Lower Columbia Fish Recovery Board

Climate Change and Habitat Priorities

Introduction

The WA Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan (Recovery Plan) uses an ecosystem approach to salmon and steelhead recovery by considering how threats affect the viability of salmon and steelhead populations throughout their entire life cycle. The Recovery Plan identifies strategies, measures and actions based on identified threats across multiple categories[1], and establishes impact reduction targets for each potentially manageable threat category. Collectively, impact reduction targets identify the overall threat reduction needed to achieve the population viability objectives. The "recovery burden" is equitably allocated among threat categories in proportion to the significance of the threat. The goal of the Recovery Plan is to recover all lower Columbia salmon and steelhead species to healthy and harvestable levels within 25 years.

To help address identified habitat degradation threats, the Lower Columbia Fish Recovery Board (LCFRB) and its Technical Advisory Committee (TAC) annually review and evaluate restoration and protection project proposals for funding through the Salmon Recovery Funding Board (SRFB). Projects are evaluated based on expected Benefits to Fish, Certainty of Success, and Cost (see the LCFRB Evaluation Criteria for more details). An essential component of these evaluation criteria is how well projects target key habitat limiting factors, in the context of both reach- and watershed-scale conditions. Projects that incorporate both short- and long-term habitat needs and consideration of watershed processes over site-specific symptoms are encouraged (see TAC Evaluation Questions). As part of implementing the broader Recovery Plan, this evaluation guidance can also inform water supply and streamflow actions from the Water Resource Inventory Area (WRIA) plans[2].

The Recovery Plan calls for consideration of climate change in establishing protection and restoration priorities for fish populations, and for development of recovery objectives, strategies and measures that adequately consider the likely long-term impacts of climate change on population viability[3]. To help initiate a discussion about incorporating climate change into restoration and protection project evaluation, LCFRB staff formed a TAC sub-committee in Fall 2017 to:

1. Collect and discuss literature related to climate change patterns and impacts to salmon and steelhead habitat in the Pacific Northwest; and to
2. Recommend additional or updated guidance in grant round materials to incorporate climate change considerations into project development and evaluation.

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[1] Seven threats are identified in the recovery plan: subbasin stream habitat and watershed conditions; estuary and mainstem habitat; tributary habitat; hydro-regulation; harvest; hatcheries; ecological; and climate and ocean conditions (LCFRB 2010).

[2] WRIA 25/26, WRIA 27/28, and WRIA 29A Watershed Management and Detailed Implementation plans.

[3] See Volume 1, Chapter 5 (Climate and Ocean Effects) for details on this guidance (LCFRB 2010).

Predicted Climate Change Effects on Watershed Processes

One consideration of long-term habitat restoration needs is the effect of climate change on watershed processes. Watershed processes and habitat conditions are influenced by climate, geology, vegetation, and topography across space and time (Montgomery 1999; Wiens 2002). In terms of climate change, multiple models predict effects to temperature and precipitation patterns in the Pacific Northwest (Mantua et al. 2009; Dalton et al. 2013). In Washington State, temperature is expected to increase from 1.8 – 6.1 ° Celsius by 2070-2099, with the largest increases occurring in eastern Washington and during the summer across the state (Mantua et al. 2009; Dalton et al. 2013). Precipitation changes are more variable and expected to shift seasonally, with greater frequency and magnitude of winter high flow and summer low flow events (Mantua et al. 2009; Dalton et al. 2013). The majority of watersheds in the Pacific Maritime Mountain and Western Cordillera ecoregions[4] are expected by the 2040's to experience increases in bankfull flows by 17.2% and 26.5%, respectfully (Wilhere et al. 2017a). These increases in flows are expected to result in increases in bankfull widths, with a mean percent increase of 8.1 % in the Pacific Maritime Mountain Ecoregion and of 5.6% for the Western Cordillera Ecoregion by the 2040's (Wilhere et al. 2017a). In addition to hydrologic regime shifts, human water supply demand will likely also change, further increasing the demand for water during hot, low flow periods (Mantua et al. 2009; Mote and Snover 2014). These climate and water demand increases could result in changes in both quality and quantity of habitat available to salmon and steelhead, with potential losses and gains. For example, larger and more frequent high flow events may lead to greater floodplain inundation and reconnection of higher elevation habitats, although these gains may be negated by stranding issues as flows decline, or thermal barriers during low flow periods.

Temperature increases are expected to not only directly warm fish habitat, but also shift hydrologic regimes. The transition from snowmelt-dominated and transitional hydrologic regimes (snow and rainfall) to transitional and rainfall-dominated regimes are predicted across the Pacific Northwest (Mantua et al. 2009; Beechie et al. 2013). In the Columbia River basin, rainfall-dominated regimes are expected for almost all watersheds by 2070-2099 (Mantua et al. 2009; Beechie et al. 2013). Similarly to thermal regime changes, predicted flow conditions will affect the quality and quantity of habitat that is seasonally available to salmon and steelhead. Habitat project planning and design should consider all of these current and predicted watershed processes trends in order to successfully address long-term habitat needs for targeted species.

Estuarine habitat is essential for rearing and migration for all Columbia River salmon and steelhead, and is predicted to be impacted by climate change effects on sea level, food webs, and ocean acidification (Mote and Snover 2014). In general, climate change is expected to increase the volume of water via thermal expansion, glacier and ice sheet melting, and increases in on-land water storage, leading to global sea level rise. Absolute sea level rise is expected across Washington State, although relative sea level rise, which is effected by local vertical land movement, is still being assessed (Morgan et al. 2017). Modeling specific to the Columbia River shows increased salinity intrusion distance upstream and plume volume decreases relative to 2010 across most climate model scenarios (Baptista et al. 2016). These ocean and estuarine conditions could result in coastal wetlands, tidal flats, and beach habitat changes in

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[4] The Pacific Maritime Mountains ecoregion includes the coast strata of the Lower Columbia region, while the Western Cordillera ecoregion includes the cascade and gorge strata.

quality and quantity (Mote and Snover 2014). This will especially be an issue where natural and anthropogenic barriers prevent habitats from shifting further inland.

Climate Change and Fish Life Histories

Salmon and steelhead will be effected by flow and temperature shifts differently, depending on their life history patterns and temperature tolerances (Figure 1). Stream-type fish, such as coho salmon, steelhead, and spring Chinook, will be more negatively affected by summer flow and temperature changes than ocean-type fish like fall Chinook and chum salmon (Mantua et al. 2009). This is especially true for populations that rely on higher-elevation habitat, such as spring Chinook (Battin et al. 2007). Ocean-type fish will likely be more affected by reduced spawning habitat conditions in the fall, as well as redd scour from earlier and more severe peak winter flood conditions (Mantua et al. 2009). Fish movement could also be impacted, as water temperatures of 21 – 22 ° Celsius can prohibit migration (Mantua et al. 2009). Temperature changes can also result in community shifts. For instance, water temperatures greater than 15 ° Celsius can increase predation and competition from warm water fish, (summarized in Mantua et al. 2009). Given the number of ESA-listed species and diversity of life history patterns exhibited in the Lower Columbia Region, it is important to understand how climate change will influence effectiveness of habitat restoration and protection efforts at addressing key and diverse life history needs.

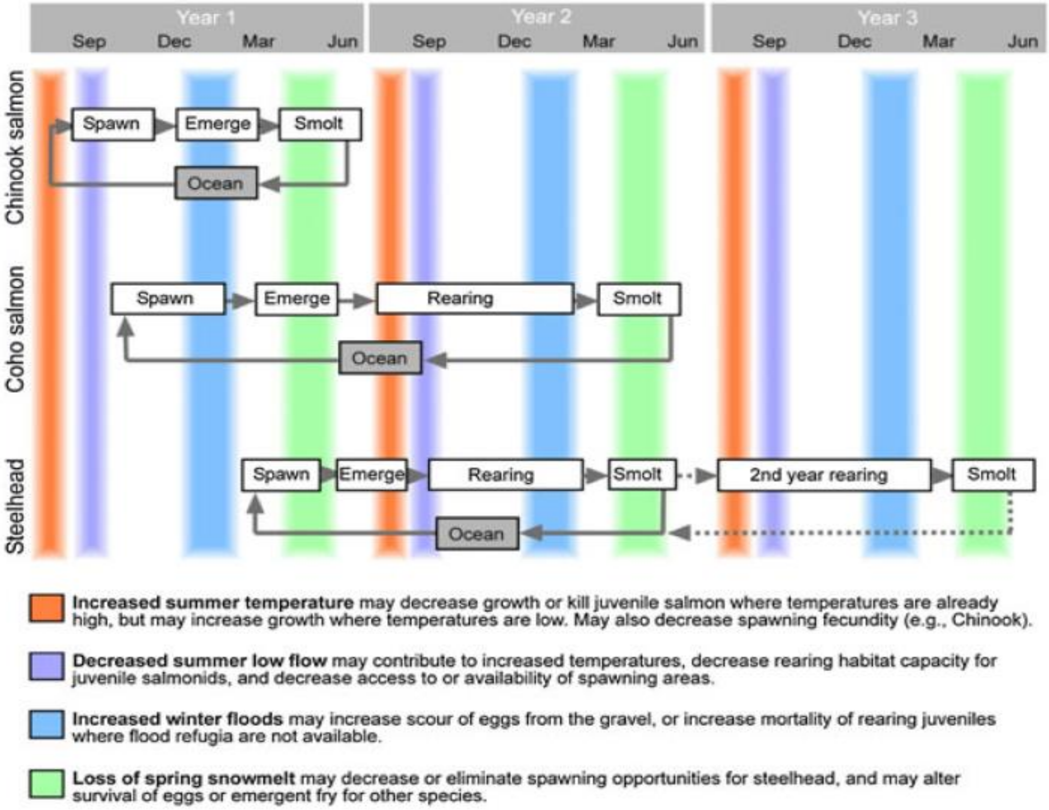


Figure 1. The overlap between expected climate change effects to stream flow and temperature and fall Chinook, coho salmon, and steelhead (Beechie et al. 2013).

Considerations for Project Design and Evaluation

Multiple studies synthesize predicted temperature and flow conditions under climate change scenarios with fish life histories and restoration project design considerations. Below is a synopsis of this information, and how to apply it to regional habitat restoration and protection project evaluation. Sponsors are also encouraged to consult other manuals and resources as they select project sites and develop designs, including Washington Department of Fish and Wildlife's Stream Habitat Restoration Guidelines and the University of Washington Climate Impact Group online resources. Additionally, staff will consider a climate change scenario in future Ecosystem Diagnosis and Treatment (EDT) model runs for tributary habitat in the region, as this information is used to inform the regional habitat strategy.

Certain restoration and protection approaches are expected to mitigate for some climate change impacts to salmon and steelhead habitat. However, as climate change is expected to degrade watersheds across the full region, protection efforts alone are not likely to mediate for losses in habitat quality and quantity (Battin et al. 2007; Wade et al. 2013). Studies recommend that restoration and protection efforts in the Pacific Northwest focus on floodplain and off-channel connectivity to mediate for increased winter flow events, and to increase local water storage in basins where summer flow conditions are expected to decline (Battin et al. 2007; Mantua et al. 2009; Beechie et al. 2013). Local water storage can be increased through improving hyporheic exchange, as well as increasing local water infiltration in slow velocity habitats. Reducing effective impervious surface area can also lead to increased local water infiltration and reduced risk of habitat loss during high flow events (Mantua et al. 2009). Riparian restoration could reduce summer temperature increases, although efforts should focus on headwater areas more so than wide, mainstem lower watershed reaches (Battin et al. 2007).

As stream flows and sediment transport increase in the winter, channel area is expected to increase in response. As culverts are typically designed with a 50 – 100 year life span, it is essential that designs today consider how future flow and sediment processes may affect channel conditions (Wilhere et al. 2017a). As stream flow and bankfull widths are expected to increase by the 2040's in regional streams, culverts installed today will likely be interacting with these wider channel conditions (Wilhere et al. 2017a). If culverts are not designed to accommodate expanding bankfull widths, undersized culverts could create fish passage barriers, damage habitat, and require increased maintenance and repair (Wilhere et al. 2017b). Therefore, it is important to weigh the risks and benefits from incorporating climate change projected bankfull width changes into current designs (Wilhere et al. 2017b).

It is not well understood how fish may adapt to changing habitat conditions, and it is therefore important to protect genetic and life history diversity where possible (Battin et al. 2007; Crozier et al. 2008; Mantua et al. 2009). Part of this entails restoring and protecting habitat diversity across species ranges (Wade et al. 2013; Beechie et al. 2013). However, main channel habitat diversity alone will not support resiliency in light of climate change scenarios. Restoring incised channels so that they are more frequently laterally connected to complex floodplains and ponded, off-channel habitat could promote life history diversity and greater population resiliency (Beechie et al. 2013).

Climate change effects on watershed processes, and how restoration and protection projects can address negative impacts to fish, are summarized in Table 1 below.

Table 1. Summarized climate change effects to watershed processes in the Lower Columbia region. Expected habitat responses are included for each climate change effect, as well as subsequent fish impacts due to habitat changes. Restoration and protection efforts that could support resiliency of fish in light of these changes are recommended in the last column. Arrows indicate the direction of change: ↓ = decrease, ↑ = increase, and ↕ = unknown or both increase and decrease specified response or action.

Climate Change Effect	Watershed location	Habitat Impacts	Fish impact	Restoration/Protection Considerations
↑ sea level rise	Tidally-influenced habitat	↓ tidal edge habitat quantity, quality, and diversity ↑ salinity intrusion upstream and upland ↓ ocean plume volume	↓ tidal edge rearing habitat ↓ tidal edge (wetland) nutrient sources ↓ support of life history diversity	↓ barriers to fish laterally (floodplain) and longitudinally (upstream) of current tidal range ↑ complexity to floodplain, wetland, and upland habitat to promote diverse tidal edge habitat and to support life history diversity ↑ upland habitat area in acquisition projects to provide adequate buffer to vertical sea level encroachment ↕ incorporate expected relative sea level rise in designing water crossing structures in tidal areas.
↑ water temperatures	Throughout, but biggest impacts in areas without adjacent or upland mature forests, and surface water withdrawals.	↑ rainfall-dominated flow regimes ↑ warm water species range ↓ dissolved oxygen ↑ primary production	↑ stress and mortality ↓ fish passage and habitat availability ↕ altered food webs ↓ support of life history diversity	↑ complexity and connectivity of floodplain, off-channel/side-channel, wetland, and tributary headwater habitat to promote local water infiltration, storage, and temperature moderation, and to support life history diversity ↑ mature forest and riparian stands to promote local water infiltration, storage, and temperature moderation, and to support life history diversity ↑ connectivity and quality of cold water refugia ↑ implementation of WRIA water supply and instream flow actions that support improvement to instream flows

Climate Change Effect	Watershed location	Habitat Impacts	Fish impact	Restoration/Protection Considerations
↑ winter flow magnitude and frequency	Throughout, but greater impacts in watersheds with current and future rainfall-dominated regimes and urbanized areas.	↑ floodplain and off-channel/side-channel inundation ↑ headwater and tributary connectivity ↑ wood and sediment mobility ↑upland material inputs ↑ bankfull widths ↑ bed scour ↑ water velocity ↑ interaction with developed areas	↕ altered habitat availability depending on complexity of connected refugia and/or stream crossing structure design ↑ stranding (in flashy systems) ↕ redd scour and egg-to-fry survival changes ↕ altered life history diversity from potential additional habitat connectivity and/or increased stranding	↑ complexity and connectivity of floodplain, off-channel/side-channel, wetland, and tributary habitat to provide juvenile flood refugia and protected spawning habitat to support life history diversity and resiliency ↓ effective impervious surface area and stormwater runoff to moderate instream flows by providing local water infiltration and storage ↑ bankfull width conditions for project design
↓ low flow magnitude and frequency	Throughout, but greater impacts in watersheds with current and future rainfall-dominated regimes, urbanized areas, and surface water withdrawals.	↓ floodplain and off-channel/side-channel, wetland connectivity and area ↓ headwater and tributary connectivity and area ↓ instream flows from increased and/or greater impact of water withdrawals ↑ predation and competition from reduced habitat quality and quantity	↑ stress and mortality for rearing fish ↑ stranding ↓ fish passage and habitat availability ↓ support of life history diversity ↕ altered food webs ↓ holding and spawning opportunities for fall spawners	↑ complexity and connectivity of floodplain, off-channel/side-channel, wetland, and tributary habitat to promote local water storage, to moderate low flow conditions, and to support life history diversity ↑ mature headwater forest and riparian habitat to promote local water storage, to moderate low flow conditions, and to support life history diversity ↑ connection and quality of cold water refugia ↑ implementation of WRIA water supply and instream flow actions that support improvement to instream flows

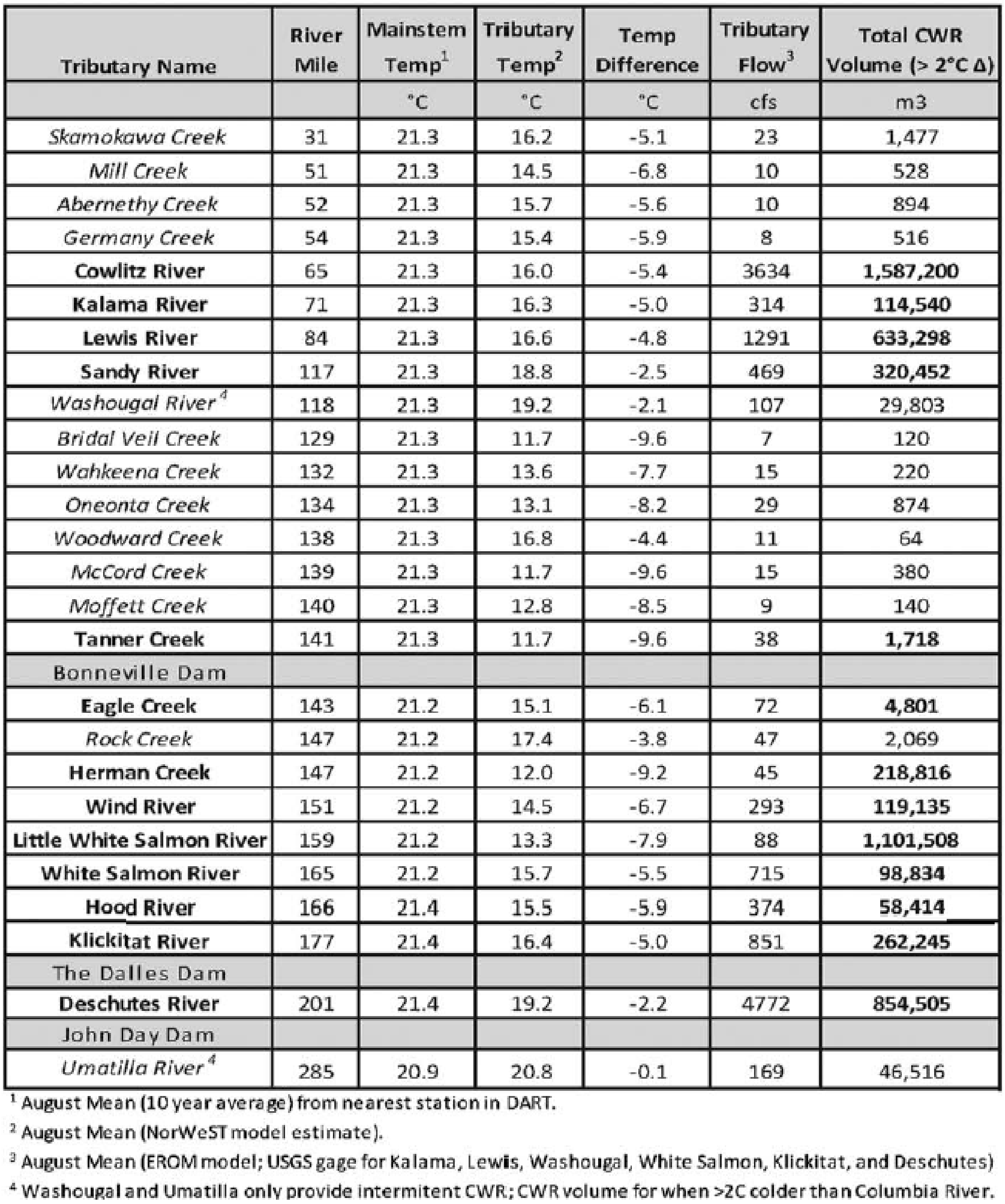
In addition evaluating projects in relation to watershed processes, it is important to consider how these processes may shift due to climate change. To address climate change considerations, staff is recommending the following language be added to the TAC evaluation questions:

- Certainty of Success, Scope and Approach (Question 1a):
  - Does the proposed approach adequately provide for and incorporate watershed and site conditions that could affects its success in the long-term, including climate change effects on watershed processes?
  - To what extent does the proposal address how watershed conditions and processes will affect the long-term success of the proposed project, including climate change effects on watershed processes?
- Certainty of Success, Scope and Approach (Question 1b):
  - Will the proposed approach adequately address watershed and site conditions in the long-term, including climate change effects on watershed processes?

Staff is also recommending that the following restoration and protection considerations, along with Table 1, be added to the Evaluation Criteria for sponsors to consider when developing proposals:

1. Proposals should address **habitat diversity**, which is necessary to support life history diversity and population and species resiliency. Establishing, improving or preserving longitudinal (tributaries), lateral (off-channel/side-channel, floodplains, wetlands), and vertical connections (re-aggrading channels) are important considerations for effectively addressing climate change. Life history diversity is supported when a variety of complex and diverse (i.e. flow heterogeneity) habitats are available to fish to use across life stages.
2. Connection to and enhancement/preservation of **cold water refugia** are essential for priority populations that are, or likely will be, limited by thermal stress, such as stream-type salmon and steelhead populations. Table 2 below identifies preliminary cold water refugia habitat available to fish migrating through the Lower Columbia mainstem. Increasing hyporheic exchange via increased vertical habitat connectivity can also support cold water refugia.
3. **Mature riparian and upland forest** restoration and protection is essential to reducing temperature increase rates, although watershed-scale benefits are more likely in small tributary and headwater habitats.
4. Providing and maintaining access to **high quality floodplain habitat** is essential to reducing negative impacts to fish resulting from increased magnitude and frequency of high flow events. Efforts to increase quality and connectivity of floodplain areas will benefit both stream-type and ocean-type salmon and steelhead.
5. **Mid and lower watershed areas** should be targeted for restoration and protection efforts when additional headwater work cannot fully offset climate change impacts. This may be true for headwater areas with already mature forest stands and limited anthropogenic fish barriers.
6. Implement **WRIA water supply and instream flow actions** that directly and/or indirectly support increased quality and quantity of fish habitat. This is especially important when addressing impacts to fish habitat from expected increases in low flow magnitude and frequency, as well as increases in summer temperatures.

Table 2. Preliminary results of identified tributaries that provide cold water refuge to salmon and steelhead in the Lower Columbia mainstem (Palmer 2017). The 13 tributaries in bold text provide the most cold water refuge area based on modeled flow, cold water refuge (CWR) volume, and temperature. The italicized tributaries listed provide less cold water habitat because of lower relative temperature differences between tributaries and the Columbia River and/or lower available CWR area.



Tributary Name	River Mile	Mainstem Temp[1]	Tributary Temp[2]	Temp Difference	Tributary Flow[3]	Total CWR Volume (> 2°C Δ)
		°C	°C	°C	cfs	m3
Skamokawa Creek	31	21.3	16.2	-5.1	23	1,477
Mill Creek	51	21.3	14.5	-6.8	10	528
Abernethy Creek	52	21.3	15.7	-5.6	10	894
Germany Creek	54	21.3	15.4	-5.9	8	516
Cowlitz River	65	21.3	16.0	-5.4	3634	**1,587,200**
Kalama River	71	21.3	16.3	-5.0	314	**114,540**
Lewis River	84	21.3	16.6	-4.8	1291	**633,298**
Sandy River	117	21.3	18.8	-2.5	469	**320,452**
Washougal River[4]	118	21.3	19.2	-2.1	107	29,803
Bridal Veil Creek	129	21.3	11.7	-9.6	7	120
Wahkeena Creek	132	21.3	13.6	-7.7	15	220
Oneonta Creek	134	21.3	13.1	-8.2	29	874
Woodward Creek	138	21.3	16.8	-4.4	11	64
McCord Creek	139	21.3	11.7	-9.6	15	380
Moffett Creek	140	21.3	12.8	-8.5	9	140
Tanner Creek	141	21.3	11.7	-9.6	38	**1,718**
Bonneville Dam						
Eagle Creek	143	21.2	15.1	-6.1	72	**4,801**
Rock Creek	147	21.2	17.4	-3.8	47	2,069
Herman Creek	147	21.2	12.0	-9.2	45	**218,816**
Wind River	151	21.2	14.5	-6.7	293	**119,135**
Little White Salmon River	159	21.2	13.3	-7.9	88	**1,101,508**
White Salmon River	165	21.2	15.7	-5.5	715	**98,834**
Hood River	166	21.4	15.5	-5.9	374	**58,414**
Klickitat River	177	21.4	16.4	-5.0	851	**262,245**
The Dalles Dam						
Deschutes River	201	21.4	19.2	-2.2	4772	**854,505**
John Day Dam						
Umatilla River[4]	285	20.9	20.8	-0.1	169	46,516

[1] August Mean (10 year average) from nearest station in DART.

[2] August Mean (NorWeST model estimate).

[3] August Mean (EROM model; USGS gage for Kalama, Lewis, Washougal, White Salmon, Klickitat, and Deschutes)

[4] Washougal and Umatilla only provide intermitent CWR; CWR volume for when >2C colder than Columbia River.

Reference Library

Literature on climate change impacts to salmonids and tributary and tidal habitat were collected by staff and sub-committee members. Collected information was centralized in a Dropbox folder for future reference and updates[5]. References cited in in this document are listed below:

1. Baptista, A., Rostaminia, M., Turner, P., Kärnä, T., and Lopez, J. 2016. Salinity in the Willamette River, Seriously: Estuarine tales of rising seas, seismic subsidence, and uncertainty. *Presentation at the Columbia River Estuary Conference*, Astoria, OR.
2. Battin, J., Wiley, M., Ruckelshaus, M., Palmer, R., Korb, E., Bartz, K. and Imaki, H., 2007. Projected impacts of climate change on salmon habitat restoration. *Proceedings of the National Academy of Sciences*, *104*(16), pp.6720-6725.
3. Beechie, T., Imaki, H., Greene, J., Wade, A., Wu, H., Pess, G., Roni, P., Kimball, J., Stanford, J., Kiffney, P. and Mantua, N., 2013. Restoring salmon habitat for a changing climate. *River Research and Applications*, *29*(8), pp.939-960.
4. Crozier, L., Zabel, R. and Hamlet, A., 2008. Predicting differential effects of climate change at the population level with life-cycle models of spring Chinook salmon. *Global Change Biology*, *14*(2), pp.236-249.
5. Dalton, M., P. Mote, and A. Snover [Eds.]. 2013. *Climate Change in the Northwest: Implications for Our Landscapes, Waters, and Communities.* Washington, DC: Island Press.
6. Lower Columbia Fish Recovery Board, 2010. Washington Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan.
7. Mantua, N., Tohver, I., Hamlet, A. 2009. Ch. 6: Salmon. *The Washington Climate Change Impacts Assessment: Evaluating Washington's Future in a Changing Climate*. Climate Impacts Group, University of Washington, Seattle, Washington.
8. Montgomery, D., 1999. Process domains and the river continuum. *Journal of the American Water Resources Association*, *35*(2), pp.397-410.
9. Morgan, H., G. Mauger, and I. Miller. 2017. Probabilistic projections of absolute SLR in WA: the devil is in the deep tail. *Presentation at the Northwest Climate Conference*, Tacoma, WA.
10. Mote, P., A. Snover, S. Capalbo, S. Eigenbrode, P. Glick, J. Littell, R. Raymondi, and S. Reeder, 2014: Ch. 21: Northwest. *Climate Change Impacts in the United States: The Third National Climate Assessment*, J. M. Melillo, Terese (T.C.) Richmond, and G. W. Yohe, Eds., U.S. Global Change Research Program, 487-513. doi:10.7930/J04Q7RWX.
11. Palmer, J. 2017. Cold Water Fish Refuges. *The Water Report.* 164. pp. 1-31.
12. Wade, A., Beechie, T., Fleishman, E., Mantua, N., Wu, H., Kimball, J., Stoms, D. and Stanford, J., 2013. Steelhead vulnerability to climate change in the Pacific Northwest. *Journal of Applied Ecology*, *50*(5), pp.1093-1104.
13. Wiens, J., 2002. Riverine landscapes: taking landscape ecology into the water. *Freshwater biology*, *47*(4), pp.501-515.
14. Wilhere, G., Atha, J., Quinn, T., Tohver, I., and Helbrecht, L. 2017a. Incorporating climate change into culvert design in Washington State, USA. *Ecological Engineering*, 104, pp.67-79.
15. Wilhere, G., Atha, J., Quinn, T., Helbrecht, L., and Tohver, I. 2017b. *Incorporating climate change into the design of water crossing structures.* Washington Department of Fish and Wildlife, Climate Impacts Group, and University of Washington.

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[5] Dropbox folder location: https://www.dropbox.com/sh/9em7t76adoqlv5h/AAA3WMD6GE87g8_gRKIY90Lua?dl=0