Rebuilding Interior Columbia Basin Salmon and Steelhead

Regional Fishery Co-manager Review Draft

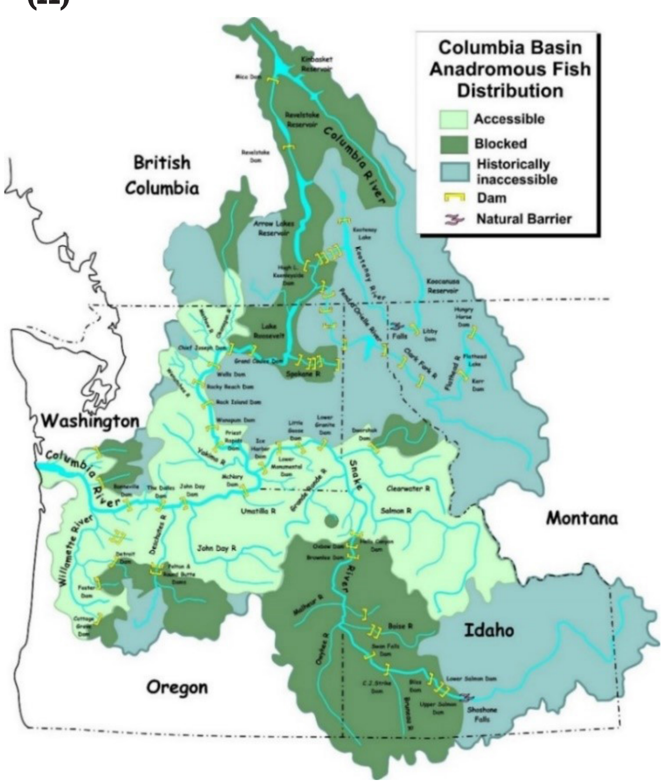
v2.5 July 11, 2022

Introduction

Rebuilding salmon and steelhead stocks in the Columbia River Basin to levels that are healthy and harvestable requires careful consideration of the science that informs rebuilding strategies and actions. This document[1] provides a high-level response to eight common questions about the science[2] surrounding Columbia River basin salmon and steelhead rebuilding efforts. The questions and responses are meant to inform the broader discussion around the socio-economic factors and resources necessary to help these species recover.

The **scope** of this analysis includes the clusters of populations, or stocks, of natural-origin Pacific salmon and steelhead originating above Bonneville Dam (i.e., in the interior Columbia River basin), as well as their life-cycle needs associated with freshwater, estuary, and marine habitats (Figure 1).

(A)



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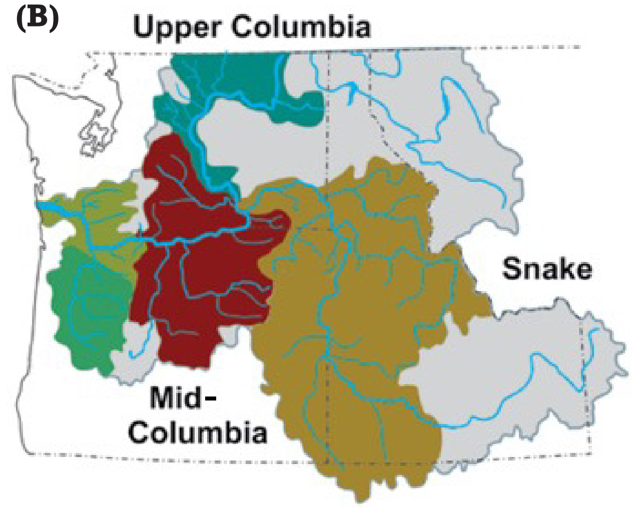

Figure 1. Maps of the Columbia River basin. **(A)** shows areas a) currently occupied by anadromous salmon and steelhead (light green), b) historically used by anadromous fish but currently inaccessible due to dams blocking fish passage (dark green), and c) historically inaccessible due to natural migration barriers (light blue). **(B)** shows regional areas associated with stock delineations in this report (modified from NMFS 2020).

These stocks are critically important to Columbia River basin tribes, as well as to the economy and overall ecological health of the region. Despite their undisputed value, they have been negatively affected by extensive anthropogenic activity—in particular, the dams and reservoirs that form the Columbia River

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[1] This draft report was prepared by the National Oceanic and Atmospheric Administration, with input from and support of the U.S. Fish and Wildlife Service and input from scientists and fishery managers from the Nez Perce Tribe and State of Oregon. The draft will be circulated to state and Tribal co-managers for input before being finalized. Whenever possible, responses are informed by NMFS (2020), *Phase 2 Report of the Columbia Basin Partnership Task Force of the Marine Fisheries Advisory Committee.*

[2] Does not consider socioeconomic or political science.

System[3] (CRS; NAS 1996). The CRS has been the subject of decades of litigation regarding the effects on salmon and steelhead and modifications to their stream, river, floodplain, and estuary habitats. In addition, and as identified in the ESA Recovery Plans (NOAA 2017, UCSRB & NMFS 2007) as factors for listing and key areas of concern for recovery actions, historic and ongoing degradation of stream, river, floodplain, and estuary habitats severely limit the biological potential of all interior Columbia River basin stocks.

The **goals** of this analysis are to inform achieving the mid-range Columbia Basin Partnership (CBP)[4] Task Force's naturally produced adult salmon and steelhead abundance goals by 2050, and, by 2030, the Northwest Power and Conservation Council's (NPCC 2020) productivity goals, as measured by smolt-to-adult return rates (SARs). These goals are commonly understood and referenced by fish managers and the public because of the transparent public processes used to establish them; they are reasonable quantitative targets that we embrace for the purposes of this analysis. Mid-range abundance goals exceed ESA recovery thresholds for abundance, and represent progress toward healthy and harvestable status of these stocks (NMFS 2020). The CBP low-, mid-, and high-range quantitative goals are all substantially greater than the ESA Section 7(a)(2) conservation standard of not likely jeopardizing the continued existence of listed species that is applied to federal agency actions in ESA Section 7(a)(2) consultations.

Achieving these fish-related goals would also provide the highest certainty for meeting multiple objectives that address tribal inequities, securing a pathway to harvestable abundance levels, and meeting ESA needs in the face of climate change (Figure 2).

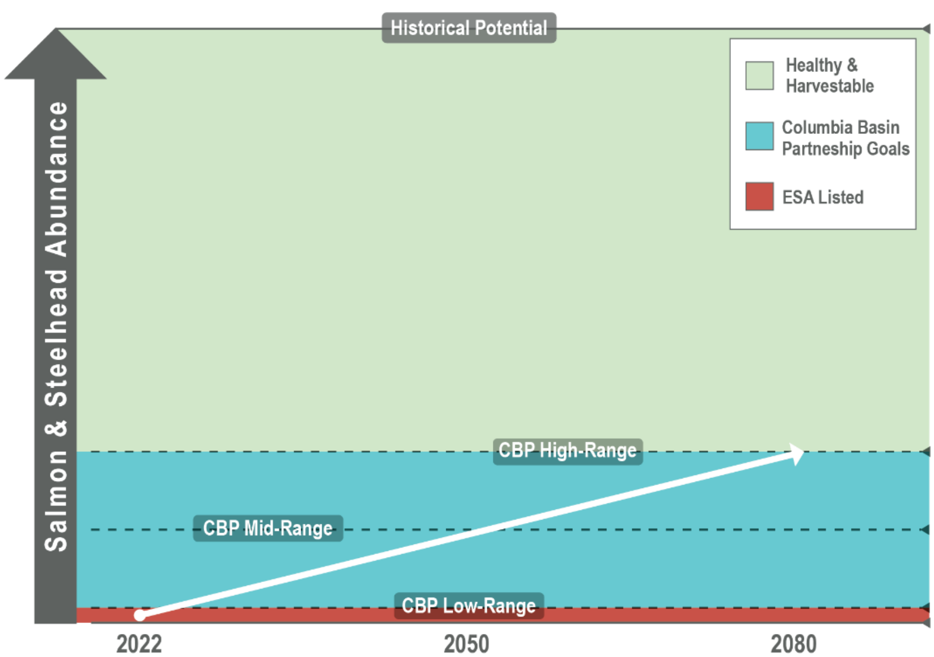

Figure 2. Conceptual abundance continuum of salmon and steelhead, aggregated across the 16 stocks (ESA listed and non-listed) upstream of Bonneville dam, relative to management thresholds and goals. Mid-range goals exceed ESA recovery abundance thresholds and represent progress toward high-range goals associated with healthy and harvestable status (NMFS 2020).

[3]Fourteen federally owned and operated hydroelectric dams (projects) on the Columbia and Snake rivers, including: Libby, Hungry Horse, Albeni Falls, Grand Coulee, Chief Joseph, Dworshak, Lower Granite, Little Goose, Lower Monumental, Ice Harbor, McNary, John Day, The Dalles, and Bonneville.
[4]NOAA Fisheries and its Marine Fisheries Advisory Committee (MAFAC) convened the CBP Task Force in 2017, bringing together diverse representatives from across the Columbia River basin to a) establish a common vision and goals for the basin and its salmon and steelhead (NMFS 2020), and b) establish urgency to achieve the agreed-upon high-range goals.

The **criteria for species and area priorities** include: 1) level of extinction risk, 2) current spatial structure and diversity, 3) importance to tribal communities, 4) habitats essential for life-cycle needs, and 5) resilience of habitat to climate change. Although they in no way reduce the importance of all extant and extirpated Columbia Basin native salmon and steelhead, the criteria allow for a broad-level analysis that helps provide a draft context for sequencing and prioritizing multifaceted, long-term, and complex rebuilding actions.

Question 1: What is the **relative priority of stocks** for protection and rebuilding given the scope and criteria above?

The Columbia Basin Partnership *Phase 2 Report* describes 27 stocks of Columbia River basin salmon and steelhead, with a subset of 16 stocks[5] having populations distributed entirely upstream of Bonneville Dam (hereafter, "interior Columbia stocks;" Table 1). The distribution of interior Columbia stocks is further subdivided geographically into three areas: Snake, upper Columbia, and mid-Columbia (Figure 1).

Overall, protection and rebuilding priority is highest for Snake River spring/summer Chinook salmon, Snake River steelhead, upper Columbia River fall Chinook, upper Columbia spring Chinook, and upper Columbia steelhead (Table 1). With the exception of upper Columbia fall Chinook, this approach prioritizes stocks that are at high risk of extinction.

In addition, with respect to tribal needs, the prioritized spring Chinook stocks exhibit early return timing to the Columbia River. As such, they support important tribal ceremonial purposes, as well as subsistence harvests.

The upper Columbia fall Chinook stock is the only significant commercial fishery remaining for the Columbia River treaty tribes. This stock requires protection to maintain that purpose and rebuilding efforts to reach CBP high-range goals. It is also important to rebuild steelhead stocks, which—by being intercepted as bycatch—can limit the remaining fall Chinook fishery. Steelhead also provide an important late-winter subsistence fishery for tribal members in the tributaries.

Prioritizing certain stocks for protection and rebuilding in no way indicates low priority or diminished importance for any other stocks; the CBP Task Force set healthy and harvestable abundance targets for all Columbia basin stocks. However, for this analysis focusing on interior Columbia basin stocks, we applied the five criteria[6] outlined in the Introduction as a general context that informs the sequencing of restoration actions. As such, all stocks were given high-, higher-, or highest-priority designations. The latter applies to Snake River spring/summer Chinook and steelhead and upper Columbia River fall Chinook, spring Chinook, and steelhead. Continued monitoring and analyses over time will allow the co-manager community to reassess these designations as conditions change (Williams et al. 2009).

[5] Nine stocks spawn primarily in the lower Columbia River, downstream of Bonneville Dam (a small number of lower Columbia River populations spawn and rear in streams just above Bonneville Dam, primarily in the White Salmon, Hood, and Wind River sub-basins). In addition, two stocks spawn and rear entirely in the Willamette River basin. Lower Columbia and Willamette River stocks are not included in this summary.
[6] The five criteria are: 1) level of extinction risk, 2) current spatial structure and diversity, 3) importance to tribal communities, 4) habitats essential for life-cycle needs, and 5) resilience of habitat to climate change.

Table 1. Columbia Basin salmon and steelhead stocks prioritized for protection and rebuilding.

Stock	Priority
Snake Spring /Summer Chinook	Highest
Snake Steelhead	Highest
Upper Columbia Fall Chinook[a]	Highest
Upper Columbia Spring Chinook	Highest
Upper Columbia Steelhead	Highest
Mid-Columbia Spring Chinook	Higher
Mid-Columbia Steelhead	Higher
Upper Columbia Sockeye	Higher
Snake River Fall Chinook	Higher
Snake Sockeye	Higher
Upper Columbia Summer Chinook	Higher
Mid-Columbia Summer/Fall Chinook	High
Mid-Columbia Coho	High
Mid-Columbia Sockeye	High
Upper Columbia Coho	High
Snake Coho	High

[a]Upper Columbia River fall Chinook salmon are included with the highest-priority stocks to emphasize the importance of protecting their current abundance (to achieve CBP mid-range goals) and further increasing the stock (toward CBP high-range goals).

Question 2: What is the **status and outlook** for each stock?

The current abundance and productivity (viable salmonid population (VSP) parameters, McElhany et al. 2000) of interior Columbia salmon and steelhead stocks are at dramatically reduced levels. Sixteen stocks historically spawned above Bonneville Dam. Of those, four are now extinct, seven are listed under the federal Endangered Species Act (ESA)—including one reliant on a captive breeding program—and of the remaining five, only one even approaches its historical numbers (Table 2).

The short-term outlook for most interior Columbia stocks is grim. Recent abundance trends (where data are available) are negative, while productivity values are below replacement (Ford 2022). The extinction risk from demographic collapse is moderate-to-high for all ESA-listed stocks, as is the risk of evolutionary simplification due to reduced adaptive capacity (Ford 2022), all resulting from small population size.

The long-term outlook does provide a bit of hope, as most stocks continue to demonstrate inherent resiliency. We see this in their ability to respond positively (i.e., their survival and numbers increase) when environmental conditions align favorably. At the same time, stream and estuary rehabilitation programs are becoming more effective at restoring the physical and biological processes necessary for salmon and steelhead life cycles, as well as for other resident native fish species. Large-scale habitat access projects have demonstrated that they can promote dramatic abundance and productivity gains, and artificial production and reintroduction tools have proven the potential to reestablish some extirpated stocks.

However, all optimism about potential future stock status must be tempered by the continued pressure from a changing climate and the ever-expanding human footprint. Only rapid, concerted, system-wide actions keyed to existing strongholds of stock potential will result in durable biological benefits to interior Columbia stocks. And, as with all region-scale natural resource management strategies, the implementation of such management actions should be embedded within a framework of ongoing scientific monitoring and analyses, as environmental conditions are expected to change in an increasingly unpredictable manner (Kocik et al. 2022).

Table 2. Current (through return year 2019) status of 16 interior Columbia River basin salmon and steelhead stocks (Ford 2022).

Stock	Number of Historical Populations	Number of Current (Extant) Populations	ESA-Listing Status	Current Blocked Areas (Yes/No)	Historic Abundance	CBP Medium Goal	Current Abundance (10yr geomean)	Current as Percent of Historic	Current as Percent of CBP Medium	Recent Abundance Trend (15yr period)	Recent (10yr) Smolt to Adult Return Rate (SAR)	Extinction Risk	Spatial Structure / Diversity Risk
Mid-Columbia Spring Chinook	14	7	None	No	246,500	40,425	11,600	4.7%	28.7%			Low	Moderate
Mid-Columbia Summer/Fall Chinook	1	1	None	No	17,000	13,000	11,500	67.6%	88.5%		1.0	Low	Low
Mid-Columbia Coho	4	1	Extirpated	No	75,000	11,600	6,324	8.4%	54.5%			NA	NA
Mid-Columbia Sockeye	2	0	Extirpated	No	230,000	45,000	1,036	0.5%	2.3%			NA	NA
Mid-Columbia Steelhead	20	17	Threatened	No	132,800	43,850	18,044	13.6%	41.1%	−0.02		Moderate	Moderate
Upper Columbia Spring Chinook	10	3	Endangered	Yes	259,450	19,840	1,131	0.4%	5.7%	−0.06	0.9	High	High
Upper Columbia Summer Chinook	14	7	None	Yes	733,500	78,350	16,920	2.3%	21.6%		1.2	Low	Low
Upper Columbia Fall Chinook	5	4	None	Yes	680,000	62,215	92,400	13.6%	148.5%		1.4	Low	Low
Upper Columbia Coho	5	0	Extirpated	Yes	44,500	15,000	392	0.9%	2.6%		1.7	NA	NA
Upper Columbia Sockeye	5	2	None	Yes	1,800,000	580,000	40,850	2.3%	7.0%			Low	Low
Upper Columbia Steelhead	11	4	Threatened	Yes	1,121,400	31,000	2,052	0.2%	6.6%	−0.07	1.1	High	High
Snake Spring /Summer Chinook	68	28	Threatened	Yes	1,000,000	98,750	7,013	0.7%	7.1%	−0.03	0.7	High	Moderate
Snake Fall Chinook	2	1	Threatened	Yes	500,000	10,780	9,207	1.8%	85.4%	0.06	0.8	Moderate	Moderate
Snake Coho	6	2	Extirpated	Yes	200,000	26,600	100	0.1%	0.4%			NA	NA
Snake Sockeye	9	1	Endangered	Yes	84,000	15,750	46	0.1%	0.3%		0.3	High	High
Snake Steelhead	40	25	Threatened	Yes	600,000	75,000	18,689	3.1%	24.9%	−0.03	0.9	Moderate	Moderate

Question 3: What is the **importance and context of climate change** (e.g., ocean conditions, snowpack, drought, flow, mainstem/tributary water temperature, etc.) on the life-cycle productivity, resilience, extinction risk, and recovery potential of priority stocks?

Climate change generally exacerbates threats and limiting factors, including those currently impairing salmon and steelhead survival and productivity. The growing frequency and magnitude of climate change related environmental downturns will increasingly imperil many ESA-listed stocks in the Columbia River basin and amplify their extinction risk (Crozier et al. 2019, 2020, 2021). This climate change context means that opportunities to rebuild these stocks will likely diminish over time. As such, management actions that increase resilience and adaptation to these changes should be prioritized and expedited. For example, the importance of improving the condition of and access and survival to and from the last best high-elevation spawning and nursery habitats is accentuated because these habitats are the most likely to retain remnant snowpacks under predicted climate change (Tonina et al. 2022).

Climate change is already evident. It will continue to affect air temperatures, precipitation, and wind patterns in the Pacific Northwest (ISAB 2007, Philip et al. 2021), resulting in increased droughts and wildfires and variation in river flow patterns. These conditions differ from those under which native anadromous and resident fishes evolved. The frequency, magnitude and duration of elevated water temperature events have increased with climate change and are exacerbated by the CRS (EPA 2020a, 2020b; Scott 2020). Thermal gradients (i.e., rapid change to elevated water temperatures) encountered while passing dams via fish ladders can slow, reduce, or altogether stop the upstream movements of migrating salmon and steelhead (e.g., Caudill et al. 2013). Additional thermal loading occurs when mainstem reservoirs act as a heat trap due to upstream inputs and solar irradiation over their increased water surface area (EPA 2020a, 2020b, 2021). Consider the example of the Snake River sockeye salmon in 2015, when high water temperatures in their adult migration corridor resulted in catastrophic mortalities during passage through the hydrosystem (Crozier et al. 2020). Also, Bowerman et al. (2021) concluded that climate change will likely increase the factors contributing to prespawn mortality of Chinook salmon across the Columbia River basin.

Columbia Basin salmon and steelhead spend a significant portion of their lifecycle in the ocean, and as such the ocean is a critically important habitat influencing their abundance and productivity. Climate change is also altering marine environments used by Columbia Basin salmon and steelhead. This includes increased frequency and magnitude of marine heatwaves, changes to the intensity and timing of coastal upwelling, increased frequency of hypoxia (low oxygen) events, and ocean acidification. These factors are already reducing, and are expected to continue reducing, ocean productivity for salmon and steelhead. This does not mean the ocean is getting worse every year, or that there will not be periods of good ocean conditions for salmon and steelhead. In fact, near-shore conditions off the Oregon and Washington coasts were considered good in 2021 (NOAA 2022). However, the magnitude, frequency and duration of downturns in marine conditions are expected to increase over time due to climate change. Any long-term effects of the stressors that fish experience during freshwater stages that do not manifest until the marine environment will be amplified by the less-hospitable conditions there due to climate change. Together with increased variation in freshwater conditions, these downturns will further impair the abundance, productivity, spatial structure, and diversity of the region's native salmon and steelhead stocks (ISAB 2007, Isaak et al. 2018). As such, these climate dynamics will reduce fish survival through direct and indirect impacts at all life stages (NOAA 2017, ODFW 2020).

All habitats used by Pacific salmon and steelhead will be affected by climate dynamics. However, the impacts and certainty of the changes will likely vary by habitat type. Some affect salmon at all life stages in all habitats (e.g., increasing temperature), while others are habitat-specific (e.g., stream-flow variation in freshwater, sea-level rise in estuaries, upwelling in the ocean). How climate change will affect each individual salmon or steelhead stock also varies widely, depending on the extent and rate of change and the unique life-history characteristics of different natural populations (Crozier et al. 2008). In light of this variability, habitat restoration actions should support climate resilience (Jorgensen et al. 2021) in freshwater spawning, rearing, and migratory habitats. We also underline the need for ongoing analyses of changing conditions in order to provide the most relevant science support for regional management action strategies.

The increasing role of deteriorating ocean or freshwater conditions from climate change on the health of salmon and steelhead stocks does not diminish the importance or necessity of taking meaningful actions in areas society has more direct influence over. In fact, the importance and necessity of meaningful actions is heightened, not diminished because of the impacts of climate change. For example, as the frequency of drought, low snowpack, elevated water temperature and poor marine conditions increase, managers must do more, not less, to restore properly functioning tributary habitats and mainstem migration corridors currently degraded by human uses (Jordan and Fairfax 2022). These changes are necessary to offset the less-manageable deficits created by climate change in degraded tributary and mainstem habitats.

Question 4: What are the primary ecological **threats or limiting factors**, by life stage, to achieving abundance and productivity goals? What is the relative and collective importance of addressing these threats? How much have these threats changed?

The Columbia Basin Partnership examined limiting factors[7] in its *Phase 2 Report* to identify constraints on natural production of salmon and steelhead and the potential pathways for achieving the CBP's quantitative and quantitative goals. While some factors are specific to a given life stage (e.g., fisheries largely affect adult life stages), most negatively impact multiple points in the life cycle—e.g., by reducing not only freshwater survival, but also SARs and the numbers of returning adults.

In general, the Partnership found the biggest threats and limiting factors to be:

- Large-scale tributary and estuary habitat impacts.
- Hydrosystem impacts, including direct and indirect mortality, where delayed effects from transiting the hydrosystem occur during the first year of ocean residence.
- Impassable human-constructed barriers prohibiting access to much of the habitat historically accessible throughout the basin.
- Predation from pinnipeds, native and non-native fishes, and birds that are taking advantage of the altered Columbia River System.

Fisheries and hatcheries also impact interior Columbia salmon and steelhead stocks, and, when improperly managed, can have demographic impacts. This underscores the importance of continued hatchery risk management and reform and maintaining harvest regimes that are responsive to stock status and run size.

Table 3 shows limiting factors ranked according to their relative impacts (i.e., ranked 1 through 7 based on largest to smallest impact)[8] for each interior Columbia Basin salmon and steelhead stock. Hydrosystem impacts are the largest threats, followed by habitat made inaccessible due to human-constructed impassable barriers and degradation of tributary habitats.

Unsurprisingly, given the broad weight of evidence, hydrosystem-related limiting factors have the largest impacts on survival for the most interior (furthest upstream) stocks, including all four extant Snake River basin stocks, and four of the six upper Columbia River stocks. Blocked access to historical habitats was the highest limiting factor for the remaining two upper Columbia stocks. For mid-Columbia stocks, the primary limiting factors were mixed, with no single factor emerging as the largest across most stocks.

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[7] Did not explicitly include ocean or climate change threats.

[8] Table 3 is modified from Figure 13 in the CBP's *Phase 2 Report*. The report displayed each impact as a percentage reduction in abundance from historical conditions as a result of that limiting factor. Here, Table 3 displays only the relative impacts. In addition, the report displayed impacts for direct (mainstem) and indirect (latent) hydrosystem mortality separately, while in Table 3 they are combined. The CBP separated direct and indirect hydrosystem mortality because one is estimated directly and the other inferred based on trends in time series. The CBP identified a range of values for indirect hydrosystem mortality that was generally consistent with existing information, and Table 3 combines the direct mainstem mortality and the mid-point of the range identified by the CBP for indirect mortality.

Table 3. Ranking of limiting factor impact levels (modification of CBP *Phase 2 Report*, Figure 13). Ranking of 1 indicates highest magnitude of impact.

Stock	Tributary Habitat	Estuary Habitat	Hydro-system (Direct and Indirect)	Blocked	Predation	Fisheries	Hatcheries
Snake Spring /Summer Chinook	2	5	1	3	4	7	6
Snake Steelhead	2	5	1	4	3	6	7
Upper Columbia Fall Chinook	4	3	1	7	5	2	6
Upper Columbia Spring Chinook	3	6	1	2	5	7	4
Upper Columbia Steelhead	4	4	2	1	3	7	6
Mid-Columbia Spring Chinook	1	6	2	3	3	7	5
Mid-Columbia Steelhead	1	3	4	5	2	7	6
Upper Columbia Sockeye	3	5	2	1	4	6	7
Snake Fall Chinook	5	4	1	2	6	3	NA
Snake Sockeye	5	4	1	2	3	6	NA
Upper Columbia Summer Chinook	3	5	1	3	7	2	5
Mid-Columbia Summer/Fall Chinook	4	2	3	6	5	1	7
Mid-Columbia Coho	6	4	1	5	3	2	NA
Mid-Columbia Sockeye	6	3	2	1	4	5	NA
Upper Columbia Coho[a]	3	6	1	2	5	7	4
Snake Coho[a]	2	5	1	3	4	7	6
Average	**3.4**	**4.4**	**1.6**	**3.1**	**4.1**	**5.1**	**5.8**

Although the CBP assessment is several years old (2020) and efforts to understand and improve fish conditions are ongoing, we believe this general approach for ranking limiting factors and threats by their potential manageability is still both relevant and accurate for current (2022) conditions. It is important to recognize the backdrop of climate change (see Question 3) and the way it exacerbates these identified manageable threats, while also magnifying less-manageable threats such as deteriorating ocean conditions, reduced snowpack, and increased drought.

We also recognize that some of these threats have been present far longer than others that have only recently emerged as primary limiting factors. Similarly, some threats are far more limited in scope than others. For example, some of the worst degradation of tributary habitats occurred generations ago, whereas avian and pinniped predation and alteration of mainstem habitats in the lower Snake and Columbia rivers only became problematic more recently, with the development of the Columbia River System. Although harvest was historically a significant threat to some stocks, fisheries are currently managed conservatively and are the only threat category responsively managed to run size, with fewer impacts allowed as runs diminish. The scope of tributary habitat threats remains large and is not just limited to habitats degraded anthropogenically, but more broadly across remote, wilderness-designated watersheds vulnerable to climate change and ongoing deficits of marine-derived nutrients from collapsed anadromous fish runs.

Taken together with the widely recognized, pervasive impacts of predator communities and other survival threats resulting from altered mainstem habitats, the main limiting factors present in the Columbia River basin dramatically impact all interior Columbia salmon and steelhead stocks. They require a comprehensive suite of actions, coupled with robust scientific monitoring to continually evaluate and adjust its implementation (Williams et al. 2009).

Question 5: Which **actions** have the highest likelihood of helping (e.g., of avoiding additional generational downturns and providing reasonable certainty of achieving the goals by addressing primary life-cycle threats and bottlenecks to survival, distribution, etc.) in the face of climate change?

No single action is enough, given the abundance and survival goals for rebuilding, the stock priorities, the stocks' current status, and the primary threats within the context of climate change. Achieving healthy and harvestable stocks will require a comprehensive suite of management actions that includes:

- Significant reductions in direct and indirect mortality from mainstem dams, including restoration of lower Snake River.
- Direct and indirect management of predator numbers and behavior.
- Focused tributary and estuarine habitat restoration and protection.
- Passage and reintroduction into priority blocked areas, including upper Columbia River.
- Focused hatchery and harvest reform.

These actions are needed to provide the highest likelihood of reversing near-term generational declines[9] and to rebuilding towards healthy and harvestable runs in the face of climate change.

Primary life-cycle threats to survival and distribution vary across and even within stocks (NMFS 2020). Thus, the successful restoration of interior Columbia stocks will require a diverse suite of actions. Generally, actions that benefit multiple stocks, and multiple populations within a stock, will have the greatest impact on overall adult returns. Likewise, actions that provide more immediate effects, rather than actions with longer time-lagged benefits, are necessary to help avoid near-term generational decline and help reduce extinction risk while providing an additional buffer to climate change effects.

The importance of the comprehensive suite of actions listed above cannot be overstated. It is also important to recognize that, within this suite, several centerpiece actions are paramount for specific stocks. If the comprehensive suite of actions fails to implement the centerpiece actions listed below, we cannot be confident in meeting the goals.

- **For Snake River stocks, it is essential that the lower Snake River be restored via dam breaching.**[10] To restore more normative river conditions and function in the lower Snake River, it is essential that dams be breached. This is necessary to provide the highest likelihood of achieving the NPCC 2–6% SAR goal by 2030 and the mid-range CBP abundance goals for Snake River stocks by 2050. Breaching helps address the hydrosystem threat by decreasing travel time for water and juvenile fish, reducing powerhouse encounters, and reducing stress on juvenile fish associated with their hydrosystem experience that results in delayed mortality after reaching the ocean.
- **For upper Columbia River stocks, it is essential to provide passage into blocked areas.**[11] Establishing adult and juvenile passage to and from areas of the upper Columbia River blocked by high-head dams provides the highest and only reasonable likelihood for achieving mid-range CBP goals for upper Columbia River stocks by 2050. This action helps address the blocked area threat by providing access to additional and more productive spawning and nursery areas.

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[9] Generational decline means the population is shrinking from one generation to the next, as evidenced by fewer progeny surviving to spawn than in the class of parents that produced them.
[10] Breaching is specifically recommended for the four lower Snake River dams. The earthen portion of each dam would be removed, and a naturalized river channel would be established around the concrete spillway and powerhouse structures.
[11] Passage into blocked areas specifically recommended for high-head dams that lack fish ladders and/or juvenile bypass facilities (e.g., Grand Coulee and Dworshak). Restoring adult and/or juvenile passage within tributaries (e.g., culverts, irrigation diversions) is covered under tributary habitat restoration.

- **For mid-Columbia stocks, in addition to improved passage through lower mainstem dams, it is necessary to improve water quality and quantity and passage survival in focused areas of low to mid-elevation tributary habitats.** Maximizing functional tributary habitats (primarily instream flows, water quality, and fish passage improvements) and improving passage in the lower mainstem Columbia River is necessary to provide the highest likelihood for achieving mid-range CBP goals for mid-Columbia stocks by 2050. For example, for high-risk Yakima Basin stocks, smolt survival through the Yakima River should be significantly increased by increasing spring flows, implementing structural and operations improvements at Federal diversion dams, and targeting specific habitat improvements. These actions help address habitat threats in tributaries and help reduce direct and indirect effects of the hydrosystem threat in the mainstem.

The urgency of the comprehensive suite of actions is accentuated by ongoing climate change. Actions that have the highest likelihood to **buffer climate change** impacts and support restoration fit into three categories:

1. *Maintaining suitable water temperatures and flows in mainstem and tributary habitats.* Juvenile and adult salmon and steelhead use migration corridors in the mainstem Columbia and Snake Rivers to move between their spawning and rearing areas and the ocean. These corridors suffer from rising water temperatures and reduced flows. Increased temperature and reduced flow in adult holding and spawning areas and juvenile rearing areas is also becoming a concern. Some examples of actions necessary to provide reasonable confidence in addressing this need include:
    - Normalizing the hydrograph of mainstem Columbia and Snake Rivers. This will, for example, reduce thermal loading in the lower Snake River and increase benefits of cold-water releases from Dworshak Reservoir.
    - Attaining EPA Clean Water Act water quality standards and associated TMDLs for temperature, turbidity, toxics, and nutrient loading.
    - Maintaining and enhancing flow augmentation from Columbia River Treaty and U.S. storage projects for spring and summer juvenile migration.
    - Systematically and extensively restoring riverscape-scale tributary habitat. Restoring natural rates and dynamics of biological and physical processes that create and maintain healthy functioning riparian and floodplain habitats.
    - Durable, targeted agreements to accomplish increased instream flow volumes through water acquisitions, irrigation system conversions, and land-use modification.
2. *Maximizing survival and production from freshwater habitats (including migration corridors).* This will help reduce generational declines during periods of poor ocean conditions, and increase rebuilding during periods of good ocean conditions. Some examples of actions necessary to provide reasonable confidence in addressing this need include:
    - Maximize fish protections at remaining mainstem dams and reservoirs. This will increase juvenile survival, decease indirect mortality, and increase adult return survival.
    - Minimizing predation on juveniles as they migrate to the ocean.
    - Minimizing predation on adults as they return to their spawning grounds.
    - Minimizing passage delays and removing passage barriers to adults returning to spawning grounds.
    - Increasing freshwater tributary habitat quality and/or quantity through focused actions that support sustained productivity of at least 100 smolts per female.
    - Increasing quality and access to estuary habitat that acts as migration corridor refugia and highly productive juvenile rearing environments.

3. *Maintaining and restoring access to climate resilient habitats for spawning and rearing (e.g., high-elevation spawning and rearing habitats with snowpack-driven hydrology, or extensive connected floodplain habitats).* Some examples of actions necessary to provide reasonable confidence in addressing this need include:

   - Restoring or improving adult and juvenile passage to and from high elevation upper Columbia and upper Snake historical production areas and reintroduction and passage into currently blocked areas of the upper Columbia River (e.g., above Enloe Dam).
   - Protecting and restoring cold-water refuges in tributary adult holding areas and in spawning and nursery areas.
   - Maintaining and maximizing thermal refuges within the mainstem migration corridor
   - Restoring connected floodplain habitat across all ecoregions of the interior Columbia River basin.

Building off the CBP effort, Table 4a generally assesses action urgency and priority based on stock status and limiting factor impact level.[12] From there, further refinement helps provide stock-specific priority actions. Table 4b identifies the most common actions that need attention now or for which action is warranted: hydro (11 stocks), tributary habitat (10 stocks), blocked habitat (10 stocks), and predation (7 stocks).

Table 4a. Biological criteria matrix for action prioritization.

Stock Status	Impact Level Low (less 20%)	Impact Level Medium (20-30%)	Impact Level High (31-50%)	Impact Level Very High (>50%)
Low (<25%)	Consider Action	Action Warranted	Needs Attention Now	Needs Attention Now
Medium (26-50%)	Back Burner	Back Burner	Action Warranted	Action Warranted
High (51%-75%)	Good Shape	Back Burner	Consider Action	Action Warranted
Very High (>75%)	Good Shape	Good Shape	Back Burner	Back Burner

[12] Impact levels in Table 4a utilize information from Figure 13 in the CBP *Phase 2 Report*, which displayed each limiting factor impact as a percentage reduction in productivity from historical conditions as a result of that limiting factor. Stock status in Table 4a applies average annual returns of natural-origin salmon and steelhead to the Columbia River, 2008–2017 (as displayed in the CBP *Phase 2 report*, Table 8) relative to the CBP medium-range abundance goal (as displayed in the CBP *Phase 2 Report*, Table 8).

Table 4b. Stock-specific priority actions for rebuilding based on integration of Columbia Basin Partnership biological criteria of stock status and limiting factor impact level.

Stock	Needs Attention Now	Action Warranted	Consider Action	Back Burner	Good Shape
Snake Spring / Summer Chinook	Hydro, Tributary Habitat	Predation, Blocked Habitat	Estuary Habitat, Fishery, Hatchery		
Snake Steelhead		Tributary Habitat, Hydro, Blocked Habitat, Predation		Estuary Habitat, Fishery, Hatchery	
Upper Columbia Fall Chinook				Hydro, Fishery	Tributary Habitat, Estuary Habitat, Blocked Habitat, Predation, Hatchery
Upper Columbia Spring Chinook	Tributary Habitat, Hydro, Blocked Habitat, Hatchery	Predation	Estuary Habitat, Fishery		
Upper Columbia Steelhead	Tributary Habitat, Estuary Habitat, Hydro, Blocked Habitat, Predation	Hatchery	Fishery		
Mid-Columbia Spring Chinook		Tributary Habitat, Hydro		Estuary Habitat, Blocked Habitat, Predation, Fishery, Hatchery	
Mid-Columbia Steelhead		Tributary Habitat, Predation		Estuary Habitat, Hydro, Blocked Habitat, Fishery, Hatchery	
Upper Columbia Sockeye	Tributary Habitat, Hydro, Blocked Habitat	Predation	Estuary Habitat, Hatchery	Fishery	
Snake Fall Chinook				Hydro, Blocked Habitat, Fishery	Tributary Habitat, Estuary Habitat, Predation, Hatchery
Snake Sockeye	Hydro, Blocked Habitat	Predation	Tributary Habitat, Estuary Habitat, Fishery, Hatchery		
Upper Columbia Summer Chinook	Tributary Habitat, Hydro, Blocked Habitat, Fishery	Estuary Habitat, Hatchery	Predation		
Mid-Columbia Summer/Fall Chinook				Fishery	Tributary Habitat, Estuary Habitat, Hydro, Blocked Habitat, Predation, Hatchery
Mid-Columbia Coho			Hydro	Fishery	Tributary Habitat, Estuary Habitat, Blocked Habitat, Predation, Hatchery
Mid-Columbia Sockeye	Blocked Habitat	Hydro	Tributary Habitat, Estuary Habitat, Predation, Fishery		Hatchery
Upper Columbia Coho	Tributary Habitat, Hydro, Blocked Habitat	Predation	Estuary Habitat	Fishery	Hatchery
Snake Coho	Hydro, Tributary Habitat	Blocked Habitat	Estuary Habitat, Predation	Fishery	Hatchery

Question 6: Given the status in Question 2 above, what is the **urgency** for implementation of actions toward the goals? What sequencing of actions achieves the highest likelihood of minimizing the potential for generational declines and achieving the generational growth necessary to achieve goals?

Given the status of interior Columbia stocks and ongoing climate change described in Question 2, achieving the Columbia Basin Partnership mid-range goals by 2050 requires urgent action.

Improvements in ocean conditions during 2021 provided a welcome respite, but are not expected to reverse ongoing trajectories (i.e., the increased frequency, magnitude, duration, and scope of environmental downturns) associated with a changing climate.

All actions identified under Question 5 need to be implemented as soon as possible, but the most urgent are those that a) provide tangible benefits shortly after implementation, and b) provide the most significant survival boost for a broad range of priority populations. Additional predator controls in the mainstem and expedited restoration of the lower Snake River address this need, but must be part of a comprehensive package that provides additional fish protections at mainstem dams, fish passage into critical blocked areas, focused habitat protection and restoration in tributaries and the estuary.

Only this comprehensive package is likely to provide the generational growth and expanded capacity necessary to achieve the abundance and survival goals.

All but one of the interior Columbia salmon and steelhead stocks are below their Columbia Basin Partnership mid-range goals (Table 2). On average, stock abundance is 33% of its goal (range: 0–149%). With most stocks at extremely low abundance, achieving mid-range abundance goals requires increasing stock productivity (by, for example, reducing mortality) to levels well above replacement rate, and sustaining these levels for multiple generations. Simply put, survival under the best conditions can only double or triple abundance in a single generation. Generation time varies by stock, ranging from three to six years. Depending on the stock, this provides five to nine generations between 2023 and 2050 for generational increases to reach CBP mid-range goals.

Generational productivity varies over time. A base-level positive generational growth rate (analogous to continuous interest with compounding gains over time) must be met each generation between now and 2050—the necessary average rate across stocks being 36% (range: –8% to +83%; Figure 3). This required generational growth rate increases if crucial survival rate improvements are not realized until after 2023. Survival rate increases will be delayed unless the following are begun immediately: 1) actions that are likely to produce benefits relatively quickly after implementation, and 2) actions that have a lag time between implementation and environmental response.

Unfortunately, not all restoration actions will achieve their intended benefit. In addition, disturbance events are likely to occur that will reduce productivity. As such, the suite of targeted restoration actions should exceed the minimum level of necessary improvement. Otherwise, there is a potential for extreme natural events to cause localized extinctions (McElhany et al. 2000).

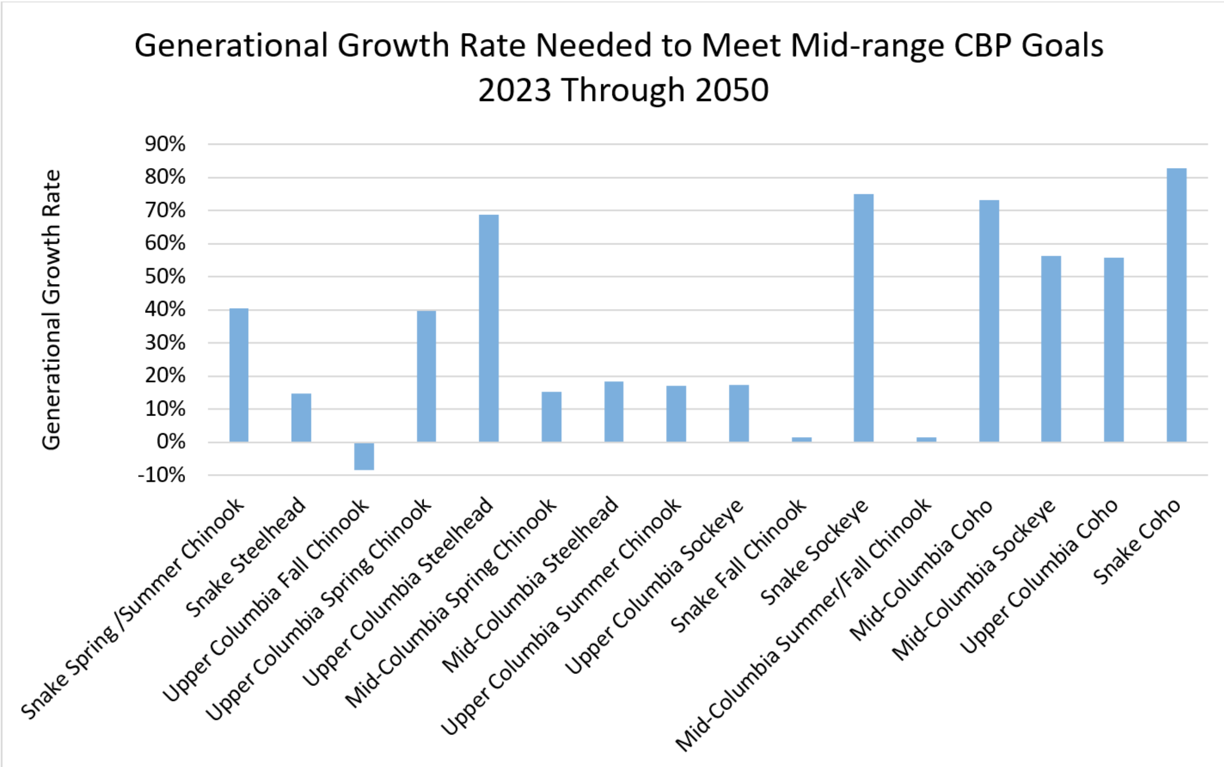

Figure 3. Stock-specific generational growth rate needed to achieve Columbia Basin Partnership mid-range goals by the year 2050.

Quasi-Extinction Thresholds (QETs) are a standard commonly applied metric for evaluating population viability and the risk of extinction. QETs represent tipping points for population collapse, where the actual extinction potential may not be predictable or, in some cases, avoidable. Populations that fall below their QETs face higher genetic, demographic, and environmental risks, reducing their resilience and increasing their risk of extinction. The result can be an extinction vortex and a greatly reduced likelihood of recovery (Gilpin and Soulé 1986, Simberloff 1988, Fagan and Holmes 2006). Stock status assessments indicate numerous populations within the Columbia River basin are already at or below QET, with more likely to hit this threshold in the next five years (Storch et al. 2022).

To achieve the Partnership's mid-range goals, given the current stock status and demographic inertia identified above, it is imperative to start taking actions. Also, given the large-scale, long-term nature of the necessary actions, it is critically important to continue and expand scientific monitoring and adaptive management to most effectively achieve these goals.

Question 7: Given the status in Question 2, what **confidence** do we have that salmon and steelhead will respond favorably if the actions identified in Question 5 are implemented comprehensively?

We are confident that extant interior Columbia stocks still retain the inherent resilience to respond favorably once the recommended actions are implemented. This confidence is informed by the strong positive responses observed in the early 2000s among natural-origin Snake River spring/summer Chinook salmon and steelhead when favorable ocean conditions and high snow pack aligned in the late 1990s. We are also confident that the comprehensive suite of actions identified in Question 5 provides the highest and only reasonable certainty of achieving survival goals necessary to minimize generational declines during periods of poor environmental conditions and secure the overall generational growth necessary to meet long-term abundance goals.

Salmon life-cycle models predict that breaching lower Snake River dams—in combination with other fish protection measures (e.g., enhanced spill at the four lower Columbia River dams and freshwater habitat restoration)—will likely achieve regional survival and productivity targets for Snake River Chinook salmon and steelhead.[13] The range of current population projection models varies, both in the proposed mechanisms, and in the magnitude of direct and indirect mortality associated with fish passage through the mainstem hydrosystem in the Columbia River basin. However, the common message is clear across all the work: **salmon recovery depends on large-scale actions**, including breaching dams, systematically restoring tributary and estuary habitats, and securing a more functional salmon ecosystem.

Our certainty that actions must be large-scale, comprehensive, and begin immediately to avoid continued declines and achieve abundance and survival goals—is driven by the pace and completeness of implementation, tempered by ongoing climate change, and deteriorating environmental conditions beyond society's direct or immediate influence. However, we are less confident in the responsiveness of the more highly imperiled populations currently on life support through hatchery intervention (e.g., Snake River sockeye) and the reintroduction of populations into currently blocked areas.

Nonetheless, our lack of precise measures or estimates of the magnitude of biological benefit expected from large-scale management actions in no way indicates that we lack confidence in their efficacy. The science robustly supports process-based stream habitat restoration, dam removal (breaching), and ecosystem-based management, and overwhelmingly supports acting, and acting now. To minimize additional generational declines and accomplish the broad-sense recovery goals of the Columbia Basin Partnership requires a suite of aggressive, dramatic, region-wide actions implemented with an ambitious, but necessary, immediacy. Inaction will result in the catastrophic loss of the majority of Columbia River basin salmon and steelhead stocks. Some uncertainty surrounding the exact magnitude of beneficial response of acting does not warrant inaction.

The fisheries management community of the Columbia River basin have identified a wide range of management actions with confidence in achieving intended physical and biological benefits. Recent, large-scale dam removal projects on the Elwha, Nooksack, Hood, Wind, White Salmon, Sandy, and Rogue rivers have all resulted in broader and quicker biological and physical benefits to local and regional riverscapes than expected. Process-based stream, river, and floodplain restoration projects in portions of many watersheds across the West (e.g., Lemhi, Pahsimeroi, John Day, McKenzie, Whychus, Fivemile, and Bell rivers) have resulted in rapid increases in abundance and productivity of resident or anadromous salmonids.[14] Ecosystem-based management actions have addressed natural and artificial predator impacts in the mainstem and estuary of the Columbia and Snake Rivers, effectively reducing impacts on migrating juvenile and adult salmonids.

[13] Ranges of scenarios across all management sectors evaluated are presented in McCann et al. (2018), Petrosky et al. (2020), and Zabel and Jordan (2020).

[14] I.e., by returning some normative fluvial and biogeomorphic processes to these riverscapes.

Question 8: If the actions identified in Question 5 are implemented comprehensively for salmon and steelhead, how would they benefit or degrade conditions for **other species**?

Aquatic native species will all generally benefit from restoration actions implemented for anadromous salmon and steelhead due to the resulting improved natural ecosystem structure and function (Storch et al. 2022). Some exceptions to this general rule may result from actions to intentionally reduce the abundance or distribution of species that feed on salmon and steelhead, e.g., lethal removal or hazing of pinnipeds, northern pikeminnows, and birds, such as gulls, terns, cormorants, and pelicans. We recognize the complexity inherent in balancing the recovery of multiple overlapping and interacting protected species.

While most potential restoration actions simply improve impacted habitats, breaching the lower Snake River mainstem dams would be transformative, changing the anthropogenic reservoir habitats back into a river with more functional connected floodplains, naturalized water velocity, and favorable river-channel morphological conditions.

Restoring and reconnecting floodplains clearly provides a myriad of benefits. A floodplain-connected valley is inherently more diverse and productive, not only for aquatic species, but across the entire floodplain (Bellmore and Baxter 2014). On the seasonally wet floodplain surface, vegetation productivity and plant and animal species richness and diversity are higher than on a disconnected, permanently dry terrace (Wohl et al. 2021). In the channels of a connected floodplain reach, primary productivity is higher, macroinvertebrate communities are richer and more productive (Nummi et al. 2021), and amphibian and fish productivity is higher (Anderson et al. 2015, Bouwes et al. 2016) than in the simple channels of a disconnected reach. But, while these internal benefits are independently valuable, they are only a small fraction of the potential benefits that restored riverscapes can provide in the face of climate change (Wohl et al. 2017). When we reconnect streams and rivers to their floodplains, we perform both climate mitigation work (slowing/stopping the trajectory of global warming impacts) and climate adaptation work (building resilience and resistance to climate-driven disturbances that are already occurring; Skidmore and Wheaton 2022).

Breaching the lower Snake River dams would directly increase white sturgeon habitat, allowing for viable natural recruitment and continuous connectivity with areas upstream in the Snake and Clearwater Rivers (Storch et al. 2022). Spawning and subsequent juvenile production is currently constrained to the free-flowing reach of the Snake River between the upper end of Lower Granite Reservoir and Hells Canyon Dam. As there is currently no upstream passage for adult sturgeon at the dams, breaching the lower Snake River dams would ultimately allow unrestricted movement of juvenile and adult sturgeon throughout the expanded free-flowing reach from McNary Dam all the way to Hells Canyon Dam.

Current mainstem dam adult fish ladder structures preclude passage of about 50% of adult Pacific lamprey, such that fewer than 1% make it to the upper portions of the Columbia and Snake River basin. Juvenile Pacific lamprey suffer mass mortality when they impinge on the turbine screens designed to protect juvenile salmonids as they emigrate to the ocean. Breaching the lower Snake River dams would remove both of these threats to adult and juvenile lamprey in the lower Snake River reach, as well as the juvenile mortality associated with dredging navigation channels in that reach.

As with breach, actions to restore access to blocked areas (e.g., above dams that provide no upstream passage) would benefit not only salmon and steelhead, but also other anadromous and resident species. For example, Fish and Hanavan (1948) reported the construction of Grand Coulee Dam, in the upper Columbia River, precluded anadromous fish from over 1,000 miles of spawning and rearing streams, and as a result, substantial fish production was lost (UCUT 2019). The reintroduction of anadromous fish into blocked areas will inject currently missing marine derived nutrients into these blocked areas, benefitting ecosystem function, aquatic and terrestrial connectivity, and a broad swath of native aquatic biota, e.g., bull trout, white sturgeon (Gende et al. 2002, Mathewson et al. 2003, Francis et al. 2006, Tonra et al. 2015, Bryson et al. 2022). However, threatened Kootenai River white sturgeon are unlikely to be impacted positively or negatively as they have been geographically isolated from other Columbia River white sturgeon populations for approximately 10,000 years (Alden 1953, USFWS 1999).

Although native fish communities in the Columbia River Basin represent a broad range of life-history strategies and have varying habitat requirements, many of the processes and mechanisms that dictate survival and productivity likely overlap. Thus, it stands to reason actions that would restore and reconnect floodplains essential to support the life histories of salmon and steelhead would also benefit other native migratory species (e.g., Pacific lamprey) that have been imperiled by partial or complete loss of access to essential spawning and rearing habitat.

Bull trout, listed as Threatened under the ESA, exhibit a continuum of life histories involving migrations, spawning, rearing, and foraging over broad ranges in space and time. Maintaining connectivity between tributaries and within the mainstem Columbia and Snake rivers is essential for genetic exchange among core populations, supporting their resiliency against environmental and anthropogenic disturbances and ensuring a high likelihood of population viability and recovery (Barrows et al. 2016). The Bull Trout Recovery Plan (USFWS 2015) specifies removing constraints to these life-history processes to develop an adequate number of sufficiently large, genetically diverse populations as a buffer against catastrophic events. Connectivity is essential to the recovery of bull trout, within mainstem habitats and between mainstem and sub-basin habitats (Storch et al. 2022). For example, the value of basin-scale connectivity was well demonstrated in the Elwha River, where bull trout exhibited long-distance migrations (~168 km) soon after dam removal (Brenkman et al. 2019).

Elimination of reservoir habitat will decrease the abundance of northern pikeminnow. Although native to the Columbia River basin, the current abundance of northern pikeminnow is unnaturally high due to their increased productivity in reservoir habitats. Elevated pikeminnow population levels have resulted in unnaturally high predation rates on juvenile salmon and steelhead, necessitating a "bounty" program for northern pikeminnow within the mainstem Columbia and Snake Rivers.

Restoring a more natural water velocity and riverine channel morphology in the mainstem reaches of the Columbia and Snake Rivers will dramatically reduce the abundance, distribution and encroachment of undesirable non-native species that thrive in reservoir habitats. Several of these species (walleye, northern pike, smallmouth bass, and catfish) feed on native juvenile salmon, steelhead, and lamprey. Several other non-native species (carp and American shad) alter the food web and likely compete with native species for food. Native, diverse macro-invertebrate communities will be restored, and while eliminating the reservoir environments will not preclude future invasion by zebra or quagga mussels, it would add ~140 miles of viable habitat for native mussel species.

Within the lower Snake River corridor, gulls, terns, cormorants, and pelicans congregate and feed on disoriented juvenile salmon and steelhead in dam forebays and tailraces. Avian nesting colonies are not prevalent within this reach, so breaching the lower Snake River dams would not alter nesting habitat, but it could change the distribution of avian species that feed on interior Columbia priority stocks, likely displacing the birds into the mid- and lower Columbia reservoir habitats.

Healthy, productive salmon and steelhead populations are critical to multiple aquatic and human ecosystems in our region. The marine-derived nutrients from spawned-out salmon carcasses fertilize low-productivity, high-elevation streams, setting the stage for the next generation of juveniles emerging from the gravel. Adult and juvenile salmon are the natural prey base for marine mammals—in particular, for the imperiled Southern Resident killer whales. Tribal cultural and subsistence harvest opportunities have become limited, and commercial and recreational fisheries are closing. At vanishingly low abundances, salmon and steelhead can no longer be the base for key biological and social networks across the region. Mainstem river rehabilitation, together with stream restoration across the tributary environment, is a powerful set of additive actions. It is not too late to rebuild the vibrant, productive ecosystems on which most fish and wildlife resources, as well as the people of the Columbia River basin, depend.

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