Climate Change and Fish Habitat Restoration on Columbia River Tribal Lands

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The Columbia River InterTribal Fish Commission Climate Change Project

Introduction

Climate change presents an existential challenge to salmon and steelhead populations in the Columbia River Basin, which are already imperiled from loss of habitat and other limiting factors. Warmer water temperatures, lower summer stream flows, and other impacts are all predicted to become increasingly severe during this century. Freshwater habitat protection and restoration offers an opportunity to mitigate these impacts and increase the resilience of these fish, offering them time while larger scale solutions to the climate crisis are enacted. Ongoing habitat restoration and protection activities have successfully enacted a large number and variety of actions across the watersheds of the Columbia Basin, and are an integral part of tribal salmon recovery plans. Future habitat actions should consider the impacts of climate change including their varying effect across different watersheds in order to ensure long term effectiveness. We analyze past tribal habitat actions in the context of these projections and summarize recommendations for future habitat actions from current research on this topic.

Climate Change and Fish Habitat Restoration in the Pacific Northwest

Native salmon and steelhead fish populations are imperiled throughout their range in the Pacific Northwest because of a variety of causes, notably including the impediments presented by dams and impounded reservoirs along their migratory corridors, freshwater habitat degradation and destruction from human land and water use practices, invasive predators, and changing conditions in the Pacific Ocean. Climate change is exacerbating these effects in freshwater rivers and tributary streams where adult fish migrate and spawn, and juvenile fish rear and out migrate, as well as in the estuary and marine environments, where juvenile fish feed and mature to adulthood. Habitat restoration and protection in Columbia Basin streams and rivers presents an opportunity to mitigate past damage from human disturbances and to help restore fish populations, while also providing resilience to withstand some of the negative impacts of climate change, both present and future.

Climate change is affecting the ecosystems of the Pacific Northwest in a myriad of different ways, many of them detrimental. These changes have become apparent in recent years and are predicted to accelerate in their severity during the 21st century. While the future pace and magnitude of changes include uncertainty, regional downscaling of climate models and simulations provide a high degree of confidence about the most significant effects to expect. Warmer air temperatures during the winter months will cause a transition in precipitation type from snow to rain, especially in mid-elevation mountain watersheds. This change in precipitation type shifts the hydrologic cycle of these watersheds and downstream basins, and has consequent effects on water temperature and quality. Changes to stream flow and water temperature affect salmon and steelhead, both directly through increased stress and mortality and migratory barriers, and indirectly, by making the rivers systems more hospitable to warm-water predators (Crozier et al. 2015, Mantua et al. 2015, Wade et al. 2013). Additionally, many streams and rivers in the range of salmon are already limited by factors from human effects, and climate change presents a synergistic increase in the severity of these factors.

Habitat restoration and protection offers a means to offset at least some of the negative effects of climate change in the streams and rivers that native anadromous fish use during their juvenile and adult life stages. Stream restoration projects have occurred in the Columbia River Basin for many decades, and since the late 1990's/early 2000s, have received steady support from the Bonneville Power Administration (BPA) Fish and Wildlife Program, and the National Oceanic and Atmospheric Administration (NOAA) Pacific Coastal Salmon Recovery Fund (PCSRF), as well as through other funding entities. Projects are implemented by Tribal Nations, State and Federal agencies, and Non-Profit entities. Many of these projects have been designed to address existing problems, such as land use and agricultural practices that have degraded watershed health, development and alteration of the instream and riparian corridors that have compromised the natural function of streams and rivers, barriers that have blocked fish migration, and diversions and consumptive water use that have reduced seasonal stream and river flows. Many of the actions designed to address these problems also ameliorate climate change effects, but generally climate change has not been taken into direct consideration when selecting and designing projects until in recent years.

In order to effectively address these effects, projects must be prioritized and designed to address the changing conditions that are anticipated to occur in the future, rather than the more static historical condition. Climate change effects on the Columbia River Basin and its tributaries have been thoroughly considered in the scientific literature in recent decades (Elsner, et al. 2010, Hamlet, et al. 2013, Isaak, et al. 2012, Vano, et al. 2015). The outputs of general circulation models are downscaled to accurately predict changes in the varied topography of the Pacific Northwest, and used to model future changes to climate, vegetation, and hydrology. In general, the most substantial impacts are derived from the process of warmer air temperatures causing a shift in precipitation type from snowfall to rainfall during the late fall and winter months. Consequent effects include a diminished seasonal snowpack, larger volumes of stream flow during the winter months (as rainfall runs off more quickly), lesser volumes of stream flow during the summer months (as less snowpack remains to support runoff), an earlier peak in the spring freshet, and warmer summer stream temperatures (as a consequence of both lower stream levels and higher air temperatures). The magnitude of this shift will vary by watershed, with transitional zones (where winter air temperatures are currently near freezing) being most affected because they will experience a larger shift from snow to rain with small levels of warming. Snow-dominant watersheds are better situated to withstand temperature increases in the near-term, but susceptible in the long-term depending on quickly and dramatically air temperatures rise.

In recent years, researchers have proposed methods to prioritize and design habitat restoration and protection to better incorporate the implications of climate change for salmon and steelhead.

Battin, et al. (2007) addressed how best to prioritize areas for restoration to withstand climate change. They investigated the impacts of climate change on the effectiveness of proposed habitat restoration efforts designed to recover depleted Chinook salmon populations in a Pacific Northwest river basin. They found that river basins that span the current snow line appear especially vulnerable to climate change, and salmon recovery plans that enhance lower-elevation habitats are likely to be more successful over the next 50 years because those habitats will change less than the higher-elevation basins likely to experience the greatest snow–rain transition.

Nelitz, et al. (2007) researched and presented an approach to help government decision makers and local communities decide upon appropriate actions to protect salmon in western Canada against climate change. This approach included a discrete set of steps for robust habitat protection planning including to (i) Identify issues of concern; (ii) Assess vulnerabilities; (iii) Summarize assets; and (iv) Describe adaptation strategies. More specifically, they found it likely that physical (in-stream) habitat modifications will likely not be effective in the long term, and watershed-scale actions were instead needed.

Beechie, et al. (2013) considered how habitat restoration planning should be altered to consider projected decreases to summer stream flow and increases to summer water temperature by evaluating habitat restoration actions and whether they are likely to ameliorate these climate change effects. They developed a decision support process for adapting salmon recovery plans that incorporates (1) local habitat factors limiting salmon recovery, (2) scenarios of climate change effects on stream flow and temperature, (3) the ability of restoration actions to ameliorate climate change effects, and (4) the ability of restoration actions to increase habitat diversity and salmon population resilience. They found that actions that restore floodplain connectivity, restore stream flow regimes, and re-aggrade incised channels are most likely to ameliorate stream flow and temperature changes and increase habitat diversity and population resilience. By contrast, they found that "most restoration actions focused on in-stream rehabilitation are unlikely to ameliorate climate change effects."

Perry, et al. (2015) advocated for using flexible approaches to plan future restoration methods given the uncertainty surrounding future climate change effects. They provided examples of how climate change might be incorporated into restoration planning at the key stages of assessing the project context, establishing restoration goals and design criteria, evaluating design alternatives, and monitoring restoration outcomes. Using their approach, planners can incorporate predictions of climate change impacts to assess which species or ecosystem services will be most vulnerable under future conditions, and which sites will be most suitable for restoration. In order to accommodate future changes, planners may need to adjust their methods for "planting, invasive species control, channel and floodplain reconstruction, and water management". Given the "considerable uncertainty" of future climate outcomes, planners will need to "consider multiple potential future scenarios, implement a variety of restoration methods, design projects with flexibility to adjust to future conditions, and plan to respond adaptively to unexpected change".

Justice, et al. (2017) implemented a water temperature model to assess the benefits of habitat restoration scenarios in a N.E. Oregon Basin and considered these in the context of projected water temperature increases. They found that a combination of riparian restoration and channel narrowing could reduce peak summer water temperatures by 6.5 C on average in the Upper Grande Ronde River and 3.0 C in Catherine Creek if fully implemented, with substantial consequent increases in Chinook Salmon parr abundance of 590% and 67% respectively.

Quaempts, et al. (2018) presented an approach to protect tribal first foods that builds a management vision supported by "resilient and functional river ecosystems." This approach recognizes the "reciprocity between humans and their environment" and has been used at the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) to guide habitat restoration and protection activities. They discuss how this holistic approach has better helped align management values and goals with the goals to build long-term resilience, producing better results for both human communities and the ecosystems that they depend on.

Ebersole, et al. (2020) compared the management of climate- refugias management in Oregon and Massachusetts. These refugia offer land and water-based protection for species from the effects of climate change and other human disruptions. They found that while many earlier efforts to establish climate refugia have rightfully focused on water temperature, best approaches should also include they consideration of the core factors and processes that regulate climate refugia including stream flow and groundwater availability. They also proposed that climate refugia be assessed and mapped to establish their ecological values and to prioritize protection.

Specific tribal planning efforts are underway to create climate change adaptation plans, illustrating the advantages of performing a comprehensive of review of resources and their vulnerabilities and climate change impacts to best plan and prioritize meaningful restoration activities.

The Yakama Nation developed a Climate Adaptation Plan in 2016 (Yakama Nation 2016) to address the future impacts of climate change on fish, wildlife, and other important resources. This plan Includes a background of tribal resources, a scientific review of projected climate change impacts, and vulnerability assessment of cultural and environmental resources. Their planning approach will involve multiple stages and began by identifying (i) the important resources and cultural components most likely to be impacted by climate change; (ii) the tribal projects and work that are already underway that recognizes and will help to reduce climate change impacts; and developing (3) specific recommendations for "deeper analyses of vulnerabilities and risks" to their important resources; and (4) a set of adaptation actions with the highest priority for immediate implementation.

The Confederated Tribes of the Umatilla Indian Reservation (CTUIR) are also active in planning for climate change adaptation. In 2015, staff from the CTUIR, in collaboration with Adaptation International and the Oregon Climate Change Research Institute completed a climate change vulnerability assessment (CTUIR 2015, et al.) Through two workshops and a series of interviews with tribal members and key stakeholders, they compiled a list of the first foods and other resources important to tribal members and prioritized these. These were then assessed for their vulnerability to future climate change using regional projections of changes to seasonal climate, streams and rivers, and upland areas. The key items of concern identified during this assessment included water, chinook salmon, elk, cous, huckleberry, agriculture (irrigated and non-irrigated), human health (susceptible to wildfires, heat waves, and vector borne diseases), forest health, and human population dynamics. Chinook salmon were identified as the most vulnerable from climate change and a high priority due to their integral importance to tribal culture and health. The CTUIR has since developed a draft Climate Adaptation Plan that develops strategies to reduce vulnerabilities identified in this process and to help the Tribes prepare for climate impacts.

The Nez Perce Tribe completed an adaptation plan for the Clearwater River basin in 2011 (Nez Perce Tribe Water Resources Division 2011). This plan examined the likely impacts of climate change on the natural and human resources in the basin and considered adaptation strategies to mitigate these impacts. Strategies to protect salmon and steelhead habitat included protecting water quality and quantity, affecting zoning changes to protect the 100-year floodplain, and developing a connected public/private network of lands and waterways to assist fish (and other animal) migration. The Nez Perce Tribe has since established a climate change resilience task force. This team has identified impacts throughout the lifecyle of local salmon populations, and the need for traditional ecological knowledge to be included in planning to protect these and other first foods.

Staff at the Columbia River InterTribal Fish Commission (CRITFC) have been active in assessing climate impacts to fish, hydrology, and water quality, and developing strategies to mitigate them. These include a proposal for modified hydro regulation operations on the mainstem Columbia and Snake Rivers that preserve water for the spring freshet to aid downstream juvenile migrants, and for the hot summer months to ameliorate high water temperatures. They also include the identification and protection of thermal refugia along the mainstem rivers and tributaries, and the study of tributary restoration practices most likely to offset increases in water temperature. CRITFC scientists are also studying genetic material to better understand which traits will be most helpful to salmon, steelhead, and lamprey to survive climate change conditions, and how hatchery supplemented fish may assist the protection and restoration of native fish populations.

Methods

To understand tribal habitat restoration efforts in the context of climate change, we analyzed the habitat actions that have occurred over the last twenty years and their geographic relationship to projected changes at the watershed scale. This analysis used the locations and type of these habitat restoration activities, identifying the actions most likely to provide a sustained improvement in habitat resiliency. Projected changes to stream flow and water temperature from climate change impacts provided the context for these actions once they were categorized and mapped.

In order to accomplish this, we obtained and summarized data that describe the historic restoration sites and activities of our member tribes from the two principal funding agencies: the Bonneville Power Administration (BPA) Fish and Wildlife Recovery Fund, and the Pacific Coastal Salmon Recovery Fund (PCSRF) of the National Oceanic and Atmospheric Administration (NOAA) Fisheries Program. We focused on the past two decades of work (2000-2019), as this period includes the active effort when habitat restoration activities were supported and coordinated in response to declining salmon and steelhead abundance, and also the period when climate change impacts were being largely recognized in the region. These data were standardized and summarized to reflect the key attributes needed for the analysis, including the type of activity and the locations and dates of the activities. Projects were grouped into consistent habitat action types (Table 1), while retained the more detailed work element information. Once standardized, the project data were migrated to a GIS layer for mapping and analysis. In a GIS, each project worksite was linked to a specific watershed where the work occurred.

Habitat Action Type
Instream Passage (Operation and Maintenance)
Instream Fish Passage (Improvement)
Land Acquisition / Conservation Easement
Habitat Improvement
Water Conservation and Irrigation Practices
Water Transactions
Multiple Categories of Habitat Actions

Table 1: Habitat Action Types

To determine whether the habitat actions were relevant to the focal climate change impacts (higher summer water temperatures and lower summer stream flows), each action was linked to limiting factors that were identified during the Subbasin Planning process (NW Power and Conservation Council 2004). These plans addressed the sub-basins of the Columbia River and were composed as guiding documents for fish restoration as amendments to the Fish and Wildlife program. Within each plan, the principal factors that limit salmon and steelhead recovery were identified at the stream or watershed level. As part of this analysis, we evaluated habitat actions that occurred in watersheds with either of these two limiting factors were considered to address current conditions that will be exacerbated by climate change (i.e. if a stream or river is already limiting fish abundance or survival for these factors, warmer future temperatures will worsen this factor absence mitigation). Each stream or river with tribal habitat restoration activity was assessed to determine whether it was identified during Subbasin Planning to be limited by one of these two factors.

To summarize projected future climate change impacts at the subbasin and watershed scale, we used information from regional research of downscaled climate impacts at the sub-basin and watershed scale. Hamlet, et al. (2013) performed an analysis of historic and projected winter precipitation to group sub-basins according to their current and future hydrologic regime. Using the information reported in this effort, we created a GIS layer that projects future shifts in precipitation patterns at the subbasin scale. Each subbasin in the Columbia River Basin was classified as either snow-dominant, rain-snow transitional, or rain-dominant for the historic (1970-2000) period, and a future period (2020-2049). Basins that will shift (from snow-dominant to transitional, or transitional to rain-dominant) will likely see the greatest impact to seasonal hydrology, as transition of snow to rain as dominant winter precipitation leads to greater winter flows, earlier spring runoff, and consequent diminishment of summer stream flows and higher summer water temperatures. These impacts are broadly considered to be detrimental to the survival and abundance of native salmon and steelhead. Once this subbasin-scale precipitation shift layer was created, we overlaid it with the locations of the historic habitat restoration activities, and classified each restoration project according to the shift in precipitation regime in the sub-basin that it occurred in.

Each site was then evaluated to discern how restoration efforts may interplay with climate change metrics, according using a matrix (Table 2). Habitat actions were classified to be most susceptible to be overwhelmed by climate change impacts if they occurred in watersheds that were already limited for summer low flows or high temperatures, and in sub-basins with projected precipitation regime shifts. Habitat actions in watersheds with no current summer low stream flow or high-water temperature limiting factor and no near-term projected precipitation regime shift were classified as not as likely to address near-term climate change constraints. Actions that occurred in watershed where only one of these conditions existed (either a current limited factor or a projected precipitation regime shift) were classified as most likely to potentially mitigate climate change impacts.

Precipitation Regime Shift	**Limiting Factor Vulnerability**	**Classification**
Stable (Snow Dominant)	Low Summer Flow or High Summer Temperature	CC+: Potential to Mitigate Climate Change Impacts (current limiting factor)
Stable (Snow Dominant)	No	CCx: Climate Change Impacts Not as Likely a Near Term Issue

Stable (Rain Dominant)	Low Summer Flow or High Summer Temperature	CC+: Potential to Mitigate Climate Change Impacts (current limiting factor)
Stable (Rain Dominant)	No	CCx: Climate Change Impacts Not as Likely a Near Term Issue
Stable (Snow/Rain Transitional)	Low Summer Flow or High Summer Temperature	CC+: Potential to Mitigate Climate Change Impacts (current limiting factor)
Stable (Snow/Rain Transitional)	No	CCx: Climate Change Impacts Not as Likely a Near Term Issue
Shift (Snow Dominant to Transitional)	Low Summer Flow or High Summer Temperature	CC-: Current and Future Climate Change Impacts may overwhelm Habitat Work
Shift (Snow Dominant to Transitional)	No	CCm: Potential to Mitigate Climate Change Impacts (future limiting factor)
Shift (Transitional to Rain Dominant)	Low Summer Flow or High Summer Temperature	CC-: Current and Future Climate Change Impacts may overwhelm Habitat Work
Shift (Transitional to Rain Dominant)	No	CCm: Potential to Mitigate Climate Change Impacts (future limiting factor)

Table 2: Matrix of Future Projected Precipitation Regime Shifts and Watershed-Scale Limiting Factor Vulnerability

These classifications thus are an attempt to sort project activity based on the current condition of the stream or river and contextual projected near-term climate change impacts. Actions sited in watersheds with current low summer flows or high summer water temperatures and projected precipitation regime shifts may be overwhelmed by these impacts without a large magnitude of work. Conversely, actions sited in watershed without these current limiting factors and no near-term projected precipitation regime shift may not be as relevant to climate change impacts (however, may still provide important benefits, recognizing that salmon and steelhead habitat is impaired by a variety of causes). Habitat actions that are occurring in areas that are not currently limited for summer flows or temperature but with projected precipitation regime shifts, or conversely with these limitations but a stable near-term precipitation regime may offer the most likely benefit for climate change impacts.

Results

The results of this analysis are shown below. In general (as would be expected) the project sites varied in their relationship to the climate change factors listed. Table 3 shows the number of habitat action sites falling into the four different categories detailed above. A small proportion (6%) of project sites occurred in areas where there was no current limiting factor for summer low flow or high-water temperature and no projected near-term change in climate precipitation regime, suggesting possibly no need for mitigation. Over one third of sites occurred in areas where there was either an existing (22.5%) or a projected future limiting factor (14.6%), but not both, suggesting a potential achievable benefit to habitat actions as mitigation. Over half (53.2%) of all sites, however, occurred where both the current and future projected limiting factors exist, suggesting a formidable task to mitigate these factors. A small proportion (3.7%) of sites occurred in areas where the factors could not be resolved sufficiently.

Classification	Number of Sites	Percentage of Sites
CCx: Climate Change Impacts Not as Likely a Near Term Issue	283	6.0%
CC+: Potential to Mitigate Climate Change Impacts (current limiting factor)	1060	22.5%
CCm: Potential to Mitigate Climate Change Impacts (future limiting factor)	688	14.6%
CC-: Current and Future Climate Change Impacts may overwhelm Habitat Work	2191	53.2%
Not Applicable	173	3.7%
Total	4708	100.0%

Table 3: Summary of Habitat Site Classifications

In order to show these results geographically across the Columbia River Basin, the map layers that were constructed for this analysis were composed in an interactive map, which is available at the following URL: https://critfc-gis.maps.arcgis.com/apps/webappviewer/index.html?id=f34b0606e1794b358f975cbbf7e99d22

(Figure 1).

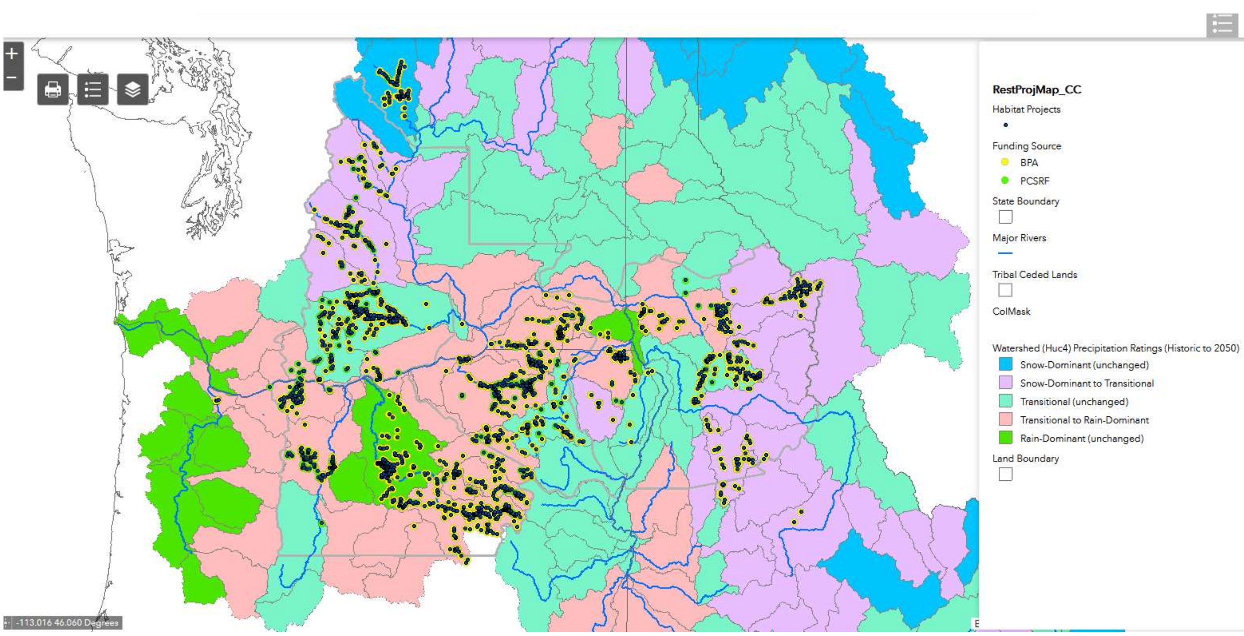

Figure 1: Screen view of the interactive map showing summarized habitat actions and projected precipitation regime shifts.

At this site, a user may view the project site locations and types in the context of the projected precipitation regime shifts. By selecting a project site, a view is displayed (Figure 3) with information about the project including its funding source, Project ID, project type, specific work element and category, location, regime classification of the sub-basin it falls in, whether it is currently in a summer limited factor watershed, and the evaluation of this site.

PCSRF_BPA_HabWorksites_Combined: BPA

FundSource	BPA
Project_Nu	2008-206-00
Project_Ti	Instream Flow Restoration
WorkElemen	Acquire Water Instream
WorkCatego	Habitat - Water Transactions
Work_Site	33963
Latitude	45.21
Longitude	-117.85
YearStart	2,014
ClimateClass	StableTransitional
LFTemporFlow	Yes
SiteEval	ModSited

Figure 2. Example view of project information with site selected on interactive map.

The geographic distribution of these sites in the interactive map demonstrates that sites in the mid-Columbia (central Oregon and central Washington) tend to occur in areas that are projected to transition to rain-dominant or a snow/rain mix by mid-21st century. When these habitat sites are located on streams or rivers that are already limited for summer low flow or high-water temperature, they are faced with both current and future factors that may limit their success unless substantial actions occur in conjunction. Only one sub-basin where substantial habitat actions occurred (the Methow) is projected to remain snow-dominant through mid-century, offering a potential refugia to salmon and steelhead where habitat actions may be focused on other factors.

Discussion

The impetus for this study was to examine the siting and type of tribal habitat restoration activities, their potential to ameliorate the effects of climate change, and whether they may occur in watersheds that are prone to be overwhelmed by climate change impacts. This assessment has several limitations, including the following:

1) Even though restoration actions were narrowed to those types that would likely provide resilience to summer water temperature increases and lower stream flows, these activities are by no means consistent in their effect. Some actions include considerably greater resources and consequent impact, and the time scale of the benefits are dependent on both the actions and their geographic context. Actions typically respond to a specific need within a watershed or

stream, and cross-comparisons lose this context. As such, this analysis is a broad scale evaluation to identify trends and not suitable to evaluate the merit of individual actions.

2) Subbasin planning occurred during the early-2000's in part to provide an assessment of the factors that limit salmon and steelhead population health and recovery within individual sub-basins, but did not purport to discriminate the relative differences in magnitude of these factors between subbasins. Two streams that are limited for high summer water temperatures in different sub-basins may vary in the severity of the limitation, the potential for restoration, and the magnitude that these limitations will be magnified by future climate change.

3) Future climate change impacts were summarized for this analysis with a single metric (the shift in precipitation regimes), which most effectively captures the expected change to hydrography in each sub-basin and the consequent effects on summer stream flows and water temperature. While this metric is effective as a single proxy for the myriad climate change impacts that are expected, it does not consider other important factors that will also influence these conditions, including the groundwater component of base flows in each basin, nor human activities that affect summer stream flows including irrigation, land use, and river impoundments. It is also selected for a distinct near-term period (2020-2049). The magnitude of future shifts in the latter 21st century and beyond are less certain depending on the societal response to climate change and complex global physical processes, but it is likely that the shifting of precipitation type from snow to rain will continue, and sub-basins with stable snowpack in the near term may very well lose this in the more distant future.

Given these limitations, the results of this analysis should not be used to evaluate the merit of individual actions, or efforts on single streams or rivers, but rather to consider the overall scope of past tribal Columbia Basin restoration activities in the context of near-term climate change. By considering the most relevant current limiting factors, siting of past restoration activities, and the magnitude and geography of future expected changes, it is possible to consider whether restoration programs are effectively targeting areas where improvement is both needed and has the potential to provide resiliency from climate change impacts, a consideration that until recent years, may have not been at the forefront given the many degradations to fish habitat.

The analysis did show that almost all areas where these restoration activities have occurred are of concern for the near-term climate change impacts identified. Of these, however, approximately half occurred in areas where the combination of current limiting factors and near-term projected changes to the precipitation regime suggest that it may be difficult to improve the habitat condition. It is quite possible that local actions may be adequate to both improve the current limiting factors and build resilience against expected changes, but this is something that should be addressed in the future when habitat actions are considered. A triage approach may be needed in some sub-basins to ensure that habitat actions occur in areas with the best potential improvement and chance for success, and future predicted conditions (climate, flow, and water temperature) should be considered as a baseline rather than the historical state. The geographic context makes this difficult in practice, however, because the ceded areas of some tribes (for example the mid-Columbia sub-basins) are expected to bear a larger brunt from climate change than others (for example the upper Columbia and middle Snake sub-basins).

Overall, habitat restoration activities should be prioritized and designed with climate change projections in mind and can follow a set of principles that guide activities to build resilience to these impacts. These include:

1) Recognize and advocate for the ability of habitat restoration and protection to counteract climate change effects on salmon, steelhead, lamprey, and other native coldwater fish;
2) Incorporate projections of future climate, stream flow, and stream temperature conditions into restoration planning;
3) Prioritize areas where restoration activities will occur with future projections as a consideration, aiming to site activities where actions will have a high likelihood of success and provide a long-term benefit under changing conditions;
4) Assess vulnerabilities to fish and their habitat under future rather than historical conditions;
5) Design restoration actions that build habitat diversity, fish resilience, and long-term ecosystem health and watershed connectivity;
6) Protect existing refugia that provides cold summer water temperature sources and sufficient year-round flows from surface and groundwater;
7) Build habitat restoration programs with flexibility so that changes may be made to address unexpected future outcomes.

Past stream habitat restoration and protection actions have clearly provided a benefit to restoring and sustaining native fish in the Columbia River Basin. Future efforts should build on these successes by considering climate change projections and aiming to help these fish survive and thrive in a challenging future.

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