors to maintain priority species or systems. A species or ecosystem can avoid or tolerate the climate change impacts when it is resistant.
- Restoring **resilience** to provide a better chance at surviving the changes. The species is resilient when it has the ability to recover from a disturbance (or climate change impact) without significant loss and is able to return to a given ecological state.
- Planning for and facilitating ecological **transitions** to reflect changing environmental conditions.

To evaluate whether a restoration plan or action should be adapted in order to support coho salmon resilience to climate change, Beechie *et al* (2012) identified four questions to consider when determining climate change impacts on restoration project prioritization and design:

- 1) What habitat restoration actions are necessary for the recovery and conservation of local coho populations?
- 2) Do future stream flow and temperature scenarios alter the types of habitat restoration actions necessary for recovery?
- 3) Does the restoration plan or action improve a projected climate change impact on stream flow or temperature?
- 4) Will the restoration plan or action increase habitat diversity and coho population resilience?

As noted by Glick *et al.* (2011), several general adaptation principles are broadly applicable:

- Reducing existing stressors

- Manage for ecosystem function
- Protect refugia and improve habitat connectivity
- Implement proactive management and restoration

Coho salmon adaptive responses to climate change include the use of climate-buffered habitat such as floodplains and off-channel habitat, the use of thermal refugia, or changes in migration timing. Some anthropogenic threats specifically affect these responses, such as loss of hydrologic connectivity, loss of riparian vegetation and run-off from impermeable surfaces, these tend to increase stream temperature and flash flows. Beechi *et al* (2012) found that restoring floodplain connectivity, restoring stream flow regimes, and re-aggrading incised channels were most likely to improve stream flow and temperature changes and increase habitat diversity and resilience in light of climate change impacts. Riparian ecosystems that are not degraded are naturally resilient and may provide adaptive support in mitigating adverse climate change impacts (Seavy *et al.*, 2009). The table below combines the effects and ecological consequences to coho salmon identified in Table 1 with potential adaptation strategies and actions that were identified in the 2019 OC Coho Conservation Plan 12-year Assessment found [here](#).

Table 2. Effects and ecological consequences to coho salmon with adaptation strategies and actions. Modified from Beechie *et al* (2013), Wainwright and Weitkamp (2013), and Reeves *et al.* (2018).

Projected Effects	Potential Ecological Consequences for Coho Salmon	Adaptation Strategies	Priority Actions
Increased summer water temperature	<p>Reduced juvenile rearing habitat</p> <p>Reduced or increased juvenile growth rates depending on temperature and available food resources</p> <p>Increased susceptibility to disease</p> <p>Increased predation risk from non-native warmwater fish species</p>	<p>Prioritize restoration actions in watersheds (e.g. fifth-field HUCs) with cooler water</p> <p>Increase stream shading</p> <p>Protect and restore instream flows</p> <p>Increase surface-subsurface water exchange</p>	<p>Increase temperature monitoring</p> <p>Restore incised channels and riparian vegetation</p> <p>Purchase or lease water rights from willing sellers to place instream</p> <p>Increase floodplain connectivity</p> <p>Restore access to cooler water</p>

		Restore lateral and longitudinal connectivity	
Reduced summer flows	<p>Reduced juvenile rearing habitat</p> <p>Reduced juvenile growth rates</p>	<p>Protect and restore instream flows</p> <p>Restore floodplain aquifer storage</p> <p>Manage watersheds to reduce evapotranspiration loss</p>	<p>Purchase or lease water rights from willing sellers to place instream</p> <p>Promote beavers and beaver-related pool habitat</p> <p>Restore incised channels</p> <p>Research forest management options to increase base flows</p>
Increase in winter flows and major storm events	<p>Increased sediment input and transport</p> <p>Increased large wood recruitment and transport</p> <p>Increased redd scour and egg mortality</p> <p>Reduced juvenile overwinter survival transport</p>	<p>Increase stream complexity</p> <p>Increase estuary rearing habitat</p>	<p>Restore incised channels and riparian vegetation</p> <p>Protect and enhance large wood sources in landslide-prone areas</p> <p>Increase floodplain connectivity</p> <p>Promote beavers and beaver-related pool habitat</p> <p>Restore and improve access to key estuary habitats</p>
Increased sea surface temperature	<p>Altered marine food web</p> <p>Increased predation risk</p> <p>Increased thermal stress</p> <p>Reduced marine growth and survival</p>	<p>Increase freshwater and estuarine rearing habitat</p> <p>Promote life history diversity</p>	<p>Monitor ocean ecosystem indicators</p> <p><i>See freshwater and estuarine adaptive habitat actions listed above</i></p>

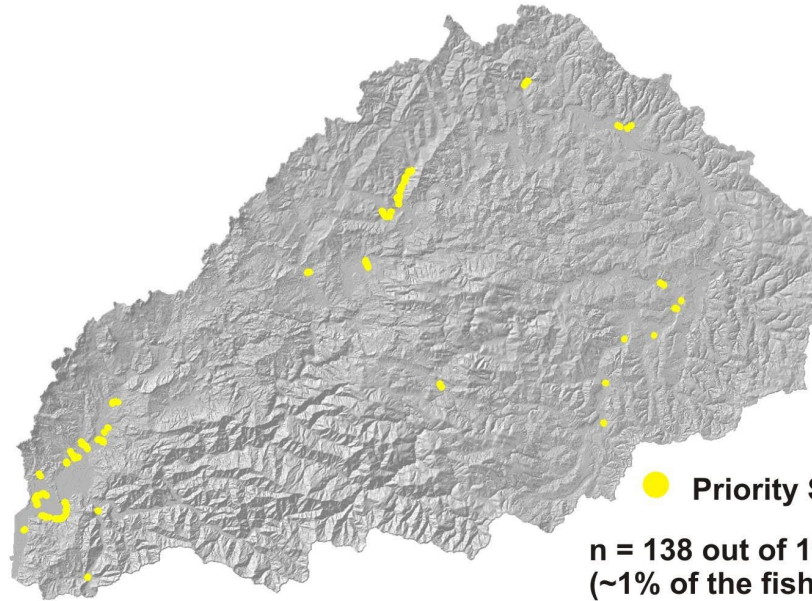
<p>Sea Level Rise</p>	<p>Reduced tidal wetland habitat</p> <p>Altered estuarine food web</p> <p>Reduced or increased estuarine rearing habitat</p>	<p>Reduce anthropogenic barriers to tidal influence and estuarine habitat expansion</p> <p>Improve estuary water quality</p> <p>Improve fish access to estuary habitat</p>	<p>Restore natural tidal flow where possible</p> <p>Support land acquisition and easements along estuaries</p> <p>Reduce nonpoint pollution to improve coastal water quality</p> <p>Prioritize and implement tidegate fish passage improvements</p>
<p>Increased ocean Acidification</p>	<p>Altered marine food web</p> <p>Sensory impacts</p> <p>Reduced marine growth and survival</p>	<p>Increase freshwater and estuarine rearing habitat</p> <p>Promote life history diversity</p> <p>Reduce local stressors that increase ocean acidification impacts</p>	<p>Monitor ocean ecosystem indicators</p> <p><i>See freshwater and estuarine adaptive habitat actions listed above</i></p> <p>Reduce nonpoint pollution to improve coastal water quality</p>

Along with adaptation strategies and actions, we need to adapt how we monitor for and measure success when implementing a restoration action. Due to climate change impacts and rapidly changing climate conditions, we must not only consider historical reference conditions but also projections of future climate and ecological conditions to gauge success (Glick *et al* 2011). Additional filters to consider when evaluating measures for success are whether better conditions for the following year were promoted, and whether biological integrity was improved.

Tools for Optimizing Restoration Outcomes

The NetMap Portal free online mapping application (<https://terrainworks.com/netmap-portal>) was developed to ease access and use of virtual watershed information in the form of maps. Searches can be made to identify locations where multiple attributes overlap, like the highest 1% of coho salmon habitat quality and the highest 10% of erosion potential. Using stream layer and landscape attributes, NetMap can be used to identify potential restoration targets, such as the example below.

Highest 10% of coho habitat + highest 10% of floodplain width + lowest 10% wood recruitment + lowest 10% of basal area (shade)



● Priority Sites

n = 138 out of 11,518 reaches
(~1% of the fish network, length
19.5 km)

Note: The resources provided include references from the resources cited, in addition to other available resources not referenced that may be useful for planning processes.

Resources

- Beechi, T., Imaki, H., J. Greene, J., Wade, A., Wu, H., Pess, G., Roni, P., Kimball, J. Stanford, J., Kiffney, P. & Mantua, N. 2012. Restoring Salmon Habitat for a Changing Climate. *River Research and Applications*, Wiley Online Library, doi: 10.1002/rra.2590
- Brophy, L., & Ewald, M. (2017). Modeling sea level rise impacts to Oregon's tidal wetlands: Maps and prioritization tools to help plan for habitat conservation into the future. [10.13140/RG.2.2.19021.79845](https://doi.org/10.13140/RG.2.2.19021.79845)
- Brophy, L.S., Greene, C.M., Hare, V.C., Holycross, B., Lanier, A., & Heady, W.N. (2019) Insights into estuary habitat loss in the western United States using a new method for mapping maximum extent of tidal wetlands. *PLoS ONE* 14(8): e0218558. doi.org/10.1371/journal.pone.0218558

- Cai, W.J., Feely, R. A., Testa, J. M., Li, M., Evans, W., Alin, S. R., & N. Bednaršek. (2020). Natural and anthropogenic drivers of acidification in large estuaries. *Annual Review of Marine Science*, 13(1), 23–55. doi.org/10.1146/annurev-marine-010419-011004
- Dalton, M., & Fleishman, E. editors. 2021. Fifth Oregon Climate Assessment. Oregon Climate Change Research Institute, Oregon State University, Corvallis, Oregon. <https://blogs.oregonstate.edu/occri/oregon-climate-assessments/>.
- Glick, P., Stein, B.A., & Edelson, N.A. (eds.) 2011. *Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment*. National Wildlife Federation, Washington, D.C.
- Halofsky, J., Peterson, D., & Harvey, B. 2020. Changing wildfire, changing forests: the effects of climate change on fire regimes and vegetation in the Pacific Northwest, USA. *Fire Ecology*. 16. 4. 10.1186/s42408-019-0062-8. <http://dx.doi.org/10.1186/s42408-019-0062-8>
- Hamman, J.J., B. Nijssen, T.J. Bohn, D.R Gergel and Y. Mao. 2018. The Variable Infiltration Capacity model version 5 (VIC-5): infrastructure improvements for new applications and reproducibility, *Geoscientific Model Development*, 11:3481–3496. doi.org/10.5194/gmd-11-3481-2018
- IPCC (Intergovernmental Panel on Climate Change). 2007. *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*. Metz, B., Davidson, O.R., Bosch, P.R., Dave, R. & Meyer, L.A. (eds.) Cambridge University Press, Cambridge, UK.
- IPCC, 2012: Glossary of Terms. In: *Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation* [Field, C.B., Barros, V., Stocker, T.F., Qin, D., Dokken, D.J., Ebi, K.L., Mastrandrea, M.D., Mach K.J., Plattner G.K., Allen, S.K., Tignor, M. & Midgley, P.M. (eds.)]. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, Cambridge, UK, and New York, NY, USA, pp. 555-564. https://archive.ipcc.ch/pdf/special-reports/srex/SREX-Annex_Glossary.pdf
- IPCC. 2014: *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team, Pachauri, R.K. & Meyer, L.A. (eds.)]. IPCC, Geneva, Switzerland, 151 pp.

- Isaak, D.J.; Wenger, S.J.; Peterson, E.E.; Ver Hoef, J.M.; Hostetler, S.W.; Luce, C.H.; Dunham, J.B.; Kershner, J.L.; Roper, B.B.; Nagel, D.E.; Chandler, G.L.; Wollrab, S.P.; Parkes, S.L.; & Horan, D.L. 2016. NorWeST modeled summer stream temperature scenarios for the western U.S. Fort Collins, CO: Forest Service Research Data Archive. <https://doi.org/10.2737/RDS-2016-0033>. <https://usfs.maps.arcgis.com/apps/webappviewer>
- Kauffman, J.B., Giovanonni, L., Kelly, J., Dunstan, N., Borde, A., Diefenderfer, H., Cornu, C., Janousek, C., Apple, J., & Brophy, L. 2020. Total ecosystem carbon stocks at the marine-terrestrial interface: Blue carbon of the Pacific Northwest Coast, United States. *Global Change Biology*. 2020; 00:1–14. [doi:10.1111/gcb.15248](https://doi.org/10.1111/gcb.15248)
- Liang, X., D.P. Lettenmaier, E.F. Wood and S.J. Burges. 1994. A simple hydrologically based model of land surface water and energy fluxes for general circulation models. *Journal of Geophysical Research: Atmospheres*, 99:14415-14428. doi.org/10.1029/94JD00483
- NetMap Portal is a free online mapping application that was developed to ease access and use of virtual watershed information in the form of maps. Users can pan, zoom in and out, and search for specific watershed attributes, like the best fish habitats, highest erosion potential, best riparian areas and widest floodplains, among other attributes. <https://terrainworks.com/netmap-portal>
- Olsen, L.M., Major, G., Shein, K., Scialdone, J., Ritz, S., Stevens, T., Morahan, M., Aleman, A., Vogel, R., Leicester, S., Weir, H., Meaux, M., Grebas, S., Solomon, C., Holland, M., Northcutt, T., Restrepo, R. A., & Bilodeau, R. 2013. NASA/Global Change Master Directory (GCMD) Earth Science Keywords. <https://svs.gsfc.nasa.gov/30556>
- Peck, E. K., Wheatcroft, R. A., & Brophy, L. S. 2020. Controls on sediment accretion and blue carbon burial in tidal saline wetlands: Insights from the Oregon coast, USA. *Journal of Geophysical Research: Biogeosciences*, 125, e2019JG005464. doi.org/10.1029/2019JG005464
- Perry, T., & Jones, J. 2016. Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA: Summer streamflow deficits from regenerating Douglas-fir forest. *Ecohydrology*. <http://dx.doi.org/10.1002/eco.1790>.
- Reeves, G.H., Olsen, D. H., Wondzell, S. M., Bisson, P. A., Gordon, S, Miller, S.A., Wang, J.W. & Furness, M.J. 2018. Chapter 7: The aquatic conservation strategy of the northwest forest plan—A review of the relevant science after 23 years. In: Spies, T.A.; Stine, P.A.; Gravenmier, R.; Long, J.W.; Reilly, M.J., tech. coords. 2018. Synthesis of science to inform land management within the Northwest Forest Plan area. Gen. Tech. Rep. PNW-GTR-966. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station: 461-624.

- Seavy, N.E., Gardali, T., Golet, G.H., Griggs, F.T., Howell, C.A. , Kelsey, R., Small, S. L., Viers, J.H. & Weigand, J.F. 2009. Why climate change makes riparian restoration more important than ever: Recommendations for practice and research. *Ecological Restoration*, 27:3.
- The Climate Impact Lab explores the ways climate change will impact where you live, work and do business. Building the world’s most comprehensive body of research quantifying the impacts of climate change, sector-by-sector and community-by-community around the world. Provides air temperature projection map of USA. <https://impactlab.org/>
- The State of the Climate is a collection of monthly summaries recapping climate-related occurrences on both a global and national scale. <https://www.ncdc.noaa.gov/sotc/>
- USGCRP (U.S. Global Change Research Program), 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II [Reidmiller, D.R., Avery, C.W., Easterling, D.R., Kunkel, K.E., Lewis, K.L.M., Maycock, T.K. & Stewart B.C. (eds.)]. U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. <https://nca2018.globalchange.gov/>
- Wainwright, T.C., & Weitkamp, L.A. 2013. Effects of climate change on Oregon Coast Coho Salmon: Habitat and life-cycle interactions. Newport Research Station, Northwest Fisheries Science Center, National Oceanic and Atmospheric Administration, 2032 SE OSU Drive, Newport, Oregon 97365
- Williams, J. E., Neville, M., Haak, A., Coyler, W. T., Wenger, S. J. & Bradshaw, S. 2015. Climate Change Adaptation and Restoration of Western Trout Streams: Opportunities and Strategies. *Fisheries*, 40:7.

Other Resources

- Climate Change 101-Frequently asked questions and answers are from the USDA Forest Service Climate Change Resource Center (CCRC), which addresses more questions on ecosystem effects and management options. <https://www.climatehubs.usda.gov/climate-change-101>
- NOAA Climate.gov-Provides scientific data and information about climate, including reusable climate maps. <https://www.climate.gov/maps-data>

- The NatureServe Climate Change Vulnerability Index identifies plant and animal species that are particularly vulnerable to the effects of climate change.
<https://www.natureserve.org/conservation-tools/climate-change-vulnerability-index>
- Managed by EcoAdapt, the Climate Adaptation Knowledge Exchange (CAKE) is a knowledge sharing platform featuring high-quality climate change adaptation case studies, tools, and resources spanning all phases of the adaptation process (assessment, planning, implementation, evaluation and monitoring).
<https://www.cakex.org/resources/region/northwest-6996>
- Yale Program on Climate Change Communication developed a geographic and statistical model to downscale national public opinion results to the state, congressional district, and county levels. We can now estimate public opinion across the country and a rich picture of the diversity of Americans' beliefs, attitudes, and policy support is revealed.
<https://climatecommunication.yale.edu/visualizations-data/ycom-us/>