TECHNICAL STUDY #3 (2023)

Risk and Benefit Assessment of a Multi-year Salmon Reintroduction to the Upper Columbia River

The Columbia River Salmon Reintroduction Initiative

BRINGING *the* SALMON HOME
kɬ cp̓əlḱ stiḿ iʔ ntytyix
ʔatɬ suʔkiniɬ swaq̓mu
Tspelq̓entém re Sqlélten

Risk and Benefit Assessment of a Multi-year Salmon Reintroduction to the Upper Columbia River

Technical Study #3 (2023)

Bringing the Salmon Home: The Columbia River Salmon Reintroduction Initiative (CRSRI)

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Suggested Citation:

Burke, P., B. Rost-Komiya, E. Parkinson, C. Alexander, C. Morton, and M. Kang. 2023. Risk and Benefit Assessment of a Multi-year Salmon Reintroduction to the Upper Columbia River. Report prepared on behalf of Bringing the Salmon Home: The Columbia River Salmon Reintroduction Initiative by ESSA Technologies Ltd. for the Ktunaxa Nation Council (KNC). 41 pp plus 6 Appendices

Cover Photo: Eiko Jones

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Table of Contents

List of Figures

List of Tables

Acknowledgements

We would like to thank the Ktunaxa Nation, Syilx Okanagan Nation, and Secwépemc Nation for their support on this project; their guidance has been invaluable. Our work was further generously guided by the Bringing the Salmon Home Initiative's Indigenous Knowledge Counsel and informed by the Indigenous Knowledge Statement. We would also like to thank the expert participants who attended either or both project workshops, including Adam Neil, Ben Meunier, Chad Fuller, Chris Deeg, Conor Giorgi, Daniel Selbie, Herb Alex, Howard Stiff, Jon Bisset, Kaitlyn Dionne, Kyle Garver, Laura Robinson, Mindi Sheer, Misun Kang, Rhiannon Kirton, Richard Bussanich, Sierra Sullivan, Simon Jones, Stewart Johnson, Thomas Biladeau, Tyler Weir, and Will Warnock. We are especially grateful to Will Warnock, Michael Zimmer, Richard Bussanich, and Howie Wright who participated in interviews, discussions, and additional reviews.

The findings in this technical report represent the authors' understanding about the current state of knowledge based on input gathered through this research. The intent is that this work and related knowledge serves as a foundation for future salmon reintroduction efforts that will continue to evolve as future research and next phases of work are completed.

Bringing the Salmon Home: The Columbia River Salmon Reintroduction Initiative brings together five governments, the Syilx Okanagan, Ktunaxa, and Secwépemc Nations, with Canada and British Columbia, in an innovative Indigenous-led process to explore feasibility and options for salmon reintroduction to the Canadian portion of the upper Columbia River basin.

The Indigenous-led governance structure upholds the leadership of the three Nations, including as working group chairs. These tables include the Executive Working Group, Implementation Team, Indigenous Knowledge Counsel, Technical Working Group, and Communications Advisory Group.

This collaborative work is supported by the Indigenous Host Secretariat (Okanagan Nation Alliance) and the Management Team. Community engagement is facilitated by a team of three Nation-based Outreach & Engagement Organizers.

The shared long-term vision is to return fish stocks for Indigenous food, social and ceremonial needs, and to benefit all Columbia River residents and ecosystems as a whole.

Delivery of this study and development of this technical report was made possible with collaborative guidance, review and input across the Bringing the Salmon Home working groups.

For more information please see: **ColumbiaRiverSalmon.ca**

Glossary

ACB	Attributes of concern or benefit is a statement describing a relationship between a reintroduced donor stock and the recipient ecosystem, which represents a potential risk or benefit resulting from salmon reintroduction into the Columbia Basin
CRSRI	Bringing the Salmon Home: The Columbia River Salmon Reintroduction Initiative
DFO RAMS	Fisheries and Oceans Canada Risk Assessment Method for Salmon
ITC	Introductions and Transfers Committee of Fisheries and Oceans Canada
UN Declaration	United Nations Declaration on the Rights of Indigenous People (UNDRIP)
RBAF	Risk and Benefit Assessment Framework
Reintroduction Strategy	Salmonid species or ecotype being considered for reintroduction
Residualization	Ecological process wherein anadromous fish remain and reside in their natal stream instead of migrating into the ocean during their adult phase
SPU	Salmon Planning Unit
TI	Topic of Interest
TWG	Technical Working Group of Bringing the Salmon Home: The Columbia River Salmon Reintroduction Initiative
UCUT	Upper Columbia United Tribes
USGS	United States Geological Survey

Executive Summary

The extirpation of anadromous salmon from the Upper Columbia River has had a profound effect on the Syilx Okanagan Nation, Ktunaxa Nation, and Secwépemc Nation. These Nations are working with the governments of Canada and British Columbia to bring salmon home to the Upper Columbia.

During the 1940s, anadromous fish passage to the Canadian waters of the Columbia River was blocked by the construction of the Grand Coulee dam in Washington State. The dam was built without a fish ladder, which has effectively prevented traditional harvest of ocean-run salmon for nearly a century in the Upper Columbia. However, this is beginning to change. Bringing the Salmon Home: The Columbia River Salmon Reintroduction Initiative (CRSRI) is working to implement a long-term vision to return salmon stocks to the Upper Columbia for Indigenous food, social, and ceremonial needs, and to benefit the region's residents and ecosystems.

CRSRI commissioned this technical study to examine the potential effects of multi-year salmon reintroductions on the recipient ecosystem in the Upper Columbia Basin. The reintroduction of salmon and the re-establishment of salmon populations in the Upper Columbia after a three-quarter-century absence may have positive and/or negative effects on the recipient ecosystem. CRSRI is taking a precautionary approach to salmon reintroduction, whereby the potential effects of specific reintroduction actions are carefully assessed, uncertainties are identified, and mitigation strategies are put in place before reintroduction interventions are implemented. An important context for salmon reintroduction is the state of the recipient ecosystem. Despite historic presence of salmon throughout many reaches of the upper Columbia River, reintroduced salmon will encounter a novel ecosystem largely impacted by hydroelectric facilities without engineered fish passage and with altered fish communities. As a result, certain phases of reintroduction could result in unforeseen challenges and risks given how salmon and salmon reintroduction activities (e.g., fish passage) might interact with the ecosystem in its currently altered state.

This technical study describes a risk and benefit assessment designed for the purpose of supporting anadromous salmon reintroduction in the Upper Columbia. The focus of this technical study is to identify how salmon and salmon reintroduction strategies will interact with the current ecosystem and identify any possible ecological risks or benefits. The outcome of this technical study is a framework to identify key potential ecological risks or benefits associated with reintroduction strategies to support effective planning to avoid, minimize, and mitigate adverse impacts on the ecosystem. Specifically, **this study examines the risks and benefits of multi-year salmon reintroduction on the recipient ecological system in the Canadian waters of the upper Columbia River**. The purpose of this technical study is to:

1. Describe a comprehensive and replicable risk and benefit assessment framework for the reintroduction of salmonids to the Canadian waters of the Columbia River and;
2. Examine the risks and benefits of two multi-year salmon reintroduction strategies using expert elicitation, which we call a Phase I risk and benefit assessment (Phase I Assessment).

Section 1 provides background context for this work. Section 2 describes the objectives and methodology used for developing a Risk and Benefit Assessment Framework (RBAF) to assess the effects of salmon reintroduction on the recipient ecological system. This framework uses an expert

elicitation approach to assess risks and benefits within a structured process that can be replicated in the future. Section 1 of this study describes the results of the first application of the Risk and Benefit Assessment Framework to a subset of the proposed reintroduction strategies. Section 0 addresses future applications of the framework, identifies knowledge gaps relevant to reintroduction, and summarizes key steps in mitigation planning. A short summary of Sections 2, 3, and 4 can be found below.

Section 2 Summary: This study developed a custom Risk and Benefit Assessment Framework for the Canadian waters of the Upper Columbia based on existing risk assessment methods for salmon. The scope of the present assessment involves determining how salmon reintroduction strategies and reintroduced salmon populations will affect the recipient ecological system within the next seven human generations. The first step in developing an assessment framework was to enumerate all the potential risks and benefits of salmon reintroduction on the recipient ecosystem. We developed a process for articulating the directionality, impact, and causal mechanism for each risk and benefit using a consistent structure that could be rated by experts using standardized rubrics to prioritize risks and benefits with the greatest potential for impact. We recognized that risk or benefit of interactions between reintroduced anadromous salmon and the existing ecological system is dependent on the reintroduction strategy selected, so we worked with the leads for the CRSRI Technical Study #2 to establish the context for potential reintroduction. We convened a workshop with 18 technical experts to finalize the list of risk and benefit attributes and the draft assessment rubrics. Following the workshop, we refined our list of attributes of concern and benefit and prepared assessment materials for engaging experts to rate each attribute.

Section 3 Summary: Following the completion of the draft assessment framework, ESSA reconvened the same group of experts to complete a preliminary assessment using the framework, what we call the Phase I Risk and Benefit Assessment. This workshop represented the first phase in assessing risks and benefits associated with a salmon reintroduction program in the Upper Columbia, covering only a subset of total risks and benefits that would be considered as part of salmon reintroduction. Additional risks and benefits associated with other reintroduction strategies will be assessed in subsequent phases. The assessment involved an online pre-rating exercise, in-workshop re-rating for key attributes with uncertain risk, and group discussion on the nature of uncertainty and appropriate mitigation strategies to manage risk.

The two reintroduction approaches were assessed during the Phase I Assessment workshop: 1) Sockeye Salmon (*Oncorhynchus nerka*) from Okanagan-Wenatchee stock reintroduced into the Arrow Lakes Reservoir-Revelstoke Reach and 2) Summer-fall Chinook (*Oncorhynchus tshawytscha*) from the Okanagan-Methow-Wenatchee and Hanford and Chief Joe Tailrace stocks reintroduced into the Transboundary Reach. A total of 27 attributes of concern and benefit were assessed for Sockeye and 25 attributes of concern and benefit were assessed for summer-fall run Chinook. Attributes of greatest concern for both Sockeye and Chinook reintroduction approaches include (i) the risk of increase in invasive fish biomass due to predation on reintroduced Sockeye eggs, juveniles, and adults; (ii) the risk of increasing distribution and abundance of aquatic invasive species by establishing fish passage infrastructure (e.g., fishways or trap and truck) for reintroduced Sockeye; (iii) the risk of introduction and spread of pathogens that do not currently occur in the Canadian Upper Columbia and the risk of amplification of pathogens that already occur the Canadian Upper Columbia; and (iv) the risk of local decline in native fish biomass due to increased predation by residualized reintroduced Chinook.

Additional key risks for Sockeye included the risk of local decline in zooplankton abundance in oligotrophic lakes due to predation from reintroduced Sockeye and the risk of local decline in Kokanee biomass due to competition with reintroduced Sockeye. Key genetic risks included the risk of loss of genetic integrity to extant natural populations of Chinook below Chief Joseph Dam due to hybridization with reintroduced hatchery salmon and the risk of genetic homogenization and loss of local adaptation in Kokanee populations due to hybridization with reintroduced Sockeye. Key risks considered to be of moderate consequence include the risk of radioisotopes, heavy metals, and polychlorinated biphenyls being introduced to the Upper Columbia from downstream marine and riverine waters by migrating adult Chinook and the risk of increased human-wildlife conflict along riverbanks (e.g., with skunks, bears, etc.) due to increased Chinook carcass availability after spawning.

Section 4 Summary: We discuss how the framework can be applied in the future to additional reintroduction strategies, identify knowledge gaps that need to be filled with research, and describe the key approaches to mitigating risk that were raised during expert elicitation workshops. We identify five steps to be taken for future application of the framework, including considerations of efficiencies in the process. We then make recommendations for filling knowledge gaps in the categories of disease risk, mussel distribution, nutrient sinks, invasive fish passage, and ecotoxicology. Finally, we provide a short, prioritized list of mitigation strategies that can be initiated immediately.

We close the report with a series of appendices. Appendix A provides comprehensive information on expert ratings for each attribute of concern, a summary of expert discussion on the topic, suggested mitigation approaches, and outstanding questions relevant to the topic. Appendices B and C provide summary charts of all risk ratings for the Phase I Assessment. Appendix D is a short research memorandum relevant to current understanding of ecotoxicology risks. Appendix E is a list of the workshop Participants. Appendix F is the report bibliography, containing both core resources and additional materials cited and uncited.

In summary, this report establishes a framework for an assessment process that will support salmon reintroductions into the Upper Columbia. CRSRI is leading a rigorous reintroduction planning process with the aim to return anadromous stocks for Indigenous food, social and ceremonial needs, and to benefit the region's residents and ecosystems as a whole. The results of the Phase I Assessment represent a screening-level tool to prioritize risk to inform next steps in the salmon reintroduction process. Although the assessment was limited by data availability, which necessitated a qualitative approach, our methodology followed best practices for semi-quantitative risk assessments. We believe the limitations in the approach can be managed through careful planning and continuous risk management throughout the salmon reintroduction process, especially when carried out within the context of an adaptive management strategy. Ultimately, the results of this risk and benefit assessment, together with the results of the concurrent habitat and reintroduction studies (Technical Studies #1 and #2) and guidance from Indigenous knowledge, will inform collaborative salmon reintroduction planning and associated monitoring activities for anadromous salmon reintroduction into the Canadian waters of the Upper Columbia. After nearly a century of absence, the time is now to bring the salmon home. This report supports an informed, diligent, and efficient salmon reintroduction program for the Upper Columbia.

1. Introduction

Starting in the late 1930s, anadromous fish passage to the Canadian waters of the Columbia River was blocked by the construction of the Grand Coulee dam in Washington State. The dam was built without a fish ladder, which effectively prevented the Syilx Okanagan Nation, Ktunaxa Nation, and Secwépemc Nation from traditional harvest of ocean-run salmon that they have practiced since time immemorial. Subsequently, additional dams have been constructed on the river's mainstem, amounting to a total of three dams in Canada, and eleven in the United States, with many more along the river's tributaries. The Syilx Okanagan Nation, Ktunaxa Nation, and Secwépemc Nation are working with the governments of Canada and British Columbia to implement a long-term vision to return salmon stocks to the Upper Columbia for Indigenous food, social, and ceremonial needs, and to benefit the region's residents and ecosystems. Together, these five governments form Bringing the Salmon Home: The Columbia River Salmon Reintroduction Initiative (CRSRI) and together they are bringing the salmon home (https://columbiariversalmon.ca/).

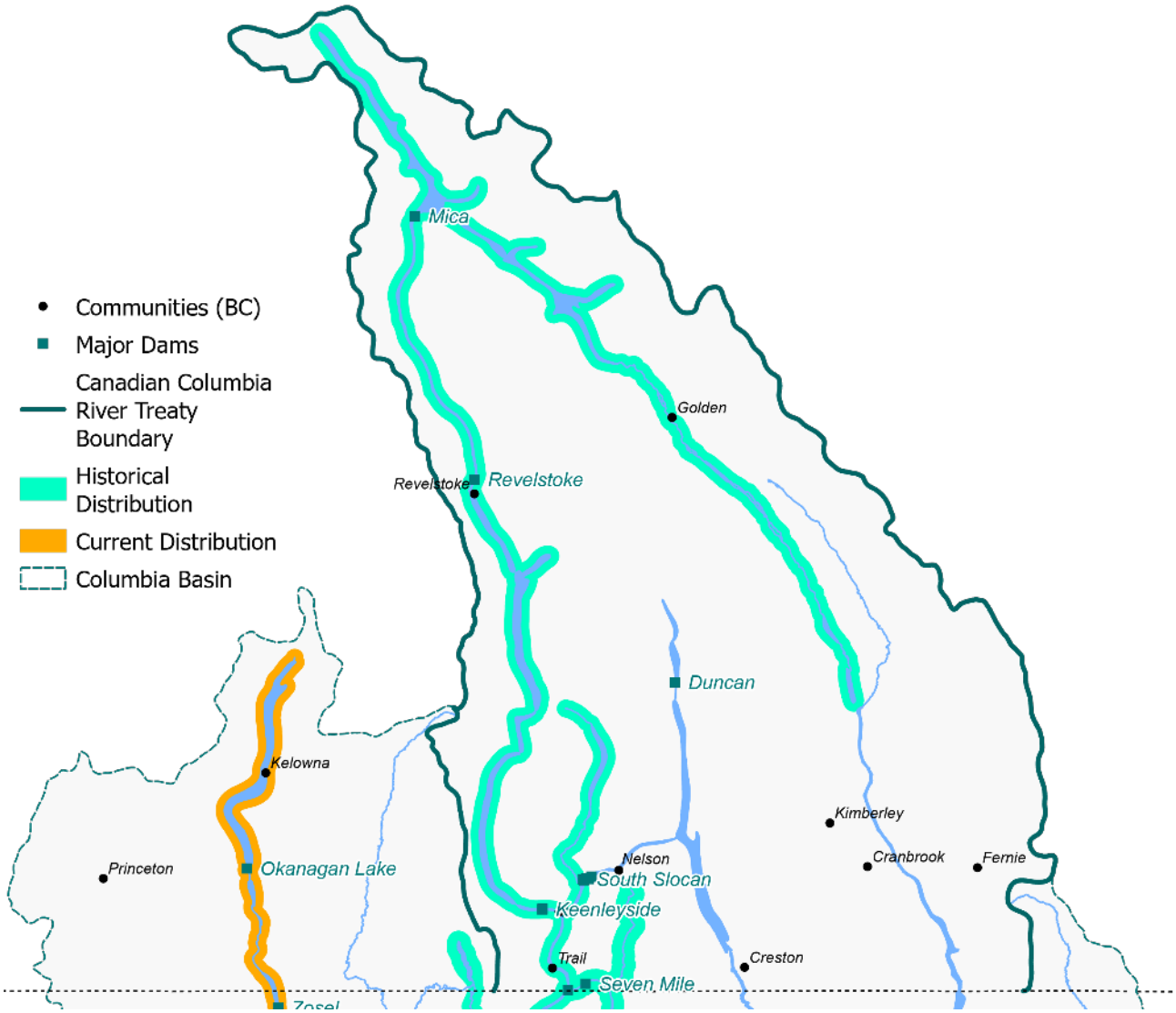
As part of its mission to bring the salmon home, CRSRI commissioned three technical studies in 2022 to support salmon reintroduction planning. The first technical study synthesizes what is known about salmon habitat capacity in the Upper Columbia and provides guidance on assessing the distribution, abundance, and quality of habitat for multiple salmon species. The second technical study provides recommendations on salmon reintroduction, including identifying high-potential donor stocks, conceptualizing effective reintroduction methodologies, and determining ecological and physio-chemical limitations to reintroduction. The third technical study is the topic of this report. The purpose of this technical study is to help characterize the risk of salmon reintroduction on the recipient ecosystem. Our technical study describes an **approach for developing a replicable risk and benefit assessment framework** for salmon reintroduction as well as **findings from an application of the framework** (i.e., Phase I Assessment). This work is expected to support future risk and benefit assessment in the Upper Columbia (i.e., Phase II and subsequent assessments).

Reintroducing anadromous salmon to the Canadian portion of the Upper Columbia River Basin is an Indigenous-led, collaborative initiative, which endeavors to return salmon to their historical range while supporting Indigenous self-determination and reconciliation. Bringing salmon home to unceded Indigenous territory has been a central issue for the Syilx Okanagan, Ktunaxa, and Secwépemc Nations for over 80 years.

1.1 Historical Salmon Use of the Upper Columbia River

Prior to the extirpation of anadromous salmon from the Upper Columbia River Basin following the completion of Grand Coulee Dam in 1941, distributions of Sockeye Salmon (*Oncorhynchus nerka*), Chinook Salmon (*Oncorhynchus tshawytscha*), and Steelhead (*Oncorhynchus mykiss*) occupied an extensive area of United States and Canada (see Figure 1). Between 14 to 18 lakes in the region provided nursery habitat for Sockeye Salmon, including Upper Arrow, Lower Arrow, and Slocan Lakes. Tributaries to these lakes provided important spawning and incubation habitat for Sockeye (CRSRI 2022).

Figure 1. Historical and Current Range of Chinook in the Upper Columbia River Basin



Multiple life histories of Chinook Salmon historically had unrestricted access to the mainstem of the Columbia River throughout its course to Columbia Lake, the mainstem of the Pend d'Oreille River below Metaline Falls, and 80 kilometers of the Kootenay River and its tributaries below Bonnington Falls, including the Slocan River. Adult Chinook used the Columbia River throughout the season, from June to October. It is possible that Chinook were also present in the Kettle River, but habitat in this reach is likely to have been restricted by natural falls just upstream of the US-Canada border (CRSRI 2022 and Warnock 2016).

Salmon production attributable to the Canadian Upper Columbia River Basin prior to the construction of Grand Coulee Dam cannot be estimated using direct observations from the historical record. There is, however, evidence that places the historical average returning spawner abundance above the

dam between 2.6 and 3.7 million adult salmon across all species; maximum spawner abundance could be substantially higher in any given year (CRSRI 2022).

1.2 Context for Collaborative Salmon Reintroduction

The five governments represented by CRSRI – the Syilx Okanagan Nation, the Ktunaxa Nation, the Secwépemc Nation, the Government of Canada, and the Government of British Columbia – have an interest in working together on an urgent basis to identify common interests, develop options and explore their feasibility, and take appropriate collective action to reintroduce anadromous salmon into the Upper Columbia River Basin. To demonstrate their interest and commitment to working together, these five governments signed a Letter of Agreement (LoA) on July 29, 2019, to formally establish their working relationship in good faith and in a respectful and transparent manner, to explore the risks and benefits of pursuing different actions in support of salmon reintroduction.

In the Letter of Agreement, the five governments have committed to:

- Acknowledge that the reintroduction and passage of anadromous salmon into the Upper Columbia River Basin is of critical importance to the Indigenous Nations due to their connections to anadromous salmon for cultural, spiritual, and livelihood purposes since time immemorial;
- Advance reconciliation between the Government of Canada, the Government of British Columbia, and the Indigenous Nations;
- Acknowledge the goal of the Indigenous Nations to achieve self-sustaining anadromous salmon populations and their passage throughout their historic range in the Upper Columbia River Basin;
- Accept that technical, scientific, and governance complexities and uncertainties require collaboration amongst the five governments;
- Align, complement, and share expertise from existing initiatives and priorities related to the reintroduction of anadromous salmon stocks and their habitats, where possible; and
- Benefit from the distinct perspectives, authorities, attributes, and capacities that each of the five governments brings to the collaborative effort.

In advancing reconciliation, the Parties also acknowledge that existing Aboriginal and treaty rights are recognized and affirmed in Section 35 (1) of the *Constitution Act, 1982*. Both Canada and British Columbia have committed to a renewed path of reconciliation with Indigenous peoples. This commitment includes working on a nation-to-nation and government-to-government basis, through discussion and engagement with the Indigenous Nations to advance reconciliation and renew the relationship through cooperation and recognition of Indigenous rights. Canada has fully endorsed the United Nations Declaration on the Rights of Indigenous Peoples (the “UN Declaration”) without qualification and is committed to implementing the UN Declaration. British Columbia has agreed to adopt the UN Declaration as a framework for reconciliation and to align provincial laws with the UN Declaration through the *Declaration on the Rights of Indigenous Peoples Act* [SBC 2019, c. 44].

2. Risk & Benefit Assessment Framework Development

The reintroduction of salmon and the re-establishment of salmon populations in the Upper Columbia after a three-quarter-century absence may have positive and/or negative effects on the recipient ecosystem. CRSRI is taking a **precautionary approach** to salmon reintroduction, whereby the potential effects of specific reintroduction actions are carefully assessed, uncertainties are identified, and mitigation strategies are put in place before reintroduction interventions are implemented.

An important context for salmon reintroduction is the state of the recipient ecosystem. Despite historic presence of salmon throughout many reaches of the upper Columbia River, reintroduced salmon will encounter a novel ecosystem largely impacted by hydroelectric facilities without engineered fish passage (except for the upper reaches to Mica dam) and with altered fish communities. Invasive species have entered the ecosystem, such as Mysis shrimp, Walleye (*Sander vitreus*), and Northern Pike (*Esox lucius*). As a result, certain phases of reintroduction could result in unforeseen challenges and risks given how salmon might interact with the ecosystem in its currently altered state.

This technical study describes a risk and benefit assessment to identify activities (which may have high risk of adverse impact), to identify activities that may have a beneficial impact, and to identify activities (which may have irreversible effect on the recipient ecosystem). Section 2 of this technical study describes the objectives and methodology used for developing a framework to assess risk and benefits on the recipient ecological system associated with the reintroduction of anadromous salmon into the Canadian waters of the Columbia River basin. This **framework uses an expert elicitation approach to assess risks and benefits within a structured process that can be replicated in the future**. Experts were identified from CRSRI institutions, academic researcher institutions, governments, and others familiar with salmon ecology in the region. Expert opinion was used to both identify key risk attributes and rate the attributes for prioritization.

The framework includes elements from other risk assessment methodologies but was tailored to the unique geographic and data availability context of the Canadian Upper Columbia River Basin. In Section 2.2, we describe other frameworks considered in developing our approach. In Section 2.3, we describe the methodology and components of a framework relevant to the Upper Columbia region. In Section 2.4, we discuss how the framework can be used to support salmon reintroduction planning.

2.1 Risk and Benefit Assessment Objectives

The focus of this technical study is to develop a framework to identify key potential ecological risks or benefits associated with reintroduction strategies to support effective planning to avoid, minimize, and mitigate adverse impacts on the ecosystem. Specifically, **this study examines the risks and benefits of multi-year salmon reintroduction on the recipient ecological system** in the Canadian waters of the upper Columbia River. The purpose of this technical study is to:

3. Describe a comprehensive and replicable risk and benefit assessment framework for the reintroduction of salmonids to the Canadian waters of the Columbia River and;
4. Conduct a preliminary prioritization exercise with a group of expert participants, which we call a Phase I risk and benefit assessment (Phase I Assessment).

Ultimately, the results of this risk and benefit assessment, together with the results of the concurrent habitat and reintroduction studies (Technical Studies #1 and #2) and guidance from Indigenous knowledge, will inform collaborative salmon reintroduction planning and associated monitoring activities. This comprehensive process will also support the Introductions and Transfers Committee (ITC) permitting processes.

Below, we outline the steps in developing a risk and benefit framework for salmon reintroduction.

2.2 Review of Existing Risk Assessment Frameworks Considered

Following the completion of the Grand Coulee dam, salmon were extirpated from waters of the Upper Columbia in Canada and the United States. More planning has been completed for salmon reintroductions in United States than in Canada. The Upper Columbia United Tribes (UCUT) – which include Coeur d'Alene Tribe of Indians, Confederated Tribes of the Colville Reservation, Kalispel Tribe of Indians, Kootenai Tribe of Idaho, and Spokane Tribe of Indians – and the United States Geological Survey (USGS) have collaborated to investigate reintroduction strategies and risks of reintroducing salmon to the US waters of the Upper Columbia.

The UCUT-USGS risk assessment for the reintroduction of anadromous salmon to the American portion of the Upper Columbia River (Hardiman et al. 2017) is a comprehensive and informative report that synthesizes relevant information on risk. Hardiman et al. (2017) focussed on evaluating the risks associated with a series of potential donor stocks for each species being reintroduced: Steelhead, spring Chinook, summer/fall Chinook, Sockeye, and Coho. The four general topics of concern considered by Hardiman et al. (2017) were: a) pathogen risks to resident species, b) genetic risks to resident and downstream anadromous conspecifics, c) competition with resident species, and d) predation on reintroduced salmonids by resident species. Across two workshops, these topics of concern were further broken down into more specific attributes of concern that were then assigned risk ratings by a panel of experts based on a given set of rubrics.

Hardiman et al. (2017) found that disease risks were generally considered to be higher with reintroduction through increasing pathogen burden to resident fish, but manageable in Chinook and Sockeye with appropriate surveillance, biosecurity, and treatment. Rainbow Trout (*Onchorhynchus mykiss*), Kokanee and Burbot (*Lota lota*) were considered the primary competitors of anadromous salmon, whereas non-native Walleye, Smallmouth Bass (*Micropterus dolomieu*), and Northern Pike were considered the primary predators of juvenile salmon.

These ecosystem interactions and risks are expected to be similar in the Canadian portion of the Columbia River. Unlike downstream reaches in the U.S., the Canadian Columbia River contains large, cold, and deep reservoirs/natural lakes (e.g., Slocan Lake) which support substantial populations of native cold-water fish (e.g., Kokanee, Bull Trout (*Salvelinus confluentus*), and Rainbow Trout). The specific pathways and magnitudes of ecological interactions between anadromous salmon, Mysis shrimp (*Mysis diluviana*), and these resident fish communities are uncertain, and it will be difficult to predict, detect, and attribute changes in these populations to salmon reintroductions. For instance, there is the potential that Sockeye and Kokanee fry compete for pelagic foods, adult Sockeye and Kokanee compete for spawning areas, and hybridization occurs between these eco-types (particularly for Arrow and Slocan Lakes) at levels beyond what would have been expected naturally prior to the exclusion of salmon from the upper Columbia. There is also the

potential for residualization (i.e., completion of entire life cycle in freshwater) of both Sockeye and Chinook Salmon, which might affect the current fish community and may be counter-productive to reintroduction goals.

The extensive data and resources made available to Hardiman et al. (2017) allowed the authors to assess risk at a higher resolution than is possible in Canadian waters. Given data availability, resources available for this project, and key geographic differences identified above, **we have used elements of existing risk assessment approaches to inform a novel approach to risk in Canadian waters of the Upper Columbia River**. Our approach still incorporates many of the aspects identified by Hardiman et al. (2017), as well as all the topics of interest specific to the Canadian Upper Columbia River identified in the CRSRI scope of work for Technical Study #3.

2.3 Development of Risk and Benefit Assessment Framework

ESSA technologies Ltd. (ESSA) has developed a Risk and Benefit Assessment Framework (RBAF) that borrows elements of both the UCUT-USGS (Hardiman et al. 2017) and Fisheries and Oceans Canada Risk Assessment Method for Salmon (RAMS) (Pearsall et al. 2020) risk approaches. We have diverged from the UCUT-USGS approach to accommodate the level of information available about donor stocks and the availability of resources in Canada.

The scope of the present assessment involves **determining how salmon reintroduction strategies and re-established salmon populations will affect the recipient ecological system within the next seven human generations**. Therefore, the directionality of the assessment is in assessing the risks and benefits of salmon reintroduction on the recipient ecological system. This section describes the development of the RBAF for the Canadian waters of the Upper Columbia.

2.3.1 Attributes of Concern or Benefit (ACBs)

In developing an RBAF, our first step was to identify the **attributes of concern and benefit (ACBs)** to be assessed. An ACB is a statement describing a relationship between a reintroduced donor stock and the recipient ecosystem that represents a potential risk or benefit resulting from salmon reintroduction. ACB statements are developed to be rated using a repeatable and comparable method for prioritizing risks across multiple reintroduction strategies during planning phases of a salmon reintroduction initiative.

The first step in developing an RBAF for the Canadian Upper Columbia was to determine all the potential risk and benefits to the recipient ecosystem resulting in reintroduction of anadromous salmon. We developed a long list of attributes that included 36 ACBs each for Sockeye and Chinook. We then refined this list through an expert elicitation workshop and follow-up discussions with experts.

To clearly communicate the risk or benefit being rated in each ACB, we developed a structure for consistently and clearly articulating the statements. Each statement includes three components: *directionality*, *impact*, and *causal mechanism*. Below, we provide an example using the statement: “Risk of local decline in Rainbow Trout abundance due to competition for food and space with introduced Chinook.”

Directionality: Answers the question: is the statement a benefit or risk? Each statement begins with directionality.

For example: **Risk of** local decline in Rainbow Trout abundance due to competition for food and space with introduced Chinook.

Impact: Answers the question: risk or benefit to what component of the recipient ecological system? Each statement includes an impact immediately after directionality and includes the following components:

- **Location & Scale:** Where does the impact occur and at what scale?
- **Recipient:** Risk to what part of the ecological system?

For example: Risk of **local decline in Rainbow Trout abundance** due to competition for food and space with introduced Chinook.

Causal mechanism: Answers the question: risk or benefit derives from what process? Each statement concludes with a cause and includes the following component:

- **Source:** From what source does the impact originate?

For example: Risk of local decline in Rainbow Trout abundance **due to competition for food and space with introduced Chinook**.

In using this structured approach to construct ACB statements, the goal was to ensure that risks and benefits are articulated clearly for expert rating.

After finalizing a long list of ACBs, we organized the risk and benefit statements into groups. We used the attributes and attribute groups identified in the UCUT-USGS and RAMS approaches as a point of departure to organize the list of ACBs. We settled on an attribute structure organized around the following **6 topics of interest (TIs)** based on the scope of work and the objectives of this study: 1) **ecological and biological interactions**, 2) **diseases and pathogens**, 3) **genetics**, 4) **ecotoxicology**, 5) **nutrient cycling**, and 6) **other**.

The resulting structure of the RBAF is:

Salmon lineage / reintroduction strategy (e.g., Sockeye in SPU#5 "S5")

Topic of Interest: Genetics "GE"

Attribute of Concern or Benefit 1: S5.GE.1

Attribute of Concern or Benefit 2: S5.GE.2

…

Topic of Interest: Disease and pathogens "DP"

Attribute of Concern or Benefit 3: S5.DP.1

Attribute of Concern or Benefit 4: S5.DP.2

…

We recognize that risk or benefit of interactions between reintroduced anadromous salmon and the existing ecological system **is dependent on the reintroduction strategy selected**. The donor

stock, the evolutionary history, the reintroduction methods (e.g., net pens versus truck and transport), the life stage of reintroduced fish, the number of reintroduced fish, and other aspects of the reintroduction strategy, will influence how reintroduced salmon and re-established salmon populations affect the ecological system. We worked with the leads for the CRSRI technical study who are developing the salmon reintroduction initial design (Technical Study #2: Plan for Experimental Reintroduction of Anadromous Salmon into Upper Columbia River: Proposed Implementation, Monitoring, and Evaluation) to establish the context for potential reintroduction. This context is summarized below in Section 3.1.

2.3.2 Expert Validation of Initial Framework

Development of the RBAF was informed by expert elicitation at multiple steps. ESSA coordinated multiple expert workshops to validate of the framework during the following events:

1. RBAF Scoping Workshop, which included a review of TIs, ACBs, and assessment rubrics;
2. Phase I Assessment Workshop, which involved a full assessment for a subset of reintroduction strategies; and
3. Independent engagement with experts to refine ACB statements that required expert knowledge.

Risk and Benefit Assessment Framework (RBAF) Scoping Workshop [April 7, 2022]

An RBAF Scoping workshop was held on April 7th, 2022, with 23 attendees, 18 of which were technical experts representing various interested parties (see Appendix E for a complete list of workshop participants and their respective affiliations). The purpose of this 4-hour workshop and the ensuing follow-up workshop debrief meetings was fourfold:

1) Review and revise the components of the proposed RBAF approach;
2) Clarify participants' understanding of the proposed reintroduction strategies for Sockeye and Chinook Salmon;
3) Refine lists of ACBs to be formally rated during a later workshop. This included being clear wherever possible about where the attributes of interest are relevant and to which salmon life-stages they can be applied; and
4) Refine three draft RBAF assessment rubrics – for (i) consequence, (ii) likelihood, and (iii) uncertainty – that would be employed in the Phase I Assessment Workshop.

The RBAF Scoping Workshop was successful in soliciting feedback on the proposed components of the RBAF. The collective expertise of the group covered key topics of interest for the RBAF and included expertise from the salmon reintroduction risk assessment conducted in the US waters of the Upper Columbia. Feedback and insights on the proposed RBAF were collected in a MURAL collaboration board and synthesized by ESSA.

The sections below summarize feedback received during the expert validation process for each topic of interest (TI):

> **Ecological and Biological Interactions:** The number of ACB statements for this TI decreased due to consolidating some redundant statements, which had low relevance to the

TWG (e.g., invasive species) and due to removing statements where the directionality of risk was on the reintroduced salmon population (e.g., Northern Pike predation on Sockeye).

Prior to this workshop, 23 draft ACB statements had been developed for assessment rating within this topic of interest. These attributes were sorted according to the direction of effect of the given risk or benefit; 13 attributes addressed the effects of salmon reintroduction on resident species, and 10 attributes addressed the effects of resident species on reintroduced salmon. Based on feedback received during the workshop and debrief meetings, it was decided that focussing only on the effects of reintroduction on resident species is more in line with the scope of work of this technical study. Moreover, there was consensus among experts that for the ACBs concerning competition, *abundance* and *size/condition* of resident fish species could be summarized using *biomass.* As such, these filters were applied to the 23 original ACBs to produce a revised list of 13 ACBs for Summer-fall Chinook and 15 ACBs for Sockeye that can be formally rated in a workshop setting.

Genetics: Prior to the RBAF Scoping Workshop, only one single potential ACB had been proposed for assessment rating under the genetic topic of interest: *the risk of genetic homogenization and loss of local adaptation in resident fish populations due to hybridization with introduced salmon*. Several other candidate ACBs were added to the MURAL board by workshop participants; however, for the most part they addressed risks that are out of scope for this study. As a result of workshop and debrief discussions, the originally proposed ACB was refined to specifically address the concern of hybridization with resident Sockeye and Chinook. One additional ACB was added to specifically address the risk of hybridization between Sockeye and Kokanee.

Diseases and Pathogens: Prior to the RBAF Scoping Workshop, two potential ACBs had been proposed for assessment rating within this topic of interest. These ACBs specifically addressed the *spread* of endemic and non-endemic pathogens within the system but did not address the *introduction* of new pathogens to the system. To accommodate this, the two candidate ACBs were modified to address the potential for reintroduced salmon to introduce pathogens to the local ecosystem. An additional two new ACBs were identified: 1) to characterize the risk to terrestrial predators associated with exposure to salmon poisoning disease from consumption of reintroduced fish and 2) the risk of reintroduced salmon providing evolutionary space for endemic pathogens to increase in virulence. The final list of ACBs resulting from the scoping workshop was 4 ACBs for this TI.

Ecotoxicology: In addition to one ACB proposed within this TI prior to the scoping workshop, two additional ACBs were added. Many other ACBs relevant to ecotoxicology were suggested by workshop participants, but these ACBs were more relevant to how the environment may affect reintroduced salmon, rather than vice versa, which is the subject of this assessment. These ACBs were rejected for inclusion in the RBAF because these ACBs were out of scope for this study. However, these items were addressed in the habitat study (Technical Study #1) or will be addressed in future studies.

Nutrient Cycling: Workshop participants confirmed the importance of two candidate ACBs that addressed the beneficial role of reintroduced salmon in delivering nutrients from downstream marine environments to upstream aquatic and terrestrial habitats. An additional

ACB was added to characterize the risk that out-migrating reintroduced salmon smolt may create a nutrient sink in the local ecosystem by net export of nutrients.

Other Attributes: One candidate ACB was proposed within this topic of interest prior to this workshop. This ACB addressed the issue of human safety along shorelines due to increased bear presence as a result of salmon reintroduction. Based on workshop feedback, this ACB was reworked to more broadly address the concern that decomposing fish carcasses on shorelines may attract nuisance or dangerous animals to urbanized shorelines. While a series of other candidate ACBs was proposed by workshop participants, all were rejected from the final list of ACBs to be formally rated because they were out of scope of this study and characterized various risks to reintroduction success, rather than to resident species. As such, the risks that were raised were addressed in the other technical studies or will be addressed in future studies.

A summary of key refinements to the list of candidate ABCs resulting from the RBAF Scoping Workshop includes:

- The directionality of effect was clarified (i.e., risk or benefit). The scope of the present study is to assess the risks of reintroduced salmon on the recipient ecological system.
- The TI's for diseases and pathogens were grouped together. Further, they were categorized based on current known presence or absence in the Canadian Upper Columbia River Basin.
- For the Ecological and Biological TI, many ACBs were grouped to simplify the assessment. Aquatic species were grouped together in categories – (i) invasive species, (ii) listed fish species (special concern, threatened, endangered), and (iii) fish species native to the Canadian Upper Columbia River – considering that the impact mechanism, location, and scale of potential effects would be similar across groups. Where individual species characteristics diverged from the group characteristics, a separate ACB was used.
- Keystone species that warrant independent consideration due to their potential to have significant interactions with reintroduced salmonids were identified.

In addition to meaningful discussion about the list of candidate ACBs, the RBAF Scoping Workshop provided opportunity for participants to comment on the three draft assessment rubrics for (i) consequence, (ii) likelihood, and (iii) uncertainty. The rubrics were updated with comments received during the workshop. The expert elicitation workshop was followed by focused interviews with experts and members of the CRSRI Technical Working Group to refine ACB statements in preparation for the Phase I Assessment Workshop.

Framework Assessment Rubric Updates: Based on discussion during the Phase I Assessment Workshop and feedback from participants, a key outcome of the workshop was adjustment of the consequence rubric (see Section 2.3.3 for a full discussion of the framework assessment rubrics). During the Phase I Assessment, we recognized that the consequence rubric could be aggregated by using a 3-point rating scale rather than a 5-point rating scale.

Table 1 shows the obsolete consequence rubric used for Phase I Assessment, which included reference to *potential mitigation* that could be applied to risks. During the workshop, ESSA provided explicit direction to participants to rate risks and benefits considering that no mitigation would be undertaken to represent a baseline risk level.

In the RBAF, the purpose of our framework assessment rubrics is to provide explicit evaluation criteria for assigning a *risk rating* to an attribute of concern or benefit. When applying the rubric during the Phase I Assessment Workshop, we identified two limitations of our preliminary approach to rating risk: 1) when using integer ratings in the rubric, the categorical nature of the risk rating become diluted and confusing to participants; however, this method was selected due to a more robust risk assessment approach (see Cox 2008) and 2) mitigations are best considered after specific risks and benefits are assessed. Because each ACB does not include a mitigation in the statement, rating risk with consideration for potential future mitigation introduced uncertainty into the rating, since each participant may consider different mitigation approaches. To simplify and minimize uncertainty, we made the following changes to the RBAF assessment rubrics for future use: 1) **rating categories will be used instead of scores**, and 2) **the consequence rubric was re-scaled from a 5-point to a 3-point scale**. These changes will enable effective future risk and benefit assessment in the basin.

Considering these changes to the framework assessment rubrics, we aggregated the consequence ratings from a 5-point scale to a 3-point scale (see Appendix B and Appendix C), which did not change the consequence rating (see Table 1).

Table 1. Obsolete Consequence Rubric Used for the Phase I Assessment Workshop

Consequence Score	Consequence Rating	Description
1	**Negligible**	The degree of impact to habitat or populations is **NEGLIGIBLE**
2	**Modest**	The degree of impact to habitat or populations is **MODEST**. For risk of adverse impacts, **mitigation actions are expected to partially or fully offset impacts** within seven human generations
3	**Modest**	The degree of impact to habitat or populations is **MODEST and cannot easily be mitigated**
4	**Substantial**	The degree of impact to habitat or populations is **SUBSTANTIAL**. For risk of adverse impacts, **mitigation actions are expected to partially or fully offset impacts** within seven generations
5	**Substantial**	The degree of impact to habitat or populations is **SUBSTANTIAL and cannot easily be mitigated**

2.3.3 Framework Assessment Rubrics

This risk and benefit assessment framework for reintroduction of salmon into the Canadian waters of the Columbia River uses expert elicitation to assess three aspects of risk and benefit: 1) consequence, 2) likelihood, and 3) uncertainty. Each of these three aspects is addressed using standardized rubrics described in detail below.

Consequence Rating: Consequence describes the extent of impact of a given risk or benefit on the recipient ecosystem, including habitats and populations, over the next seven human generations. The RBAF asks experts to assign a consequence rating using a 3-point rubric (Table 2). Ratings are categories of consequence subjectively assigned given an expert's knowledge of the attribute. Refer to Section 2.3.2 for methods used to finalize the consequence rubric following the Phase I Assessment Workshop.

Table 2. Consequence Rubric for the Risk and Benefit Assessment Framework

Consequence Rating	Description
Negligible	The degree of impact to recipient ecosystem is **NEGLIGIBLE**
Modest	The degree of impact to recipient ecosystem is **MODEST**
Substantial	The degree of impact to recipient ecosystem is **SUBSTANTIAL**

Likelihood Rating: Likelihood describes the probability of a given risk or benefit occurring over the next seven human generations. The RBAF asks experts to assign a likelihood rating using a 5-point rubric (Table 3). Ratings represent a subjective expectation of how probable an impact may be given an expert's knowledge of the attribute. The probability of occurrence is not equal across each category in the rubric, with ratings of negligible and nearly certain representing a small total percentage probability.

Table 3. Likelihood Rubric for the Risk and Benefit Assessment Framework

Likelihood Rating	Description
Negligible	The risk or benefit has little to no chance to occur (**0% to 1% probability**)
Low	The risk or benefit is unlikely but might occur (**1% to 33% probability**)
Moderate	The risk or benefit is likely to occur (**33% to 66% probability**)
Substantial	The risk or benefit is very likely to occur (**66% to 99% probability**)
Nearly Certain	The risk or benefit is expected to occur (**99% to 100% probability**)

Uncertainty Rating: Uncertainty describes the level of knowledge, research, and evidence in the validity of a risk or benefit impact. The RBAF asks experts to assign an uncertainty rating using a 3-point rubric for high, medium, and low uncertainty.

High: Uncertainty is high when understanding is low and/or the nature of the outcome is greatly dependent on highly variable ecosystem processes or other external confounding factors. Many important aspects of the attribute are subject of active ongoing research or have theoretical support with some evidence, semi-quantitative relationships, several alternative hypotheses and/or confounding factors. Data in support of the functional relationship is derived from lab or theoretical studies without field evidence.

Medium: Uncertainty is medium when understanding is moderate to high, but the nature of outcome is moderately dependent on other variable ecosystem processes or uncertain external confounding factors. Some strong evidence but not conclusive, only medium strength predictive power, some evidence for competing hypotheses and/or confounding factors. Data in support of the effect pathway(s) is derived from direct field observations or from field observations outside the Columbia Basin.

Low: Uncertainty is low when understanding is high, and nature of outcome is largely unconstrained by variability in ecosystem dynamics or other confounding external factors. Is generally accepted, peer reviewed empirical evidence, strong predictive power and understanding, for which evidence is not contested or confounded. Data in support of the effect pathway(s) is derived from direct Columbia Basin field observations.

2.3.4 Assignment of Risk and Benefit

Risk can be defined as uncertainty in the outcome of a future action, although in this study we specifically define risk of salmon reintroduction in the Canadian Columbia Basin as **uncertainty in adverse outcomes on the recipient ecosystem**. We use benefit to refer to the inverse, which are beneficial outcomes. In this study, we used expert elicitation to assign a category of risk and benefit for each ACB based on ratings of consequence and likelihood using a semi-quantitative risk matrix approach as shown in

Figure 2 below. We used a semi-quantitative approach that satisfies the principle of weak consistency (Cox 2008) based on ratings assigned by experts to determine where point coordinate pairs (i.e., likelihood and consequence ratings) occurred on the risk matrix. In Figure 2a below, likelihood and consequence ratings for the ACB Csf1.EI.6 are displayed using a jitter to avoid point overlap, with likelihood on the x-axis and consequence on the y-axis. The figure displays 10 pre-

workshop ratings with a coordinate average for all ratings indicated by the number "1," which obscures an eleventh rating of modest consequence and low likelihood (i.e., located "behind" the coordinate average). This coordinate average is shown for display and is not the exact method used to calculate risk. The risk matrix in Figure 2 shows spread in ratings from low to high risk, indicated by a range of ratings across both axes.

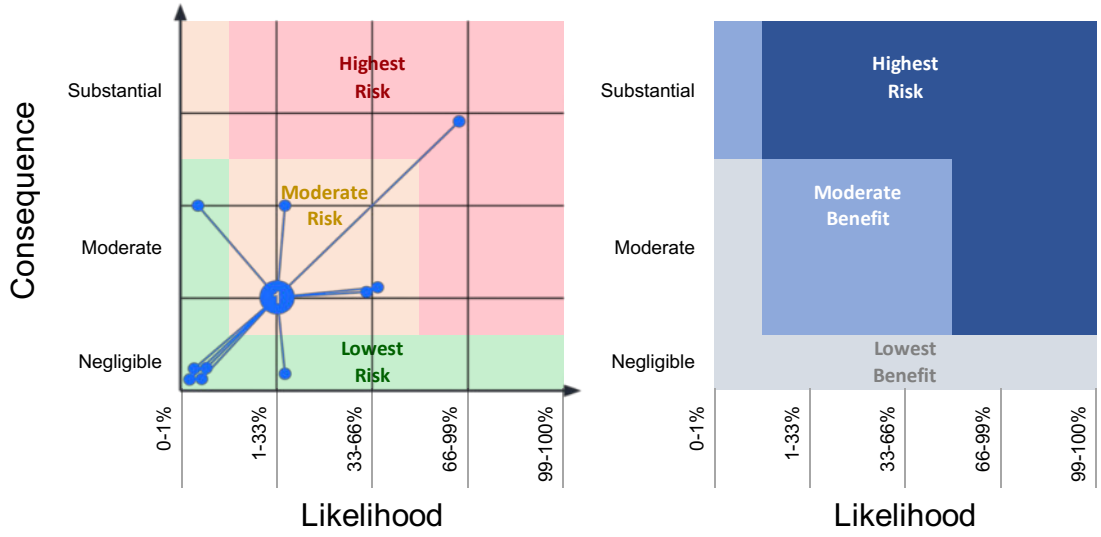


Figure 2. Assignment of Risk and Benefit Categories Based on Likelihood and Consequence (Using a Single ACB as an example)

Phase I Assessment Workshop [May 13th, 2022]

ESSA reconvened the same group of experts who validated the risk and benefit framework to complete a risk and benefit assessment. The 4-hour Phase I Assessment workshop included 16 expert attendees and was held on May 13th, 2022 (see Appendix E for a complete list of workshop participants and their respective affiliations). This workshop represents the **first phase** (i.e., Phase I) in assessing risks and benefits associated with a salmon reintroduction program in the Upper Columbia, as the workshop covered a subset of total risks and benefits that should be considered as part of salmon reintroduction (see Section 3.1 for details on the reintroduction strategies considered). Additional risks and benefits associated with other reintroduction strategies will be assessed in subsequent phases.

The Phase I Assessment involved (i) an online pre-rating exercise, (ii) in-workshop re-rating for key ACBs, and (iii) group discussion of uncertainty and mitigation strategies. The 16 experts were placed into two groups aligned with their area of expertise, which included either ecological and biological interactions or diseases and pathogens, genetics, ecotoxicology, nutrient cycling, and other attributes. The primary purpose of the workshop was to rate and prioritize risk and benefits using the RBAF (results are presented in Section 1), but a secondary outcome was additional insight into structuring the RBAF for future application.

Phase I Assessment Pre-rating, Re-rating, and Discussion: A key aspect of the Phase I Assessment Workshop included a group discussion of consequence, likelihood, and uncertainty

ratings. Prior to the workshop, experts were asked to assign ratings to each ACB using an online interactive survey using Mentimeter. The results of the survey were visualized and shared during the workshop using figures like

Figure 2 above. Breakout groups were assembled to facilitate small group discussion for key attributes with high divergence in survey results. We used the pre-scoring results to encourage discussion on the ACBs with highest uncertainty, spread, and divergence in survey ratings. Discrepancies in ratings were discussed during breakout groups and attributes that required reassessment were re-rated. In some cases, the group of experts reached general consensus on the ratings. Experts also discussed mitigations strategies that may be relevant to each ACB. All comments and discussion were recorded and have been synthesized and reported in Appendix A of this report.

Methodology for Assigning Risk and Benefit

Two sets of ratings were developed for *likelihood* and *consequence* during the risk assessment: 1) **pre-workshop ratings** and 2) **adjusted in-workshop re-ratings**. These ratings represent an iterative approach to improving the quality of the rating, given the subjective nature of expert elicitation. Not all ACBs were re-rated during the second workshop, due to time constraints. We selected the ACBs with greatest uncertainty and widest spread in pre-workshop ratings to re-rate. We calculated risk from the adjusted in-workshop re-ratings for 25 ACBs and from the pre-workshop ratings for 27 ACBs.

The level of risk and benefit for each ACB was calculated using the mode of all ratings. Where consensus was reached during the workshop, the in-workshop re-rating was used. We assigned unique risk values to each ACB by applying the following rules, resulting in a unitless scale with values ranging between 0 and 60, where *L* stands for likelihood, *C* stands for consequence, and *R* stands for risk:

$$\mathrm{Mo}_C = 1 \implies \mathrm{R} = \mathrm{Mo}_L * \mathrm{Mo}_C$$

$$\mathrm{Mo}_C = 2 \implies \mathrm{R} = \mathrm{Mo}_L * 6$$

$$\mathrm{Mo}_C = 3 \implies \mathrm{R} = \mathrm{Mo}_L * 12$$

Lowest risk was assigned to ACBs with *R* between 1 and 10. Moderate risk was assigned to ACBs with *R* between 11 and 15. Highest risk was assigned to ACBs with *R* between 16 and 60. For both reintroduction strategies, the range of risk values was 1 to 48. For chinook, the mean risk value was 14.64 ± 11.6 and for sockeye, the mean risk value was 16.63 ± 12.4. Risk values for each ACB are reported in Section 3 below.

A risk matrix is a common tool used in risk assessment, and although this approach suffers from known limitations (Cox 2008), our methodology met the needs of this study considering substantial data limitations for the Canadian Columbia Basin, time and resources available to this assessment, and the qualitative nature of our expert-elicitation process. The **results of our risk analysis represent a screening-level assessment suitable for prioritization of risk to inform next steps in the salmon reintroduction process**. Key limitations in this approach include: 1) a generalizing of risk into broad categories (i.e., highest, moderate, and lowest risk), necessitating judgement on behalf of users of the risk assessment and 2) the possibility that “liminal” risks have been mis-classified and therefore may not be adequately managed through avoidance and mitigation stages.

These limitations can be managed through **careful planning** and **continuous risk management** throughout the salmon reintroduction process, **especially when carried out within the context of adaptive management**.

2.4 Applying the Risk and Benefit Assessment Framework

The RBAF was designed to be applied repeatably for all reintroduction strategies under consideration for the Canadian waters of the Upper Columbia River. This section describes how the RBAF can be used to support salmon reintroduction planning. A summary of the steps in conducting the Phase I Assessment for salmon reintroduction in the Upper Columbia includes:

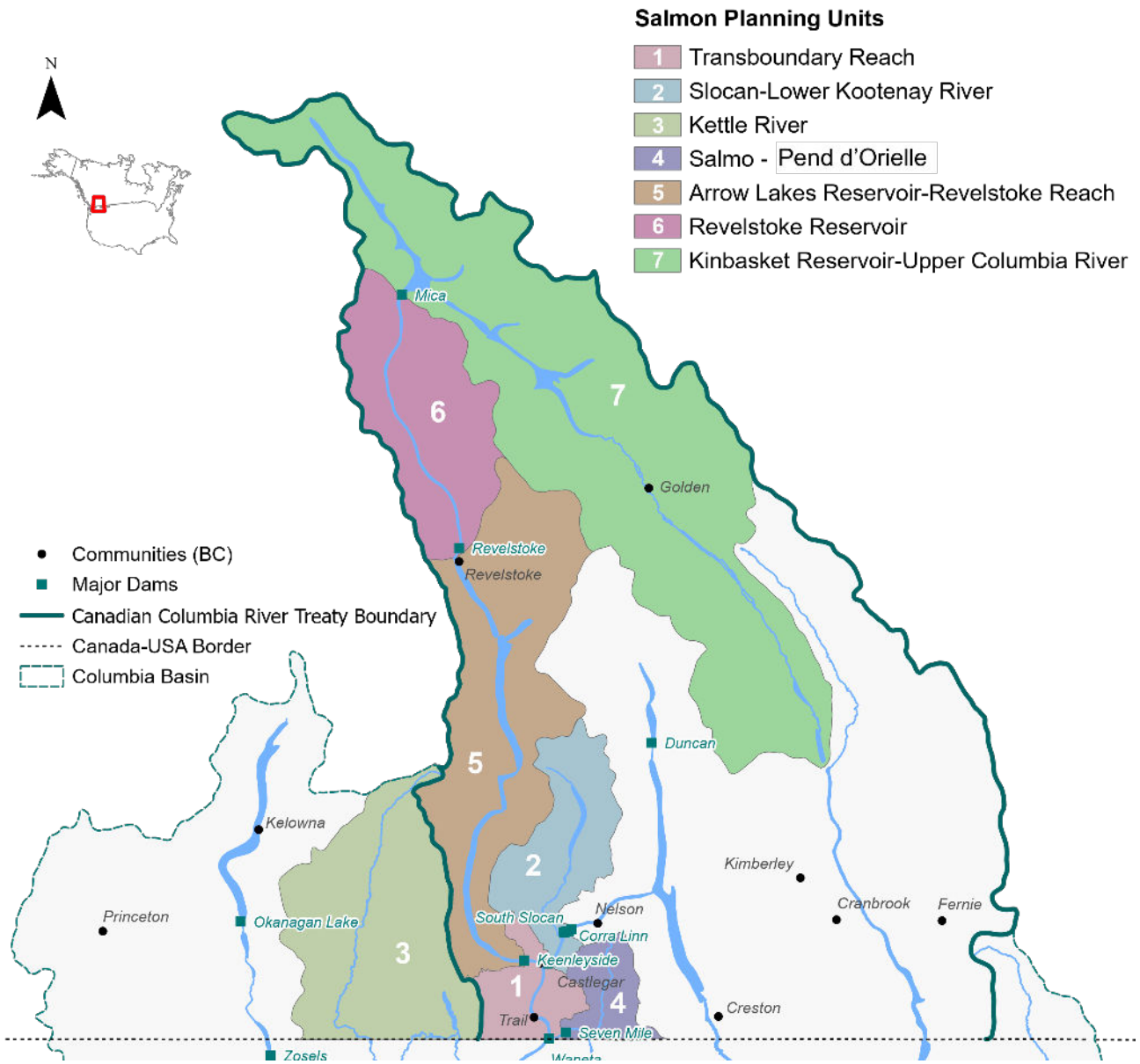
1) Define the scope of assessment through:
    a. Identification of the reintroduction strategy to be employed, and
    b. Identification of the spatial and temporal scale of assessment;
2) Engage a group of taxa experts to assign consequence, likelihood, and uncertainty ratings using the RBAF; and
3) Prioritize the greatest risks and key mitigation measures resulting from expert elicitation.

This methodology was developed to be repeatable in assessing future reintroduction approaches in other regions of the Canadian Columbia basin.

Defining the scope of each phase of an assessment involves explicitly identifying what will be done, where it will be done, and how long the effects may last. At the time of writing, the anadromous **salmon lineages** that are under consideration for reintroduction in the Canadian waters of the Columbia River include: 1) Sockeye Salmon, 2) spring Chinook, and 3) summer-fall Chinook. The **temporal scale** of reintroduction and re-establishment is the next seven human generations. The **spatial scale** of reintroduction may vary for each lineage and will be planned within the seven salmon planning units (SPUs) of the Canadian Upper Columbia basin (Figure 3).

The RBAF provides a list of ACBs tailored to each salmon lineage within each salmon planning unit. Given the habitat diversity and species habitat preference across the basin, the relevance of the attributes of concern or benefit for each salmon lineage varies across salmon planning units. A total of 16 salmon planning unit / species lineage combinations occur in the Canadian Upper Columbia basin, and **two salmon planning unit / species lineage combinations were assessed in this report**. The complete RBAF is available as an .xls workbook and can be accessed here.

Figure 3. Salmon Planning Units in the Upper Columbia River Basin



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3. Phase I Risk and Benefit Assessment Findings

The Phase I Assessment involved applying the Risk and Benefit Assessment Framework (RBAF) to a subset of the most likely reintroduction strategies. Future phases will use the RBAF to assess risk to other reintroduction strategies as planning advances. The Phase I Assessment was completed on

May 13th, 2022, by a group of experts with broad technical knowledge relevant to salmon reintroduction in the upper Columbia River.

This section summarizes the Phase I Assessment findings. A comprehensive accounting of risk ratings and potential mitigation strategies to reduce risk can be found in Appendix A.

3.1 Reintroduction Strategies Considered

The full RBAF is long, with 16 salmon planning unit / species lineage combinations, each with 20 to 30 attributes of concern or benefit (ACBs). To maximize efficiency for the Phase I Assessment, ESSA worked with Bringing the Salmon Home: The Columbia River Salmon Reintroduction Initiative Technical Working Group (CRSRI TWG) to prioritize two reintroduction strategies for the first implementation of the RBAF. Each of these strategies represents a unique salmon planning unit / species lineage combination. The two reintroduction strategies implemented during the Phase I Assessment workshop were:

1. **Summer-fall Chinook strategy:** Chinook from the Okanagan-Methow-Wenatchee and Hanford and Chief Joe Tailrace stocks reintroduced into the Transboundary Reach (SPU #1; Figure 4).
2. **Sockeye strategy:** Sockeye Salmon from Okanagan-Wenatchee stock reintroduced into the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5; Figure 5).

The proposed donor stock for Sockeye reintroduction into Arrow Lakes Reservoir-Revelstoke Reach (SPU #5) is the Okanagan-Wenatchee stock. During the pilot phase of the project, eggs, and sub-yearlings from Okanagan or Osoyoos lake will be reintroduced, whereas phases 1 and 2 will likely use eggs and sub-yearlings from Shingle Creek and Wenatchee (UCUT). In time, fish release volumes are estimated to amount to up to 100,000 adults and 10,000,000 juveniles.

The proposed donor stocks for summer-fall Chinook reintroduction into the Transboundary Reach (SPU #1) are the Okanagan-Methow-Wenatchee and Hanford and Chief Joe Tailrace stocks. During the pilot phase of the project, adults from Wells Dam and Douglas County, and eggs from incubation-matching environments and acclimation ponds will be reintroduced. It is likely that fish from the same regions will also be used during reintroduction phases 1 and 2 of the project, although this is yet uncertain. Fish volumes are estimated to amount to up to 50,000 adults and 1,000,000 juveniles.

Across all TIs, a total of **27 ACBs were identified for Sockeye** and **25 ACBs were identified for summer-fall run Chinook**. Future applications of this RBAF include assessing the risks associated with spring Chinook reintroduction, as well as reintroduction of other salmonid species across the 7 SPUs.

Figure 4: Salmon Planning Unit # 1: Transboundary Reach

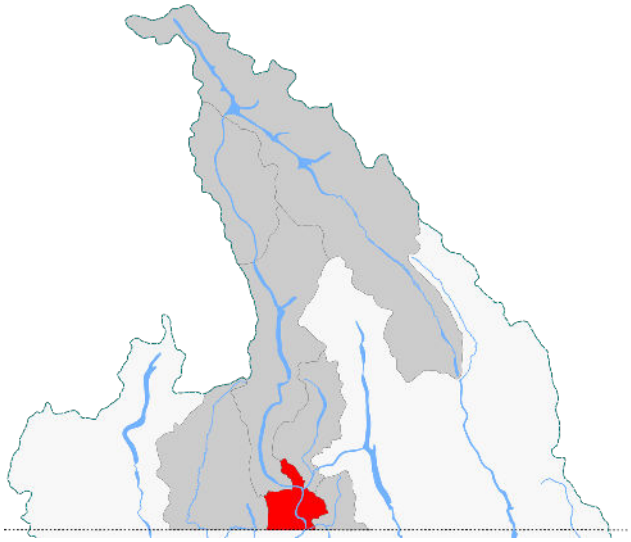
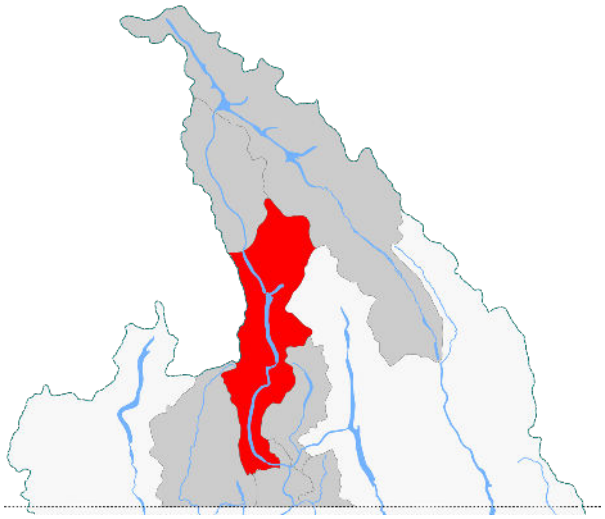


Figure 5: Salmon Planning Unit # 5: Arrow Lakes Reservoir - Revelstoke Reach



3.2 Areas of Highest Risk and/or Uncertainty

Attributes of greatest risk were identified based on the intersection of their consequence and likelihood ratings following expert in-workshop scoring and discussion. Appendix A includes methodology for assigning risk ratings. All ACBs in this section were assigned consequence ratings of **Substantial** or **Modest**, and likelihood ratings of **Substantial** or **Moderate**. Attributes of benefit are included in Section 3.4.

3.2.1 Sockeye Salmon Reintroduction

Twelve (12) key risks for Sockeye were identified using the consequence and likelihood ratings assigned based on expert rating of the ACBs. The risk values and ratings are provided in Table 4 and are discussed in greater detail below. See Appendix A for detailed reports of expert ratings and in-workshop discussion for each ACB and Appendix B for a summary table of risk ratings.

Table 4. Attributes of Highest Risk Identified During Phase I Assessment of Sockeye Reintroduction into SPU #5

ACB No.	Risk Value	Consequence	Likelihood	Uncertainty
S5.EI.11	**48**	**Substantial**	**Substantial**	**Medium**
Risk of increasing distribution and abundance of aquatic invasive species by establishing fish passage infrastructure (e.g., fishways or trap and truck) for reintroduced Sockeye				
S5.EI.13	**48**	**Substantial**	**Substantial**	**Medium, High**
Risk of increase in **invasive fish** biomass due to predation on **reintroduced Sockeye** eggs, juveniles, and adults				

ACB No.	Risk Value	Consequence	Likelihood	Uncertainty
S5.DP.1	**36**	**Substantial**	**Moderate**	**High**
Risk of introduction and spread of pathogens that do not currently occur in the Canadian Upper Columbia (e.g., IHNV M-clade, IPNV, Whirling Disease) by reintroduced Sockeye				
S5.EI.3	**24**	**Modest**	**Substantial**	**Low, Medium**
Risk of local decline in Kokanee biomass due to competition with reintroduced Sockeye				
S5.DP.2	**24**	**Modest**	**Substantial**	**High**
Risk of spread/amplification of pathogens that already occur the Canadian Upper Columbia (e.g., IHNV U-clade, BKD, Columnaris) by reintroduced Sockeye				
S5.EI.10	**24**	**Modest**	**Substantial**	**Low, Medium**
Risk of local decline in zooplankton abundance in oligotrophic lakes due to predation from reintroduced Sockeye				
S5.EI.4	**18**	**Modest**	**Moderate**	**Medium**
Risk of local decline in Kokanee biomass due to competition or demographic sinks with residualized reintroduced Sockeye, which are specialist zooplankton feeders				
S5.EI.2	**18**	**Modest**	**Moderate**	**High**
Risk of local decline in large Rainbow Trout (>50 cm) biomass due to decline in prey size resulting from competition with reintroduced Sockeye				
S5.EI.5	**18**	**Modest**	**Moderate**	**High**
Risk of local decline in Mountain Whitefish biomass due to competition with reintroduced Sockeye				
S5.EI.6	**18**	**Modest**	**Moderate**	**High**
Risk of local decline in large Bull Trout (>50 cm) biomass due to decline in prey size resulting from competition with reintroduced Sockeye				
S5.GE.1	**18**	**Modest**	**Moderate**	**Low, High**
Risk of genetic homogenization and loss of local adaptation in Kokanee populations due to hybridization with reintroduced Sockeye				
S5.OA.1	**18**	**Modest**	**Moderate**	**n/a**
Risk of increased human-wildlife conflict along riverbanks (e.g., with skunks, bears, etc.) due to increased Sockeye carcass availability after spawning				

ACB Number S5.EI.11: Risk of increasing distribution and abundance of aquatic invasive species by establishing fish passage infrastructure (e.g., fishways or trap and truck) for reintroduced Sockeye

Currently, there are very few aquatic invasive species in SPU #5 except for yellow perch, making the area especially vulnerable to the establishment of other invasives that are abundant below Arrow Lake. Keenleyside dam represents an important dividing point because it is a low-head dam alongside which a fishway could be constructed. While the trapping of upstream migrants at large dams is possible using short fishways to reduce the attraction for non-migrating fish and to control which migrants are moved above the dam, many of the low-head dams on the lower Columbia River use simple volitional fishway passage for all fish. A trap and truck system may be an effective proactive mitigation strategy if migrants are dewatered and sorted by species prior to transport; however, significant effort to mitigate introductions are required once invasive species are established in a region. The boat lock at Keenleyside dam is currently operating independently of

Chinook and Sockeye reintroduction activities, and there is pressure from boat owners to keep it running; however, good management practices can reduce passage of non-target species.

ACB Number S5.EI.13: Risk of increase in invasive fish biomass due to predation on reintroduced Sockeye eggs, juveniles, and adults

Aquatic invasive species are opportunistic, and populations may grow at rapid rates where there is high prey availability; however, the medium to high uncertainty surrounding the risks associated with this ACB may be due to the influence of habitat suitability in determining species biomass. Experts felt that the strong habitat preferences of aquatic invasive species may result in a lack of overlap with Sockeye habitat, reducing the consequence of the effects of this ACB. Aquatic invasive species predation on Sockeye is expected to be highest of Arrow Lakes, in the Transboundary Reach, during the migration of smolting Sockeye downstream from Arrow Lakes Reservoir-Revelstoke Reach. While concurrent invasive species control was proposed as a possible mitigation for this ACB, there are few, if any, examples of this working successfully without significant effort in other similar systems.

ACB Number S5.DP.1: Risk of introduction and spread of pathogens that do not currently occur in the Canadian Upper Columbia (e.g., IHNV M-clade, IPNV, Whirling Disease) by reintroduced Sockeye

Good hatchery practice such as screening for infectious agents during egg collection, disinfection procedures, minimizing the number of reintroduction events, and reducing water transfers are all strategies proposed by experts to mitigate the risks associated with this ACB. There is, however, a high level of uncertainty associated with the lack of information about the current disease burden on resident fish. Experts recommended a research program to inventory which diseases and pathogens are present in the Canadian Upper Columbia and would allow for a better estimate of risk. An additional driver of uncertainty is the complexity of interactive effects between environmental variables and disease, particularly considering climate change and the resulting changes to freshwater ecosystems. Tissue samples taken after major Kokanee mortality events in Arrow Lake and Kinbasket Lake (2012, 2016) tested positive for infectious hemotopoietic necrosis (IHN); however, it remains unclear whether the pathogen was the direct cause of the mortality events.

ACB Number S5.EI.3: Risk of local decline in Kokanee biomass due to competition with reintroduced Sockeye

The distinction between competition for habitat and competition for food was highlighted during workshop discussion of this ACB (Alexander and Hyatt 2015; Hyatt, Withler, and Garver 2019). Species interactions in Skaha Lake and Osoyoos Lake suggest that the risk of food competition between Kokanee and Sockeye will be low; however, productivity in Arrow Lakes Reservoir is significantly lower and more subject to reservoir operations than in these other systems. As such, some experts felt that there may be evidence for food competition, particularly for *Daphnia* spp., a preferred food source for both species. Additionally, the high flow rates in Arrow Lakes Reservoir may reduce the potential of salmon carcasses to provide a source of marine-derived nutrients to offset productivity lost to Sockeye.

There was greater consensus among the group that the risk of competition for spawning habitat is an important consideration in reintroduction, and that Sockeye may limit Kokanee spawning

activities. Both Kokanee and Sockeye typically spawn within streams or rivers but are also able to spawn in areas of shallow water along shorelines or island beaches when spawning habitat is scarce. One reviewer noted that some kokanee also spawn in deep water in parts of British Columbia. An action proposed to mitigate the risk of spawning habitat competition is habitat restoration and improvement.

ACB Number S5.DP.2: Risk of spread/amplification of pathogens that already occur the Canadian Upper Columbia (e.g., IHNV U-clade, BKD, Columnaris) by reintroduced Sockeye

Based on the data collected during the pre-workshop rating exercise, this ACB was rated as having modest consequence and moderate likelihood; however, due to time constraints during the Phase I Assessment Workshop, it was not further discussed or re-rated. One expert did highlight the uncertainty associated with our lack of knowledge about the combination of factors required to turn endemic pathogens into disease states. They also proposed reduced water transfers and hatchery screening for infectious pathogens as possible mitigation strategies. We recommend that this ACB be re-assessed in future uses of this RBAF, including additional discussions of mitigation options.

ACB Number S5.EI.10: Risk of local decline in zooplankton abundance in oligotrophic lakes due to predation from reintroduced Sockeye

It is unlikely that Sockeye reintroduction will have a large effect on the average density of zooplankton. Nutrient trapping in upstream reservoirs and high nutrient flushing rates in Arrow Lakes Reservoir (turnover of 33 days in high-flow years) limit phytoplankton production and zooplankton growth, which, along with predation from introduced *Mysis relicta*, and are thought to be the main determinants of *Daphnia* spp. biomass. High flow rates in this reservoir can also directly affect zooplankton abundance by increasing entrainment during water discharge. Studies in other lake systems such as Okanagan Lake have found that large pelagic fish including large Kokanee have been drivers of predation on zooplankton; however, the comparatively highly oligotrophic conditions in Arrow Lakes Reservoir make it difficult to apply these data to make predictions about the effects of Sockeye reintroduction to SPU #5. Possible mitigation actions include gradual reintroductions of Sockeye, and nutrient treatments, although the latter have proven to be less effective in Arrow Lakes where flushing rates are high. Entrainment of higher densities of phytoplankton and zooplankton into Arrow from Revelstoke might be an argument for upstream fertilization.

ACB Number S5.EI.4: Risk of local decline in Kokanee biomass due to competition or demographic sinks with residualized reintroduced Sockeye, which are specialist zooplankton feeders

The percentage of residualized fish depends on the balance between the advantages of migrating downstream to the ocean and the advantages of non-anadromy; migration may result in higher fecundity, but non-anadromy reduces mortality associated with dam passage and predation by marine species. Generally, shorter, and less complex migration routes favour Sockeye, suggesting that in the case of Arrow Lakes Reservoir, the presence of dams and the length of the migration may drive selection for Sockeye to stay and residualize in this system. However, the oligotrophic nature of the Arrow Lakes system may offset this selection pressure to favour smoltification and migration. Because residualization rate is density-dependent (e.g., Elliot et al. 2020), the proportion of Sockeye that residualize should decline when stocking magnitude is reduced, offering a potential mitigation

for the risks associated with this ACB. Artificial propagation can also increase residualization rates, especially if fish are released at larger sizes (Cannamela, 1992).

ACB Number S5.EI.2: Risk of local decline in large Rainbow Trout (>50 cm) biomass due to decline in prey size resulting from competition with reintroduced Sockeye

This size (>50 cm) is usually an indication of a unique ecotype of Rainbow Trout – pelagic piscivores – which are unique to Kokanee-based ecosystems like Kootenay Lake, Okanagan Lake, Shuswap Lake, Quesnel Lake, Eutsuk Lake, and the original Arrow Lakes (De Gisi 2003; Sebastian et al. 2000). Another important Rainbow Trout ecotype occurs in the Columbia River Transboundary Reach. There is compelling evidence that Sockeye and Rainbow Trout interactions are strong in large lakes, which has major implications for Sockeye and the large lake ecosystem. In Skaha Lake, larger/older pelagic fish, including large Kokanee, and mysids were found to be the dominant consumer of the zooplankton prey base, not reintroduced Sockeye fry. There is more uncertainty in Arrow Lakes because the system is less productive. In Quesnel, when Sockeye abundance age 0+ went up dramatically, Rainbow Trout size and numbers declined because it is bioenergetically less optimal for large fish to feed on Sockeye-sized prey (Walters et al. 1991; Korman et al. 1993). When Sockeye numbers decreased, larger Rainbow Trout become more abundant. One reviewer suggested this could be offset with management of the Hill Creek spawning channel (i.e., allow fewer Kokanee spawners).

ACB Number S5.EI.5: Risk of local decline in Mountain Whitefish biomass due to competition with reintroduced Sockeye

Sockeye fry introductions may impact resident whitefish and the pelagic fish community, but uncertainty is high among experts.

ACB Number S5.EI.6: Risk of local decline in large Bull Trout (>50 cm) biomass due to decline in prey size resulting from competition with reintroduced Sockeye

Sockeye fry introductions may impact resident bull trout or the pelagic fish community. Charr population dynamics will probably be less coupled to Sockeye than rainbow because of their slower growth, energetics and longer generation time.

ACB Number S5.GE.1: Risk of genetic homogenization and loss of local adaptation in Kokanee populations due to hybridization with reintroduced Sockeye

Natural pairs of Sockeye and Kokanee ecotypes that inhabit the same nursery lake typically maintain reproductive isolation (Wood et al. 2008), but F1 hatchery Sockeye from a donor stock are unlikely to maintain the same degree of isolation from native Kokanee. As such, experts felt that hybridization was possible, especially given that this mechanism has been observed in a small portion of the Okanagan Lake population and in a much larger portion of the Skaha Lake population (Elliot et al. 2020; Veale and Russello 2016; Hyatt et al. 2019). Compared to the Skaha Lake population, the scale of hybridization in Okanagan Lake is smaller due to the inhibition of genetic introgression through size segregation. It remains unclear whether hybridization will result in homogenization in the future. Candidate mitigation recommendations from respondents include promoting spawning segregation by manipulating gravel size to an appropriate ratio for reintroduced Sockeye, selecting hatchery stock to best match the extirpated Sockeye population, re-introducing low numbers of

Sockeye, using imprinting to physically separate ecotypes, maintaining high genetic diversity in hatchery stocks, choosing Sockeye release sites that facilitate segregated spawning, and building spawning channels or on-site hatcheries that ensure segregation of Sockeye spawners. One reviewer also suggested that more study is needed about the genetic composition and origins of Kokanee in Arrow Lakes to determine whether historical stocking of strains from elsewhere has occurred.

S5.OA.1: Risk of increased human-wildlife conflict along riverbanks (e.g., with skunks, bears, etc.) due to increased Sockeye carcass availability after spawning

Human wellbeing is an important outcome of salmon reintroduction. The risk of increased human-wildlife conflict along salmon spawning streams in the summer and fall has medium uncertainty and is worth considering at local scales. Experts suggested that interior bears have lower proportion of calories from salmon and that if the number of carcasses is in surplus, bear aggression may go down. Mitigation strategies include changes to human behaviour, such as seasonal area closures and education programs, as well as carcass removal.

3.2.2 Summer-fall Chinook Reintroduction

Six (6) key risks for summer-fall Chinook were identified using the consequence and likelihood ratings assigned based on expert rating of the ACBs. The risk values and ratings are provided in

Table 5 and are discussed in greater detail below. See Appendix A for detailed reports of expert rating and in-workshop discussion for each ACB and Appendix C for a summary table of risk ratings.

Table 5. Attributes of Highest Risk Identified During Phase I Assessment of Summer-fall Chinook Reintroduction into SPU#1

ACB No.	Risk Value	Consequence	Likelihood	Uncertainty
Csf1.EI.10	**36**	**Substantial**	**Moderate**	**Medium**
Risk of increasing distribution and abundance of aquatic invasive species by establishing fish passage infrastructure for reintroduced Chinook				
Csf1.DP.1	**36**	**Substantial**	**Moderate**	**Medium**
Risk of introduction and spread of pathogens that do not currently occur in the Canadian Upper Columbia (e.g., IHNV M-clade, IPNV, Whirling Disease) by reintroduced Chinook				
Csf1.EI.13	**18**	**Modest**	**Moderate**	**n/a**
Risk of local decline in native fish (e.g., Kokanee) biomass due to increased predation by residualized reintroduced Chinook				
Csf1.EI.11	**18**	**Modest**	**Moderate**	**Medium**
Risk of increase in invasive fish biomass due to predation on reintroduced Chinook eggs, juveniles, and adults				
Csf1.DP.2	**18**	**Modest**	**Moderate**	**Medium**
Risk of spread/amplification of pathogens that already occur the Canadian Upper Columbia (e.g., IHNV U-clade, BKD, Columnaris) by reintroduced Chinook				
Csf1.GE.1	**18**	**Modest**	**Moderate**	**Medium**

Risk of loss of genetic integrity to extant natural populations of Chinook below Chief Joseph Dam due to hybridization with reintroduced hatchery salmon

ABC Number Csf1.EI.10: Risk of increasing distribution and abundance of aquatic invasive species by establishing fish passage infrastructure for reintroduced Chinook

Aquatic invasive species are already present in the Transboundary Reach, but the high-risk rating of this ACB is due to this region's close geographic proximity to the Arrow Lakes Reservoir. The potential that these invasives will move to higher parts of the watershed and become established in areas that are mostly free of aquatic invasive species presents a major concern. Northern Pike are moving down the Pend d'Oreille River towards the Transboundary Reach, and it will be of great importance to Chinook reintroduction to consider how to exclude these pike, as well as bass and walleye from the Arrow Lakes Reservoir. Fish passage infrastructure can be designed to permit passage of certain species, and these should be co-designed with CRSRI. Even volitional fish passage infrastructure, like fish ladders, can be designed to prevent some species from passing, such as a system that requires more leaping than walleye are capable of.

The boat lock at Keenleyside dam is currently operating independently of Chinook and Sockeye reintroduction activities, and there is pressure from boat owners to keep it running; however, good management practices can reduce passage of non-target species. Experts also proposed invasive species prevention, monitoring, and interception as mitigations for the risks associated with this ACB. Additionally, invasive species suppression in regions where they are already established may be helpful. Where possible, a trap and truck system using only upstream water or groundwater could be implemented to reduce transfers from one drainage to another.

ACB Number Csf1.DP.1: Risk of introduction and spread of pathogens that do not currently occur in the Canadian Upper Columbia (e.g., IHNV M-clade, IPNV, Whirling Disease) by reintroduced Chinook

The moderate consequence and likelihood ratings assigned to this ACB during the pre-workshop rating exercise reflect the uncertainty associated with the limited disease surveillance in the Canadian portion of the Upper Columbia River basin. Screening donor populations for pathogens, developing an understanding of the disease history of donor populations, applying proper hatchery management practices, and reducing water transfers during stocking were all proposed as potential mitigation strategies for this ACB; however, there is concern among experts that these strategies may not be scalable as increasing numbers of Chinook are reintroduced to the Transboundary Reach. Experts also suggested conducting a thorough environmental disease study to determine at what level pathogens are already present in the environment; this becomes especially complex because the study would need to consider all water sources that may drain into the Columbia River.

ACB Number Csf1.EI.13: Risk of local decline in native fish (e.g., Kokanee) biomass due to increased predation by residualized reintroduced Chinook

Experts discussed that residualized Chinook could travel upstream through the navigation lock, or through future fish passage infrastructure, to establish a residualized population in the Arrow Lakes, where they could become a landlocked population of large bodied piscivores, similar to Lake Coeur d'Alene. These residualized Chinook may adversely impact native Kokanee through competition and

predation. One expert also mentioned that Chinook residualization is unlikely to occur in the Transboundary Reach, and more likely to occur in lake systems such as Roosevelt Lake.

ACB Number Csf1.EI.11: Risk of increase in invasive fish biomass due to predation on reintroduced Chinook eggs, juveniles, and adults

There was consensus among experts that the high consequence rating assigned to this ACB assumes that many Chinook will become re-established. If few Chinook become re-established, and if there is already an abundance of food sources available to invasive fish in the Transboundary Reach, this ACB will be of little concern. While Northern Pikeminnow (*Ptychocheilus oregonensis*) are not invasive species in this area, they have adapted well to the Lower Columbia and will likely predate heavily on juvenile Chinook further downstream below Grand Coulee. There are successful Northern Pikeminnow suppression programs that could be implemented as mitigation.

Experts also discussed the establishment of Lake Trout (*Salvelinus namaycush*) in Flathead Lake as a case study that could be relevant to Chinook reintroduction and the assessment of this ACB. Lake Trout were stocked in Flathead Lake in the early 1900s, but trophic change did not occur until mysids also established themselves in the watershed. Lake Trout had few direct effects on the resident fish population but were able to outcompete Westslope Cutthroat Trout (*Oncorhynchus clarkii lewisi*) and Bull Trout because of mysid establishment. Trophic interactions in this system may suggest that Chinook reintroduction will have little effect on both resident and invasive fish species biomass. There are similar studies in New Zealand, California, and the Great Lakes.

ACB Number Csf1.DP.2: Risk of spread/amplification of pathogens that already occur the Canadian Upper Columbia (e.g., IHNV U-clade, BKD, Columnaris) by reintroduced Chinook

To capture the risks of consequence and likelihood of this ACB at a higher resolution, some experts felt that it will be important to separate out life-stages in future uses of this framework. While hatchery-reared juvenile Chinook are unlikely to spread and amplify pathogens that already occur in the area, the risk associated with returning adult Chinook is much higher. Workshop discussion also addressed the existing uncertainty surrounding the main drivers of disease spread and amplification; environmental and host factors influencing disease occurrence in recipient populations will continue to occur and may be more influential than the introduction of infected Chinook. Moreover, it is possible that endemic pathogens can be slightly amplified with little effect. Mitigation strategies proposed by the experts include screening hatchery stock, minimizing the number of reintroduction events, establishing surveillance programs for early disease detection in recipient populations, ensuring that there are enough brood fish to allow for the discarding of disease carriers, designing hatcheries appropriately with reintroduction in mind.

ACB Number Csf1.GE.1: Risk of loss of genetic integrity to extant natural populations of Chinook below Chief Joseph Dam due to hybridization with reintroduced hatchery salmon

The likelihood of reintroduced Chinook hybridizing with extant natural Chinook populations downstream depends highly on the efficacy and ease of dam passage by migrating fish; if upstream dam passage is ineffective, there is likely to be substantial straying to downstream populations. The degree of straying among reintroduced Chinook may also be influenced by the release strategies and hatchery management strategies applied during reintroduction. Natural populations of Chinook below Chief Joseph Dam are also genetically diverse, making the risk of a loss of genetic integrity

less likely. However, one expert commented that many US hatchery stocking programs along the Columbia have likely been homogenizing these stocks for multiple generations. Careful monitoring and maintenance of diversity in hatchery stocks, rearing hatchery fish to imprint on natal streams, choosing the correct growth rate and size for release, selecting brood that allows for genetic diversity, and choosing donor stocks with appropriate life history strategies are all mitigations that can be applied to this ACB. Unfortunately these are difficult strategies to effectively put into practice.

3.3 Areas of Moderate Risk

Attributes of moderate risk were identified based on a combination of their consequence, likelihood, and uncertainty ratings that suggested they may cause modest impacts to local habitats and/or resident populations but are unlikely to occur. All ACBs in this section were assigned consequence ratings of "**Modest**", and likelihood ratings of "**Low**".

3.3.1 Sockeye Salmon Reintroduction

Five (5) areas of moderate risk were identified for Sockeye. The risk values and ratings are provided in Table 6 below. See Appendix A for detailed reports of expert ratings and in-workshop discussion for each ACB and Appendix B for a summary table of risk ratings.

Table 6. Attributes of Moderate Risk Identified During Phase I Assessment of Sockeye Reintroduction into SPU #5

ACB No.	Risk Value	Consequence	Likelihood	Uncertainty
S5.DP.4	**12**	**Modest**	**Low**	**High**
Risk of reintroduced Sockeye providing evolutionary space for endemic pathogens to increase in virulence				
S5.EI.8	**12**	**Modest**	**Low**	**n/a**
Risk of local decline in native fish biomass due to indirect effects of aquatic invasive species predation on reintroduced Sockeye (e.g., pike population increase due to predating reintroduced salmon and increase predation pressure on Kokanee)				
S5.ET.1	**12**	**Modest**	**Low**	**n/a**
Risk of radioisotopes, mercury, and PCBs being introduced to the Upper Columbia from downstream marine and riverine waters by migrating adult Sockeye				
S5.NC.3	**12**	**Modest**	**Low**	Low, High
Risk of creating a freshwater nutrient sink by out-migrating reintroduced Sockeye smolt exporting nutrients downstream				

3.3.2 Summer-fall Chinook Reintroduction

Eight (8) areas of moderate risk were identified for summer-fall Chinook. The risk values and ratings are provided in Table 7 below. See Appendix A for detailed reports of expert rating and in-workshop discussion for each ACB and Appendix C for a summary table of risk ratings.

Table 7. Attributes of Moderate Risk Identified During Phase I Assessment of Summer-fall Chinook Reintroduction into SPU#1

ACB No.	Risk Value	Consequence	Likelihood	Uncertainty
Csf1.EI.2	**12**	**Modest**	**Low**	**High**
Risk of local decline in Rainbow Trout biomass due to decline in prey size resulting from competition with reintroduced Chinook				
Csf1.OA.1	**12**	**Modest**	**Moderate**	**Medium**
Risk of increased human-wildlife conflict along riverbanks (e.g., with skunks, bears, etc.) due to increased Chinook carcass availability after spawning				
Csf1.EI.7	**12**	**Modest**	**Low**	**High**
Risk of local decline in native fish (e.g., Kokanee) biomass due to indirect effects of aquatic invasive species predation on reintroduced Chinook				
Csf1.EI.12	**12**	**Modest**	**Low**	**High**
Risk of reintroduced Chinook negatively affecting the biomass and distribution of fish species listed as special concern, threatened, or endangered (i.e., White Sturgeon (*Acipenser transmontanus*), Umatilla Dace (*Rhinichthys umatilla*), and Columbia Sculpin (*Cottus hubbsi*))				
Csf1.DP.4	**12**	**Modest**	**Low**	**High**
Risk of reintroduced Chinook providing evolutionary space for endemic pathogens to increase in virulence				
Csf1.NC.3	**12**	**Modest**	**Low**	**High**
Risk of creating a freshwater nutrient sink by out-migrating reintroduced Chinook smolt exporting nutrients downstream				
Csf1.ET.2	**12**	**Modest**	**Low**	**n/a**
Risk of local point-source contaminants from industrial sites being redistributed through the local ecosystem by migrating adult Chinook				

3.4 Areas of Least Risk and/or Uncertainty

Attributes of least risk and/or uncertainty were identified based on a combination of their consequence, likelihood, and uncertainty ratings that suggested they are unlikely to occur or cause significant impacts to local habitats and/or resident populations. ACBs of least risk were assigned consequence ratings of "**Negligible**", and likelihood ratings of "**Low**".

3.4.1 Sockeye Salmon Reintroduction

Six (6) areas of least risk were identified for the Sockeye reintroduction into Arrow Lakes Reservoir-Revelstoke Reach. See Appendix A for detailed reports of rating and in-workshop discussion for each ACB and Appendix B for a summary table of risk ratings.

Table 8. Attributes of Least Risk Identified During Phase I Assessment of Sockeye Reintroduction into SPU #5

ACB No.	Risk Value	Consequence	Likelihood	Uncertainty
S5.DP.3	**6**	**Modest**	**Negligible**	**High**
Risk of bear and other terrestrial predator exposure to salmon poisoning disease from consumption of reintroduced Sockeye				
S5.EI.12	**6**	**Modest**	**Negligible**	**High**
Risk of decline in the biomass and distribution of fish species listed as special concern, threatened, or endangered (i.e., White Sturgeon (*Acipenser transmontanus*), Umatilla Dace (*Rhinichthys umatilla*), and Columbia Sculpin (*Cottus hubbsi*)) de to Sockeye competetion				
S5.ET.2	**2**	**Negligible**	**Low**	**n/a**
Risk of local point-source contaminants from industrial sites being redistributed through the local ecosystem by migrating adult Sockeye				
S5.EI.7	**2**	**Negligible**	**Low**	**High**
Risk of local decline in juvenile White Sturgeon survival due to competition with reintroduced Sockeye				
S5.GE.2	**2**	**Negligible**	**Low**	**Low, Medium**
Risk of loss of genetic integrity to extant natural populations of Sockeye below Chief Joseph Dam due to hybridization with reintroduced hatchery salmon				
S5.ET.3	**1**	**Negligible**	**Negligible**	**Low**
Risk of micro-plastics from downstream marine and riverine waters being introduced into lakes and rivers by migrating adult Sockeye				

3.4.2 Summer-fall Chinook Reintroduction

Eight (8) areas of least risk were identified for the Summer-fall Chinook reintroduction into the Transboundary Reach. See Appendix A for detailed reports of rating and in-workshop discussion for each ACB and Appendix C for a summary table of risk ratings.

Table 9. Attributes of Least Risk Identified During Phase I Assessment of Summer-fall Chinook Reintroduction into SPU#1

ACB No.	Risk Value	Consequence	Likelihood	Uncertainty
Csf1.DP.3	**6**	**Modest**	**Negligible**	**High**
Risk of bear and other terrestrial predator exposure to salmon poisoning disease from consumption of reintroduced Chinook				
Csf1.ET.1	**6**	**Modest**	**Negligible**	**n/a**
Risk of radioisotopes, mercury, and PCBs being introduced to the Upper Columbia from downstream marine and riverine waters by migrating adult Chinook				
Csf1.EI.3	**4**	**Negligible**	**Low**	**High**
Risk of local decline in Mountain Whitefish (*Prosopium williamsoni*) biomass due to competition with reintroduced Chinook				
Csf1.ET.3	**1**	**Negligible**	**Negligible**	**n/a**
Risk of micro-plastics from downstream marine and riverine waters being introduced into lakes and rivers by migrating adult Chinook				
Csf1.EI.5	**1**	**Negligible**	**Negligible**	**High**
Risk of local decline in White Sturgeon (Acipenser transmontanus) biomass due to competition with reintroduced Chinook				
Csf1.EI.6	**1**	**Negligible**	**Negligible**	**Medium**
Risk of local decline in Kokanee biomass due to competition with residualized reintroduced Chinook				
Csf1.EI.4	**1**	**Negligible**	**Negligible**	**High**
Risk of local decline in Bull Trout biomass due to competition with reintroduced Chinook				
Csf1.EI.9	**1**	**Negligible**	**Negligible**	**Medium**
Risk of local decline in zooplankton abundance in oligotrophic lakes due to predation from reintroduced Chinook				

3.5 Areas of Benefit

Attributes with beneficial impact were rated using the same methods as attributes of adverse impact. All attributes of benefit are listed in an unordered table below.

3.5.1 Sockeye Salmon Reintroduction

Five (5) areas of benefit were identified for the Sockeye reintroduction into Arrow Lakes Reservoir-Revelstoke Reach. See Appendix A for detailed reports of rating and in-workshop discussion for each ACB and Appendix B for a summary table of risk and benefit ratings.

Table 10. Attributes Benefit Identified During Phase I Assessment of Sockeye Reintroduction into SPU #5

ACB No.	Benefit Value	Consequence	Likelihood	Uncertainty
S5.NC.1	**4**	**Negligible**	**Substantial**	**Medium, High**
Beneficial delivery of marine-derived nutrients to upstream aquatic habitats by migrating adult Sockeye				
S5.NC.2	**30**	**Modest**	**Nearly Certain**	**High**

Beneficial delivery of marine-derived nutrients to terrestrial habitats via terrestrial predators by Sockeye carcasses				
S5.EI.1	**24**	**Modest**	**Substantial**	**Low**
Beneficial increase in foraging opportunities and prey availability for native fish biota (e.g., Bull Trout (*Salvelinus confluentus*), Rainbow Trout (*Oncorhynchus mykiss*), Burbot (*Lota lota*), White Sturgeon (*Acipenser transmontanus*)) due to predation on reintroduced Sockeye eggs, juveniles, and adults. **Note*: One reviewer indicated that the piscivorous Rainbow Trout require Kokanee, which are larger than Sockeye fry but would otherwise enjoy fertilizer and eating bugs on carcasses.				
S5.EI.9	**12**	**Modest**	**Low**	**High**
Beneficial increase in distribution of native mussels due to larval attachment to reintroduced Sockeye				
S5.EI.14	**12**	**Modest**	**Low**	**High**
Beneficial decline in invasive mysid shrimp abundance due to competition with reintroduced Sockeye				

3.5.2 Summer-fall Chinook Reintroduction

Four (4) areas of benefit were identified for the Summer-fall Chinook reintroduction into the Transboundary Reach. See Appendix A for detailed reports of expert rating and in-workshop discussion for each ACB and Appendix C for a summary table of risk ratings.

Table 11. Attributes of Benefit Identified During Phase I Assessment of Summer-fall Chinook Reintroduction into SPU#1

ACB No.	Benefit Value	Consequence	Likelihood	Uncertainty
Csf1.NC.1	**48**	**Modest**	**Substantial**	**High**
Beneficial delivery of marine-derived nutrients to upstream aquatic habitats by migrating adult Chinook				
Csf1.NC.2	**24**	**Modest**	**Substantial**	**High**
Beneficial delivery of marine-derived nutrients to terrestrial habitats via terrestrial predators by Chinook carcasses				
Csf1.EI.1	**24**	**Modest**	**Substantial**	**Low, Medium**
Beneficial increase in foraging opportunities and prey availability for native fish biota (e.g., Bull Trout (*Salvelinus confluentus*), Rainbow Trout (*Oncorhynchus mykiss*), Burbot (*Lota lota*), White Sturgeon (*Acipenser transmontanus*)) due to predation on reintroduced Chinook eggs, juveniles, and adults				
Csf1.EI.8	**12**	**Modest**	**Low**	**High**
Beneficial increase in distribution of native mussels due to larval attachment to reintroduced Chinook				

4. Recommendations for Future Assessment

This report describes the process for developing and applying a Risk and Benefit Assessment Framework (RBAF) for anadromous salmon reintroduction to the Canadian waters of the Upper Columbia using expert opinion. Applying the RBAF to a salmon reintroduction strategy with expert opinion results in a prioritized list of risk factors and mitigation strategies that inform reintroduction planning and practice. ESSA has developed this framework to be replicated for reintroduction strategies that may be considered in the future in the Canadian Columbia Basin. Below, we discuss

how the framework can be applied in the future, identify knowledge gaps that need to be filled with research, and describe approaches to mitigating risk.

4.1 Limitations of the Framework

The RBAF was developed as a transparent, scientifically defensible risk assessment methodology to support salmon reintroduction into the Upper Columbia River, based on a Scope of Work developed by CRSRI. The Scope of Wok proposed that the methodology use expert opinion originating from within the basin and downstream portions of the watershed to assign risk ratings for several factors determined to be important in the region. The Scope of Work also proposed to use a risk matrix based on likelihood and consequence to screen potential risks and prioritize mitigation actions. Although the results of this study closely align with the proposed Scope of Work, a few important limitations and considerations are worth noting.

One key limitation in the development of this risk assessment was lack of empirical data to support a quantitative risk assessment, such as that completed for the Lower Columbia (Hardiman et al. 2017). We currently lack the resolution of data required to identify key stressor-response effects, assign thresholds, and characterize risk using quantitative methods. As such, a qualitative assessment was required.

A second key limitation is the lack of cross-pollination between the three parallel technical studies due to timing mismatches. Given project timelines and resource availability, some decisions about the direction of this framework were made with limited information from the other studies. Refinement of reintroduction strategies was occurring in parallel with development of the RBAF methodology used here. Without a clear understanding of the interventions being considered, the methodology we developed for the framework was necessarily broad and it was challenging for the experts to assign risk ratings during the participatory assessment. New information about the feasibility of proposed reintroduction strategies could alter the outcome of some assessment findings in this report. Other risks may also surface as important to include, for example uncertainty about source lakes for potential donor stocks.

Thirdly, the CRSRI Indigenous Knowledge Counsel (IKC) was unable to engage and provide direction on project deliverables or draft content during the development of the framework. As such, the risk assessment lacks perspectives from Indigenous Knowledge holders.

Although the methodology developed for this report is mostly robust to general risk assessment limitations (Cox 2008), the result of this Phase I Assessment may be biased by the following considerations:

- If you don't select the right experts, or experts with sufficient knowledge, then the methodology could lead to spurious conclusions;
- If expertise varies considerably, using a simple statistical method, like the mode, reduces the effect of the most knowledgeable experts;
- In many cases, experts did not find consensus around characterizing risk, but the methodology does not meaningfully consider uncertainty in risk characterization;

One reviewer questioned whether the assessment results could be validated by an independent group of experts. Below, we suggest a few considerations for building on the findings of the Phase I Assessment and resolving existing uncertainty around risk associated with key values in the Columbia basin.

One approach to increasing rigour of the assessment is through quantitative analysis. Hyatt et al. (2019) assessed a specific stocking rate of Sockeye in Okanagan Lake and used quantitative analyses of observed data to determine if a risk threshold to Kokanee was exceeded, for example by density dependent interactions or genetic hybridization. Another approach would be to supplement expert opinion with a more thorough literature review. Hardiman et al. (2019) used a combined approach of expert elicitation to inform some conclusions, and in-depth analysis/literature review by a dedicated group of experts. Below, in Section 4.3 we outline the key knowledge gaps that arose during this risk assessment. A useful next step could be a literature review to validate the expert assessment conducted during this study.

The results of our risk analysis represent a screening-level assessment suitable for prioritization of risk to inform next steps in the salmon reintroduction process. The limitations above can be managed through future planning, research, and continuous risk management throughout the salmon reintroduction process, ideally within the context of an adaptive management strategy.

4.2 Future Application of the Framework

This Phase I Assessment assessed risk for two reintroduction approaches that were considered most likely to be implemented at the time of writing. Within the Canadian Columbia Basin, experts identified at least 16 salmon planning unit / species lineage combinations that could become reintroduction approaches (see **Error! Reference source not found.**). The intention of this process is that each of t he remaining reintroduction approaches is subject to a risk assessment of similar rigour as the one completed for Phase I (this phase).

During Phase I, we asked experts to rate the consequence and likelihood of 52 attributes of concern or benefit using an asynchronous survey, which we estimate took between 45 to 90 minutes to complete. Then, experts were asked to participate in a 4-hour workshop to discuss the results of the survey. During the workshop, experts worked in small groups to re-assess ratings for key attributes and discussed mitigation approaches for key risks. This information was then summarized in this report. The total Phase I effort per individual for each expert to assess two reintroduction approaches was 5 to 6 hours.

Future application of the RBAF will involve assessing risk to the remaining 13 salmon planning unit / species lineage combinations that represent feasible reintroduction approaches. Forthcoming phases are expected to reuse the RBAF and engage many of the same experts that participated in Phase I. These phases will be implemented on an as needed basis prior to reintroduction implementation. We also expect that some efficiencies may be found to reduce total effort, both for experts and facilitators. However, we do suggest that synchronous workshops and discussion among experts is fundamental to successful risk planning.

The process for reapplying the framework in the future involves the following steps:

1. **Identify and clearly articulate the scope of the reintroduction approach** under consideration. This involves identifying the species lineage and salmon planning units where the re-established population will end up, but also estimating the total size of the re-established population over the next seven generations.
2. **Identify a group of experts** available to determine risk ratings and participate in a group discussion about risk and mitigation approaches.
3. Review the list of attributes of concern and benefit to **identify which attributes are relevant to the reintroduction approach** being assessed. A key efficiency here is to determine which attributes have the greatest probability of risk. We suggest that the findings of the Phase I Assessment may inform the selection of attributes in future phases, including the elimination of attributes with least risk. This must be done in consultation with experts.
4. Where new attributes need to be defined, attributes **must be constructed according to the structure** listed in Section 2.3.1.
5. **Convene a survey and workshop to implement the RBAF** on a tailored list of ACBs relevant to the reintroduction approach under consideration.

Efficiencies in Future Assessment

If all 13 additional reintroduction approaches are assessed at the same level of effort, the total effort for all experts combined could be substantial. A key purpose of the RBAF Scoping and Phase I Assessment was to develop a scientifically rigorous and exhaustive risk and benefit assessment. We suggest a few changes may be made to increase efficiency while maintaining scientific credibility.

First, as mentioned in bullet three above, we suggest that not every attribute needs to be rated for each subsequent assessment. Out of the 52 attributes of concern or benefit that were rated in Phase I, 16 (31%) of these were identified as areas of least risk and/or uncertainty or of benefit. It is expected that many of these attributes will have a similar risk profile to other reintroduction strategies. If the assessment is modified to focus more clearly on adverse risks and mitigation approaches, many of the least risk and perhaps some moderate risk attributes can be excluded.

Secondly, assessments could be aggregated across salmon planning units that share suitable characteristics. The Field Key to the Freshwater Fishes of British Columbia (McPhail and Carveth 1993), describes an important ecotone separating the Upper Columbia, extending upstream from Arrow Lakes, and the Lower Columbia, which includes Arrow Lakes and the Transbounday Reach. The important hydrological and ecological distinctions among regions will be important to consider if future risk assessments aggregate across SPUs.

Third, our Phase I Assessment identified similar risks across both reintroduction strategies. It is likely that these consequence and likelihood of these risks are shared across potential additional reintroduction approaches.

Fourth, we expect that the attributes of greatest benefit to the recipient ecosystem (namely beneficial delivery of marine-derived nutrients) will be the same for all reintroduction strategies. Further, we expect the background nutrient load to be orders of magnitude larger than salmon return or smolt departure, even at high salmon volumes. Although the nutrient input would be positive from returning

salmon, estimating a positive effect would be difficult. Future assessments could focus on potential risks only.

Fifth, although two reintroduction strategies were completed together during Phase I, we suggest that future assessments focus on a single reintroduction strategy to simplify the assessment for experts.

Finally, the Introduction Transfer Committee (ITC) is responsible for permitting reintroduction projects but permitting is typically done at a much smaller scale and the ITC's focus has historically been the introduction of non-native species, not the reintroduction of extirpated species. There are unique considerations regarding what is needed from a risk assessment to inform permitting decisions at larger scales that will need to inform any future applications of this approach. Ideally the number of permits required can be adjusted to suit the scale of the reintroduction effort and reduce administrative burden. An alternative approach to evaluating risk that might better support the permitting process is basing risk evaluations on a *threshold* of number of fish (donor stocks) beyond which we might expect risk to materialize rather than on the static number of fish assumed in this assessment (See Section 3.1). During this assessment it became clear that the assumed number of fish would not be accessible, so using a quantitative threshold-based approach like that illustrated by Hyatt et al. (2019) could help address the issue.

4.3 Recommendations for Filling Knowledge Gaps

The Phase I Assessment identified several knowledge gaps. The following areas for research were identified during the workshop, following the workshop during synthesis, and during the report review. Resolving these uncertainties could help mitigate higher levels of risk:

- **Residualization.** What are the base rates of residualization and what affects these rates and how can we use best reintroduction pathways to minimize residualization, commensurate with natural expression.
- **Sockeye spawning locations.** Where are spatial locations of overlap between kokanee and sockeye? What is the degree of hybridization?
- **Invasive fish interactions with reintroduced salmon.** Develop a baseline for understanding the current demands (energetics, nutrient uptake, competition) for introduced species occupying historical salmon distribution (among each salmon planning unit). Emphasis on mysis, walleye, lake whitefish, as primary examples. Experts suggested considering invasive fish interactions across two categories: a) intentionally introduced species (e.g., Mysis, Walleye, Lake Whitefish, etc.) and b) unintentionally introduced species (e.g, Northern Pikeminnow, Bass, and Lake Trout).
- **Disease risk.** Currently, the presence and distribution of diseases and pathogens are present in the Canadian Upper Columbia is unknown. Because the risk of introduction and spread of pathogens is substantial, experts suggested that a field inventory program should be implemented to understand the current state of disease and pathogens in the basin. Future

risk assessment should use this information to also consider the potential interaction of effects of disease and environmental change, such as climate change.

- **Mussel distribution.** Aquatic mussel life history is associated with fish dispersal, but little is known about this interaction. Further research is needed about the role of host fishes in mobility of freshwater native mollusc larvae. Resolving uncertainties about this interaction could help determine the degree of benefit that salmon reintroduction has on native mussels and the potential adverse impact of reintroduction on the spread of invasive mussels.
- **Nutrient sinks.** Outmigration of smolts from reintroduced salmon may result in a net nutrient sink out of the freshwater environment. The magnitude of this nutrient sink is expected to be small, but experts agreed that further research is needed to fully understand the nutrient dynamics of the source and downstream lakes of all reintroduction sites, as well as the potential for nutrient returns from migrating adults. Predictions of nutrient dynamics could be monitored during the early years of reintroduction to ensure predicted dynamics were accurate. Research into lake fertilization and nutrient treatments should be conducted where this is recommended as a mitigation practice. Additionally, the nutrient dynamics of invasive species (e.g., mysids) could be included.
- **Invasive fish incursions.** There are currently few aquatic invasive species in some parts of the Canadian Columbia basin. Additional research is needed to identify the risk of increasing distribution and abundance of aquatic invasive species through establishing fish passage infrastructure. Risk and dispersal may vary between species of aquatic invasive organisms, so research and mitigation actions should be species-based where possible.
- **Ecotoxicology.** Anadromous salmon have the potential to bring radioisotopes, heavy metals, and polychlorinated biphenyls (PCBs) into the Upper Columbia watershed from downstream marine and riverine waters through the process of migration. Our research in Appendix D indicates that the likelihood of contamination from salmon interacting with radioactive isotopes from nuclear accidents in the Pacific rim is currently low. However, future accidents may have different implications and may warrant future monitoring. Our research did not conclusively determine the risk of transfer of heavy metals, PCBs, or tire-wear chemicals upstream into the Upper Columbia basin. Further research on contaminant loads, epigenetic effects, human health risks, and mitigation strategies for toxicology should be considered.
- **Transboundary Reach.** The scope of the present assessment was the Canadian waters of the Columbia River basin. However, it is important to consider that the Transboundary Reach includes free flowing waters and connected habitat within both Canada and the Unites States. Future assessment should confirm that the risks identified and assessed in Canada are similar south of the border.

We recommend that any research activities implemented in the Canadian Columbia Basin to address these knowledge gaps be designed in consultation with CRSRI and the reintroduction planning technical team to ensure the appropriate scope is achieved. Ideally, research and monitoring are embedded within a long-term adaptive management approach for salmon reintroduction. Where possible, future monitoring strategies will be linked to explicit thresholds and/or decision points that trigger specific actions to mitigate or eliminate critical impacts or risks. Long-term strategies for risk

monitoring and management should be explored in a consensus-based approach amongst the CRSRI partners for critical risk pathways identified in this study.

4.4 Avoidance and Mitigation Planning

The Phase I Assessment identified 8 risk factors of greatest concern for the Sockeye reintroduction strategy and 8 risk factors of greatest concern for the summer-fall Chinook reintroduction strategy. Avoidance and mitigation planning is needed to articulate the necessary strategies and implementation actions, as well as to identify short term actions that will address more immediate, acute risks versus long term actions to deal with chronic/ongoing risks or risks that will unfold over longer time frames. This planning can also help to further prioritize which risks to focus on, while making trade-offs with other risks transparent. Notes from the workshop discussion are included in rough form (i.e., not validated) in Appendix A and should be reviewed during avoidance and mitigation planning.

During this assessment, there was substantial discussion of the value of nearest neighbor donor stocks in reducing risk (e.g., of disease, invasives, and genetic impacts). Based on this discussion, we suggest that an important **avoidance strategy** for reintroduction is:

- Use of nearest neighbor donor stocks

Based on our assessment, top candidates for immediate **mitigation planning** include:

- Monitor and manage for residualization. Fish are known to stray and residualize at higher rates depending on certain hatchery, domestication, rearing and release strategies, and stocking/outplants should explicitly consider designs to minimize the likelihood of these events. Some possible strategies include:
    - Segregate spawning areas between sockeye and kokanee as much as possible
    - Don't stock sockeye on top of core resident kokanee populations
    - Consider alternative infrastructure (e.g., spawning channels) for sockeye spawning
    - Release fish from the hatchery as young as possible to ensure imprinting and reduction of possibility of residualization
    - Reduce stocking magnitude if residualization is high. It will be important to establish science-based thresholds for action, and what adaptive management strategy will be used to inform management? For example, is 5% residualization too high? 20%? In the case of hybridization, what rate triggers a mitigation program or adjustment to strategy? Answers to these questions can be advanced prior to reintroductions.
- Establish concurrent invasive control projects that reduce potential predation on reintroduced salmon eggs, juveniles, and adults
- Establishing robust invasive species prevention, monitoring, and interception programs
- Best practices for invasive management in water transfer, movement of fish in water, and operation and design (retrofit) of locks in dams

- Establishing and training on best practices for infectious disease screening and disease management of hatchery stock, including egg collection and disinfection
- Planning reintroduction to minimize total number of water transfer events (e.g., as part of truck and haul programs)
- Using fertilization to ensuring level so productivity limits adverse competition with Kokanee?

Appendix A: Summary of Outcomes from Expert Elicitation Process

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.1: Beneficial increase in foraging opportunities and prey availability for native fish biota (e.g., Bull Trout, Rainbow Trout, Burbot, White Sturgeon) due to predation on reintroduced Sockeye eggs, juveniles, and adults

Benefit Summary: Highest Benefit. *R* = 24. The **consequence is modest** and the **likelihood of this benefit is substantial**, expected to occur between **66% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Substantial	Low	12
Adjusted Re-Rating	Modest	Substantial	n/a	16 (70%) [2]

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts

Contents of Expert Workshop Discussion

- The addition of Sockeye generally enhances energy flow through the pelagic food chain relative to lakes with Kokanee only
    - Juvenile Sockeye generally depend on lake rearing, but there are exceptions, (e.g., Harrison Rapids, Alaska-BC transboundary rivers Donor stock originates in the Okanagan/Osoyoos region and is lake rearing
    - Benefits are to smaller piscivores (<50 cm)
    - Kokanee, and their predators (large Bull and large Rainbow Trout) may be negatively affected. This is a contentious issue in the management literature.
    - Sockeye have a broader range of life histories - some stream, some river. Juvenile and eggs available in a wider range of foraging preferences. This increases food web complexity, energy flow, and perhaps also biodiversity. However, stream rearing sockeye are not very common, and don't have the numerous adult returns that lake rearing produces. RB and BT have more life-histories compared to sockeye
        - This also emphasizes uncertainty, risk and need for effective monitoring and assessment

- Rainbow and Bull Trout expected to benefit most during juvenile migrations in bottleneck habitats (e.g., lake outlets)

Mitigation Recommendations

- None required for beneficial change

Outstanding Questions

- In Quesnel when Sockeye abundance age 0+ went up dramatically, rainbow size declined, because large piscivores are bioenergetically less efficient when they are forced to depend on smaller prey. When Sockeye numbers declined, larger rainbow more abundant
- There are already Kokanee in the lake providing foraging opportunities for native fish, will reintroduced Sockeye increase prey availability substantially?
    - Reply: among lake comparisons suggest that they do.
- The Sockeye/Kokanee competition paradigm assumes that zooplankton density limits the growth and/or survival of both ecotypes. Evidence from bioenergetic demand models and predation rates on zooplankton suggest that food may not be a limiting factor, except at very high Sockeye density.
- Arrow and Revelstoke are not similar to Okanagan, so lessons and data from the interior should be used as a guidance only, until local data from the Columbia is available

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.2: Risk of local decline in large Rainbow Trout (>50 cm) biomass due to decline in prey size resulting from competition with reintroduced Sockeye

Risk Summary: Highest Risk. *R* = 18. The **consequence is modest** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	13
Adjusted Re-Rating	Modest	Moderate	n/a	16 (70%) [2]

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- In Quesnel, when Sockeye abundance age 0+ went up dramatically, Rainbow Trout size and numbers declined because it is bioenergetically less optimal for large fish to feed on Sockeye-sized prey. When Sockeye numbers decrease, larger Rainbow Trout become more abundant.
- There is very compelling evidence that Sockeye and Rainbow Trout interactions are strong in large lakes, which has major implications on the Sockeye themselves and the large lake ecosystem. Larger/older pelagic fish (incl. large Kokanee) and mysids were found to be the dominant consumer of zooplankton prey base, not reintroduced Sockeye fry, in productive Okanagan lakes; unproductive Arrow may make that less certain.
- Smaller mean size of prey may make the mean size of predators drop. It has been observed in other systems (Schuter et al. 2016), but is this an especially significant thing for Arrow where the predominant problem is large Bull Trout? The abundance of exceptionally large-bodied Rainbow Trout is low except in a few exceptional years; however, they are an important component of native biodiversity and should not be margilanized

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.3: Risk of local decline in Kokanee biomass due to competition with reintroduced Sockeye

Risk Summary: Highest Risk. *R* = 24. The **consequence is modest** and the **likelihood of this risk is substantial**, expected to occur between **67% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Substantial	Low, Medium	13
Adjusted Re-Rating	Modest	Substantial	n/a	13 (70%) [2]

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

The distinction between competition for habitat and competition for food was highlighted during workshop discussion with regards to this ACB. While there is some evidence that Sockeye and Kokanee will compete for prey species such as Daphnia, another concern is that Sockeye spawners may limit Kokanee spawners by outcompeting them for spawning habitat. Kokanee typically use shallower water and smaller substrate, though there is substantial overlap in habitat use. Both can spawn on lake beaches with spawning habitat is scarce, but it is not clear why this is not always the case.

- Creel survey data suggest declining Kokanee/Rainbow Trout/Bull Trout catch (and angler days) over past two decades, despite nutrient addition.
    - On one hand, growth of Kokanee is clearly density dependent, but in Sockeye, growth is only density dependent at very high densities. Calculations of predation rates on zooplankton suggest that the presence/absence of Sockeye has little effect on zooplankton density. The alternative hypothesis is that intraspecific competition in age-0 Sockeye mainly affects survival, whereas competition in age-1 and older Sockeye mainly affects growth. Age-0 Sockeye avoid predators by feeding < 2hrs a day and optimizing temperature and predator avoidance by vertically migrating. Larger Sockeye appear to switch strategies to spend most of the day on the surface in an effort to get enough food to sustain growth and pay a lower mortality cost because they are larger.
- May be lower risk of food competition (based on Skaha/Osoyoos lakes). But Arrow productivity is lower than Okanagan and more subject to reservoir operations (x1)

  - Others feel there is evidence for competition for food. If focus is on preferred Daphnia, can find evidence for competition

- May be higher consequences for spawning habitat competition
  - May be competition for spawning habitat; but alternatively, they can clean/improve spawning habitat in some cases
  - Sockeye spawners may limit Kokanee spawners due to habitat competition
- Natural effect of returning anadromous fish to habitat
- Hydraulic storage will likely decrease with climate change as the dams can't hold back the water, which will serve to change seasonal nutrient delivery to the reservoir (winter delivery), as well as flush nutrients from it (winter flushing when food webs dormant). This depends on dam infrastructure and operation.
- If marine-derived nutrients (or some other factor) aren't enough to offset lost productivity to Sockeye, which is likely in a fast-flowing river-lake like Arrow Reservoir, competition will likely make the situation worse for both sympatric forms.
- Sockeye Salmon fry introductions are unlikely to have major ecological impacts on resident Kokanee or the pelagic fish community (most applicable to productive lakes, not oligotrophic lakes)
- High rate of residualized Sockeye would increase competition risk. Depends on numbers of juvenile Sockeye stocked.
- Kokanee population is all over the map. Stocking and growing in the lake there will be food competition. Stocking of spring age Kokanee
- High controversy on impact of Sockeye on food. The relationship between growth and size is density-dependent, but bioenergetic modelling approaches do not always show this.
- Might be useful to separate competition into (a) prey competition and (b) competition for spawning habitat between Kokanee and Sockeye as these would be independent.

Mitigation Recommendations

- Habitat restoration
- Lake fertilization (Woodruff et al. 2021)

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.4: Risk of local decline in Kokanee biomass due to competition or demographic sinks with residualized reintroduced Sockeye, which are specialist zooplankton feeders

Risk Summary: Highest Risk. *R* = 18. The **consequence is modest** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Moderate	Medium	13
Adjusted Re-Rating	Modest	Moderate	n/a	16 (70%) [2]

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

The available literature and data collected in Skaha Lake show that high residualization rates are likely when stocking is hatchery-dominant. Moreover, in Okanagan Lake, larger pelagic fish species and mysids rather than Sockeye are the main consumers of zooplankton; however, Arrow Lake is also much less productive than Skaha and Osoyoos.

- Literature suggests higher rates of residualization with hatchery dominant stocking (Elliott et al. 2020)
- Competition for food: larger/older pelagics (and mysids) were the main consumers of zooplankton in Okanagan, so residualized Sockeye may be a factor
- Natural effect of returning anadromous fish to habitat
- Short + less difficult migration routes favour Sockeye. Oligotrophic lakes (less productive) favour Sockeye. On BC coast there is not a lot of residualization. In case of Arrow, there may be selection for fish to stay/residualize because of how many dams, etc. but the low productivity of the lake should select for anadromy
- Percent of residualized fish depends on the balance between the advantages of going to sea (higher fecundity) and advantages of non-anadromy (higher survival in the absence of mortality from dam passage, migration, ocean predators etc.)
- Residualization levels in Skaha Lake of Sockeye found to be occurring at high rate
- Redfish Lake another study area

- Arrow Lake is less productive than Skaha/Osoyoos, so the risk of residualization may be lower. But also potentially confounded by dam operations
- Compete for spawning grounds
- If growth of juvenile Sockeye low, mortality rates go up in fall as they take more risk. But these fish smolt and migrate.

Mitigation Recommendations

- Reduce stocking magnitude if residualization is high
    - The proportion of Sockeye that residualize should decline with increasing density (a result of slower growth) however the absolute number that residualize may increase

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.5: Risk of local decline in Mountain Whitefish biomass due to competition with reintroduced Sockeye

Risk Summary: Highest Risk. *R* = 18. The **consequence is modest** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	13
Adjusted Re-Rating	Modest	Moderate	n/a	14 (70%) [2]

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- None discussed

Mitigation Recommendations

- None available or required

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.6: Risk of local decline in large Bull Trout (>50 cm) biomass due to decline in prey size resulting from competition with reintroduced Sockeye

Risk Summary: Highest Risk. *R* = 18. The **consequence is modest** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Negligible	High	12
Adjusted Re-Rating	Modest	Moderate	n/a	13 (70%) [2]

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Charr population dynamics will probably be less coupled to Sockeye than rainbow because of their slower growth, energetics and longer generation time
- Larger/older pelagic fish (incl. large Kokanee) (and mysids) were found to be the dominant consumer of zooplankton prey base, not reintroduced Sockeye fry, in productive Okanagan lakes; unproductive Arrow may make that less certain.

Mitigation Recommendations

- Harvest reduction on Bull Trout populations
- Restocking Bull Trout

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.7: Risk of local decline in juvenile White Sturgeon survival due to competition with reintroduced Sockeye

Risk Summary: Lowest Risk. *R* = 2. The **consequence is negligible** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Negligible	Negligible	High	12
Adjusted Re-Rating	Negligible	Low	n/a	13

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- None discussed

Mitigation Recommendations

- Population protections for sturgeon to reduce extrinsic threats

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.8: Risk of local decline in native fish biomass due to indirect effects of aquatic invasive species predation on reintroduced Sockeye (e.g., pike population increase due to predating reintroduced salmon and increase predation pressure on Kokanee)

Risk Summary: Moderate Risk. *R* = 12. The **consequence is modest** and **the likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	n/a	12
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- None discussed

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.9: Beneficial increase in distribution of native mussels due to larval attachment to reintroduced Sockeye

Benefit Summary: Moderate Benefit. *R* = 12. The **consequence is modest** and the **likelihood of this benefit is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	11
Adjusted Re-Rating	Modest	Low	n/a	14 (70%) [2]

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Mussels are typically going to be in shallow littoral zones, so distribution/interactions with Kokanee may be limited
- There are 3 possible species (or clades) of mussel present: the western pearlshell, western floater and winged floater. The winged floater is probably the rarest, if present
- One participant felt hard to see a significant consequence for this attribute

Mitigation Recommendations

- None required for beneficial change

Outstanding Questions

- What is larval attachment to existing Kokanee in the system? Stream dwelling fish tend to be candidate carriers for larvae
- What is the host fish for species?
- Do Rocky Mountain Ridged Mussels occur in this portion of the Columbia?

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.10: Risk of local decline in zooplankton abundance in oligotrophic lakes due to predation from reintroduced Sockeye

Risk Summary: Highest Risk. *R* = 24. The **consequence is modest** and the **likelihood of this risk is substantial**, expected to occur between **67% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Moderate	Low, Medium	13
Adjusted Re-Rating	Modest	Substantial	n/a	17

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

It is unlikely that Sockeye reintroduction will have a large effect on the average density of zooplankton, but it may be an important consideration for preferred zooplankton species like Daphnia. Overall zooplankton abundance in SPU #5 is primarily determined by flushing rate, and the water turnover in Arrow Lake is much higher than in Skaha and Osoyoos Lake. This makes it difficult to make predictions based on existing data from these areas and to apply them to Arrow Lake. However, twenty plus years of research on nutrient additions provides a good understanding of zooplankton dynamics in Arrow Lakes, including the effect of large contrasts in Kokanee density, flushing rates and other important factors.

- Arrow has much faster water turnover / low residence time (x1)
- Effects are reversible by excluding Sockeye or mitigation (nutrient addition)
- Large pelagic fish in Okanagan found to be driving predation on zooplankton (including large Kokanee)
- Divergence sometimes happens between bottom-up bioenergetic methods and top-down analysis methods
- Sockeye can be better competitors at low abundance of zooplankton
- Arrow not as productive as Skaha/Osoyoos. Arrow almost ultra oligotrophic, partially as a result of nutrient trapping in upstream reservoirs
- Flushing rate controls zooplankton abundance in Arrow Lake.

- Average density of zooplankton unlikely to decline, preferred zooplankton species, maybe yes (Daphnia)
- High flow years turnover is 33 days (can barely grow Daphnia) plus much colder than Skaha / Osoyoos
- Look at Quesnel study re: Daphnia, Sockeye
- Arrow and Okanagan - water exchange is very different between these. Arrow is also a lot warmer
- Values also key here, depending on priorities, may be "okay" to have this effect.

Mitigation Recommendations

- Gradual reintroductions
- Nutrient treatments (not necessarily that effective when flushing rates are high)

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.11: Risk of increasing distribution and abundance of aquatic invasive species by establishing fish passage infrastructure (e.g., fishways or trap and truck) for reintroduced Sockeye

Risk Summary: Highest Risk. *R* = 48. The **consequence is substantial** and the **likelihood of this risk is substantial**, expected to occur between **66% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Substantial	Moderate	Medium	12
Adjusted Re-Rating	Substantial	Substantial	n/a	18

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

There are currently few aquatic invasive species in SPU #5 other than yellow perch, making the area especially vulnerable to the establishment of other invasives that are abundant below Arrow Lake. The existing navigation lock may already provide passage for invasive species, but there was consensus among workshop participants that installing fishways without including a truck transport step would make their distribution above Keenleyside Dam much more likely.

- Currently few invasives in Arrow, one is yellow perch. Below Arrow there are a lot. So potential risk for distribution of invasives above Keenleyside
- Fishway risk likelihood higher (invasives can use these)
- Trapping of upstream migrants at large dams typically uses a short fishway to reduce the attraction for non-migrating fish and to control which migrants are moved above the dam. However, many of the relatively low head dams on the lower Columbia have simple volitional fishway passage for all fish.
- Very hard to mitigate invasives once established
- Trap and truck is very effective if migrants are dewatered and sorted by species prior to transport
- Keenleyside is a dividing point because it is a low head dam with a lock. A fishway could be constructed here. So, risk of more invasives into Arrow Lake is higher than Transboundary Reach where many invasives are either established or in the process of becoming established.

- There are other modes of spread, including unauthorized introductions, that are not connected to Sockeye reintroduction
- Could also argue that existing lock operation is happening anyway, so invasives may "get there anyway". Pike eDNA is confirmed in HLK Forebay

Mitigation Recommendations

- Careful movement of fish
- Careful operation of lock
- Invasives monitoring
- Reduction in water transfer

Outstanding Questions

- If a fishway there already, is it not in operation?
    - Reply: There is a navigation lock that is still in operation. Locks provide less efficient passage than fishways because each cycle is a 2-step process (filling from upstream, emptying downstream) rather than a continuous flow that is more attractive to upstream migrants.

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.12: Risk of reintroduced Sockeye negatively affecting the condition, abundance, and distribution of fish species listed as special concern, threatened, or endangered (i.e., White Sturgeon, Umatilla dace, and Columbia sculpin)

Risk Summary: Lowest Risk. *R* = 6. The **consequence is modest** and the **likelihood of this risk is negligible**, expected to occur between **0% and 1%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Negligible	Negligible	High	13
Adjusted Re-Rating	Modest	Negligible	n/a	15

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

The consensus among workshop participants was that it is relatively improbable that reintroduced Sockeye would have any significant biological interactions with the species listed in the ACB; however, competitive effects are not well understood due to low population sizes.

- High uncertainty because competitive effects are largely unknown due to low population sizes
- Hard to see how Sockeye would interact at all with these species? Surprised some people had high consequence ratings.
- Relatively improbable there would be ecologically significant interactions

Mitigation Recommendations

- None available or required

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.13: Risk of increase in invasive fish biomass due to predation on reintroduced Sockeye eggs, juveniles, and adults

Risk Summary: Highest Risk. *R* = 48. The **consequence is substantial** and the **likelihood of this risk is substantial**, expected to occur between **66% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Negligible	Moderate	Low, Medium	13
Adjusted Re-Rating	Substantial	Substantial	n/a	15

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Sockeye Salmon fry introductions are unlikely to have major ecological impacts on resident Kokanee or the pelagic fish community
- Invasives can have strong habitat preferences that do not overlap with those of Sockeye and Kokanee. Bass and Yellow perch are well established upstream of Kootenay lake, but not in Kootenay Lake itself (Runciman et al. 2009). Need to also consider habitat suitability for invasive species not just food sources. Biomass is often controlled by habitat suitability rather than food resources
- They are opportunistic fish, if the habitat suitable the invasive will take off
- Large number smolting fish moving down through the Transboundary Reach (SPU #1) would influence invasive piscivore biomass in that area (SPU #5 is connected through migration)

Mitigation Recommendations

- Concurrent invasive control projects

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.EI.14: Beneficial decline in invasive mysid shrimp abundance due to competition with reintroduced Sockeye

Benefit Summary: Moderate Benefit. *R* = 12. The **consequence is modest** and the **likelihood of this benefit is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Moderate	High	12
Adjusted Re-Rating	Modest	Low	n/a	18

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

Due to the diurnal vertical migration of mysids through the water column, it is unlikely that Sockeye will have large effects on their abundance. Furthermore, in Okanagan Lake, mysids –not juvenile Sockeye– have been the primary consumers more zooplankton.

- Likelihood negligible (1) in lakes >50 m mean depth (mysid refuge at depth); likelihood (2) in lakes <50 m mean depth (mysids more available to planktivores) (pers. comm. Don McQueen) (x1)
- Important to distinguish predation and competition.
- In Okanagan, mysids ate more daphnia than juvenile Sockeye. Argues that this benefit may be modest
- Mysis can deplete Sockeye food supply but not vice versa because Sockeye are specialist zooplanktivores with a preference for Daphnia, whereas Mysids are omnivores (Branstrator et al. 2000).

Mitigation Recommendations

- None required for beneficial change

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Disease and Pathogens

ACB Number S5.DP.1: Risk of introduction and spread of pathogens that do not currently occur in the Canadian Upper Columbia (e.g., IHNV M-clade, IPNV, Whirling Disease) by reintroduced Sockeye

Risk Summary: Highest Risk. *R* = 36. The **consequence is substantial** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Substantial	Low	Low to High	14
Adjusted Re-Rating	Substantial	Moderate	High	19 (60%) [2]

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

Although there are many strategies that may effectively mitigated the consequences of this ACB, there is not a lot of data available on the current disease burden of resident fish in this ecosystem. There is also a risk that climate change and associated changes to freshwater ecosystems may drive disease risk higher over time.

- Other infectious agents of potential concern: *Flavobacterium psychrophilum*, *Candidatus Branchiomonas cysticola*, Rickettsia-like organism, Pacific Salmon Paramyxovirus (PSPV), *Dermocystidium salmonis*, *Ichthyophthirius multifiliis*, *Paranucleospora theridion*, *Marinobacter arcticus*, *Candidatus Syngnamydia salmonis*, Viral Hemorrhagic Septicemia Virus (VHSV)
- Major Kokanee die-offs in Arrow and Kinbasket (2012, 2016) that seemed to be disease related --> fish tested positive for IHN (difficult to tease out cause due to interactions, naivety to pathogen)
- Reoccurring outbreaks of IHN where there are juvenile Sockeye and Kokanee; a single outbreak may not lead to immunity to subsequent outbreaks
- We don't know current disease burden on resident fish
- Climate change + associated changes to freshwater ecosystems may drive disease risk higher over time
- Split attributes by life-stage (juvenile and adult)

Mitigation Recommendations

- Screen hatchery stock for infectious agents
- No water transfers
- Minimize number of reintroduction events
- Hatchery implements egg collection, screening and disinfection procedures

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Disease and Pathogens

ACB Number S5.DP.2: Risk of spread/amplification of pathogens that already occur the Canadian Upper Columbia (e.g., IHNV U-clade, BKD, Columnaris) by reintroduced Sockeye

Risk Summary: Highest Risk. *R* = 24. The **consequence is modest** and the **likelihood of this risk is substantial**, expected to occur between **67% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Substantial	High	13
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- We don't know what combination of factors will take an endemic pathogen and turn it into a disease state. Factors such as crowding fish together, limited food, adverse temperatures, and low flows are among factors contributing to stress

Mitigation Recommendations

- Screen hatchery stock for infectious agents
- No water transfer

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Disease and Pathogens

ACB Number S5.DP.3: Risk of bear and other terrestrial predator exposure to salmon poisoning disease from consumption of reintroduced Sockeye

Risk Summary: Lowest Risk. *R* = 6. The **consequence is modest** and the **likelihood of this risk is negligible**, expected to occur between **0% and 1%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Negligible	Low, Medium	13
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- None discussed

Mitigation Recommendations

- None discussed

Outstanding Questions

- Is it not likely that the trematode, bacteria, hosts, reservoirs, and vectors are all still present in a functioning pathway, despite the absence of anadromous Sockeye?

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Disease and Pathogens

ACB Number S5.DP.4: Risk of reintroduced Sockeye providing evolutionary space for endemic pathogens to increase in virulence

Risk Summary: **Moderate Risk.** *R* = 12. The **consequence is modest** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	12
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Severity of disease is as much of a function of environmental factors as evolutionary capacity of pathogens
- Rigorous pathogen screening will help to determine consequence
- Would you be perturbing the system enough to drive any evolutionary change in pathogens

Mitigation Recommendations

- None discussed

Outstanding Questions

- Aquaculture driven selection prompted evolution of IHN-M --> is this possible in a natural environment?

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Genetics

ACB Number S5.GE.1: Risk of genetic homogenization and loss of local adaptation in Kokanee populations due to hybridization with reintroduced Sockeye

Risk Summary: Highest Risk. *R* = 18. The **consequence is modest** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Substantial	Low, High	13
Adjusted Re-Rating	Modest	Moderate	n/a	16 (50%) [2]

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

Natural pairs of Sockeye and Kokanee ecotypes that inhabit the same nursery lake typically maintain reproductive isolation (Wood et al. 2008), but F1 hatchery Sockeye from a donor stock are unlikely to maintain the same degree of isolation from native Kokanee. Hybridization between Sockeye and Kokanee has been observed in Skaha Lake.

- Hybridization is assured, homogenization is uncertain
- Key potential risks of reintroduction include genetic introgression with the Kokanee stream-spawners and potential hybridization. Impacts unpredictable (Hyatt et al. 2019).
- Spawning habitat has changed significantly since pre-reservoir impacts
- Okanagan: hybridization has been observed in Skaha Lake
- 1920 scale samples paper: missing ESU of Sockeye, not like existing Sockeye, suggesting historically two different clades of fish

Mitigation Recommendations

- Restore gravel size to appropriate ratio for reintroduced fish (selection for larger Sockeye in Arrow than Okanagan - may be related to gravel size --> adaptive scope
- Select hatchery stock to best match extirpated population and Kokanee
- Introduce low numbers of hatchery Sockeye
- Use imprinting to physically separate
- High genetic and life history diversity of hatchery fish

- Minimize the likelihood of interbreeding: use segregated spawning between Sockeye and Kokanee (release sites may be important and siting of hatchery infrastructure)

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Genetics

ACB Number S5.GE.2: Risk of loss of genetic integrity to extant natural populations of Sockeye below Chief Joseph Dam due to hybridization with reintroduced hatchery salmon

Risk Summary: Lowest Risk. *R* = 2. The **consequence is negligible** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	Low, Medium	13
Adjusted Re-Rating	Negligible	Low	n/a	18 (50%) [2]

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

There are many effective hatchery-management strategies that can be applied to mitigate the effects of this ACB.

- UC-bound Sockeye might interbreed with Okanagan Sockeye populations (shared parentage), with minimal genetic consequence
- Two known remaining sockeye stocks in the Columbia (Lake Wenatchee, Lake Osoyoos), although they may have mixed in hatcheries and may not be distinct stocks
- Okanagan H-O fish are genetically diverse & undomesticated (Hyatt et al. 2019)
- Hybridization and straying likely if upstream passage past Grand Coulee Dam and Chief Joseph Dam are not effective

Mitigation Recommendations

- High genetic and life history diversity of hatchery fish
- Maximization of homing and reduction of straying of introduced salmon by considering imprinting needs in hatchery rearing

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecotoxicology

ACB Number S5.ET.1: Risk of radioisotopes, mercury, and PCBs being introduced to the Upper Columbia from downstream marine and riverine waters by migrating adult Sockeye

Risk Summary: **Moderate Risk.** *R* = 12. The **consequence is modest** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	Low, Medium	11
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Heavy metals (Okanagan fish): accumulation depended on age
- Depends on efficacy of infrastructure to allow dam passage
- Literature to support low risk of radioisotope

Mitigation Recommendations

- None discussed

Outstanding Questions

- What remediation has taken place at Hanford nuclear site?

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecotoxicology

ACB Number S5.ET.2: Risk of local point-source contaminants from industrial sites being redistributed through the local ecosystem by migrating adult Sockeye

Risk Summary: **Lowest Risk.** *R* = 2. The **consequence is negligible** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Negligible	Low	n/a	12
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Depends on efficacy of infrastructure to allow dam passage

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecotoxicology

ACB Number S5.ET.3: Risk of micro-plastics from downstream marine and riverine waters being introduced into lakes and rivers by migrating adult Sockeye

Risk Summary: Lowest Risk. *R* = 1. The **consequence is negligible** and the **likelihood of this risk is negligible**, expected to occur between **0% and 1%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Negligible	Negligible	n/a	12
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Depends on efficacy of infrastructure to allow dam passage

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Nutrient Cycling

ACB Number S5.NC.1: Beneficial delivery of marine-derived nutrients to upstream aquatic habitats by migrating adult Sockeye

Benefit Summary: Low Benefit. $R = 4$. The **consequence is negligible** and the **likelihood of this benefit is substantial**, expected to occur between **66% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Negligible	Substantial	Low, Medium	13
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Risk depends on efficacy of infrastructure to allow dam passage

Mitigation Recommendations

- Nutrient additions (Pieters et al. 2003)

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.NC.2: Beneficial delivery of marine-derived nutrients to terrestrial habitats via terrestrial predators by Sockeye carcasses

Benefit Summary: Greatest Benefit. *R* = 30. The **consequence is modest** and the **likelihood of this benefit is nearly certain**, expected to occur between **99% and 100%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Nearly Certain	High	13
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Benefit depends on efficacy of infrastructure to allow dam passage

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.NC.3: Risk of creating a freshwater nutrient sink by out-migrating reintroduced Sockeye smolt exporting nutrients downstream

Risk Summary: **Moderate Risk.** *R* = 12. The **consequence is modest** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	Low, High	13
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Epilimnial nutrient losses due to export by migrating smolts (or fecal sedimentation) are minor relative to total epilimnial nutrient loads (Selbie et. al 2011).

Mitigation Recommendations

- Nutrients, mainly inorganic nitrogen and phosphorus fertilizer can be added to affected areas.

Reintroduction Strategy: Sockeye Salmon Reintroduction in the Arrow Lakes Reservoir-Revelstoke Reach (SPU #5)

Topic of Interest: Ecological and Biological Interactions

ACB Number S5.OA.1: Risk of increased human-wildlife conflict along riverbanks (e.g., with skunks, bears, etc.) due to increased Sockeye carcass availability after spawning

Risk Summary: Highest Risk. *R* = 18. The **consequence is modest** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Moderate	Medium	12
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

There are several strategies including changes to human behaviour that could effectively mitigate the consequences of this risk. Moreover, bears in the interior do not receive as high of a proportion of their annual calories from salmon runs relative to coastal bears.

- Increased number of carcasses leads to potential for less aggression between bears
- Interior bears don't have such a high proportion of annual calories from salmon runs (compared to coastal)

Mitigation Recommendations

- Changes to human behaviour (seasonal/area closures, education, etc.)
- Carcass removal from areas of high human-wildlife interactions

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.1: Beneficial increase in foraging opportunities and prey availability for native fish biota (e.g., Bull Trout, Rainbow Trout, Burbot, White Sturgeon) due to predation on reintroduced Chinook eggs, juveniles, and adults

Benefit Summary: Highest Benefit. *R* = 24. The **consequence is modest** and the **likelihood of this benefit is substantial**, expected to occur between **66% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Substantial	Low to High	12 (77%) [2]
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- The degree of benefit depends on the size of restored populations, with smaller numbers of reintroduced Chinook having a small beneficial effect on native fish biota. It is expected that the greatest benefits will be to Rainbow Trout, which are facultative piscivores, and Burbot, which are specialist piscivores.
- Bull Trout, Rainbow Trout, Burbot, and sturgeon will all consume Chinook eggs and juveniles in different habitats.
- Native fish foraging on adult Chinook will be low, with the possible exception of Sturgeon.
- Specifically for the Transboundary Reach:
    - Rainbow Trout are the most abundant potential predator for reintroduced Chinook. In many other locations, Trout exploit concentrations salmon eggs, fry, and smolts.
    - Sturgeon < 100 cm tend to be insectivores but will exploit concentrations of juvenile salmon. Larger Sturgeon exploit adult salmon, mainly scavenging carcasses, particularly pre-spawn mortalities.
    - Burbot and, especially, Bull Trout are rare, but will exploit concentrations of juvenile salmon. Both species are minor components of the fish fauna in the Columbia Transboundary Reach

Mitigation Recommendations

- None required for beneficial change.

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.2: Risk of local decline in Rainbow Trout biomass due to decline in prey size resulting from competition with reintroduced Chinook

Risk Summary: **Moderate Risk.** *R* = 12. The **consequence is modest** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	12 (77%) [2]
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Rainbow Trout and Chinook Salmon in streams are generally insectivorous, feeding on drift
- A significant impact would require very high densities of Chinook
    - Drift feeders generally do not deplete the benthos
    - Even at high Chinook Salmon densities, Rainbow Trout have will likely dominate the bioenergetic demand on drift because of their high abundance and larger individual size

Mitigation Recommendations

- Minimum size limits and quota restrictions are effective in reducing the impacts of recreational fishing on trout populations in streams

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.3: Risk of local decline in Mountain Whitefish biomass due to competition with reintroduced Chinook

Risk Summary: Lowest Risk. *R* = 4. The **consequence is negligible** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	12 (77%) [2]
Adjusted Re-Rating	Negligible	Low	n/a	14

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

Mountain whitefish are a dominant species in the Upper Columbia, and it is possible that they will compete with juvenile Chinook; however, uncertainty is high because little data is available on this species interaction. If an ocean-type donor stock is chosen, juvenile Chinook will likely attempt a first-year migration, which would reduce the potential for competition between Chinook juveniles and resident fish species.

- Donor stocks under consideration are summer-fall Chinook from Okanagan, Methow, and Wenatchee rivers and from the Hanford Reach and Chief Joe Tailrace. Chinook from these donor stocks can typically migrate downstream as age-0 fry or as yearling smolts in the spring (Warnock, 2016). Age-0 fry have lower potential for competition with Mountain Whitefish in comparison with yearling smolts
- Experts agree that very few data are available to directly assess this ecological interaction. More general arguments involving diet, feeding behavior and bioenergetics suggest that likelihood is high but consequence for Mountain Whitefish is low.
- Mountain Whitefish and juvenile Chinook have similar diets and habitat preferences. The impact of Chinook competition on Mountain Whitefish will be limited by the much higher biomass of Mountain Whitefish and by differences in resource utilization (Mountain Whitefish, benthos vs. Chinook Salmon drifting benthos)
- Mountain whitefish decline is unlikely and/or slight, any decline in societal value from lower Mountain Whitefish is outweighed by increase from Chinook
    - One reviewer commented: “Mountain Whitefish are a keystone species in Kootenay Rivers; they are/were also typically present/abundant in many streams where salmon

(various species are present) and have survived/thrived. I disagree with the implication that from a societal value perspective the benefits are outweighed. Whitefish are a very important food fish, and while they may not have the same "economic or commercial value" as salmon, I would argue that they are in fact 'undervalued' (until they disappear)

Mitigation Recommendations

- Current harvest on whitefish is low, but could be eliminated

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.4: Risk of local decline in Bull Trout biomass due to competition with reintroduced Chinook

Risk Summary: Lowest Risk. *R* = 1. The **consequence is negligible** and the **likelihood of this risk is negligible**, expected to occur between **0% and 1%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	12 (77%) [2]
Adjusted Re-Rating	Negligible	Negligible	n/a	16

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

The decrease in the consequence score between the pre-rating and in-workshop rating may be attributable to the discussion surrounding whether the Transboundary Reach is too warm for juvenile Bull Trout to compete with other fish species. If this is the case, there would be little interaction between Bull Trout and reintroduced Chinook in this area, but with more potential for interaction in Mica Reservoir. A low-density population of older Bull Trout in the Transboundary Reach will likely benefit from the presence of Chinook juveniles and eggs as food items.

- Uncertainty in Bull Trout temperature preference makes risk and benefit assessment difficult. The Transboundary Reach is probably too warm for juvenile Bull Trout, in which case there would be little interaction between the species and little risk to Bull Trout juveniles. Interaction with spring Chinook would be more likely with juvenile Bull Trout residing in colder tributaries.
- Adult Bull Trout may regularly migrate downstream into Transboundary Reach from the upstream areas, but return migrations to Arrow Lake, Slocan Lake and the Pend d'Oreille rivers are currently blocked by dams. The extent of juvenile movement is unknown. Adult Bull Trout are good at eating juvenile Chinook and their eggs, so Bull Trout may benefit from reintroduction. Therefore, the directionality of this effect may be positive or negative, depending on the specific geography. In Kootenay Lake, the concern is that predators (Bull Trout and Gerrard Rainbow Trout) preventing the recovery of depressed Kokanee populations
- Bull Trout outcompete other species such as Rainbow Trout in small cold-water streams, but if other species are absent, Bull Trout can tolerate temperatures up to 15ºC-20ºC. Adult Bull Trout are a top predator and would not compete with juvenile Chinook. In other locations (e.g., upper Fraser), Bull Trout move hundreds of km to take advantage of feeding

opportunities in warmer streams, but you do not find Bull Trout <200mm in these streams. Bull Trout are present in the Transboundary Reach, but their catch rates are in the 10s per year vs 10,000/year for Rainbow Trout and 1,000/yr for Kokanee.

- Temperature thresholds for Bull Trout juveniles: Rainbow Trout juveniles replace Bull Trout between 12ºC-14ºC (Parkinson et al. 2016).
- Bull Trout populations in upstream areas are doing well. Bull Trout are being culled in the Kootenay Lake area in an attempt to recover a collapsed Kokanee population.

Mitigation Recommendations

- Minimum size limits and quota restrictions have proven to be effective tools in reducing the impacts of recreational fishing on trout populations in streams (Wigwam R., Kananaskis L.)
- Habitat conservation, mostly associated with improved land use practices in forest harvesting, road construction etc.

Outstanding Questions

- Wouldn't Bull Trout populations benefit from eating juveniles and eggs of spawning Chinook?
    - Reply: Yes; Bull Trout prey on salmon juveniles in many areas.
- What about overlap in Chinook rearing habitat with juvenile Bull Trout?
    - Reply: Not summer-fall run. However, spring-run Chinook typically utilize colder headwater tributaries and are much more likely to interact with juvenile Bull Trout.

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.5: Risk of local decline in White Sturgeon biomass due to competition with reintroduced Chinook

Risk Summary: Lowest Risk. *R* = 1. The **consequence is negligible** and the **likelihood of this risk is negligible**, expected to occur between **0% and 1%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Negligible	Negligible	Low, Medium	13
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

Risk is likely low; sturgeon recruitment is thought to be limited by spawning habitat and predation on juveniles.

- Not discussed in workshop because of pre-workshop consensus that this risk has a low likelihood of occurring: competition with juvenile White Stugeon is unlikely, and competition with adult White Stugeon is non-existent.

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.6: Risk of local decline in Kokanee biomass due to competition with residualized reintroduced Chinook

Risk Summary: Lowest Risk. *R* = 1. The **consequence is negligible** and the **likelihood of this risk is negligible**, expected to occur between **0% and 1%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Negligible	Negligible	Medium	11
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Some participants felt that this was a "*Natural effect of returning anadromous fish to habitat*", but predation on Kokanee by Chinook is only a factor for Chinook that fail to migrate to the ocean, which is not consistent with the restoration of anadromous fish and has been reported in large lakes and reservoirs where ocean access is difficult.
- This will be an issue in Lake Roosevelt as well as reservoirs upstream. Residualization of Chinook from the Columbia Transboundary Reach will be flagged as an issue for the Lake Roosevelt management team.

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.7: Risk of local decline in native fish (e.g., Kokanee) biomass due to indirect effects of aquatic invasive species predation on reintroduced Chinook

Risk Summary: **Moderate Risk.** *R* = 12. The **consequence is modest** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	12 (77%) [2]
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Piscivorous invasives (Walleye, Bass) may benefit from additional prey (i.e., Chinook juveniles) but the effect is likely to be very small because the biomass of Chinook juveniles relative to the current prey base of these piscivores is expected to be relatively low.
- If piscivore populations (e.g., Walleye) are enhanced by the presence of Chinook, then mortality on native species may be higher than in the absence of Chinook.

Mitigation Recommendations

- Concurrent invasive species suppression may be possible because recreational overharvest of large (>25 cm) individuals is common in their native range. However, both bass and walleye are piscivorous at <25 cm. Suppression of piscivore recruitment is unlikely and Chinook juveniles are well within the prey size preference range of small piscivores.

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.8: Beneficial increase in distribution of native mussels due to larval attachment to reintroduced Chinook

Benefit Summary: Moderate Benefit. *R* = 12. The **consequence is modest** and the **likelihood of this benefit is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	11 (77%) [2]
Adjusted Re-Rating	Modest	Low	n/a	14

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

Mussel larvae have a symbiotic relationship with certain fish species that allows them to attach themselves to these fish to move upstream. While there are already fish in the system that can transport these larvae (e.g., Rainbow Trout), native mussel populations have been declining, in part due to the loss of other native host species like salmon and sturgeon.

- Uncertainty is high because not much research has been done in this area
- Mussel larvae attach to fish (like adult Chinook) to move upstream. There are already fish moving upstream (e.g., Rainbow Trout)., so there would be other fish to attach to regardless of salmon reintroduction.
- Mussel larval attachment is often tied to a particular host species
- Many native mussel populations are at risk, partially due to loss of native host species like salmon and sturgeon. Additional or alternative host species would be a beneficial consequence.
- Some of the uncertainty concerning host species for each mollusc species my be resolved by ongoing research on the status of native (and invasive) mussels (e.g., Maine et al. 2022)

Mitigation Recommendations

- None required for beneficial change

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.9: Risk of local decline in zooplankton abundance in oligotrophic lakes due to predation from reintroduced Chinook

Risk Summary: Lowest Risk. *R* = 1. The **consequence is negligible** and the **likelihood of this risk occurring is negligible**, expected to occur between **0% and 1%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Negligible	Medium	12 (77%) [2]
Adjusted Re-Rating	Negligible	Negligible	n/a	18

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

Due to their life history, Chinook are not expected to spend much time in oligotrophic lakes, nor are there oligotrophic lakes in the Transboundary Reach SPU. Even Sockeye, who spend more time in oligotrophic lakes, had few effects on zooplankton in the Okanagan Lake system.

- Chinook are not expected to spend much time in oligotrophic lakes and do not survive very well in reservoirs (this ACB may be more applicable to Sockeye). This ACB could have potential effects in Lake Roosevelt downstream.
- Kokanee are more effective planktivores than Chinook.
- There are no oligotrophic lakes in this SPU
- Even Sockeye, at least in the Okanagan system, did not have as large an effect on zooplankton as thought (and by extension, Chinook would have less)
- Juvenile salmon use/feeding at that life history stage in oligotrophic lakes not likely for Chinook
- Mysis entrainment from upstream (Arrow Lake) is a food subsidy for downstream fish populations, including Chinook juveniles.

Mitigation Recommendations

- Gradual reintroductions
- Nutrient supplementation treatments

Outstanding Questions

- Is there potential for/would there be juvenile Chinook feeding on mysids?
    - Reply: Chinook will likely feed on mysids, but mostly in the reach immediately downstream of Arrow Lake and mostly for Chinook > 50 mm

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ABC Number Csf1.EI.10: Risk of increasing distribution and abundance of aquatic invasive species by establishing fish passage infrastructure for reintroduced Chinook

Risk Summary: Highest Risk. *R* = 36. The **consequence is substantial** and the **likelihood of this risk is moderate**, expected to occur between **66% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Substantial	Moderate	Medium	12 (77%) [2]
Adjusted Re-Rating	Substantial	Moderate	n/a	17

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

During the workshop, participants considered risk consequence through a long-term lens (7 generations) and incorporated the possibility of reintroductions further upstream beyond the Transboundary Reach into their assessment of this ACB.

- Higher risks assume movement beyond Transboundary Reach
- A lot of invasives coming down. Risk would be bringing fish from below Grand Coulee
- Just because invasives are already in the area does not mean that this ACB is not a concern/risk
- Fish below Grand Coulee to LakeL Roosevelt. Western fish fauna tends to have fewer species that are vulnerable to invasion. A lot of invasive species coming down Pend d'Oreille
    - Northern Pike are currently moving down the Pend d'Oreille River. The concern is excluding them (& bass & walleye) from Arrow Lakes. However, the route is the boat lock at Keenleyside Dam, which operates independently of Chinook and Sockeye introduction activities. The pressure to keep this operating is from boat owners, not species reintroduction.
- This would be higher risk consequence if we were talking about passage above Transboundary Reach / higher parts of the watershed from a longer-term point of view (7 generations)
- Northern Pike are already in the Kootenay system, from sources upstream on the Kootenay above Libby, as well as downstream sources (below Libby toward the Columbia)

Mitigation Recommendations

- Invasives monitoring and careful screening
    - In locations where there is a concern, trap and truck can be used to eliminate the risk by using only upstream or ground water
    - If Chinook passage is manual, then you can use fish free water (e.g., from above the obstruction. This is an issue associated with species that are below Grand Coulee, but not above (i.e., not Walleye, Bass etc.)
- Reduction in long-distance water transfers/transfers of water from one drainage to another
    - Low water transfer

Outstanding Questions

- What about Northern Pike upstream (if fish passage is established)?
    - Reply: Passage of non-target species can be almost eliminated by good practices. This includes other species such as walleye.

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.11: Risk of increase in invasive fish biomass due to predation on reintroduced Chinook eggs, juveniles, and adults

Risk Summary: Highest Risk. *R* = 18. The **consequence is modest** and the **likelihood of this risk occurring is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	Low, Medium	12 (77%) [2]
Adjusted Re-Rating	Modest	Moderate	n/a	16

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

The consensus among workshop experts was that the consequence of this ACB is highly density dependent. If many Chinook become re-established, bass and walleye lower in the Columbia are likely to prey extensively on migrating Chinook smolts. Native Northern Pikeminnow have adapted well in the Lower Columbia and will also benefit from Chinook re-establishment by preying on juveniles downstream of Grand Coulee dam.

- Highly dependent on the number of Chinook that get established. More likely a concern where larger numbers established; not likely very substantial if few Chinook establish.
- Re-ratings reflect that over 7 human generations there is an ecologically significant population of Chinook that have re-established themselves.
- Lower in the Columbia, bass and walleye prey extensively on migrating Chinook smolts. Terns and cormorants have also targeted Chinook smolts.
- Assuming that there is currently an abundance of food for invasive species, Chinook reintroduction may not generate a large effect.
- For perspective, it took about 100 years for Lake Trout to establish in Flathead Lake (stockings were in early 1900's and trophic crash/change didn't occur until mysids became established and Lake Trout could outcompete Westslope Cutthroat Trout and Bull Trout
    - Lake Trout are very effective Mysis predators, but prefer to eat Kokanee
- Lots of work on Northern Pikeminnow (not an invasive species here, but may give some indication on risk)

- Pikeminnow will benefit, but mainly downstream of dams. They aren't invasive, but a predation issue. They've adapted well in the Lower Columbia.
- That would assume we know something about status of invasive populations/biomass and density
- The pikeminnow issue is a real concern for juveniles, but only if there were fish passing from upstream, below Grand Coulee maybe.

Mitigation Recommendations

- Concurrent invasive species suppression may be an option; however, there are almost no successful examples of this mitigation being applied.

Outstanding Questions

- What are limiting factors for invasive species? Habitat? Food availability? Unclear.
- Agree numbers would have to be so high - is this currently an issue for other salmonids there?
- Is this a density-dependent response?

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.12: Risk of reintroduced Chinook negatively affecting the biomass and distribution of fish species listed as special concern, threatened, or endangered (i.e., White Sturgeon, Umatilla dace, and Columbia sculpin).

Risk Summary: **Moderate Risk.** *R* = 12. The **consequence is modest** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	n/a	12 (77%) [2]
Adjusted Re-Rating	n/a	n/a	High	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- High uncertainty because competitive effects are largely unknown due to low population sizes
- Chinook in large lakes tend to be pelagic predators; the listed species are not pelagic specialists (Jacobs et al. 2013)

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecological and Biological Interactions

ACB Number Csf1.EI.13: Risk of local decline in native fish (e.g., Kokanee) biomass due to increased predation by residualized reintroduced Chinook

Risk Summary: Highest Risk. *R* = 18. The **consequence is modest** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Moderate	n/a	12 (77%) [2]
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- This is an issue in Roosevelt Lake, not the Transboundary Reach; large (>25cm) Chinook residualize in lakes, not streams.

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Disease and Pathogens

ACB Number Csf1.DP.1: Risk of introduction and spread of pathogens that do not currently occur in the Canadian Upper Columbia (e.g., IHNV M-clade, IPNV, Whirling Disease) by reintroduced Chinook

Risk Summary: Highest Risk. *R* = 36. The **consequence is substantial** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Substantial	Moderate	Medium	11 (62%) [2]
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Disease management strategies may not be scalable, which affects mitigation strategies
- Water sources that may drain into the Columbia need to be considered when thinking about what pathogens are present in the ecosystem
- Develop a risk matrix: fish species, susceptibility x agents
- Listed species risk to novel agents
- Limited disease surveillance in Canada
- One commenter suggested:
    - Whirling disease currently isn't documented in BC streams; current source populations seem to be in Montana and potentially Alberta
    - Didymo might be a concern and is present in Kootenay streams (native to the Kootenay) and Montana streams

Mitigation Recommendations

- Disease screening donor populations
- Proper hatchery management practices
- Reduction in water transfer during stocking
- Knowledge of disease history in donor populations

- Environmental disease study to determine at what level pathogens are present in the environment

Outstanding Questions

- Are there pathogens present in Canadian region that aren't present in US Columbia? We may eventually be the source for Whirling Disease
- What is the frequency of pathogens in the donor population? Risk of selecting fish that carry pathogens
- When is screening happening?
- Presence of WD in Upper Columbia? WD occurs in adjacent Alberta and US waters. Limited screening in Canadian waters.

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Disease and Pathogens

ACB Number Csf1.DP.2: Risk of spread/amplification of pathogens that already occur the Canadian Upper Columbia (e.g., IHNV U-clade, BKD, Columnaris) by reintroduced Chinook

Risk Summary: Highest Risk. *R* = 18. The **consequence is modest** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Moderate	Medium	12 (62%) [2]
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Crucial to separate out life-stages: hatchery-reared juveniles pose a low risk, risk associated with returning adults is much higher
- We don't know what the drivers of disease are. but endemic pathogens can probably be slightly amplified with little effect
- Other pathogens: *Piscine orthoreovirus* (PRV), *Flavobacterium psychrophilum*, *Marinobacter arcticus*, *Renibacterium salmoninarum*, *Ichthyophthirius multifiliis*, *Cryptobia salmositica*, *Parvicapsula kabatai*, *Candidatus Branchiomonas cysticola*, *Ceratonova shasta*, *Listonella anguillarum*, viral hemorrhagic septicemiaep virus (VHSV), *Aeromonas hydrophila*, *Aeromonas salmonicida*
- Environmental and host factors influencing disease occurrence in recipient populations will continue to occur and may be more influential than introduction of infected fish

Mitigation Recommendations

- Screening of hatchery stock
- Minimize number of reintroduction events
- Establish surveillance programs for early disease detection in recipient populations
- Ensure that there are enough brood fish to be able to discard fish that carry disease
- Appropriate hatchery design – potentially individual rearing

Outstanding Questions

- How do you screen them, how do you manage the agents?
- Effects of multiple pathogens? Can become very complex
- How much do we care about endemic disease?
- Which agents of concern are we able to effectively detect? Which donor stocks carry these agents? If there is a problem in the hatchery, how do we treat it?
- Is there a different response to disease for wild fish vs. hatchery fish? If so, how important is the difference?

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Disease and Pathogens

ACB Number Csf1.DP.3: Risk of bear and other terrestrial predator exposure to salmon poisoning disease from consumption of reintroduced Chinook

Risk Summary: Lowest Risk. *R* = 6. The **consequence is modest** and the **likelihood of this risk is negligible**, expected to occur between **0% and 1%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Negligible	High	10 (62%) [2]
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- This was mentioned in Thompson's journals. He was told by the locals not to feed the Chinook to their dog as they would die. They fed the dogs anyway and they died. As long as it was limited to Chinook as host then the pathogen is probably gone, however many pathogens affect several species of salmonid so theoretically could be a reservoir (in WCT for example), but unlikely

Mitigation Recommendations

- None discussed

Outstanding Questions

- Is it not likely that trematode, bacteria, hosts, reservoirs, and vectors are all still present in a functioning pathway, despite the absence of anadromous Chinook?

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Disease and Pathogens

ACB Number Csf1.DP.4: Risk of reintroduced Chinook providing evolutionary space for endemic pathogens to increase in virulence

Risk Summary: **Moderate Risk.** *R* = 12. The **consequence is modest** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	10 (62%) [2]
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- None discussed

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Genetics

ACB Number Csf1.GE.1: Risk of loss of genetic integrity to extant natural populations of Chinook below Chief Joseph Dam due to hybridization with reintroduced hatchery salmon

Risk Summary: Highest Risk. *R* = 18. The **consequence is modest** and the **likelihood of this risk is moderate**, expected to occur between **33% and 66%** of the time**.**

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Substantial	Moderate	Medium	10 (58%) [2]
Adjusted Re-Rating	Modest	Moderate	n/a	17

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

Many proactive mitigation strategies exist for this risk which can be applied in hatcheries and during the donor stock selection process. Existing downstream Chinook populations also have high levels of genetic diversity; however, if there is constant introduction of hatchery fish over the long-term (i.e., over seven human generations), homogenization is likely to occur.

- Likelihood: propagule pressure from Upper Columbia. Higher numbers create more downstream pressure
- Different release/hatchery strategies influence degree of straying
- If upstream dam passage is ineffective, straying to downstream populations is likely to be substantial.
- Natural populations have lots of genetic diversity.
- But over 7 human generations, constant introduction of hatchery fish will cause homogenization, pending propagule pressure
- No extant natural populations below dam
- Considering the broad portfolio of Chinook in the lower Columbia, this seems unlikely that these are all hatchery stocks.
- Likelihood of hybridization depends on ease of dam passage

Mitigation Recommendations

- Careful monitoring and maintenance of diversity in hatchery stocks

- Rearing hatchery fish so they imprint properly on natal streams
- Choose the correct growth rate and size for release
- Brood selection that allows for genetic diversity
- Choice of donor stock includes doing an ancestry match with nearest neighbor and a matching of life history strategy

Outstanding Questions

- Are donor populations being screened for being summer Chinook genotypes? Or is this only being screened for phenotypically?

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecotoxicology

ACB Number Csf1.ET.1: Risk of radioisotopes, mercury, and PCBs being introduced to the Upper Columbia from downstream marine and riverine waters by migrating adult Chinook

Risk Summary: **Lowest Risk.** *R* = 6. The **consequence is modest** and the **likelihood of this risk is negligible**, expected to occur between **0% and 1%** of the time**.**

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Negligible	n/a	11
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Depends on efficacy of infrastructure to allow dam passage

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecotoxicology

ACB Number Csf1.ET.2: Risk of local point-source contaminants from industrial sites being redistributed through the local ecosystem by migrating adult Chinook

Risk Summary: **Moderate Risk.** *R* = 12. The **consequence is modest** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time**.**

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	n/a	11
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Depends on efficacy of infrastructure to allow dam passage

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Ecotoxicology

ACB Number Csf1.ET.3: Risk of micro-plastics from downstream marine and riverine waters being introduced into lakes and rivers by migrating adult Chinook

Risk Summary: Lowest Risk. *R* = 1. The **consequence is negligible** and the **likelihood of this risk is negligible**, expected to occur between **0% and 1%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Negligible	Negligible	n/a	11
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- Depends on the biomass of fish that move upstream over dams; the concentration of toxicants in salmon tissue has been measured.

Mitigation Recommendations

- None discussed

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Nutrient Cycling

ACB Number Csf1.NC.1: Beneficial delivery of marine-derived nutrients to upstream aquatic habitats by migrating adult Chinook

Benefit Summary: Highest Benefit. R = 48. The **consequence is substantial** and the **likelihood of this benefit is substantial**, expected to occur between **66% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Substantial	Substantial	High	12 (52%) [2]
Adjusted Re-Rating	Substantial	Substantial	n/a	19

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

The magnitude of the beneficial delivery of marine-derived nutrients to the existing ecosystem depends on the density of fish that are reintroduced: 50,000 Chinook will not materially influence nutrient cycling at such a large geographic scale.

- Columbia River environment is highly productive (high fish yield, etc.) compared to many other regional large river habitats
- High uncertainty due to unknown efficacy of dam passage
- Consequence range comes down to numbers:
    - 50,000 returning fish will not materially influence nutrient cycling at the geographic scale of the basin
    - Low consequence ratings may be due to number of carcasses from reintroduced fish being too low to affect nutrient loads
    - High consequence score may be due to cultural components (connectivity to ocean is important for local First Nations)

Mitigation Recommendations

- None required for beneficial change

Outstanding Questions

- Are fish that were spawned in the hatchery returned to the river? How many are taken out for harvest?

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Nutrient Cycling

ACB Number Csf1.NC.2: Beneficial delivery of marine-derived nutrients to terrestrial habitats via terrestrial predators by Chinook carcasses

Benefit Summary: Highest Benefit. *R* = 24. The **consequence is modest** and the **likelihood of this benefit is substantial**, expected to occur between **66% and 99%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Nearly Certain	Low, Medium	13
Adjusted Re-Rating	Modest	Substantial	n/a	18

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- High uncertainty associated with expected spawner density, wildlife utilization and transport rates in large rivers. Some nutrient transport is almost certain to occur, but consequence will be much lower than in streams with mass spawning species (Pink, Chum, Sockeye Salmon),

Mitigation Recommendations

- None required for beneficial change

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Nutrient Cycling

ACB Number Csf1.NC.3: Risk of creating a freshwater nutrient sink by out-migrating reintroduced Chinook smolt exporting nutrients downstream

Risk Summary: **Moderate Risk.** *R* = 12. The **consequence is modest** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	High	12 (52%) [2]
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- None discussed

Mitigation Recommendations

- Nutrient treatments

Reintroduction Strategy: Summer-fall Chinook Reintroduction in the Transboundary Reach (SPU #1)

Topic of Interest: Other Attributes

ACB Number Csf1.OA.1: Risk of increased human-wildlife conflict along riverbanks (e.g., with skunks, bears, etc.) due to increased Chinook carcass availability after spawning

Risk Summary: **Moderate Risk.** *R* = 12. The **consequence is modest** and the **likelihood of this risk is low**, expected to occur between **1% and 33%** of the time.

Rating Session	Consequence Rating[1]	Likelihood Rating[1]	Level of Uncertainty	Number of Responses
Pre-workshop Rating	Modest	Low	Medium	12
Adjusted Re-Rating	n/a	n/a	n/a	-

[1] Ratings represent categories of risk. In the survey, respondents were asked to provide report consequence and likelihood score as a numerical value which was converted to ratings as discussed in the rubrics in Section 2.3.3.
[2] Percentage refers to the cumulative self-identified expertise of respondents, where 100% indicates that all respondents self-identify as experts. Number includes all respondents in the survey and in discussion combined.

Contents of Expert Workshop Discussion

- None discussed

Mitigation Recommendations

- Changes to human behaviour (seasonal area closures, education)
- Carcass removal from areas of high human-wildlife interactions

Appendix B: Summary of Phase I Ratings for Sockeye Reintroduction in SPU#5

ACB	Risk Category (Risk Value)	Consequence				Likelihood						Uncertainty
		Rating[a]	Probability			Rating[a]	Probability					
			N[b]	M[c]	S[d]		N[b]	L[e]	M[c]	S[d]	C[f]	
S5.EI.1	**Greatest Benefit (24)**	Modest	0.13	**0.56**	0.31	Substantial	0.00	0.00	0.13	**0.69**	0.19	Low
S5.EI.2	**Highest Risk (18)**	Modest	0.21	**0.64**	0.15	Moderate‡	0.21	**0.43**	**0.21**	0.14	0.00	High
S5.EI.3	**Highest Risk (24)**	Modest	0.13	**0.69**	0.19	Substantial	0.13	0.25	0.19	**0.38**	0.06	Low, Medium
S5.EI.4	**Highest Risk (18)**	Modest	0.36	**0.50**	0.14	Moderate	0.13	0.25	**0.38**	0.19	0.06	Medium
S5.EI.5	**Highest Risk (18)**	Modest	0.36	**0.50**	0.14	Moderate‡	0.36	**0.50**	**0.07**	0.07	0.00	High
S5.EI.6	**Highest Risk (18)**	Modest	0.31	**0.54**	0.15	Moderate‡	0.38	**0.38**	**0.08**	0.15	0.00	High
S5.EI.7	Lowest Risk (2)	Negligible	**0.46**	0.31	0.23	Low‡	0.46	**0.46**	0.00	0.08	0.00	High
S5.EI.8	Moderate Risk (12)	Modest	0.08	**0.83**	0.08	Low	0.17	**0.50**	0.33	0.00	0.00	n/a
S5.EI.9	Moderate Benefit (12)	Modest	0.21	**0.57**	0.21	Low	0.14	**0.43**	0.21	0.21	0.00	High
S5.EI.10	**Highest Risk (24)**	Modest	0.06	**0.82**	0.12	Substantial‡	0.06	0.18	**0.35**	**0.35**	0.06	Low, Medium
S5.EI.11	**Highest Risk (48)**	Substantial	0.00	0.22	**0.78**	Substantial	0.00	0.17	0.22	**0.50**	0.11	Medium
S5.EI.12	Lowest Risk (6)	Modest‡	0.27	**0.47**	0.26	Negligible	**0.53**	0.40	0.00	0.07	0.00	High
S5.EI.13	**Highest Risk (48)**	Substantial‡	0.27	0.27	**0.47**	Substantial‡	0.13	0.20	0.27	**0.40**	0.00	Medium, High
S5.EI.14	Moderate Benefit (12)	Modest	0.31	**0.56**	0.13	Low	0.25	**0.44**	0.25	0.00	0.06	High
S5.DP.1	**Highest Risk (36)**	Substantial	0.05	0.21	**0.74**	Moderate‡	0.00	0.32	**0.42**	0.21	0.05	High
S5.DP.2	**Highest Risk (24)**	Modest	0.15	**0.69**	0.15	Substantial	0.15	0.23	0.23	**0.38**	0.00	High
S5.DP.3	Lowest Risk (6)	Modest	0.38	**0.54**	0.08	Negligible	**0.46**	0.31	0.15	0.00	0.08	High
S5.DP.4	Moderate Risk (12)	Modest	0.16	**0.67**	0.17	Low	0.17	**0.58**	0.25	0.00	0.00	High
S5.GE.1	**Highest Risk (18)**	Modest‡	0.13	**0.50**	0.38	Moderate‡	0.13	0.19	**0.44**	0.25	0.00	Low, High
S5.GE.2	Lowest Risk (2)	Negligible‡	**0.39**	0.44	0.17	Low	0.22	**0.44**	0.22	0.06	0.06	Low, Medium
S5.ET.1	Moderate Risk (12)	Modest	0.45	**0.55**	0.00	Low	0.18	**0.36**	0.36	0.09	0.00	n/a
S5.ET.2	Lowest Risk (1)	Negligible	**0.50**	0.50	0.00	Low	0.33	**0.58**	0.36	0.09	0.00	n/a
S5.ET.3	Lowest Risk (2)	Negligible	**0.67**	0.33	0.00	Negligible	**0.50**	0.25	0.25	0.00	0.00	n/a

S5.NC.1	Least Benefit (4)	Negligible	**0.38**	0.33	0.00	Substantial	0.08	0.00	0.15	**0.46**	0.31	**Medium, High**
S5.NC.2	**Greatest Benefit (30)**	Modest	0.23	**0.46**	0.31	Nearly Certain	0.08	0.15	0.15	**0.31**	**0.31**	**High**
S5.NC.3	Moderate Risk (12)	Modest	0.23	**0.69**	0.08	Low	0.23	**0.54**	0.08	0.15	0.00	**Low, High**
S5.OA.1	**Highest Risk (18)**	Modest	0.33	**0.60**	0.07	Moderate	0.17	0.25	**0.33**	0.25	0.00	**High**

[a] Rating is determined by the ratings collected during the Phase I Assessment survey, as adjusted during the workshop discussion. Refer to Section 2 for details.

[b] N represents negligible probability across all ratings, defined as the number of negligible ratings divided by the total number of ratings. Refer to rubrics in Section 2.3.3.

[c] M represents modest/moderate probability across all ratings, defined as the number of modest/moderate ratings divided by the total number of ratings.

[d] S represents substantial probability across all ratings, defined as the number of substantial ratings divided by the total number of ratings.

[e] L represents low probability across all ratings, defined as the number of low ratings divided by the total number of ratings.

[f] C represents considerable probability across all ratings, defined as the number of considerable ratings divided by the total number of ratings.

‡ indicates a rating change based on expert discussion during the Phase I Assessment.

2

Appendix C: Summary of Phase I Ratings for Chinook Reintroduction in SPU#1

ACB	Risk Category (Risk Value)	Consequence				Likelihood						Uncertainty
		Rating[a]	Probability			Rating[a]	Probability					
			N[b]	M[c]	S[d]		N[b]	L[e]	M[c]	S[d]	C[f]	
Csf1.EI.1	**Greatest Benefit (24)**	Modest	0.00	**0.50**	0.50	Substantial	0.00	0.00	0.25	**0.50**	0.25	Low, Medium
Csf1.EI.2	Moderate Risk (12)	Modest	0.17	**0.67**	0.17	Low	0.25	**0.67**	0.00	0.00	0.08	High
Csf1.EI.3	Lowest Risk (4)	Negligible‡	**0.36**	**0.50**	0.14	Low	0.21	**0.64**	0.07	0.07	0.00	High
Csf1.EI.4	Lowest Risk (1)	Negligible	**0.50**	0.38	0.12	Negligible	**0.44**	**0.44**	0.06	0.06	0.00	High
Csf1.EI.5	Lowest Risk (1)	Negligible	**0.50**	0.25	0.25	Negligible	**0.50**	0.42	0.00	0.08	0.00	High
Csf1.EI.6	Lowest Risk (1)	Negligible	**0.45**	**0.45**	0.10	Negligible	**0.45**	0.27	0.18	0.10	0.00	Medium
Csf1.EI.7	Moderate Risk (12)	Modest	0.42	**0.50**	0.08	Low	0.42	**0.50**	0.00	0.08	0.00	High
Csf1.EI.8	Moderate Benefit (12)	Modest	0.21	**0.64**	0.14	Low	0.14	**0.57**	0.14	0.14	0.00	High
Csf1.EI.9	Lowest Risk (1)	Negligible‡	**0.50**	0.39	0.11	Negligible	**0.61**	0.17	0.11	0.11	0.00	Medium
Csf1.EI.10	**Highest Risk (36)**	Substantial	0.06	0.29	**0.65**	Moderate	0.00	0.24	**0.29**	**0.29**	0.06	Medium
Csf1.EI.11	**Highest Risk (18)**	Modest	0.06	**0.75**	0.19	Moderate‡	0.06	**0.38**	**0.19**	0.25	0.00	Medium
Csf1.EI.12	Moderate Risk (12)	Modest	0.17	**0.58**	0.25	Low	0.42	**0.42**	0.00	0.17	0.00	High
Csf1.EI.13	**Highest Risk (18)**	Modest	0.00	**0.83**	0.17	Moderate	0.08	0.33	**0.50**	0.08	0.00	n/a
Csf1.DP.1	**Highest Risk (36)**	Substantial	0.00	0.27	**0.73**	Moderate	0.00	0.09	**0.55**	0.18	0.18	Medium
Csf1.DP.2	**Highest Risk (18)**	Modest	0.08	**0.58**	0.33	Moderate	0.08	0.25	**0.42**	0.17	0.08	Medium
Csf1.DP.3	Lowest Risk (6)	Modest	0.30	**0.50**	0.20	Negligible	**0.50**	0.00	0.50	0.00	0.00	High
Csf1.DP.4	Moderate Risk (12)	Modest	0.00	**0.70**	0.30	Low	0.20	**0.50**	0.20	0.10	0.00	High
Csf1.GE.1	**Highest Risk (18)**	Modest	0.12	**0.53**	0.35	Moderate	0.12	0.24	**0.41**	0.00	0.00	Medium
Csf1.ET.1	Lowest Risk (6)	Modest	0.27	**0.64**	0.09	Negligible	**0.27**	**0.27**	0.18	0.27	0.00	n/a
Csf1.ET.2	Moderate Risk (12)	Modest	0.27	**0.64**	0.09	Low	0.36	**0.45**	0.09	0.09	0.00	n/a
Csf1.ET.3	Lowest Risk (1)	Negligible	**0.45**	**0.45**	0.10	Negligible	**0.36**	**0.36**	0.18	0.09	0.00	n/a

Csf1.NC.1	**Greatest Benefit (48)**	Substantial	0.21	0.32	**0.47**	Substantial	0.00	0.05	0.11	**0.47**	0.37	High
Csf1.NC.2	**Greatest Benefit (24)**	Modest	0.17	**0.50**	0.33	Substantial‡	0.00	0.08	**0.33**	0.25	0.33	High
Csf1.NC.3	Moderate Risk (12)	Modest	0.17	**0.83**	0.00	Low	0.17	**0.58**	0.08	0.17	0.00	High
Csf1.OA.1	Moderate Risk (12)	Modest	0.33	**0.58**	0.08	Low	0.17	**0.33**	**0.33**	0.17	0.00	Medium

[a] Rating is determined by the ratings collected during the Phase I Assessment survey, as adjusted during the workshop discussion. Refer to Section 2 for details.

[b] N represents negligible probability across all ratings, defined as the number of negligible ratings divided by the total number of ratings. Refer to rubrics in Section 2.3.3.

[c] M represents modest/moderate probability across all ratings, defined as the number of modest/moderate ratings divided by the total number of ratings.

[d] S represents substantial probability across all ratings, defined as the number of substantial ratings divided by the total number of ratings.

[e] L represents low probability across all ratings, defined as the number of low ratings divided by the total number of ratings.

[f] C represents considerable probability across all ratings, defined as the number of considerable ratings divided by the total number of ratings.

* single asterisk indicates attributes of greatest benefit.

** double asterisk indicates attributes of greatest risk.

‡ indicates a rating change based on expert discussion during the Phase I Assessment.

Appendix D: Ecotoxicology Research Report

Traditional food systems play a fundamental role in maintaining food security in Indigenous communities, and are closely linked to culture, land, and self-determination (Kuhnlein et al. 2012). A study of traditional food use in British Columbia (BC) found that Indigenous people consume salmon an average of 47 days per year, relying on this food source for 5.4% of their protein and 45.5% of their vitamin D intake; the same study also concluded that 41% of Indigenous households are food insecure and that 91% of Indigenous households would like to consume more traditional foods like salmon (Chan et al. 2011). In the Fraser River, the annual catch stability of Chinook and Sockeye Salmon is directly driven by population diversity (Nesbitt et al. 2016), suggesting that proper management practices in the reintroduction of these species to the Canadian Upper Columbia River can aid in the re-establishment of this important traditional fishery within the next seven generations.

Pacific Salmon (*Oncorhynchus* spp.) are also a compelling example of migratory species that control the flow of material across ecosystems, acting as both a resource subsidies and potential contaminant biovectors (Blais et al. 2007). Due to their semelparous and anadromous life history strategy, these animals can provide vast quantities of nutrient-rich carcass and egg material to a variety of terrestrial and aquatic organisms – including stream-resident fish – in locations where they spawn and die (Gerig et al. 2016; Janetski et al. 2009). Their migratory life-history may also create the potential to encounter and transfer contaminants such as radioisotopes, polychlorinated biphenyls (PCBs), and heavy metals from down-river and marine environments, representing a to-date poorly understood stressor in ecological systems (Gerig et al. 2018).

Water Quality in the Canadian Portion of the Upper Columbia River Basin

The Columbia River Integrated Environmental Monitoring Program (CRIEMP) was established in 1991 by key stakeholders including Canada, the government of BC, First Nations, and non-government organizations to assess the status of ecological health of the Columbia River between Hugh Keenleyside Dam and the Canada-US border. The results of this program have shown that water quality concerns in this watershed can mainly be attributed to dams and industrial activities (Columbia Basin Trust 2017). Water quality in the tributaries of the Columbia River is highly variable and strongly influenced by sources of impact such as mining, forestry, range, agriculture, rural development, and transportation infrastructure. Effluent from municipal sewage treatment plants is also released into many of these tributaries and may have significant effects on local water quality in smaller systems; however, the effects diminish rapidly where tributaries join the river's mainstem further downstream.

Radioisotopes

The Fukushima Daiichi nuclear disaster of 11 March 2011 raised global concerns over the release of fission fragments and nuclear fuel into the atmosphere and the Pacific Ocean (Domingo et al. 2017). Models projecting the path and dilution of the radioactive plume from Japan across the Pacific Ocean suggested that it would arrive and remain at the northwest American continental shelf from 2014 to 2020 (Domingo et al. 2017). Although it has been calculated that radiocesium activity concentrations in the plume during this time were well below Canadian action levels for contamination in commercial food and beverages, one of the largest persisting concerns is the

perceived risk to human health associated with the consumption of Pacific seafood contaminated with Fukushima-derived radionuclides (Health Canada 2000; Rossi et al. 2013).

Studies conducted along the coast of British Columbia and Alaska to investigate possible radiocesium contamination in Pacific salmon have concluded that contamination from the Fukushima disaster has been negligible (Alaska Department of Environmental Conservation 2021; Chen et al. 2019; Domingo et al. 2017). Ten Sockeye Salmon were collected from First Nations food, social, ceremonial, and commercial fisheries in the Alberni Inlet on the west coast of Vancouver Island, British Columbia in 2014. In the subsamples measured, the highest total radiocesium activity concentration measured was 1.76 Bq/kg, suggesting that there would need to be 500x as much cesium before any governmental intervention for the public would be required (Domingo et al. 2017). In other words, any individual could consume over 190,000-kg of contaminated salmon per year and still not reach the effective dose limit from anthropogenic sources. Radiological analysis of adult Pacific salmon collected in BC, the Yukon and Alaska from 2013 through 2021 have primarily resulted in non-detectable levels of radiocesium and radioactive iodine (Alaska Department of Environmental Conservation 2021; Chen et al. 2019). Together, these results suggest that the public's concern about radioactive contamination of Pacific salmon is unsupported by the data.

Stormwater and Roadway Runoff

Stormwater and roadway runoff in watersheds where salmon habitat and urban land use overlap has become an important consideration in the planning and management of urban development in the Pacific Northwest. Concerns about the effects of watershed contamination due to runoff are based primarily on studies of Coho salmon (*Oncorhynchus kisutch*), which have been shown to die at rates of between 40% and 100% due to exposure to stormwater runoff as they return from the ocean to spawn in urban and urbanizing watersheds (McIntyre et al. 2021; Scholz et al. 2011). This acute mortality syndrome is characterized by changes in behaviour and blood parameters consistent with the symptoms of cardiorespiratory distress (Blair et al. 2021; Chow et al. 2019; McIntyre et al. 2018; McIntyre et al. 2021).

While the complete spectrum of substances responsible for high Coho mortality rates remains poorly understood, two groups of nitrogen-containing compounds derived from tire tread wear particles (TWP) have been identified as potential candidates (Peter et al. 2018). This finding is particularly significant because TWP accounted for 15% of all chemical detections in roadway runoff in western North America (Peter et al. 2018). By contrast, Chum Salmon (*Oncorhynchus keta*) that were co-exposed to urban stormwater runoff in the field, and roadway runoff under controlled conditions appeared unaffected by both behavioural and physiological metrics (McIntyre et al. 2018; Scholz et al. 2011). Moreover, chum salmon were insensitive to TWP leachate at concentrations that were lethal to Coho (McIntyre et al. 2021). It has been hypothesized that this species-level variation in sensitivity to contaminants can be attributed to differences in life-history strategies. Following gravel emergence, juvenile Coho spend more time in freshwater than Chum, thereby lengthening the window of exposure to land-based pollution (McIntyre et al. 2018). Support for this hypothesis would point to the vulnerability of other salmon species such as Sockeye, who reside in nursery lakes for a year prior to downstream migration (Ross et al. 2013). Chinook, on the other hand, may be less at risk because they spawn primarily in relatively non-urbanized upper reaches of major river basins (McIntyre et al. 2018).

PCBs, Mercury, and Estrogenic Compounds

There are currently thirteen salmon stocks that spawn in the Lower Columbia River, a highly urbanized watershed that encompasses the major industrial centers of Portland, Oregon and Vancouver, Washington. Information on contaminant burdens in salmon in the Columbia River is limited; however, analyses have shown that PCB concentrations in outmigrating juvenile fall Chinook can exceed the estimated thresholds for adverse health effects in juvenile salmonids (Johnson et al. 2007). PCB concentrations showed no spatial gradient between sampling sites but tended to be higher in larger and older fish. This is consistent with the idea that the longer estuary residency times of fall run Chinook increase their risk of exposure to contaminants, and that pelagic and benthic contaminant sources are important determinants of exposure (Johnson et al. 2007).

Pacific salmon were introduced to the Laurentian Great Lakes in the 1960s to control invasive prey fish, rehabilitate native predator populations, and to establish a recreational fishery (Dettmers et al. 2012). Since then, Chinook Salmon have established naturally reproducing populations in many tributaries, providing a valuable opportunity for the study of the transfer of lake-derived contaminants to streams in the greater watershed (Gerig et al. 2018; Kerns et al. 2016). Due to the extensive legacy of industrial pollution in the region, studies have been conducted to investigate the accumulation of lake-derived persistent organic pollutants (POPs) such as PCBs and heavy metals such as mercury (Hg) within salmon muscle and gametic tissues and their transfer to stream-resident fish (Gerig et al. 2016; Janetski et al. 2012; Murphy et al. 2012). PCB concentrations in stream-resident fish were found to be higher in reaches with salmon, whereas mercury concentrations were similar or lower in reaches with salmon compared to reaches without. A similar pattern was found in salmon eggs wherein they were enriched in PCBs, but depleted in mercury, pointing to the importance of salmon egg consumption as a driver of contaminant loads in resident fish (Gerig et al. 2018). High concentrations of PCBs in stream-resident fish can have important implications for species biomass; they have been shown to possess estrogenic activity, with effects manifesting themselves as reproductive, developmental, behavioural, or smoltifaction abnormalities (Morley et al. 2019; Tyler et al. 1998). Estrogen-like compounds have also been found in pulp mill and sewage effluent in southern British Columbia (Afonso et al. 2002). At high concentrations, exposure to these effluents resulted in gonadal differentiation of male Chinook such that the physiological female condition was observed in genetic males (Afonso et al. 2002).

Appendix E: Workshop Participants

Name	Affiliation	RBAF Scoping Workshop	Phase I Assessment Workshop
Adam Neil	Secwépemc Nation	✓	✓
Beatrice Rost-Komiya	ESSA Technologies	✓	✓
Ben Meunier	KNC		✓
Chad Fuller	ONA	✓	✓
Chris Deeg	UBC/PSF/DFO		✓
Clint Alexander	ESSA	✓	✓
Conor Giorgi	Spokane Tribe	✓	
Daniel Selbie	DFO	✓	
Eric Parkinson	ESSA	✓	✓
Herb Alex	ONA	✓	
Howard Stiff	DFO	✓	✓
Jon Bisset	Bissetco	✓	✓
Kaitlyn Dionne	DFO	✓	✓
Kyle Garver	DFO	✓	✓
Laura Robinson	UCUT	✓	
Laurelle Santana	ESSA	✓	✓
Mindi Sheer	Sheer Ecological		✓
Misun Kang	KNC	✓	✓
Patrick Burke	ESSA	✓	✓
Rhiannon Kirton	Shuswap Band	✓	
Richard Bussanich	ONA	✓	
Sierra Sullivan	UBC		✓
Simon Jones	DFO	✓	✓
Stewart Johnson	DFO	✓	✓
Thomas Biladeau	The Coeur d'Alene Tribe, Schitsu'umsh	✓	
Tyler Weir	BC GOV - FLNROR	✓	✓
Will Warnock	BC GOV - FLNROR	✓	✓

Appendix F: Literature Cited and Additional Works

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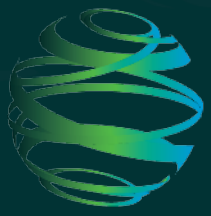

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