UPPER FRASER RIVER SPRING 5_2 CHINOOK SALMON RECOVERY PLAN

TECHNICAL SUMMARY REPORT | DRAFT V6

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EXECUTIVE SUMMARY

Upper Fraser River Spring 5_2 Chinook Salmon—comprising Designatable Units (DUs) 9 and 11—experienced substantial declines in abundance and were assessed by COSEWIC in 2019 as Threatened and Endangered, respectively. More recent information, however, indicates an important change in trajectory. Spawner abundance has increased in both DUs, both were assessed as amber under the Wild Salmon Policy in 2024, and recalculation of COSEWIC status metrics using data through 2023 suggests probable status classifications of Special Concern for DU9 and Threatened for DU11. These improvements are encouraging, but they do not indicate full recovery or support relaxation of existing conservation measures. Important uncertainties remain regarding productivity, life-stage survival, and the durability of recent increases.

This Technical Summary presents the results of a recovery planning process co-led by the Upper Fraser Fisheries Conservation Alliance and the Pacific Salmon Foundation. The assessment considered population status, life history, environmental conditions, threats across the full freshwater–marine life cycle, and feasible actions to support recovery. Indigenous Knowledge, local and expert knowledge, and western scientific information were used to inform the assessment and action-prioritization process.

A central conclusion is that the historic population aggregate decline cannot be attributed to a single bottleneck or threat. The most plausible explanation is that observed declines are the result of the cumulative effects of multiple pressures operating across life stages and environments. The evidence also indicates that broad-scale pressures experienced in shared environments, particularly marine environments, are important in explaining population-level trends. Similar abundance trajectories among geographically dispersed spawning populations, despite considerable differences in geography and human pressures among natal watersheds, point to the influence of conditions encountered in the Fraser River migration corridor, estuary and marine environment. Local freshwater conditions nevertheless remain important and help explain differences among individual spawning populations.

The DU-level threat assessment identified three broad tiers of concern. Competition in offshore marine environments was the only threat assessed as high or very high at the DU level. Increasing abundance of pink and chum salmon, arising in part from large-scale hatchery production and changes in northern salmon productivity, has increased potential competition for marine food resources. Low stream flows and elevated water temperatures formed a second tier of threats. These conditions are increasingly common in natal watersheds and migration habitats and are expected to become more significant with climate change. Predation, disease and pathogens, reduced prey availability, and fisheries comprise a third group of moderate but more uncertain threats. Together, threats assessment results indicate that recovery planning must extend beyond natal watersheds to pressures operating at the scale of the Fraser migration corridor and North Pacific, while retaining targeted freshwater actions where local conditions constrain individual populations.

The threats assessment also highlights that factors that contributed to historical population declines are not necessarily the same factors currently constraining recovery. Fisheries provide an important example. Major reductions in exploitation have coincided with the recent improvement in population status; recent total exploitation has averaged approximately 4%, compared with approximately 24% during 2014–2018. Consequently, further reductions in fishing alone are unlikely to produce recovery at the scale required, although cumulative fisheries mortality remains relevant and current restrictions should not be interpreted as no longer necessary.

No single intervention is likely to recover UFR Spring 5_2 Chinook Salmon. The report therefore recommends a **portfolio approach** combining actions to increase abundance, measures that prevent further deterioration, and research and monitoring actions that reduce critical uncertainty. Among actions assessed as capable of reversing the population trend, conservation hatchery supplementation received the highest overall score, although this action only has potential to increase abundance directly and does not address the underlying threats that have resulted in population decline. Removal of remaining finfish aquaculture sites on the migration route ranked next, followed by actions intended to reduce competition associated with industrial-scale production of hatchery-origin pink and chum salmon. Freshwater habitat restoration and measures addressing predation and fisheries also ranked among the higher-priority interventions.

Preventative actions are equally important to maintaining and consolidating recent gains. The highest-ranked preventative action was establishment of a structured engagement framework for rights holders, stakeholders and technical experts. Other priorities include improving capacity to identify and respond to low-flow and high-temperature events, assessing hydrological and flood risks, strengthening protection of riparian and aquatic habitats, and advancing Indigenous Protected and Conserved Areas.

The highest-ranked research priority is completion and maintenance of a publicly accessible life-cycle model for UFR Spring 5_2 Chinook Salmon. Such a model would improve the ability to quantify the relative influence of threats, evaluate

alternative recovery actions, and update priorities as new information becomes available. Other priorities include improving understanding of early marine and offshore survival, monitoring freshwater discharge and temperature, and defining environmental flow requirements. Significant information gaps remain regarding aspects of marine distribution, life-stage-specific survival, freshwater habitat use, productivity, and demographic characteristics.

Action rankings should be interpreted with appropriate caution. In the absence of a life-cycle model, the assessment is qualitative and provides a structured basis for comparing actions rather than precise estimates of population-level benefits. High scores for preventative or research actions often reflect their feasibility and comparatively low cost, not necessarily greater biological benefit than more difficult actions intended to increase abundance. Recovery will require advancing those more challenging interventions while simultaneously protecting existing habitat and reducing key uncertainties.

Importantly, remaining uncertainty does not justify postponing recovery action. Where evidence is sufficient and the risk of unintended consequences is relatively low, actions can proceed now while their effectiveness is evaluated through monitoring and adaptive management. Higher-risk or more consequential interventions may require additional research and evaluation. Recovery efforts should address multiple threats simultaneously, focus on vulnerable life stages and populations, integrate monitoring and adaptive management, and use the best available evidence while explicitly acknowledging uncertainty.

The overall conclusion is therefore cautiously positive. UFR Spring 5_2 Chinook Salmon appear to be responding to conservation measures and are in better condition than indicated by assessments based on data from the previous decade. However, the populations remain vulnerable, and recent gains should be viewed as an opportunity to accelerate recovery rather than evidence that recovery has been achieved. Sustained progress will require coordinated action across freshwater and marine environments, protection of existing gains, targeted interventions capable of increasing population productivity and abundance, and an adaptive approach that changes as evidence improves.

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1. INTRODUCTION

Salmon connect people and place. For thousands of years, Pacific salmon have contributed to local First Nations' social, cultural, economic, psychological, and spiritual wellbeing (Carothers et al. 2021; Reid et al. 2022). In British Columbia, First Nations have a long history of salmon stewardship (e.g. Atlas et al. 2021; Morin et al. 2021). This practice continues today in the middle and upper Fraser River watersheds where Upper Fraser First Nations are actively working to rebuild salmon populations.

The upper Fraser River Spring 5_2 Chinook Salmon Recovery Plan provides a coordinated, evidence-based framework to identify priority threats and guide recovery actions across all life stages and environments of middle and upper Fraser River Spring 5_2 Chinook salmon (hereafter UFR Spring 5_2 Chinook salmon). Co-led by the Upper Fraser Fisheries Conservation Alliance (UFFCA) and Pacific Salmon Foundation (PSF), the plan integrates data, along with Indigenous, expert, and local knowledge to support strategic investment, coordinated management, and recovery benefits across spawning populations. By focusing on the most biologically impactful threats and effective interventions, the plan aims to align rights holders, decision-makers, and the public around shared priorities for salmon recovery.

1.1 Population and Geographic Context

Many Chinook salmon (*Oncorhynchus tshawytscha*) populations across the Pacific Ocean have experienced substantial declines in abundance and shifts in population demographics (e.g. size- and age-at-maturity) over recent decades (Dorner et al. 2017; Ohlberger et al. 2018; COSEWIC 2019; Oke et al. 2020; Atlas et al. 2023; Lamborn et al. 2025). Although trends vary among regions and populations, patterns of decline are particularly pronounced for interior populations (COSEWIC 2019; Atlas et al. 2023), such as those from the middle and upper Fraser River.

This recovery planning process focuses on middle and upper Fraser River Spring 5_2 Chinook salmon, a collective grouping of spawning populations making up Designatable Units (DUs) 9 and 11 (COSEWIC 2019). DU9 corresponds to the Middle Fraser River Spring 1.3 Conservation Unit (CK-10), while DU11 corresponds to the Upper Fraser River Spring 1.3 Conservation Unit (CK-12; COSEWIC 2019). The two DUs are dominated by five-year-old spawners that spend at least one winter in freshwater before migrating to the ocean (COSEWIC 2019). Both DUs have long and energetically costly in-river migrations, and are exposed to multiple stressors across freshwater, estuary, and marine environment types.

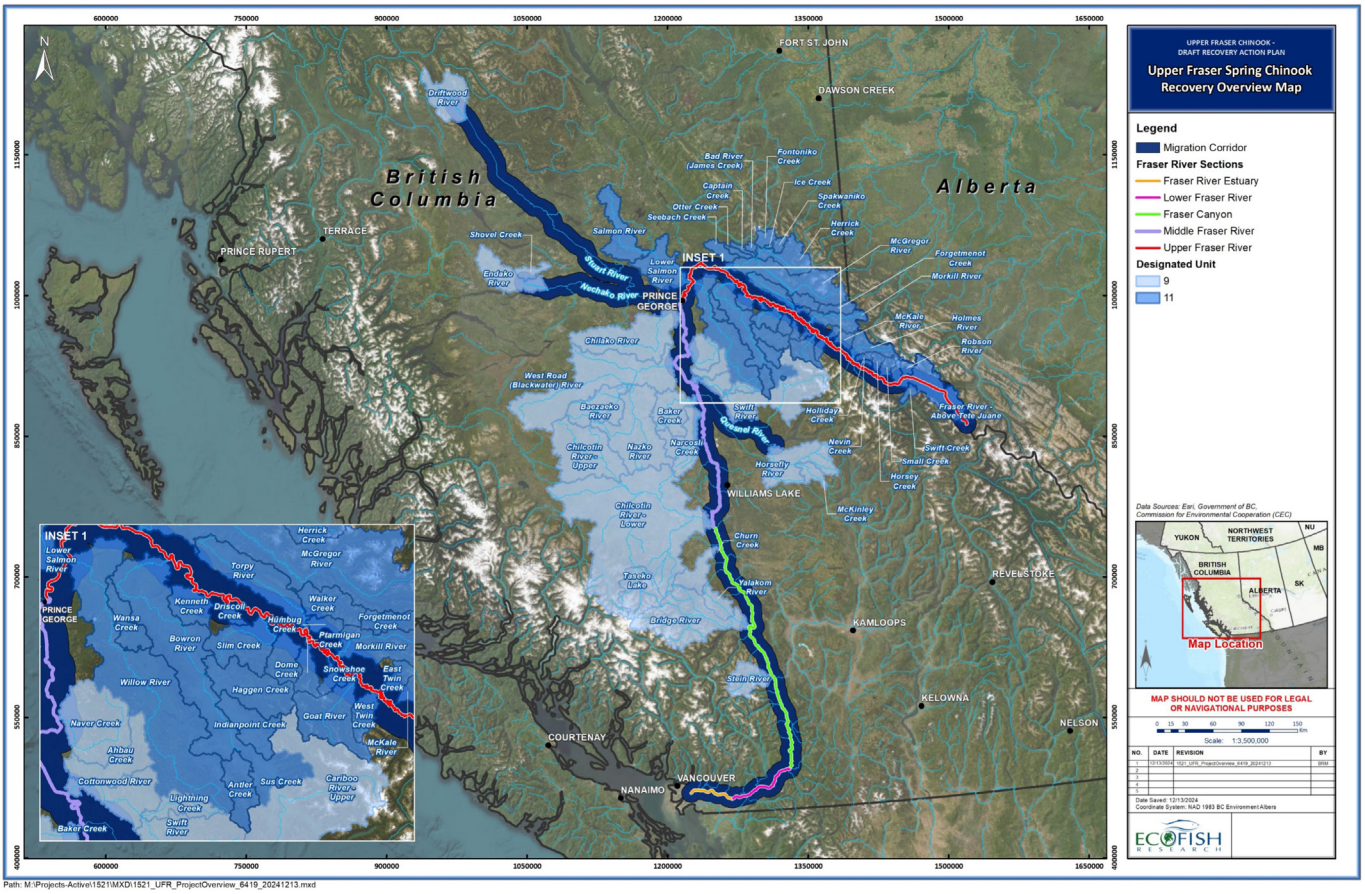
The geographic scope of this recovery plan encompasses environments used throughout the full UFR Spring 5_2 Chinook salmon life cycle, including natal watersheds, the Fraser River mainstem, Fraser River estuary, and nearshore and offshore marine areas of the North Pacific Ocean (Table 1). UFR Spring 5_2 Chinook salmon natal watersheds span a broad geographic range across the middle and upper Fraser River watersheds, encompassing a diverse array of physical environments, from warm, arid environments near the Bridge River, to high-elevation areas in the Chilcotin and Fraser Plateaus, and glacially fed systems in the Robson Valley (Map 1).

The Fraser River mainstem is subdivided into the middle Fraser River and the Upper Fraser River. The middle Fraser River watershed covers approximately 48,000 km^2 and includes nine distinct spatial areas, stretching from the Driftwood River in the north to the Stein River near Skihist Mountain in the south, and from the Nadina River in the west to the Cariboo River near Mount Lunn in the east (COSEWIC 2019). The upper Fraser River watershed is smaller, encompassing roughly 24,000 km^2 in a single spatial area that extends from the Fraser River near the Salmon River in the northwest, to the Raush River at Mount Sir Wilfrid Laurier in the south, and east to Overlander Falls, the anadromous barrier on the Fraser River (COSEWIC 2019).

Following freshwater rearing, juveniles migrate through the Fraser River estuary and enter nearshore marine environments of the Salish Sea, where they are exposed to a complex mosaic of habitats and stressors before dispersing along the continental shelf and into offshore regions of the North Pacific Ocean. During this marine phase, individuals undertake extensive migrations across the coastal and open ocean environment, where growth, survival, and maturation are influenced by large-scale oceanographic conditions, prey availability, and ecosystem interactions that operate well beyond Canadian waters.

Table 1. Distinct environments considered within the recovery plan.

Environment Type	Environment	Life Stages Present	Description
Freshwater	Natal watershed	Incubation Juvenile rearing Adult upstream migration Adult staging Adult spawning	Natal habitats used by DU9 or DU11 UFR Spring 5_2 Chinook Salmon spawning populations for spawning and early juvenile rearing. Includes tributary streams within the middle and upper Fraser River watersheds and/or mainstem spawning habitat in the upper Fraser River mainstem. Locations of natal watersheds are shown in Map 1.
	Fraser River mainstem	Juvenile rearing	River mainstem occurring within the middle and upper Fraser River watersheds as well as Fraser River mainstem reaches (i.e. lower/non-tidal, canyon) and associated off-channel areas (e.g. non-natal tributaries, side channels, floodplain).
		Adult upstream migration	River mainstem extending from the Sumas River (downstream boundary) to upstream of Tête Jaune Cache (upstream boundary).
		Adult staging	River mainstem occurring within the middle and upper Fraser River watersheds.
		Adult spawning	Mainstem areas upstream of Tête Jaune Cache.
Estuary	Fraser River estuary	Juvenile Returning adult	Area extending > 200 km^2 comprised of the Fraser River mainstem and associated off-channel areas under tidal influence (i.e. occurring downstream of the Sumas River), as well as shoreline areas from Point Grey (northern boundary) to Roberts Bank (southern boundary) extending offshore into the Salish Sea where Sturgeon and Roberts Banks drop off into the Strait of Georgia.
Marine	Nearshore	Juv. | Sub-adult returning adult	Coastal waters generally located along the inner continental shelf and typically within 100 km of shore. This includes portions of the Salish Sea and other coastal areas of British Columbia (including the west coast of Vancouver Island), Alaska (Southeast Alaska, Alaska Peninsula and Aleutian Islands), and Russia (specifically, the Kuril Islands and Kamchatka Peninsula).
	Offshore	Sub-adult | Adult	Open ocean areas of the north Pacific Ocean, including the Gulf of Alaska and Bering Sea, including and extending offshore from the outer continental shelf. The spatial extent of offshore environment used by UFR Spring 5_2 Chinook specifically is not known, but at the provincial level (i.e. BC) is thought to extend > 20,000 km^2.



Map 1. Geographic distribution of freshwater and estuarine environments used by DU9 and DU11 spawning populations, including the locations of natal spawning tributaries.

1.2 Defining the Recovery Path: Approach and Rationale

The objective of this process was to conduct recovery planning for Chinook salmon at the DU level (i.e. regional scale), evaluate whether it could reduce the need for time- and resource-intensive assessments at the individual watershed scale, and assess whether different types of actions would be emphasized.

Undertaking an assessment at this regional scale also has drawbacks, such as reduced watershed-level resolution. Outputs from this process indicate which watersheds are most affected by different threats but do not provide the detail needed to determine precisely where actions should be implemented. Consequently, we recognize that finer-scale watershed-level assessments will still be required before implementing some of the actions specified for natal streams (e.g. habitat restoration actions).

The regional scale of this recovery plan has important implications for interpretation of the results. Threats operating in environments shared by most or all spawning populations have greater potential to emerge as priorities at the DU level than threats that are severe but geographically restricted to individual natal watersheds. Consequently, the DU-level assessment is particularly useful for identifying broad-scale recovery needs that may be difficult to address through individual watershed plans, including threats operating during migration and marine residence. This does not imply that natal-watershed threats are unimportant. Rather, the within-environment assessment retains finer-scale information that can support watershed-specific recovery planning, where local threats and actions can be evaluated at an appropriate spatial resolution. In this way, the regional and watershed-scale approaches are complementary.

The recovery planning effort for UFR Spring 5_2 Chinook salmon was guided by three central questions:

1. **What is the current status of UFR Spring 5_2 Chinook salmon and their environments?**
2. **What caused the decline of UFR Spring 5_2 Chinook salmon and what is preventing recovery?**
3. **What actions can be taken to stop the decline of UFR Spring 5_2 Chinook salmon and promote recovery?**

To address these questions, the recovery process is organized into four integrated components designed to support evidence-based conservation and recovery planning (Figure 1):

1. **Current Knowledge Review:** This component aimed to answer the question, *"What is the current status of UFR Spring 5_2 Chinook salmon and their environments?"*

   The review compiled existing information on UFR Spring 5_2 Chinook salmon population status, life history, habitat use and environmental setting and identified possible threats by life stage that affect population viability. Information specific to UFR Spring 5_2 Chinook salmon is limited across most topics. As a result, the review drew broadly from the literature, prioritizing the most relevant sources (e.g. studies on interior stream-type populations) while incorporating the extensive body of related work available for Chinook salmon coastwide and, where relevant, other Pacific salmon.

   The current knowledge review provided the foundation for recovery planning by identifying population trends, the life stages and environments most vulnerable to stressors, and the threats most likely to limit population recovery. By synthesizing this information, the review informed the threats assessment and action planning so that it focused on actions likely to be effective. It also established a scientific baseline to support prioritized, efficient, and context-appropriate recovery strategies, while ensuring that the recovery plan was transparent and evidence-based. Given the substantial body of existing research on Pacific salmon, the review relied, where possible, on existing studies and syntheses. This approach supported a broad assessment across the UFR Spring 5_2 population aggregate using the best available information, rather than undertaking new watershed-specific analyses.

2. **Life Cycle and Population Ecology Assessment:** This component identified the life stages that most strongly influence population growth to support evaluation and prioritization of threats to answer the question "What caused the decline of UFR Spring 5_2 Chinook salmon and what is preventing recovery".

   This component combined quantitative modeling with a literature review of salmon population ecology to support threat evaluation by identifying where changes in life-stage-specific survival are expected to have the largest influence on population growth. The quantitative analysis was restricted to a sensitivity analysis that evaluated how variation in key life-stage survival parameters affect model estimates of population growth. This analysis identified the life stages that exert the greatest influence on population dynamics. The sensitivity analysis was supported by a broad literature review of Chinook salmon population ecology and salmonid life-history dynamics. This review synthesized theoretical and empirical studies examining how survival at different life stages contributes to Pacific salmon population productivity.

   This assessment informed recovery planning by helping interpret the importance of threats within the context of population dynamics and by highlighting the life stages where threats are most likely to influence overall population trajectories. By linking life-stage-specific evidence from the literature with the model sensitivity analysis, this work provided a structured basis for assessing threat magnitude and prioritizing actions by identifying where threats and actions are most likely to influence population viability.

3. **Threats Assessment:** This component aimed to answer the question, *"What caused the decline of UFR Spring 5_2 Chinook salmon and what is preventing recovery?*

   Using the scientific baseline established during the preceding steps, this component systematically identified the primary threats affecting UFR Spring 5_2 Chinook salmon production during each life stage. This approach ensured that threat evaluations were evidence-based, to focus action planning on the most critical factors influencing population growth. The assessment was completed in two stages: (1) a within-environment threats assessment conducted at the sub-watershed scale; and (2) a DU-level threats assessment. We developed this two-step process to efficiently and systematically assess life-stage and environment-specific threats, recognising the complexities of inter-related and indirect threats. This approach provided a structured basis to support recovery planning within the action assessment.

4. **Action Assessment:** This component aimed to answer the question, *"What actions can be taken to stop the decline of UFR Spring 5_2 Chinook salmon and support recovery?"*

   This component evaluated the feasibility of addressing identified moderate and high-risk threats and then prioritized recovery actions based on their potential to elicit recovery responses for UFR Spring 5_2 Chinook salmon. We developed a process to efficiently and systematically prioritize recovery actions, recognising trade-offs between

biological response, financial costs, and other factors, and assessed overall feasibility for each identified action pathway by considering both technical and social feasibility. This approach provided a structured framework to guide strategic and achievable recovery planning.

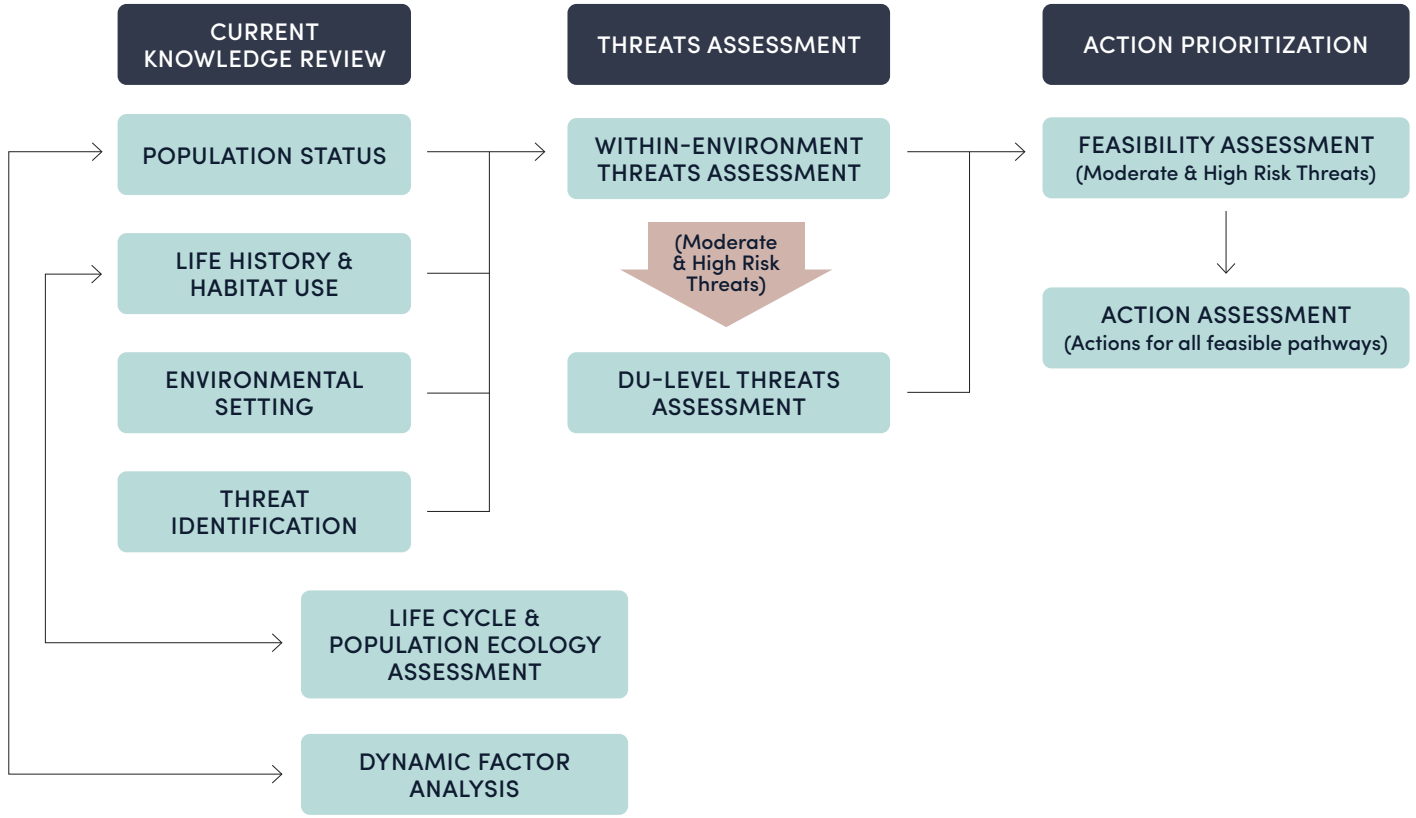


Figure 1. Overview of individual components comprising recovery planning processes.

Multiple assessment and recovery planning frameworks are currently used for Pacific salmon in Canada. These include Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessments (COSEWIC 2019), Recovery Potential Assessments (RPAs; Doutaz et al. 2021), biological status assessments under DFO's Wild Salmon Policy (WSP; DFO 2016) Rebuilding Plans under the *Fisheries Act* (DFO 2024a, DFO 2025a), and the Risk Assessment Method for Salmon (RAMS; e.g. Hyatt et al. 2017). Comparable approaches are also used within the US, such as NOAA Endangered Species Act Recovery Plans (UCSRB 2007) and the Klamath Basin Integrated Fisheries Restoration and Monitoring Plan (Klamath IFRMP 2023).

Our recovery planning process builds on the strengths of these established frameworks, borrowing heavily from their methods where appropriate, while adapting the structure to meet the specific objectives of this recovery plan. The goal of this process was not to replicate or critique existing frameworks, but rather to synthesize and expand upon them to create a rapid, comprehensive, and actionable planning process for UFR Spring 5_2 Chinook salmon. Within this recovery planning process, we sought to design an approach that:

1. **Considers the full life cycle** (i.e. all life stages) of UFR Spring 5_2 Chinook salmon;
2. **Systematically assesses and ranks threats** in each environment for each life stage;
3. **Prioritizes actions** to promote long-term population aggregate recovery by addressing the most critical threats;
4. **Completes the core elements of the recovery plan rapidly** (i.e. within 18 months or less); and
5. **Develops a repeatable and efficient methods framework** that could be applied to other populations in future recovery planning processes.

Recovery planning for Pacific salmon has rarely been conducted at this spatial scale. This broad-scale approach was necessary given the biology and ecology of UFR Spring 5_2 Chinook salmon and the need to consider the full breadth of geography and ecology if the population aggregate is to be recovered.

This plan intentionally does not include detailed action plans or fully developed implementation designs. Instead, actions are articulated to a level of detail sufficient to understand the scope, intent, and expected outcomes. This approach provides the clarity needed to support prioritization and program development, while acknowledging that further planning and consultation will be required prior to implementation. This allows the plan to remain strategic and adaptive to new information, local conditions, and collaborative processes while still providing clear direction for recovery efforts.

Our approach offers several benefits. It ensures that recovery planning is comprehensive and life cycle-based, recognizing that effective recovery may require coordinated action across environments and life stages. It supports transparent and evidence-based prioritization of threats and recovery actions, increasing the likelihood that limited resources will be directed toward the most beneficial interventions. By building on existing processes, the approach maintains alignment with national and international conservation frameworks while avoiding unnecessary duplication of effort. The relatively short planning timeline ensures that results are timely and actionable. Finally, the development of a transferable methods template creates an opportunity to harmonize recovery planning across populations and jurisdictions, improving consistency and efficiency.

1.3 Recovery Objectives

Consensus is that the status of these Chinook salmon is poor, and the objective of this plan is to provide a path to greatly improve that status by describing actions that are most likely to elicit a strong recovery response for both DUs. As such, we have chosen to defer the establishment of detailed recovery objectives. Identifying and prioritizing actions can be done in the absence of detailed objectives. Conversely, deciding how many of the actions to implement requires discussions of "how much" improvement is needed; therefore, we expect discussions of objectives to continue beyond this stage of the recovery planning process and to be supported by the various analyses and prioritized actions provided here.

An interim, overarching objective was developed by the Working Group for this stage of the recovery planning process:

- Self-sustaining, resilient UFR Spring 5_2 Chinook salmon spawning populations over a widespread geographical area

The First Nations rightsholders and those undertaking the next steps of recovery planning and implementation, including monitoring and assessment, may develop more specific objectives that address their conservation and cultural goals. Future work may develop specific objectives by adopting benchmarks used in other recovery plans or take advantage of analyses completed in other planning processes.

1.4 Intended Audience

This report provides detailed descriptions of the technical process and results used to derive recommended actions for recovery. The intended audience for this technical report is technically minded or subject-matter experts who are taking part in recovery work for UFR Spring 5_2 Chinook salmon or those who are undertaking recovery planning for other salmon populations and wish to learn from this process. A companion report, referred to as the Capstone Report, provides details in a more accessible format for a broader audience. Beyond guiding recovery actions, this Technical Summary and the Capstone Report are intended to serve as tools for communication, coordination, and strategic investment. They aim to convey to rights holders, decision makers, and the public which threats are posing the greatest biological impact, and which actions are most likely to result in meaningful contributions to UFR Spring 5_2 Chinook salmon recovery. Both support in aligning shared priorities on policy and management decisions that can drive meaningful change. Finally, the Technical Summary and Capstone Report help focus limited resources and capacity where they are most likely to generate population-level benefits and raise attention on research and monitoring actions that would have the greatest return on investment.

1.5 Project Structure

The UFR Spring 5_2 Chinook Salmon Recovery Plan developed from a shared interest of PSF and UFFCA around the need to identify and address priority issues facing salmon populations in BC. Both groups acknowledged recent recovery planning initiatives such as RAMS and were interested in building on those through a process that was rigorous, informed by data and expert knowledge, replicable, rapid, and flexible to local context. UFR Spring 52 Chinook salmon were identified as a priority based on recent population declines and compounded by threats such as the Big Bar landslide, which led to the choice to focus on this geographic area and the UFR Spring 5_2 Chinook salmon population as a pilot. Regional

rebuilding work on these populations was also undertaken by DFO through the Integrated Planning for Salmon Ecosystems pillar and Integrated Rebuilding Unit of the Pacific Salmon Strategy Initiative (PSSI), as well as through the rebuilding plans mandated under the Fish Stock Provisions of the Fisheries Act. Our process provided an opportunity to parallel those recovery processes while piloting a regional recovery plan led by Indigenous and non-profit entities rather than crown governments.

The UFR Spring 5_2 Chinook salmon recovery planning process was co-led by UFFCA and PSF as partner project leads. The project leads held final decision-making authority, with support from a Working Group, a Steering Committee, and a Technical Advisory Group (Table 2). Trinity Consulting Canada was retained as the primary contractor providing much of the background and technical data and analysis. The working group was responsible for day-to-day tasks and comprised of staff from PSF and UFFCA as well as Trinity Consulting Canada. The Steering Committee included a representative from Fisheries and Oceans Canada (DFO), the Provincial Ministry of Water Lands and Resource Stewardship, a subject matter expert on behalf of the local First Nations group, and a subject matter expert who is a professor from a local university (Table 3). The Steering Committee met approximately quarterly and provided support, feedback, and direction on the recovery planning process, timelines, and major project milestones. Individuals were selected and invited to join based on their subject matter expertise, relevancy of current job position, involvement and knowledge of similar processes, recommendations by the co-lead organizations, and availability, and, critically, this group stayed consistent throughout the process. Additional support came from a Technical Advisory Group comprised of subject matter experts from sub-watersheds in the middle and upper Fraser region. Members included local First Nations biologists and technicians, government staff, as well as independent and academic biologists. Advisors were chosen for their expertise, local knowledge, and recommendations by the co-lead organizations, ensuring representation across the project area. This group fluctuated somewhat throughout the process with individuals being invited to address gaps as they were identified. The Technical Advisory Group and the Steering Committee attended in-person workshops to provide feedback on key project milestones approximately twice a year.

In November 2024, UFFCA and PSF held an Indigenous Knowledge workshop in partnership with the Early Stuart (Talo) sockeye salmon recovery process. The goal was to determine how this Chinook salmon recovery strategy would embody Indigenous values and knowledge systems. Reflections on the loss of salmon in the Upper Fraser region carried through to views on what "recovery" means, in relation to culture, food security, and ecological well-being. The Indigenous values and priorities from this workshop and other sources steered the course for this recovery plan, particularly in actions and recommendations. This plan is not intended to make decisions on behalf of First Nations, but rather to provide a framework to support Chinook salmon recovery planning that respects First Nations' rights, priorities, and independent decision-making authority.

Table 2. Agenda and schedule of meetings between working group, steering committee and technical working group.

Attendees	Date	Meeting Format	Agenda
Working Group	Weekly	Online	Project status updates and process development
Working Group, Steering Committee, and Technical Advisory Group	May 22, 2024	In-person (Prince George)	Review of proposed recovery planning process and accuracy of background information collected to date
Steering Committee	June 27, 2024	Online	Review of progress, roadmap of next steps, and how to incorporate of indigenous perspectives and knowledge
Steering Committee	October 7, 2024	Online	Review process development, including modelling options to determine highest value recovery actions
Working Group, Steering Committee, and Technical Advisory Group	February 6, 2025	In-person (Prince George)	Review of threats and limiting factors affecting UFR Spring 5-2 Chinook Salmon, life cycle model, and identification of recovery actions to address threats and limiting factors
Steering Committee	April 23, 2025	Online	Review goal setting plans related to the action planning
Working Group, Steering Committee, and Technical Advisory Group	June 18, 2025	In-person (Prince George)	Review and discuss threats summary to come to agreement on top threats to UFR Spring 5-2 Chinook Salmon, and to discuss the next steps of Action Planning
Steering Committee	October 6, 2025	Online	Review of Technical Summary Report and discussion of next steps
Working Group, Steering Committee, and Technical Advisory Group	December 10, 2025	In-person (Prince George)	Summary of recent progress, interpretation of work to date and outstanding and ongoing analyses, summary of action recommendations, and discussion of next steps

Table 3. Project lead, working group, steering committee, and technical advisory group membership.

Project Role	Name	Organization and Title
Project Lead	Gord Sterrit	Upper Fraser Fisheries Conservation Alliance (UFFCA, Executive Director)
	Jason Hwang	Pacific Salmon Foundation (PSF, Chief Program Officer & Vice President of
Working Group	Jane Pendray	PSF (Manager of Recover and Resilience Program)
	Jane Healey	PSF (Salmon Recovery Coordinator)
	Eric Hertz	PSF (Science Mobilization Team Lead)
	Linda Stevens	UFFCA (Stewardship Coordinator)
	Todd Hatfield	Ecofish Research Ltd. (Ecofish Project Director)
	Kirsten Lyle	Ecofish Research Ltd. (Ecofish Project Manager)
	Eric Vogt	Ecofish Research Ltd. (Fisheries Biologist)
	Rachel Chudnow	Ecofish Research Ltd. (Fisheries Biologist)
Steering Committee	Brian Toth	Lheidli T'enneh First Nation and Carrier Sekani Tribal Council (Biologist) and UFFCA (Board Member)
	David Travia	BC Ministry of Water, Land & Resource Stewardship (Executive Director of Fisheries, Aquaculture and Wild Salmon Branch)
	Eduardo Martins	University of British Columbia (UNBC, Associate Professor and Principal Investigator at Freshwater Fish Ecology Laboratory)
	Teri Ridley	Fisheries and Oceans Canada (DFO, Senior Stock Rebuilding Biologist)
Technical Advisory Group	Annika Putt	UNBC (PhD Student)
	Chelton van Geloven	Lheidli T'enneh First Nation (Director of Natural Resources and Stewardship)
	Claire Menendez	DFO (Salmon Rebuilding Coordinator)
	Cory Williamson	Takla First Nation (TFN, Fisheries Biologist)
	David Levy	Levy Research Services Ltd. (Biologist)
	Erica Jenkins	BC Ministry of Water, Land & Resource Stewardship (Salmonid Specialist)
	Jason Yarmish	Jason A. Yarmish Consulting Services Ltd. (Consulting Biologist)
	John DeGagne	BC Ministry of Water, Land & Resource Stewardship (Director of Restoration and Recovery)
	Keith West	TFN (Fisheries and Wildlife Coordinator)
	Kilian Stehfest	PSF (Government and Policy Manager)
	Luc Turcotte	BC Ministry of Water, Land & Resource Stewardship (Regional Aquatic Specialist)
	Marc Porter	PSF (Senior Analyst)
	Mike Bradford	DFO (Retired)
	Richard Bailey	DFO (Retired)
	Rick Holmes	Cariboo Envirotech Ltd. (Biologist)
	Shamus Curtis	UFFCA (Fisheries Biologist)
	Tina Donald	Councillor, Simpcw First Nation Councillor (Councillor)
	Tyler Thibault	DFO (Community Advisor)

2. KEY DEFINITIONS

- **Action Pathway:** The means by which a threat is addressed. For example, action pathways to address the threat of elevated water temperature include reducing warming (e.g. reducing solar radiation) or increasing cool water inputs; action pathways to address competition would include increasing prey abundance or reducing the abundance of competitors.

- **Conservation hatchery:** A fish culture facility designed primarily to support the recovery and longterm persistence of at-risk salmon populations. Unlike production hatcheries focused on harvest, these facilities prioritize genetic diversity and natural behaviors to support long-term species recovery (see NOAA 1999 and Bradford et al 2025).

- **Designatable Unit (DU):** A DU is defined by COSEWIC (2019) as a discrete and evolutionarily significant unit (i.e. population or group of populations) within a species, where "significant" means the unit contributes meaningfully to the species' overall evolutionary legacy and is unlikely to be replaced if lost. Discreteness is based on factors such as genetic differences, geographic separation, and/or occupation of distinct eco-geographic regions. Evolutionary significance is determined by multiple criteria such as genetic distinctiveness and/or representing a large portion of the species' range.

- **Environment:** Refers to a distinct geographic and ecological setting used by Chinook salmon during one or more stages of their life cycle. Each environment represents a functionally different habitat area that supports key biological processes (e.g. feeding and growth, overwintering). Five environments are defined for Chinook salmon within this recovery plan, including *natal watershed*, *Fraser River mainstem*, *Fraser River estuary*, *nearshore marine*, and *offshore marine* (Table 1).

- **Environment type:** A broad classification that groups environments based on their general ecological and geographic characteristics. Three environment types are defined for Chinook salmon within this recovery plan (i.e. *freshwater*, *estuary*, and *marine*; see Table 1). These types reflect major transitions in biophysical setting across the salmon life cycle.

- **Escapement:** The number of fish that are observed (or estimated) to reach spawning grounds. It does not account for harvested individuals or fully correct for gaps in monitoring. As such, escapement represents a subset of the total population, whereas run reconstruction aims to quantify the entire returning population.

- **Life history strategy:** A life history strategy describes the characteristic pattern of growth, development, and reproduction exhibited by a Chinook salmon population or individual. This includes the timing and duration of freshwater rearing, age and size at smoltification, migration patterns, ocean residence, age- and size-at-maturity, spawning timing and location, and sex-specific differences in growth and reproductive investment. Life history strategies determine how individuals and populations respond to environmental conditions, habitat availability, and anthropogenic threats, and are critical for informing conservation and recovery planning.

- **Life history type:** A classification describing the characteristic pattern of growth, migration, and timing of key life events (e.g. freshwater rearing, ocean entry, spawning migration) within a species. In Chinook salmon, life history types reflect distinct juvenile rearing strategies and migration phenology that influence habitat use, marine distribution, and population vulnerability (Healey 1991; Quinn 2005). The two primary life history types are stream-type and ocean-type Chinook salmon. See ocean-type Chinook salmon and stream-type Chinook salmon.

- **Marine anthropogenic stressors:** Human-caused factors that alter ecosystems, species interactions, or population dynamics, creating additional risks to salmon beyond those imposed by natural environmental conditions. Examples include hatchery releases causing density-dependent competition, coastal habitat modification (shoreline armouring, dredging), and bycatch in commercial fisheries.

- **Marine conditions:** Naturally occurring environmental factors in the ocean and estuarine habitats that influence salmon growth, survival, and behaviour. These include physical, chemical, and biological characteristics of the marine environment, as well as natural temporal variability. Examples include sea surface temperature, salinity, currents, upwelling, prey availability, natural predation, disease prevalence, and interannual climate variability (e.g. El Niño-Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO).

- **Middle and upper Fraser River Spring 5_2 Chinook salmon** (or **UFR Spring 5_2 Chinook salmon).** Refers to the collective grouping of spawning populations making up Designatable Units (DUs) 9 and 11. This term is used to represent all individual spawning populations within both DUs as a single unit for the purposes of recovery planning. The DU

grouping is based on shared seasonal migration timing (e.g. spring-run in the case of DU9 and DU11) and common geographic or genetic characteristics, as defined by COSEWIC (2019).

- **Natal watershed:** The river basin or drainage system in which an individual Chinook salmon originates, encompassing the spawning, incubation, and early freshwater rearing habitats used before downstream dispersal. Adult salmon typically return to their natal watershed to spawn due to strong homing behavior (Healy 1991). For UFR Spring 5_2 Chinook salmon this includes tributary streams within the middle and upper Fraser River watersheds and/or mainstem spawning habitat in the upper Fraser River mainstem upstream of Tête Jaune Cache.
- **Natal watershed group:** A functional grouping of fish originating from spawning populations used for the within-environment assessment. It refers to a group of spawning populations rather than a defined geographic area. A natal watershed group may include spawning populations within a single watershed (e.g. sub-watersheds; the Willow River natal watershed group includes Willow River and Wansa Creek, a tributary of the Willow River) or spawning populations from distinct watersheds that are in close proximity and share similar physical characteristics (e.g. the Middle Fraser West natal watershed group includes Baker and Narcosli creeks, both of which are tributaries to the Fraser River).
- **Ocean-type Chinook salmon:** A life-history type characterized by a brief freshwater residency after incubation, with juveniles typically spending less than one year in freshwater before migrating to the ocean (i.e. sub-yearling migrants). Ocean-type juveniles generally enter estuaries at smaller body size than yearling ocean entrants and typically use estuarine habitats for a longer period (weeks to months) than stream-type juveniles before moving into nearshore marine areas. Their marine distribution tends to be more coastal than stream-type fish with marine distributions centered on the continental shelf. They are also predominated by summer- and fall-run populations, especially in coastal and lower-mainstem rivers.
- **Population aggregate:** Within this recovery plan, the term "population aggregate" is used interchangeably with UFR Spring 5_2 Chinook salmon to refer to the collective group of spawning populations comprising DU9 and DU11 combined. This usage reflects a management-level definition and may differ from more specific biological or genetic definitions of "population" used elsewhere.
- **Production hatchery:** A facility that breeds and rears salmon to increase overall fish abundance for harvest opportunities or to augment stock sizes for commercial, recreational, or subsistence fisheries. It is focused on increasing population size rather than restoring the natural spawning component of depleted wild populations.
- **Run timing:** The seasonal timing of adult Chinook salmon returning from the ocean to freshwater to begin their spawning migration (Healey 1991; Quinn 2005). Run timing reflects genetically and environmentally shaped adaptations to local flow and temperature regimes, migration distance, and spawning habitat characteristics (Waples et al. 2004; Quinn 2005). Chinook salmon populations are commonly classified into "spring," "summer," and "fall" runs (and, in some regions, "winter" runs), each entering freshwater at different times and at varying degrees of sexual maturity (Healey 1991). Spring-run fish typically enter freshwater months before spawning and migrate long distances into interior watersheds, whereas summer- and fall-run fish enter later, closer to the spawning period and often migrate shorter distances (Healey, 1991; Quinn, 2005; Waples et al., 2004).
- **Spawning population:** Refers to a group of Chinook salmon that return to reproduce in a specific natal stream (e.g. Willow River, Dome Creek). These individuals share a common spawning location and typically exhibit similar genetic, behavioural, and life-history traits as a result of homing to the same stream.
- **Stream-type Chinook salmon:** A life-history type characterized by extended freshwater residency, with juveniles typically spending one year or more in freshwater before migrating to the ocean (i.e. yearling migrants). Stream-type juveniles generally enter estuaries at larger body size than sub-yearling ocean entrants and typically use estuarine habitats only briefly (days to weeks) before moving into nearshore marine areas. Their marine distribution often extends farther offshore or northward compared to ocean-type fish. As adults, stream-type Chinook salmon commonly undertake long migrations to interior spawning areas, entering freshwater months before spawning and staging for extended periods prior to spawning. The life history type predominates in spring-run and many interior populations.
- **Sub-yearling Chinook salmon:** See ocean-type Chinook salmon.
- **Terminal run reconstruction:** A reconstruction of the abundance of returning adults after marine fisheries have occurred, based on terminal fishery removals and spawning escapement. Because marine fishery removals are

not included, the estimates represent terminal returns rather than total run size or pre-fishery abundance. See English et al. 2007.

- **Threat:** We define threats as per COSEWIC (2023): "Activities or processes that directly and negatively affect [UFR Spring 5_2 Chinook Salmon]. Although threats are often related to human activities, natural phenomena can be regarded as direct threats in some situations, particularly when a species has lost its resilience from other threats and is thus vulnerable to the point where a population decline is observed, projected, or suspected. Threats can be ongoing, and/or likely to occur in the future. Threats are proximate or direct causes of decline. Where possible, links have been made between proximate threats and biological features of the species or population such as inbreeding depression, small population size, genetic isolation, or their likelihood of regeneration or recolonization for ecosystems, all of which are considered limiting factors."
- **Yearling Chinook salmon:** See stream-type Chinook salmon.

3. METHODS

3.1 Current Knowledge Review

The current knowledge review involved a comprehensive assessment designed to provide an evidence-based foundation to support and inform the threats and action assessments. The objective of this work was to describe the status of UFR Spring 5_2 Chinook salmon, identify factors influencing that status across life stages and environments, identify potential threats, and to compare status to other Chinook salmon populations or conservation groupings. The review was organized into four components: (1) Population Status, (2) Life History, (3) Environmental Setting, and (4) Threat Identification, which are summarized in Sections 3.1.1 – 3.1.4, below.

A core element of each component was a targeted literature review that synthesized existing peer-reviewed and grey literature relevant to UFR Spring 5_2 Chinook salmon and their environments. Given that information on each topic above specific to UFR Spring 5_2 Chinook salmon is limited, or in many cases absent, the review also drew on a broader body of Pacific salmon research, with emphasis where possible on other stream-type Chinook salmon populations. Across all literature reviews, discussion primarily describes Chinook salmon generally. Information specific to the UFR Spring 5_2 population aggregate is included only where such data are available and is explicitly identified when presented. Wherever possible, new analyses were not conducted, and the review relied on existing work to streamline the process and produce results efficiently (see objectives in Section 1.2). Broader technical and scientific literature was reviewed to describe coast-wide patterns, trends, and processes, while information specific to UFR Spring 5_2 Chinook salmon was integrated when available to provide local context.

3.1.1. Population Status

This component examined status and trends of spawning populations comprising the UFR Spring 5_2 Chinook salmon population aggregate using three complementary approaches that span from local (i.e. population-specific monitoring data) to broader regional context (i.e. coast wide trends), providing a synthesis of current knowledge, identifying shared and unique temporal patterns in population status, and situating UFR Spring 5_2 Chinook salmon trends within coast-wide patterns.

1. **Monitoring data synthesis:** Reviewed UFR Spring 5_2 Chinook salmon population status information to summarize status, historical trends, and variability at the local scale;
2. **Dynamic factor analysis of stream-specific spawner abundance trends:** Identified shared and unique temporal patterns, helping to distinguish synchronous versus independent population trends.
3. **Literature-based evaluation of coast-wide trends:** Reviewed Chinook salmon abundance and demographic trends across different life history types (e.g. stream vs. ocean type) and run timing variants (e.g. spring, summer, fall, winter) to provide broader regional context to situate UFR Spring 5_2 Chinook salmon trends within coast-wide patterns.

3.1.1.1. Monitoring data synthesis

This synthesis summarizes existing government assessments (i.e. COSEWIC 2019, DFO 2020, and DFO 2025b) and monitoring data (DFO Fraser River run terminal reconstruction results and NUSEDS escapement estimates; DFO 2025b), including stream-specific spawner abundance trends to characterize the status of UFR Spring 5_2 Chinook salmon.

Enhancement activities to support UFR Spring 5_2 Chinook salmon were also reviewed to assess their potential influence on spawning population abundance and demographics.

3.1.1.2. Dynamic factor analysis of stream-specific spawner abundance trends

The objective of this analysis was to support evaluation of UFR Spring 5_2 Chinook salmon status by assessing whether abundance trends are consistent among spawning populations within and between DUs. Specifically, we examined whether populations exhibit similar temporal trajectories in abundance or divergent trends. The degree of synchrony among spawning populations provides insight into the spatial scale at which threats may be operating: similar trends suggest shared drivers acting across broad geographic areas (e.g. marine conditions or freshwater migration corridors), whereas divergent trends indicate more localized pressures, particularly within freshwater spawning and rearing habitats.

We applied dynamic factor analysis (DFA), a multivariate time-series approach used to identify shared variability among spawning populations. This method allowed identification of spawning populations with similar or divergent trajectories, providing a quantitative basis for assessing synchrony within and between DUs and for inferring whether observed patterns were driven by broad-scale or localized processes. See Appendix A for detailed analysis methodology.

3.1.1.3. Evaluation of coast-wide Chinook salmon trends

To provide context for the status of UFR Spring 5_2 Chinook salmon, a literature review was conducted to identify and synthesize studies that examined coast-wide trends in Chinook salmon abundance and demographics. The review focused on publications that compared spawning population trajectories among different life history types (e.g. stream- vs. ocean-type) and run timing variants (e.g. spring, summer, fall, and winter runs).

Comparisons among geographically distinct interior stream-type populations were emphasized to explore broader regional patterns while recognizing that each population occurs in a unique ecological and management context, with differences in habitat conditions, anthropogenic influences, and local stressors. Despite these differences, interior stream-type populations share key life-history traits, such as extended freshwater residency and similar nearshore and offshore marine use, providing a meaningful basis for comparison. Comparisons across life-history strategies, including stream- versus ocean-type fish, allow evaluation of whether observed trends are broadly shared among Chinook salmon populations or are associated with differences in freshwater residency duration, size at ocean entry, and estuary or marine habitat use.

Relevant peer-reviewed articles, technical reports, and government assessments were compiled and their findings summarized to highlight identified regional or coast-wide patterns in abundance, productivity, demographics, and survival, as well as to identify where differences exist between spawning populations or population aggregates. Together, these insights provide a comparative context for interpreting UFR Spring 5_2 Chinook salmon status.

3.1.2. Life History

This component synthesized current knowledge on the biology, life history, and life-stage-specific habitat use of Chinook salmon. The primary objective was to summarize Chinook salmon life history strategies and habitat requirements to provide a foundation for the life cycle and population ecology assessment, threat identification, threats assessment, and action planning processes. Understanding the timing, duration, and location of Chinook salmon habitat use across freshwater, estuary, and marine environments, along with their associated vulnerabilities and ecological needs, is critical for identifying periods of heightened risk. Throughout the review, information specific to the UFR Spring 5_2 population aggregate is included only where such data are available and is explicitly identified when presented. The synthesis also describes ocean-type life history strategies and other run-type variants (e.g. summer and fall runs) to highlight key differences in life history traits. These comparisons support interpretation of Chinook salmon population trends (Section 3.1.1.3) and Question 2 (Sections 1.2 and 5.2.1) and provide context for exploring potential causes of variation in population status across the species' range.

3.1.3. Environmental Setting

This component summarized available information on the environments used by UFR Spring 5_2 Chinook salmon throughout their life cycle (see Table 1). Due to differences in data types and availability, different environments were assessed using distinct approaches.

In the freshwater environments of the middle and upper Fraser River watersheds, the environmental setting was summarized using three approaches:

1. **Literature review** of regional environmental conditions using several key resources (i.e. Federal Science Libraries Network [FSLN; Government of Canada 2021], provincial Cross-Linked Information Resources libraries [Government of BC 2025a], Pacific Salmon Explorer [PSF 2025a]) and relevant peer-reviewed and grey literature.

2. **Spatial analysis** of relevant data sources available through iMapBC (Government of BC 2025b) to quantify habitat conditions at the natal watershed level, including watershed area, total areas of lakes, wetlands, and glaciers, total area affected by wildfire and forest harvesting, distribution of mining claims and tenures, and stream order and magnitude. Habitat pressure indicators developed by PSF and presented in the Pacific Salmon Explorer web application were also used in the spatial analysis.

3. **Expert and local knowledge** was solicited from members of the Technical Advisory Group to verify that information compiled during the literature review and spatial analysis accurately reflected current and historical environmental conditions.

The information was synthesized into standardized summaries for each natal watershed that described watershed hydrology, morphology, habitat conditions (including land use history, development, and disturbance), known threats, historical and contemporary UFR Spring 5_2 Chinook salmon distribution, and enhancement activities and fisheries opportunities. Results of this synthesis are presented in Appendix C and supporting summary and supplemental tables.

For environments downstream of the middle Fraser River watershed (i.e. Fraser River Canyon, lower Fraser River, Fraser River estuary, and nearshore and offshore marine environments), available data on the timing, duration, and spatial extent of UFR Spring 5_2 Chinook salmon occupancy is limited. Therefore, the environments were assessed through a broad literature review focused on describing the ecosystems and environmental conditions encountered by Chinook salmon in these areas. The discussion describes Chinook salmon generally; information specific to the UFR Spring 5_2 population aggregate is included only where such data are available and it is explicitly identified when presented. In the absence of detailed, habitat-specific threat data, the review provided general discussion of potential threats and their expected impacts, including quantified values where available. Where relevant, the review also considered ecological factors that may influence exposure to, or the magnitude of impact of specific threats.

3.1.4. Threat Identification and Evidence Synthesis

The threat identification process developed a comprehensive and biologically grounded summary of potential threats influencing UFR Spring 5_2 Chinook salmon, with a focus on how each threat may act across different environments and life stages. The objective was to provide foundational information to support subsequent threats assessment and action planning. Specifically, the threat identification process aimed to link each potential threat to its associated causes or activities, mechanisms or pathways of effect, and expected life stage-specific impacts, including both lethal and sublethal outcomes. Threats, which included both natural and anthropogenic factors, were compiled from multiple established sources (e.g. COSEWIC reports, RPAs, RAMS reports) and targeted reviews of peer-reviewed and grey literature (e.g. Riddell et al. 2013). This multi-source approach ensured a robust and comprehensive threat inventory based on established conservation assessments and current scientific understanding and provided the most comprehensive inventory of threats we could compile.

Threats were organized into three environment type-specific tables (freshwater, estuary, marine; see Table 1) and assigned to life stage and environment combinations based on where they are known or expected to occur. For each applicable combination, we summarized the known or expected mechanisms of impact and described how these pathways may affect UFR Spring 5_2 Chinook salmon, emphasizing life stages or habitats with heightened vulnerability. The threat identification process focused on broad-scale and cross-cutting threats rather than local, site-specific pressures, and was intended to support subsequent threats assessment and action planning processes by clearly linking each possible threat to the biological pathway(s) through which it may influence UFR Spring 5_2 Chinook salmon.

Threats were categorized based on their mechanisms of impact on salmon rather than the specific causes of those mechanisms. For example, sedimentation was identified as a threat, rather than the various activities that can lead to sedimentation (e.g. logging, land use change, wildfire). We attempted to treat all threats as independent, however this was not always possible. In some cases, a stressor was assessed both as a direct threat and as an underlying driver of other threats. For example, the physiological effects of elevated water temperature on salmon were evaluated directly under the water temperature threat. However, temperature can also influence salmon indirectly through ecological pathways, such as changes in prey availability, predator communities, or disease manifestation. In these cases, the proximate ecological process (e.g. reduced prey availability) was assessed as the threat itself, while factors such as fishing pressure or temperature were considered potential mechanisms contributing to that pathway.

We did not include climate change as a stand-alone threat in the threat identification process or threats assessment. However, we acknowledge that climate change has significant and pervasive effects on nearly all aspects of Chinook salmon life history and is expected to exacerbate the threats (and their effects) that have been described and evaluated in this recovery plan. Since climate change is a broad, systematic driver, rather than a discrete actionable threat (i.e. addressing climate change will require substantial and complex international efforts), we considered its role in shaping each assessed threat rather than evaluating it independently. For example, climate-driven ocean warming has shifted the timing, abundance, and distribution of key forage species, altering prey availability for Chinook salmon during critical marine rearing periods, assessed herein under the threat "changes in the abundance and distribution of preferred prey". Our decision to consider climate change as an exacerbating influence rather than an independent threat was driven by our objective within the threat identification and threat assessment processes to identify and assess threat mechanisms that directly affect Chinook salmon to inform recovery actions most likely to be effective at the scale of the UFR Spring 5_2 Chinook salmon population aggregate.

Finally, we conducted a targeted literature review for each identified threat to evaluate its relevance and impact on UFR Spring 5_2 Chinook salmon. The review focused on three components: (1) a description of each threat and its relevance to UFR Spring 5_2 Chinook salmon; (2) the mechanism(s) of impact, outlining how each threat affects specific life stages or their environments; and (3) the strength of supporting evidence, including documentation of the threat's occurrence in environments used by UFR Spring 5_2 Chinook salmon and its observed or inferred effects. These summaries provide a systematic, evidence-based foundation for scoring threats in the assessment and informing recovery objectives and actions. Wherever possible, threats were described using information specific to their occurrence and impacts on UFR Spring 5_2 Chinook salmon and their environments. However, due to substantial data limitations, assessments were based on research on other Chinook salmon populations, population aggregates, or Pacific salmon species under the assumption that UFR Spring 5_2 Chinook salmon respond to each threat in comparable ways. The UFR Spring 5_2 population aggregate is included only where such data are available and is explicitly identified when presented.

3.2 Life Cycle and Population Ecology Assessment

Insufficient empirical data at the population-aggregate level prevented full parameterization of a life-cycle model for UFR Spring 5_2 Chinook salmon. Consequently, a sensitivity analysis was conducted to evaluate how variation in key life-stage specific parameters influenced estimates of population growth, thereby identifying the life stages with the greatest potential to contribute to population improvement. In the absence of population-specific data, the analysis used a data-rich proxy population (i.e. Nicola River Spring 42 Chinook salmon). Although the proxy population differs in age-at-maturity, it was considered appropriate for this exploratory analysis due to its stream-type life history and origin within interior British Columbia.

To complement the quantitative analysis, a targeted literature review was conducted on Chinook salmon population ecology and salmonid life-history dynamics. This review synthesized theoretical and empirical studies examining how survival at different life stages contributes to Pacific salmon population growth. The combination of the sensitivity analysis and supporting literature review provided complementary lines of evidence to identify the life stages during which changes in survival are likely to have the greatest influence on population growth and to inform threat evaluation and recovery planning.

3.3 Threats Assessment

The threats assessment used a structured, two-step approach to evaluate risks to UFR Spring 5_2 Chinook salmon across all life stages and environments. In Step 1, a within-environment assessment evaluated threats in specific environments, providing detailed, localized risk information. In Step 2, a broader DU-level assessment integrated these findings to identify the threats most likely influencing the status of UFR Spring 5_2 Chinook salmon.

3.3.1. Within-Environment Threats Assessment

The within-environment threats assessment was developed to identify and characterize threats affecting UFR Spring 5_2 Chinook salmon across all life stages and environment types used across the full life cycle (i.e. freshwater, estuary, marine). To improve efficiency, assessments were conducted at the natal watershed group level rather than for individual spawning populations. The list of threats considered in each environment was derived from Appendix D (Threat Identification) and refined through input from technical advisors. The assessment was conducted by two biologists using a modified RAMS Level 1 risk assessment framework (Hyatt et al. 2017). Each unique combination of threat × natal watershed group × life stage × environment was scored for biological risk, confidence (i.e. uncertainty in the assessment), and trend (i.e. past and future threat magnitude). Scoring followed RAMS Level 1 definitions (Hyatt et al. 2017) and was informed by Chinook salmon life history (Appendix B) and environmental conditions (Appendix C), with additional details provided in the Threats Assessment Appendix (Appendix F).

Threats in the natal watershed environment were scored separately for each watershed group, while threats in shared environments (i.e. mainstem Fraser River migratory corridor, Fraser River estuary, and nearshore and offshore marine) were assessed collectively under the assumption that shared environments are used by multiple watershed groups of Chinook salmon in similar ways, such that the potential exposure to threats in these areas is largely comparable across spawning populations[1].

The primary output of the assessment was a within-environment biological risk score, representing the predicted change in Chinook salmon population growth for each threat × watershed group × life stage × environment combination. This score incorporated key factors[2]:

1. **Spatial extent** of the threat (i.e. how widespread the threat is across relevant life stages and environments);
2. **Temporal extent** of the threat (i.e. how frequently and for how long the threat occurs); and
3. **Impact** of the threat (i.e. the expected or observed effect of each threat on subsequent adult returns).

Each within-environment biological risk score reflected the current impact of a threat on the natal watershed group. The within-environment assessment used a simplified categorical scoring scale (Table 4). By assigning standardized categories (low, moderate, high), we were able to integrate expert judgment and heterogeneous evidence and compare across threats, life stages, and natal watershed groups. This approach provides a transparent and consistent framework for evaluating risk despite data limitations. The within-environment biological risk scores were used to evaluate the spatial and temporal distribution of threats and identify which life stages were most vulnerable. It is important to note that these scores are intended only to compare the relative importance of threats within each life stage and environment. They should not be interpreted as estimates of the overall population-level effect of each threat.

A separate confidence score was assigned to each combination to capture uncertainties in the assessment (e.g. data gaps, management effectiveness, cumulative effects, and watershed group-specific responses). While the confidence scores were not included in the biological risk calculation, they provide valuable context, support precautionary decision-making, and help identify where further research or monitoring is needed.

Within the recovery plan, the within-environment threats assessment also served as a screening tool to identify moderate and high-risk threats, which were advanced to Step 2 for further evaluation at the DU-level. Within-environment assessment results are also directly applicable to action planning, particularly for user groups aiming to identify and address threats affecting specific spawning populations or natal watershed groups.

Table 4. Within-environment threats assessment parameter definitions and scoring

Scoring Parameter	Description	Score	Score Description
Spatial Extent	Percentage of environment used by a particular life stage affected by each threat OR as the percentage of the spawning population of each life stage that would be affected by each threat, whichever was greater	Low (1) Moderate (3) High (5)	≤ 10% of natal watershed group affected > 10 – 50% of natal watershed group affected >50% of natal watershed group affected
Temporal Extent	Frequency at which each threat would impact each life stage in each environment	Low (1) Moderate (3) High (5)	< 1 time per decade ≥ 1 – <5 time per decade ≥ 5 time per decade
Impact	Expected severity of impact of each threat on subsequent adult returns	Low (1) Moderate (3) High (5)	≤ 10% change in returns to natal watershed group > 10 – 30% change in returns to natal watershed group > 30% change in returns to natal watershed group

[1] *We acknowledge that this assumption oversimplified the complex life history of UFR Spring 5_2 Chinook salmon (e.g. there is known variation in juvenile mainstem rearing and downstream migration including use of non-natal tributaries, see Appendix B). However, due to limited data on life-stage-specific habitat use and timing, treating shared environments as having similar exposure was necessary to complete the assessment. The recovery plan is intended to be updated iteratively as new information becomes available.*

[2] *Climate change was not assessed as a stand-alone threat in the threats assessment; however, its influence was considered in multiple components of the assessment, including evaluation of future trends and in the scoring of key factors, as described in Section 3.1.4.*

3.3.1.1. Additional Considerations

A key challenge in the threats assessment was balancing the level of environmental detail with the practical constraints of the assessment's broad geographic scope, limited data, and the goal of completing the process rapidly. We refer to this as a splitting vs. lumping conundrum. Ideally, each watershed or environment would be assessed independently to address site-specific conditions and context. However, a fine-scale approach was not feasible due to limitations of information availability and overall assessment effort requirements.

To manage complexity and accelerate the planning process, natal watersheds with similar ecological and environmental characteristics were grouped into broader watershed clusters ("lumping"). This approach substantially reduced the scale of the assessment (i.e. from 60 individual natal watersheds, or more if a finer scale was used, to 20 watershed groups) thereby streamlining efforts. Despite this reduction, the within-environment threats assessment still required nearly 32,000 individual evaluations to comprehensively characterize threats.

The balance between splitting and lumping reflects a critical methodological decision: while finer-scale assessments offer greater resolution, they substantially increase workload, time requirements, and information requirements. The chosen approach aimed to maintain ecological relevance while enabling a rapid, yet robust, assessment across a large and diverse area.

3.3.2. DU-Level Threats Assessment

Building on the within-environment assessment, Step 2 involved a DU-level evaluation to identify which moderate- and high-risk threats are most likely influencing the status of UFR Spring 52 Chinook salmon. In the assessment, threats in the natal watershed environment were scored separately for each DU, while threats in shared environments were assessed collectively, under the assumption that shared environments are used by multiple watershed groups of Chinook salmon in similar ways, such that the potential exposure to threats in these areas is comparable across DUs[3].

Scoring definitions for the DU-level assessment were adapted from the RAMS Level 1 methodology (Hyatt et al. 2017). We retained key themes related to the spatial and temporal extent of threats and their expected or known impacts on fish but modified the parameters and calculations to identify threats most likely contributing to population-level declines in UFR Spring 5_2 Chinook salmon.

The primary output of the assessment was a DU-level biological risk score which represented the predicted change in UFR Spring 5_2 Chinook salmon growth for each threat × life stage × environment combination. Risk scores were calculated as the product of three components; each rated on a five-point scale (1 = very low risk to 5 = very high risk; Table 5):

1. **Spatial extent** of the threat: proportion of each DU exposed to the threat[4]
2. **Timing** of the threat: likelihood that exposure to the threat occurred alongside changes in population status; and
3. **Magnitude of effect:** predicted effect of each threat on subsequent adult returns.

The calculation assumed that threats affecting a larger proportion of the DU (i.e. broader spatial extent), that have increased in severity over time (i.e. timing) with greater severity (i.e., magnitude) are most likely to have contributed to declines in UFR Spring 5_2 Chinook salmon.

Three confidence scores were assigned for threat timing and threat magnitude to capture uncertainties in the assessment (e.g. data gaps, management effectiveness, cumulative effects, and DU-specific responses). Timing confidence scores reflected knowledge of changes in threat prevalence over time, and magnitude confidence scores reflected certainty in the impact rating. An overall confidence score was then calculated as the product of these two scores. As with the within environment threats assessment, confidence scores were used for context and were not incorporated into the biological risk scores. In addition, future DU-level biological risk was assessed by considering how threat spatial extent, timing, and magnitude are anticipated to change over the next 50 years. This trend score also remained separate from the biological risk calculation but provides context for action planning.

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[3] We acknowledge that this assumption oversimplified the complex life history of UFR Spring 5_2 Chinook salmon (see Section 3.3.1). However, due to limited data on life-stage-specific habitat use and timing, treating shared environments as having similar exposure was necessary to complete the assessment. The recovery plan is intended to be updated iteratively as new information becomes available.

[4] Threat exposure in each DU was estimated as the proportion of DU spawning populations affected by each threat at each life stage, based on average escapement (DFO 2025b) to natal watershed groups relative to the DU mean. Threats were categorized by risk level (low, moderate, high) across all confidence rankings, providing a quantitative measure of population exposure to guide management priorities.

Following the initial scoring, the Working Group identified a small number of threat categories where additional technical review was warranted. For these threats (including fisheries and predation), a focused expert review was undertaken to evaluate the available evidence and reach consensus on the final DU-level biological risk scores. This additional step ensured that the final scores were consistent with the assessment framework and reflected the collective interpretation of the available scientific evidence.

Table 5. Description and scoring criteria of components used to assess DU-level biological risk.

Scoring Parameter	Description	Score	Scoring Criteria
Spatial Extent	Proportion of DU affected by threat at moderate and high biological risk. For freshwater environments, this was calculated based on within-environment threats assessment results and mean escapement data for natal watersheds in each DU (see section 3.2.2.1 of Appendix F). For environments used by all UFR Spring52 Chinook salmon (e.g., marine environments and mainstem migration corridors) it was assumed that all fish were exposed (i.e., spatial extent score = 5)	5	> 80% of DU exposed to threat
		4	≥ 60 – ≤ 80% of DU exposed to threat
		3	≥ 40 – < 60% of DU exposed to threat
		2	≥ 20 – < 40% of DU exposed to threat
		1	< 20% of DU exposed to threat
Timing	Likelihood that increased exposure to the threat occurred alongside changes in DU status (i.e., whether a change in threat prevalence or severity coincided with observed declines in abundance at DU-level)	5	Very likely
		4	Likely
		3	Possible
		2	Unlikely
		1	Very unlikely
Magnitude	Expected severity of impact(s) of each threat on subsequent adult returns, at DU-level	5	Estimated ≥ 20% change in returns
		4	Estimated ≥ 15 – < 20% change in returns
		3	Estimated ≥ 10 – < 15% change in returns
		2	Estimated ≥ 5 – < 10% change in returns
		1	Estimated < 5% change in returns
Overall Biological Risk	Spatial Extent × Timing × Magnitude	Very High	Score: > 100
		High	Score: 75 – 99
		Moderate	Score: 50 – 74
		Low	Score: 25 – 49
		Very Low	Score: < 25

3.4 Action Prioritization

We developed a structured, two-step process to evaluate and prioritize recovery actions for UFR Spring 5_2 Chinook salmon. In Step 1, we identified potential actions to address threats rated in the DU-level threats assessment as moderate or higher. We then removed those actions (via feasibility assessment) deemed too difficult to implement due to social or technical constraints. Then in Step 2, we added detail to the recovery actions that had been deemed feasible in Step 1, organized these actions into categories, evaluated them using standardized scoring criteria, and prioritized them based on the scores. A group of subject-matter experts scored the social and technical feasibility of actions, which were then averaged and included in the standardized scoring criteria. At the end of Step 2, the actions were further refined and elaborated based on internal review and discussions. While the approach described here was only applied to DU-level threats, that approach could be extended to prioritize actions for within-environment threats at the natal tributary or watershed level and/or the addition of alternate prioritization criteria that reflect values of different user groups.

3.4.1. Action Pathway Identification and Feasibility Assessment

To guide the selection of recovery actions, we first broadly described how threats could be addressed (called action pathways) for each threat that scored moderate or higher in the DU-level threats assessment. Each action pathway was then evaluated for feasibility, and action pathways with substantial social or technical limitations that would likely restrict implementation were removed from consideration.

An overall feasibility score for each action pathway was calculated as the sum of two sub-scores (Table 6):

1. **Technical feasibility:** Assessed whether the necessary methods or technologies exist to address a particular action pathway and if there is evidence of successful implementation.
2. **Social feasibility:** Evaluated whether social constraints may prevent implementation, even if an action is technically possible.

Scoring applied the criteria in Table 6, and rationales for all assignments were documented. Action pathways with overall feasibility scores of six or higher were considered sufficiently feasible to advance to Step 2 of the action assessment process, whereas those scoring five or less were not considered further.

It is important to note that the feasibility assessment considered only whether an action pathway was technically or socially possible and did not address other aspects of implementation such as how or where the action would be implemented or costs of implementation (this is considered in Step 2, Section 3.4.2).

Table 6. Description and scoring criteria used to assess technical and social feasibility of action pathways.

Score	Definition	Description
5	High	There are no substantial barriers or uncertainties for implementation; the action pathway has been actioned elsewhere.
4	-	-
3	Moderate	There are moderate barriers or uncertainties for implementation.
2	-	-
1	Low	There are substantial barriers or uncertainties for implementation; the action pathway has not been actioned elsewhere.

3.4.2. Action Assessment

After feasible action pathways were identified, specific recovery actions for each pathway were developed and ranked. Actions are described to a level of detail sufficient to understand the scope, intent, and expected outcomes. It is assumed that additional feasibility work will be completed prior to implementing any action. Each action was scored using pre-defined criteria, and an overall score was calculated to reflect the action's potential to achieve its recovery objective. In some cases, too little was known about a threat or its mitigation to confidently develop a proposed action. Additional information collection was therefore proposed as a research-based action. A separate list of research actions was developed and evaluated using pre-defined criteria and scores.

3.4.2.1. Development of More-Detailed Actions and Classification

Candidate recovery actions were developed and refined by the recovery team using information from technical reports, recovery planning documents, and both peer-reviewed and grey literature. A minimum of three recovery actions were sought for each feasible action pathway to ensure a range of options were evaluated. Each action was described in enough detail to convey the general concept and allow scoring, while recognizing that detailed implementation plans will be required for most of the actions selected for implementation. Generally, an action was linked to the threat it was intended to address. However, actions that were not directly associated with a specific threat but were identified during the knowledge review as important (e.g. hatchery enhancement, stock assessment programs, etc.) were also considered.

Actions were categorized by action type and linked to an associated recovery objective (Table 7):

1. Reverse the trend of population aggregate decline,
2. Prevent further population aggregate decline, and/or
3. Refine understanding of threats and how best to mitigate them.

We also noted whether an action would provide benefit specifically to UFR Spring 5_2 Chinook salmon or benefit to salmon generally.

These objectives were supported through six action types (Table 7):

- **Habitat protection, emergency response, and coordination** actions to prevent further population aggregate decline,
- **State and management** actions to reverse the population aggregate trend, and
- **Research** actions to refine threat and action assessment results.

Table 7. Description of action types associated with each recovery objective.

Recovery Objective	Action Type	Description
Prevent further population aggregate decline	Habitat Protection	Actions that prevent further population aggregate decline by protecting aquatic and/or terrestrial habitats (e.g. critical rearing or spawning habitats, high-flow refuge habitats, intact riparian vegetation, etc.)
	Emergency Response	Actions that aim to prevent further population aggregate decline by ensuring adequate emergency planning and response procedures are developed (e.g. responses to slide, dewatering or flood events)
	Recovery Coordination	Actions that strengthen protections by strategically engaging with and/or leveraging parallel recovery processes focused on other species
Reverse the population aggregate trend	State	Actions that promote population aggregate recovery by altering environmental conditions (e.g. water temperature, flow, water quality, predation, riparian cover, etc.)
	Management	Actions that promote population aggregate recovery by changing how natural resources are managed or utilized (e.g. fisheries quotas, forest harvesting rates, water withdrawals, etc.)
Refine threat and action assessments	Research/ Monitoring	Actions that collect information required to refine threats and action assessments (i.e. by reducing uncertainty, verifying assumptions, etc.)

3.4.2.2. Action Scoring

Each individual action was scored based on a set of common scoring criteria for action feasibility, geographic scale, expected cost, and a set of biological criteria (Table 8). The same feasibility and cost scoring criteria were used to assess all threats, whereas biological criteria scoring varied based on action type (Table 9 and 10). For example, a population response score is relevant to actions intended to mitigate a threat, but a slightly different criterion is needed to score research-based actions or emergency-response actions. As a result, scoring outputs allow comparison and ranking of actions with shared recovery objectives but direct comparisons of actions are more difficult when they are addressing different objectives. The cost of each action considered only the direct cost of implementing the action, not the broader economic spinoff. Actions that would have significant, broader economic impacts, for instance, would be generally assessed as less socially feasible, but still may have a low cost if the direct implementation cost was assessed to be low.

Scores were calculated for each action as the sum of individual criteria scores. A weighted action assessment score was calculated to provide a biological emphasis to the scores. This weighting applied a 50% weight to scores of biological response magnitude (to reverse the population aggregate trend), biological value (to prevent population aggregate decline), or criticality (for research action types; see Table 8). All scoring assignments were completed by an experienced biologist engaged in the recovery process and then reviewed by select members of the project team (i.e. Working Group, Technical Working Group, and Steering Committee). When scoring actions with similar intentions, it was assumed that they would elicit similar biological response (e.g. equal reductions in production hatchery releases could be achieved via financial incentives or establishment of an international regulatory body).

Action assessment scores provide a systematic basis for comparing and prioritizing actions based on their expected biological benefit or value, feasibility, spatial scale, timing, and cost. However, the scores reflect the available evidence and associated uncertainty and should be interpreted as relative rankings rather than precise measures of expected outcomes. The highest-ranked actions should therefore undergo a final critical review of the underlying evidence, assumptions, uncertainty, and implementation context before being advanced for implementation. Scores were summarized in tables presented and described in Section 4.5.3.2; detailed results are provided in Appendix G.

3.4.2.3. Location Prioritization

Priority locations for action implementation in DU9 and DU11 were identified by reviewing within-environment threat assessment results to identify locations where primary threat(s) relevant to each action occurred as well as the environmental settings appendix (Appendix C) and habitat pressure indicator scores to identify locations (e.g., identify locations with extensive agriculture or that have been extensively disturbed by forest harvesting, etc.). Habitat pressure indicator scores were compiled from the Pacific Salmon Explorer (PSF 2025a) and incorporated into a spatial analysis to calculate the percent of natal watershed area and percent of natal watershed group area with low, moderate or high habitat pressure indicator scores (see Appendix C).

Table 8. Action types and scoring criteria associated with each recovery objective.

Recovery Objective	Associated Action Types	Scoring Criteria											
		Feasibility			Geographic Scale	Cost			Biological Assessment[1]				
		Technical	Social	Overall		Initial	Ongoing	Overall	Magnitude	Value	Criticality	Duration	Timing
Prevent further population aggregate decline	Habitat Protection, Emergency Response, Recovery Coordination	✓	✓	✓	✓	✓	✓	✓	-	✓	-	✓	-
Promote population aggregate recovery (i.e. reverse-the-trend)	State & Management	✓	✓	✓	✓	✓	✓	✓	✓	-	-	✓	-
Refine threats and action assessments	Research & Monitoring	✓	✓	✓	✓	✓	✓	✓	-	-	✓	-	✓

[1] *Red check mark ✓ symbols identify weighted parameter.*

Table 9. Feasibility and cost criteria for scoring of candidate actions. Biological criteria are described in Table 10.

Recovery Objective	Parameter	Description	Scoring Criteria	
			Value	Description
All recovery objectives	Technical Feasibility	Technical feasibility considers whether proven methods or technologies exist.	5	There are no significant technical uncertainties for implementation; there is reliable evidence the action has achieved the intended response when implemented elsewhere.
			4	–
			3	There are moderate technical barriers or uncertainties for implementation.
			2	–
			1	There are significant technical uncertainties about how to undertake the action; the action has not been implemented or there is evidence the action did not achieve intended response when implemented elsewhere.
	Social Feasibility	Social feasibility considers how an action is likely to be received or supported.	5	There are no significant social barriers or uncertainties for implementation; there is evidence the action has received strong social
			4	–
			3	There are moderate technical or social barriers or uncertainties for implementation.
			2	–
			1	There are significant technical or social uncertainties about how to undertake the action; the action has not been stronlgy opposed when
	Overall Feasibility	Product of technical and social feasibility scores.	5	Technical Feasibility + Social Feasibility > 8
			4	Technical Feasibility + Social Feasibility ≤ 8
			3	Technical Feasibility + Social Feasibility ≤ 6
			2	Technical Feasibility + Social Feasibility ≤ 4
			1	Technical Feasibility + Social Feasibility ≤ 2
	Initial Cost	Cost required to implement action.	5	Total cost of implementation is expected to cost <$1M.
			4	–
			3	Total cost of implementation is expected to cost <$5M.
			2	–
			1	Total cost of implementation is expected to cost >$10M.
	Ongoing Cost (Decadal)	Cost required to continue or maintain action beyond one decade (2 generations).	5	Total cost of implementation is expected to cost <$1M. Or no ongoing
			4	–
			3	Total cost of implementation is expected to cost <$5M.
			2	–
			1	Total cost of implementation is expected to cost >$10M.
	Overall Cost	Product of initial and ongoing cost scores.	5	Initial Cost + Ongoing Cost > 8
			4	Initial Cost + Ongoing Cost ≤ 8
			3	Initial Cost + Ongoing Cost ≤ 6
			2	Initial Cost + Ongoing Cost ≤ 4
			1	Initial Cost + Ongoing Cost ≤ 2

Table 10. Biological criteria for scoring of candidate actions. Feasibility and cost criteria are described in Table 9.

Parameter	Description	Scoring Criteria	
		Value	**Description**
Geographic Scale	Proportion of wild population aggregate or study area that will be affected by action implementation.	5	Response is expected to occur within all or most (71 – 100%) of both DUs.
		4	Response is expected to occur within much (31 – 70%) of both DUs.
		3	Response is expected to occur within some (11 – 30%) of both DUs.
		2	Response is expected to occur within a small (1 – 10%) of both DUs.
		1	Response is expected to occur within less than 1% of both DUs.
Magnitude of Biological Response	Estimated magnitude of change in population aggregate size of wild Chinook Salmon anticipated to occur following action implementation.	5	Total population aggregate is expected to increase by >10%.
		4	-
		3	Total population aggregate is expected to increase by >5%.
		2	-
		1	Total population aggregate is expected to increase by <1%.
		0	No response is expected.
Duration of Biological Response	Anticipated duration of time between action implementation and realization of anticipated magnitude of biological response (escapement of wild Chinook Salmon).	5	Biological response is expected within 5 years (1 generation).
		4	Biological response is expected within 10 years (2 generations).
		3	Biological response is expected within 15 years (3 generations).
		2	Biological response is expected within 20 years (4 generations).
		1	Biological response is expected in 20+ years (>4 generations).
Value	Potential for action to mitigate or offset impacts to the population aggregate	5	Likely to fully mitigate or offset impacts to population aggregate (i.e. population loss that would have resulted from emergency or habitat loss is unlikely to occur).
		4	-
		3	Potential to partially mitigate or offset potential impacts to population aggregate (i.e. population loss that would have resulted from emergency or habitat loss may occur).
		2	-
		1	Unlikely to mitigate or offset potential impacts to population aggregate (i.e. population loss that would have resulted from emergency or habitat loss will likely occur).
Criticality	Probability that research action will change interpretation of threat status or action assessment.	5	Very high probability that results will change threat or action assessment.
		4	-
		3	Moderate probability that results will change threat or action assessment.
		2	-
		1	Very low probability that results will change threat or action assessment.
Timing	Duration of time required to implement research action.	5	Assessment results anticipated within 1 year of implementation.
		4	-
		3	Assessment results anticipated within 5 years of implementation.
		2	-
		1	Assessment results anticipated to 10+ years of implementation.

4. RESULTS

The results section is structured to present information at three different levels of detail with the aim of allowing readers to efficiently work through the material by diving into details as they wish. Each topic begins with an overview that summarizes its purpose (i.e. what type of information is presented), rationale (i.e. how the topic supports the recovery planning process), and key takeaways (i.e. a brief technical interpretation that links the material to the core recovery questions presented in the Introduction and Discussion). The overview is followed by a detailed summary that elaborates on statements made in the key takeaways. Additional technical detail and all relevant citations are provided in the accompanying appendices.

4.1 Current Knowledge Review

4.1.1. Population Status

4.1.1.1. Overview

- **Purpose:** This section provides an evaluation of UFR Spring 5_2 Chinook salmon status and places it within the context of coastwide Chinook salmon trends.
- **Rationale:** Assessing status provides a scientific foundation to guide recovery actions, prioritize management efforts, and monitor progress toward recovery objectives.
- **Key Takeaways:**
  - **UFR Spring 5_2 Chinook salmon status:**
    - **Abundance is slowly rebuilding after long-term declines:** UFR Spring 5_2 Chinook salmon have experienced long-term declines in abundance, with historical COSEWIC assessments reflecting elevated extinction risk for both DUs. Assessments using more recent data show incremental increases in abundance, especially in DU 11 (DFO 2026b). Although caution remains needed in the management of these DUs, there is currently low risk of extirpation.
    - **Spawning populations show similar trends:** Visual inspection of terminal run reconstruction results shows broadly similar patterns in abundance across spawning populations within both DUs since 1995, with many populations exhibiting comparable year-to-year fluctuations. DFA results support this interpretation, with the preferred four-trend model identifying one dominant trend shared across many spawning populations, while additional trends capture regional and population-specific variation. This indicates that broad-scale drivers influence many populations, although local processes also contribute to differences among spawning populations.
    - **Hatchery influence is minimal:** Historical hatchery production (1980–2001) likely contributed minimally to overall abundance; the impact of contemporary conservation hatchery efforts (post-Big Bar) remains unknown because of the long generation length and limited monitoring in the Upper Fraser, but is likely low.
    - **Data Gaps Limit Assessment:** Both DU9 and DU11 have limited biological data due to large geographic ranges, remote spawning sites, and monitoring resource constraints, with most estimates based on relative escapement and few absolute counts. Both DUs lack up-to-date productivity, marine survival, and size-at-age data. The lack of data creates uncertainty in assessing population status and trends, constrains life cycle modeling, and makes it challenging to fully assess threat impacts.
  - **Coastwide Chinook salmon status**
    - **Abundance declines are widespread, with interior stream-type populations hardest hit:** many Chinook salmon populations across the Pacific Northwest show negative abundance trends, with spring-run, stream-type populations in interior rivers (e.g. populations spawning in the Fraser River, Columbia River, and Snake River watersheds) experiencing steep reductions in abundance over the past several decades.
    - **Coastwide declines in Chinook salmon survival are widespread but variable:** smolt-to-adult (SARs) return rates for stream-type Chinook salmon have largely declined since the 1960s. Several interior stream-type populations show synchronized declines, which have been attributed to large-scale drivers in marine environments. However, survival trends are not uniform, with some ocean-type populations maintaining relatively higher survival and showing stable or increasing abundance.

- **Coastwide demographic shifts threaten stability:** Chinook salmon across their range have experienced long-term declines in size-at-age and earlier age-at-maturity. These changes likely reduce population resilience and growth by lowering total reproductive output.

4.1.1.2. Detailed Summary

UFR Spring 5_2 Chinook salmon abundance trends

Data from 1995-2015 showed that UFR Spring 5_2 Chinook salmon had elevated extinction risk, with DU9 assessed as "Threatened" and DU11 as "Endangered" by COSEWIC (2019). These status assignments reflect declines in abundance (Figure 2), with DU9 showing a 49% reduction in mature fish over the assessed time series[5] (i.e. 1995 – 2015; three-generation decline of 28% [2000 – 2015]) and DU11 showing a 43% reduction in mature fish over the assessed time series (i.e. 1995 – 2015; three-generation decline of 29% [2000 – 2015]), with continuing future declines expected (COSEWIC 2019). Available marine survival data suggest the population aggregate has very low smolt-to-adult survival[6] (Welch et al. 2021; ~1% for DU11, with no comparable data for DU9).

Since the COSEWIC assessments, both CUs have shown incremental increases in abundance. The exception to this overall trend is 2019 for DU11, where spawners experienced greater than 70% mortality because of the Big Bar landslide, which has now been remedied via a nature-like fishway (DFO 2024). A reassessment of the COSEWIC data suggests that if the assessments were to be repeated with current data, each DU would improve in status, with DU9 moving from Threatened to Special Concern and DU11 moving from Endangered to Threatened (Connors et al. 2024). These incremental increases in abundance have resulted in an overall improvement in Wild Salmon Policy status in 2024 from red to amber, though this approach uses a different methodology than COSEWIC (DFO *in press*). A Wild Salmon Policy amber status suggests that, though caution is required in the management of these DUs, they are currently at low risk of extirpation. This improvement in status does not imply that increases in exploitation are warranted for these DUs under current conditions; merely that fisheries management measures may be beginning to show dividends.

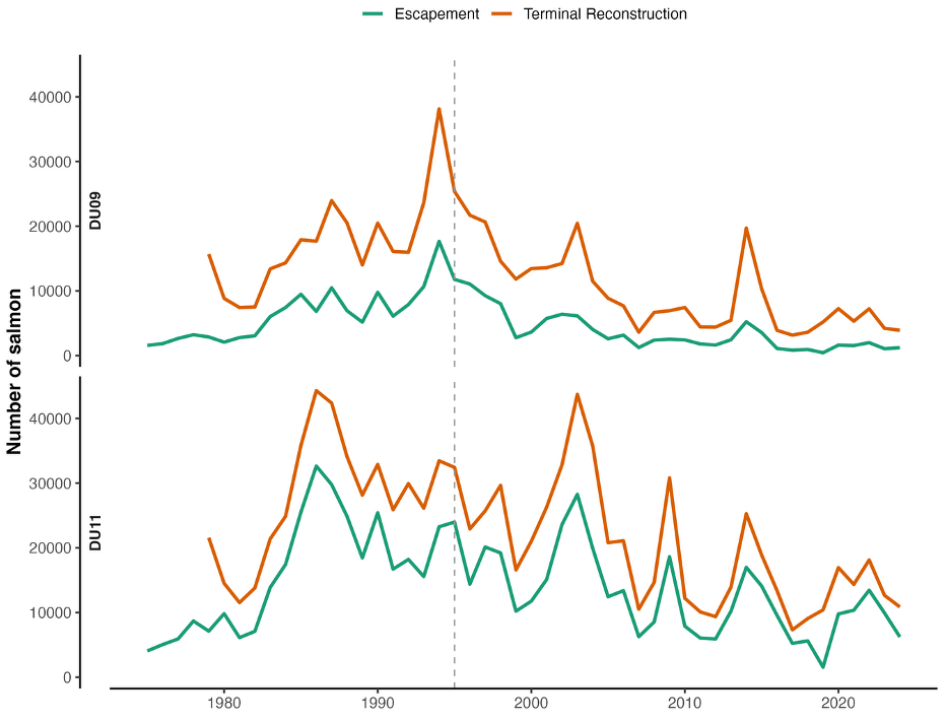

Figure 2. Comparison of abundance estimates for Chinook salmon in DU9 (top) and DU11 (bottom) based on terminal run reconstruction results (orange; DFO 2025) and NuSEDS escapement estimates (green; DFO 2025b). The vertical dashed line marks 1995; earlier data should be interpreted with caution, as their quality has not been fully reviewed (Pestal et al. 2020).

[5] *The time series ends in 2015 because it reflects the most recent data available at the time of the 2019 COSEWIC assessment.*

[6] *Note smolt-adult marine survival rates are based on data for hatchery origin fish, which are known to have lower survival rates than wild fish (Beamish et al. 2011; USGS 2012; Pearsall et al. 2021).*

Historical enhancement efforts for UFR Spring 5_2 Chinook Salmon have been intermittent and varied in scale, location and approach. Enhancement was undertaken at several facilities beginning in the 1980s, including substantial production at the Quesnel River facility as well as smaller programs associated with the Stuart River, Dome Creek/Penney and, more recently, the Spruce City Wildlife Association. Early programs were developed during a period when SEP hatchery practices were still evolving for interior stream-type Chinook Salmon, and some facilities experienced poor adult returns. Several programs were subsequently discontinued as SEP budgets contracted in the 1990s and production was consolidated, limiting the opportunity to evaluate newer rearing approaches better aligned with stream-type life histories. Consequently, historical enhancement experience provides useful context but may not be directly representative of contemporary conservation hatchery approaches.

Following the 2019 Big Bar Landslide, collaborative incubation and rearing programs were established at the DFO SEP Chehalis Hatchery and the Quesnel River Research Facility. The population-level effect of this recent enhancement cannot yet be determined because UFR Spring 5_2 Chinook Salmon have a predominantly five-year generation time; adult returns from these releases are only beginning, and aggregate-level responses have not yet been assessed.

Table 11. Hatchery enhancement programs to support DU9 and DU11 spawning populations from 1981 to 2022 (PSF 2025b).

DU	Natal Watershed Group	Natal Stream	Release Period			# Fish Released		
			n	Earliest	Latest	Fry	Smolt	Total
11	Fraser River Mainstem (Upper)	Fraser River Mainstem (Upper)	1	2019	2019	3,735	0	3,735
	Upper Fraser Group (South)	Swift Creek	1	2022	2022	18,066	0	18,066
	Torpy River	Torpy River	1	2022	2022	36,060	0	36,060
	Dome Creek	Dome Creek	39	1987	2006	1,585,508	1,076,174	2,661,682
	Slim Creek	Slim Creek	6	1981	2022	662,450	14,000	676,450
	Bowron River	Bowron River	12	1981	2022	254,125	2,176,074	2,430,199
		Indianpoint Creek	6	1984	2021	3,946	462,376	466,322
	McGregor River	Fontoniko Creek	4	1985	2022	104,707	347,956	452,663
		Bad River - James Creek	3	1983	1985	318,080	85,595	403,675
		Seebach Creek	2	1985	2021	11,944	116,219	128,163
	Willow River	Willow River	3	1985	2022	8,164	270,105	278,269
	Salmon River	Salmon River	18	1983	2022	10,038	527,100	537,138
	Total DU11 Releases	-	-	-	-	**3,016,823**	**5,075,599**	**8,092,422**
9	Nechako River	Chilako River	8	1985	2002	0	34,456	34,456
		Endako River	2	2020	2022	11,709	0	11,709
	Middle Fraser East	Cottonwood River	2	1985	2021	9,859	84,854	94,713
		Swift River	2	1986	1987	0	523,184	523,184
	West Road (Blackwater)	Baezaeko River	3	1985	1987	0	401,131	401,131
		Nazko River	6	1983	2022	12,195	486,158	498,353
		West Road River	6	1983	2021	53,762	965,297	1,019,059
	Middle Fraser West	Baker Creek	10	1995	2022	3,760	540	4,300
9	Quesnel River	Cariboo River - Upper	11	1984	2022	79,231	1,317,559	1,396,790
		Horsefly River	4	1984	2022	16,676	56,459	73,135
		McKinley Creek	2	1985	1987	0	39,092	39,092
	Chilcotin River	Chilcotin River - Lower	2	2021	2022	16,021	0	16,021
		Chilcotin River - Upper	1	2022	2022	13,666	0	13,666
		Chilcotin River - Not specified	8	1988	2021	674	1,080,715	1,081,389
	Fraser Canyon Group	Yalakom River	4	1987	1993	25,466	52,490	77,956
	Bridge River	Bridge River	23	1989	2022	152,013	297,963	449,976
	Total DU9 Releases	-	-	-	-	**395,032**	**5,339,898**	**5,734,930**

Visual inspection of terminal run reconstruction results indicates that many spawning populations within both DUs share broad temporal patterns since 1979 (Figure 4; Figure 5). Most populations exhibited relatively high abundance during the late 1980s and 1990s, followed by periods of decline beginning in the early to mid-2000s. Several spawning populations also experienced pronounced peaks during the late 1990s and early 2000s, suggesting the influence of broad-scale drivers affecting multiple populations simultaneously. However, the magnitude and timing of these responses varied among spawning populations, with some watersheds exhibiting substantially stronger increases, declines, or interannual fluctuations than others. For example, Nevin, Torpy, Twin, Walker, and McGregor experienced pronounced increases during the late 1990s and early 2000s, whereas populations such as Horsefly and Swift exhibited comparatively weaker responses. Likewise, while many populations declined after the early 2000s, the rate and magnitude of decline differed considerably among watersheds, indicating that there were both common regional trends and idiosyncratic spawner population-specific dynamics.

These observations are further supported by the dynamic factor analysis (DFA), which identified four latent trends underlying population abundance dynamics (Figure 6). These latent trends represent common patterns of change in abundance over time that are shared to varying degrees among spawning populations. Collectively, these trends indicate that abundance trajectories are influenced by multiple temporal patterns rather than a single dominant signal. Latent Trends 3 and 4 explained the greatest proportion of variance (30.4% and 31.0%, respectively), while Trends 1 and 2 accounted for 24.1% and 14.5% of the variance. Trends 1 and 4 describe broad patterns shared across many populations, including periods of elevated abundance during the 1990s and subsequent declines through the 2000s, consistent with patterns observed in the terminal run reconstruction results. In contrast, Trend 3 captures population-specific interannual variability and contrasting responses among watersheds, while Trend 2 reflects a weaker temporal pattern expressed in a smaller subset of populations. The mixture of shared and contrasting factor loadings across the four latent trends suggests that both broad-scale regional drivers and local watershed-specific processes contribute to variation in abundance across spawning populations in DU9 and DU11.

An important caveat is that these analyses are based on reconstructed terminal abundance estimates and therefore reflect both underlying population productivity and fisheries mortality occurring before fish reach the Fraser River. Historically, many UFR Chinook salmon populations were exposed to substantial mixed-stock fisheries in marine and lower Fraser River environments, which would have imposed a common source of mortality across populations and potentially increased synchrony among abundance trends. Although the run reconstruction accounts for major terminal fisheries, including the historical Fraser River gillnet fishery, estimates of abundance remain influenced by broader exploitation patterns that have varied through time. The substantial reductions in exploitation rates since the 1990s, with contemporary fisheries mortality generally below 5% of returning adults, may have reduced the influence of fisheries as a synchronizing force and increased the relative importance of population-specific responses to local habitat conditions and environmental variability.

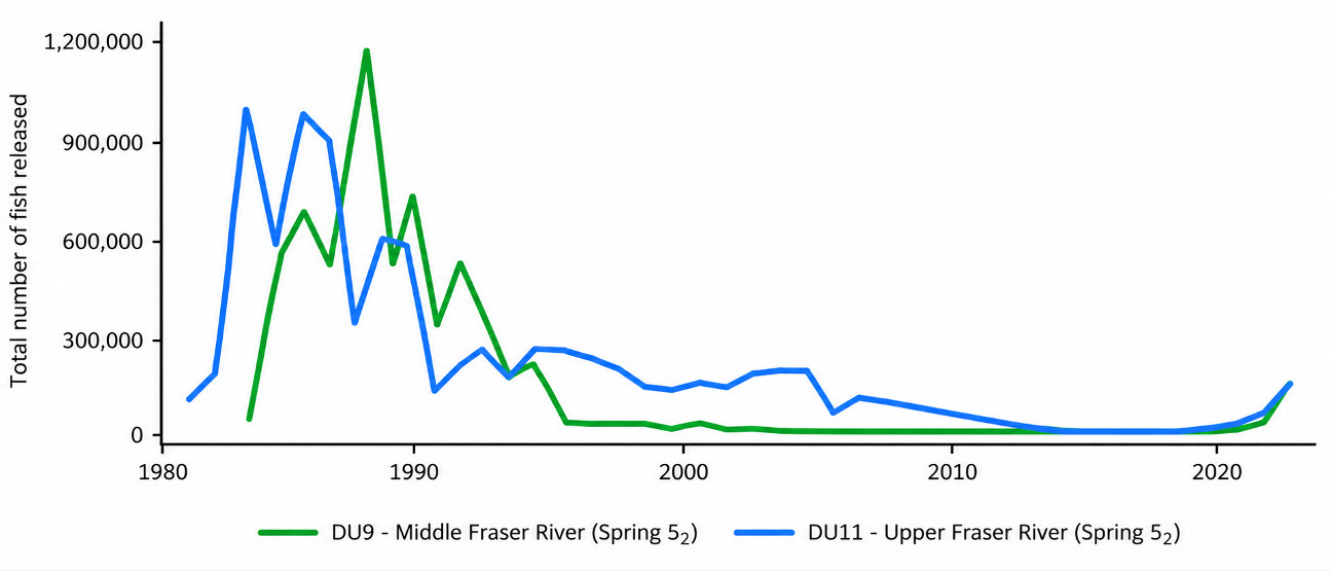

Figure 3. Releases of UFR Spring 5_2 Chinook salmon in DU9 and DU11 (PSF 2025b).

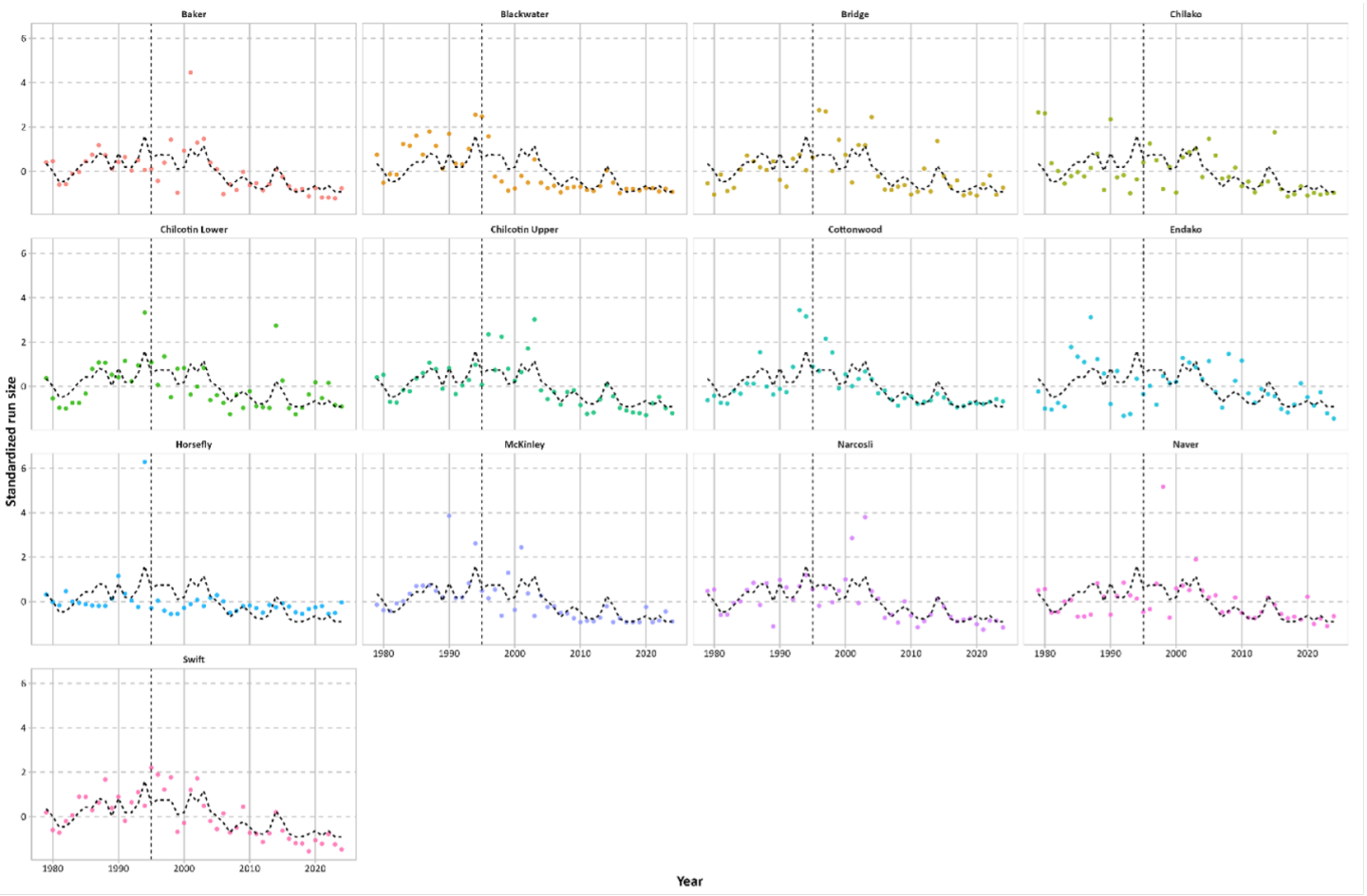

Figure 4. Stream-specific standardized terminal run reconstruction results from the Chinook Technical Committee sourced from PSC (2026) for DU9 Chinook salmon. Individual points represent stream-level estimates, and the dotted trend lines show the DU mean (i.e. the same dotted line is shown for all streams within a DU). The vertical dashed line marks 1995; earlier data should be interpreted with caution, as their quality has not been fully reviewed (Pestal et al. 2020)

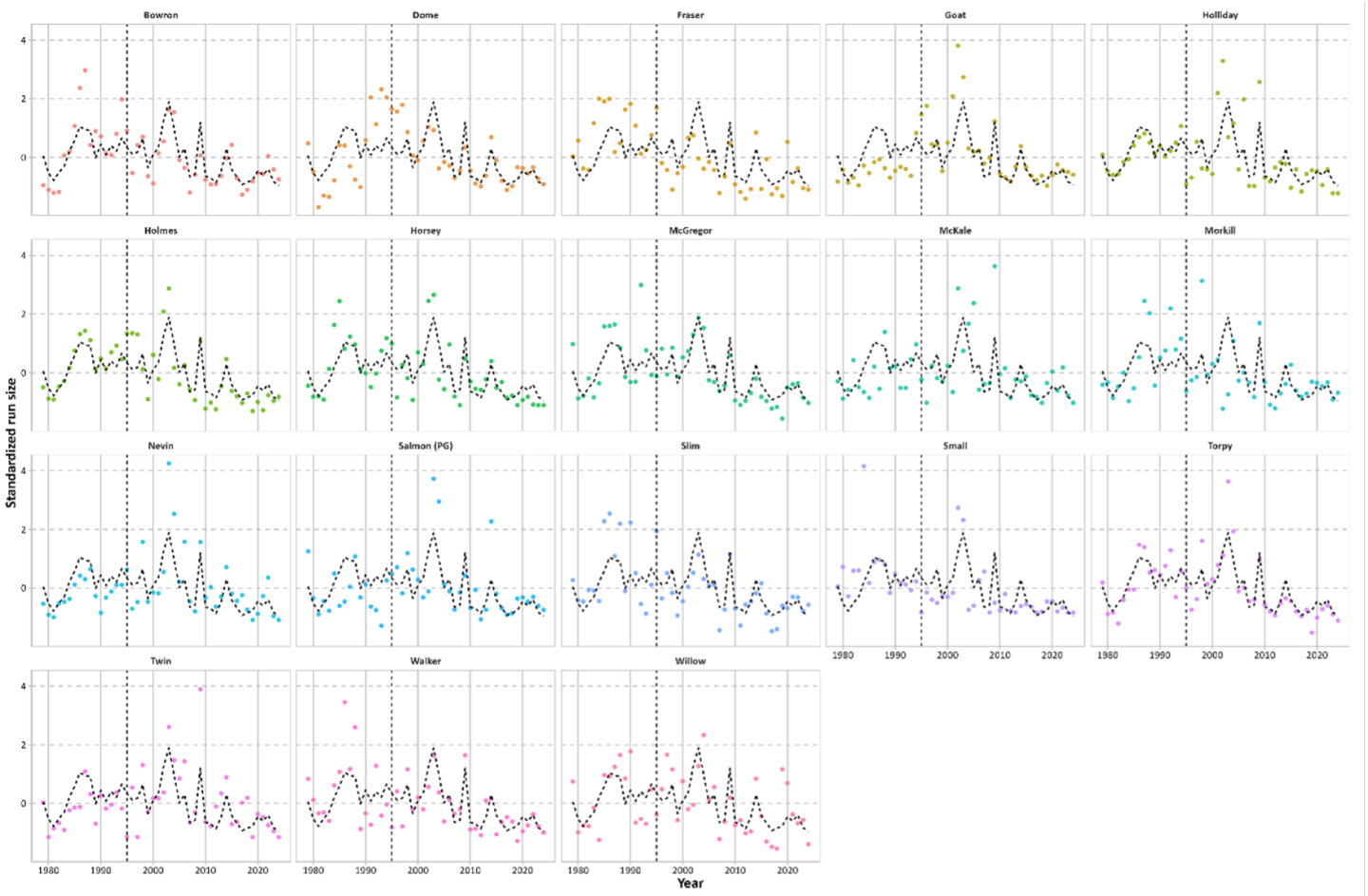

Figure 5. Stream-specific standardized terminal run reconstruction results from the Chinook Technical Committee sourced from PSC (2026) for DU11 Chinook salmon. Individual points represent stream-level estimates, and the dotted trend lines show the DU mean (i.e. the same dotted line is shown for all streams within a DU). The vertical dashed line marks 1995; earlier data should be interpreted with caution, as their quality has not been fully reviewed (Pestal et al. 2020)

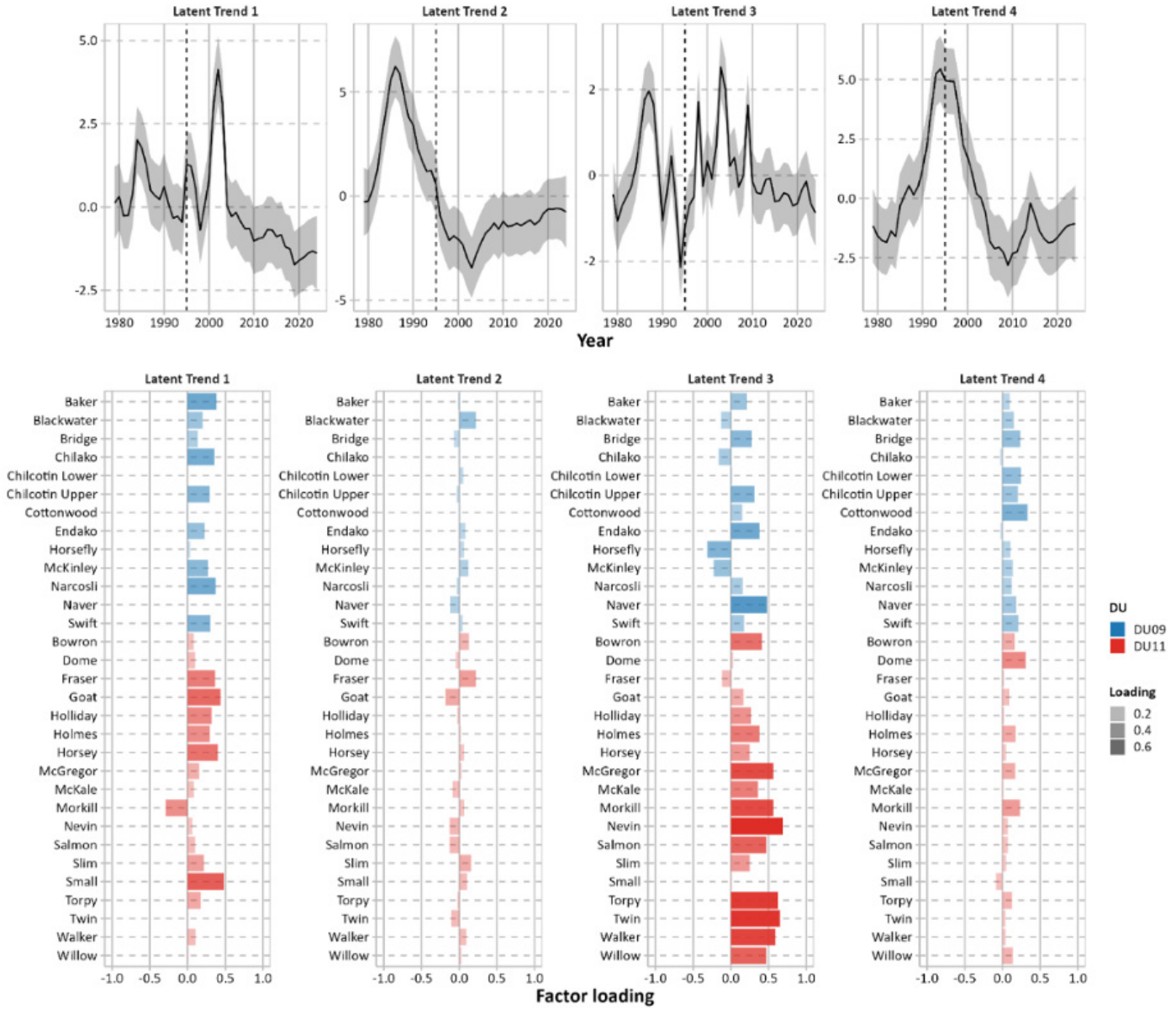

Figure 6. Common trends for the UFR Spring 5_2 terminal run reconstruction results obtained by the model containing four common (latent trend 1, 2, 3 and 4) and a symmetric, nondiagonal matrix (top panel) and factor loadings for the terminal run reconstruction time series. Note common trends and factor loadings are unitless.

Future analyses could build on the DFA by incorporating environmental or anthropogenic covariates to evaluate direct relationships between threats and population abundance, an assessment that was beyond the scope of the present study. Additional insight could also be gained by re-running the analysis using alternative groupings (e.g. watershed units, additional DUs, or geographically defined regions) to examine whether patterns differ at finer or broader spatial scales. However, these approaches were not pursued here because the primary objective was to evaluate whether UFR Spring 5_2 spawning populations exhibit shared temporal dynamics across spawning populations and DUs.

UFR Spring 5_2 Chinook salmon status within broader regional trends

Chinook salmon exhibit substantial life-history diversity across their range, with populations differing in migration timing, freshwater residency, and ocean entry strategies. Across the northeast Pacific Ocean, many Chinook salmon populations have experienced persistent declines in abundance, but trends vary among life-history types (Atlas et al. 2023). The most severe reductions have occurred in spring-run, stream-type populations from large interior watersheds, whereas ocean-type Chinook salmon across much of the coast have generally shown more stable population status (Atlas et al. 2023).

Analysis of coastwide patterns demonstrates that most of the assessed stream-type populations have negative escapement trends, with interior populations in the Fraser, Columbia, and Snake rivers having particularly steep drops in spawner abundance over recent decades (COSEWIC 2019; Atlas et al. 2023). This is reflected by the southern British Columbia DU Chinook salmon COSEWIC assessment, where all "Endangered" statuses were from stream-type spawning populations (COSEWIC 2019). Additional comparisons within the Fraser River watershed illustrate consistent declines across multiple stream-type spawning populations within several DUs, such as Nicola (spring-run), Cariboo (summer-run), Clearwater (summer-run), and Quesnel (summer-run) rivers (Levy and Nicklin 2018; COSEWIC 2019; Chudnow et al. 2022).

Coastwide analyses also indicate that Chinook salmon marine survival has declined substantially for many populations (ADFG 2013; Sharma et al. 2013; Kilduff et al. 2015; Dorner et al. 2019; Crozier et al. 2021; Pearsall et al 2021; Welch et al., 2021), with smolt-to-adult return rates for some stream-type populations decreasing from 2–6% in the 1960s to around 1% or less today[7] (Welch et al., 2021). Declines are evident across many interior watersheds (e.g. Columbia, Fraser, and Snake rivers), suggesting that large-scale processes are a primary driver (Comparative Survival Study Oversight Committee 2025). However, population outcomes are also shaped by life-history traits and freshwater conditions prior to ocean entry. Interior stream-type populations typically undertake long downstream migrations after relatively long freshwater residency (i.e., 1 year; see Appendix B). This extended freshwater phase and migration distance can increase cumulative exposure to freshwater stressors such as elevated temperatures, altered flow regimes, predation, and migration barriers before juveniles reach the ocean. Together, these factors can compound mortality risks and contribute to lower overall survival in interior stream-type populations.

Low productivity and poor smolt to adult survival have also been observed in Chinook salmon populations across both heavily disturbed and relatively intact watersheds (Welch et al. 2021; Atlas et al. 2023). This suggests that broad-scale environmental processes, particularly those operating in shared environments (i.e., marine environments and freshwater migratory corridors) may be preventing recovery (Welch et al. 2021; Freshwater et al. 2022; Atlas et al. 2023, Comparative Survival Study Oversight Committee 2025).

In contrast to the general negative patterns observed for stream-type Chinook salmon, some ocean-type populations show positive trends. Most assessed ocean-type summer and fall Chinook salmon returning to interior portions of the Columbia and Fraser River watersheds have exhibited stable or increasing escapement (e.g. South Thompson), with some supporting substantial fisheries harvest (COSEWIC, 2019; Atlas et al. 2023). These patterns suggest that certain life-history traits, such as shorter freshwater rearing may confer resilience under changing freshwater and marine conditions.

Compounding observed declines in abundance and survival, Chinook salmon have also experienced significant coastwide reductions in population demographics (Ohlberger et al. 2020; Oke et al. 2020; Xu et al. 2020; Manishin et al. 2021; Maharaj et al. 2023). Decreases in body size and shifts in age structure, including losses of older age classes and increased early maturation have reduced average fecundity and overall population productivity, amplifying the vulnerability of declining populations (Ohlberger et al. 2018, 2020; Maharaj et al. 2023).

4.1.2. Life History

4.1.2.1. Overview

- **Purpose:** This section provides a brief description of the life history (e.g. life stage duration, timing, location, and habitat requirements) of UFR Spring 5_2 Chinook salmon. It leverages the broader body of research on stream-type Chinook salmon to explain these attributes, highlighting UFR Spring 5_2 Chinook salmon specific data when available and contrasts this with the ocean-type life history.
- **Rationale:** A clear understanding of life history is essential for identifying when and where UFR Spring 5_2 Chinook salmon are most vulnerable to threats and how the stream-type populations may differ from ocean-type populations with relatively better population status. Life history information is also critical for developing and prioritizing effective recovery actions.
- **Key Takeaways:**
    - **Divergent life histories of stream- vs. ocean-type Chinook salmon: S**tream-type Chinook salmon rear in freshwater for a year or more and migrate to the ocean as larger yearlings, have short estuary residency (i.e. days to weeks) and tend to have broader marine distributions which extend into the offshore environment. In contrast, ocean-type Chinook salmon migrate to the ocean as smaller sub-yearlings after only weeks to

[7] *Note smolt-adult marine survival rates are based on data for hatchery origin fish, which are known to have lower survival rates than wild fish (Beamish et al. 2011; USGS 2012; Pearsall et al. 2021).*

months in freshwater, with longer estuary residency and generally more coastal-oriented marine distributions. These differences in life stage duration and habitat use lead to differences in the types, timing, and duration of exposure to threats.

- **Habitat knowledge supports recovery actions:** Freshwater habitat characteristics for successful incubation and juvenile and adult survival are relatively well understood, providing a strong foundation for targeted recovery actions. In contrast, habitat use and survival during estuary and marine life stages remain poorly understood due to the difficulty of studying the vast spatial scale of ocean habitats and historically limited direct observations. This uncertainty constrains the ability to identify threats to UFR Spring 5_2 Chinook salmon in marine environments (and their magnitude of impact) and develop targeted recovery actions.

- **Supporting Information:** A detailed description of Chinook salmon life history is presented in Appendix B.

4.1.2.2. Detailed Summary

Understanding Chinook salmon life history is essential for conducting and interpreting the threats assessment and prioritizing recovery actions. Given that life history information specific to UFR Spring 5_2 Chinook salmon is highly limited, the discussion primarily describes general Chinook salmon life history patterns. Information specific to the UFR Spring 5_2 Chinook salmon population aggregate is included only where such data are available and is explicitly identified when presented.

Chinook salmon have a complex anadromous life cycle, using multiple freshwater, estuarine, and marine environments. Survival and growth during each life stage depends on environmental conditions and exposure to both natural and human-induced stressors. While all life stages contribute to overall population dynamics, evidence suggests that some phases (e.g. early marine period) have a disproportionately strong influence on cohort strength (Beamish and Mahnken 2001; Howard et al. 2016; COSEWIC 2019; see Section 4.2).

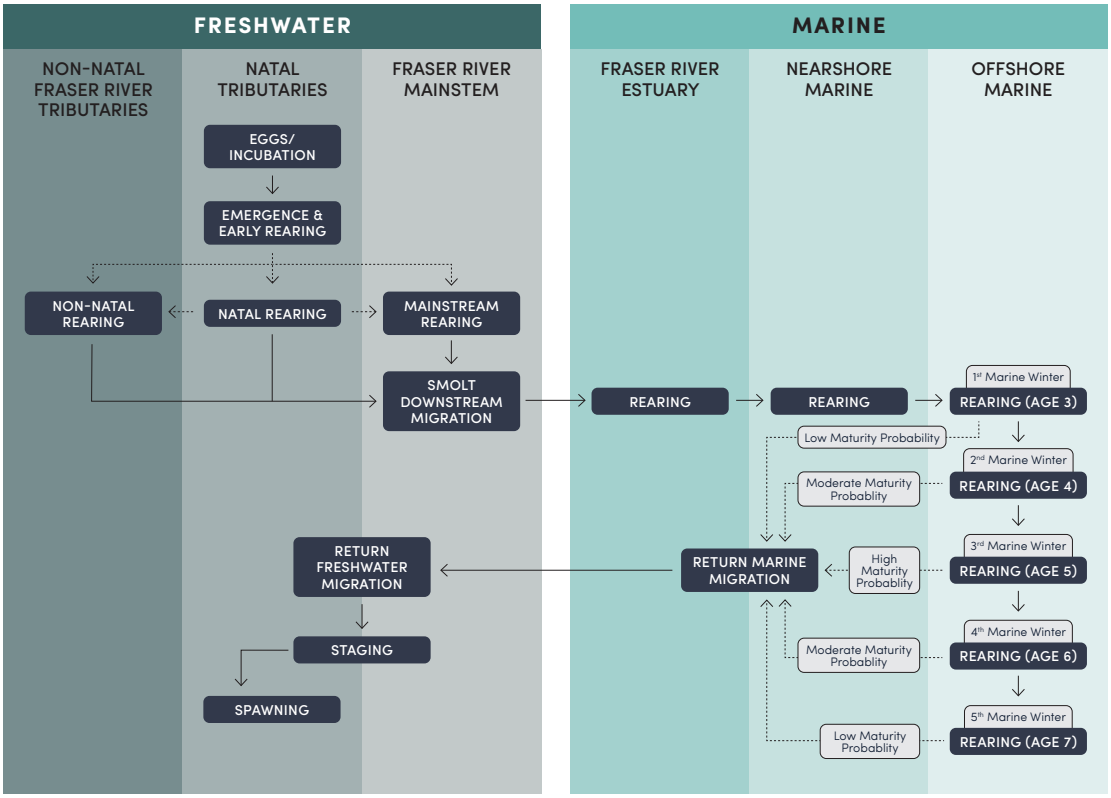

Figure 7. Conceptual model of the upper Fraser River (UFR) Spring 5_2 Chinook salmon life history, illustrating transitions across six distinct freshwater (blue) and marine (green) environments. Solid arrows indicate transitions undertaken by all spawning populations and dashed arrows represent alternative pathways or transitions completed by only a portion of some or all spawning populations.

Chinook salmon spawn in late summer and fall, with peak spawning in August and September (FRJAB 1974; Komori 1995). Spawning occurs in gravel nests ("redds") constructed by females, typically in locations with stable water flow and access to groundwater or subsurface flows, which help maintain favorable oxygen and temperature conditions around the eggs (DFO 2020). Eggs incubate buried in gravel throughout winter, relying on subsurface water flow for oxygen (McPhail 2007). Despite exposure to risks such as predation, disease, high flows, freezing, and low oxygen, Chinook salmon eggs generally have relatively high survival rates compared to other salmon species (Healey 1991; Bradford 1995). After approximately four months of incubation (DFO 2020), alevins hatch and remain in the gravel, relying on their yolk sacs for nourishment. In the Fraser River watershed, fry emerge in the spring between April and July, with timing coinciding with the Fraser River's freshet (Bradford 1994; Healey 1991; Curry and Zwiers 2018).

UFR Spring 5_2 Chinook salmon exhibit a stream-type life history, with juveniles typically spending at least one year in freshwater before migrating to the ocean as smolts (Table 12; COSEWIC 2019). UFR Spring 5_2 Chinook salmon juveniles are known to use diverse rearing strategies: some rear entirely in natal streams until outmigration at age 1+[8] or 2+; others rear in natal streams until late summer, then overwinter in the Fraser River mainstem or non-natal tributaries; while a third group disperses early after emergence to non-natal rearing habitats in the Fraser River mainstem, associated tributaries and side channels, or the Fraser River estuary (Levings and Lauzier 1991; Scrivener et al. 1994; Bourret et al. 2016; Bradford and Taylor 2022). The proportion of the population using each life history strategy is currently unknown (Bradford and Taylor 2022). Similarly, the specific contributions of natal tributary, mainstem, and non-natal tributary rearing pathways to overall production are unknown. Ongoing otolith microchemistry work in the upper Fraser will help to answer this question. Juveniles are known to rely on complex freshwater habitats such as stream margins, side channels, and floodplains that provide cover, food, and refuge from predators and high flows. High quality habitat (i.e. availability of areas with suitable water velocity, depth, temperature, turbidity, and cover) is crucial for growth and survival during this stage (Everest and Chapman 1972; Healey 1991; Bradford and Taylor 2022).

Table 12. General life-history patterns in Chinook salmon: Intra-specific variation in stream- vs. ocean-type life history types.

Trait	Stream-Type	Ocean-Type
Geographic distribution	Most common at **higher latitudes**. South of ~56°N, **important component of runs in larger river systems** but generally occur at lower proportions than ocean-type fish.	Most common at **lower latitudes** along the North American Pacific coast. Dominate populations south of ~56°N, particularly in **smaller coastal systems** and **lower-river systems.**.
Spawning location within watershed (river size and upstream distance)	Typically spawn in **upstream headwater areas** of **larger river systems** and **migrate long distances inland** to reach spawning habitats.	Typically spawn in **lower river reaches** and **downstream portions** of watersheds, often in areas **near river mouths** and frequently within **smaller coastal systems.**
Juvenile Rearing Location & Duration	Rear in freshwater streams for **1+ year** before migrating to the ocean.	Migrate to estuaries or the ocean **within a few months** of hatching, often in their first year.
Size at Ocean Entry	**Larger (**and **older)** at **ocean entry.**	**Smaller (**and **younger)** at **ocean entry.**
Marine Migration Pattern	Generally **longer**, more **offshore migration routes**	Generally **shorter**, more **coastal migration routes**
Spawning Migration Timing	Typically **spring** or **summer** migration timing.	Typically **summer** or **fall** migration timing.
Pre-Spawn Staging	Generally **longer freshwater holding** (weeks to months) in natal streams before spawning.	Generally **shorter freshwater holding**; may move quickly to spawning grounds after return to freshwater.
Life Cycle Length	Longer freshwater residency results in **later ocean entry** and often **later age-at-maturity.**	Shorter freshwater residency results in **earlier ocean entry** and often **earlier age-at-maturity.**
Fecundity	Generally **higher**, producing more eggs per female due to larger body size at maturation.	Generally **lower**, producing fewer eggs per female due to smaller body size at maturation.

[8] *Age notations such as 0+, 1+, 2+, and so on indicate the number of winters a fish has survived, with 0+ representing the first year of life. For example, the designation "age 1+" refers to fish that have completed one full year of life and are in their second calendar year.*

Chinook salmon life history diversity has been shown to generate heterogeneity in lifetime demographic rates, with different strategies contributing variably to survival, growth, and adult returns across years and environmental conditions (Sorel et al. 2023; Sorel et al. 2024). Evidence from the broader literature indicates that these diverse strategies function as a "portfolio," where different strategies confer advantages under different environmental regimes, enhancing population stability by spreading risk across habitats and environmental conditions and collectively buffering populations against variability (i.e. reduces the potential of "bottlenecks" at this life stage; Kendall and Fox 2002; Hilborn et al. 2003; Healey 2009; Schindler et al. 2010; Sorel et al. 2024). For example, juveniles that rear in natal tributaries may benefit in streams with intact instream cover and in locations and years with cool summer flows, producing larger, competitively strong smolts. Those that rear in the Fraser River mainstem may be favored when natal tributaries experience conditions such as low summer flows, high temperatures, or where there is high density dependence, provided that mainstem habitats offer adequate overwintering refuge. In contrast, juveniles that disperse to non-natal tributaries may succeed when habitat capacity in natal streams is limited, or when mainstem conditions are unsuitable, by exploiting alternative rearing opportunities.

In British Columbia, Chinook salmon smolt outmigration usually occurs between April and July, with timing influenced by fish size, river discharge, and other environmental cues (Bell 1958; Raymond 1968; Healey 1991). Poor timing or suboptimal flow and temperature conditions can increase energetic stress and predation risk, reducing juvenile survival during this life stage. Stream-type Chinook salmon typically enter estuarine and marine habitats in spring at significantly larger sizes than ocean-type conspecifics and spend only a short time (i.e. days to weeks) in the estuary before moving into adjacent nearshore marine areas (Healey 1991; Trudel et al. 2007; Brown et al. 2019; Scott et al. 2024). Given that they are smaller and more dependent on estuarine habitats for growth and refuge, habitat loss and alteration in the Fraser River estuary is expected to have more profound effects on most ocean-type Chinook salmon than on stream-type individuals (Riddell et al. 2018; Chalifour et al. 2021; Scott et al. 2024). However, despite their brief residency, estuaries provide critical transitional habitat for juvenile stream-type Chinook salmon, where individuals acclimate to saltwater and benefit from abundant food resources (Taylor 1990; McCormick 2006).

After leaving the estuary, Fraser River stream-type Chinook salmon juveniles disperse throughout the Salish Sea, where they spend their first summer (Healey 1991; Trudel et al. 2009; Beamish et al 2011; Tucker et al 2011; Riddell et al. 2018; DFO 2020). Early migrants from the Salish Sea appear to use the northern migratory route through Johnstone Strait, while later migrants leave via Juan de Fuca Strait (Pardo et al. 2026). This period (often defined as the 'early marine phase') is widely considered the most consequential phases influencing overall population strength (Beamish and Mahnken 2001; Howard et al. 2016; Riddell et al. 2018). Early marine survival of juvenile Chinook salmon is generally low, with substantial mortality occurring during the first weeks to months after ocean entry (Beamish et al. 2010; Neville et al. 2015; Connelly et al. 2018; Pearsall et al. 2021). Further there is substantial evidence that early marine survival has declined in the Salish Sea over the past several decades (Pearsall et al. 2021), due to factors such as limited prey availability and high predation pressure (Beamish et al. 2010; Burke et al. 2013; Pearsall et al. 2021). Generally, larger, healthier smolts are thought to be better equipped to avoid predators, forage effectively, and endure periods of low food availability: traits that significantly improve their likelihood of survival (Beamish and Mahnken 2001; Duffy and Beauchamp 2011; Howard et al. 2016; Gamble et al. 2018). Conversely, poor freshwater, estuarine, or early marine rearing habitat quality that produce smaller or physiologically compromised smolts can compound mortality risk during this vulnerable stage.

The spatial distribution of Chinook salmon juveniles following the early marine phase is not well known but thought to be influenced by population, lineage (i.e., Beringia-origin verse Cascadia or Columbia refugia) and life history type (i.e., stream- vs. ocean-type; Healey 1991; Riddell et al. 2018; COSEWIC 2019; DFO 2020). Sub-adult and adult distributions of UFR Spring 5_2 Chinook salmon, specifically, are also poorly understood once they shift to open-ocean marine environments. However, these fish are rarely encountered in coastal waters until their return migration, which is different than the more coastal distribution of some other Chinook salmon populations (Healey 1991; Heard et al. 2007; Myers et al. 2009; Weitkamp 2010; Riddell et al. 2018). Marine conditions and anthropogenic stressors during this life stage (e.g. temperature, productivity, and competition) strongly influence growth rates and size- and age-at-return, which subsequently affect fecundity and spawning success (Riddell et al. 2018).

Spring-run Chinook salmon adult return migration (i.e. marine return migration and freshwater migration) occurs in spring and early summer (Waples et al. 2004; Parken et al. 2008). During this adult migration phase, fish must traverse long distances and may need to overcome energetic challenges posed by warm water temperatures, altered flows, and physical barriers. High mortality during migration can occur when cumulative stress from multiple threats (e.g. warm water temperatures, low flows, and disease exposure) reduces physiological condition (Healey 1991; COSEWIC 2019).

Stream-type populations typically enter rivers months before spawning and migrate long distances to upstream habitats where they may hold for extended periods (Healey 1991; Quinn 2005). During staging, adults cease feeding and rely on

stored energy reserves to support maturation and spawning, and the timing, location, and duration of staging can vary depending on environmental conditions such as water temperature, flow, and habitat availability.

Available data on UFR Spring 5_2 Chinook salmon age-at-maturity are limited to a few spawning populations in the 1980s and may not represent all spawning populations or contemporary age-at-maturity. This work found most adults were age 5_2, with almost all females in this age class, while males were split between age 4_2 and 5_2 (Bérézay et al. 1988). More contemporary work has documented a downward shift in age composition for both wild and hatchery-origin Chinook salmon in multiple regions (Oke et al. 2020; Maharaj et al. 2023). It is not known whether similar shifts in age-at-return have occurred for UFR Spring 5_2 Chinook salmon due to a lack of recent population-specific data; however, evidence from the nearby Nechako Summer 5_2 population suggests that decreases in age-at-return may also be occurring (Maharaj et al. 2023).

4.1.3. Environmental Setting

4.1.3.1. Overview

- **Purpose:** This section provides a description of the environmental conditions encountered by UFR Spring 5_2 Chinook salmon during their full life cycle.
- **Rationale:** An understanding of environmental setting provides the foundation for threats assessments and action planning by linking life history information and identified threats to the current environmental conditions and historical and contemporary land use practices that have shaped the freshwater, estuarine, and marine environments used by UFR Spring 5_2 Chinook salmon.
- **Key Takeaways:**
    - **Freshwater environment mosaic shapes vulnerability:** The freshwater environment used by DU9 and DU11 spawning populations exhibits a mosaic of conditions across sub-watersheds and individual streams, contributing to spawning population-specific vulnerabilities to different threats. Common regional patterns in geography and historical and contemporary land use allow threats to be assessed at a regional scale while accounting for sub-watershed-specific differences.
    - **Contrasting environments are encountered by DU9 and DU11 spawning populations:** The upper Fraser Basin (DU11) is predominantly mountainous terrain with relatively low human disturbance, limited water withdrawals, and some impacts from wildfire, forestry, and road development. In contrast, the middle Fraser Basin (DU9) spans mountains, plateaus, grasslands, and dry interior valleys and has been exposed to relatively more widespread disturbance from wildfire, forestry, agriculture, and urban, industrial, and mining developments.
    - **Marine environments influence vulnerability across life stages:** Estuarine, nearshore, and offshore marine environments share common functional attributes, such as providing feeding, rearing, and migratory pathways for Chinook salmon, but conditions within each environment are shaped by distinct combinations of oceanographic processes (e.g. currents, temperature, stratification) and anthropogenic factors (e.g. coastal development, fisheries, pollution). These interacting influences create environment-specific variation in threat exposure and survival.
- **Supporting Information:**
    - A detailed description of Environmental Setting for UFR Spring 5_2 Chinook salmon is presented in Appendix C.
    - A supplementary table summarizing information on each natal watershed is available for download from Dropbox.

4.1.3.2. Detailed Summary

The Fraser River watershed provides habitats for UFR Spring 5_2 Chinook salmon across all freshwater life stages. Spawning occurs in sub-watersheds from the Bridge River confluence upstream to Overlander Falls, with habitats grouped into five DFO sub-districts (Lillooet, Williams Lake, Quesnel, Prince George, and McBride-Clearwater), spanning diverse terrain from coastal mountains to the Rocky Mountain foothills. In addition, the lower Fraser mainstem and non-natal tributaries throughout the Fraser River watershed support juvenile rearing, while the river functions as a key migratory corridor for both juveniles and adults.

The upper Fraser River basin, upstream of the Nechako River, supports DU11 Chinook salmon spawning populations and includes the McBride-Clearwater (29J) and Prince George (29I) sub-districts. The McBrideClearwater sub-district (5,062 km^2) is mountainous, with high peaks (1,540–2,033 m) and ten largely intact watersheds. Habitat pressures in this region are primarily associated with forest harvesting, which has occurred throughout lower elevation terrain and is now expanding to access old growth timber in higher elevations. Water withdrawals support agriculture throughout the Robson Valley and wildfire has affected less than 2% of the area over the past 60 years. In contrast, the Prince George sub-district (29I, 30,030 km^2) spans plateaus and mountains, with 32 watersheds, including large tributaries like the McGregor River, and elevations ranging from 660 to 1,658 m. Dominated by Sub-Boreal Spruce forests, most watersheds face high-risk habitat pressures from forestry and road development, notably impacting hydrology, erosion, and vegetation. Fire disturbance has increased over the past 20 years.

The middle Fraser River basin, from the Nechako River confluence to Yale, supports multiple DU9 Chinook salmon spawning populations and includes the Williams Lake (29G), Quesnel (29H), and Lillooet (29F) subdistricts. The Williams Lake sub-district (30,815 km^2) spans mountains to plateau and grasslands, with six sub-watersheds including the lower Chilcotin River; all face high-risk pressures for vegetation, erosion, water quantity, and hydrology, with fire disturbance increasing over the past 20 years. The Quesnel sub-district (27,559 km^2) comprises twelve sub-watersheds, including the West Road (Blackwater) River, with most watersheds highly affected by disturbance, erosion, vegetation loss, and water issues; fire impacts have risen, affecting up to 70% of some areas. The Lillooet sub-district (7,459 km^2) includes four subwatersheds and the Fraser Canyon, with high habitat pressures and increasing fire disturbance. Historic barriers to salmon migration, including the Hell's Gate rockfall (1914) and Big Bar landslide (2018), have been largely mitigated.

The lower Fraser River basin, stretching 180 km from Yale to the Pacific Ocean, serves mostly as a migratory corridor for DU9 and DU11 spawning populations. Juvenile rearing in non-natal tributaries has been recorded here, though timing and usage are poorly understood (Levings and Lauzier 1991; Bradford and Taylor 2022; DFO 2024b). The basin lies within the densely populated Greater Vancouver area (>3 million people), where urbanization, agriculture, and resource extraction have heavily altered habitat (Statistics Canada 2023). Approximately 85% of the historical floodplain is now inaccessible, with dikes, floodgates, channelization, and log storage reducing habitat complexity and quality, creating migration barriers, and altering water flow (Finn et al. 2021, 2023; DFO 2023; Port of Vancouver 2024). Flooding remains a threat, as seen in the 2021 event that introduced pollutants, while water quality is compromised by agricultural runoff, industrial effluent, urban stormwater, and contaminants (Shaw and Tuominen 1999; Tian et al. 2021; Minton et al. 2022; DFO 2024b; Lo et al. 2026). Infrastructure development, including roads, bridges, and culverts, further fragments habitat (Finn et al. 2021), while log booms and artificial lighting increase predation risk (Nelson et al. 2021; Atkinson et al. 2022; Kussin-Bordo 2022). The Fraser River watershed also supports constitutionally protected First Nations fisheries under s. 35(1) of the *Constitution Act, 1982*, as well as recreational fisheries targeting Chinook salmon, with impacts discussed separately (Appendix D). These freshwater fisheries are managed to minimize impacts on UFR Spring 5_2 Chinook salmon, and recent fishery mortality rates have averaged less than 5% in the Fraser River (DFO 2025).

The Fraser River estuary (>20,000 ha) provides important transitional habitat for out-migrating juvenile Chinook salmon before they enter nearshore marine environments (Water 2003; DFO 2024b; Scott et al. 2024). It encompasses tidal marshes, eelgrass beds, and large tidal flats, with physical conditions such as salinity, temperature, turbidity, and dissolved oxygen varying seasonally and with the tidal cycle (Chalifour 2022; DFO 2024b). Eelgrass beds and marshes offer nursery areas with food and cover, while tidal flats provide shallow feeding grounds (Kennedy et al. 2018; Rubin et al. 2018; Scott et al. 2024). Peak river discharge occurs May–July, influencing salinity and temperature patterns (Chapman and Brinkhurst 1981; Government of Canada 2024). Extensive urban, agricultural, and industrial development has altered estuary habitats, reducing wetland area by ~70%, modifying hydrology, restricting fish access via dikes, floodgates, and jetties, and increasing pollution (Finn et al. 2021, 2023; BC MOE 2006; Hodgson et al. 2020; DFO 2024b). Features like log booms can increase predation risk (BC MOE 2006).

Juvenile Chinook salmon from the Fraser River begin their marine life in the Salish Sea, a 1.78 million ha estuarine and marine system spanning Puget Sound, the Strait of Juan de Fuca, and the Strait of Georgia (Sobocinski 2021). The Salish Sea receives freshwater and sediment from multiple rivers, with the Fraser River contributing approximately 50% of inputs. Water circulation features westward surface freshwater flow and eastward deep ocean water, with seasonal variation in temperature, salinity, and mixing (Thompson 1981; Riche et al. 2014; MacCready et al. 2021). Surrounding land supports nearly nine million people, and rapid urbanization, industrialization, agriculture, and infrastructure development (e.g. including ports, piers, and shoreline armouring) have altered habitat conditions (Sobocinski 2021).

Juveniles exiting the Salish Sea generally migrate north and west along the continental shelf, rearing in nearshore habitats of north and central BC and Alaska before dispersing offshore across the North Pacific to the Bering Sea (Healey 1991; Trudel et al. 2009; Beamish et al. 2011; Tucker et al. 2011; Riddell et al. 2018; DFO 2020; Pardo et al. 2026). Nearshore

environments contain diverse habitats including estuaries, river deltas, rocky shores, and coastal bluffs providing complex habitat supporting predator avoidance and foraging, with kelp forests and eelgrass meadows offering key cover and feeding opportunities (Sobocinski 2021; Shaffer et al. 2020). The nearshore marine zone also supports Canadian and US commercial, recreational, tribal and First Nations fisheries targeting Chinook salmon, with impacts discussed separately (Appendix D). Marine fisheries are also managed to minimize impacts on UFR Spring 5_2 Chinook salmon, and the Canadian marine fishery mortality index has recently averaged less than 5% annually (DFO 2025). Open-net pen aquaculture is a use of nearshore habitats in BC. These were historically concentrated in northern and southern Johnstone Strait and along Vancouver Island, expanding from the 1970s to 80 farms by the mid-1990s (Johnson 2019). Since this period of expansion, all but one salmon farm in the Discovery Islands has been removed, substantially reducing the overlap between aquaculture operations and the migration route of UFR Spring 5_2 Chinook salmon. Environmental concerns have led to a federal plan to phase out open-net pens by 2029 (DFO 2024c).

Offshore marine environments used by UFR Spring 5_2 Chinook salmon encompass a vast area >20,000 km^2 of the North Pacific Ocean that stretches from the Bering Strait to ~47° N along the Washington coast and east towards the Kamchatka Peninsula and Kuril Islands (COSEWIC 2019; DFO 2019). Surface temperature is understood to be a driver of productivity in the North Pacific Ocean and is influenced by complex seasonal, regional and longer-term climatic trends. North Pacific Ocean surface temperatures exhibit strong seasonal and regional variation and are shaped by warm currents (Kuroshio, North Pacific Subtropical Gyre), cold currents (Oyashio, California, Alaskan Coastal), and the eastward-flowing North Pacific Current (James and Stull 2019; Qui 2019). Long-term climate variability, such as the Pacific Decadal Oscillation, alternates warm and cool phases every 20–30 years, influencing sea surface temperatures (Mantua et al. 1997). Overlaid on these cyclical dynamics is the long-term warming trend, driven by climate change. In the offshore environment, UFR Spring 5_2 Chinook salmon are subject to predation from multiple species such as salmon sharks, Orca, and Steller sea lions (Christensen and Trites 2011; Seitz et al. 2019; Manishin et al. 2021). They are also exposed to commercial fisheries8 that can result in incidental catch and mortality, particularly those targeting Walleye Pollock in the Bering Sea Aleutian Islands and Gulf of Alaska (Witherell et al. 2002; NOAA 2024).

4.1.4. Threat Identification

4.1.4.1. Overview

- **Purpose:** This section provides a description of the environment-specific threats, their known or expected life stage-specific effects, and the evidence supporting their occurrence in the environments used by UFR Spring 5_2 Chinook salmon throughout their life cycle.
- **Rationale:** Threat Identification provides a structured foundation for threat assessment and recovery action planning components by linking Chinook salmon life stages and environments to potential threats.
- **Key Takeaways:**
    - **Threats span environments and life stages:** We identified 19 threats, some limited to a single environment (e.g. low flows in freshwater) and others spanning multiple environments (e.g. high water temperature in freshwater, estuary, and marine). Most threats affected multiple life stages.
    - **Single threat, multiple origins:** A single threat can have multiple causes, and the same threat can arise from different causes in different places. For example, low flows may be driven by drought and warming temperatures in one watershed, while in another they stem from water withdrawals, altered snowpack dynamics, groundwater depletion, or upstream regulation. Even when the observed threat looks the same, and has similar biological effects, the underlying drivers, and therefore the effective management responses, can differ substantially across locations.
    - **Exposure and risk vary in time, space, and context:** Threats differ in duration, spatial extent, and effect. Some are immediately lethal (e.g. predation), while others accumulate risk over longer exposures or larger areas (e.g. reduced foraging success due to inter- or intra-specific competition), and most threats are influenced by seasonal conditions (e.g. high water temperature). Further, many freshwater threats (e.g. contaminants, sedimentation) are localized (i.e. variable within and/or across streams or due to seasonal conditions), limiting population-level exposure, whereas marine threats typically span larger areas and longer durations, increasing cumulative exposure and risk.

- **Interactions and context amplify uncertainty:** Threats often co-occur and interact, making it difficult to isolate their individual effects. Responses to threat exposure vary depending on a fish's condition and the magnitude, duration, and frequency of exposure. Likewise, it can be hard to distinguish between proximate and ultimate drivers; for example, it is difficult to know whether one threat (e.g. disease) has made an individual fish more susceptible to another threat (e.g. predation). We have tried to identify plausible threats and results of threat exposure, but it is near impossible to determine the interactions between threats with certainty.

- **Evidence varies:** Some threats are well-documented (e.g. stream temperature or flow), but many, particularly in marine habitats and some natal streams, lack direct evidence, creating uncertainty about their magnitude. Where evidence of threat occurrence was limited, threat presence was assessed based on relevant adjacent information (e.g. by considering land use activities known to occur in an area and how those activities may affect habitat conditions) and professional judgement. For many threats, evidence describing impacts specific to UFR Spring 5_2 Chinook salmon was absent. In these cases, the assessment relied on documented effects from other Chinook salmon populations or Pacific salmon species in comparable systems, where similar mechanisms of impact are expected to occur.

- **Supporting Information:** A detailed description of Threat Identification is presented in Appendix D.

4.1.4.2. Detailed Summary

Threats were assessed across three main environment types used by UFR Spring 5_2 Chinook salmon: freshwater (including natal tributaries and the Fraser River mainstem), the Fraser River estuary, and the marine environment (including both nearshore and offshore areas). Evidence of population-specific impacts on UFR Spring 5_2 Chinook salmon was limited or absent for all threats. As a result, potential threats were assessed based on documented effects on other Chinook salmon populations or Pacific salmon species in comparable systems (e.g. studies from regions such as Puget Sound), under the assumption that similar mechanisms would operate in relation to UFR Spring 5_2 Chinook salmon.

In freshwater, 18 distinct threats were identified and evaluated. Most threats were evaluated across all freshwater life stages, although some were life-stage specific. For example, incubating eggs are not directly affected by fisheries, while returning adults that are staging or spawning do not feed and are therefore not affected by prey availability. Additionally, threats related to ice formation are only relevant during winter months and do not impact juvenile or adult migration, staging, or spawning.

In nearshore and offshore marine environments, 11 threats were identified and evaluated, and all were relevant across all life stages present in the environment. Twelve threats were identified as relevant to the estuary. This included all marine threats with the addition of migration barriers.

4.2 Life Cycle and Population Ecology Assessment

4.2.1. Overview

- **Purpose:** To identify the life stages and processes most influential to Chinook salmon population productivity and recovery potential by combining a life-cycle model sensitivity analysis with a review of salmon population ecology literature. The sensitivity analysis evaluated how variation in life-stage survival and other key parameters influence population growth, while the literature review provided empirical context to interpret model results and identify life-stage bottlenecks shaping population dynamics.

- **Rationale:** Identifying the life stages and demographic processes that most influence population growth is essential for evaluating threats and prioritizing recovery actions. By understanding where improvements in survival are expected to produce the largest gains in productivity, recovery efforts can be directed toward the life stages and ecological processes most likely to influence population rebuilding.

- **Key Takeaways:**

  - **Variation in survival among life stages influences recovery potential: S**urvival across life stages is cumulative, with adult returns reflecting the combined survival from egg to spawner. As a result, improving survival at a single stage will not necessarily lead to recovery if high mortality persists elsewhere. However, life stages do not contribute equally to population dynamics. Stages where survival is low, variable, and responsive to environmental conditions or management tend to exert a disproportionate influence on cohort strength. Density-dependent processes can further moderate how gains at one stage translate to subsequent stages and ultimately to adult abundance. For UFR Spring 5_2 Chinook salmon, life cycle modelling and the broader literature suggest

that early freshwater rearing and the early marine period are key bottlenecks, where variation in survival is most likely to shape overall productivity.

- **Data limitations constrain model application and interpretation:** We decided that there was insufficient empirical data to fully parameterize a life-cycle model for UFR Spring 5_2 Chinook salmon. Consequently, the modeling exercise was limited to a sensitivity analysis parameterized using a proxy population (Nicola River Spring 4_2 Chinook salmon). These limitations reflect a broader challenge in modeling Pacific salmon populations, where fragmented monitoring across freshwater, estuarine, and marine life stages often prevents estimation of complete life-stage-specific survival parameters, constraining the ability to fully evaluate population dynamics and recovery scenarios.
- **Life cycle modeling remains an important component of future work:** Resolving data gaps surrounding key population parameters remains important; however, modeling exercises can be conducted now to further inform recovery planning. Such approaches can use expert judgment to translate the scope, intensity, and timing of restoration actions into changes in model parameters (e.g., habitat capacity or productivity), enabling evaluation of potential recovery outcomes despite limited life-history and habitat data. Future application of the full CEMPRA model (or a similar population model) will require development of population-specific parameter estimates for UFR Spring 5_2 Chinook salmon through targeted studies or expert elicitation. Once parameterized, the model can be used to evaluate relationships between population productivity, habitat capacity, and specific threats through stressor–response functions, enabling assessment of cumulative stressor effects and helping prioritize effective recovery actions. This work would strengthen the threats assessments and provide support for action recommendations.

- **Supporting Information:** A detailed description of the life cycle and population ecology assessment is presented in Appendix E.

4.2.2. Detailed Summary

A full stage-structured life-cycle model for UFR Spring 5_2 Chinook salmon could not be completed within the timeframe of this project due to insufficient population-specific data. Instead, a sensitivity analysis based on proxy data from Nicola River Spring 42 Chinook salmon was used to explore how variation in survival and productivity across life stages influences population growth.

The analysis indicated that early freshwater rearing and pre-spawn (staging) survival have the greatest influence on population productivity, whereas later marine survival and maturation parameters were comparatively less influential. These findings are broadly consistent with salmon population ecology, where recruitment is often strongly affected by survival during freshwater rearing and the early marine period (Healey 1991; Beamish and Mahnken 2001; Quinn 2018). However, this sensitivity analysis only identifies which parameters have the greatest mathematical influence on population growth and should not be interpreted as direct evidence that these life stages represent the most important threats to recovery.

Improvements in early-life survival do not necessarily translate into proportional increases in adult abundance. Density-dependent processes can regulate juvenile survival and dampen the benefits of increased freshwater productivity, while mortality during later freshwater and marine life stages can further reduce gains before recruitment to the spawning population (Hilborn and Walters 1992; Haeseker et al. 2012; Gibeau et al. 2020).

Although the preliminary analysis provides insight into the relative importance of different life stages, substantial uncertainty remains regarding the factors limiting population productivity and abundance. Future work should focus on developing a simplified life-cycle model tailored to UFR Spring 5_2 Chinook salmon that can evaluate the expected effects of recovery actions on habitat capacity, productivity, survival, and supplementation programs. Such a model would provide a transparent framework for comparing recovery strategies, identifying key uncertainties, and evaluating the likely magnitude and timing of population responses. While additional data would improve model performance, existing uncertainties should not be viewed as a barrier to developing a useful decision-support tool for recovery planning.

4.3 Threats Assessment

4.3.1. Overview

- **Purpose:** The threats assessment evaluated risks to UFR Spring 5_2 Chinook salmon across all life stages and environments to identify the threats most likely affecting the population aggregate.

- **Rationale:** Understanding which threats most affect UFR Spring 5_2 Chinook salmon, and where uncertainty is potentially the greatest, is essential for prioritizing recovery actions. Assessing risks across all life stages and environments provides a comprehensive view of the pressures on the population aggregate and identifies where interventions may be most effective.

- **Key Takeaways:**

  - **DU-level threats split out into three tiers:** UFR Spring 5_2 Chinook salmon face a myriad of threats across environments, yet the top threats at the DU-level can be organized into three tiers, ordered by hypothesized importance, from 1-3:

    - **Tier 1:** The highest-ranked threat was **competition in the marine environment** associated with natural population increases in many wild pink and chum salmon populations and industrial-scale hatchery production of pink and chum salmon, primarily from Alaska, Russia and Japan. This was the only threat to score high or very high in the DU-level threat assessment. The threat of competition coincides with the decline of UFR Spring 5_2 Chinook salmon, operates across the population's marine range, and is supported by peer-reviewed evidence linking increased salmon abundance in the North Pacific to reduced Chinook salmon growth and productivity. Although direct evidence for UFR Spring 5_2 Chinook salmon is limited, the available evidence suggests this is the most plausible broad-scale driver of population-wide declines.

    - **Tier 2:** the next most likely threat identified for UFR Spring 5_2 Chinook salmon was low flows and high temperatures in the freshwater environment. The widespread synchrony in population trends across streams with differing freshwater habitat conditions suggests that low flows and high temperatures are unlikely to be the sole or dominant driver of the overall decline. However, they remain important limiting factors in many systems and are expected to become increasingly significant under future climate change.

    - **Tier 3:** moderate, but uncertain threats of predation in the Fraser River estuary, and offshore environments, disease/parasites in the nearshore marine environment, and reduced prey in the nearshore marine environment were also identified. The threat of predation in the Fraser River estuary and offshore marine environments has likely intensified for UFR Spring 5_2 Chinook salmon because of human modifications to habitats and changes in predator populations. Disease and parasites could be a threat for UFR Spring 5_2 Chinook salmon as aquaculture has generally intensified coincident with population trends, yet the distribution of UFR Spring 5_2 Chinook salmon is largely unknown, and it is unclear how much exposure they have to aquaculture sites. The threat is also exacerbated by climate change, as increased infection rates and physiological impacts of several pathogens in Pacific salmon have been linked to increased temperature. Similarly, abundance of some prey species, such as Pacific sandlance (*Ammodytes personatus*), could be reduced in the nearshore environment through multiple mechanisms including shoreline development, historical fisheries, and prey shifts resulting from climate change. At present however, it is unclear how food-limited UFR Spring 5_2 Chinook salmon are throughout their nearshore rearing period. Finally, the overall threat of fisheries falls within this tier. While there was no identified fishery that scored above a low threat, the cumulative impact of multiple directed and bycatch fisheries operating across life stages could impact UFR Spring 5_2 Chinook salmon.

  - **Threats contributing to decline may not be the primary factors limiting recovery:** Based on the DU-level threats assessment, it seems likely that some of the threats contributing to UFR Spring 5_2 Chinook salmon population aggregate decline are not currently limiting recovery. For example, current directed fisheries are considered unlikely to constrain recovery because significant regulatory changes and reduced harvest were implemented. Yet historical fisheries likely impacted population status in the past.

  - **Highest risk threats occur primarily in the marine environment:** At the DU-level, very high- and high-risk threats were identified exclusively in marine environments (i.e. competition). Moderate-risk threats were identified in marine and freshwater habitats (nearshore marine, offshore marine, DU9 natal watersheds, and Fraser River mainstem), and in DU11 natal watersheds only low-risk threats were identified.

  - **DU9 and lower Fraser River mainstem face more high-risk threats than DU11 and upstream habitats:** Within-environment level assessment identified that threat risk is highest in the lower Fraser River mainstem and decreases with distance upstream. DU9 natal watershed groups were more frequently identified with moderate-risk to high-risk threats across multiple life stages than DU11.

- **Confidence in threat assessment ratings vary:** Some threats, such as flow alterations and elevated water temperatures, are well-documented in certain areas (e.g. natal streams with long-term datasets) and have relatively well-quantified impacts (e.g. exceedances of lethal temperature limits for all life stages). However, direct evidence for most threats potentially affecting UFR Spring 5_2 Chinook salmon is limited. While the impacts of these have been studied, and in many cases quantified, in other systems or for other populations, their population aggregate-level impacts on UFR Spring 5_2 Chinook salmon have not been evaluated. For this assessment, we have assumed that responses observed in other populations are broadly applicable to UFR Spring 5_2 Chinook salmon.
- **Threat interactions and context amplify uncertainty:** Threats often co-occur and interact, making it difficult to isolate their individual effects. Responses to threat exposure vary depending on a fish's condition and the magnitude, duration, and frequency of exposure (e.g. high temperatures exacerbate low oxygen, or marine conditions and anthropogenic stressors affecting prey availability).

- **Supporting Information:**
  - A detailed description of the Threats Assessment is presented in Appendix F.
  - Within-environment and DU-level threats assessment scoring tables are available for download from Dropbox.

4.3.2. Detailed Summary

4.3.2.1. Within-Environment Threats

In this assessment, we considered each environment (each natal watershed, three Fraser River mainstem segments, estuary, nearshore marine, offshore marine) separately and independently. Factors contributing to scores in each natal watershed are described in Appendix C and Appendix D.

For DU11 spawning populations, most threats across life stages and natal watershed groups were assessed as low risk, with generally consistent patterns except in the Salmon River, where multiple threats were moderate to high risk (Figure 7). Flow-related threats (i.e. high and low flows) and high-water temperatures were ranked as moderate- to high-risk for early life stages in several natal watersheds, although confidence varied and was often limited by available data. For natal watersheds used by DU9 spawning populations, threats were more frequently assessed as moderate to high-risk across life stages and natal watersheds compared to DU11 spawning populations, with the highest risks in the Quesnel and West Road (Blackwater) rivers (Figure 8). Risk patterns were broadly similar among natal watersheds used by DU9 spawning populations but more variable than in the upper Fraser River watershed. In addition to common drivers such as climate change and forestry, natal watersheds in the middle Fraser River were more affected by watershed-specific impacts from wildfire, salvage logging, and pollution (e.g. from mining, agriculture, and urban and industrial developments). Flow-related threats (i.e. high and low flows) were consistently assessed as moderate to high-risk for early life stages and, unlike in DU11 natal watersheds, also for adults. High water temperature and sediment deposition were also widespread, with sediment risks greatest in Middle Fraser East and West Road (Blackwater) natal watershed groups. Pollution was identified as a moderate threat in three watersheds, while predation was uniformly assessed as a low risk.

In the Fraser River mainstem migratory corridor, approximately half of assessed threats were rated moderate or high-risk in at least one reach (Figure 9). The number of moderate to high threats generally decreased in an upstream direction. Specifically, the lower river had the highest number of moderate and high threat ratings, followed by the canyon, with the fewest in the middle river. Threat patterns were generally consistent across reaches, except for habitat modification/loss, which was high in the lower river due to extensive development but low in the canyon and middle reaches. In the canyon and middle reaches, moderate to high risks were mostly associated with adult migration, while in the lower river they were linked to juvenile rearing and migration. Confidence was generally higher for high-risk ratings than for moderate- or low-risk ratings. Disease and fisheries for returning adults were moderate threats in all reaches. High water temperature was assessed as a high-risk for juvenile rearing in the lower river and as moderate to high in the canyon and middle reaches.

In the marine environment types, moderate to high-risk threats varied by life stage and environment (Figure 10). Competition scored as a high risk in the nearshore environment for juveniles and in the offshore environment for subadults. Predation scored as a moderate threat in the Fraser River estuary for out-migrating juveniles, due to extensive habitat modification by humans that has potentially increased the susceptibility of Chinook salmon to predators (increases in pinniped numbers are not considered directly as part of the threat here, since they could be just an increase to a natural state in the absence of human intervention). In the offshore marine environment, there is increasing evidence of salmon shark predation on maturing Chinook salmon, which could influence the size-structure and productivity of UFR Spring

5_2 Chinook salmon. While still speculative, the abundance of salmon sharks may be enhanced by the abundant hatchery releases of Chum and Pink salmon. Other threats, including high temperature and pollution, were moderate risk for multiple life stages. Generally, juvenile life stages were assessed as being exposed to more moderate to high risks than adults. Confidence in assessments was typically low, except for fisheries, which were rated with low to high confidence.

Comparison of Threat Risk Profiles Between DU9 and DU11 — DU9 spawning populations were exposed to moderate- and high-risk threats more frequently than DU11 across nearly all life stages. For several life stages, these threats affected an estimated 25–50% of spawning populations. Key threats within natal watersheds included low and high flows, high temperatures, and sediment deposition, which were consistently assessed as high-risk. By contrast, threats identified for DU11 spawning populations were mostly low-risk threats, with high-risk threats generally affecting less than 10% of the DU. Flow-mediated moderate risks were particularly widespread during incubation, affecting nearly 100% of DU 9 under high flows and ~60% under low flows.

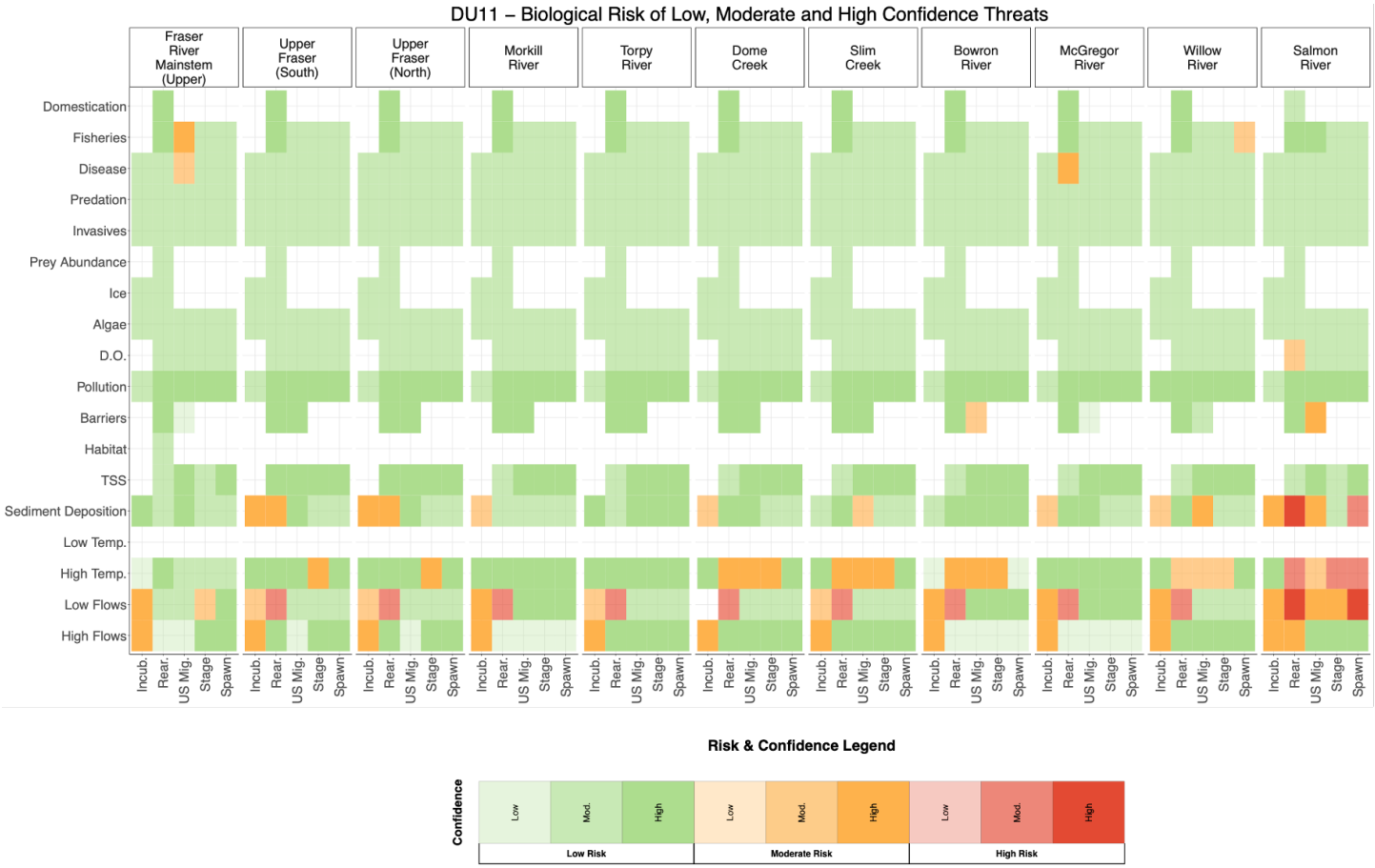

Figure 8. Distribution of low, moderate and high-risk threats assessed in the within-environment threats assessment for natal watersheds used by DU11 spawning populations.

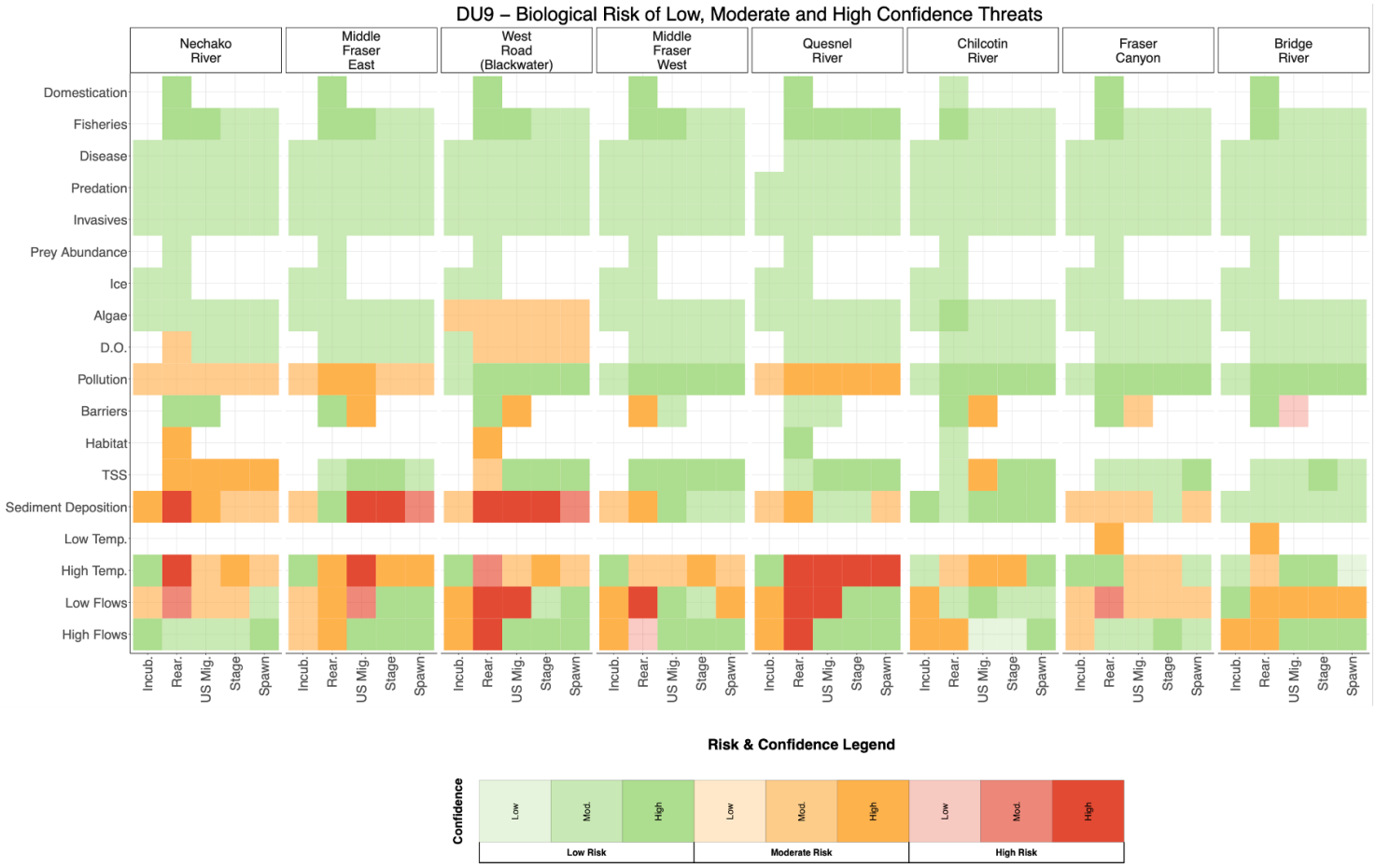

Figure 9. Distribution of low, moderate and high-risk threats assessed in the within-environment threats assessment for natal watersheds used by DU9 spawning populations.

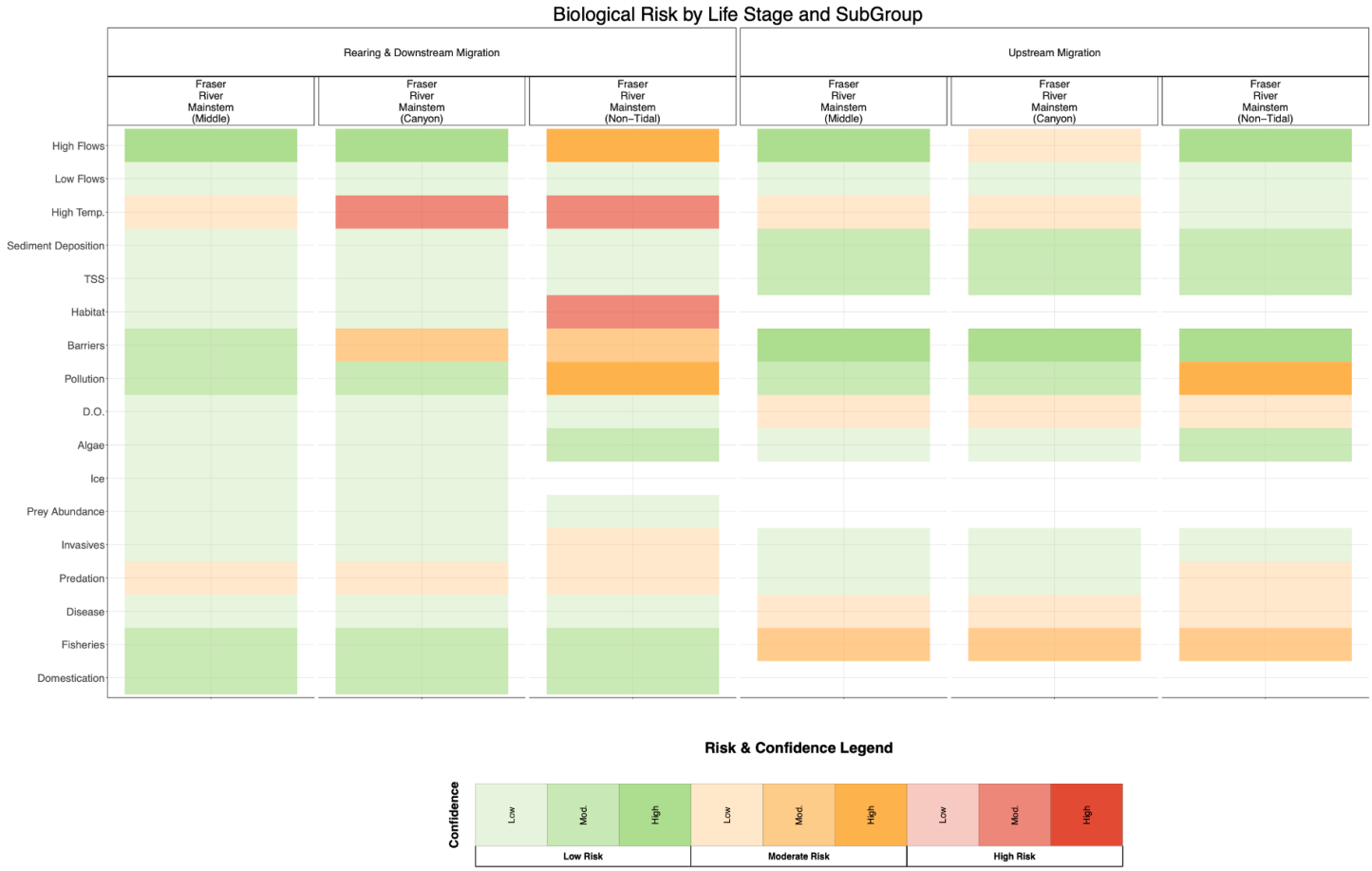

Figure 10. Distribution of low, moderate and high-risk threats assessed in the within-environment threats assessment across life stages present in three reaches of the Fraser River mainstem.



Figure 11. Distribution of low, moderate and high-risk threats assessed in the within-environment threats assessment across life stages present in the Fraser River estuary and marine environments.

4.3.2.2. DU-Level Threats Assessment

The DU-level threats assessment evaluated 77 threat × life stage × environment combinations and focussed on "rolling up" the within-environment threats assessment to evaluate how threats influenced each DU as a whole. These DU-level threats can be split into three tiers, by hypothesized order of importance from 1 to 3.

Tier 1: The highest-risk threats occur exclusively in marine environments, where inter- and intra-specific competition with other Pacific salmon was identified as affecting multiple life stages.

Tier 2: In natal watersheds, low flow was identified as a moderate-risk threat in streams used by DU9 and DU11 spawning populations and, high water temperature was identified as a moderate-risk threat in streams used by DU9 spawning populations.

Tier 3: Moderate marine / estuarine threats included predation in the Fraser River estuary and offshore marine environments, changes in prey availability in nearshore and offshore areas, and disease in nearshore environments. The cumulative impact of fisheries also falls into this tier. Although there was no individual fishery that scored above a low risk at the DU-level, the cumulative impact of fisheries across life stage and environment could still prove to be significant.

Tier 1

Competition with other Pacific Salmon (offshore and nearshore marine environments)

There are more salmon in the North Pacific ocean than anytime in recorded history. While some of this increase has come from increases in productivity in wild salmon, nearly 40% of the biomass of salmon in the North Pacific Ocean is now estimated to come from hatchery-produced salmon, with the vast majority of hatchery production originating from

Alaska, Russia, and Japan (Ruggerone and Irvine 2018). Thus, there is a significant human dimension to this threat. This threat occurs at a broad enough spatial scale that it could affect all UFR Spring 5_2 Chinook salmon, and the timing of increased hatchery releases and overall salmon abundance in the North Pacific Ocean aligns with overall population trends. The total biomass of salmon in the North Pacific Ocean has been repeatedly correlated with overall declines in the size and productivity of multiple salmon populations, though there are no studies specific to UFR Spring 5_2 Chinook salmon (Ruggerone et al. 2024).

While most of the evidence of a competition effect on UFR Spring Chinook salmon comes from the offshore marine environment, there is also potential for competition to be occurring in the nearshore environment. The Salish Sea, where UFR Spring 5_2 Chinook salmon spend their early marine life, supports substantial hatchery production of Chinook salmon from Puget Sound and the East Coast of Vancouver Island. While there is a plausible mechanism for competition, quantitative evidence is limited (Table 12 and Table 13).

Tier 2:

Low flows and high water temperatures

Freshwater habitats of UFR Spring 5_2 Chinook salmon are subject to a mosaic of pressures, including forestry, wildfire, and insect disturbance, which can exacerbate the effects of low flows and high water temperatures, particularly in DU9 where the human footprint is greater. These stressors can cause both direct mortality and sublethal effects, including reduced gamete quality and potential epigenetic impacts. Although these threats are important and are expected to intensify with climate change, the available evidence suggests they are unlikely to fully explain the observed population-wide declines, as broadly similar population trends occur across watersheds with varying degrees of freshwater habitat disturbance (Table 14).

Tier 3:

Predation

Predation was assessed as a moderate threat in the estuary, reflecting evidence that human activities and habitat modifications may alter predator–prey interactions and increase predation risk for Chinook salmon. Pinniped populations have increased substantially following reductions in historical harvest, including First Nations harvest, and subsequent marine mammal protections. However, neither current pinniped abundance nor abundance immediately prior to protection necessarily represents an undisturbed baseline, and increased pinniped abundance alone was not considered an anthropogenic threat. Human modifications can nevertheless alter predator–prey interactions and increase salmon vulnerability. In the lower Fraser River and estuary, structures such as log booms can concentrate predators at migration chokepoints and reduce habitat complexity, potentially increasing predation risk for UFR Spring 5_2 Chinook salmon. In other nearshore environments, artificial lighting, marinas, and other coastal infrastructure may similarly alter predator behaviour, concentrate predators or prey, and increase predation risk.

Predation was also assessed as a moderate threat in the offshore marine environment. This score reflects the potential, although currently uncertain, increase in predation of subadult and adult Chinook salmon by salmon sharks (Seitz et al. 2019; Manishin et al. 2021). Increased shark abundance may be indirectly subsidized by the large abundance of hatchery-origin pink and chum salmon in the North Pacific, providing a potential anthropogenic mechanism linking hatchery production to increased predation risk (Table 14).

Parasites and disease

Similar to predation, parasites and diseases are natural processes that lead to the mortality of Chinook salmon; this assessment focuses on anthropogenic amplification of these threats. Historically, the most significant concern has been open-net pen aquaculture sites within the marine migration routes of UFR Spring 5_2 Chinook salmon. Farmed salmon raised at high densities in open-net pens share numerous infectious agents with wild Pacific salmon, and farms can amplify and release viruses, bacteria, and parasites into the surrounding marine environment, potentially increasing pathogen exposure of migrating juvenile UFR Spring 5_2 Chinook salmon (Krkošek et al. 2024; Di Cicco et al. 2024). This threat is currently ranked moderate due to the uncertainty of UFR Spring 5_2 Chinook salmon early marine migratory route, as it is not clear how much exposure they have to the remaining aquaculture sites at the north end of Vancouver Island (they are not thought to be exposed to sites on the West Coast of Vancouver Island or Central Coast of BC). Climate change is also expected to exacerbate this threat (Table 14).

Climate change may further amplify disease and parasite impacts by altering both pathogen dynamics and salmon susceptibility. Warmer marine temperatures can increase the development, prevalence, and virulence of some pathogens

and parasites, while simultaneously increasing physiological stress and reducing the ability of salmon to respond to infection (Godwin et al. 2020a, 2020b; Bateman et al. 2022; Bass et al. 2022). Marine heatwaves have also been associated with increased pathogen prevalence and infection loads, and continued ocean warming may shift the distribution of some pathogens and parasites into new areas (Bass et al. 2022, 2023; Mastick et al. 2024). These effects may be particularly important during physiologically sensitive periods such as early marine entry.

Prey availability

Early marine growth is critical to salmon survival, with growth rates strongly influenced by the quantity and quality of available prey (Beamish and Mahnken 2001; Beauchamp 2009). Salmon that make the ontogenetic shift to higher-quality fish prey may achieve a growth advantage (Post 2003; Hertz et al. 2015). Nearshore habitats in the Salish Sea provide spawning habitat for many prey species consumed by juvenile Chinook salmon but have been heavily modified by human activities (Fresh et al. 2011; Dethier et al. 2016; Pacific Salmon Foundation 2026). As a result, critical prey resources such as Pacific sand lance may be less available in modified nearshore habitats than in natural shorelines due to loss of suitable spawning habitat (Rice, 2006; Tomlinson et al., 2021; Huard et al. 2022). Changes in prey composition may also affect prey quality. Thiamine deficiency has recently been documented in several BC Chinook salmon populations and may be influenced by marine diet, including consumption of prey containing thiaminase. Northern anchovy are one such prey species, although the occurrence and significance of thiamine deficiency in UFR Spring 5_2 Chinook salmon remain unknown (McLaskey et al. 2024). However, there is currently limited evidence that juvenile Chinook salmon are experiencing limitation of prey quality in the Salish Sea under current conditions (Innes et al. 2026, Table 14).

Fisheries

UFR Spring 5_2 Chinook salmon have been harvested for thousands of years, yet by the mid 19th century the colonial government removal of traditional fishing practices, along with technological advancement, led to very high exploitation rates on UFR Spring 5_2 Chinook salmon. However, since the 1960's, there has been long history of conservation concerns associated with fisheries on UFR Spring 5_2 Chinook salmon and many of the fisheries that historically intercepted UFR Spring 5_2 Chinook salmon have been modified to avoid them. Low escapement numbers in the 1960s and 1970s prompted DFO to introduce mesh size restrictions and close the commercial terminal Area E Lower Fraser gillnet fishery (DFO 1995). Further commercial fishery restrictions followed with the Pacific Salmon Treaty in 1985, and restrictions with the objective of protecting UFR Spring 5_2 Chinook salmon were substantially expanded again in 2008, with additional protective measures implemented in 2010, 2012 and 2019 (Dobson et al. 2020).

Despite these measures, the broad freshwater and marine distribution of UFR Spring 5_2 Chinook salmon exposes them to multiple potential fisheries. Bycatch (i.e. capture in fisheries focused on non-salmon species) occurs for juveniles and returning adults in the nearshore marine environment, and on juveniles/subadults in the offshore marine environments. Directed salmon fisheries operate in nearshore marine environments of Canada and Alaska and may impact both juveniles and returning adults, while fisheries in the Fraser River may impact adults. From 2019-2024, there was an estimated 2.8% fishing mortality in the Fraser River while there was an estimated 1.7% in the nearshore marine environment (DFO 2025). Most of the Fraser River fishing mortality comes from Fraser River First Nations S.35.1 FSC fisheries (1.7%), with the remainder coming from Fraser River test (0.8%), and recreational fisheries (0.2%). In the nearshore marine environment, the southern BC recreational fishery comprises the largest impact (0.9%), with the remainder coming from the Northern BC commercial (0.3%), northern BC recreational (0.2%) and southern BC commercial and First Nations fisheries (0.1% each). This DFO analysis does not include all fisheries, such as US commercial pollock fisheries in the Bering Sea where UFR Spring 5_2 Chinook salmon are encountered occasionally, but is expected to comprise the most significant sources of fisheries mortality for these DUs. In summary, due to the fisheries restrictions mentioned above, the impact of any single fishery is expected to be low; however cumulative impacts across all fisheries remains an important consideration.

While fisheries are not currently thought to be a significant threat to the recovery of UFR Spring 5_2 Chinook salmon, this conclusion should not be interpreted as suggesting that current fisheries management is without consequence. In particular, there remains a misalignment between the current operation of fisheries and the rights-based precedence of First Nations fisheries. In accordance with s. 35(1) of the Constitution Act, 1982, and as reflected in the Salmon Allocation Policy and Wild Salmon Policy, after conservation needs are met, First Nations fisheries have priority allocation of the available harvest. However, the principal First Nations fishing areas for UFR Spring 5_2 Chinook salmon are hundreds of kilometres from the ocean, and these fish have a long, protracted migration period. As a result, they are encountered in small numbers in numerous fisheries along the coast and Fraser River, limiting the potential access of upriver First Nations to available harvest.

There are no simple solutions to this issue. However, recovery provides the clearest path toward improving access over the long term. Rather than focusing only on allocation of increasingly constrained harvest opportunities, successful recovery could support First Nations fisheries, alongside other sustainable fisheries, while continuing to meet conservation objectives (see Appendix Table F.14).

Table 13. Summary of DU-level threat assessment results highlighting all threats ranked moderate or higher

Threat	Environment	Life Stage	Rationale
		Tier 1	
Competiton with other Pacific salmon	Offshore Marine, Nearshore Marine	Juvenile | Sub-adult	Increase in Pacific salmon biomass in the North Pacific ocean as a result of production hatcheries correlates with decline in size and productivity of wild salmon including UFR Spring 5_2 Chinook.
		Tier 2	
Low stream flows & high water temperatures	Natal Watershed (DU9 & DU11)	Juvenile rearing, Adult upstream migration, Staging	Increased frequency and magnitude due to climate change and land use practices and processes (e.g. forestry, mining, agriculture, urban development, wildfire)
		Tier 3	
Predation	Estuary Offshore Marine	Juvenile, Juvenile | Sub-adult, Adult, Returning adult	Human-caused habitat modifications leading to increased pinniped predation exposure.
Parasites & Disease	Nearshore Marine	Juvenile | Sub-adult	Increased parasite and disease prevalence due to open-net pen aquaculture and climate change
Prey availability	Nearshore Marine	Juvenile | Sub-adult	Modified nearshore habitats result in reduced populations of prey species.
Fishing	Nearshore Marine, Offshore Marine	Juvenile | Sub-adult, Returning adult	Despite low mortality from any single fishery, cumulative impacts are evident across multipe fisherires throughout freshwater and marine range.

Table 14. Scoring and rationale of threats assessed to have "very high" overall DU-level biological risk. High scoring parameters (value = 5 or 125) are shaded with red text.

DU-Level Biological Risk Rating (Likelihood × Timing × Magnitude): VERY HIGH															
Within-Environment Assessment Results				**Spatial Extent Assessment[2]**		**Threat Timing Assessment[4]**			**Threat Magnitude Assessment[5]**			**DU-Level Biological Risk**			**Assessment Rationales**
Threat, DU or Environment, Life Stage Affected by Threat	**% of DU or Environment Affected by Threat[1]**													**Overall Confidence Score**	**Threat Timing, Threat Magnitude**
	Mod. Risk	**High Risk**	**Total (Mod. + High)**	**Current Score**	**Future Trend[3]**	**Current Score**	**Future Trend[3]**	**Conf. Score**	**Current Score**	**Future Trend[3]**	**Conf. Score**	**Current Score**	**Future Trend[3]**		
Threat: Increased inter- and intraspecific competition **DU or Environment:** Offshore **Life Stage Affected by Threat:** Sub-Adult | Adult	–	–	100%	5	↑	5	↑	2	5	↑	2	125	↑	3	**Threat Timing:** Increased competition resulting from increases in hatchery releases since 1990s. **Threat Magnitude:** Assume that greatest magnitude of impact occurs in years with high pink salmon abundance. Well established link between pink salmon abundance and survival of Chinook salmon in nearshore and offshore environments.

[1] Proportion of DU affected by threat at moderate and high biological risk. For freshwater environments, this was calculated based on within-environment threats assessment results and mean escapement data for natal watersheds in each DU from 1990 to 2024. Mean escapement estimates for each natal stream and watershed group are presented in Table F.9 in Appendix F, and calculation methods are described in section 3.2.2.1 in Appendix F. For environments used by all UFR Spring52 Chinook salmon (e.g. marine environments and mainstem migration corridors) it was assumed that all fish were exposed (i.e. Total = 100%).

[2] Proportion of DU affected by threat at moderate and high risk. A score of 5 indicates >80% of DU is exposed to the threat, a score of 3 indicates ≥40% to <60% of DU exposed to threat, and a score of 1 indicates <20% of DU exposed to threat (see section 3.2.2.1 of Appendix F, including Table F.8 and Table F.9 in Appendix F).

[3] ↑ indicates future value is hypothesized to be at least 10% greater than current. ↓ indicates future value is hypothesized to be at least 10% less than current. → indicates future value is hypothesized to be stable (changing by less than 10% from current value).

[4] Likelihood that increased exposure to the threat occurred alongside changes in status (i.e. whether a change in threat prevalence or severity coincided with observed declines in abundance at DU-level). A score of 5 indicates it is very likely that increased exposure to the threat occurred alongside changes in population status, while a score of 3 indicates it is possible and a score of 1 indicates it was very unlikely (see section 3.2.2.1 of Appendix F).

[5] Expected severity of impact(s) of each threat on subsequent adult returns, at DU-level

Table 15. Scoring and rationale of threats assessed to have "high" overall DU-level biological risk. High scoring parameters (value = 5 or 125) are shaded with red text.

DU-Level Biological Risk Rating (Likelihood × Timing × Magnitude): HIGH															
Within-Environment Assessment Results				**Spatial Extent Assessment[2]**		**Threat Timing Assessment[4]**			**Threat Magnitude Assessment[5]**			**DU-Level Biological Risk**			**Assessment Rationales**
Threat, DU or Environment, Life Stage Affected by Threat	**% of DU or Environment Affected by Threat[1]**													**Overall Confidence Score**	**Threat Timing, Threat Magnitude**
	Mod. Risk	**High Risk**	**Total (Mod. + High)**	**Current Score**	**Future Trend[3]**	**Current Score**	**Future Trend[3]**	**Conf. Score**	**Current Score**	**Future Trend[3]**	**Conf. Score**	**Current Score**	**Future Trend[3]**		
Threat: Increased inter- and intraspecific competition **DU or Environment:** Nearshore **Life Stage Affected by Threat:** Juvenile | Sub-Adult	–	–	100%	5	↑	5	↑	2	4	↑	2	100	↑	3	**Threat Timing:** Increased competition resulting from increases in hatchery releases since 1990s. **Threat Magnitude:** Assume that greatest magnitude of impact occurs in years with high pink salmon abundance. Well established link between pink salmon abundance and survival of Chinook salmon in nearshore and offshore environments. Some evidence of density-dependence between wild and hatchery Chinook in the Salish Sea

[1] Proportion of DU affected by threat at moderate and high biological risk. For freshwater environments, this was calculated based on within-environment threats assessment results and mean escapement data for natal watersheds in each DU from 1990 to 2024. Mean escapement estimates for each natal stream and watershed group are presented in Table F.9 in Appendix F, and calculation methods are described in section 3.2.2.1 in Appendix F. For environments used by all UFR Spring52 Chinook salmon (e.g. marine environments and mainstem migration corridors) it was assumed that all fish were exposed (i.e. Total = 100%).

[2] Proportion of DU affected by threat at moderate and high risk. A score of 5 indicates >80% of DU is exposed to the threat, a score of 3 indicates ≥40% to <60% of DU exposed to threat, and a score of 1 indicates <20% of DU exposed to threat (see section 3.2.2.1 of Appendix F, including Table F.8 and Table F.9 in Appendix F).

[3] ↑ indicates future value is hypothesized to be at least 10% greater than current. ↓ indicates future value is hypothesized to be at least 10% less than current. → indicates future value is hypothesized to be stable (changing by less than 10% from current value).

[4] Likelihood that increased exposure to the threat occurred alongside changes in status (i.e. whether a change in threat prevalence or severity coincided with observed declines in abundance at DU-level). A score of 5 indicates it is very likely that increased exposure to the threat occurred alongside changes in population status, while a score of 3 indicates it is possible and a score of 1 indicates it was very unlikely (see section 3.2.2.1 of Appendix F).

[5] Expected severity of impact(s) of each threat on subsequent adult returns, at DU-level

Table 16. Scoring and rationale of threats assessed to have "moderate" overall DU-level biological risk.

DU-Level Biological Risk Rating (Likelihood × Timing × Magnitude): MODERATE																	
Within-Environment Assessment Results						Spatial Extent Assessment[2]		Threat Timing Assessment[4]			Threat Magnitude Assessment[5]			DU-Level Biological Risk			Assessment Rationales
Threat	DU or Environment	Life Stage Affected by Threat	% of DU or Environment Affected by Threat[1]			Current Score	Future Trend[3]	Current Score	Future Trend[3]	Conf. Score	Current Score	Future Trend[3]	Conf. Score	Current Score	Future Trend[3]	Overall Confidence Score	Threat Timing, Threat Magnitude
			Mod. Risk	High Risk	Total (Mod. + High)												
High water temperature	Mainstem	Juvenile Rearing	–	–	100%	5	↑	5	↑	2	3	↑	2	75	↑	3	**Threat Timing:** Threat frequency and magnitude has increased as a result of climate change and land use practices and processes (e.g. forestry, mining, agriculture, urban development, wildfire). **Threat Magnitude:** Potential for threat to have direct and indirect effects at the population level, however, assume that impact in most years is low-to-moderate and that most fish will access thermal refugia during periods of extreme heat.
	Natal Watershed (DU9)	Juvenile Rearing	61%	34%	95%	5	↑	5	↑	2	3	↑	2	75	↑	3	**Threat Timing:** Threat frequency and magnitude has increased as a result of climate change and land use practices and processes (e.g. forestry, mining, agriculture, urban development, wildfire). **Threat Magnitude:** Potential for local (e.g. stream or reach level) and DU level impacts (e.g. during extreme heatwave), however, assume that impact is low in most years, that sufficient thermal refugia exist, and that impacts will be variable across streams.
		Adult Upstream Migration	37%	52%	89%	5	↑	5	↑	2	3	↑	2	75	↑	3	**Threat Magnitude:** Potential for local impacts (e.g. at stream or reach level where solar radiation is increased) and/or DU level impacts are possible, but less likely (e.g. across DU during extreme heatwave). Assume that impacts are low in most years as adults are migrating in the spring when temperatures are typically cool and that impacts will be greater during staging/holding.
		Adult Staging	72%	16%	89%	5	↑	5	↑	2	3	↑	2	75	↑	3	**Threat Magnitude:** Potential for local (e.g. stream or reach level) and DU level impacts (e.g. during extreme heatwave), however, assume that impact is low in most years, that sufficient thermal refugia exist, and that impacts will be variable across streams.
Low stream flows	Natal Watershed (DU11)	Juvenile Rearing	0%	88%	88%	5	↑	4	↑	2	3	↑	2	60	↑	3	**Threat Timing:** Threat frequency and magnitude has increased as a result of climate change and land use practices and processes (e.g. forestry, mining, agriculture, urban development, wildfire). **Threat Magnitude:** Potential for local (e.g. stream or reach level) and DU level impacts (e.g. during extreme drought), however, assume that impact is low to moderate in most years, that sufficient refugia exist, and that impacts will be variable across streams.
	Natal Watershed (DU9)	Juvenile Rearing	47%	48%	95%	5	↑	5	↑	2	3	↑	2	75	↑	3	**Threat Magnitude:** Potential for local (e.g. stream or reach level) and DU level impacts (e.g. during extreme drought), however, assume that impact is low to moderate in most years, that sufficient refugia exist, and that impacts will be variable across streams.
Increased predation Reduction in abundance / distribution of preferred prey	Estuary	Juvenile	–	–	100%	5	↑	5	↑	3	3	↑	2	75	↑	3	**Threat Timing:** Increase in pinniped predation risk as human development increased in estuary **Threat Magnitude:** Potential for impact at population scale, all fish are equally exposed.
	Nearshore	Juvenile | Sub-Adult	–	–	100%	5	↑	3	↑	2	4	↑	1	60	↑	3	**Threat Timing:** Increased rate of change and frequency of prey-mismatch due to changing marine conditions. **Threat Magnitude:** Potential for DU level impact. Prey abundance and distribution has strong influence on early growth and survival. Mismatch in prey availability due to changes in outmigration timing (occurring later) and changes in timing of spring plankton blooms (occurring earlier).
	Offshore	Sub-Adult | Adult	–	–	100%	5	↑	3	↑	2	4	↑	2	60	↑	3	**Threat Timing:** Increased rate of change and frequency of prey-mismatch due to changing marine conditions. **Threat Magnitude:** Potential for DU level impact. Changes in prey composition and abundance may result in a shift to less nutritious food sources, may increase or decrease inter- and intra-specific competition and contribute to reductions in size and survival of Chinook salmon.
Increase in disease and parasites	Nearshore	Juvenile | Sub-Adult	–	–	100%	5	↑	3	↑	2	4	↑	2	60	↑	3	**Threat Timing:** Change in disease and parasite prevalence is unknown, however, presumed to have increased in response to enhancement and aquaculture. **Threat Magnitude:** Potential for DU level impact. Disease can have direct or indirect effects (e.g. reduced fitness or condition). Southern Strait of Georgia has been identified as a disease hotspot, with susceptibility influenced by water temperature, salinity and contaminant loads. Survival is dependent on length and intensity of exposure. Limited use of estuary habitats may expose

4.4 Action Prioritization

4.4.1. Overview

- **Purpose/Rationale:** The action prioritization assessment identified, systematically assessed, and ranked feasible recovery actions for threats most likely affecting UFR Spring 5_2 Chinook salmon (i.e. threats that scored moderate or higher during the DU-level threats assessment). The assessment also considered actions that could directly improve population abundance or resilience without addressing a specific underlying threat. Rankings provide a relative measure of action priority and should be interpreted in light of the uncertainty associated with the underlying evidence and scoring.

- **Key Takeaways:**

    - The top ranked action to reverse the trend is to support recovery through a conservation hatchery. This action provides a moderate biological response at a relatively low cost. The next ranked action is to support the removal of aquaculture sites on the migration route of UFR Spring 5_2 Chinook salmon. This action scored as feasible and low cost, since the Government of Canada has already committed to phase out open net pen aquaculture in the Pacific. Then, there are a number of actions that address the threat of high seas competition from industrial-scale hatcheries. The remaining highly-ranked actions include actions to address freshwater habitat condition, predation, and fisheries.

    - The top ranked action to prevent further decline is to develop and implement a structured engagement framework to ensure coordinated participation of rights holders, stakeholders, and technical experts in recovery planning and implementation. Actions to increase capacity to report low flows and high-water temperatures, assess flood risk, increase riparian protections, and establish IPCAs were also highly ranked.

    - The top ranked research action was to further develop a life cycle model for UFR Spring 5_2 Chinook salmon. Research actions surrounding better understanding marine survival, expanding water level and temperature monitoring, and improving understanding of environmental flow needs were also highly ranked.

    - Actions focused within marine environments ranked highest and are most likely to elicit the greatest population level response. Many of the actions targeting marine threats will provide benefit to salmon generally (i.e. they will benefit UFR Spring 5_2 Chinook salmon, other Chinook salmon populations, population aggregates, and/or other Pacific salmon species both within the Fraser River watershed and elsewhere).

- **Supporting Information:**

    - Methods used to complete the action prioritization assessment are presented in Section 3.4.

    - The full action evaluation and prioritization framework, including scoring results for all actions is provided in Appendix G and can be downloaded from Dropbox.

4.4.2. Detailed Summary

Actions were identified and prioritized for threats that rated moderate or higher during the DU-level threats assessment. Action prioritization involved two steps: 1) conducting a feasibility assessment, during which we narrowed the full initial list of possible actions to only those that are technically and socially feasible, 2) identifying the top-ranked priority feasible actions (those ranked highest and moderate priority) by threat grouping (summarized in the text and presented in Table 14-19). Action priorities were evaluated by applying a set of standardized criteria to score each action and then using those scores to determine the actions we consider to be the essential actions for recovery.

4.4.2.1. Feasibility Assessment

The feasibility assessment was completed to winnow the number of potential actions that needed to be developed and evaluated. The feasibility assessment was applied to a total of 17 environment × life stage × threat combinations that were rated as moderate to high biological risk in the DU-level threats assessment (see Appendix F). Feasibility was evaluated via consideration of social and technical feasibility, such as whether the action would likely be opposed by some groups (social feasibility), or whether the action used existing techniques and had been effectively implemented elsewhere (technical feasibility).

High water temperature and low flows in natal watersheds and predation in the Fraser River mainstem were assessed as having at least one feasible action pathway, so detailed actions were developed for those pathways and evaluated with additional criteria.

A total of 24 action pathways were identified for threats occurring in marine environments. At least one feasible action pathway was identified for all marine threats, except for predation in the offshore marine environment. Actions to address anthropogenically driven threats were deemed to be feasible; whereas actions to address threats associated with marine conditions (e.g. PDO) were deemed to be infeasible, or in the case of climate change were deemed to be beyond the scope of this recovery plan. Specifically, the following actions moved beyond the feasibility assessment to be further developed and evaluated using additional criteria: threats of fisheries (a cause of mortality that is anthropogenically driven and which we have control over), competition with other Pacific salmon, and changes in prey abundance in near-shore marine areas. Actions to reduce predation were considered feasible in both estuary and nearshore environments but not offshore.

4.4.2.2. Action Assessment and Prioritization

Our recovery planning framework assumes that addressing the primary population aggregate-level threats to UFR Spring 5_2 Chinook salmon, together with interventions that directly improve population abundance and resilience, provides the most effective path toward recovery. We consider this framework to be the best available approach for guiding the development of meaningful recovery actions, while acknowledging its potential limitations. The actions presented here were developed within this framework and then evaluated against multiple criteria (e.g. expected biological response, duration of implementation, direct financial cost, feasibility) to identify actions most likely to be successfully implemented and contribute to population recovery. The actions identified are relatively high level at this stage with the understanding that actions will be further developed in the next stages of recovery planning.

Following the feasibility assessment, a total of ~100 actions were identified and assessed. These were refined to a total of 66 unique recovery actions: 23 actions specific to freshwater environments (i.e. to address threats of low stream flows, high water temperature, and predation) and 31 actions specific to marine environments (i.e. to address threats of competition, changes in prey abundance, predation, and fisheries bycatch; Table 14). An additional 12 actions were developed that are not related to specific threats or environments, such as hatchery enhancement, integration of traditional ecological knowledge, coordination among recovery initiatives, and a variety of additional basic research needs. In all cases, addressing a threat requires multiple simultaneous actions. In many cases, actions provide benefits across multiple threats, and we have tried to capture this complementarity in the tables.

The highest-ranking actions for each threat are summarized below and presented in Table 15-17. Evidence to support all statements about threat occurrence with relevant citations is presented in Appendix D. Action rankings should not be interpreted as a direct ranking of threat importance. Threat severity and action priority were assessed separately. A high-risk threat may have few interventions that are technically, socially, or economically feasible, while an action addressing a lower-ranked threat or broader recovery need may rank highly because it is expected to provide a meaningful biological benefit and can be implemented at an appropriate scale and cost. Consequently, the highest-ranked recovery actions do not necessarily correspond directly to the highest-ranked threats. The action assessment also included several recovery actions, such as conservation hatchery supplementation, that were not developed in response to a single assessed threat but were identified as potential means of directly increasing population abundance or resilience.

4.5 Recovery Actions

Recovery actions were categorized according to their primary objective: actions intended to **reverse the trend** in UFR Spring 5_2 Chinook salmon abundance or productivity, actions intended to **prevent further decline,** and **research actions** intended to reduce key uncertainties and improve future recovery planning. Within each category, actions were ranked based on their biological response, cost, feasibility, and other assessment criteria.

4.5.1. Actions to Reverse the Trend

The highest-ranked action to reverse the trend was to utilize hatchery enhancement as a tool to support the rebuilding, conservation, and assessment of UFR Spring 5_2 Chinook salmon (Table 15). For the purposes of this assessment, the action was defined at a relatively high level, recognizing that more detailed planning for hatchery production in the Upper Fraser is occurring through other processes. The action received a weighted final assessment score of 3.6, reflecting a moderate expected biological response at relatively low cost (assuming the enhancement facility is constructed, as announced).

Unlike most actions evaluated in this assessment, conservation hatchery supplementation is not intended to mitigate a single identified threat. Rather, it is intended to address the cumulative demographic consequences of mortality occurring across the life cycle by increasing the number of juveniles entering subsequent life stages and, ultimately, the number of adults returning to spawn. This distinction is important because UFR Spring 5_2 Chinook salmon are exposed to multiple threats across freshwater, estuarine, and marine environments, and many of the highest-ranked threats are difficult to

mitigate directly at the scale required to produce a near-term population response. Conservation enhancement can therefore provide a complementary recovery tool while actions to reduce underlying threats are pursued.

Conservation hatchery implementation should be explicitly recovery-focused and adaptive, with production levels, broodstock collection, release locations, and release strategies guided by clearly defined conservation objectives and monitoring of biological response. The objective is not hatchery production as an end in itself, but targeted supplementation that contributes to recovery while generating information needed to evaluate effectiveness and refine the program over time. The biological response score was based on the estimated increase in hatchery production required to generate a 5% increase in UFR Spring 5_2 Chinook salmon abundance. Recent returns have been approximately 20,000 adults, meaning that approximately 1,000 additional returning adults would be required to achieve a 5% increase. Conservatively assuming 1% marine survival, this corresponds to the annual release of approximately 100,000 additional Chinook salmon. Cost estimates assumed that these fish would be produced at the new hatchery in Prince George and released across 5–10 well-assessed sites in the Middle and Upper Fraser.

The conservation hatchery action was conceived as an adaptive management strategy. In addition to increasing juvenile survival rates and abundance, implementation would provide opportunities to evaluate release strategies, including release timing, size, and life stage. Marking hatchery-origin fish could also provide information on the freshwater and marine distribution of UFR Spring 5_2 Chinook salmon.

The next highest-ranked action was to support the removal of finfish aquaculture sites along the migration route of UFR Spring 5_2 Chinook salmon. This action received a weighted final assessment score of 3.3. More than 40 salmon farms have been removed from BC coastal waters since the 1990s, but active finfish aquaculture sites remain along portions of the migration route. The action ranked highly largely because the Government of Canada's commitment to transition from open net-pen salmon aquaculture in BC coastal waters by 2029 made further site removals relatively feasible and low in direct implementation cost, despite the modest and uncertain magnitude of the expected biological response.

Several of the next highest-ranked actions addressed competition with industrial-scale hatchery-origin pink and chum salmon in the North Pacific. These included developing financial tools to discourage large-scale hatchery production, supporting legal processes aimed at reducing hatchery releases in the United States, developing or strengthening international governance of pink and chum salmon enhancement, and engaging with international fisheries management processes to prioritize reductions in hatchery production. These actions received weighted final assessment scores ranging from 3.1 to 3.2. High levels of hatchery-origin pink and chum salmon may increase competition for prey resources and reduce Chinook salmon growth, survival, and productivity. However, because hatchery production occurs internationally and provides substantial social and economic benefits to other nations, actions to reduce production generally scored lower for social and technical feasibility than the two highest-ranked actions.

The remaining higher-ranked actions addressed freshwater habitat condition, predation, and fisheries. Freshwater actions included increasing prey availability through habitat restoration and undertaking low-tech, process-based restoration to improve hydrological function and habitat complexity. Both actions had relatively high technical and social feasibility but were expected to operate over smaller spatial scales than the highest-ranked actions.

Predation and fisheries actions had lower expected biological responses, despite some having relatively high feasibility. The highest-ranked predation action was to support the development of marine mammal harvest plans intended to reduce pinniped abundance. Because the population-level response to predator management remains uncertain, implementation was recommended within an explicit adaptive management framework.

Fisheries actions included supporting transitions toward more selective and terminal fisheries and reducing recreational catch-and-release openings that intercept returning UFR Spring 5_2 Chinook salmon. These actions were expected to provide relatively small increases in abundance because current fisheries mortality on the population is already low.

Additional actions to reverse the trend included restoring connectivity to natural water-storage features, developing local water-storage infrastructure, restoring forage fish habitat, improving implementation of temporary water-protection measures, creating thermal refugia, undertaking instream habitat restoration, reducing groundfish bycatch, increasing fisheries enforcement, strengthening and restoring riparian habitat, modifying reservoir operations to increase cool-water inputs, and modifying habitats that may increase pinniped predation. These actions generally ranked lower because of smaller expected biological responses, more limited spatial scales, higher costs, or some combination of these factors.

4.5.2. Actions to Prevent Further Decline

The highest-ranked action to prevent further decline was to develop and implement a structured engagement framework to guide the participation of rights holders, stakeholders, and technical experts in recovery planning implementation (Table 16). This action received a weighted final assessment score of 4.5, reflecting its broad geographic applicability, relatively high technical and social feasibility, and low implementation costs. The framework would identify relevant participant groups, clarify their roles at different stages of action planning and implementation, and establish mechanisms for consultation, collaboration, and integration of diverse knowledge. The intent is to improve coordination and accountability while ensuring that engagement is appropriate to the scale and nature of individual recovery actions.

Several of the next highest-ranked actions focused on preventing further degradation of freshwater habitats. Increasing capacity to identify and report critical low-flow and high-water-temperature events received a weighted final assessment score of 3.8. This action would provide training and support to guardians and local environmental groups to monitor stream conditions, identify locations where low flows or high temperatures pose particular risk to fish, and document and report critical events. Expanded monitoring would increase the likelihood that potentially harmful conditions are identified and addressed, including in smaller and more remote streams.

Assessing downstream flood risk and the hydrological consequences of forest disturbance and climate change also ranked highly, with a weighted final assessment score of 3.7. This action recognizes that forest harvesting, wildfire, disease, development, and climate change can alter watershed hydrology and potentially increase downstream flood risk. Quantifying these broader consequences may help build support for watershed protection and restoration actions that also benefit UFR Spring 5_2 Chinook salmon.

Two actions received weighted final assessment scores of 3.5: leveraging existing legislation and regulations to strengthen protection of riparian and aquatic habitats and developing priority Indigenous Protected and Conserved Areas (IPCAs) to protect critical salmon habitats. The former focuses on using existing regulatory tools, such as fisheries-sensitive watershed or temperature-sensitive stream designations, to protect functional habitat. IPCAs provide a complementary, potentially longer-term approach to protecting critical salmon habitats.

Additional preventative actions focused on preparing for and responding to critical freshwater conditions. Establishing emergency response protocols for critical environmental flow events received a weighted final assessment score of 3.4 and would include training, predefined response procedures, and an emergency fund that could be accessed rapidly when low flows or high water temperatures pose a serious risk to fish. Contributing to collaborative development of water sustainability plans under the BC Water Sustainability Act received a score of 3.2 and could provide a longer-term mechanism for addressing water quantity, water quality, environmental flows, and ecosystem health through legally recognized watershed planning.

The lowest-ranked action in this category was to facilitate a rapid and coordinated response to proposed changes in recreational or commercial fisheries regulations that could increase direct harvest or bycatch of UFR Spring 5-2 Chinook salmon. This action received a weighted final assessment score of 2.6.

4.5.3. Research Actions

The highest-ranked research action was to develop and maintain a publicly accessible life cycle model for UFR Spring 5_2 Chinook salmon (Table 17). This action received a weighted final assessment score of 4.3. A life cycle model would provide a structured framework for integrating information across life stages, improving understanding of population dynamics and sensitivity to different sources of mortality, and evaluating the potential influence of alternative recovery actions. Making the model publicly accessible would also allow it to be updated as new information becomes available and adapted for use with other populations.

Research to improve understanding of early marine survival of juvenile and sub-adult UFR Spring 5_2 Chinook salmon was the next highest-ranked action, with a weighted final assessment score of 4.2. The early marine period has been identified as an important determinant of year-class strength, but relatively little empirical information is available on the specific conditions and mechanisms affecting survival during this life stage. Research priorities include improving understanding of habitat use and distribution in estuarine and nearshore marine environments and identifying the mechanisms regulating survival.

Three research actions received weighted final assessment scores of 3.9. Two focused on freshwater conditions: expanding real-time water-level and temperature monitoring and improving understanding of environmental flow needs in natal streams. Together, these actions would improve the ability to identify streams and populations at greatest risk from low flows and high temperatures, support emergency and regulatory responses to critical conditions, and inform the

prioritization of freshwater recovery actions. The third focused on identifying the major biological mechanisms regulating survival of sub-adult and adult UFR Spring 5_2 Chinook salmon in offshore marine environments, where limited information currently constrains assessment of the threats affecting this life stage.

A broad suite of additional research actions also ranked highly, with weighted final assessment scores of 3.7–3.8. These addressed fisheries bycatch and monitoring, life-history variation, predator management, the costs and benefits of reducing industrial-scale pink and chum salmon hatchery production, climate vulnerability, fecundity and escapement targets, freshwater habitat condition, competition in marine environments, and fisheries-related incidental mortality. The breadth of these priorities reflects substantial remaining uncertainty about both the factors limiting UFR Spring 5_2 Chinook salmon and the effectiveness of potential recovery interventions.

Table 17. Recommended recovery actions to reverse the trend.

Action ID[1]	Action Description	Rationale and Supporting Information	Action Score (Weighted Final Assessment)
RT.22	Expand conservation hatchery supplementation programs to support population recovery	• Conservation hatcheries can play a role in accelerating recovery • These scores are based on the estimated release numbers to get to a 5% increase in run size. Recent run size of approximately 20,000 -> need 1000 more adults back for 5% population increase. Conservatively assume 1% marine survival, means we need to release 100,000 Chinook annually (spread out across 5-10 closely assessed systems in the Middle and Upper Fraser)	3.6
RT.01	Continue removal of finfish aquaculture sites on the migration route of UFR Spring 5_2 Chinook.	• Reduces juvenile Chinook salmon exposure to aquaculture-associated pathogens and parasites during early marine life • Targets a directly manageable anthropogenic pressure during a critical life stage	3.3
RT.04	Support development and application of financial tools to reduce hatchery production of pink and chum salmon internationally. This action was originally presented in Holt et al. (2008) and reframed by Connors et al. (2025)	• High hatchery production of pink and chum salmon in the North Pacific contributes to increased interspecific competition with wild Chinook salmon for food resources in the marine environment, potentially reducing Chinook salmon growth, survival, and productivity. • By making large-scale hatchery releases more costly, this will discourage excessive hatchery production. Additionally, using generated funds to support research and transition strategies could facilitate international cooperation and long-term reductions in hatchery dependence.	3.2
RT.06	Support groups engaged in legal processes focused on reducing the releases hatchery pink and/or chum salmon in the United States.	• The United States is the primary producer of hatchery pink salmon, releasing an average of ~57% of global annual releases from 2015 to 2024 (NPAFC 2025). A lawsuit that successfully demonstrates how wild salmon are impacted by high hatchery production of pink and chum salmon has potential to provide significant benefit to wild salmon, including Upper Fraser Spring 5_2 Chinook salmon.	3.1
RT.05	Revise the mandate and powers for an organization that oversees international hatchery production of pink and chum salmon (e.g., North Pacific Anadromous Fish Commission (NPAFC) or Pacific Salmon Commission (PSC). This revision in mandate should ensure an equitable distribution of net benefits among member states and explicitly recognize ecological interactions among species that share a common pool of prey resources. This action was presented in Connors et al. (2025).	• Holt et al. (2008) note that countries with fisheries that rely solely on hatchery fish, such as Japan and Korea, will be most affected and least benefited by efforts to curb hatchery production of pink and chum salmon production. • To receive international support, Holt et al. (2008) argue that countries that receive the greatest benefit from reduced hatchery production (i.e., countries with significant wild salmon stocks, such as Canada, United States and Russia) may need to offset losses in countries that are most impacted.	3.1

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RT.07	Engage with international fisheries management to prioritize the reduction of international pink and chum salmon enhancement (e.g., DFO, PSC, federal Fisheries Minister, local members of parliament).	• High hatchery production of pink and chum salmon in the North Pacific contributes to increased interspecific competition with wild Chinook salmon for food resources in the marine environment, potentially reducing Chinook salmon growth, survival, and productivity. • Raising the profile of this threat among individuals (e.g., federal Fisheries Minister or local Member of Parliament) and organizations involved in international fisheries managers will increase the likelihood that actions are undertaken to reduce enhancement of pink and chum salmon in Canada and internationally.	3.1
RT.14	Provide financial and/or technical support to increase the abundance of prey within freshwater.	• Lusardi et al. (2020) report that coho salmon achieved maximum growth rates at mean daily water temperatures of >16.5°C when abundant prey was available and suggest that increasing prey availability may be a strategy to mitigate negative effects of elevated water temperature. • Increasing prey availability may be achieved via riparian habitat restoration to promote primary and secondary productivity, and nutrient enrichment.	3.1
RT.13	Undertake low-tech process-based restoration projects (e.g., beaver dam analogues or post assisted log structures), that aim to slow water and increase habitat complexity in smaller, low-order streams.	• Low-tech process-based restoration refers to low cost/effort practices ideal for smaller (i.e., wadable) low-order streams that are ideal for reducing sediment transport, increasing habitat complexity, and restoring hydrological function (Wheaton et al. 2019).	3
RT.15	Restore connectivity to natural water storage features affected by linear development (e.g., wetlands and marshes affected by FSR, road, highway, railway or pipeline development).	• Off-channel wetland and marsh habitats provide natural water storage. Restoring connectivity to natural water storage features will increase water available during low flow periods and buffer against low summer flows.	2.9
RT.02	Advocate for groups that are engaged in development of marine mammal harvest plans with the intent of reducing pinniped abundance (e.g., to re-establish First Nations harvests).	• There is evidence of pinniped predation as a source of mortality for juveniles and returning adults. • The outcome of this action remains uncertain, so implementation should occur with a explicit experimental framework (i.e., adaptive management). • Predator management is likely to be controversial and may receive limited public support without strong evidence of the benefits to Chinook salmon recovery.	2.8
RT.08	Support entities that are actively transitioning towards alternate fishing practices that limit impacts to UFR Spring 5_2 Chinook salmon (e.g., groups supporting a transition to terminal and selective salmon fisheries, changes in catch methods, timing and spatial boundaries of seasonal openings, etc.).	• Many commercial fisheries are mixed-stock, meaning vulnerable Chinook populations are often caught along with more abundant ones. Post-release mortality from catch-and-release practices further reduces the number of fish that survive to spawn. • Terminal fisheries reduce the mixed-stock risks of ocean-based fisheries. They occur nearer to locations where fish spawn, such as in a river or near a river mouth of a specific natal stream, often after a minimum number of fish have been allowed to access spawning habitats.	2.7
RT.09	Reduce openings for recreational catch-and-release fisheries that have potential to intercept returning adult Spring 5_2 Chinook salmon.	• Returning adult UFR Spring 5_2 Chinook salmon are exposed to non-retention recreational Chinook salmon fisheries within Area 20 (Juan de Fuca Strait) and to a lesser extent non-retention fisheries within Georgia Strait and Discovery Islands. • Catch-and-release recreational fisheries can cause mortality or sublethal stress to returning adult Spring 5_2 Chinook salmon, which can reduce the number of adults that reach spawning habitats in natal streams, lowering total reproduction and overall population abundance. • Instituting seasonal closures would prevent catch-and-release interactions during critical periods of the Spring 5_2 Chinook salmon migration.	2.7

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RT.17	Develop local water storage infrastructure (e.g., ponds, reservoirs, etc.) that can be naturally recharged (i.e., by snowmelt or rain) as an alternate water source during periods of low stream flows.	• Development of water storage infrastructure and alternate water supplies will reduce surface water extraction during low flow periods and increase the total volume of water available to fish during periods of drought.	2.6
RT.11	Enhance/restore forage fish habitat used by Chinook prey.	• Forage fishes are an important food source for many species, and herring and sand lance are particularly important for juvenile and sub-adult Chinook salmon.	2.6
RT.18	Implement a centralized water level and temperature monitoring and assessment program that can be used to inform when BC Water Sustainability Act (WSA) temporary protection orders (TPO) may be warranted (i.e., when there is risk that stream flows are below Critical Environmental Flow Thresholds [CEFT]). This action will require installation of expanded water-level monitoring infrastructure (see action RM.19) and assessments of Environmental Flow Needs (EFN, see action RM.20).	• The BC WSA defines EFN as "the volume and timing of water required for proper functioning of the aquatic ecosystem of the stream" and CEFT as the "volume of water flow below which significant or irreversible harm to the aquatic ecosystem of the stream is likely to occur". • Temporary protection orders are regulatory measures within the WSA intended to curtail water use during times of water scarcity. Examples of TPOs include Fish Population Protection Orders (section 88), Critical Environmental Flow Protection Orders (section 87) and Declaration of Significant Water Shortage (section 86).	2.6
RT.19	Construction of thermal refugia (e.g., groundwater additions) in streams with identified risk of high temperatures.	• Thermal refugia habitat provide respite from elevated water temperatures. • Groundwater typically maintains a stable temperature year-round and groundwater inputs are often associated with thermal refugia, both as cool-water refugia during summer and as warm water refugia during winter. Water temperature can be reduced at the site or reach level by increasing groundwater inputs through installation of a pumped or artesian well (Smith and Kurylyk 2025). Creation of thermal refugia via groundwater additions is likely to be more persistent form of restoration than instream works (e.g., pool creation).	2.5
RT.20	Implement high-tech instream works (e.g., channel excavation, LWD placement) to reduce channel width and increase habitat complexity in over-widened, aggraded reaches. This action should be coupled in conjuction with riparian revegetation (e.g., willow staking) to increase channel stability. Noting that instream works are unlikely to persist unless completed in conjunction with actions that aim to restore hydrological integrity (e.g., replanting upslope habitats, see action RT.16).	• Aggradation and channel widening spreads water across a wider area, resulting in shallower stream depths and increased water surface area exposed to solar radiation. The effects of channel aggradation on fish are pronounced during adult upstream migration when water levels are low, temperatures are high and migration-related stress has potential to reduce gamete viability.	2.8
RT.03	Support continued implementation and evaluation of measures that reduce Chinook salmon bycatch in commercial groundfish fisheries, including improved accountability, monitoring, hotspot avoidance, gear innovations, and other evidence-based management approaches.	• Chinook salmon bycatch occurs in several commercial groundfish fisheries despite existing avoidance measures. • Continued improvements in accountability, monitoring, spatial and temporal avoidance, gear technology, and bycatch forecasting may further reduce bycatch. Because management frameworks differ substantially among fisheries (e.g., Alaska pollock versus Canadian hake), recovery actions should support fishery-specific, evidence-based approaches rather than prescribe a single management system.	2.4

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RT.10	Increase enforcement of early season non-retention fisheries to limit number of illegally harvested UFR Spring 5_2 Chinook salmon.	• Recreational fisheries with potential to intercept UFR Spring 5_2 Chinook salmon remain open (e.g., non-retention fisheries for Chinook salmon are open in Area 20 from April 1 to July 14). • Creel survey data suggest that early season captures of Chinook salmon in Area 20 (East) are increasing across years in June and July but decreasing in April and May (DFO 2025c) • Increasing enforcement and monitoring of early season non-retention recreational fisheries is a proven method to reduce illegal retention of Chinook salmon.	2.4
RT.16	Support policy and regulatory changes that strengthen protection of riparian areas, particularly in headwater and non-fish-bearing streams that influence downstream salmon habitat.	• Riparian areas provide important ecological functions and influence how streams respond to landscape disturbances. • Current forest management policy does not require forest harvesting reserve zones (i.e., riparian buffers) on non-fish-bearing streams and on fish-bearing streams with average channel widths >100 m or <1.5 m (FRPA 2002). • The removal of riparian vegetation on these smaller and more upslope streams has a direct influence on water quality (e.g., stream temperature, sediment loads, flashiness, primary productivity, etc.).	2.8
RT.21	Increase cool water inputs via installation of variable depth water intakes (e.g., existing and new reservoir systems). This action is best suited to locations with existing hydropower or water storage infrastructure.	• Thermal stratification often occurs in large and deep water bodies during warm periods (i.e., lakes in summer), resulting in warm surface water and cooler waters at depth. • Variable depth water intake structures can reduce thermal stress because they permit the addition of relatively cooler waters during warm periods and warmer waters during colder periods.	2.2
RT.12	Support groups engaged in habitat modifications that would reduce pinniped abundance within the lower Fraser River mainstem and estuary (e.g., reducing habitat quality via relocation of log booms or installation of predator avoidance devices, etc.).	• There is strong evidence of pinniped predation, especially from recovering and expanding populations of harbour seals and sea lions, as a significant source of mortality for juveniles and returning adults. • The outcome of this action remains uncertain, so implementation should occur with a explicit experimental framework (i.e., adaptive management). • Predator management is likely to be controversial and may receive limited public support without strong evidence of the benefits to Chinook salmon recovery.	2.7

[1]Action IDs are unique to each action. The letters at the start of the Action ID identify the action objective (RT = actions to reverse the trend, PD = action to prevent decline, RM = research and management). Subsequent numeric values are unique to each individual action and do not imply rank.

Table 18. Recommended recovery actions to prevent further decline.

Action ID[1]	Action Description	Rationale and Supporting Information	Action Score (Weighted Final Assessment)
PD.08	Develop a structured engagement framework to guide the participation of rights holders, stakeholders, and others, in action planning and implementation.	• High technical and social feasibility, low cost • Supports adaptive management by incorporating feedback and local and traditional knowledge • Supports collaboration and communication across government agencies and entities with varying levels of decision-making authority	4.5
PD.04	Increase capacity to identify and report critical low flow and high water temperature events. Increase stream flow monitoring, identification of areas where low stream flows and/or high water temperature are most likely to harm fish, and processes to document and report incidents of critical low stream flow or high water temperature. This action will require expanded water level monitoring infrastructure (see action RM.19).	• Expanding the number of locations that are monitored as well as the number of persons involved in water level and temperature monitoring will increase the likelihood that conditions with potential to harm fish are identified and mitigated, including on smaller and more remote streams.	3.8
PD.03	Assess the potential downstream flood risk and hydrological impacts of different forest disturbance and climate change scenarios (i.e., vegetation loss due to forest harvesting, wildfire, disease/parasites, development, etc.) throughout the middle and upper Fraser River watershed.	• Forest disturbances within the upper Fraser River have altered hydrological processes and flow regimes and may increase flood risks sownstream. The magnitude and frequency of these events is anticipated to increase as a result of climate change. • Actions to restore watershed processes in efforts to mitigate flood risk (i.e., reduced forest harvest, strategic replanting) are also likely to benefit UFR Spring 5_2 Chinook salmon. • Quantifying future flood risk and costs associated with different forest harvesting scenarios throughout the upper Fraser River may be a more compelling argument to protect functional habitats and/or restore watershed function than advocacy to protect a single species (i.e., most communities along the Fraser River are likely to support actions that reduce flood risk and flood mitigation/response costs).	3.7
PD.05	Leverage existing legislation and regulations that can increase protections for riparian and aquatic habitats (e.g., "fisheries sensitive watershed" or "temperature sensitive stream" designation under Forest and Range Practices Act [2002]). A similar action was presented by Ulaski et al. (2025)	• Protecting functional intact habitats is generally a more economical, efficient, and effective approach than restoring degraded habitats (Dodds et al. 2008, Benayas et al. 2009, Roni et al. 2002). • Tools and processes to establish riparian and aquatic habitat protections are embedded within existing resource management legislation (e.g., Forest and Range Practices Act, Water Sustainability Act) and can be used to protect functional habitats.	3.5
PD.10	Develop and implement priority IPCAs to protect critical salmon habitats	• IPCAs have been used to protect salmon habitat on the West Coast of Vancouver Island and in the Mainland Inlets. • Both the Province of BC and the Government of Canada are committed to meeting 30 x 30 committments, and have spoken to how IPCAs will be an important tool to do so.	3.5

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PD.06	Establish emergency response protocols to respond to critical environmental flow events. Provide training to guardians and local environmental groups on response procedures. Establish a low flow emergency response fund that can be accessed to rapidly initiate emergency low flow response.	• Droughts are anticipated to occur more frequently and in greater severity as a result of climate change, landscape modification and water withdrawals. • Extreme low stream flows and high water temperatures can have sub-lethal and lethal effects, reduce habitat area/ quality, and restrict passage. • Emergency response protocols will ensure action is taken efficiently and effectively when there is a serious risk of significant fish mortality. • Emergency response actions may include fish salvage and transport, instream works (e.g., excavation of exposed gravel bars), monitoring, etc. Additional examples of emergency response processes are presented in Naman and Reid (2025).	3.4
PD.07	Contribute to the collaborative development (i.e., between First Nations and Province) of water sustainability plans under the BC Water Sustainability Act.	• Water sustainability plans are water-focused tools used to assess risks to water quantity, quality, or ecosystem health (e.g., who can use water, how much is available for use, and how to maintain environmental flows).	3.2
PD.11	Increase emphasis of fecundity in assessment of escapement targets. This action was presented in Malick et al. (2024).	• Both interior stream-type and coastal ocean-type Chinook salmon have experienced considerable reductions in body size over the past 25 years due to changes in size-at-age and/or age-at-maturity, associated with declines in productivity.	
PD.01	Facilitate rapid and coordinated response to any proposed changes to recreational and commercial fisheries regulations that may increase direct harvest or bycatch of UFR Spring 5_2 Chinook salmon in mixed stock fisheries.	• Fisheries are understood to have significantly contributed to the current status of UFR Spring 5_2 Chinook salmon, though current harvest appears to be playing a lesser role in preventing recovery. • Engaging with fisheries managers may be necessary to emphasize the potential impact to Chinook salmon from increased fisheries pressures.	2.6

Table 19. Recommended research and monitoring actions.

ID	Description	Rationale	Action Score (Weighted Final Assessment)
RM.26	Develop and maintain a publicly accessible life cycle model for UFR Spring 5_2 Chinook salmon.	• Life cycle models provide a structured framework to understand basic population dynamics (e.g., how fast a population can grow and how sensitive the dynamics are to different population parameters), assess threats across life stages, and evaluate the influence of potential recovery actions. • Providing access to a working model that users could manipulate to align with their study populations will increase utilization of this tool.	4.5
RM.01	Undertake studies to improve understanding of mechanisms regulating early marine survival of juvenile and sub-adult UFR Spring 5_2 Chinook, including habitat use and distribution in estuary and nearshore marine environments.	• The early marine phase has been identified as a critical bottleneck that determines overall year class strength. • Despite this recognition, relatively few studies have attempted to empirically assess the specific conditions and factors that contribute to early marine survival.	4.2
RM.19	Expand real-time water-level and temperature monitoring infrastructure to identify when emergency response efforts may be necessary. Leverage existing infrastructure where feasible (e.g., install temperature monitoring equipment on operational Water Survey of Canada hydrometric stations).	• The majority of active real-time water-level and temperature monitoring infrastructure is installed in larger river systems where high flows have potential to damage physical infrastructure. • Real-time monitoring of smaller streams for the purpose of monitoring habitat conditions is relatively limited, but also necessary to evaluate risk across streams used by UFR Spring 5_2 Chinook salmon in DU9 and DU11. • Over time, this dataset could be used to assess which streams are most at risk and where recovery actions intended to reduce high water temperatures should be prioritized.	3.9
RM.20	Improve understanding of environmental flow needs (EFN) and critical environmental flow thresholds (CEFT) in natal streams of DU9 and DU11.	• Establishing EFN and CEFT on at risk streams with real-time water-level monitoring will permit implementation of regulatory measures within the WSA intended to protect aquatic health during periods of low flow, and evaluate how proposed development projects may affect fish and fish habitat, and evaluate how flows change in response to disturbance. • Action is required to support prioritization of recovery efforts and to inform hydrological impacts assessments of future/proposed resource development projects that may affect water availability.	3.9
RM.02	Aim to identify the major biological mechanisms regulating survival of sub-adult and adult UFR Spring 5_2 Chinook salmon in offshore marine environments.	• Information on Chinook salmon in offshore marine environments is limited. • Additional information is required to accurately assess the threats to Chinook salmon in offshore marine environments.	3.9
RM.03	Assess how different fisheries methods (e.g., gear, openings, deterrent devices, etc.) can be employed to further reduce bycatch of Chinook salmon in nearshore and offshore commercial fisheries.	• A growing body of research is focused on mitigating incidental capture of Chinook salmon. • These studies have informed fisheries management by identifying when and where Chinook salmon are most exposed to fisheries, and how different tools or technologies may reduce bycatch rates. • Chinook salmon will continue to be captured as incidental bycatch in fisheries directed at other species, however, research that informs best practices has potential to reduce this risk.	3.8

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RM.21	Undertake studies that improve understanding of life history variation in UFR Spring 5_2 Chinook salmon (e.g., natal stream affinity, size-at-age, age-at-maturity, mechanisms influencing freshwater distribution, continued analysis of genetic population substructure).	• Available information suggests there are different life history strategies used by UFR Spring 5_2 Chinook salmon (e.g., natal vs non-natal rearing strategies). • An improved understanding of life history and factors influencing life history variation in UFR Spring 5_2 Chinook salmon can refine assessments of when, where, and why fish are exposed to different threats.	3.8
RM.04	Assess the costs and benefits (ecological, social and financial) of predator management in estuary, nearshore and offshore marine environments.	• To ensure that predator management does not have unintended ecological, financial, and/or social consequences, it is imperative that comprehensive assessments are completed prior to implementation within estuary, nearshore and offshore marine environments. Adaptive management should be leveraged to allow timely implementation of recovery actions while simultaneously monitoring outcomes and adjusting strategies as new information becomes available, preventing research needs from unnecessarily delaying action.	3.7
RM.11	Establish an independent scientific review panel that can evaluate the full costs and benefits (ecological, social, and economic) of reducing hatchery pink and chum salmon production. This action assumes that education on costs and benefits will persuade managers/nation states to reduce overall hatchery production, if analyses indicate this is needed. This action was presented in Connors et al. (2025).	• Scientific review panels typically consist of an independent panel of relevant subject matter experts tasked with systematically reviewing the best available scientific information on a subject, evaluating whether management practices are functioning as intended, and providing recommendations for management, research, and monitoring.	3.7
RM.22	Identify streams and UFR Spring 5_2 Chinook salmon populations most at risk from climate change in DU9 and DU11.	• Climate change is expected to increase the risk of high water temperature and low stream flows across all streams in DU9 and DU11, the extent of which will vary among streams. • Research to identify which streams are likely to experience the greatest change is necessary to inform future recovery planning.	3.7
RM.09	Expand and maintain fisheries monitoring programs in nearshore and offshore commercial fisheries that intercept Chinook salmon (i.e., mandate monitoring in all programs that do not currently have 100% coverage) and expand sample collection from Chinook salmon captured incidentally in these fisheries (i.e., coded wire tagging [CWT] and genetic stock identification [GSI])	• There is considerable variation in monitoring requirements across fisheries that have potential to intercept UFR Spring 5_2 Chinook salmon (e.g., 100% and mandated in East Bering Sea pollock fishery, but not mandated in Gulf of Alaska groundfish fisheries).	3.7

5. DISCUSSION

We developed a recovery plan for UFR Spring 5_2 Chinook salmon; a population aggregate that has a complex life history and occurs over a vast and diverse geographic area with equally diverse threats. In the following sections, we revisit the core questions addressed during the recovery planning process that summarize our explorations of the available evidence for different aspects of population status, causes of decline, and the best actions for encouraging recovery of UFR Spring 5_2 Chinook salmon.

5.1 Population Status and Environmental Context

Overall, the available evidence indicates that UFR Spring 5_2 Chinook salmon spawning populations declined in recent decades but are now showing some signs of improvement. Historical status assessments indicated elevated extinction risk, with DU9 assessed as "Threatened" and DU11 as "Endangered" (COSEWIC 2019), though the data used in these status

assessments was only current to 2016. Re-calculating the COSEWIC metrics with data to 2023 results in probable status assessments of "Special Concern" and "Threatened" respectively (Connors et al. 2024). More recent escapement estimates provide further evidence of increased abundance, particularly for DU11, where escapement increased to approximately 22,000 fish in 2025. Whether these recent increases represent a sustained change in population trajectory remains uncertain.

Important uncertainties remain regarding the relative influence of freshwater, migration corridor, and marine stressors due to limited population-specific data. Dynamic Factor Analysis identified four common trends underlying variation in spawning population abundance across UFR Spring 5_2 Chinook salmon populations. Collectively, these trends indicate that population dynamics are influenced by a combination of broad-scale and regionally structured processes operating across multiple spatial scales. While the increasing synchrony observed among populations since the mid-1990s suggests an important role for shared conditions, differences in how individual spawning populations tracked these trends indicate that local watershed characteristics and population-specific processes also influence population dynamics.

The assessment of population status remains constrained by substantial data gaps. Monitoring coverage across the large and remote geographic range of UFR Spring 5_2 Chinook salmon spawning populations is limited, resulting in reliance on relative escapement estimates and incomplete biological information. Key demographic parameters (e.g. productivity, life-stage specific survival rates, age-at-maturity estimates, etc.) remain poorly quantified, or estimates are based on decades-old information. These limitations increase uncertainty in evaluating the drivers of decline and constrain our ability to fully assess the magnitude of threats or model population dynamics.

5.2 Drivers of Decline and Factors Limiting Recovery

The decline of UFR Spring 5_2 Chinook salmon appears to have resulted from multiple threats that intensified during the period of population decline and operate across several life stages and environments rather than from a single dominant threat. Potentially key current threats include estuarine and marine threats of increased inter- and intra-specific competition, predation, reduced prey availability, elevated disease and parasite exposure, and freshwater threats of low stream flows and high water temperatures. The highest ranked threat of competition operates at broad spatial scales in marine environments where individuals from multiple spawning populations mix. Freshwater conditions have also changed during the period of decline, with increasing water temperatures and more frequent low-flow conditions across many watersheds due to climate-related hydrologic changes and landscape disturbances.

Largely synchronized abundance trends across UFR Spring 5_2 Chinook salmon spawning populations suggest a strong influence of drivers in shared environments, although there are stream-specific trends that suggest freshwater drivers as well. All populations experience marine habitats and the Fraser River mainstem, and the fact that declines occur despite differing conditions in natal watersheds indicates that factors in shared environments are likely contributing to the observed synchrony. Evidence supporting marine influences is strong, as coastwide reductions in smolt-to-adult survival and correlations in annual survival among geographically distant stream-type populations highlight the role of broad-scale oceanic conditions (Riddell et al 2013; Kilduff et al. 2015; Dorner et al. 2019; Crozier et al. 2021; Pearsall et al 2021; Welch et al., 2021; Atlas et al 2023).

The DU-level threat assessment identified three broad tiers of threats: marine competition was ranked highest, followed by low flows and elevated water temperatures in freshwater, with predation, disease and pathogens, prey availability, and fisheries comprising a third tier of generally moderate threats. These results are described in detail in Section 4.3 and reflect varying levels of evidence and uncertainty. In particular, the evidence for effects of competition on Chinook salmon is substantial, but direct evidence for UFR Spring 5_2 Chinook salmon remains limited. Similarly, although broad-scale marine conditions appear important in explaining population trends, freshwater conditions remain important because the extended freshwater residency and long migration distances of interior stream-type Chinook salmon increase exposure to local stressors. Rather than identifying a single limiting factor, the threat assessment indicates that UFR Spring 5_2 Chinook salmon are exposed to multiple interacting pressures whose relative importance likely varies among life stages, populations, and years.

The threat of fisheries illustrates the difference between the drivers of declines and factors currently limiting recovery. Historically, UFR Spring 5_2 Chinook salmon sustained high exploitation rates of 40-60% (Doutaz et al. 2021). However, beginning in the 1980s, DFO recognized population declines and began to implement fisheries management measures to reduce exploitation (Dobson et al. 2019). These measures were substantially expanded in 2008, 2012, and 2019. These management measures have proven to be very successful, with the Canadian marine fishing mortality being reduced to 1.7% from 2019-2024, compared to 11.2% from 2014-2018 (DFO 2025). The difference in exploitation including marine and freshwater fisheries is even more stark, with recent exploitation rates of 4.4%, compared to 23.7% from 2014-2018. The populations are showing signs of responding to lower exploitation rates, with DFO Wild Salmon Policy status moving

from red to amber for both populations in 2024 (DFO 2026b). These improvements suggest that fisheries management measures have contributed to recent gains and that maintaining low exploitation rates remains important to sustaining them. This is not to suggest that fisheries did not influence the population historically, or that recent increases in abundance necessarily can support increased harvest. Rather, at current low exploitation rates, further reductions in fishery mortality are expected to provide limited additional benefit to population recovery. The potential effects of any future increase in exploitation would need to be evaluated separately in the context of abundance, productivity, density dependence, and recovery objectives.

More broadly, both DUs have shown recent increases in abundance, including a substantial increase in UFR Spring 5_2 Chinook salmon escapement in 2025. This return occurred after completion of the threat assessment and was therefore not incorporated into the temporal scoring. The factors contributing to the recent increase are not yet known, and it is too early to determine whether it represents a sustained change in population trajectory. Accordingly, the 2025 return does not alter the historical relationships evaluated in the threat assessment but highlights the importance of continuing to evaluate population responses as additional years of data become available.

Attributing a specific proportion of UFR Spring 5_2 Chinook salmon decline to a specific threat is challenging. The drivers of the original decline may not be the same as factors currently preventing recovery. Smaller population sizes, reduced body size, and modified age structure may further reduce productivity and resilience to environmental variability. Uncertainty also remains high due to limited information on the spatial distribution, timing, and survival of UFR Spring 5_2 Chinook salmon in estuarine and marine environments and limited understanding of juvenile use of shared freshwater habitats such as the Fraser River mainstem and non-natal tributaries. Despite these uncertainties, the available evidence indicates that cumulative effects of multiple threats across life stages and environments are the most plausible explanation for the decline.

A key recommendation of our work is the completion of a life cycle model that will allow explicit exploration and quantification of the influence of different threats. Such a model would complement the threats assessment and provide more certainty about the influence of individual threats.

Primary drivers in shared environments

Multiple lines of evidence indicate that threats in shared environments are important factors limiting the recovery of UFR Spring 5_2 Chinook salmon. Stream-type Chinook salmon populations have declined coastwide despite substantial variation in freshwater conditions, including populations facing relatively limited anthropogenic freshwater impacts (Riddell et al. 2013; COSEWIC 2019; Ohlberger et al. 2020; ADFG 2022; Atlas et al. 2023). Correlations in abundance patterns among geographically distant interior Spring Chinook salmon populations support an important role for broad-scale drivers operating in shared environments (Welch et al. 2021; Atlas et al. 2023). For UFR Spring 5_2 Chinook salmon specifically, the four trends identified by the Dynamic Factor Analysis indicate that population dynamics reflect a combination of shared and more regionally or population-structured drivers. Similarities in abundance trends among many spawning populations, despite substantial variation in the magnitude and prevalence of freshwater threats among natal watersheds, are consistent with an influence of conditions experienced in shared environments. At the same time, differences among population trends indicate that natal watershed conditions and other population-specific processes also contribute to variation in abundance. Collectively, these patterns suggest that shared-environment threats are important at the population-aggregate scale, but do not support attributing observed trends to shared environments alone.

Comparisons of the two DUs reinforce this interpretation. Although DU9 spawning populations experience more extensive and higher-magnitude threats in natal watersheds than DU11, the status of DU9 is better than that of DU11 (based on the assessment presented in COSEWIC 2019 and DFO in press). While differences between the two DUs (e.g., migration distance and potential life-history differences) could contribute to differences in status, they do not provide a compelling explanation for the broadly similar declines observed across both DUs. If natal watershed threats were the primary determinant of DU-level trends, DU11, where natal watershed impacts are generally lower, might be expected to exhibit better population status than DU9. The observed pattern therefore suggests that differences in natal watershed condition alone are insufficient to explain DU-level status and trends, are consistent with an important role for drivers operating in shared environments.

Our ability to identify the relative impact of specific threats in shared environments is constrained by data gaps and because of the potential for complex interactions and amplification among threats. There is limited information on the spatial distribution and life-stage specific survival of UFR Spring 5_2 Chinook salmon, making it difficult to quantify when and where individuals are most exposed to potential stressors. In addition, the proportion of juveniles that use shared freshwater habitats (e.g. rear in the Fraser River mainstem or non-natal tributaries) and their absolute and relative survival

(contribution to total recruitment) is poorly understood. These gaps limit our capacity to link observed population declines directly to shared-environment threats or to evaluate how habitat use patterns mediate exposure and survival.

What is different about UFR Spring 5_2 Chinook salmon?

There are two key life-history differences between ocean- and stream-type populations that suggest they may experience quite different exposure threats. In the marine environments this includes substantial differences in migration distance and early marine strategies. Ocean-type Chinook salmon tend to migrate shorter distances in marine waters, remaining near their freshwater entry points and closer to shore. In contrast, stream-type fish like UFR Spring 5_2 Chinook salmon migrate farther offshore, potentially encountering different threats or ocean conditions. These groups also show different early marine strategies: ocean-type Chinook salmon enter the estuary at relatively small sizes and remain there for months, whereas stream-type Chinook salmon spend only days to weeks in the estuary before dispersing into nearshore environments. Consistent with these life-history differences, early-migrating stream-type Chinook salmon populations have generally shown stronger declines in abundance and survival in recent decades than many ocean-type populations (Atlas et al. 2021).

UFR Spring 5_2 Chinook salmon may also experience greater exposure to some threats in natal habitats or shared freshwater environments (i.e., the Fraser River mainstem) than populations with different freshwater life histories. A portion of juveniles disperse from their natal tributaries into the Fraser River mainstem to rear in on- and off-channel non-natal environments. Although the proportion of juveniles using these habitats, their residence times, and associated survival remain uncertain, this behaviour may increase exposure to threats occurring in the mainstem. Conversely, dispersal among natal and non-natal habitats may spread risk across multiple environments, and in some years non-natal habitats may contribute substantially to smolt production. UFR Spring 5_2 Chinook salmon also undertake relatively long freshwater migrations, increasing the duration of exposure to conditions in the mainstem corridor compared with populations with shorter migrations. Whether these differences in exposure translate into greater population-level effects remains uncertain.

5.3 Recovery Actions

Actions were prioritized using multiple evaluation criteria that considered expected biological response or value to recovery planning alongside feasibility, spatial scale, timing, and cost. Although the assessment was qualitative due to the absence of a life-cycle model, the scores provide a structured and transparent basis for comparing actions within three categories: actions intended to reverse the population trend, actions intended to prevent further decline, and research actions intended to reduce critical knowledge gaps. Among actions intended to reverse the trend, conservation hatchery supplementation received the highest overall score, followed by removal of finfish aquaculture sites along the migration route, and several actions addressing competition with industrial-scale hatchery-origin pink and chum salmon. Actions addressing freshwater habitat condition, predation, and fisheries also ranked among the higher-priority interventions.

The high ranking of conservation hatchery supplementation should be interpreted differently from actions intended to mitigate individual threats. Supplementation does not remove the underlying factors limiting UFR Spring 5_2 Chinook salmon; rather, it provides a potential means of increasing abundance and reducing demographic risk while those factors are addressed. Its ranking reflects the combination of a potentially meaningful near-term biological response, relatively low estimated cost, and the opportunity to implement the action adaptively. Accordingly, conservation enhancement should be viewed as complementary to, rather than a substitute for, actions that reduce mortality and improve habitat across the life cycle. Actions to prevent further decline focused primarily on protecting existing habitat and reducing exposure to future pressures, while research priorities addressed uncertainties that currently constrain recovery planning and evaluation. These rankings should be interpreted alongside the threat assessment and the uncertainty associated with individual action scores when determining which actions to advance for implementation.

Interactions among recovery actions and threats across life stages are also important to consider. Actions that increase freshwater survival or smolt production may increase the number of UFR Spring 5_2 Chinook salmon entering the marine environment, but gains in juvenile abundance may not translate proportionally into increased adult returns where marine survival is constrained by density-dependent processes, including competition. Reducing such threats at sea could therefore increase the benefits realized from actions implemented earlier in the life cycle and may also benefit other salmon populations exposed to the same pressures.

An important pattern emerging from the action assessment was that many of the highest overall scores were associated with actions intended to prevent further decline or reduce key knowledge gaps, rather than actions expected to directly reverse the population trend. This pattern should not be interpreted as indicating that preventative or research actions will necessarily provide greater biological benefits. Direct comparisons among action categories should also be interpreted

cautiously, as some scoring criteria differed depending on the objective of the action. Rather, it reflects the difficulty of identifying interventions that are both capable of producing a meaningful increase in UFR Spring 5_2 Chinook salmon abundance and feasible to implement at an appropriate scale. Actions to reverse the trend often require substantial intervention, operate across large or international spatial scales, have uncertain population-level effects, or face significant social, political, or economic constraints. In contrast, many preventative and research actions can be implemented with relatively high technical and social feasibility and at comparatively low cost, resulting in high overall assessment scores. These results highlight the value of pursuing a portfolio of actions: implementing feasible measures now to protect existing habitat and prevent additional pressures, investing in research that reduces uncertainty and improves future decision-making, while simultaneously advancing the more challenging interventions needed to achieve measurable increases in population abundance.

Socioeconomic, governance, and socio-cultural (rights-holder) considerations play an important role in shaping the feasibility and prioritization of recovery actions. Different rights holders, communities, and institutions may place varying emphasis on social, cultural, and economic values, which influences emphasis on which actions should be prioritized. To support transparent decision-making, we provide a scoring framework that can be adjusted using alternative criteria to reflect local priorities and governance contexts. While governance considerations were outside the scope of this recovery plan, previous planning efforts have identified potential improvements to support more effective decision-making and dialogue. As these discussions progress, evolving governance arrangements will continue to influence how recovery actions are assessed, prioritized, and implemented.

The apparent tension between conservation hatchery supplementation as the highest-ranked action and competition among salmon in the North Pacific as the highest-ranked threat highlights a broader challenge for salmon recovery. Individual jurisdictions have incentives to maintain or increase salmon production for conservation, cultural, and fisheries objectives, while the cumulative abundance of hatchery- and wild-origin salmon can intensify density-dependent competition in a shared marine environment. This creates an asymmetry in which enhancement can be implemented independently by individual jurisdictions, whereas meaningful reductions in high seas competition require coordinated action among North Pacific salmon-producing nations. Targeted conservation enhancement of UFR Spring 5_2 Chinook salmon may therefore provide a practical means of increasing abundance and reducing demographic risk in the near term, but it does not resolve the broader constraint imposed by high seas competition.

Next steps: research or action?

The available evidence provides a reasonable basis for identifying the major threats that may be limiting recovery of UFR Spring 5_2 Chinook salmon and for prioritizing actions to address them, although substantial uncertainty remains regarding the relative importance and magnitude of individual threats. Further research will improve understanding of UFR Spring 5_2 Chinook salmon biology, threat exposure, and the likely effectiveness of different interventions, but this uncertainty does not preclude taking recovery action. Similarly, where multiple threats interact, an inability to fully disentangle their relative contributions should not preclude action where there is sufficient evidence that they are collectively limiting recovery. Where the evidence is sufficient and the risks of unintended consequences are relatively low, actions can (and should) proceed while their effectiveness is evaluated through monitoring and adaptive management. For actions associated with greater uncertainty, potential unintended consequences, or substantial social and economic trade-offs, additional research and careful evaluation may be warranted alongside continued action planning. Importantly, some management choices will involve trade-offs that additional research can better characterize but may not ultimately resolve.

The general framework guiding this recovery plan assumes that reducing important threats will promote recovery. Given remaining uncertainty about the relative influence of individual threats and the population-level response to specific interventions, recovery effectiveness can be strengthened by applying several principles:

Address multiple threats simultaneously – Single-threat reductions may not elicit measurable recovery, so planning should consider complementary actions that address multiple important threats.

Focus on life-stage and population-specific vulnerabilities – Actions should target life stages and populations where increased survival has the greatest potential to produce meaningful biological responses.

Incorporate monitoring and adaptive management – Monitoring should include both ongoing population and threat monitoring and action-specific monitoring where outcomes are uncertain. Recovery strategies can then be refined as new information emerges, and the effectiveness of implemented actions becomes clearer.

Use the best available evidence while acknowledging uncertainty – Causal relationships between threats and population status will rarely be fully resolved before management decisions are required. Multiple lines of evidence, including population monitoring, threat assessments, life cycle models, and new research, should be used to prioritize actions and update decisions as understanding improves.

Prioritization at the DU level does not imply that lower-ranked actions lack value at finer spatial scales. Threats that are spatially restricted or affect only a small proportion of the population aggregate may have limited influence on DU-level recovery while still being important to individual spawning populations. Groups working within individual watersheds or marine areas can therefore use the within-environment threat assessment and action prioritization to identify locally important interventions, while the DU-level assessment provides guidance on actions expected to have broader population-level benefits.

Together, these approaches allow recovery efforts to proceed despite uncertainty while providing mechanisms to evaluate outcomes, refine priorities, and adapt management as new information becomes available.

Broader and complementary benefits of recovery actions

Although this recovery planning process focused on UFR Spring 5_2 Chinook salmon, many of the identified actions have the potential to provide benefits beyond the focal DUs. This is particularly true for actions that improve freshwater habitat and watershed processes or address threats operating in shared marine environments. Benefits are likely to be greatest for salmon populations that overlap with UFR Spring 5_2 Chinook salmon in their freshwater or marine distributions or are affected by similar threats.

Other Chinook salmon DUs with similar freshwater and marine distributions and habitat requirements, including Spring 4_2 and Summer 5_2 Chinook salmon, may benefit from many of the same freshwater and marine recovery actions (Dobson et al. 2020). Interior Fraser coho salmon (*Oncorhynchus kisutch*) also rear extensively in freshwater before migrating through the Strait of Georgia and into coastal and offshore marine environments (DFO 2019). Actions that restore freshwater habitat and watershed processes may therefore benefit coho, while actions addressing shared marine pressures may provide additional benefits. For example, pinniped predation can contribute substantially to marine mortality of juvenile coho salmon in the Strait of Georgia (Nelson et al. 2024), and competition with hatchery-origin pink salmon has also been implicated in variation in coho salmon productivity (Shaul and Geiger 2016).

Lake-type sockeye salmon (*O. nerka*) in the upper Fraser, including Early and Late Stuart, Bowron, and Quesnel populations, may similarly benefit from actions addressing freshwater temperature and watershed condition. Sockeye salmon can be particularly vulnerable to elevated water temperatures during upstream migration (Rand et al. 2006). They may also benefit from actions that reduce competition with highly abundant pink and chum salmon in marine environments, for which evidence of competition effects on sockeye salmon productivity is particularly strong (e.g., Beamish et al. 2010; Bugaev et al. 2001; Ruggerone et al. 2003; Ruggerone and Nielsen 2004; Ruggerone and Connors 2015; Connors et al. 2020).

Recovery of UFR Spring 5_2 Chinook salmon itself would also provide broader ecological, cultural, and social benefits. Increased abundance would support First Nations throughout the middle and upper Fraser that have relied on these populations for food, social, and ceremonial purposes since time immemorial. Increased abundance of large-bodied Chinook salmon could also contribute to prey availability for Southern Resident Killer Whales, for which Chinook salmon are an important, preferred prey (Lerner and Hunt 2023). Finally, actions that protect and restore riparian areas, improve watershed function, maintain environmental flows, or improve forest and water management can provide benefits extending beyond salmon recovery, including improved aquatic and terrestrial habitat, water quality, and resilience to climate-related disturbances.

These complementary benefits provide an additional consideration when prioritizing recovery investments. Actions that simultaneously benefit UFR Spring 5_2 Chinook salmon, other species, Indigenous and local communities, and broader ecosystem function may provide greater overall value than is captured by an assessment focused solely on the biological response of the focal DUs.

Uncertainties

Throughout the report we have described various uncertainties. Here, we reiterate the key uncertainties and some of their implications. We encountered significant data limitations across all life stages and environments. Existing habitat data for natal watersheds is incomplete and dated; much of the information is from the 1990s. To help overcome this limitation, we used input from individuals with local knowledge to confirm the current relevance of older information and to help fill

knowledge gaps. Present-day quantitative habitat assessments are needed across DU9 and DU11 to verify current conditions. Furthermore, the spatial and temporal distribution of several life stages is not well understood. This makes assessing the potential impact of threats as well as the efficacy of recovery actions very difficult. Significantly, there is evidence that juveniles rear in natal, non-natal, and mainstem habitats; however, we do not understand the mechanisms influencing the use of these different habitats, the proportions of fish using these different habitats, and the timing of movements to those locations. Information on marine distribution is also limited. The lack of data creates uncertainty in assessing population status and trends, constrains life cycle modeling, and makes it challenging to fully assess threat impacts. This finding is consistent with Riddell et al. (2013).

We chose to acknowledge climate change as a significant and persistent threat to both DUs but to focus on individual threat mechanisms. Addressing climate change will require substantial and complex international efforts that are outside the purview of this plan. We chose to consider the role of climate change in shaping each assessed threat rather than evaluating it independently.

Influence of assessment scale

The large geographic scale of this recovery assessment influenced the relative ranking of threats and recovery actions. Threats that operate across shared environments or affect a large proportion of UFR Spring 5_2 Chinook salmon will generally have greater potential to influence DU-level abundance than threats restricted to individual natal watersheds. Consequently, threats and actions operating in shared environments, including the Fraser River mainstem and marine environments, can rank highly even where their effects on individual populations remain uncertain. Conversely, a threat that is severe within a particular watershed may receive a relatively low DU-level score because only a small proportion of the population aggregate is exposed.

The DU-level rankings should therefore not be interpreted as indicating that lower-ranked threats or actions are unimportant at local scales. To address this distinction, the assessment includes both within-environment and DU-level results. Groups working within individual watersheds or marine areas can use the within-environment assessment to identify locally important threats and actions, while the DU-level assessment provides guidance on priorities expected to have the greatest influence on recovery of the population aggregate. More detailed watershed- and reach-scale planning will still be required to identify appropriate site-specific interventions.

This scale dependency is also a strength of the regional approach. By emphasizing threats and actions that operate across spawning populations, the DU-level assessment identifies broad-scale recovery needs that may be difficult to address through individual watershed planning, particularly during shared migration and marine life stages. Future watershed- or population-specific recovery plans can therefore build on the shared-environment assessment and associated actions identified here, while placing greater emphasis on locally specific natal-watershed threats and implementation priorities. In this way, regional- and watershed-scale recovery planning are complementary rather than interchangeable.

Conclusions

UFR Spring 5_2 Chinook salmon have experienced substantial long-term declines, although recent increases in abundance provide encouraging signs of improvement. This assessment presents a new method to assess threats affecting salmon and prioritize feasible recovery actions at a broad spatial scale, but can also be refined to support assessments at the watershed level. The results of this assessment indicate that recovery is influenced by multiple threats operating across freshwater, estuarine, and marine environments, with no single threat or life stage adequately explaining observed population trends. Despite important uncertainties, there is sufficient information to advance recovery through a portfolio of actions that directly increase abundance, prevent further decline, and address critical knowledge gaps. The priorities identified in this plan provide a basis for coordinated action and strategic investment, while monitoring, research, and adaptive management will allow recovery efforts to be refined as new information becomes available.

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