STATEWIDE BARRIER PRIORITIZATION STRATEGY

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EXECUTIVE SUMMARY

To be added to final draft

ACKNOWLEDGEMENTS

The development of the Statewide Strategy was a collaborative effort of Washington Department of Fish and Wildlife (WDFW) technical staff and leadership, Cramer Fish Sciences, Triangle Associates, and Science Panel members with input from the Tribes and partners across the State of Washington. Thus, numerous individuals and organizations provided input and comments and deserve thanks for their assistance. Jane Atha and Tom Jameson from WDFW directed development of the strategy and Phil Roni (Cramer Fish Sciences) and Jane Atha (WDFW) led writing of the strategy. Hilary Wilkinson, Betsy Daniels, and Kate Galambos from Triangle Associates led all facilitation for both internal meetings and outreach to partners which was critical to development of the Strategy. During outreach sessions numerous individuals from Tribes, lead entities, recovery boards, cities, states and counties provided valuable input on the direction of Strategy and potential challenges. Science Panel members —Dan Auerbach (WDFW) , Pete Bisson (U.S. Forest Service, retired), Thomas Buehrens (WDFW), Ken Currens (Northwest Indian Fisheries Commission), Robby Fonner (NOAA), Robyn Pepin (Aspect Consulting), Jason Nuckols (The Nature Conservancy), and George Pess (NOAA) — provided technical input on development of the Strategy and review and comments on the draft strategy. Their input was critical in developing the approach and ensuring that the strategy considered the latest science. Jason Hall (Cramer Fish Sciences) and Kai Ross (Cramer Fish Sciences) provided technical assistance and Kai Ross helped develop the optimization section of the draft strategy. Margen Carlson, Chris Conklin, and Tim Quinn from WDFW provided direction and helpful comments on the draft strategy and Lauren Ellenbecker (Cramer Fish Sciences) provided technical editing of the document.

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BACKGROUND

In the last 20 years, many stocks of salmon and steelhead *Oncorhynchus spp.* have been listed as threatened or endangered under the Endangered Species Act in Washington State. (https://www.fisheries.noaa.gov/species/pacific-salmon-and-steelhead/esa-protected-species). While factors for decline such as over-harvest, hydropower, hatcheries, climate change, and habitat degradation and loss have had a prevailing influence, one of the most effective habitat restoration techniques includes removing manmade instream barriers to reconnect isolated stream habitat (Roni et al. 2002; 2008; Pess et al. 2014; Bilby et al. 2024; Rogosch et al. 2024). The success of barrier removal projects in restoring fish populations is related to the fact that 1) salmonid and other fishes can rapidly recolonize newly accessible habitats; 2) many populations are limited by the amount of available freshwater habitat; and 3) removal of barriers often reconnects existing functional fish habitat that may not require additional restoration (e.g., Pess et al. 2014; Anderson et al. 2015; Erkinaro et al. 2017; Anderson et al. 2019; Clark et al. 2020; Knoth et al. 2022).

Thousands of miles of anadromous and migratory fish habitat have been isolated by roads, culverts, dams, tide gates, and other human infrastructure (Gibson et al. 2005; Price et al 2010; Pess et al. 2014; Finn et al. 2021). Nowhere is this more evident than in Washington State, where the Washington Department of Fish and Wildlife (WDFW) has estimated that there are currently at least 20,000 barriers to salmon and steelhead across the state (WDFW et al. 2024) (Figure 1). Water crossing features that were once passable can become barriers over time as site conditions in the stream change, making both prompt and ongoing barrier inventories critical to track success. Additional culverts and other road crossings that are partial or full barriers to fish passage are identified each year. Addressing instream migration barriers is critical for salmon recovery, recovering fisheries, and maintaining tribal fishing rights. In 2016, the U.S. Supreme Court issued an injunction directing Washington State to correct impassable culverts because they violate the Stevens Treaties, which were entered in 1854 and 1855 between Indian tribes in the Pacific Northwest and the Governor of Washington Territory (U.S. vs Washington 13-35474). The injunction required Washington State to restore 90% of the habitat blocked by state owned culverts by 2030.

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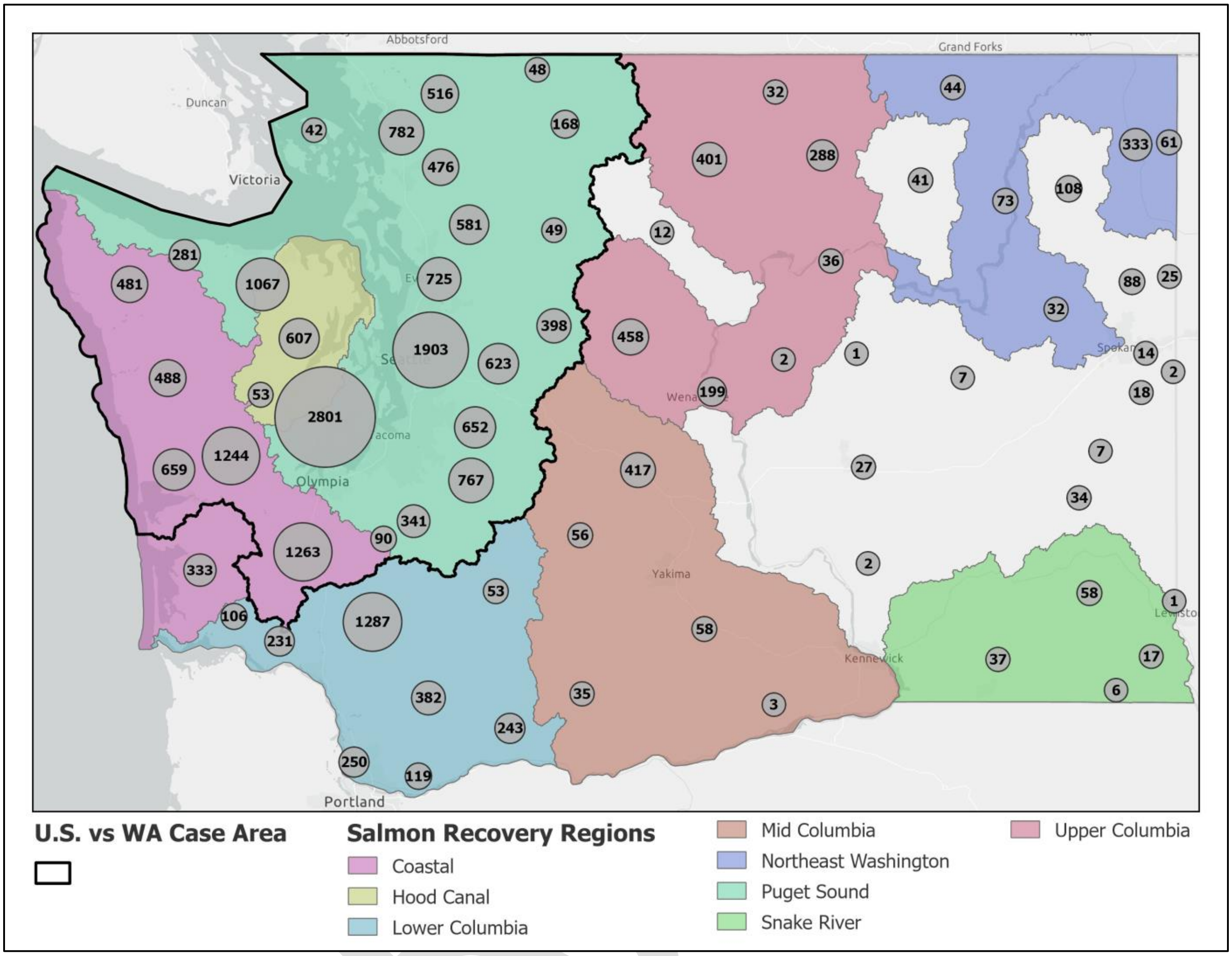

Figure 1. Map of fish passage barriers (by HUC 8 watershed) identified in Washington State and reported in the Washington Fish Passage database (https://geodataservices.wdfw.wa.gov/hp/fishpassage/index.html).

Funding for barrier removal in Washington State comes from a variety of sources including multiple tribal, federal, state, and local government entities that are prioritizing and implementing removal of manmade fish passage barriers, such as road crossings and culverts. For example, the Washington Department of Transportation (WSDOT), Department of Natural Resources (WDNR), Recreation and Conservation Office (Salmon Recovery Funding Board, Brian Abbott Fish Barrier Removal Board), and other state agencies have programs for addressing culverts that create barriers to fish passage. The magnitude of the problem, costs of repairs, and time needed to permit and correct barriers, highlight the need to prioritize fish passage repair efforts that provide the greatest gain to the most imperiled fish stocks.

There are a variety of regional strategies for prioritizing barriers for removal, including those developed by salmon recovery boards, lead entities, tribes, cities, counties, and other groups (e.g., Maier and Pepin 2020; Nuckols et al. 2021; Burch et al. 2024). Unfortunately, this has resulted in a variety of processes for prioritizing barriers for correction or removal with different entities using different prioritization methods and criteria (Burch et al. 2024). Modeling efforts indicate that coordinated efforts of barriers across individual or even multiple states are more efficient and effective at reconnecting isolated habitat than individual watershed-scale prioritization strategies (Neeson et al. 2015).

In 2020, the Washington State Legislature directed WDFW, WSDOT, and the Brian Abbott Fish Barrier Removal Board (FBRB) to develop a comprehensive statewide strategy through legislative provisos in the state's supplemental Operating Budget (ESSB 6168), the supplemental Capital Budget (ESSB 6248), and the Transportation Budget (ESHB 2322). The resulting strategy must align with the U.S. vs. Washington permanent injunction and fish passage barrier removal program (RCW 77.95.180). In turn, this strategy will focus all culvert correction programs into a single strategic approach that seeks to maximize salmon and orca recovery benefits from public investments (Figure 2). Furthermore, the strategy is designed to guide the FBRB's funding recommendations, as well as other state fish passage barrier correction programs.

Following this guidance, the WDFW initiated the development of a comprehensive barrier removal strategy that is scientifically defensible and transparent and widely supported by the restoration community to prioritize fish passage barrier removal at barrier and stream system (watershed) scales[1]. The intent of the strategy is not to create a prioritized list of individual barriers from 1 to 20,000, rather to have an interconnected singular strategy of varying tactics that, when applied sequentially and consistently at the state, regional, or watershed level, results in the maximum benefit possible for

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[1] Barrier scale refers to the individual barrier.

improving habitat for ESA-listed salmon and trout, orca recovery, and salmon populations that constrain fisheries[2]. Moreover, the comprehensive strategy will guide funding recommendations of the FBRB, as well as other state fish passage barrier correction programs.

This document outlines the proposed statewide strategy including goals and methods, approach, criteria, and recommendations for implementation, as well as data gaps and future data needs.

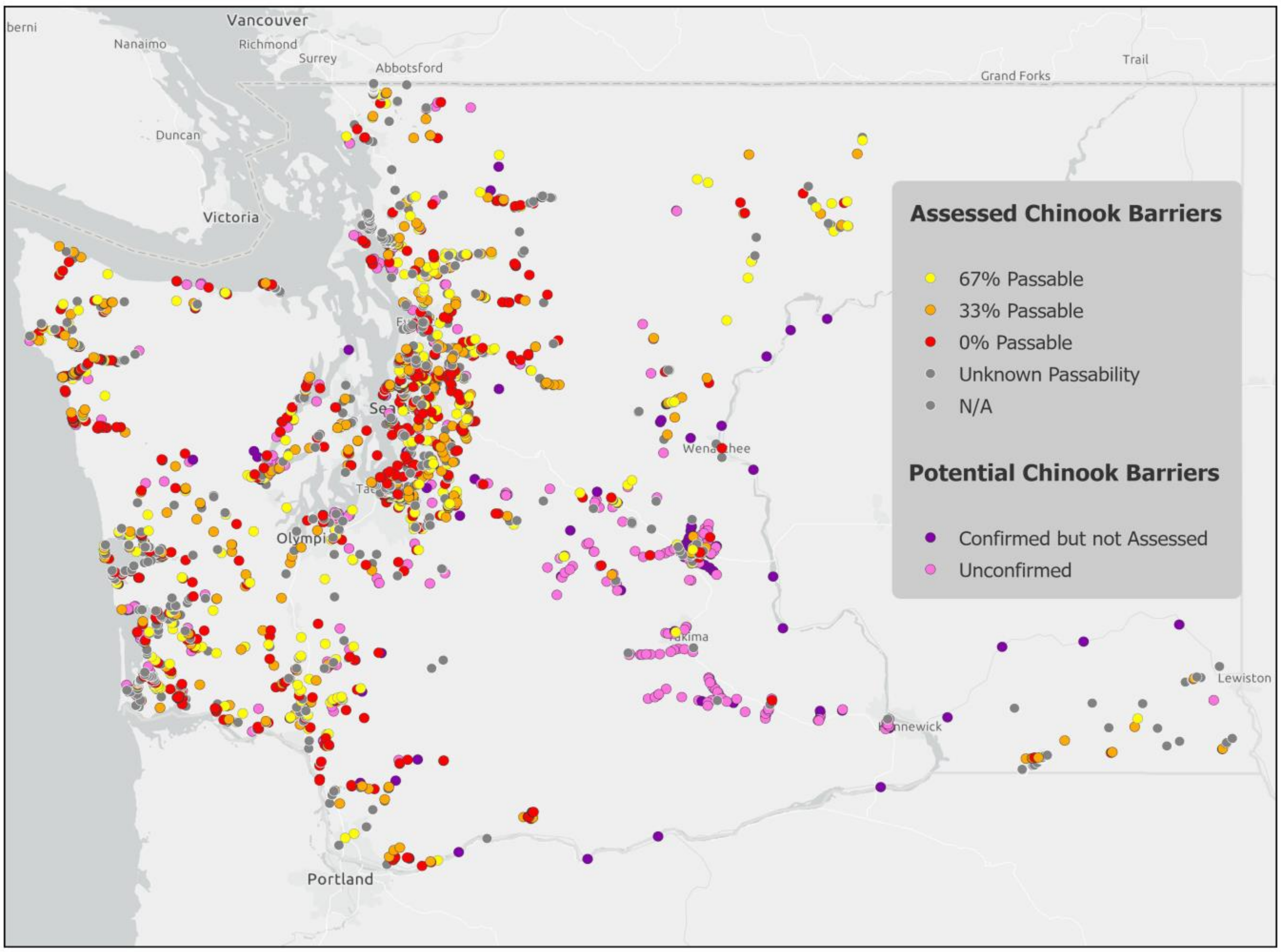

Figure 2. Map of WDFW-inventoried and potential Chinook fish passage barriers in Washington State (https://wdfw.maps.arcgis.com/home/webmap/viewer.html?webmap=def763e1e64842a9bd3780784a0bd8d3).

[2] Salmon populations that limit the harvest of anadromous fish in the Pacific Salmon Treaty or North of Cape Falcon fishery negotiations

METHODS FOR DEVELOPING A STATEWIDE STRATEGY

The overall goal of the statewide strategy is to help develop a repeatable or iterative process to prioritize and reduce fish passage barriers to benefit depressed, threatened, and endangered stocks, as well as other priority species and is informed by the best available science. Based on proviso guidance and input from WDFW leadership, the strategy will consider:

- barriers to listed salmon and steelhead populations and potentially limit prey for southern resident orca populations,
- benefits of barrier removal to upstream, as well as lateral habitat[3],
- access to high quality salmonid spawning and rearing habitat,
- consider existing approaches to barrier prioritizations, including criteria used to inform other state fish passage barrier removal funding programs, and
- whether an existing culvert (barrier) is a full or partial barrier.

Steps for developing robust strategies to prioritize restoration actions, including barrier removal, have been well established (Roni et al. 2013) (Figure 2). Key steps include:

1. Determine goals, objectives, and scale of prioritization.
2. Select a technical team to develop prioritization approach.
3. Select criteria to include in priorization approach.
4. Detemine weighting/relative importance of each criteria and their scoring (if using a scoring approach).
5. Collect data
6. Run the model or calculate scores.
7. Examine project ranking and conduct sensitivity analysis.

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[3] The strategy focuses on stream crossings that are fish passage barriers and thus addresses lateral habitat indirectly through crossing that are located on levees, roads, or infrastructure that isolate lateral habitats. Mapping and quantification of isolated floodplains and lateral habitat is a pressing need that is outside the scope of the current strategy.

These seven steps are sometimes done sequentially but are often done iteratively where steps are revisited or done simultaneously. The statewide strategy focuses on the first four steps. The goal of the strategy is not to prioritize all the barriers but rather to develop the strategy, including the approach, criteria, and any suggestions for weighting that can be used by partners and the restoration community to prioritize barriers or modify their current prioritization strategy. We used a collaborative science-based approach to develop the Strategy, including the following three components:

1. Outreach and engagement— Conduct outreach efforts to inform Tribes, Salmon Recovery Regions, and other key partners of this effort, followed by additional outreach to obtain input on draft and final strategy.
2. Science panel — Convene a science panel composed of regional experts to help inform and develop the strategy using best-available science.
3. Review literature and existing strategies — Review existing science-based fish passage barrier prioritization schemes in the western U.S.

WDFW staff worked with the Science Panel throughout development and writing of the strategy. In addition, the WDFW leadership team helped guide the development, review, and approval of the strategy to ensure it met the intent of the provisos and WDFW techncial and regulatory requirements.

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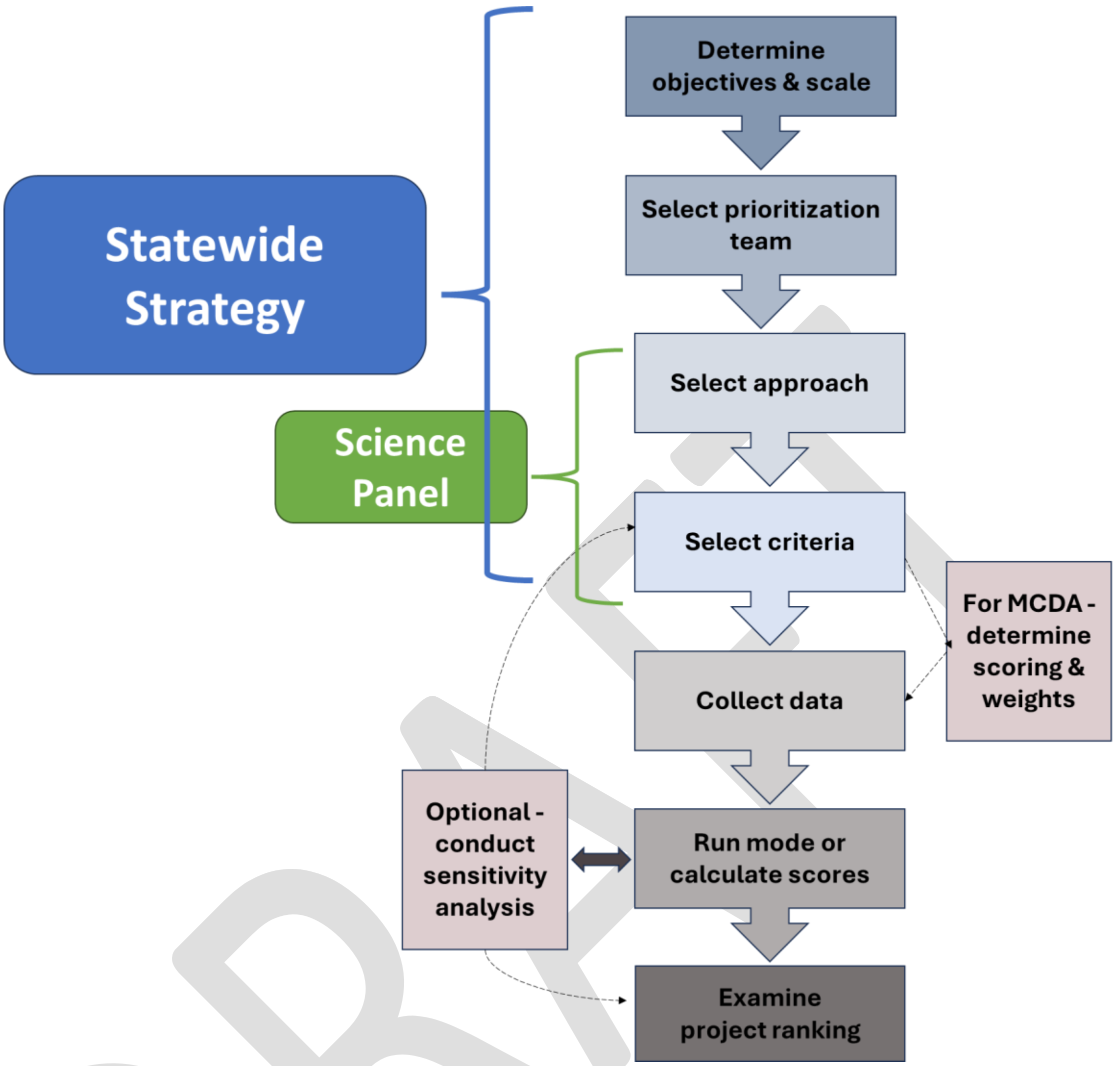

Figure 3. Steps in the process of designing a prioritization strategy for barriers or other restoration projects. The statewide strategy will cover the first four steps with the Science Panel providing technical input on the best approach and criteria to include in the approach(s). MCDA = multi-criteria decision analysis also known as scoring and ranking. Modified from Roni and Beechie (2013).

Outreach and Engagement

The Fish Passage Strategy project team conducted extensive outreach and engagement to get input from Tribes, regional recovery groups, and other partners on the development of the strategy. This occurred in two phases: Phase 1 occurred prior to convening the Science Panel and developing the strategy and was designed to solicit initial input on strategy development from Tribes and partners; Phase 2 will occur during Summer 2024 and is designed to gather feedback on the draft strategy, as well as input on its implementation.

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Phase I occurred in Spring and Summer 2023 and included:

- *Presentation and assessment interviews* with Tribes and key partners to share information about the project and identify interests and concerns regarding fish passage barriers. The presentation included an overview of the strategy, how it aligns with other state-led fish passage efforts, how it will be developed and used, the role of the Science Panel, how WDFW will partner with Tribes, and its approximate schedule. These interviews also provided an opportunity to determine where fish passage inventories and prioritization strategies have already been developed. A list of participants in the assessment interviews is provided in Appendix A.
- *A Tribal Briefing* on March 22, 2023, provided an overview of the strategy and gathered input, insight, interests, and concerns from Tribal partners on the impacts of the barrier removal strategy. Interviewees and participants in the Tribal Briefing are also included in Appendix A.

Phase II is scheduled for Summer and early Fall of 2024 and, like Phase 1, will include:

- Extensive Tribal engagement, including one-on-one briefings and meetings, to share preliminary approaches and get input on specific sections and recommendations for implementation.
- Meetings/briefings with regional recovery groups and others to share preliminary approach to the strategy and get input on specific sections and recommendations for implementation.

During Phase I, input focused on several key themes, such as obstacles and challenges to implementation, Science Panel recommendations, process recommendations, and general values. A summary of the input received during Phase I and how it was addressed during strategy development is included in Table 1.

Table 1. Summary of input and response during initial outreach and engagement sessions in 2023 prior to development of the statewide strategy.

Topic	Input	How input was addressed
Obstacles and Challenges	• Capacity is limited • Complexity and scale of some projects (e.g., multiple barriers) • Data availability, especially on tide gates • Funding is limited	All obstacles and challenges identified by partners and stakeholders were discussed and considered throughout the process and are reflected in the Science Panel's recommended approach.

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	• Partnerships with landowners is a key consideration • Prioritizing projects • Understanding relative costs and benefits	
Recommendations for focus areas for Science Panel	• Upstream habitat • Passability ratings • Limiting factors • Population viability • Grouping barriers in context of other work underway • Funding and cost/benefit	All recommendations provided were shared and discussed with the Science Panel and are reflected in the strategy.
Process Recommendations	• Define a scope, goals and purpose and communicate it early • Consider how the strategy will be used by those on the ground to focus funding and partnerships (e.g., injunction) • Refine decision making process to develop the strategy and continue strong tribal engagement	Scope, goals and purpose of project were defined and shared extensively throughout engagement; considerations for how the strategy can be used on-the-ground were discussed extensively and reflected in both the strategy and its implementation[4].
Values	• Salmon recovery • Population viability • Leveraging expertise • Economics and focused investments • Partnerships and collaboration • Watershed function and climate resilience • Focusing funding and efforts in a coordinated way	All values described by partners and stakeholders were considered for inclusion by the Science Panel as it developed criteria for the optimization and rank-and-score approaches.
Other	• Regions with more needs will need to be more engaged throughout the process	Regions identified as having greater need (Puget Sound and Lower Columbia) are

[4] The implementation section will be revised based on additional input from the Tribes and key partners in summer and early fall of 2024.

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	• Consider using the State of Our Watersheds Report by NWIFC • The strategy should be widely adopted • Be sure to clarify what this project is in relation to other work related to culverts and barriers	being engaged more extensively than others.
Questions	• How will the strategy address different barrier types? What is the scope? • How will the state use the strategy? • What does success look like for the strategy?	FAQs developed to address questions. Scope and goals of strategy defined. Described in the implementation section.

Science Panel

A group of experts, all of whom brought diverse backgrounds and experiences, was convened to provide input, review key products, and ensure a strong scientific foundation for the strategy's development. Science Panel members had expertise in fish passage, WDFW fish passage criteria, salmon and steelhead life history, ecology, population dynamics, and genetics, habitat and geomorphology, prioritization, climate change, optimization, and fish passage economics. Furthermore, members were selected to represent diverse backgrounds and research experience in state, federal, tribal, non-profit, and for-profit research. Rather than regional representation, the panel members seleceted had experiene across the Washington State and the Pacific Northwest. The panel consisted of nine members including:

- Dan Auerbach, Washington Department of Fish and Wildlife
- Pete Bisson, U.S. Forest Service, retired
- Thomas Buehrens, Washington Department of Fish and Wildlife
- Ken Currens, Northwest Indian Fisheries Commission[5]
- Robby Fonner, NOAA Northwest Fisheries Science Center
- Robyn Pepin, Aspect Consulting

[5] Ken Currens, retired before completion of the draft strategy and did not provide input on the final development.

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- Jason Nuckols, The Nature Conservancy
- George Pess, NOAA Northwest Fisheries Science Center
- Phil Roni (Science Panel Chair), Cramer Fish Sciences and University of Washington

The Science Panel provided input and review for WDFW (from July 2023 to present) to consider in the final strategy's development. Specifically, the Science Panel was asked to:

- Help identify and review regional prioritization stategies and literature.
- Provide recommendations on prioritization approach, including the scale, prioritization criteria, weighting, and minimum data needs.
- Review the draft prioritization approach developed based on Science Panel input.
- Review the draft prioritization strategy prior to being provided to WDFW leadership for review

The charter and guidelines for the Science Panel are provided in Appendix B.

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Review of Literature and Existing Strategies

We conducted a detailed literature review to obtain information on strategies and approaches for barrier removal project prioritization. Our focus was the western U.S. and Canada, but we included key literature from other areas in the U.S. and abroad where appropriate. We used three sources to identify prioritization strategies. First, the NOAA Central Library conducted a literature review and prepared a bibliography of available literature on fish passage project prioritization in 2020 (Shinn 2020). We first screened this source for relevant papers. Next, Dr. Phil Roni maintains an Endnote database of more than 1,000 papers related to restoration effectiveness, and prioritization, which is updated annually. We searched Dr. Roni's Endnote database for any additional papers on barrier prioritization strategies, specifically looking for key words, "barrier(s)," "culvert(s)," "fish passage," "passage," "dam(s)," "diversion(s)," and "tide gate(s)," in any field. We then reviewed these to see if they were relevant to barrier prioritization and not already included in sources we obtained from the Shinn (2020). Next, we conducted a Google Scholar search using similar terms to locate newer publications on barrier prioritization that may not have been included in Shinn or the Endnote database. Finally, we presented this list to the Science Panel and asked if there were any sources we overlooked. Ultimately, we identified 95 relevant published papers and technical reports (grey literature) that provided information on prioritization of fish passage barriers (Appendix C). This includes 16 websites that provided either online prioritization tools or online descriptions of prioritization strategies. The bibliography was provided to the Science Panel for review and to assist with their input on strategy development.

We also identified and reviewed other barrier prioritization strategies developed and used throughout Washington State by various groups and entities (e.g., agencies, tribes, recovery boards, lead entities, counties, cities, restoration practitioners). We identified 10 of these fish passage barrier prioritization strategies based on web searches and information provided during outreach sessions which were available online or in print (Table 2). All current strategies used some type of scoring and ranking system. A scoring and ranking system simply uses multiple criteria (e.g., area of habitat restored, cost, increase in biota) that are given individual scores (e.g., 0 to 5, 1 to 10) and are then aggregated into a combined score (Roni et al. 2013). These scores are ranked in order from highest to lowest based on the final scores. Scores are often given different weights based on their importance to those prioritizing. It is sometimes known as multi-criteria decision analysis (MCDA) and has been widely used in engineering and environmental sciences (Haung et al. 2011), though MCDA is often focused on the optimal decision. Eight of these strategies are based on, or were informed by, a strategy developed by the Upper Columbia Salmon Recovery Board and their partners (Maier and Pepin 2020). The remaining two strategies (City of Bellingham, North Olympic Peninsula) are based on the WDFW Prioritization Index (2009, 2019). A recent comparison of prioritization approaches indicates that some smaller organizations are also using the WDFW Prioritization Index (Burch et al. 2024). The Hoko (North Olympic Peninsula) strategy, which is also based on the Upper Columbia strategy, is somewhat unique in that it prioritizes reaches above or between barriers rather than the barrier itself. In addition, there are barrier prioritization strategies under development in the Lower Columbia and South Puget Sound, which are modifying the Upper Columbia strategy. While not a barrier prioritization strategy, the Brian Abbott Fish Barrier Removal Board (FBRB) recently developed criteria that will be used to evaluate grants for fish passage barrier removal projects from 2025 to 2027. These contain many of the same criteria found in regional prioritization strategies. We also examined two optimization approaches: the Oregon Tide Gate Optimization Tool (Nuckols et al. 2021) and Upstream (https://upstream-wca.app The Tide Gate Optimization Tool was developed and is currently being used to prioritize tide gate removal on the Oregon Coast. It is based on the OptiPass software developed for prioritization of passage barriers (O'Hanley 2014). Upstream is an online barrier optimization tool that is being developed by the

University of Washington to assist with prioritizing barriers in Puget Sound that allows the use to explore different optimal combinations of barriers based on objectives, habitat definitions, weighting, species, and cost.

Table 2. List of current barrier prioritization strategies in Washington State. Note that Lower Columbia and South Puget Sound are under development. The asterisk (*) indicates the strategy is based on or a modification of the approach developed in the Upper Columbia recovery region. Also included are recently developed criteria for statewide FBRB grant evaluation.

Strategy	Sponsor	Region	WRIA
Chehalis Fish Passage Barrier Prioritization*	Washington Dept. Fish & Wildlife	Chehalis River/Grays Harbor	22, 23
City of Bellingham Fish Barrier Prioritization Update (2019)	City of Bellingham	Whatcom County	1
Hoko Fish Barrier Prioritization*	North Olympic Salmon Coalition	Hoko River	19
King County Fish Passage Barrier Prioritization Report*	King County DNR&P	Middle Puget Sound	7, 8, 9
Lower Columbia – Under development*	Lower Columbia Fish Recovery Board	Lower Columbia?	25, 26, 27, 28, 29
North Olympic Culvert Inventory and Prioritization	North Olympic Peninsula Lead Entity	Clallam County within NOPLE boundary	17, 18, 19,
Snake Barrier Prioritization*	Snake River Salmon Recovery Board	Snake River	32,33,35
South Puget Sound – Under development*	South Puget Sound Fish Enhancement Group	South Puget Sound	?
Upper Columbia Fish Passage Barrier Removal Priority Ranking*	Upper Columbia Salmon Recovery Board	Upper Columbia	45,46,48,49

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Western OP Fish Barrier Decision Support Tool Scores*	Coast Salmon Partnership	Coastal OP	20, 21
Willapa Bay Fish Barrier Prioritization*	Coast Salmon Partnership	Willapa Bay	24
Yakima Barrier Prioritization*	Yakima Basin Fish and Wildlife Recovery Board	Yakima River	37,38,39
2025–2027 FBRB Grant Round Proposed Evaluation Criteria	Brian Abbott Fish Barrier Removal Board	Statewide	NA

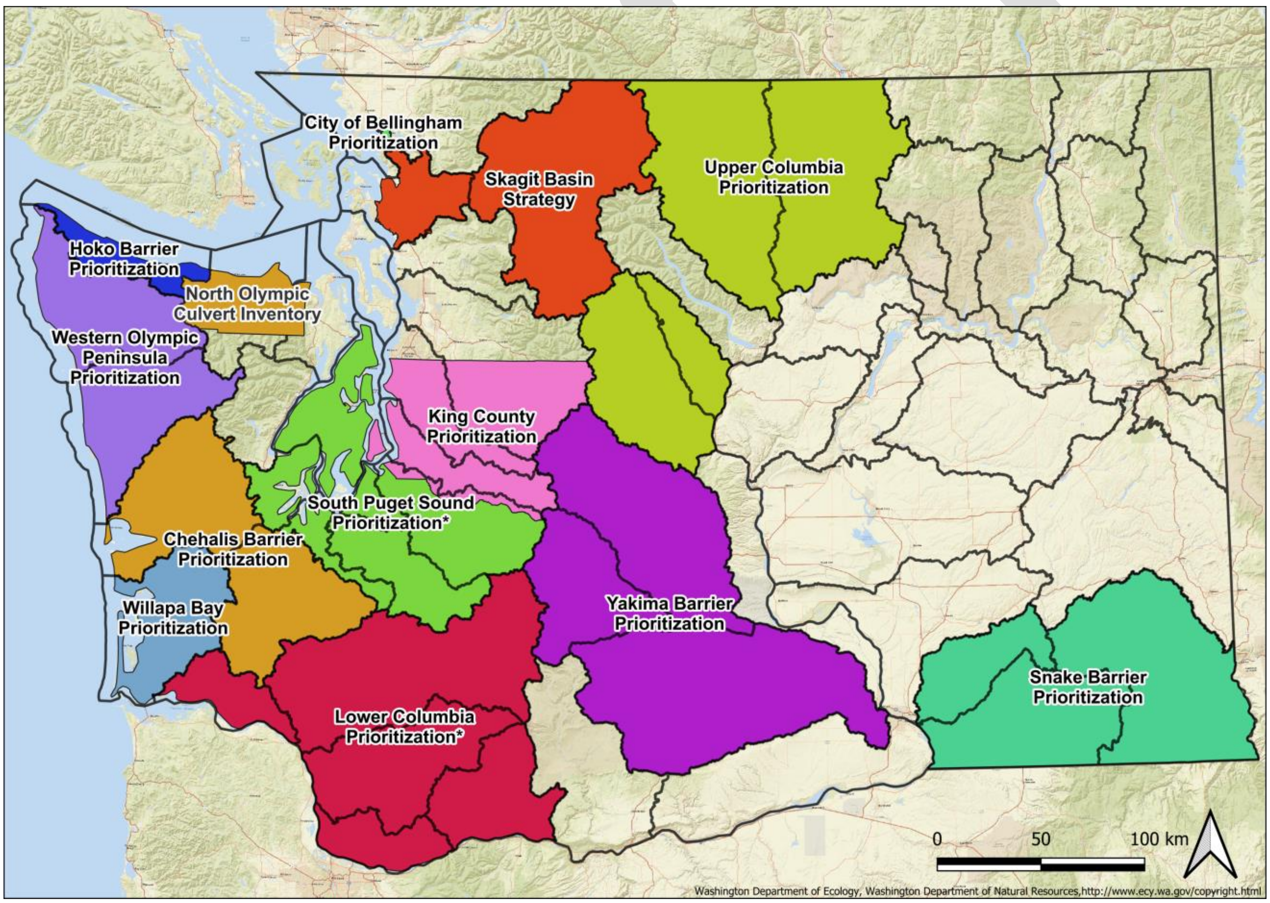

Figure 4. Map of existing barrier prioritization strategies examined. The South Puget Sound, Lower Columbia, and Skagit Basin Strategy are under development.

We grouped criteria used by different strategies into seven general categories including:

- Barriers — criteria that focus on the type, passability, connectivity, and order of the barrier in relation to other barriers (e.g., passability (0%, 33%, 67%, 100%)[6], upstream barrier count, barrier density).
- Habitat quantity – criteria that focus on the amount (length or area) of habitat upstream of the barriers (e.g., water quality, intrinsic potential, gradient, stream temperature).
- Habitat quality – criteria that focus on the condition or quality of stream habitat typically upstream of the barrier (e.g., length of accessibly stream upstream of barrier, access to quality rearing and spawning habitat, riparian buffer width).
- Species – criteria that focus on the fish species present or benefiting (e.g., number of endangered species, benefits orca, benefits Chinook salmon, priority watershed for recovery).
- Climate/future conditions — criteria that focus on the predicted changes in future conditions such as predicted temperature and stream flow under climate change (e.g., 2040 stream temperature, 2040 flood events, 2040 hydrologic regime shift, climate resiliency index[7]).
- Feasibility – criteria that focus on the ease or difficulty of project implementation (e.g., community support, cost, funding sources available).

Many strategies use similar or identical criteria related to the fish passage barriers (e.g., passability, downstream barriers), habitat quantity, habitat quality, species, and climate/future conditions (Table 3). Only one strategy and the FBRB grant round consider project feasibility (e.g., cost, funding, community support, design), and only the Chehalis strategy specifically called out riparian condition (canopy cover, tree height, buffer width) as a separate category rather than part of habitat quality. However, three other strategies included canopy cover or riparian condition as a criterion under habitat quality (North

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[6] The WDFW determines passability of a barrier based on swimming abilities of adult trout (> 6” or 152mm) and adult salmon and steelhead. 0% passability indicates that the feature is a total barrier to some adult salmonids during period during the range of fish passage flows; 33% passability indicates that the feature is a severe partial barrier to some adult salmonids; 67% passability indicates that the feature is a moderate partial barrier to some salmonids; and 100% passability indicates that no adults salmonid should be impeded when attempting to pass through the feature. See WDFW (2019) for additional information.

[7] https://coast-salmon-partnership.shinyapps.io/CRI_app/

Olympic Peninsula, Upper Columbia, Willapa), and the Yakima and Snake strategies indicate canopy cover is incorporated in stream temperature criteria.

Table 3. Major categories of criteria covered by existing Washington State barrier prioritization strategies. Also included are criteria for evaluating Fish Passage Recovery Board grants for funding of barrier removal projects. The Hoko strategy also included one other undefined criterion. Upper Columbia* prioritizes species separately so there appear to be two species criteria used for each Chinook salmon, steelhead, and bull trout.

Strategy	Barrier	Habitat Quantity	Habitat Quality	Species	Climate/ Future Conditions	Feasibility	Total No. Criteria
Chehalis Fish Passage Barrier Prioritization	3	5	9	1	1		19
City of Bellingham Fish Barrier Prioritization Update (2019)	2	3	1	2		4	12
Hoko Fish Barrier Prioritization	2	1	5	2			10
King County Fish Passage Barrier Prioritization Report	3	1	3				7
North Olympic Culvert Inventory and Prioritization	2	1		2			5
Skagit Basin Barrier Culvert Analysis	2	1	2				5
Snake Barrier Prioritization	5	1N	2	2	4		14
Upper Columbia Fish Passage Barrier Removal Priority Ranking	3	1	4	2/5*	4		14/17*

Western OP Fish Barrier Decision Support Tool Scores	5	2	2	2	4		15
Willapa Bay Fish Barrier Prioritization	5		3	2	4		14
Yakima Barrier Prioritization	5	1	2	2	4		14
2025–2027 FBRB Grant Round Proposed Evaluation Criteria	2	1	3	2	1	6	15

SELECTION OF A PRIORITIZATION APPROACH

There are various methods and approaches for prioritizing barriers and other types or restoration projects, including but not limited to: professional opinion, species, refugia, project effectiveness, cost, cost-effectiveness, scoring and ranking, mathematical optimization, and a variety of models (Beechie et al. 2008; Roni et al. 2013; McKay et al. 2020; Finn et al. 2023; Garcia di Leaniz et al. 2022). Simple approaches to prioritize restoration projects such as species, refugia, project effectiveness and cost have been incorporated as criteria in scoring and ranking or optimization approaches (Roni et al. 2013). The two most frequently used and those recommended for prioritizing barrier removals projects are scoring and ranking systems and optimization models, with some authors recommending one or the other in part based on their own experiences (i.e., Beechie et al. 2008; McKay et al. 2020). Many current prioritization strategies use a weighted sums of various criteria to create a “score” or index that is used to rank projects. As demonstrated in Table 3, strategies often included criteria related to the barrier itself or relation to other barriers (e.g., passability, barrier order), habitat quantity (e.g., length or area of upstream habitat), measures of habitat quality (temperature, pool frequency, large wood, riparian condition), species (e.g., number of species present, benefits to other species, endangered species), and other non-habitat or biological criteria such as social benefits. Moreover, criteria can be both quantitative or qualitative with qualitative and selected criteria often weighted based on their relative importance to partners. Those barriers with the highest cumulative score are ranked the highest.

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Scoring and ranking systems used in salmon recovery and restoration ecology are not designed to identify one optimal project, rather to identify those projects that should be higher priority and implemented prior to lower scoring projects. Thus, in practice, barrier removal projects prioritized are often broken into tiers of high, medium, and low priority projects. Restoration practitioners do not necessarily focus on working down the list from the highest ranked project to the second ranked project, etc., as many factors can influence whether a project can be implemented immediately. Rather, restoration practitioners typically focus on the those that are in the top tier. In addition, sometimes projects are bundled because of proximity and some low or medium priority projects are implemented with high priority projects due to logistics (opportunity, access), cost, or other reasons. However, when scoring and ranking approaches are used by funding entities, they often select the projects in order of their ranking until they reach the total available funding limit.

Optimization is a prescriptive, mathematical approach that produces a recommended course of action (Garcia de Leaniz and O'Hanley 2022). For barriers removals, it typically attempts to identify the optimal portfolio or combination of barrier removals to maximize connectivity based on a specified set of objectives, time-scale, and budget (McKay et al. 2020). It is fully capable of accounting for spatial structure of barrier networks and the interactive effects of correction on barrier connectivity (Garcia de Leaniz and O'Hanley 2022). Because of this, it is increasingly being used to prioritize barriers and rank barriers or to find the optimal group of barriers to remove to maximize amount of accessible habitat for specific constraints, such as a fixed budget, number of barriers, or other constraints (McKay et al. 2020; Nuckols et al. 2021; Garcia de Leaniz and O'Hanley 2022). Optimization tends to work best with many barriers and at broad scale where the available budget allows examining a portfolio of projects (McKay et al. 2020).

There are a number of similarities between the optimization and scoring and ranking approaches, such as similar data requirements and ability to incorporate non-quantitative criteria through converting quantitative measures into categorical measures. Both approaches can include connectivity though in score and rank approaches connectivity is often incorporated through qualitative measures or as barrier order. Both approaches are mathematical equations and can incorporate cost. In score and rank, cost can be included as a criterion (e.g., total cost or cost per mile) though cost is often considered later when

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searching for funding to implement the highest priority projects. In optimization, cost is often used as a constraint and the optimal portfolio of barriers determined given the objectives and a specific budget. Scoring and ranking approaches are often used by funding organizations such as salmon recovery boards to rank proposed barrier removals, with the top ranked proposed projects sequentially selected until the funding is exhausted. Therefore, the key differences in the two approaches are in how they treat cost, barrier order, and connectivity, as well as whether the solution is a based on individual versus a group of barriers. The strengths and weaknesses of these two and other approaches have been reviewed by several authors (e.g., Roni et al. 2002, 2008 Beechie et al. 2008; Kemp and O'Hanley 2010, Roni et al. 2013; McKay et al. 2020; Garcia de Leaniz et al. 2022).

The key strengths of the optimization approach include its explicit accounting for connectivity (order and timing of barrier removals), recognition of scarce resources, and examination of multiple scenarios (Table 4). Optimization is computationally more complex, requiring considerable expertise and computing power, and the calculations may not be readily understood by a broad range of users. It also provides an optimal group of barriers that should be addressed and works best when there are many barriers. The strengths of the score and rank approach include that it can typically incorporate professional opinion and a variety of non-quantitative criteria, as well as is computationally simple and often done in a simple spreadsheet, making it transparent and understood by a broad range of users. This approach ranks each barrier individually, which allows for selecting an individual barrier or groups of barriers and allows for flexibility in implementation though it does not necessarily provide the most efficient use of resources (Table 4).

Table 4. Appropriate scale, similarities, strengths, and weakness identified for optimization versus scoring and ranking approach for prioritizing barriers. Strengths and weaknesses taken from Kemp and O'Hanley (2010), McKay et al. 2020; and Garcia de Leaniz 2023).

Mathematical Optimization	Scoring and ranking
Appropriate scale(s)	
Statewide, regional or basins/WRIA. Best return on investment occurs at largest scales when the most options are considered.	Regional scale, multi-basin/WRIA, basin, or sub-watershed.
Key Strengths	
• Solution set can be designed to effectively handle barriers in a series	• Computationally simple and easy to implement (e.g., using spreadsheets)

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• Capable of balancing multiple, possibly competing, objectives and constraints • Cost-efficient - optimal solution is provided to maximize benefit for a given budget • Objective and systematic approach to decision making	• Easy to integrate multiple objectives and criteria, even those that are hard to quantify • Minimally prescriptive and easier to align with implementation constraints • Facilitates stakeholder buy-in
Potential Weaknesses	
• Often solutions require action on a set of barriers, requiring cooperation and coordination • Challenging to account for factors that are not easily quantified • Changes to budgets and project costs can have a substantial impact on priorities • Often requires high level of mathematical and programing expertise	• Barriers normally evaluated independently, thus ignoring spatial connectivity • Typically, multi-objective analyses rely on subjective weighting schemes • Assigning scores and determination of how to weight different criteria is very often ad hoc • Cost and budget are often incorporating indirectly and thus can produce highly inefficient solutions
Common challenges	
• Data must be kept current and available in a commonly accessible database • Data availability and inconsistent quality • How you present the data can make a difference on utility and transparency etc.	

Recommended Prioritization Approach and Scale

The best approach depends on several factors including the goals and objectives, the scale at which it will be applied, how the prioritization strategy will be used by practitioners, prioritization criteria, legal mandates, and how barrier removals will be funded (Roni et al. 2013). To select an approach for the strategy, the Science Panel discussed the strengths and weaknesses of various approaches, examined the various strategies across the state, and key literature on barrier prioritization strategies (Appendix C). Some panel members preferred one approach over the other; however, the majority of the Science Panel recommended a hybrid which include:

- Using an optimization approach to prioritize barriers at a statewide scale[8], and
- Scoring and ranking approach to prioritize barriers at a regional or watershed scale[9].

[8] Across the entire state.

[9] Regional scale refers to the recovery region and watershed can be at the WRIA or smaller scale delineated by a specific drainage basin.

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This approach recognizes the need to determine the optimal combination of barriers statewide to help recover listed species while using statewide resources and authorities strategically. Further, this approach also allows regional groups to modify their scoring and ranking approaches to be in line with the strategy. This also recognizes regional differences in data, species passage priorities, and leverages existing regional prioritization strategies. From an implementation standpoint, the statewide optimization approach would provide a statewide categorization of high, medium, and low priority barriers that would also be included as additional criteria in regional prioritization approach based on scoring and ranking. A recent review of barrier prioritization strategies also recommended that a hybrid approach that used optimization and scoring and ranking or other approaches as the most tractable (Garcia de Leaniz and O'Hanley 2022). In addition, given that most existing strategies in Washington State use a scoring and ranking approach, the use of this approach at the regional level will allow groups to simply modify their existing approaches to be consistent with the strategy and, more nimbly, consider emerging implementation opportunities and logistics. Thus, the hybrid approach is a flexible approach that leverages the strengths of both optimization and scoring and ranking approaches and allows for local input and modification. Optimization models do take considerable expertise to develop and run, though the Science Panel suggested that the optimization approach may become feasible at the regional level in the near future as optimization software, more complete data, and expertise become more widespread.

The appropriate scale for the prioritization can refer to the regional area across which barriers will be prioritized, whether one is talking about prioritizing the barriers themselves, or prioritizing the reaches or sub-watersheds that might be isolated by a barrier (Roni et al. 2013). First, as the name implies, the strategy is intended to prioritize barriers across Washington State, yet it also recognizes existing regional strategies that will prioritize barriers at region (recovery region) watershed (WRIA or HUC), county or even city scale. Thus, the scale of the strategy is at the state, as well as regional or watershed level. Second, based on the provisos, it is clear the intent was to prioritize the barriers themselves rather than watersheds or stream reaches. The Science Panel also recommended barriers as the unit of prioritization because barriers, unlike other restoration techniques, focus on a specific point in the landscape. Considering this, the focus should be on the barrier as the unit of prioritization not a reach or watershed. However, in some cases, multiple barriers in a stream system should be examined as a group or cluster

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and barriers in some sub-watersheds or areas may be given higher priority than others. For visualization and mapping purposes, it may be helpful to show heatmaps of watersheds or regions with different densities or numbers of priority barriers (e.g., color coding watersheds by number of priority barriers or length that could be opened up or scalable heat maps showing benefits to orcas and listed species). Using a multi-scale prioritization approach is common for prioritizing not only barrier removal projects, but habitat restoration projects where watersheds are often prioritized for salmon recovery (Roni et al. 2013). For example, some recovery plans for ESA-listed species often identify key watersheds that are important to recovery across an evolutionarily significant unit (ESU), which are as a criteria by local watershed groups to help prioritize projects within their watershed or region.

CRITERIA SELECTION

Optimization Approach

As stated previously**, the goal of the strategy is to help prioritize and reduce fish passage barriers to benefit depressed, threatened, and endangered stocks, as well as other priority species and is informed by the best available science.** Using the overall strategy goal and list of criteria extracted from existing regional prioritization strategies, we worked with the Science Panel to develop a comprehensive list of potential criteria for barrier prioritization using either the optimization or scoring and ranking approaches. We also identified whether data were currently available for these criteria statewide or regionally (Appendix D). Ultimately, with input from the Science Panel, more than 50 different criteria were considered. We combined similar criteria that were worded slightly differently in existing strategies or by Science Panel members. Using this information, we narrowed down the list for inclusion in the statewide optimization approach. Many potentially useful criteria were not included because data simply are not yet available across the state or in some cases even regionally (Appendix D).

Optimization Function

Optimization requires a function (equation) with a clear objective to be maximized. The strategy's main objective is to "Maximize amount of accessible high-quality habitat for listed salmon and to benefit orcas." Recommended key criteria to incorporate as variables and constraints in the function include:

- Barrier type (full, partial)
- Connectivity (order in relation to other barriers)

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- Length of upstream anadromous habitat
- Benefits Chinook salmon/orca
- Number of threatened, endangered, depressed species or stocks

These criteria include the objective (length of habitat upstream from the barrier) and constraints (things that limit the potential barriers selected). Using this, we developed an initial objective function that seeks to maximize the amount of upstream length opened by restoring barriers with the idea that this function would be refined when the model is fully developed. Areas that benefit Chinook salmon are given additional weight, as are areas that benefit other imperiled species. Conversely, partial barriers have the weight reduced to account for the fact that they already provide limited access. Thus, the optimization model includes the following:

- Constraint 1: This constraint enforces connectivity. It requires that all barriers downstream of a barrier selected for restoration are also removed.
- Constraint 2: This constraint limits the total number of selected barriers to remove. This constraint is meant to help identify priority barriers. Increasing the limit will allow the model to select more barriers and could be used to identify priority barrier tiers (e.g., high, medium, low).
- Constraint 3: This constraint declares the decision variables to be binary. This means each barrier can only be selected once, and that there is no ability to partially remove a barrier.

Objective function:

$$\text{Maximize} \quad \sum_i \left((5B_i + S_i) \cdot L_i \cdot Q_i \cdot x_i \right)$$

Subject to:

(1) Connectivity: $x_i \leq x_j \quad \forall j \in Con_i$
(2) Total barriers Selected: $\sum_i x_i \leq 50$
(3) Binary Decision Variables: $x_i \in \{0,1\}$

Definitions:

x_i = Decision to restore barrier i. Binary decision variable.

Q_i = Barrier passability factor for barrier i. $Q = 1$ for full barriers, 0.67 for severe partial barriers, and 0.33 for moderate partial barriers[10].

L_i = Length up upstream anadromous habitat opened by restoring barrier i. Continuous parameter[11].

B_i = Indicates if restoring Barrier i would benefit Chinook salmon. Binary parameter.

S_i = Number of threatened, endangered, depressed species or stocks (not including Chinook salmon) that would benefit from restoring barrier i. Integer parameter with max value of 5.

Con_i = Set of all barriers downstream of barrier i. Derived list.

We proposed some initial weighting values for barrier passability with the assumption that these would be refined when the optimization model is fully developed by the WDFW. Cost is commonly used in optimization models and incorporating cost in conservation and recovery planning has been shown to lead to improved success and efficiency of programs (Balmford et al. 2000; Naida et al. 2006;Newbold and Siikamai 2009). We did not include cost or budget constraints in the optimization model in part because WDFW does not want to the cost or budget to influence the initial priorities and in part because cost and budget are typically secondary factors used by recovery boards and project sponsors to determine funding necessary or which projects to fund.

Scoring and Ranking Approach

For the scoring approach, we selected a set of "core" and "optional" criteria. The core criteria are those that should be included in any regional barrier prioritization strategies and for which data are believed to be available across all regions. Optional criteria represent additional criteria that could be considered depending upon regional goals and whether data are available as data for many optional criteria are not available in all regions. The following are the list of core criteria recommended for all regional strategies to be consistent with the Strategy:

- Statewide priority (high, medium, low)

[10] Note that to incorporate barrier passability into the equation the percentages are the opposite of WDFW criteria for barriers. For example, WDFW defines a completely impassible barrier is 0% passable, a severe partial barrier 33% passable, and a moderate barrier 67% passable.

[11] The length of habitat upstream from the barrier will be determined on best available science.

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- Barrier type (full, partial)
- Barrier order – one of the following
  - Connectivity index[12]
  - Upstream passability
  - Downstream passability
  - Barrier order (correct lowest barrier first)
- Length of upstream anadromous habitat[13]
- Benefits Chinook salmon/orca
- Number of threatened, endangered, depressed species or stocks affected by barriers

Additional optional criteria to consider based on data availability and regional objectives include but are not limited to:

- Species - Colonization potential (larger population leads to colonization)
- Species - Priority watershed recovery
- Habitat quantity - Total area inundated (tide gates - total area of habitat gain)
- Habitat quality - Upstream reach gradient
- Habitat quality - Land/riparian cover upstream from the barrier
- Habitat quality - Pool and wood frequency upstream from the barrier
- Temp, Climate, and Water Quality (WQ) - Temperature (2040 or 2080)
- Temp, Climate, and WQ - Summer low flow (2040 or 2080)
- Temp, Climate, and WQ - Hydrologic regime shift (2040 or 2080)
- Temp, Climate, and WQ - Flood events (2040 or 2080)
- Temp, Climate, and WQ - Upstream migration distance to barrier from nearest summer suitable habitat (<20C mean august temperature in NorWest 2040 Model)
- Current Temp, Climate, and WQ - Temp or WQ

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[12] A variety of indices of barrier connectivity have been developed (e.g., Cote et al. 2009; King and O'Hanley 2016).
[13] As determined by best available science.

- Feasibility - ownership, community support, logistic considerations
- Feasibility - Benefit-cost (number of miles/kms per dollar)

This core and optional regional scoring criteria are designed to allow regions with existing strategies to easily modify those strategies and develop new regional strategies to be consistent with other strategies throughout the state. Regional prioritization will continue to be done by recovery boards and other local entities and partners.

There were several criteria that the Science Panel recommended, yet data with adequate spatial coverage do not currently exist. For example, habitat condition (pools, riffles, large wood) and salmonid abundance, density, capacity, and life history type are rarely available across watersheds, although they would be highly desirable (Appendix D). Similarly, the Science Panel recommended using stream temperature cautiously for multiple reasons. First, dry or ephemeral stream reaches, or reaches with high summer temperatures, may provide critical rearing habitat for salmon and other fishes during winter or other seasons (Ebersole et al. 2006; Hwan et al. 2018; Larsen et al. 2018). Additionally, recent studies have demonstrated that salmonids make diel and other short term migrations from stream reaches with optimal and suboptimal temperatures to take advantage of temporary food resources (Armstrong and Schindler 2013; Barrett and Armstrong 2022).

Considerations for Selecting Criteria and Scoring

In addition to selecting a key set of criteria, there are many other important factors to consider when developing a scoring and ranking system. These include how the criteria are scored and whether the criteria are weighted differently; how they are combined to achieve final scores; and, ultimately, how the rankings are used to select and implement projects. There is an extensive body of literature on scoring and ranking systems utilizing a simple type of multi-criteria decision analysis based on a weighted (or unweighted) sum approach, which has been widely used in the ecological sciences (Beechie et al. 2008; Huang et al. 2011; Roni et al. 2013). Our intent is not to cover these approaches in detail here rather to point out key considerations for developing regional scoring and ranking approaches to prioritize fish passage barriers for removal.

First, it is important to be judicious with selecting criteria, as initially proposed criteria often overlap and can include multiple similar criteria that inadvertently bias results. For example, using a criterium, such

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as barrier removals that benefit orca, and a criterium that focuses on barriers that benefit Chinook salmon, would lead to giving double the weight to barriers that benefit Chinook salmon, as they are the preferred prey of Southern Resident orcas. Another key consideration in scoring is the range of possible numerical scores for a particular criterium. Oftentimes, scoring and ranking approaches use scores of 0 to 3, 1 to 3, 0 to 5, or 1 to 10. Using different scores for different criteria can lead to weighting of criteria. For example, scoring one criterium from 1 to 3 and another from 1 to 5 gives greater weight to the second criterium because the maximum achievable score is "5" rather than "3." Another potential bias for either scoring and ranking or optimization is determining the scores for criteria that are not inherently numeric. Factors related to feasibility, such as site access or landowner interest, need to be scored by an individual or multiple individuals and tend to be subjective rather than quantitative. Thus, it is important to define how scores will be determined and do it as consistently as possible (i.e., if it is on private land, it will get a score of "1," on state land a "2," and federal land a score of "3" for feasibility). In some cases, weights are intentionally applied to give more weight to more important factors. For example, giving extra weight (e.g., 50%) of points, or multiply the length of habitat made available by a factor greater than one. However, weights can often lead to a bias in selection of barrier removal projects based on sociopolitical factors, such as land ownership. We did not make recommendations for weighing at the regional level and the Science Panel noted that there are many pros and cons of weighting, especially in terms of subjectivity. It should be done with caution or at least with sensitivity analysis to understand how weights might influence the outcome of scores.

Sensitivity Analysis

Sensitivity analysis can and should be done for both the statewide optimization and regional scoring and ranking approaches to determine 1) which criteria have the most influence on the rankings, 2) which criteria have little to no influence and can be removed, and 3) how weighting of different factors is influencing the rankings. In some cases, this can be as simple as fixing the value of some criteria and varying one criterion or removing a criterion to see how it influences rankings. Both optimization and scoring and ranking approaches can become less efficient and transparent with more criteria or constraints and become less transparent, so a sensitivity analysis to help refine criteria included in the final approaches is important.

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Ultimately, both statewide optimization and regional scoring and ranking approaches are intended to provide barrier removals of different priorities. Optimization will provide groups of barriers that can be ranked as high, medium, and low priority. Regional scoring and ranking approaches will provide detailed scorings of all barriers ranked in order, typically from highest to lowest. However, because many factors influence when and if a project can be implemented, scores are grouped into tiers, much like optimization. This is common for barrier removal and prioritization strategies in general (Roni et al. 2013; Bowerman and Pepin 2023). For example, the existing Upper Columbia barrier strategy, which uses a simple scoring approach ranks barriers into three tiers: Tier 1 barriers represent barriers with scores that ranked in the top 95% of all scores; Tier 2 barriers ranked between 80-95%; Tier 3 barriers ranked 40-80%; and Tier 4 barriers ranked lower than 40% (Bowerman and Pepin 2023).

Data Gaps

The review and selection of potential criteria highlighted existing data gaps, as well as data sets that might need improvement. Ultimately, the lack of data eliminated many criteria and factors from consideration and inclusion in the strategy, either statewide or regionally. In other cases, data exist but the quality, granularity, and coverage of the data could improve. Two critical data components needed for any barrier prioritization strategy are the stream network and the list (database) of known fish passage barriers. The entire barrier database and many of the data available are dependent upon the stream network and hydrography used. The WDFW Fish Passage database uses the U.S. Geological Survey (USGS) National Hydrography Dataset (NHD) hydrography and states road layer to map and identify barriers. The NHD hydrography layer was mapped at 1:24,000 using USGS maps and is not entirely accurate particularly for smaller streams. WDFW field surveys are used to identify new barriers and identify the true location of the stream crossing. Therefore, having an improved stream network would help accurately locate stream crossings, as well as current and potential barriers. The WDFW database is based on field surveys and not all areas and stream crossings have been surveyed. Therefore, an important need is a complete inventory of barriers for a region on federal, state, and private lands. Complete inventories can be difficult to obtain particularly for stream crossings on private lands. It is also important to ensure the inventories are incorporated into WDFWs barrier database.

Barrier Data

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Barriers are identified in the WDFW database as 0% passable, 33% (severe partial barrier), 67% passible (moderate partial barrier), and 100% passible based on passability criteria for adult trout (> 6 inches) and adult salmon and steelhead (WDFW 2019). Thus, the passability of these barriers may be different for adult anadromous fish or juvenile fish and having data on passability for other salmonid species would allow barrier removals to be prioritized based on their passability for other species. There have been attempts to estimate costs of culvert replacement (Van Deynze et al. 2022) and information on cost and feasibility of barriers would be useful.

Species Information

Many factors that involve fish species abundance or productivity only exist in small areas and, if available, data on salmonid capacity, density, and abundance would have been recommended for use statewide or regionally. Some information exists on a regional or watershed scale, but having or working toward statewide data layers on reach-level juvenile and adult salmon and steelhead abundance, density, capacity, and population (stock) size is important information that would improve barrier prioritization. Given that efforts are underway to estimate juvenile abundance and capacity in the Columbia Basin (Leasure et al. 2019; Isaak et al. 2020), it would seem some of these data layers will be available in the near future. Having information on life history diversity and other salmon and steelhead stock information is another data need that would improve barrier prioritization.

Habitat Quality and Quantity

Similarly, species-specific intrinsic potential as well as many habitat quality factors (e.g., pool area, large wood, reach gradient, nutrients) by stream reach exists but are not available for whole watersheds or regions. An important factor identified by WDFW and the Science Panel for the Strategy was the lateral connectivity or proximity to connected or isolated floodplains. Unfortunately, few consistent data sets on lateral connectivity or extent of isolated floodplain habitat existed at region or even watershed scale and the criterion was not included at this time in either the optimization or scoring and ranking approach. The strategy focuses on stream crossing so lateral habitat is addressed indirectly for those culverts or stream crossing on roads, levees or other infrastructure that might isolate lateral habitat. Efforts are underway to map floodplains and floodplain connectivity throughout the Columbia Basin that, when available, will be useful data for prioritizing barrier removal projects that reconnect floodplains.

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Regional Optimization

We initially recommend a hybrid approach for several reasons. However, with continued advances in computing power, software, and improvements in data quality, it is likely that mathematical optimization models will become more tractable for regional groups to implement in the near future. Thus, where appropriate, optimization could be used to replace simpler score and ranking approaches in some regions in the next 5 to 10 years. The development of a statewide barrier optimization model by WDFW as part of the strategy will potentially serve as a good template for future regional optimization models.

RECOMMENDATIONS FOR IMPLEMENTATION

Currently, barrier removal projects are prioritized regionally and either regional entities or local practitioners apply to various funding sources to obtain funding and remove fish passage barriers pursue. The strategy is designed to be flexible and complement this current process by providing consistent approaches for prioritizing barriers both across the state and regionally (Figure 5).

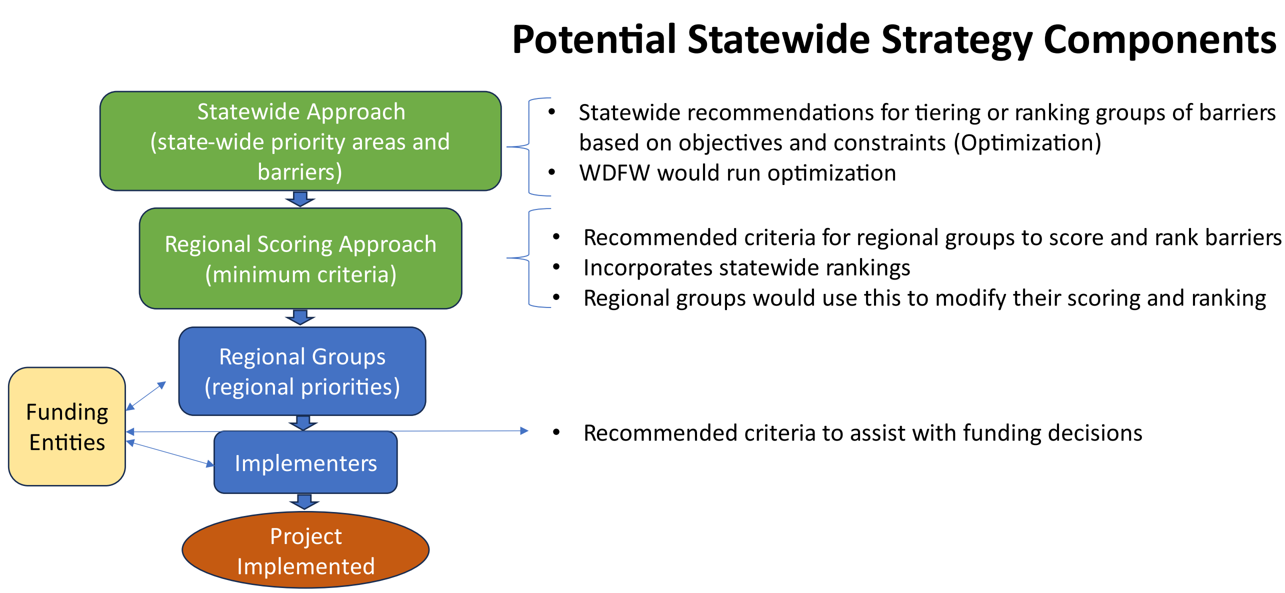

Figure 5. Diagram of how the statewide strategy and its two components would fit into existing barrier funding and implementation processes. The currently regional organizations prioritize barrier removal projects and either they or their partners (implementers) apply to funding entities to implement projects. The statewide strategy would provide statewide priorities and regional guidance.

<u>We are currently looking for input on how best to implement the statewide strategy, and this section will be completed following the Outreach and Engagement with Tribes and partners in Summer and early Fall of 2024. The following are potential topics to be covered in the implementation section.</u>

Who will use the strategy?

How will it be rolled out and implemented?

How will it be used and will it influence funding decisions?

How does it fit in with existing regional strategies and agreements?

What support will be provided for updating regional strategies and culvert inventories?

How often will the optimization be updated?

How will other important or depressed populations or stocks of fish be defined?

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APPENDICES

Appendix A. List of groups who participated in outreach and engagement.

Tribes/Tribal Entities	Phase I Tribal Briefing (2023)	Phase I Assessment Interview (2023)	Phase II Engagement (Summer 2024)
Cascadia Law Group	X		
Confederated Tribes of Colville Reservation		X	
Cowlitz Tribe	X		
Columbia River Inter-Tribal Fish Commission	X		
Dorsay and Easton Indian Law	X		
Hoh Tribe	X		
Jamestown Tribe	X		
Kalispel Tribes		X	
Nooksack Tribe	X		
Northwest Indian Fisheries Commission	X		
Lower Elwha Klallam Tribe	X		
Lummi Nation	X		
Port Gamble S'Klallam Tribe	X		
Puyallup Tribe of Indians	X		
Quinault Tribe of Indians	X		
Skagit River System Cooperative	X		
Skokomish Indian Tribe	X		
Stillaguamish Tribe of Indians	X		
Squaxin Island Tribe	X		
Suquamish Tribe of Indians	X		
Swinomish Tribe	X		
Upper Skagit Indian Tribe	X		
Yakama Nation			
Local and State Government (and related)			
Association of WA Cities (AWC)		X	
Fish Barrier Removal Board (FBRB)			
Governor's Salmon Recovery Office		X	
Puget Sound Partnership		X	
Salmon Recovery Funding Board (SRFB)			

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WA Recreation and Conservation Office (RCO)		X		
WA Association of Counties		X		
WSDOT		X		
Salmon Recovery Regions				
Coast Salmon Partnership		X		
Hood Canal Coordinating Council		X		
Lower Columbia Fish Recovery Board	X			
Snake River Salmon Recovery	X			
Upper Columbia Salmon Recovery Board		X		
Yakama Basin Fish and Wildlife Recovery Board		X		

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Appendix B: Science Panel guidelines/charter

Science Panel Guidelines

WDFW convened the Science Panel to provide scientific recommendations in support of a technically sound Fish Passage Barrier Removal Prioritization Strategy (Strategy). The goal of this strategy is to help prioritize and reduce barriers to fish passage in a way that benefits depressed, threatened, and endangered stocks, and that is informed by the best available science. The final strategy will be developed by WDFW using the recommendations from the Science Panel. This strategy will be designed to be transparent and repeatable so that it can be updated as additional data becomes available.

Considering there are broad range of methods and approaches to fish passage that have been previously considered or are underway, WDFW is requesting that the Science Panel consider the following technical factors in the development of their recommendations:

- Impacts of barriers to listed salmon and steelhead stocks and southern resident orca whale populations.
- Benefits of barrier removal to upstream as well as lateral habitat.
- Access to high quality salmonid spawning and rearing habitat.
- The appropriate spatial scale for prioritization (e.g., state, recovery region, watershed)
- How to evaluate or incorporate existing approaches to develop barrier prioritizations, including criteria used to inform other state fish passage barrier removal funding programs.
- Whether an existing culvert is a full or partial barrier and how that should be considered within a prioritization strategy.

As a result of this process, the Science Panel may also:

- Identify the most appropriate and complete datasets for use in a prioritization strategy, and potentially identify/recommend new datasets that would provide a more robust strategy.
- Consider feasibility criteria such as opportunities to couple projects with adjacent barrier removal projects and/or projects that address infrastructure improvements related to flooding, erosion, and other environmental damage, as secondary considerations to those posed above.

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Appendix C: Bibliography of prioritization literature

List of literature on barrier prioritization strategies developed from Shinn (2021), science panel, and web search of google scholar. A total of 95 sources were identified as of December 31, 2023

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Appendix D: List of prioritization criteria considered

Criteria for prioritizing fish passage barriers for correction from existing strategies and as recommended by science panel the scale of the data (B = barrier, R = reach, and W = watershed), whether data is available statewide or regionally (S = statewide, R = regionally), whether those data are recommended core data for regional strategy or optional ((C = core or O = optional), and rational for recommending including the criterion for either statewide or regional prioritization. Criteria are grouped by major categories (barrier, barrier connectivity, species, habitat quantity, habitat quality, climate, cultural importance, and feasibility.

Criteria and description	Scale	Data available statewide?	Include Statewide or Regionally	Core or optional	Rationale/Challenges
Barrier					
Full or partial barrier	B	Y	S, R	C	Key component of almost all existing strategies
Barrier type - Tide gate vs. culvert vs. fishway, tidally influenced	B	Y	R	O	Partially dependent upon region, for example not all areas have Tide gates.
Barrier - Connectivity					
Correcting the lowest barriers first	B,R W	Y	R	O	Regional scale - similar to connectivity index, regions should choose one criterion that deals with barrier order, (downstream to upstream)
Connectivity index, relation to other barriers, barrier order	B,R W	Y	S, R	C (S)/O	Not sure it can be calculated and used for all regional areas, key part of optimization
Upstream barrier count/passability	B,R W	Y	R	O	Regionally need to include something that considers order
Downstream count/passability	B,R W	Y	R	O	This overlaps with connectivity and other metrics
Barrier density	B,R W	Y	N	NA	Overlaps with other connectivity metrics
Others - Access, barrier cluster	B,R W	Y	N	NA	Overlaps with other connectivity metrics
Species					

Number species of concern or number of depressed, threatened or endangered species or stocks	R, W	Y	S, R	C	Should be available from state and federal organizations.
Colonization potential (larger population leads to colonization)	W, P	Y?	R	O	Currently there isn't a metric for this so would need to be developed.
Benefits orcas (benefits Chinook salmon)	B, R	Y	S, R	C	Key part of guidance from proviso
Priority watershed recovery	W, P	Y	R	O	Not all watersheds have priorities defined for listed species
Facilitate spread of unwanted or invasive aquatic or other species or pathogens	R	Y	N	NA	Would need to define what invasive species and pathogens
Population - is population at risk?	P	Y	N	NA	Partially covered by at risk, threatened, or endangered stocks. Would need to define "at risk"
Is population capacity (amount of habitat) limiting population?	W, P	N	N	NA	Many populations are capacity limited, data are not available
Benefits Chinook salmon (see benefits orcas)	P	Y	S, R	C	This is same as benefits orcas so choose one or the other
Improves life history diversity	P	N	N	NA	Needs further definition, but life histories not available for all species, watersheds, and reaches
Total number of native fish species	R, W	Y	N	NA	Many barriers are on small streams with low numbers of species present
Native animals or plants upstream that could be harmed by providing fish passage if non-native invasive species gain access	W, R	N	N	NA	This is meant to include other native fauna than fish, varies by region. This also less of a passage issue versus other management concerns.
Habitat Quantity					
Length of accessible habitat for salmon and steelhead habitat/Access to high-quality habitat	B, R	Y?	S, R	C	
Unobstructed distance from saltwater (maximize)	R	Y	N	NA	Redundant too habitat gain as well as barrier metrics
Total area inundated (tide gates- total area of habitat gain)	R	N	R	O	Specific to tide gates, includes lateral area reconnected, best handled at regional level.
Area of undeveloped wetlands and floodplain ponds connected to stream network	B, R	N	N	NA	Dependent upon having good wetland data, hard to determine whether wetlands are connected.

					Metrics need better definition and data. Could potentially use remotely sensing data and DEMs to examine connectivity, but not currently available everywhere.
Stream size based on mean annual discharge (modeled) at barrier	B	N	N	NA	Might be hard to link to change in quantity or quality of salmon habitat. Few streams have discharge data though NOAA has stream flow models.
Upstream Watershed Area (if mean annual discharge not available)	W	Y?	N	NA	Some regions may have these data, but most will not
			Habitat Quality		
Upstream reach gradient	R	N	R	O	Good indication of habitat suitability, included in intrinsic potential models usually,
Lateral constraints, active channel width/valley width	R	N	N	NA	These data are available for some areas but not others. See total area inundated for tide gates under t
CMIP5 RCP8.5 Jul-Sep flow deviation from 1970-2000 baseline (minimize)	R, W	Y	N	NA	Might be hard to link to change in quantity or quality of salmon habitat
Intrinsic potential/habitat quality by species	R, W	Y?	R	C	Varies by species, better for regional strategies
Land/riparian cover	R, W	Y	R	O	Puts higher emphasis on areas with intact riparian which may be desired or not depending upon region. Also barrier may be in area of poor riparian condition but upstream area may have good riparian condition
Other habitat quality (e.g., sediment, BFW, road density)	R, W	Y	N	NA	Sediment not available for most areas, BFW gets at stream size, gradient is a separate criteria road density often not available on private lands.
Extent and type of anthropogenic development (forested, urban, ag.)	R, W	Y	N	NA	This overlaps with riparian condition
Pool and wood frequency	R	N	R	O	Good indication of habitat suitability, most regions will not have complete coverage
Nutrients to support ecosystem health and function (e.g., food for other biota)	R	N	N	NA	Requires being able to differentiate "good" nutrients from "bad" nutrients (anthropogenic), usually an impossibility.

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Benefits not related to fish passage (e.g., reduced flood risk, proximity to other existing restoration efforts).	R	N	N	NA	This is something for future when these data become available
Provides access to cold water refugia or overwintering habitats?	R	N	N	NA	This information is likely available for stream reaches, but not for off-channel areas
			Quality – Temp/WQ		
Water Quality (303d, sediment, nutrients, see Temp below)	R	Y	N	NA	Could be a reasons to prioritize for removal or to rate lower
Stream temperature (species or overall)	R	Y	R	O	Many areas that are too warm in summer can be important rearing areas at other times of year
			Climate		
Temperature (2040)	R	Y	R	O	Many areas that are too warm in summer can be important rearing areas at other times of year
Summer low flow (2040)	R	Y	R	O	Many areas that are too warm in summer can be important rearing areas at other times of year
Hydrologic regime shift (2040)	W	Y	R	O	Many areas that are too warm in summer can be important rearing areas at other times of year
Flood events (2040)	W	Y	R	O	Mainly focused on whether road crossing can handle increased flood events or may be a barrier to passage at predicted higher flows.
Wildfire frequency (2040)	W	Y	N	NA	Increased wildfire can result in increased delivery of sediment so stream crossings need to be designed with that in consideration.
Percent of upstream habitat predicted to be winter suitable only (>20C mean august temperature in NorWest 2040 Model)	R	Y	N	NA	Many areas that are too warm in summer can be important rearing areas at other times of year
Upstream migration distance to barrier from nearest summer suitable habitat (<20C mean august temperature in NorWest 2040 Model)	R	Y?	R	O	Many areas that are too warm in summer can be important rearing areas at other times of year
			Cultural Importance		
Tribal fishing area; treaty agreements, traditional fishing/hunting/gathering area	W	Y?	R	C	Important consideration for tribes, data would need to be provided by tribal governments

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Provide educational opportunities (environmental restoration, fish viewing)	R, W	N	NA	NA	
Impact of populations associated with barrier on limiting fisheries for all participants (sport, commercial, treaty tribal)	R	Y	NA	NA	
Other recovery management interventions	R	N	NA	NA	Could cover a lot of things and be hard to define
Tribal fishing area; treaty agreements, traditional fishing/hunting/gathering area	W	Y?	R	C	Important consideration for tribes, data would need to be provided by tribal governments
Provide educational opportunities (environmental restoration, fish viewing)	R, W	N	NA	NA	This is a duplicate of one above.
Impact of populations associated with barrier on limiting fisheries for all participants (sport, commercial, treaty tribal)	R	Y	NA	NA	Requires answering the question “Will removing the barrier likely affect the quality of a fishery?”
Other recovery management interventions	R	N	NA	NA	Could cover a lot of things and be hard to define
			Feasibility		
Costs are prohibitive (dollars)	B	Y?	NA	NA	Cost should not be a limiting factor in initial priorities
Feasibility (ownership (state, federal, tribal, private), land owners support, community support, state road, levee, bridge, etc.	B	N	R	O	Feasibility can help determine order of implementation, but can change over time as landowner(s) change or become more willing. \
Logistical difficulties (challenges in transporting materials and equipment to site, working in designated wilderness areas)	B	N	NA	NA	Difficult to quantify for large set of barriers; more relevant to specific locations
Benefit-cost (number of miles/kms per dollar)	B	Y?	R	O	While cost should not constrain whether an important barrier is removed, knowing how much habitat would be gained per cost is helpful
permitting complexity/number of jurisdictions	B	Y?	NA	NA	This is possible, but this should be covered in feasibility
Relative cost as a function of geography	B	Y?	NA	NA	This would be covered by cost per mile
Durability of project: permanent removal/decommission vs repair/replacement	B	N	NA	NA	This is more on the design end, could be done regionally

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