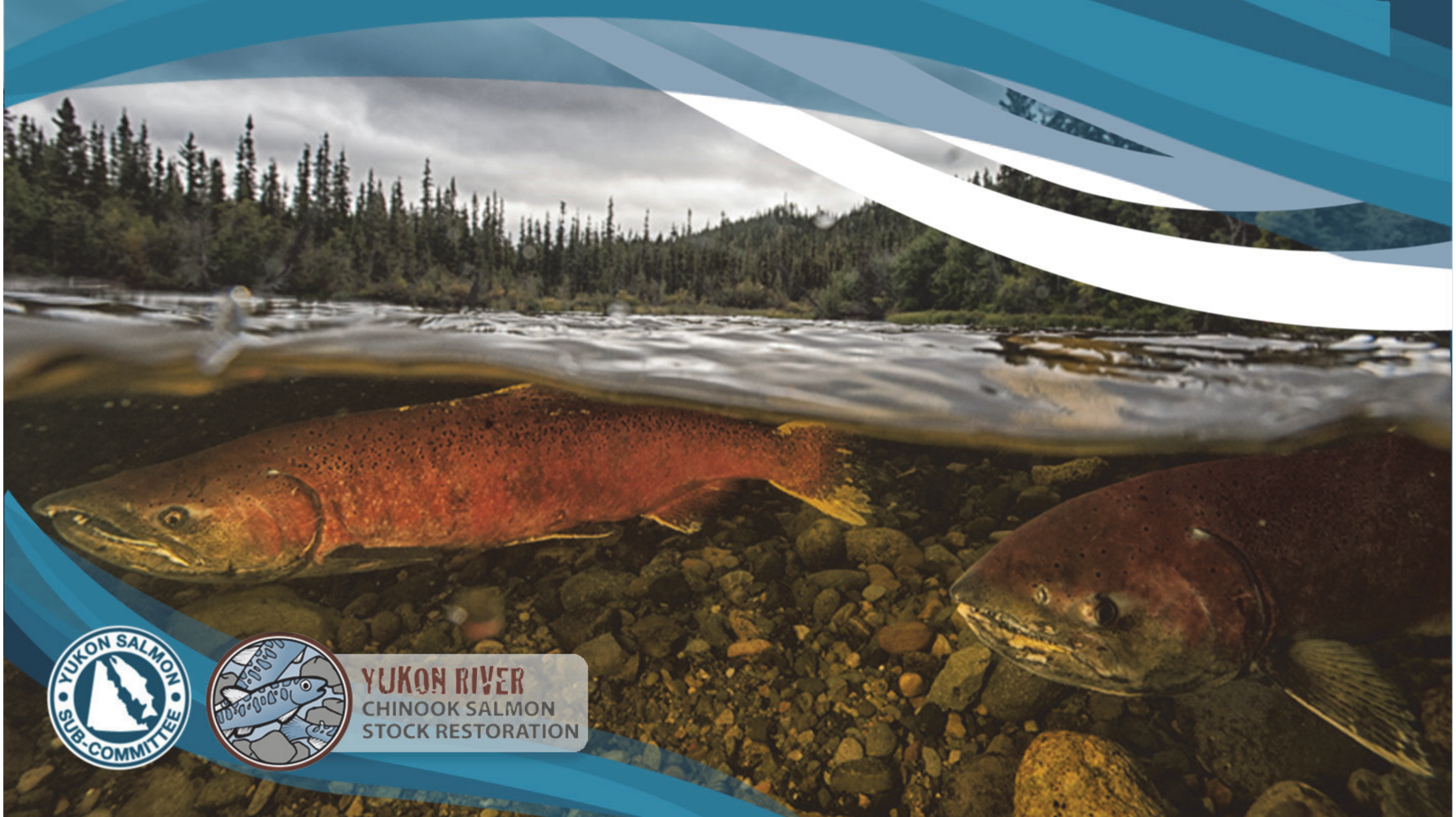
Charting a Course for Yukon Chinook

Yukon Chinook Strategic Stock Restoration Initiative

Technical Team Year 1 Final Report



YUKON SALMON SUB-COMMITTEE

YUKON RIVER CHINOOK SALMON STOCK RESTORATION

Yukon Chinook
Strategic Stock Restoration Initiative

Technical Team Year 1 Final Report

April 2016

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Front & Back Cover Photos: Chinook salmon and fishers by Peter Mather, 2014

Organization of Report

This report details the activities and outcomes of Year 1 of the Yukon Salmon Sub-Committee's (YSSC) Chinook salmon stock restoration initiative and technical team. There are seven sections in the report. Section 1 provides background on the project including the impetus for carrying it out and overarching goals. Section 2 describes the Chinook population units under consideration and is followed in Section 3 by a brief description of the current status of Chinook in the Canadian portion of the Yukon River. A conceptual model of Yukon River Chinook is described in Section 4 along with an assessment of limiting factors by life stage. Section 5 describes the outcome of a Yukon First Nation community engagement process that sought to identify and catalogue community values and objectives related to stock restoration as well as past, current and potential future stock restoration activities. This is followed by a review and summary of six general classes of restoration actions that emerged from the community engagement process as well as an inventory of specific actions that could and / or are being implemented. Section 6 details an assessment framework, which is used to qualitatively evaluate the ability of the alternative actions in Section 5 to meet the goals of the restoration initiative. Lastly, Section 7 provides recommendations for the initiative moving forward.

The main body of this report is accompanied by a number of appendices. These appendices include tables detailing an assessment of limiting factors by sub-watershed (Appendix A), insights from the community engagement (Appendix B), and inventories of past restoration and enhancement as well as stock and habitat assessment projects conducted in the Canadian portion of the Yukon River (Appendices C and D, respectively). Appendix E provides a backgrounder on beaver and salmon in the Canadian portion of the Yukon River and a discussion of the identification and management of obstructions on small, productive and vulnerable Yukon River Chinook salmon spawning streams.

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Acknowledgements

The YSSC would like to thank the Yukon First Nation Governments, Renewable Resources Councils, communities and individuals that took the time to contribute to the work detailed in this report; the Yukon River Panel – Restoration and Enhancement Fund for funding; all of the individuals who participated in, and contributed to, the workshop held in Whitehorse in November 2015; and Fisheries and Oceans Canada and the Salmonid Enhancement Program (particularly Michael Crowe, Jason Hwang, Maggie Wright and Sean Collins) for their time and support. Lastly the YSSC would like to acknowledge the Alaskan and Yukon fishers and user groups that depend on Yukon River Chinook for food, sustenance and culture.

Executive Summary

Background

Chinook salmon (*Oncorhynchus tshawytscha*) are a cultural icon for communities in the Yukon. Long-term decline in Yukon River Chinook abundance and low productivity have led to severe harvest restrictions and sacrifices on the part of First Nations in the Yukon, some of which have not harvested Chinook in over a decade. While these harvest restrictions are necessary in order to try and get sufficient numbers of salmon to the spawning grounds, there is not much more the communities can do to fish less. This has led to considerable interest in stock restoration - taking action to reverse declines and recover populations - and in doing so restoring the important role of these Chinook salmon stocks to Yukon First Nation communities and culture.

Recognizing that much could be learned from stock restoration elsewhere in the Pacific Northwest, but also that any stock restoration taking place in the Yukon needs to be community driven and reflect the priorities of local harvesters, the Yukon Salmon Sub-Committee (YSSC) secured funding from the Yukon River Panel Restoration and Enhancement Fund in the Spring of 2015 to support the development of a Yukon Chinook Strategic Stock Restoration Initiative (SSRI) and Technical Team.

The two overarching goals of the initiative and Technical Team are to:

- support the development of a stock restoration framework based on community values, which can be used to help develop, evaluate and prioritize Chinook stock restoration initiatives in the Canadian portion of the Yukon River; and
- provide technical support and capacity building at the First Nation and community level for stock restoration activities.

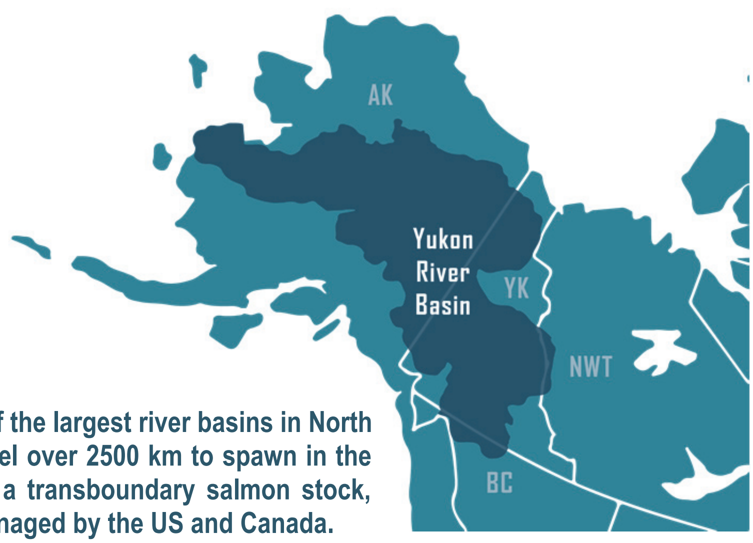


Figure E1: The Yukon River Basin is one of the largest river basins in North America. Yukon Chinook travel over 2500 km to spawn in the headwaters of the basin. As a transboundary salmon stock, Yukon Chinook are jointly managed by the US and Canada.

The Yukon Chinook SSRI is intended to be carried out over three years. The first year focused on "restoration planning" (Figure E2) and specifically: cataloguing community values, objectives and restoration opportunities; reviewing population status and potential limiting factors; forming a technical team to help guide the planning process and provide support to community-led restoration activities in the Yukon; developing a prioritization framework that matches the quantity and quality of information available in the Yukon; and then applying it. Years two and three will focus on supporting further planning, and then implementation, monitoring and evaluation of a subset of restoration actions evaluated in year 1.

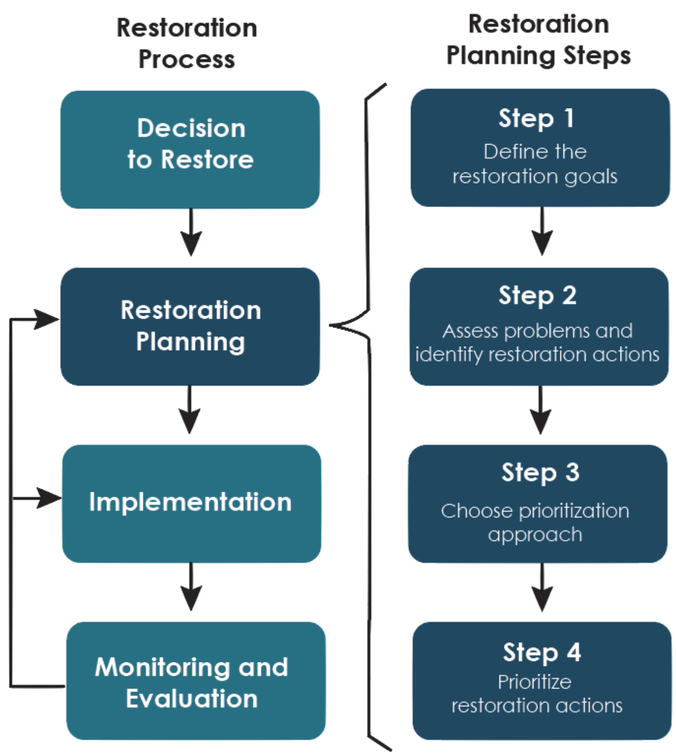


Figure E2: Schematic of the stock restoration process and the four steps for identifying and prioritize restoration actions nested within broader process. Year 1 of the SSRI was focused on the planning process while years 2 and 3 will focus on implementing and monitoring and evaluation stages. Adapted from Beechie et al. (2008).

The Yukon Chinook SSRI is an on-going project that would benefit from feedback, project ideas and general comments. Please email salmon@yssc.ca or contact the YSSC to discuss the project.

Assessing the problem, defining restoration goals and identifying opportunities

Limiting factors are the biological and physical conditions (e.g., high water temperature) that limit a population's viability. The extent to which factors that are currently limiting Yukon Chinook populations are addressed is an important determinant of the success of restoration actions. The Technical Team synthesized what is known about factors potentially limiting Yukon Chinook by life stage and sub-watershed within the Canadian portion of the Yukon River watershed and found there is limited information with which to definitively identify limiting factors for Yukon Chinook. Examples of factors potentially limiting Yukon Chinook in freshwater include anthropogenic (man-made) and natural barriers to spawning and rearing habitat; climactic and hydrologic variation leading to displacement of juveniles, changes in groundwater discharge and degradation of rearing and spawning habitat; disease in returning adults; and sedimentation and toxins from mining activity. In the marine environment potential limiting factors include changes in oceanographic conditions across the North Pacific, Bering Sea and Gulf of Alaska, increased predation on Chinook and competition for food resources.

Declines in Chinook abundance and survival are not unique to the Yukon and instead are shared across much of central and western Alaska. This suggests the factors responsible for the currently depressed populations of Yukon Chinook are, at least in part, driven by processes outside of the Yukon Basin. This highlights the importance of recognizing that recovery of the Chinook in the Yukon appears to depend, at least in part, on improvements in marine conditions.

In the summer of 2015 the YSSC met with Yukon First Nation Governments, Renewable Resources Councils (RRCs) and communities to discuss the importance of Chinook within each community; factors that may be limiting Chinook populations; stock restoration goals and objectives; and to identify past, ongoing and potential restoration actions. Although a number of social, biological and management objectives were expressed during the visits, all communities stressed that their principal objectives were to increase Chinook abundance and maintain or restore a cultural connection to salmon as well as "fish camp culture". Additional objectives that were commonly voiced included a preference to not to "mess" with nature and a strong desire for restoration actions to be community driven and supported. Taken together, these objectives lead to the identification of the primary goal of stock restoration from a Yukon First Nation perspective, which is to:

"Promote recovery of Yukon Chinook in order to maintain and re-establish cultural connections to salmon in a manner that is consistent with community values and involvement"

To identify potential restoration actions for consideration an inventory of restoration actions was generated based on the opportunities identified through the community engagement, past restoration activities supported by the Yukon River Panel's Restoration and Enhancement (R&E) fund and discussion with other stakeholders involved in salmon management and conservation in the Yukon. From this inventory, the following six broad classes of restoration actions emerged (Figure E3).

Figure E3: Schematic of the six broad classes of stock restoration activities that have been, or could be, considered in the Yukon.

For each of these classes of restoration actions, the Technical Team reviewed and summarized the details of what each action involves including the Chinook population(s) and community(ies) where the actions could take place; a general timeframe for evaluation, planning and implementation of the actions; rationale for undertaking the actions; pros and cons; and key knowledge gaps that preclude a better understanding of how successful each action may be.

In the fall of 2015 the YSSC and SSRI Technical Team held a two-day workshop in Whitehorse. The goals of the workshop were to generate a broad understanding of Yukon-wide stock restoration activities and priorities; improve understanding of current and anticipated training/educational needs to support communities in the design and implementation of restoration actions; and provide the opportunity for individual First Nation and community representatives to meet one-on-one with the Technical Team to address questions, concerns, interests and other issues based on community specific restoration priorities. In order to pilot a process for community-based stock restoration, the Technical Team provided follow-up technical advice on stock restoration activities for two FN communities during the winter of 2016.

Evaluating restoration opportunities and charting a path forward

From the inventory of 6 restoration actions identified a preliminary list of 13 stock restoration actions (or groups of actions) in specific locations within the Canadian portion of the Yukon River was developed for further consideration. A simple framework to qualitatively evaluate the ability of these alternative restoration actions to fulfill the following three primary objectives that contribute to meeting the overarching goal of the YSSC SSRI:

- **Objective 1:** increase likelihood of recovery of Yukon Chinook populations
- **Objective 2:** maintain or re-establish cultural connections to salmon
- **Objective 3:** ensure action consistent with community values, involvement and capacity

Applying the evaluation framework allowed us to qualitatively evaluate the ability of alternative restoration actions to meet the objectives of the YSSC SSRI and arrive at a preliminary classification of alternative actions. Not surprisingly, no single action, or set of actions, scored high against all performance measures. Instead there are tradeoffs where, for example, an action may score high based on biological response but low on cultural connection, or vice versa.

Year two of the SSRI should focus on those actions that strike a balance between increasing the likelihood of recovery of targeted Chinook populations, re-establishing cultural connections to salmon, and ensuring actions are consistent with community values and involvement with adequate resources to support them. For example, two restoration activities that appear to meet these criteria and which received additional Technical Team support in year 1 include: 1) the Fox Creek stock restoration initiative led by the Ta'an Kwäch'än Council and 2) the Deadman Creek re-introduction efforts led by the Teslin Tlingit Council. Year two should focus on continued identification of opportunities to support community-led stock restoration efforts and move from the planning stages to the implementation, monitoring and evaluation stages. However, it is important to recognize that progress made towards implementation, monitoring and evaluation will vary among First Nation communities. They all will be at different stages of the planning and implementation process.

In addition to a shift in focus in year 2 towards identifying and supporting priority stock restoration actions, it is recommended that the learning and synthesis captured in this report be made available to the communities that helped generate it. This will promote broader awareness of stock restoration efforts across the Canadian portion of the Yukon River, determine the ability of different types of actions to meet community stock restoration goals and objectives, and foster a sense of ownership over the process as a whole. It should be acknowledged that the Yukon River Chinook are governed under the Yukon River Salmon

Agreement, which manages this fishery between Alaska and the Yukon. The scope of stock restoration being discussed through the SSRI is focussed on Canada, however, it has treaty implications on both sides of the border.

The SSRI recognizes the role of existing and potential hatchery programs in supporting stock restoration efforts in the Yukon. Therefore the SSRI also support DFO in their ongoing efforts to review hatchery strategies and identify possible hatchery facility options that could provide capacity to rear Canadian-origin Chinook salmon fry. It is recommended that the YSSC stock restoration initiative and Technical Team and DFO staff share insights from their respective efforts in support of hatchery planning and management.

Lastly, it is recommended that as communities transition from "planning" to "doing" individual restoration actions, careful consideration should be given to the design, implementation, monitoring and assessment of these initiatives. This can be accomplished by considering stock restoration activities through the lens of adaptive management. This approach helps ensure that individual projects are well designed; enables rigorous evaluation of the effectiveness; and allows adjustment to restoration actions based on lessons learned throughout the process.

1 Background

Chinook salmon are a cultural icon for First Nation communities in the Yukon. Yukon River Chinook have been called the “Kings of Kings” due to their extensive freshwater migrations (up to ~3000 km, the furthest of any salmon) and their high oil content. These salmon have been fished for subsistence for millennia and are at the center of fisheries and fish camps where stories, food and traditional knowledge is shared.

Depressed returns of Canadian-origin Chinook in recent decades have strained the cultural fabric they historically supported. So few fish have returned in recent years that recreational and commercial fishing has been closed and some communities have voluntarily stopped subsistence fishing for over a decade. This has resulted in whole generations at risk of foregoing the traditional knowledge and culture and sustenance that comes from growing up in fish camps.

Declines in Yukon Chinook have driven intense interest in taking steps to reverse the trend and recover populations, and in doing so, restore their importance to the Yukon First Nation, recreational fishers, and communities of the Yukon. During periods of low abundance and low productivity, a crucial first step to promote recovery is to harvest fewer fish and thereby allow more salmon to make it back to the spawning grounds. Yukon First Nations have demonstrated their sacrifice over the last decade by restricting fishing or not fishing at all. Accordingly, dedicated in-season management in both Alaska and Yukon has been a commitment for agencies in the last five years. However, with extreme management restrictions already in place and voluntary sacrifices subsistence of fishing rights by Yukon First Nations, there is not much more communities can do to fish less, and so attention is now turning towards rebuilding stocks through restoration.

Stock restoration is the deliberate attempt to return a wild salmon population to natural production levels – that is, the predicted population levels in the absence of one or more limiting factors that jeopardize continued existence or drive low abundance. This is in contrast to stock enhancement, which includes actions aimed at expanding a wild salmon population beyond its carrying capacity and natural production levels. This report and the activities described within it are focused on stock restoration. At this time, the Yukon River panel has determined that, “Given the wild nature of the Yukon River and its salmon stocks, and the substantial risks associated with the large-scale enhancement through artificial propagation, such enhancement activities are inappropriate at this time” (YRP Stock Restoration Workshop, April 2015).

There is a long history of salmon stock restoration and recovery efforts in the Pacific Northwest where habitat degradation, hydroelectric dams, hatcheries and overfishing have contributed to depressed and declining salmon populations. For example, investment in stock restoration and recovery activities in the Columbia Basin alone exceeds $100 million annually. Due to the Yukon’s relatively pristine habitat and, until recently, its abundant salmon returns, stock restoration efforts in this region remain in their infancy. Though efforts have been made among federal and First Nation governments and stakeholders to develop specialized expertise and projects in the field of salmon stock restoration, there have been limited opportunities to share, consolidate and strengthen the progress made across these different groups. Recognizing that much could be learned from stock restoration in the Pacific Northwest, but also that "any stock restoration that takes place in Canada needs to be community driven and reflect the priorities of those depending on those fish stocks" (Pauline Frost, YSSC Chair), the YSSC secured funding to support the development of a Yukon Chinook strategic stock restoration initiative and Technical Team.

The two overarching goals of the initiative and Technical Team are to:

- support the development of a stock restoration framework based on community values, which can be used to help develop, evaluate and prioritize Chinook stock restoration initiatives in the Canadian portion of the Yukon River; and
- provide technical support and capacity building at the First Nation and community level for stock restoration activities.

The Yukon Chinook strategic stock restoration initiative is intended to be carried out over three-years. The first year focused on "restoration planning", and specifically:

- cataloguing community values, objectives and restoration opportunities to define restoration "goals";
- reviewing population status and potential limiting factors;
- forming a technical team that can help guide the planning process and provide support to community-led restoration activities in the Yukon;
- developing a prioritization framework that matches the quantity and quality of information available in the Yukon; and then
- applying the prioritization framework to evaluate alternative restoration actions.

Years two and three are intended to focus on supporting further planning, and then implementation, monitoring and evaluation of a subset of restoration actions that were identified in year 1.

1.1 Unique challenges to stock restoration in the Yukon

The Yukon River basin is enormous. At over 850,000 km^2 in size the Yukon basin in 25% larger than the state of Texas or the province of Alberta. Within the Canadian portion of Yukon River alone, Chinook are known to spawn at over 100 locations, but they first must migrate through Alaska to do so. Yukon River Chinook are a transboundary stock with only a portion of freshwater life history stages, and processes that affect them, occurring in the Canadian territory and can be influenced by stock restoration activities in the Yukon itself. For example, Chinook of Canadian origin have been documented travelling over 1,200 km from their natal streams to reach rearing habitat in Alaska (Daum and Flannery 2011). Such broad dispersal of juvenile Chinook both within and outside the Yukon complicates the development and assessment of restoration actions that target rearing habitat for specific populations.

In addition to the ecology of Yukon Chinook, there are a number of other unique challenges to carrying out stock restoration activities in the Yukon. These include climate and water temperatures, owing to the length and severity of northern winters; access and logistics to carry out actions; expertise and trained capacity related to stock restoration; gaps in knowledge pertaining to Chinook ecology and limiting factors; and lack of a larger planning framework to guide stock restoration programs and projects.

2 Population units

For the purposes of this project eight major Chinook populations are identified (Figure 1). These populations correspond to the eight sub-basins, or watersheds, of the Canadian portion of the Yukon River:

1. **Porcupine River**
2. **North Mainstem (downstream of Selwyn River confluence)**
3. **Stewart River**
4. **White River**
5. **Pelly River**
6. **Mid Mainstem (between confluences of the Selwyn and Teslin Rivers)**
7. **Upper Lakes/South Mainstem (upstream of Hootalinqua)**
8. **Teslin River.**

These eight populations correspond to the 12 proposed Chinook salmon Conservation Units (CUs) under DFO's Wild Salmon Policy, which further splits the Porcupine and Mid Mainstem watersheds into three and two CUs, respectively (Holtby and Ciruna 2007). These proposed CUs have not been broadly adopted in the Yukon to date and the proposed methodology used to identify them has not been reviewed. Therefore, the SSRI have chosen to focus and organize its evaluation around the eight major watersheds so as to align with both historic and contemporary management as well as community recognition of Chinook population structure in the Canadian portion of the Yukon River.

Based on available data, stock composition estimates and molecular tools, on average, the two largest producers of Chinook in the Canadian portion of the Yukon River are the Yukon River mid-mainstem sub-basin (~36%) and the Teslin River sub-basin (~24%) (Beacham et al. 2008). These two sub-basins are followed by the Pelly River (~14%) and then the remaining sub-basins (~5-8% each; Beacham et al. 2008). Though there are estimates of spawner abundance for some locations in a few of the sub-basins (e.g., the Whitehorse Rapids Fishway, and the Wolf and Nisutlin Rivers in 2015; JTC 2016), estimates of spawner abundance over time for each sub-basin are not available.

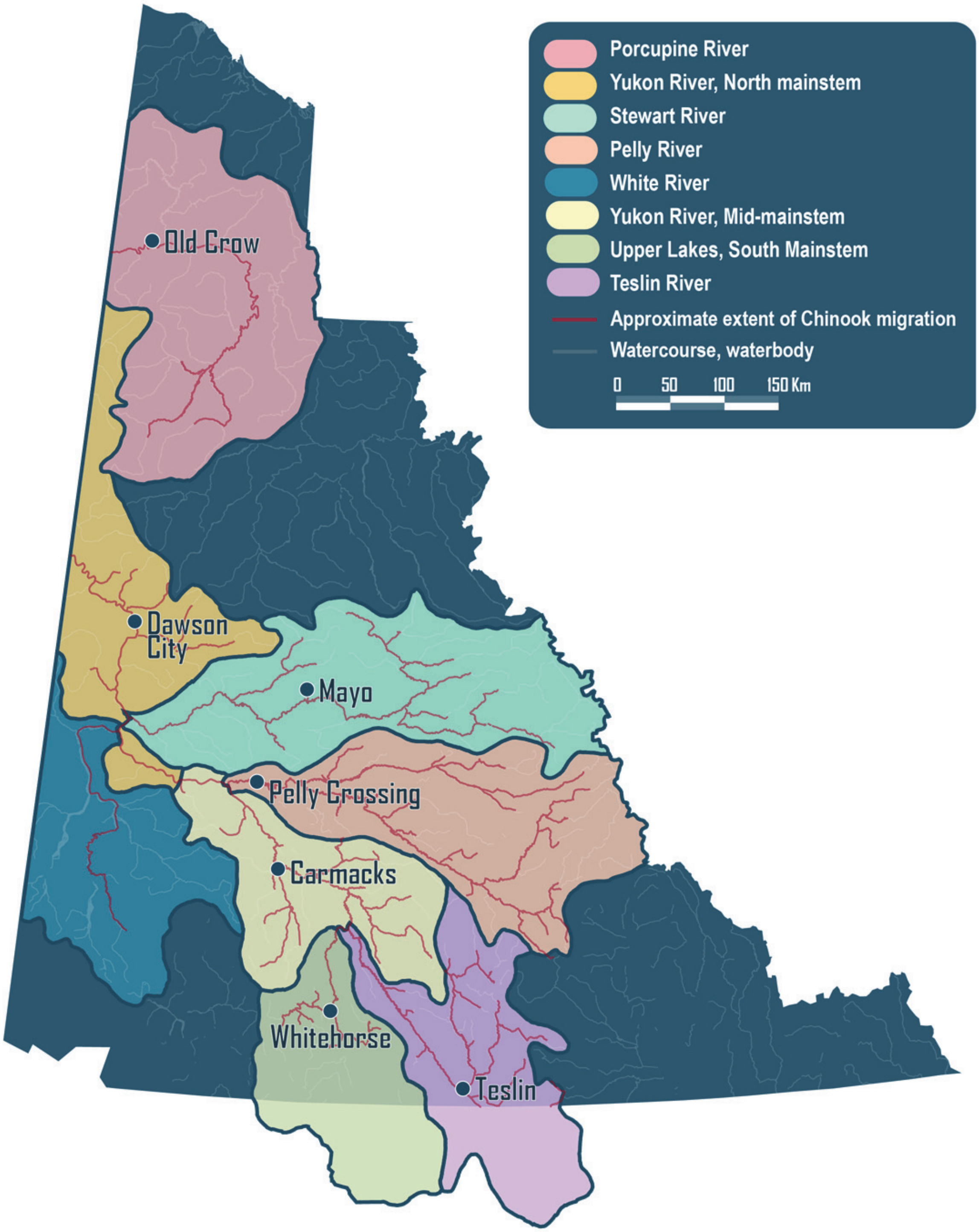


Figure 1: Location of the eight major sub-basins of the Yukon River watershed in Canada.

3 Current population status

The abundance of adult Chinook returning to the Canadian portion of the Yukon River has been near record lows in recent years. From the early 1980s to the late 1990s, run size (spawners plus harvest/catch) averaged ~ 120,000 fish before dipping briefly in the early 2000s, rebounding for a few years, and then declining to an average of ~ 60,000 fish since 2010 (JTC 2016; Figure 2). While run size has declined, the estimated number of salmon making it to the spawning grounds has remained relatively stable over time (~ 45,000 fish on average from 1982 to present) and so the consequences of declines in run size have severely limited harvest opportunities in recent years. However, it is worth noting that estimates of escapement to the spawning grounds in 2015 were the highest on record (82,615 fish) as a result of extremely limited harvest opportunities, highly conservative management approaches in Alaska and sacrifices on the part of the Yukon First Nation subsistence harvest.

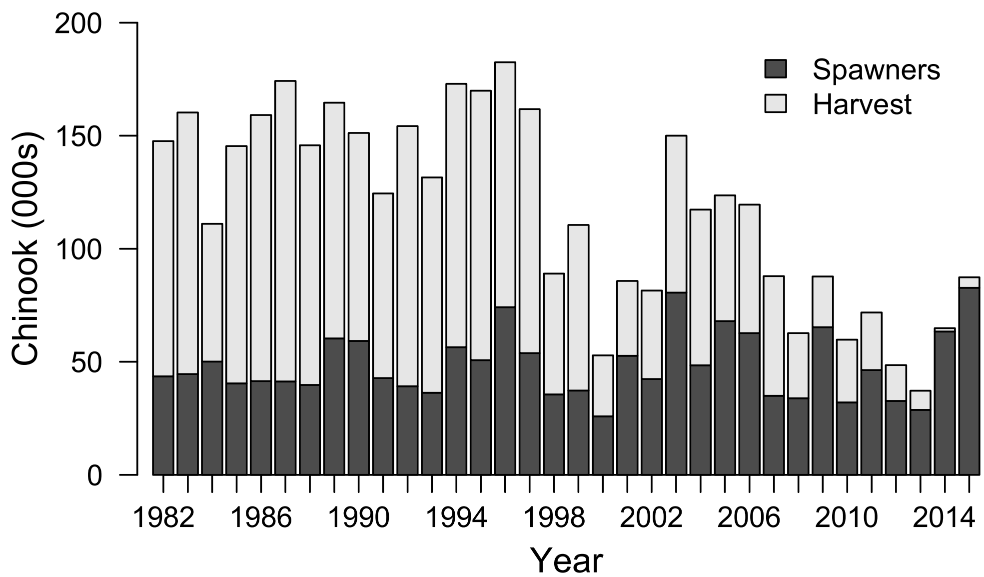


Figure 2: Estimated Yukon River Canadian-origin Chinook spawner abundance from 1982 to present.

Declines in the abundance of Yukon Chinook have been mirrored by a decline in the productivity of Yukon Chinook (adult recruits produced per spawner; Figure 3) as well as general declines in the average size and age of returning Chinook (JTC 2016; Lewis et al. 2015). This has prompted concerns about declining "escapement quality" and its consequences for the resilience of Yukon Chinook in the face of climate change. Because fecundity, and potentially egg quality, is positively correlated with female size, a reduction in the size and age of female spawners can lead to fewer eggs in the gravel and returns per spawner. Spawning Chinook salmon populations include multiple year classes, which helps buffer the population against failure of a single spawning cohort, thereby conferring resilience to environmental change.

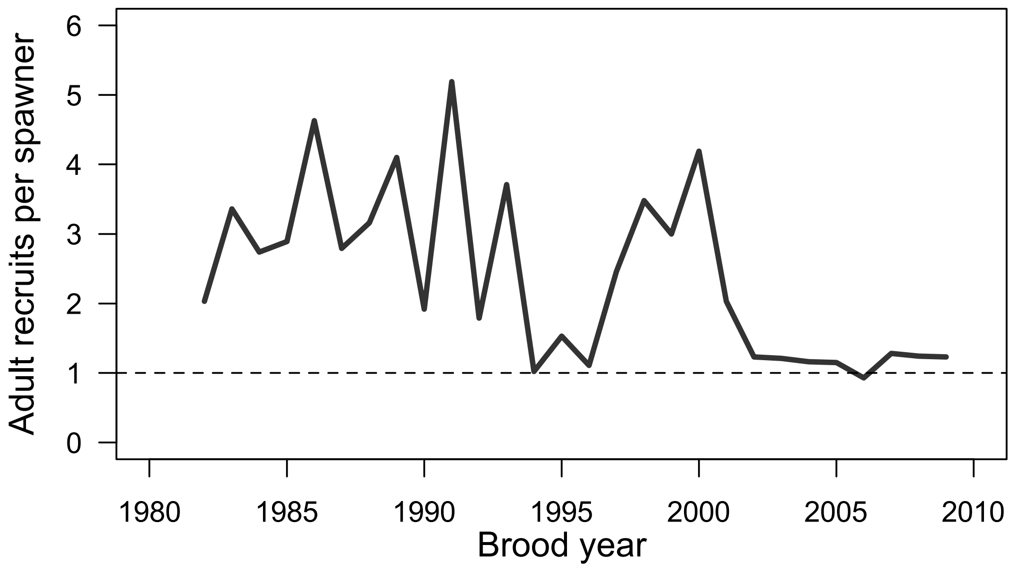


Figure 3: Estimated Yukon River Canadian origin Chinook recruits produced per spawner by brood year. The dashed line at one indicates brood years when recruitment was below replacement.

The observed declines in abundance, productivity, size and age are not unique to the Yukon. Across Western Alaska, Chinook populations have exhibited shared declines in abundance, survival, and life history and demographic characteristics (Schindler et al. 2013; Lewis et al. 2015; Ohlberger et al. 2016). These shared patterns across multiple Chinook populations suggest that broad-scale factors affecting Chinook across the region (perhaps in areas where they co-occur in estuaries and at sea) are at least partially responsible for the observed declines. These patterns should temper expectations for the ability of restoration activities within the Canadian portion of the Yukon River to recover Chinook on their own unless ocean conditions and productivity also improve.

4 Limiting factors

Limiting factors are the biological and physical conditions that limit a population's productivity and viability (e.g., high water temperature). The success of restoration actions depends in large part on the extent to which they address factors that limit Yukon Chinook populations. For example, the restoration of rearing habitat for a population that is not currently limited by rearing habitat is unlikely to have a measureable effect at the population level. However, the removal of a barrier to migration towards spawning and rearing habitat, which are currently limiting, will likely have a measureable effect on the population. Having as clear an understanding as possible about what factors may be limiting individual Chinook populations is an important steps towards evaluating the potential for restoration actions to be effective. This is part of the "assessing the problem" step in the restoration planning process (Figure E2).

In order to help support the identification of potential limiting factors, a qualitative assessment was completed for each of the eight Yukon Chinook populations identified in Section 2. This assessment documented what is currently known about:

- the **nature** of the limiting factor or threat;
- **severity** (how much is the productivity of the population likely to be affected?);
- **extent** (how much of Chinook population is likely to be affected?);
- **frequency** (how often does the threat or pressure occur?); and
- **change** (is the threat or pressure increasing or decreasing?).

Complete assessments of limiting factors by populations are provided in Appendix A. These potential limiting factors are summarized in a conceptual model illustrating key Yukon River Chinook life stages and those factors potentially affecting each stage (Figure 4). A series of color coded infographics follow the conceptual model and briefly describe, for each life stage, the current state of knowledge of the ecology of the life stage and potential limiting factors related to processes in the environment the life stage occurs. Where possible the primary literature is cited, however, much of the information presented in the boxes is based on expert knowledge and general inference because relatively little has been published on the ecology and habitat use of Chinook salmon in the Yukon River watershed.

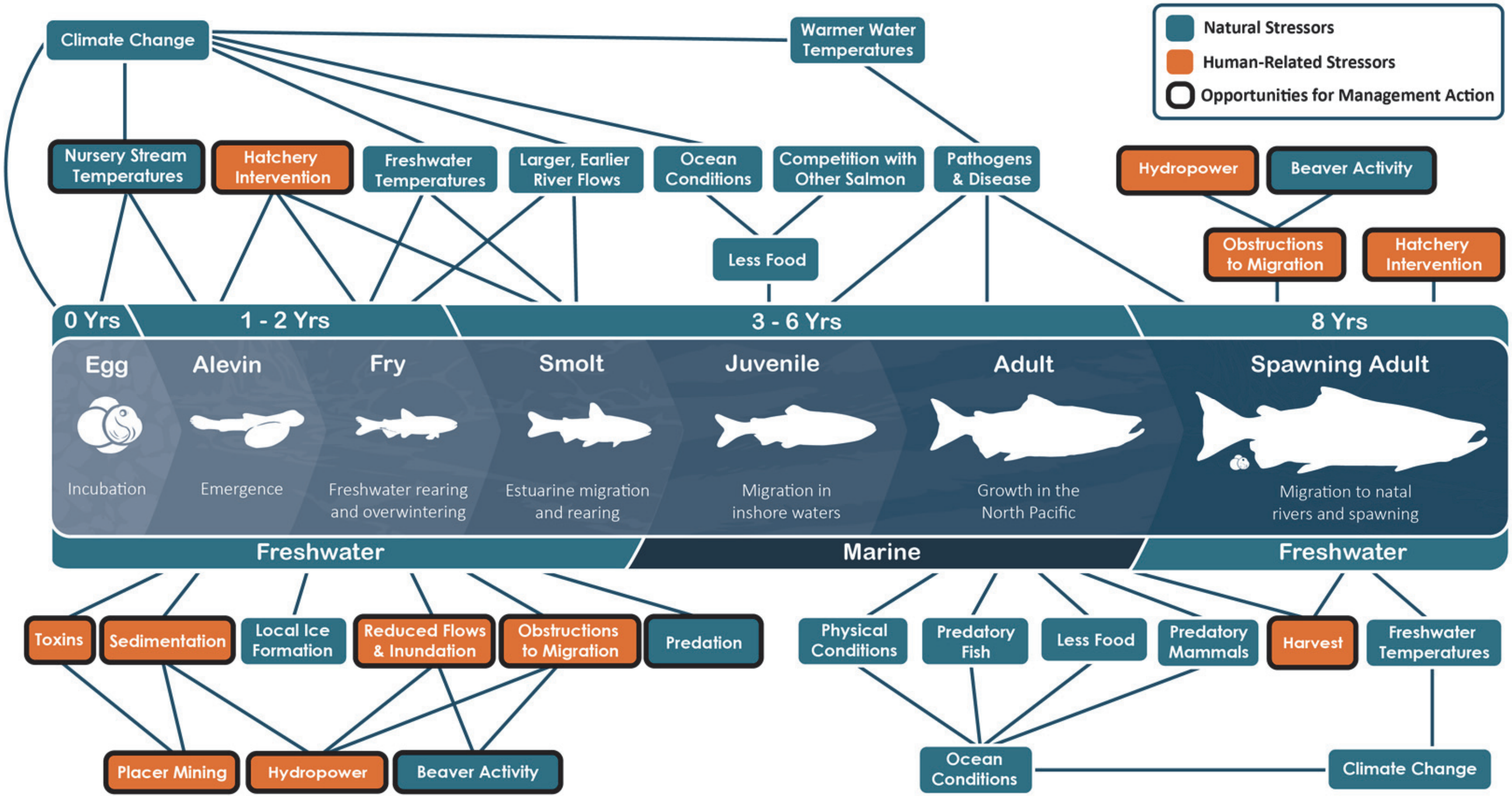
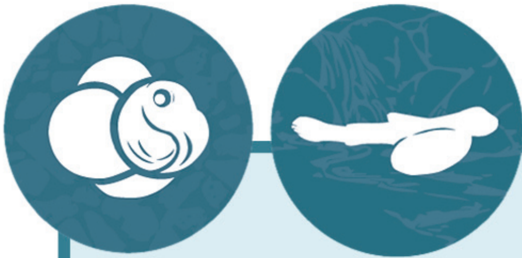


Figure 4: A conceptual model of the life history of Yukon Chinook salmon and potential stressors affecting each life stage. The life history processes and developmental stages are shown in the central row. Processes and stressors that are typically naturally occurring are highlighted in blue while those that arise from human activities are highlighted in orange. Processes and stressors that have the potential to be directly altered by human activities within the Canadian portion of the Yukon River, the focus of restoration actions, are outlined in bold.



Eggs & Alevins

Ecology

- Eggs are generally buried in redds, with the eggs at least 20 cm below the river bottom.
- Spawning rivers vary significantly in temperature, from less than 1000 Degree Days (DD) in some rivers to more than 2500 DD in others.
- Chinook salmon eggs require, nominally, 500 DD to hatch.
- Hatching may occur late in the autumn in warmer rivers, or much later in colder rivers.
- The development of alevins has not been studied in the Yukon, but requires, nominally, 500 DD between hatching and when they begin the process of leaving the river bottom.
- Emergence from the river bottom may occur between early May and late June, depending on the temperature of the natal stream or river.
- The fork length (distance between nose and tail fork) of juveniles at emergence is 35 – 38 mm.
- Emergent juveniles are found on the bottom in still-water areas such as the advancing margins of rivers and other low-velocity habitats.

Potential Limiting Factors

- Natural (e.g., permafrost-related slope deflation) and anthropogenic (e.g., placer mining) releases of sediment leading to sands/silts filling redds post egg deposition reduce egg-to-fry survival.
- Parentage and location within a basin can be important factors influencing egg-to-fry survival. Their relative influence is likely to vary as a function of the magnitude of sedimentation, high flows and scour during incubation (Roni et al. 2016).
- Effects of beaver dams in spawning streams after egg deposition specifically the conversion of stream to pond and reductions in oxygenation of redds during incubation.

Fry

Ecology

- Alevins become fry (0+ juveniles) when they can swim freely.
- Fry may remain in their natal streams for the first summer, however, most fry move downstream and ascend other streams which are referred to as non-natal and may be over 1000 km or more downstream of their natal stream (Bradford et al. 2008; Daum and Flannery 2011).
- Dispersal to non-natal tributaries in the Whitehorse area commences in late May and about a month later in the Dawson area at a fork length of 45 – 55 mm.
- Juveniles may migrate significant distances (greater than 20 km) upstream in non-natal tributaries.
- Young of year juveniles are seldom found in completely still water such as beaver ponds in non-natal rearing streams.
- At any given time during the summer, fry in upstream areas of non-natal tributaries tend to have greater average lengths than do those closer to the mouth.
- High densities of small fry may be found immediately downstream of partial- or total obstructions such as beaver dams, implying interrupted upstream migration.
- Fry are absent or present in low densities in waters with high turbidity, or where periods of high turbidity are frequent.
- Densities of fry tend to be low in clear water streams after summer storms cause high water/high turbidity events, implying displacement.
- Fry are generalist feeders, and consume all available invertebrates that are of an appropriate size.
- Aquatic predators of fry are known to include northern pike, burbot and inconnu.
- Avian predators on fry include but are not limited to kingfishers, gulls and loons.

Potential Limiting Factors

- Short-term variation in severity and timing of spring breakup, resulting in fry being exported from rivers or isolated in pools/back channels in flood plains.
- Short-term climatic/hydrologic variation resulting in reduced quantity of habitat in low water years, decreased quality of habitat (low water temperatures, limited food supply) in high water years, and displacement of fry from rearing areas at high flows (Neuswanger et al. 2015).
- Effects of sediment inputs from land instability and placer mining resulting in sands/silts/clays filling streams and reducing availability of food organisms.
- Effects of toxic materials released from developing or operating quartz mines.
- Barriers to upstream migration in natal or non-natal streams by beaver or hydroelectric dams and entrainment in hydroelectric facilities.
- Predation by avian predators (juvenile Chinook are almost absent in streams after families of mergansers have passed through, inferring significant predation).

Overwintering

Ecology

- Overwintering takes place where individual fry are located at the end of the open-water rearing season.
- Successful overwintering of fry has been documented in streams and smaller rivers, but may also occur in larger rivers.
- Overwintering survival in small streams appears to be related to local ice formation and to groundwater sources (Bradford et al. 2001).
- Overwintering has not been documented in lakes and juvenile Chinook are not present in the stomachs of predatory fish captured in lakes in the winter.
- Predation on overwintering fry by mink may be significant where the fry are confined to small areas.
- Overwintering extends until yearling (1+) juveniles leave the streams that they have spent the winter in and begin their migration to sea.

Potential Limiting Factors

- Short-term climatic/hydrologic variation resulting in decreased high quality groundwater discharge into overwintering areas following low-water summers.
- Climate change-related increased discharges of low quality ground water into overwintering habitats from melting permafrost.
- Reduced quantity/quality of overwintering habitats resulting from natural or placer mining associated fine sediment deposition on preferred cobble/rubble stream bottoms.
- Release of toxic materials from quartz mining development and operations.
- Obstruction of access by fry to overwintering habitats by beaver dams.
- Increased risk of predation from mammalian predators when fry are concentrated in small overwintering areas.
- Entrainment in hydroelectric facilities.

Downstream Migration

Ecology

- Downstream migration of 1+ juveniles may commence as early as early May, peaks in June (Bradford et al. 2008) and may be delayed if the spring is cool or late. Chinook that migrate to sea after one or more years in freshwater are referred to as "stream-type" Chinook
- Few 1+ juveniles are captured in the Canadian portion of the Yukon River after July 15 of any given year suggesting that the vast majority of Yukon Chinook smolt after 1 year in freshwater.
- Downstream migration to the ocean is direct and, given the timing of migration past Dawson City, likely results in a mid-summer entry into the Yukon estuary (Bradford et al. 2008).

Potential Limiting Factors

- Short-term climatic/hydrologic variation resulting in low spring water temperatures and delayed out-migration of overwintered yearlings.
- Entrainment in hydroelectric facilities.

Juvenile & Sub-adult Marine Stages

Ecology

- Juveniles complete the smolting process in the Yukon River Estuary and use marine habitats adjacent to, or on, the eastern Bering Sea shelf throughout most of their marine life-history stage (Myers et al. 2009).
- Marine residence may extend from 2 to 6 years and is completed as sexually mature adults return to the mouth of the Yukon River. Male Chinook will typically mature at an earlier age than females.

Potential Limiting Factors

- Growth during early marine life is an important determinant of survival and so interannual variation in the abundance and quality of food and the number of predators may be important limiting factors in some years (Murphy et al. 2013).
- Mismatch between outmigration timing (which can be driven by timing of ice breakup) and prey availability during early marine life (Schindler et al. 2013; Ohlberger et al. 2016).
- Changing oceanographic conditions and increased abundance of other Pacific salmon species leading to reduced food in the ocean and increased competition (either directly or indirectly) for available resources (Ohlberger et al. 2016). Predation by marine mammals and bycatch in Pollock fisheries (Ianelli et al. 2015).

Upstream Migration

Ecology

- Adults return to the mouth of the Yukon River from mid-to-late May through early July. The timing of entry depends on environmental conditions including sea surface and air temperatures as well as sea ice cover (Mundy and Evenson 2011).
- Peak migration timing of Chinook salmon entering the Canadian section of the drainage usually occurs mid-to-late July.
- Migration through Alaska occurs during maximum summer daylight, raising concerns of high water temperatures.
- Most adults return to their natal rivers. These may be as far upstream as the headwaters of the Stewart, Pelly and Teslin Rivers (~3000 km upstream of the Yukon estuary).
- The first adults reach the headwaters of the principal tributaries around August 1.

Potential Limiting Factors

- Short term climatic/hydrologic variation resulting in low water/warm water conditions in the Yukon River contributing to increased incidence of migration mortality, either as a result of stress, energy depletion, or increased susceptibility to parasitism and disease (Kocan et al. 2004; Kocan and Hershberger 2006).
- Migration into and up smaller, lake-dominated streams may be obstructed by beaver dams during low water years or droughts.
- Obstruction by hydroelectric dams and associated delays of migrating fish, particularly during warm water/low water years.

Spawning

Ecology

- Spawning occurs in a wide range of habitat types, including lake outlets, larger rivers and smaller streams.
- Spawning dunes resulting from the digging of redds may be well developed in buffered systems, such as those downstream from lakes.
- Substrate requirements, redd structure and spawning behaviour have not been specifically studied in the Yukon River drainage, but have been observed to vary significantly between different areas.
- Groundwater discharge areas are not preferred for spawning.
- A redd is excavated and eggs deposited.
- Spawning is usually complete for the entire Yukon River by the end of the first week in September

Potential Limiting Factors

- Short term climatic/hydrologic variation resulting in episodic extreme high flows during the spawning period in non-buffered streams resulting in reduced stock productivity, or extreme low flows in smaller streams resulting in inadequate velocities and depth of flow for spawning adults.
- Long-term trends to lower annual flows in some spawning streams.
- Sediment from natural sources and placer mining degrading spawning habitats.
- Pre-spawn mortality related to thermal stress or increased parasitism resulting in decreased spawning success (Kocan et al. 2004; Kocan and Hershberger 2006).
- Effects of flow reductions/increases below hydroelectric dams during spawning periods.
- Loss of spawning habitat due to flooding upstream of hydroelectric dams.

5 Identifying restoration objectives, opportunities and uncertainties

5.1 Community engagement and research

In May of 2015 the YSSC corresponded with Yukon First Nation Governments, Renewable Resources Councils (RRCs) and Yukon communities to introduce the SSRI and its objectives and to express interest in engaging with them over the coming months. Throughout July and August 2015, stock restoration was conducted in eight communities. Six community interviews were conducted in person, one by telephone, and, one First Nation's input is based on stock restoration documents provided by the government (Appendix B).

To structure a discussion around community values, goals, limiting factors and past, present and future stock restoration opportunities. The following questions were asked:

- Why are Chinook important to your community?
- What changes have been observed in Chinook in your community over the past few decades (e.g., in numbers, sex ratio and size)? When did they occur? Why might they be occurring?
- What factors might be limiting Chinook in your region from recovering from their currently depressed state?
- Which Chinook populations near your community were/are the most abundant or productive?
- What, if any, restoration activities have occurred in the past in your community? Were they successful? Why or why not?
- What do you see as the primary objectives of stock restoration activities in your community?
- Are there any proposed or potential stock restoration activities that have been identified in your region?
- What are the key uncertainties that make it difficult to determine the most appropriate Chinook restoration or management actions and/or to determine what factors are most likely limiting Chinook populations, in your region?

The information gathered from the community engagement process was then organized in a restoration actions and objectives spreadsheet (Appendix B), which catalogued, by community and Chinook population, information specifically related to:

- Past restoration actions including whether or not they were successful and why;
- Potential or planned restoration actions;

- Community stock restoration objectives or concise statement(s) of what matters related to existing or potential stock restoration activities in the community (e.g., maximize harvest, reduce probability of extinction, etc.);
- Descriptions of changes that have been observed in Chinook in the community over the past few decades (e.g., in numbers, sex ratio and size)? When they are thought to have occurred, and why might they be occurring?; and
- Key uncertainties that make it difficult to determine the most appropriate management strategies, and/or to determine what factors are the most limiting.

It was evident throughout the interviews with stakeholders that there is a wide spectrum of knowledge regarding stock restoration and management initiatives. The level of detail of information gathered in interviews with respect to each party varied. Each Yukon First Nation is unique in their understanding, awareness, capacity and readiness as it relates to stock restoration. Regardless, the community engagement process provided an increased understanding of the status of stock restoration in each engaged community and allowing for the clear identification of overarching objectives of Canadian Yukon River First Nations.

Although ancillary social, biological and management objectives were expressed in some interviews, all stakeholders stressed that their principal objectives were to increase Chinook abundance and maintain or re-establish a cultural connection to salmon. Additional objectives that were commonly voiced included a preference to not "mess" with nature and a strong desire for restoration actions to be driven and supported by the community. Collectively, these objectives lead to identifying the primary goal of stock restoration from a Yukon First Nation perspective, which is to:

> **"Promote recovery of Yukon Chinook in order to maintain and re-establish cultural connections to salmon in a manner that is consistent with community values and involvement"**

5.2 Inventory of stock restoration activities and opportunities

The community engagement process helped identify past, ongoing and potential restoration actions being considered by each community (Appendix B). This suite of actions was expanded based on an inventory of past restoration activities supported by the Yukon River panel R&E fund and discussion with other parties involved in salmon management and conservation in the Yukon (Appendix C). An inventory of past stock and habitat assessment projects was also compiled as a reference for the history of assessment projects in the Canadian portion of the Yukon River (Appendix D).

Six broad classes of restoration actions emerge from this inventory (Figure 5). A high-level summary of each action class is provided in the boxes that follow, including details of:

- **What:** what the action entails.
- **Where:** the geographic location of an action including the Chinook population(s) and community(ies) where it would take place.
- **When:** general timeframe for evaluation, planning and implementation of action (e.g., is this something that could be done in a year or would it need to be planned and implemented over a decade?).
- **Why:** what the action hopes to achieve (e.g., increase egg-to-fry survival) and why it is believed to be worthwhile (e.g., evidence that it addresses a limiting factor).
- **Pros and Cons of the action:** a concise list of the pros and cons of the action. For example, the action is very expensive but likely to increase the number of adults returning to the watershed. This is also where capacity issues are raised (e.g., great potential for action to address limiting factor but limited capacity to implement it) along with the sensitivity of the action to stochastic environmental conditions.
- **Critical uncertainties:** key knowledge gaps that preclude a better understanding of how successful the action may be (e.g., feasibility of trap and haul for adults at a dam or extent to which egg-to-fry survival may be limiting).
- **Supporting actions:** necessary activities to support the restoration action under consideration (e.g., juvenile stock ID work or sonar to enumerate adults).

Figure 5: Schematic of the six broad classes of stock restoration activities that have been, or could be, considered in the Yukon.

5.3 Habitat restoration and enhancement

What

Habitat restoration (return of productivity to some pre-disturbance level) and enhancement (increase in productivity beyond natural levels) includes a broad range of actions that may be taken to increase the productivity of spawning and rearing habitats. Habitat restoration can include re-vegetating stream banks, adding structures including large organic debris and other materials to stream channels, stabilizing eroding stream banks to reduce sediment input to streams, restoring access to spawning or juvenile salmon over "soft" obstructions (non-bedrock) such as roadway stream crossings, beaver dams or log jams. Habitat enhancement includes building habitats and may include the excavation of groundwater-fed channels for rearing and overwintering Chinook, removing "hard" obstructions (bedrock) to allow Chinook access to areas that they have never occupied, or connecting isolated streams or water bodies to habitats used by Chinook. Removal of hard obstructions and beaver dams are described in separate restoration action write-ups.

Where

Past restoration works in the Canadian portion of the Yukon River include:

- The South McQuesten River induced avulsion conducted by the Na-Cho Nyak Dun and DFO to provide passage around the Haggart Creek Log Jam;
- The Wolf Creek Fishway constructed by the Yukon Fish and Game Association and DFO to allow passage over a sheet pile obstruction below the Alaska Highway; and
- The Fox Creek Channel Restoration project conducted by Ta'an Kwäch'än Council to isolate the channel of Fox Creek from two major sediment sources.

Most restoration undertakings have been restoration- and maintenance of access to upstream spawning and rearing habitats through beaver dam management as described in the next section. There have been several live staking projects. However, the plant species most suitable for live staking (willow and balsam poplar) are those preferred by beaver. As a result, re-vegetating is only advised along large rivers too large for beaver to dam, but doing so in these locations provides minimal benefits to Chinook salmon.

With the exception of placer mining streams and a small number of urban streams, important riparian functions for sub-arctic streams and rivers are naturally maintained and renewed, and so opportunities for habitat restoration are limited.

However, potential restoration opportunities that could currently be carried out include:

- Stabilizing the toes of two active landslides and the Klondike Highway embankment on the Tatchun River to reduce sediment input and encourage self-stabilization of downstream channels;

- Assessing upstream juvenile Chinook salmon passage for stream crossings at Cottonwood, Hayes, and Strawberry Creeks in the upper Teslin River Basin;
- Diversion of McIntyre Creek away from an eroding bank below Mountainview Drive in Whitehorse to allow passive restoration of downstream spawning habitats.
- Development of small ground water channels in select areas of the Klondike River floodplain.

When

- Live staking is best conducted when plants are dormant. Spring live staking will require supplemental watering unless the stakes are driven into or buried below the saturated soil zone.
- Slope stabilization or channel diversion type projects will require, at a minimum, one full year of community consultation, geo-technical engineering, environmental assessment and permitting/licencing and acquisition of funds, with two years more likely. Physical works, including access to the work site could be completed in one open water period. Monitoring and maintenance would probably be required as a condition of a water license for a five-year period.
- Assessments of the upper Teslin River Watershed could be conducted in a single year but may require downstream beaver dam management to ensure that juvenile Chinook salmon could reach the stream crossings in question. If the current crossings do not allow juveniles to pass upstream, options could be explored with regulatory and other agencies to restore passage.
- Development of overwintering habitats by excavating small, groundwater-fed channels or pockets in floodplains is a possible enhancement action. Large groundwater channels are not advised due to the risk of beaver damming. Existing groundwater discharge areas can be easily identified in late winter. Water quality and quantity can be determined during the following summer and winter, with consultation/permitting in spring. Excavation could occur in the autumn of the second year, or during the year that follows.

Why

- In locations where important rearing or spawning habitat is obstructed or degraded, restoration of such habitat can increase spawning and rearing success. For example, sediment input from landslides or erosion of highway embankments destabilizes downstream channels and isolates the spawning habitats they may have formerly supported. Fine sediments can be deposited into - or over stream gravels and result in degradation of spawning habitats. Restoring these habitats can therefore increase access to spawning and rearing habitats (e.g., Tachun River).
- Restoring fish passage through highway crossings (e.g., upper Teslin River Watershed stream) would allow juvenile Chinook salmon to exploit upstream habitats, reducing densities of juveniles below the obstruction and thereby providing more food and space for the overall population.
- In areas where overwintering habitat may be limiting fry survival, the development of overwintering habitats by excavating small, groundwater-fed channels or pockets in floodplains could reduce overwinter mortality.

Pros and Cons

Pros

- Live staking is a simple technique and is a useful tool to increase community interest and support for Chinook salmon habitat stewardship. If limited to the banks and bars of larger rivers, the risk of adverse effects is low.
- Effects of sediment on spawning Chinook salmon and control of sediment through engineering is well understood and accepted by the scientific / technical community.
- Expertise in river engineering is locally available, and supplemental specific engineering advice may be available through engineers working in, or associated with, the Salmonid Enhancement Program.
- Local firms could carry out the required excavation and embankment works and associated labour. Monitoring and maintenance plans could be developed to maximize local involvement and benefits.
- Assessment of stream crossings that are owned by a third party is a low-cost activity. If juvenile Chinook salmon are abundant below the crossing and absent above it, a strong case may be made that the crossing is an obstruction, and pressure placed on regulatory agencies to require that passage be provided (and funded by) the Yukon Government as they own the crossings.
- Development of overwintering habitats could be a relatively inexpensive means of increasing the fry to yearling/pre-smolt success.
- Pre-project assessments, pocket excavation and post project monitoring could be conducted by local firms and residents under technical supervision of DFO or institutional staff.

Cons

- Live staking provides little benefit to Yukon River Chinook salmon.
- Engineering works for slide stabilization are expensive, and a single project could exhaust the YRP R&E budget for several years. Costs will be on-going for at least 5 years post construction and the proponent of any project should be required to demonstrate the capacity to maintain and fund any required maintenance and renewal of structures or access.
- Developing and maintaining funding partnerships for engineering works can be time consuming, difficult and may not be accepted as a valid expense by funding agencies/bodies.
- Most “standard” restoration opportunities in the Upper Yukon River Basin are related to restoring spawning and rearing habitat that has been degraded by placer mining. However, the Yukon placer Mining Act allows future direct and indirect disruption of restored channels and reclaimed lands and therefore these lands are poor candidates for investment as any restoration works could be immediately destroyed by the owner of the placer mining rights.
- Almost all streams and rivers in the Canadian portion of the Yukon River are unregulated and subject to a wide range of flows. Many are laterally unstable and permafrost degradation is widespread so works conducted on banks subject to shallow or deep permafrost have been short lived.
- Provision of overwintering habitats will be limited to a small number of accessible rivers.

Critical Uncertainties

- Overwintering habitats for juveniles may be a limiting factor for some Yukon River Chinook populations and some of these habitats may benefit from restoration. However, considerable uncertainty remains regarding which habitats due to a largely unknown, and possibly temporally variable, degree of emigration of 0+ fry from natal areas.
- Stabilization of the toe of landslides and isolation of the creek from sediment inputs is a recognized technique and can be conducted with a minimum of technical uncertainty. Acceptance of works in the Tatchun River by the Carmacks/Little Salmon and Selkirk First Nations is uncertain. Acceptance of works in McIntyre Creek by the Kwanlin Dun and Ta'an Kwäch'än First Nations is likely, but confirmation is required. Acceptance of assessments of stream crossings by the Teslin Tlingit Council is likely, but agreement by the DFO Fisheries Protection Program to require passage and by the Yukon Government to accept it is uncertain. All slope stabilization/sediment reduction projects will require a series of licences and authorization and application to and review by YESAB. However, the works proposed are relatively straightforward and the review should reflect this in both timing and outcome.
- Development of "pocket" type overwintering habitat for Chinook salmon is a new technique, albeit one based on naturally occurring groundwater-fed channels on the Klondike River and North Klondike River flood plains. The regulatory requirements for a project of this type are uncertain.
- Uncertainty in those factors outside of freshwater habitats in the Yukon River that may be limiting Chinook survival means that the success of this action is also uncertain.

Supporting Actions

- The positive effects of landslide toe stabilization and stream isolation from landslide-related sediment is based on general principles. If site-specific biological information is required, the pre-project assessments conducted on the Cowichan River to assess the effects of the Stoltz Bluff slide (LGL and KWL 2005) could be used as a template for designing the pre- and post-project biological monitoring.
- No supporting actions are required for live staking, except to discourage the technique on small(er) spawning and rearing streams vulnerable to beaver damming.
- Pressure may be required on both the DFO and the Yukon Government to provide passage through the upper Teslin River Watershed stream crossings.
- Formal studies of natural or semi-natural overwintering habitats in the Klondike River watershed could confirm present use and inform future use and creation.

5.4 Beaver dam management

What

For adult Chinook salmon, this entails removing or breaching beaver dams in productive streams to allow access to upstream spawning areas. For juvenile Chinook, it requires capturing fry downstream then releasing them upstream of beaver dams to restore and maintain migration to upstream rearing and over wintering habitats. The action may be associated with beaver management plans (e.g., trapping or disturbing beavers) in select streams to reduce the probability of beaver dams being established in the first place.

Industrial trapping did not begin in the Yukon until after the collapse of the global beaver market in 1843. Beaver are considered fur-bearing animals in the Yukon and therefore can only be taken by the holder of a registered trap line. Beaver pelt prices have been depressed for decades and so little harvest takes place. Beaver populations probably exceed pre-contact levels, in part as First Nation use of beaver has been constrained by the registered trap line system.

There has been considerable debate regarding the risk that beaver pose to salmonids (e.g., Malison et al. 2014; Mitchell and Cunjak 2007). Most general North American attitudes are based on situations that have occurred, and studies that have been conducted, in environments distant from the Upper Yukon River. The focus here is on the Yukon River Basin in Canada, and the effects of beaver dams on upstream migrating Chinook salmon.

Where

Beavers are most common in glaciated terrain, stream/lake complexes, and the dry belt of the Yukon. There is currently no program or process in place to identify streams at risk of obstruction, although some streams have a known history of obstruction due to beaver dams. Beaver dam management for salmon has been conducted in:

- Fox Creek, McIntyre Creek, Wolf Creek and Michie Creek in the Upper Yukon River Watershed;
- Deadman Creek, Strawberry Creek and others in the Teslin River Watershed;
- Klusha Creek, Nordenskiold River and Tatchun River in the Yukon River Mid-mainstem Watershed;
- Mica Creek, Needle Rock Creek, Willow Creek and Caribou Creek in the Pelly River Watershed;
- Janet Creek and restoration channels in the Mayo River in the Stewart River Watershed;
- Tributaries and back channels of the Kluane River in the White River Watershed; and
- Ground water channels along the Klondike River in the Yukon River North Mainstem Watershed.

Other important spawning streams within the Canadian portion of the Yukon River are likely sensitive to beaver dam effects, particularly during drought conditions.

When

- In the Yukon, beaver dam breaching or removal requires a Permit under the Wildlife Act. The permit process has been efficient in the past, and a permit could be granted almost immediately if a dam was found to be obstructing upstream migration.
- Important, vulnerable and accessible spawning streams are known to local First Nations and communities, making the development of a Beaver Management Plan fairly straightforward. Permits can be acquired, a monitoring schedule developed and dams breached as they are identified.
- Beaver management is an ongoing process and requires periodic assessment because beaver modification of habitat is a dynamic process.
- Stream levels have been high for the last 5 years and beaver dam management has therefore been less of an issue than in years of low flow. However, 2015 saw a general reduction in stream flows in parts of the upper Yukon River Basin, for example, a dam was noted in August in Tatchun Creek.
- See Appendix E for a backgrounder on beaver and salmon in the Canadian portion of the Yukon River and a discussion of the identification and management of obstructions on small, productive and vulnerable Yukon River Chinook salmon spawning streams.

Why

Beavers construct dams on streams and smaller rivers in the upper Yukon River Basin, particularly under drought conditions. These dams, and the ponds that form behind them, may have a number of effects on salmon and their habitats that are similar to those of a small man-made dam.

Adult Chinook salmon migration into spawning streams and subsequent spawning is limited to a narrow window in late summer and follows a long migration from the ocean. Flows in spawning streams and some rivers may be very low during this period and rivers may also be dammed by beaver. Beaver dams can take on various forms. Some dams are total obstructions to all adult Chinook salmon. Others may stop some adults while individuals with sufficient remaining strength and energy can swim over the dam. Multiple attempts may be required to cross each dam and can result in delay and congestion below the dam. Bears often focus their foraging efforts in the area immediately downstream of dams to take advantage of the concentration of adult salmon in these areas. Energy reserves required for the ultimate act of spawning are almost certainly depleted in avoiding predators and finding a pathway to swim over the dam.

Upstream migrating juvenile Chinook salmon can be affected by beaver dams as they attempt to access upstream to summer rearing and overwintering sites. Dams, and dam complexes (one colony may build more than 10 dams in Yukon River non-natal rearing streams) are infinitely variable in size and form. These complexes change constantly as beavers add more material to the dam while the dam settles or water erodes parts of it away. Water flow paths over dams reflect the constantly changing shape of the dam and are seldom constant in any one location. Some juvenile Chinook salmon are able to find pathways to swim over or around most beaver dams.

Observed concentrations of juvenile Chinook downstream of dams imply obstruction or delay of an undetermined portion of the total number of juvenile Chinook salmon at each dam. Juvenile Chinook salmon are limited to between ~100 and 150 days to grow and accumulate fat reserves to last them through the winter. Restoring juveniles to areas upstream of beaver dams may allow access to areas where there is less competition for food, space and cover during the remainder of the rearing period, overwintering, and the early spring feeding period prior to out migration.

Pros and Cons

Pros

- Breaching dams is a low technology activity and is within the capacity of local communities to conduct and a good source of local employment.
- First Nation and non-aboriginal trappers have generally granted social license to the activity, subject to harvested beaver being dealt with respectfully.
- Capture of juvenile salmon and restoration above beaver dams in non-natal streams is a relatively safe activity and does not require expensive certification of staff.
- Breaching dams is a potentially low cost activity.

Cons

- Resistance to beaver management may be expected from the general public given the high societal value generally attributed to the beaver in Canada.
- Only the monitoring phase of a beaver dam management program can be planned for, as the presence of the dam, and appropriate response, will not be known until the monitoring commences.
- Able-bodied persons with suitable training and certification to carry out dam breaching may be difficult to retain on short notice. Necessary certification may include chain saw operation, swift water rescue, First Aid and other Occupation Health and Safety requirements
- The present Yukon River Panel R&E fund application process is the same for a small, local beaver dam management project as for a major, agency led project. The personnel costs of applying for funds for a beaver management project may exceed the cost of the project itself. This discourages First Nation and other local applicants.

Critical Uncertainties

The degree to which beaver dams limit spawning and rearing success is in part determined by what portion of available rearing and spawning habitat for a given population is obstructed. However, the extent to which upstream adult migration and juvenile migration are altered / impeded by beaver dams is dynamic and not well known because of the cost of ongoing monitoring. As a result, the extent to which spawning and rearing success is limited in any given stream during any year is uncertain.

- Beaver management projects for juvenile Chinook salmon have only been evaluated for a single atypical stream in the Canadian portion of the Yukon River. Although these projects have shown positive results (Clinton Creek; von Finster 2012), the generality of these findings is uncertain.
- Uncertainty in those factors outside of freshwater habitats in the Yukon River that may be limiting Chinook survival means that the success of this action is also uncertain.

Supporting Actions

- Knowledge of spawning and rearing habitat within a watershed is necessary to access the risk a given dam poses to Chinook and the corresponding benefit of breaching.
- Breaching dams is a potentially low-cost activity, but realizing savings will require modification of current Yukon River Panel R&E funding processes to reduce the cost to proponents of preparing comprehensive applications for a small project.
- As noted above, addressing the high cost of applying for funds and the lack of support to conduct this type of project is the primary supporting action required.

5.5 Instream incubation

What

Instream incubation is the planting of fertilized eggs into a stream or stream bottom. Eggs may be deposited directly into holes dug into the stream bottom or more commonly, eggs are placed in incubators or groups of incubators that are deposited into, placed on, or suspended above the stream bottom. The most common type is the Jordan-Scottie system, which is based on plastic plates. Fertilized eggs are deposited in depressions on one plate, and a second plate is then bolted to it to form a "unit". The second plate is perforated to allow an emergent fry to leave the unit. Each unit has a capacity of 200 eggs and up to 5 cassettes can then be joined together to form a "set" with a capacity of 1000 eggs. Instream incubation requires egg acquisition from a hatchery or from spawning fish (which may be released back into the stream to complete their spawning). Fertilized eggs are loaded into the units and either placed or buried in the stream. Periodic monitoring of the incubator during the period that eggs or alevins are present is recommended. Fry can exit the egg pocket and enter the surface or subsurface environment. The incubators are retrieved and cleaned in the spring and used again the following summer. Alternative approaches to instream incubation, such as artificial redds, have been proposed but have yet to be evaluated in the Yukon.

Where

Instream incubators have been used in the Yukon for bio-assay purposes by DFO and others groups to assess possible hatchery sites, candidate streams for restoration, and for research. In areas with groundwater discharges that remain sufficiently warm throughout the winter, incubators can remain above stream bottoms. However, the design of the incubator makes them vulnerable to frazil/slush ice deposition, freezing, and destruction of any eggs they may contain in surface waters and so in locations where there is no groundwater the incubators must be buried in the stream bottom. Instream incubators are currently being considered for application within the Yukon River Panel R & E Fund to restore the upper Mayo River Chinook stock and to reintroduce Chinook to Deadman Creek in the Teslin River watershed.

When

- The time frame of an instream incubation project depends on the project's purpose. If the project is to re-introduce a stock, it is likely that a DFO License to Release Fish into Fish Habitat would be required, and an environmental assessment under the YESAB is triggered. The YESAB review process is at present open-ended and reviews may be lengthy. A minimum of one full year is likely, and two or more is possible.
- If the project is for stewardship/educational purposes, it is likely that the project could be conducted under a DFO License to Collect Fish for Scientific, Educational or Display and would not trigger a YESAB review. This would probably also be the case if the instream incubator is used for bio-assay purposes and is modified so that fish cannot escape. The DFO Collection License Process is efficient and a License could be in hand in as little as 3 weeks after application.

Why

- Instream incubation can increase egg to fry survival relative to naturally incubation and so in instances where egg-to-fry survival is limiting a population such an action can increase juvenile and adult abundance.

- A secondary use of the technique is in conducting bio-assays to pre-assess restoration or enhancement sites or water supply. Incubators deployed for bio-assay purposes are generally designed or modified so that the fry cannot leave. This allows investigators to remove incubators at predetermined times to assess the proportion of fry that have successfully emerged from the eggs and remain alive.

Pros and Cons

Pros

- Instream incubation can increase egg-to-fry survival relative to natural incubation.
- Instream incubation can be a useful means of engaging and maintaining public interest and participation in aquatic resources.
- Bio-assays using instream incubation is a valuable tool in the assessment of habitats and water supply for restoration or enhancement purposes.

Cons

- Egg incubation trays are not typically an efficient tool to increase the survival of large numbers of eggs because of the large number of incubation trays that would be required (i.e., typical female produces ~ 5000 eggs which would require 5 “sets” of 5 trays for each female).
- The success of this action in the Yukon is initially likely to be low, as sub-surface water flows are difficult to predict and the need to “prospect” for good sites may be required.
- It can be challenging to adequately assess adult returns from instream incubation because artificially propagated adults would be indistinguishable from wild fish unless, for example, a Parentage Based Tagging approach is used.
- Risk of frazil ice formation is sufficiently high in all but a limited number of locations in the Yukon and so incubators would typically have to be buried. Burying incubators at an acceptable depth in the streambed may require significant excavation in the loose gravels or cobbles most likely to provide adequate flow through the boxes. A group of incubators would require a correspondingly greater disturbance.
- Instream incubation devices left on the streambed are vulnerable to disturbance by people or wildlife.
- In most Chinook salmon spawning rivers and some streams water depths at deployment during natural spawning periods will be too high to wade the stream, and divers will be required.
- If fertilized eggs are acquired from broodstock that are not from the river in which the incubation trays are used then there is the potential for adverse genetic effects on the local population as a result of genetic introgression.

- Most Yukon Chinook spawning rivers and streams are unregulated. Flows will vary seasonally and annually, reducing the potential to be able to plan the deployment of incubators. In addition, water velocities at deployment will be too high to consistently deploy the incubators.
- If natural spawning stocks will be used as brood stock, trained and experienced staff will have to be available during the critical period that salmon are spawning and at the location that spawning occurs. Local hydrologic conditions during this time can make the capture of brood stock very challenging.
- If hatchery stocks are to be used, the hatchery will have to be designed or modified to accommodate the stock in isolation from other stocks.

Critical Uncertainties

- The two primary uncertainties are (1) the extent to which instream incubation increases egg-to-fry survival relative to naturally incubating eggs in a given system and (2) the sensitivity of the incubation trays to interannual variability in ice formation.
- Uncertainty in those factors outside of freshwater habitats in the Yukon River that may be limiting Chinook survival means that the success of this action is also uncertain.

Supporting Actions

- In order to deploy incubators with fertilized eggs one needs to acquire from wild brood stock or from an existing hatchery.
- If instream incubators are deployed as an educational/stewardship opportunity then agency or stewardship program support should be given to incorporate the action into existing programs where local streams may be safely accessed and are suitable for deployment.

5.6 Hatchery program including egg take, incubation and outplanting

What

A hatchery is any facility where water is taken from the ground - or surface-waters, directed through incubation and rearing facilities, and released back to the environment. Hatcheries vary in size and complexity from large, sophisticated facilities producing millions of fry to small, simple stream-side incubation boxes. Hatchery operations include egg takes, which is the artificial spawning of adult broodstock; incubation of eggs; early life rearing and out-planting of juveniles.

Hatcheries can be used for a number of purposes. Compensatory hatcheries can help replace lost productivity as a result of industrial activities such as hydroelectric dams. Conservation hatcheries can be used in an attempt to restore depleted stocks or save endangered stocks. Production hatcheries can be used to produce fish for capture in fisheries. Stewardship hatcheries provide local employment or tourism opportunities, educational services and augment local stocks, but may not be integral to the overall management regime of the stock or the fishery.

Facilities for hatcheries including water supply and treatment works require maintenance, upgrading and eventual renewal. Larger facilities require permanent and seasonal staff and substantial administrative support. Land tenure must be acquired. Licenses for the water use, collection of broodstock and movement and release of juveniles into the environment, and environmental assessment under the YESAB must be applied for and reports submitted to the regulatory authorities.

Where

Operational Chinook hatcheries within the Canadian portion of the Yukon River include the McIntyre Creek fish incubation facility and the Whitehorse Rapids fish hatchery. Both facilities are located in Whitehorse. In the past hatcheries were also located at a groundwater-fed facility on the North Klondike River upstream of the Klondike Ditch; a surface water fed facility on the Mayo River below the Wareham Dam; and a surface water fed facility on Wolf Creek downstream of the Alaska Highway. Additionally, one or more surface water fed hatcheries were located on the Klukshu River and its tributaries. In recent years there has been interest in a hatchery in the Mayo area to restore Chinook on the Mayo River and another in the Dawson area to restore Chinook in the Klondike River and to serve as an educational facility. Other communities and First Nation Governments have also considered small-scale hatcheries as a way to restore specific stocks.

When

- The length of the pre-assessment phase for a hatchery depends on the amount of existing stock and habitat information. As a general rule, at least 2 years of pre-assessment work is advisable. Facility design, consultation with First Nation, Renewable Resource Councils and communities, environmental assessment and licensing could be completed in the second year, but are more likely to take an additional year.

- Assuming a 6-year Chinook generation time, a hatchery would have to operate for a minimum of 12 years (2 generations) to allow for an evaluation of its ability to achieve its objectives (e.g., increase adult abundance). The adult enumeration phase would have to be in place and functional for 8 years of this period in order to enumerate all age classes that may return (i.e., 4 - 6 year olds).

Why

- In instances where freshwater habitat currently limits egg and fry survival or spawning success, hatcheries can be used to increase the survival of eggs and early life fry or spawning success relative to survival rates that would occur under natural conditions. Hatcheries can also produce juvenile fish that can then be used to re-establish extirpated populations.
- Areas where there is some evidence of freshwater conditions currently limiting freshwater survival of eggs and fry and/or spawning success include: the upper Mayo and the Klondike Rivers.

Pros and Cons

Pros

- Hatcheries provide a controlled environment for the incubation and early life stages of salmon, and can result in greatly increased egg-to-fry survival.
- If lack of fry is a substantive reason for the decline in productivity of a Chinook stock, hatchery production can increase the number of fry migrating to the ocean and the number of adults returning.
- A hatchery can serve as a central incubation facility, incubating eggs for a number of different stocks at one time or over a period of time.
- Data on marked fish from hatchery programs (e.g., with Coded Wire Tagging CWT) can help to inform fisheries management (e.g., run timing, exploitation rates and marine survival).
- Hatcheries can provide a focus for leveraging funding and donations from industries (as offsets for harm to fish habitat or green funding), foundations, or government agencies and can also play an important role in stewardship (i.e., outreach, education and local employment) and, when partnered with local or extra-territorial research institutions can conduct or support scientific research on Yukon River Salmon issues.

Cons

- Hatcheries can be expensive to plan, build, operate, maintain and renew.
- Hatchery-based stock augmentation programs require long term funding commitments – as a working number, a minimum of 12 years is required for the implementation of a stock restoration plan for approximately two complete Chinook cycles.
- Incubating and rearing at a central facility with water from outside the watershed where the eggs are taken from can reduce the likelihood of imprinting to target the stream/watershed and hence increase straying rates of returning adults.

- All hatcheries pose some risk to the eggs and fry incubating within them due to unanticipated operational issues. Generally:
  - new hatcheries pose a greater risk to incubating eggs and fry than similar established hatcheries;
  - larger, better staffed, secured, and funded hatcheries with backup water and electrical systems pose less risk than smaller, unstaffed hatcheries with no backup systems and no site security;
  - hatcheries using surface water pose a higher risk of fish infection from pathogens than ground water fed hatcheries, and therefore often require the use of chemical agents to control disease or parasite outbreaks;
  - hatcheries requiring surface water during winter pose a risk of mass mortality due to frazil ice blockage of pipes.
- As a result of genetic introgression, hatcheries can contribute to changes to the genetic makeup of locally adapted populations that hatchery fish are introduced to. Integrated hatchery programs which keep hatchery contributions to less than 30% (for example) of spawning populations can minimize this risk.
- Hatchery operations may result in juvenile growth rates exceeding natural rates (e.g., Whitehorse Rapids fish hatchery), leading to earlier migration to sea and age of maturity.
- Significant, and successful, enhancement of a single population can result in overharvesting of non-enhanced populations in mixed population fisheries.
- Hatchery operations require skilled and experienced staff, and certain activities may require staff certification/recertification to meet Occupational Health and Safety standards.
- Unless there is a structure where brood stock can be collected and held, such as a fish counting weir or fish ladder (e.g., at the Whitehorse Rapids dam), acquisition of brood stock may require capture of adult salmon and holding them in non-secured areas until they are ready to spawn.
- The number of adults removed for brood stock is usually limited to some percentage of the total return of adult salmon in the target stream (e.g., less than 30%). Therefore an assessment of stock size is generally required to ensure that sufficient adults are present to support the hatchery brood stock collection program.
- Flows in spawning rivers vary seasonally and annually, and brood stock may be difficult to safely and efficiently capture during high water years. Contingencies must be considered to address non-typical volumes of flow during times when brood stock need to be collected.
- When produced in sufficient numbers, hatchery reared fry that are introduced into the natural environment can compete with wild produced juveniles for food and habitat leading to unintended density-dependent reductions in growth and survival of both wild and hatchery Chinook.

Critical Uncertainties

- Both the Whitehorse Rapids and McIntyre hatcheries have successfully produced adult Chinook salmon. However, a critical uncertainty regarding the potential effectiveness of existing or new hatchery facilities is understanding what the most appropriate rearing and release strategy is to follow. For example, there have been concerns with the Whitehorse Rapids strategy of releasing juvenile Chinook salmon at the start of the open water period that approach the average size of wild Chinook at the end of the open water period, the resulting conversion of the artificially propagated fish from "stream" to "ocean" type life histories, and the return of many of the males as jacks. The McIntyre Hatchery release strategy includes releasing juveniles at sizes that approximate wild juveniles.
- Uncertainty in those factors outside of freshwater habitats in the Yukon River that may be limiting Chinook survival means that the success is also uncertain.

Supporting Actions

- A plan for monitoring the growth of the released fry and measuring critical habitat parameters to determine the degree of rearing success and whether the release strategy should be modified must also be developed. The plan should include a means of enumerating the returning adults to evaluate the success of the hatchery in producing adults.
- A third-party evaluation of hatchery practices at existing and potential hatchery facilities (e.g., brood stock collection, current and potential future rearing and release strategies like rearing temperature and size of fry at release). The results of such evaluations could inform the (re)design of facilities under consideration and the development of Hatchery Operation Plans. If more than one stock will be restored with fry produced in the hatchery, each should have its own stock restoration plan.
- Continuation of nose tagging/adipose clipping or use of Parentage Based Tagging would allow for some degree of assessment/evaluation of the return of adult Chinook.

5.7 Removal of larger natural barriers to upstream migration

What

The removal of existing natural barriers to upstream migration by adult salmon (e.g., landslides, waterfalls) through fishways or excavated channels, and modification of partial barriers to decrease delays and increase access past barriers. Increasing access could include trapping adult salmon downstream and release upstream of a barrier or out-planting of artificially propagated juveniles upstream of a barrier.

Where

There are few natural barriers to upstream migration on known spawning streams in the upper Yukon River basin. In addition to Fraser Falls, which is a partial barrier to migration, waterfalls on the following stream are known barriers to upstream migration:

- Watson Creek, tributary to the Stewart;
- Lapie River, tributary to the Pelly River;
- Squanga Creek, tributary to the Teslin River; and
- the M'clintock River, tributary to the Yukon River near Marsh Lake.

When

At least one full year of assessment of upstream habitats at flows low enough to characterize river bed materials is required to support a decision regarding provision of adult Chinook passage past natural obstructions. Each of the natural obstructions identified above has salmon spawning immediately below it, largely removing requirements for detailed and lengthy water quality/quantity studies.

Detailed geotechnical investigations of all sites where channels could be modified and/or fishways or related structures erected would be required at a range of flows. These geotechnical investigations may take one or more years to be satisfactorily completed.

Site investigations would need to be carried out to estimate the capital cost of the asset (and associated infrastructure) and the operating and maintenance requirements. If a decision is made to proceed, hatchery produced fry, native fry captured in the river downstream, or adult salmon could be released above the obstruction prior to or during construction to start the process of attempting to build the stock in the previously in-accessible habitat.

Monitoring of upstream migrants would be required during at least the first few years that the structure was completed to evaluate the degree to which the structure is successful in meeting its objective. Modifications would be required if it did not. Annual inspections would then be necessary to ensure that the channel or fishway remained open and did not impede passage during upstream migrations.

Capture and release of adults or juveniles could be conducted as soon as a decision to proceed was made and regulatory issues resolved. These regulatory issues would include licenses and authorizations from regulatory agencies, and assessment by the Yukon Environmental and Socio-economic Assessment Board (YESAB).

Why

- This action would be taken to increase accessible spawning and rearing habitat to increase spawning success and egg-to-fry survival (via increased access to high quality spawning habitat) and juvenile growth and survival (via reduced influence of density dependent effects on growth and survival). This assumes that spawning and rearing habitat are limiting the population under consideration. The extent to which this assumption is true is poorly understood, but there is some evidence of density-dependent growth in rearing habitat downstream of natural obstructions in the Squanga Creek (i.e., high abundances of smaller than average fry at the end of the growing season). Spawning and rearing habitat above these natural barriers appear to be of high quality, but further study is required to confirm this.
- Justification for modification of Fraser Falls is based on the observation that Chinook salmon experience difficulty swimming over the falls at low water levels and so if the falls were modified the condition of spawners may be improved and pre-spawn mortality may be reduced.

Pros & Cons

Pros

- Construction of fishways (including blasting graded channels through bedrock) is an accepted method of increasing salmon production and is, in general, within the scientific/technical community's comfort zone.
- Capture below and release of adults and/or juvenile Chinook upstream of obstructions could be a relatively inexpensive means of increasing available rearing and overwintering habitat and reducing competition among juvenile Chinook in habitat downstream of natural obstructions.
- Enabling natural access to habitat for spawning and rearing would ensure spawning and fry development occurs naturally and therefore that there will be limited to no unintended effects on the time of return to spawn or the size of returning adults.

Cons

- The design and construction of fishways is expensive, particularly if infrastructure such as roads is required. As a result it is likely that the cost of any fish-way would exceed the total value of the Yukon River Panel R & E Fund (~ $1 million USD per year), perhaps by many times.
- Fishways require monitoring, maintenance and periodic renewal.
- Fishways may negatively affect the bio-diversity and local adaptation of organisms residing in upstream waters isolated for thousands of years by allowing individuals of non-salmon species upstream access to areas where they could reproduce with locally adapted individuals from above the obstruction.
- Allowing access through fishways or release of adult or juvenile salmon above obstructions risks introducing of pathogens to upstream waters and to non-Chinook stocks that evolved in their absence.
- The Squanga Creek stock is very small and could not support a capture and release program. Adult Chinook could be captured in the Teslin River, but these adults would spawn with Chinook native to

the creek, potentially leading to a loss or erosion of unique local adaptation by the Squanga Creek stock.

- Evaluation of projects that enable migration and rearing upstream of barriers (e.g., fry enumeration and adult returns) is very challenging because some fry will leave the system to rear elsewhere and the origin of returning adults is logistically difficult to determine (e.g., due to stream flows during spawning).
- The community of Mayo and the First Nation of the Na-Cho Nyak Dun have rejected any modification to Fraser Falls due to its importance (e.g. cultural/spiritual value).

Critical Uncertainties

- The primary uncertainty regarding the effectiveness of this action is the degree to which the fresh water life stages of Yukon River Chinook salmon are currently limited and so the degree to which increased habitat for juveniles would lead to eventual increased return of adults. If this is believed to be true, or evidence is provided to support it, then the apparent quantity and quality of spawning and rearing habitat above the obstructions requires assessment.
- The quality and quantity of habitat in currently inaccessible habitat.
- It is uncertain whether adults returned to the river upstream of obstructions would remain there or would move back downstream to spawn.
- The YESAB application and review process is at present open-ended and may result in considerable expense and uncertain outcomes.
- Uncertainty in those factors outside of freshwater habitats in the Yukon River that may be limiting Chinook survival means that the success of this action is also uncertain.

Supporting Actions

- Limiting conditions for both eggs and fry are likely to occur under ice in the winter and the quality and quantity of habitat in areas upstream of the barrier should be confirmed through field investigations in February or March.
- The extent to which adults spawn in areas upstream of the barrier after passage has been granted could be monitored by passive integrated transponder (PIT) tagging all relocated adults and placing a tag reader at the obstruction.

5.8 Removal of larger anthropogenic barriers to upstream migration

What

The removal of existing man-made barriers to upstream migration by adult Chinook salmon through fishways or the provision of access over the man-made barriers. Provision of access could include trapping of adults downstream and release upstream of a barrier or the out-planting of artificially propagated juveniles upstream of a barrier.

Where

The only man-made obstruction that currently impedes upstream migration of adult Chinook in the Canadian portion of the Yukon River is the Wareham Dam on the Mayo River. The only other dam is in Whitehorse at the Whitehorse Rapids, where a fishway is in use to facilitate upstream migration.

When

- At least one full year of assessment of upstream habitats at flows low enough to characterize river bed materials is required to support a decision regarding provision of adult Chinook passage past anthropogenic obstructions. This is to assess suitability of spawning and rearing habitat which could have changed due to natural or anthropogenic (e.g., mining) processes since originally accessible.
- Detailed geotechnical investigations of all sites where fishways or related structures could be erected would be required at a range of flows. These geotechnical investigations may take one or more years to be satisfactorily completed.
- Site investigations would need to be carried out to estimate the capital cost of the asset (and associated infrastructure) and the operating and maintenance requirements. If a decision is made to proceed, hatchery produced fry, native fry captured in the river downstream, or adult salmon could be released above the obstruction prior to or during construction to start the process of attempting to build the stock in the previously inaccessible habitat.
- Capture and release of adults or juveniles could be conducted as soon as a decision to proceed was made and regulatory issues resolved. These regulatory issues would include licenses and authorizations from regulatory agencies, and assessment by the YESAB.

Why

- The upper Mayo River historically supported a significant Chinook population and the construction of the Wareham dam obstructed 38 km of historic Chinook habitat.
- This action would be taken to increase accessible spawning and rearing habitat to increase spawning success and egg-to-fry survival (via increased access to high quality spawning habitat) and juvenile growth and survival (via reduced influence of density dependent effects on growth and survival).

This assumes that spawning and rearing habitat in the Lower Mayo River are currently limiting the Mayo River Chinook population.

Pros and Cons

Pros

- Construction of fishways, trap and haul of adults and/or modifications to hydro facilities to support outmigration are accepted methods of increasing salmon production in areas that have been made in-accessible to salmon. As a result such actions are typically within the comfort zone of the scientific/technical community and there is a wealth of experience with such actions for Chinook in the Pacific Northwest.
- There has already been some work done surveying habitat in the Upper Mayo River and assessing the feasibility of a trap and haul system at the Wareham dam.
- There is strong support for the reintroduction of Chinook into the Upper Mayo River from the Mayo community and the First Nation of the Na-Cho Nyak Dun.
- The re-establishment of access to previously accessible upstream habitat is an action that provides a relatively quick biological response that will likely last for decades with a high probability of success.

Cons

- The design and construction of fishways is expensive, particularly if infrastructure such as roads is required. As a result it is likely that the cost of any fish-way would exceed, for example, the total value of the YRP R&E Fund (~ $1 million USD per year), perhaps by many times.
- Ongoing industrial activities (e.g., placer mining) in the upper Mayo River has the potential to compromise the success of actions taken to re-grant access to spawning and rearing habitat.

Critical Uncertainties

- The primary uncertainty is the degree to which fresh water life stages of Mayo River Chinook salmon are currently limited and so the degree to which increased access to spawning and rearing habitat in the upper Mayo River would lead to eventual increased returns of adults.
- It is uncertain whether adults returned to the river upstream of obstructions would remain there or would attempt to move back downstream to spawn.
- The YESAB application and review process is at present open-ended and may result in considerable expense and uncertain outcomes.
- Uncertainty in those factors outside of freshwater habitats in the Yukon River that may be limiting Chinook survival means that the success of this action is also uncertain.

Supporting Actions

- All juveniles produced upstream of the Wareham dam must leave the system through the turbines or over the spillway and the magnitude of potential mortality associated with this downstream migration is currently unknown. A significant body of knowledge has been developed on upstream and downstream passage past dams in the Pacific Northwest and this knowledge and experience could be drawn upon during the design and assessment of alternative approaches to restoring access to upstream spawning and rearing habitat.
- Limiting conditions for both eggs and fry are likely to occur under ice in the winter and the quality and quantity of habitat upstream of the barrier should be confirmed through field studies in February or March.
- The extent to which adults spawn in areas upstream of the barrier after passage has been granted could be monitored by PIT tagging all relocated adults and placing a tag reader at the obstruction.
- Monitoring of upstream migrants would be required each year to evaluate the degree to which the structure is successful in meeting its objective. Modifications would be required if it did not. Annual inspections would be necessary to ensure that the channel or fishway was open. The integrity of the structure would have to be assessed, with the period between assessments depending on the performance of the structure.

6 Preliminary evaluation of alternative restoration actions

6.1 Evaluation framework

From the inventory of restoration actions (Appendix B) 13 stock restoration actions (or groups of actions) were identified in specific locations within the Canadian portion of the Yukon River that warranted further consideration (Table 2). A simple framework was developed to qualitatively evaluate the ability of alternative restoration actions to meet the goal of the YSSC SSRI which is to “promote recovery of Yukon Chinook to maintain and re-establish cultural connections to salmon through the restoration of freshwater habitat and productivity in a manner that is consistent with community values and involvement”.

First the overarching goal was divided into three objectives to provide a concise statement about how to meet the goal. Objectives are typically directional (e.g., increase X or decrease Y), and specific performance measures (PMs) can be used to evaluate and report how well an action contributes to meet the objective. For each objective PMs were identified that could be qualitatively evaluated. Each objective, it’s associated PMs, and their evaluation criteria are detailed below and summarized in Table 1.

The framework that was developed is intended to be a transparent and logical process for organizing the alternative restoration actions that have been identified within the Yukon. It is necessarily high level *and* qualitative given the limited information that exists on Chinook populations in the Yukon and the scope of this project. The evaluation is relative and based on current understanding. It is important to note that the relative performance of alternative actions is likely to change over time as more information becomes available. This is also the reason the evaluations were not integrated across PMs into a single rank-order of actions. Instead, this framework is best treated as a simple organizing process that can be updated and revised to help guide and support the identification of priority actions for the YSSC to support.

Table 1: Summary of classification scheme used to evaluate the ability of alternative restoration actions to meet the objectives of the YSSC SSRI. Each objective is broken down into individual performance measures (rows) that are the criteria used to classify actions. A brief description of the attributes of restoration actions that would result in a score of "high", "medium" or "low" is provided for each performance measure (columns). See text for further description of classification process and criteria.

Objective	Performance Measure (PM)	Classification		
		Low	Medium	High
1	PM-1: Biological response	Habitat and population enhancement (incl. artificial propagation)	Restore watershed processes	Maintain access, or remove barriers, to (highest quality) habitat
	PM-2: Population status	Low degree of conservation concern and need for management intervention	Moderate degree of conservation concern and need for management intervention	High degree of conservation concern and need for management intervention (incl. extirpated populations)
2	PM-3: Cultural connection	Low likelihood of increasing cultural connection to Chinook salmon via harvest opportunities	Moderate likelihood of increasing cultural connection to Chinook salmon via harvest opportunities	High likelihood of increasing cultural connection to Chinook salmon via harvest opportunities
3	PM-4: Community capacity	Insufficient staff, equipment and / or training to support restoration action	Some staff, equipment and/or training to support restoration action but need for more	Adequate staff, equipment and training to support restoration action
	PM-5: Community support	No support in community for the restoration action	Some degree of support in community for the restoration action	High degree of support in community for the restoration action
	PM-6: Funding	Low likelihood of funding available to support restoration action	Moderate likelihood of funding available to support restoration action	High likelihood of funding available to support restoration action

Objective 1: increase likelihood of recovery of Yukon Chinook populations

PM 1: Biological response. This PM is related to the predicted response of the Chinook population(s) that the action is targeted towards. Due to a general lack of empirical data on Chinook populations and their habitats within the Canadian portion of the Yukon River, actions were classified against this PM using an adapted version of a "hierarchical approach" to prioritize restoration actions (Roni et al. 2002, 2003). This approach follows a logical sequencing of restoration project types based on their predicted probability of success, response time and longevity (Beechie et al. 2008). Doing so results in a hierarchy of actions, which, from highest to lowest, are:

1. maintain access to (highest quality) intact habitat
2. removal of barriers to intact habitat
3. restore watershed processes
4. habitat and population enhancement (including artificial propagation)

The hierarchy begins with protection of and continued access to high-quality habitats, because it is easier and more effective to maintain high-quality habitats than restore degraded ones. Following the protection of intact habitat is restoring access to previously isolated off-channel or blocked tributary spawning and rearing habitat, which provides a relatively quick biological response, and has a high likelihood of success (Pess et al. 2005). Assuming ongoing maintenance occurs, reconnection of habitats that have been fragmented due to direct human actions (i.e., culverts that limit upstream fish migration) should last for the active life of the structures involved. The third set of actions focuses on restoring watershed processes that create and sustain riverine habitat, including streamflow, water quality, sediment inputs and riparian functions. The last actions in the hierarchy include habitat enhancement such as wood and boulder placement in streams as well as actions related to artificial propagation.

The hierarchy implicitly assumes that actions should be prioritized in part based on the extent of human involvement. Actions requiring more human intervention are deemed of lower priority and should thus only be considered after, or in combination with, other efforts to restore watershed processes or when short-term increases in fish production are necessary to prevent the extirpation of a Chinook population. The hierarchy also implicitly considers the inherent genetic and ecological risks posed to populations by the actions and so places less importance on artificial breeding and translocation.

PM 2: Population status. This PM is related to the conservation status of the Chinook population(s) that would be affected by a given action. Populations classified as being of high conservation concern are presumed to be a higher priority for direct restoration actions to than those that are not. As with PM 1, in the absence of quantitative information on the status of individual Chinook spawning populations in the Yukon (or precisely what appropriate population units are), actions were classified based on the assumed relative degree of conservation concern and need for management actions. Populations classified as being of “high” conservation concern would exist at very depressed abundance resulting in no opportunity for use by communities and which may be at high risk of extirpation or have already been extirpated. Populations of “medium” conservation concern would exist at moderate abundance resulting in restricted use by communities. Populations of “low” conservation concern include those not known to be of current conservation concern, that have no restrictions on community use, and show no indication that management intervention is needed.

The distribution of Chinook spawning populations within watersheds naturally expands and contracts with changes in overall population size, whether due to natural or anthropogenic causes (Isaak and Thurlow 2006). Given the recent period of depressed productivity across Chinook populations in the Yukon and western Alaska, it would be expected that some spawning areas within specific streams and rivers used during past periods of high productivity would not be occupied in recent years. This could create the impression that a spawning population is at risk of extirpation when it is instead experiencing a temporary spatial contraction in response to environmental variation. Alternatively, the loss of spawners could also be the consequence of decades of commercial exploitation at unsustainable rates. Without a detailed understanding of population structure (e.g., molecular evidence of reproductive isolation) it is difficult to resolve which of these factors is driving the absence of a spawning population from historically known locations. In the absence of a known mechanism, it was assumed that spatial contraction is responsible for the loss of spawners such that a population would be classified as being of “low” to “medium” conservation concern for this PM.

Objective 2: maintain/re-establish cultural connections to salmon

PM 3: Cultural connection. The cultural importance of Chinook salmon to communities in the Yukon cannot be overstated. This PM is related to the potential for a given action to support the retention or re-establishment of the communities’ cultural connection to salmon. In the Yukon, this cultural connection is driven largely through First Nation fish camps and broader harvest opportunities. Actions were therefore classified based on the likelihood they would maintain or help re-establish opportunities for Chinook harvest within the community in which the action occurs. For example, an action that increases production of juveniles and subsequent availability of returning adults in a specific location amenable to harvest would be classified as “high”. However, an action that improves access to spawning and rearing habitat but not necessary increased opportunity for harvest within a community would receive a lower classification.

Objective 3: ensure action is consistent with community values, involvement and capacity

PM 4: Community capacity. This performance measure is related to the current and / or perceived potential capacity to design, implement, monitor and evaluate the action within the community undertaking it. Actions were classified based on a qualitative assessment of the existing human, physical (e.g., equipment) and technical resources available to support the action under consideration and the perceived potential to sustain it. For example an action by a First Nation which has the staff and equipment necessary to implement the action and has already engaged technical support as needed from outside sources would be classified as "high" while one with no known supporting resources would be classified as "low".

PM 5: Community support. The support of the community in which an action takes place is a critical element to identifying and implementing community-led restoration actions. This performance measure is related to the degree of support for a given action, or type of action, within the community in which it would occur. For example, there was a strong sentiment in communities that they would prefer to not "mess with nature". However, they were open to more invasive actions in situations in which they were satisfied that those actions were required. Based on these sentiments, actions were qualitatively classified based on the understanding of how in-line they are with community values. In some cases the community has explicitly stated their support for or position against a given action while in others the classification is based on a more general assessment of community support.

PM 6: Funding. The final performance measure is related to the likelihood of sufficient funding available to support a given action. Funding is an important filter of potential actions. Even actions with a high likelihood of promoting recovery will be impossible to implement without adequate resources to support their life cycle of design, implementation, monitoring and evaluation. Therefore each action was qualitatively classified based on the likelihood of there being adequate funding available to support the action. This classification implicitly considers the overall cost and duration of the action in addition to the potential for there to be sufficient funding to support it. For example, an action that requires a modest amount of financial resources but that has no known prospect of securing funding was classified as "low" while a costly action that does have funding in place was classified as "high".

6.2 Preliminary classification of Yukon stock restoration actions

Applying the framework described in Section 6 allowed the Technical Team to qualitatively evaluate the ability of alternative restoration actions to meet the goal of the YSSC SSRI (Table 2). While it is tempting to then prioritize the actions based on their classifications for a subset of the PMs (e.g., biological response) this is not advisable at this point in time. Instead, the classification framework and resulting scores should be used to guide year two of the initiative and inform ongoing discussions within and among the YSSC, communities, and DFO around tradeoffs among actions and the relative importance of each criteria used to evaluate them. The framework can be revised and refined as the initiative proceeds and more information becomes available. The preliminary results of the classification framework by objective are briefly summarized below.

Actions to maintain access to high quality spawning habitat (e.g., beaver dam management) for populations of high presumed conservation concern were classified as more likely to contribute to population recovery relative to hatchery efforts (e.g., hatchery incubation and fry out-planting) in populations of lower conservation concern. Examples of actions that received the highest relative classifications for biological response and population status included obstruction management in the Pelly, Teslin, and Yukon mid-mainstem watersheds as well as the removal of barriers to upstream migration in the Upper Mayo River (Table 2).

Some of the actions evaluated were considered to have a relatively high likelihood of maintaining or helping to re-establish opportunities for Chinook harvest within the community in which the action occurs. However, these opportunities are likely to be both modest in terms of increased opportunities for harvest and in terms of how quickly they can be implemented. Examples of actions that were classified relatively high for this performance measure include obstruction management in the Pelly, and Teslin watersheds, conservation hatchery efforts on the Klondike River, and the removal of barriers to upstream migration in the Upper Mayo River (Table 2). Actions considered to have a relatively low likelihood of maintaining or re-establishing opportunities for Chinook harvest within the community in which the action occurs included hatchery efforts in the M'Clintock River and Wolf and Michie creeks, obstruction management in Wolf Creek and instream incubation efforts to re-establish Chinook in Deadman Creek.

Restoration actions that were classified relatively high in regards to being consistent with community values, involvement and capacity included obstruction management and hatchery efforts to re-establish Chinook to Fox Creek, obstruction management in the Teslin River and Yukon River mid-mainstem watersheds, and conservation hatchery efforts on the Klondike River (Table 2). In contrast, actions that were classified as relatively low in the same regard included hatchery efforts on the Mayo River and enhancing upstream passage at Fraser Falls in the Stewart River watershed (Table 2).

Table 2: Yukon Chinook restoration actions and classification by performance measure. For classification scheme details, see Table 1 and Section 6.1.

Action[1]	Watershed / Chinook Population(s)	Type of Action	Description of Action	PM-1: Biological response	PM-2: Population status	PM-3: Cultural connection	PM-4: Community capacity	PM-5: Community support	PM-6: Funding
1	Yukon River, North Main-Stem: Klondike River Sub-Watershed		**Conservation hatchery and training institute on Klondike River**. From the 1990s to mid-2000s, the Yukon River Commercial Fishers Association and Tr'ondëk Hwëch'in partnered together on R&E projects on the North and South Klondike. From 1992 to 1995 tagged juveniles were released to the Klondike River. In 2009 the Tr'ondëk Hwëch'in conducted a hatchery feasibility study and in 2015 began seeking funds to support planning for a conservation hatchery training institute.	Low	Low	High	Medium	High	Medium
4	Stewart River Watershed: Mayo River		**Conservation hatchery on Mayo River.** A hatchery was previously built at what is now the Wareham Lake Power Generating Station. The hatchery was then abandoned, however, in recent years there has been interest in re-establishing a hatchery to support Chinook production in the Lower Mayo River. There is also the possibly of running the hatchery in support of a re-introduction program above the dam in the Upper Mayo River (cross-reference action #33).	Low	Low-Medium	Medium	Low	Medium	Low
6	Stewart River Watershed: Fraser Falls		**Barrier removal at Fraser falls.** When flows are below a certain level there is a partial barrier to upstream migration at Fraser falls. Enhancing passage through construction or excavation of a fishway has been a topic of discussion for decades. In 2010, the community was consulted and the majority rejected any modification to the falls.	Medium	Low	Medium	Low	Low	Low

Action[1]	Watershed / Chinook Population(s)	Type of Action	Description of Action	PM-1: Biological response	PM-2: Population status	PM-3: Cultural connection	PM-4: Community capacity	PM-5: Community support	PM-6: Funding
7	Yukon River Mid Main-Stem Watershed: LSCFN Traditional Territory		**Obstruction management in Yukon River Mainstem watershed**. In the early 2000s Little Salmon Carmacks First Nation conducted a Beaver Management Workshop and determined which creeks should be managed for the benefit of salmon within their territory, including Tatchun and Klusha Creeks and the Nordenskiold River. Annual monitoring coupled with active beaver obstruction management including breaching dams occurred through mid-2000s but has since ceased. Klusha Creek periodically dried up and the Chinook spawning population in the Creek is considered extirpated. There is interest in re-establishing a beaver management program in the watershed.	High	Low-Medium	Medium - High	Medium	High	Medium
12	Pelly River Watershed: watershed level		**Obstruction management in Pelly River watershed**. In the early 2000s Selkirk First Nation conducted a Beaver Management Workshop and determined which areas should be managed to maintain access for adult Chinook. Mica Creek below Towhead Lake, Willow and Needle Rock creeks were identified following the assessment and annual monitoring coupled with active beaver obstruction management including breaching dams occurred through mid-2000s but has since ceased. These creeks remain sensitive to obstructions and low flows and there is interest in re-establishing a beaver management program in the watershed.	High	Low - Medium	High	Medium	High	Medium
15	Teslin River Watershed: watershed level		**Obstruction management in Teslin River watershed**. In the early 2000s the Teslin Tlingit Council conducted an assessment of priority areas within the watershed to focus on managing obstructions for spawning Chinook. Priorities included Deadman Creek and the Swift River (North) which became the focus of active beaver dam management during the first half of the 2000s. These and other creeks in the area remain sensitive to obstructions and low flows and there is interest in re-establishing a beaver management program in the watershed. Deadman Creek no longer supports a spawning population and there is interest in re-establishing one in the creek (cross-reference action # 17)	High	Low - Medium	High	Medium	High	Medium

Action[1]	Watershed / Chinook Population(s)	Type of Action	Description of Action	PM-1: Biological response	PM-2: Population status	PM-3: Cultural connection	PM-4: Community capacity	PM-5: Community support	PM-6: Funding
17	Teslin River Watershed: Deadman Creek		**Re-establishment of Chinook spawning population in Deadman Creek.** Chinook historically spawned in Deadman Creek but have not been observed there for decades. It is not clear what factors led to the extirpation of a spawning population in the creek. The Teslin Tlingit Council identified Deadman Creek as a priority area to focus efforts on re-establishment of spawning populations. In 2015, the Teslin Tlingit Council began seeking funding to support a pilot project to evaluate alternative stream incubation approaches as a potential tool to re-establish Chinook in Deadman Creek.	Low	Medium	Low	Medium	High	Medium
18	Yukon River South Main-Stem Watershed: Fox Creek	 	**Re-establishment of Chinook spawning population in Fox Creek.** Fox Creek historically supported a spawning population of Chinook that became extirpated over 30 years ago. It is believed that extensive beaver activity on the creek may have contributed to the extirpation of the spawning population. The Ta'an Kwäch'än Council conducted assessments of the creek in the late 1990s and early 2000s and then began a re-introduction program in 2006 which included the release of hatchery reared fry broodstock from Whitehorse Rapids fishway) into the Creek each summer. In 2013 and 2014, naturally spawning Chinook were observed within the creek. 2015 marked the end of Phase I of the re-introduction program and the Ta'an Kwäch'än Council is currently seeking support for Phase II, which includes adult enumeration, ongoing fry releases, obstruction management and development of a plan to phase out hatchery intervention.	Medium	Medium	Low-Medium	High	High	Medium
24	Yukon River South Main-stem Watershed: Wolf Creek		**Enhancement of Chinook spawning population in Wolf Creek.** From the mid-1980s to present, fry from broodstock collected at the Whitehorse Rapids fishway have been released in relatively low numbers (particularly in recent years) in an effort to restore a Chinook population in the creek. Historic spawning population in Wolf Creek is poorly documented.	Low	Low	Low	High	High	High

Action[1]	Watershed / Chinook Population(s)	Type of Action	Description of Action	PM-1: Biological response	PM-2: Population status	PM-3: Cultural connection	PM-4: Community capacity	PM-5: Community support	PM-6: Funding
25	Yukon River South Main-stem Watershed: Wolf Creek		**Obstruction management in Wolf Creek**. Beaver dam obstruction monitoring and, as required, management has been periodically conducted by Whitehorse Rapids Fishway Staff, the Yukon Fish and Game Association, and local residents to ensure adults can ascend the creek. Adult Chinook were unable to migrate upstream past a sheet pile wall below the Alaska Highway Crossing during low flows and so in 1986 a weir-and-pool fishway was constructed but failed relatively quickly. In 1998 an off-channel concrete fishway was constructed to facilitate passage but it requires significant annual maintenance to operate effectively.	High	Low	Low	High	High	High
29	Yukon River South Main-stem Watershed: M'Clintock River and Michie Creek		**Enhancement of Chinook spawning population in M'Clintock River and Michie Creek.** From the mid-1980s to present fry from broodstock collected at Whitehorse Rapids Fishway have been released in Michie Creek as well as other sites (e.g., Yukon River main stem and M'Clintock River when large numbers of fry are available.	Low	Low	Low	High	High	High
31	Yukon River South Main-stem Watershed: M'Clintock River		**Obstruction management in Michie Creek**. Beaver dam obstruction monitoring and, as required, management was first conducted in 1999 and has occurred annually since 2001 led by the Kwanlin Dun First Nation.	High	Low	Medium	Medium	High	Medium-High
	Stewart River Watershed: Mayo River		**Provision of access to spawning and rearing habitat in Upper Mayo River.** The Wareham Lake Power Generating Station has impeded access to 38 km of habitat in the Upper Mayo River since ~1954. In addition to hatchery efforts to mitigate lost production from the upper river (cross reference Action #4) there has been interest in exploring options for re-introducing Chinook into the upper river via a fishway or trap-and-haul activities and evaluating alternatives for ensuring safe migration of smolts past the Wareham Dam.	High	High	Medium-High	Low	Medium	Low

[1]Action numbers correspond to complete inventory of restoration actions in Appendix C.

7 Conclusions

The preliminary evaluation of alternative restoration actions in Section 6.2 should be used as a blueprint to guide ongoing discussions among the YSSC, Yukon First Nations, Renewable Resources Councils, communities and DFO to identify priority opportunities to focus the efforts of the Initiative in year two. These activities should focus on restoration actions that strike a balance between increasing the likelihood of recovery of targeted Chinook populations, re-establishing cultural connections to salmon, and ensuring actions are consistent with community values and involvement with adequate resources to support them. For example, three restoration activities that appear to meet these criteria and which received some Technical Team support in year 1 include the Fox Creek stock restoration initiative led by the Ta'an Kwäch'än Council, the Deadman Creek re-introduction efforts led by the Teslin-Tlingit Council, and obstruction management in a number of watersheds and communities (see Appendix E). Year two should focus on continued identification of opportunities to support community-led stock restoration efforts and move from the planning stages to the implementation, monitoring and evaluation stages. However, it is important to recognize that progress made towards implementation, monitoring and evaluation will vary among First Nation communities will all be at different stages in the restoration process.

The learning and synthesis captured in this report should be made broadly available to the stakeholders that helped generate it. This could include follow-up meetings with each community, teleconference calls, presentations, and the dissemination of materials including this report and a companion summary document. Outreach and communication is crucial to ensure that the contributions of individual communities are recognized and that the insights are shared among communities. This will also help create a broader awareness of stock restoration efforts across the Canadian portion of the Yukon River and considerations of the ability of different types of actions to meet the community stocks restoration goals and objectives. Stock restoration is a long-term process and ensuring that the process is community-driven is essential to its success.

The YSSC SSRI recognizes the potential, and ongoing, role of hatcheries in supporting stock restoration efforts in the Yukon. Both the Whitehorse Rapids Hatchery and McIntyre Creek incubation facility support fry out-planting (e.g., Fox and Wolf creeks) and assessment (e.g., CWT) efforts. DFO conducted a hatchery augmentation feasibility assessment project in 2015 in order to identify possible hatchery facility options that could provide capacity to rear Canadian-origin Chinook salmon fry beyond levels that existing facilities currently accommodate. It is recommended that the insights from this effort and those from year 1 of the YSSC SSRI be shared and incorporated into ongoing hatchery planning and management moving forward.

Lastly, it is recommended that as individual restoration actions move from “planning” to “doing” that careful consideration be paid to the design, implementation, monitoring and assessment of the actions. A helpful way to think about restoration planning, implementation and evaluation is to consider it through the lens of Adaptive Management. This is a systematic, rigorous approach to environmental management that maximizes learning about key uncertainties and adapting management actions based on what is learned. Adaptive Management involves synthesizing existing knowledge, exploring alternative actions, making explicit predictions of their outcomes, selecting one or more actions to implement, conducting monitoring and research to learn if the actual outcomes match those predicted, and then using results to learn and adjust future management (Walters 1986; Walters and Holling 1990; Murray et al. 2015). This sequence can be characterized as a six-stage process (Figure 6). Considering stock restoration activities through this Adaptive Management lens will help ensure individual projects are well designed, carried out in a way that enables a rigorous evaluation of the ability of the action to achieve its intended result, and allow for the adjustment of the restoration action based on learning.

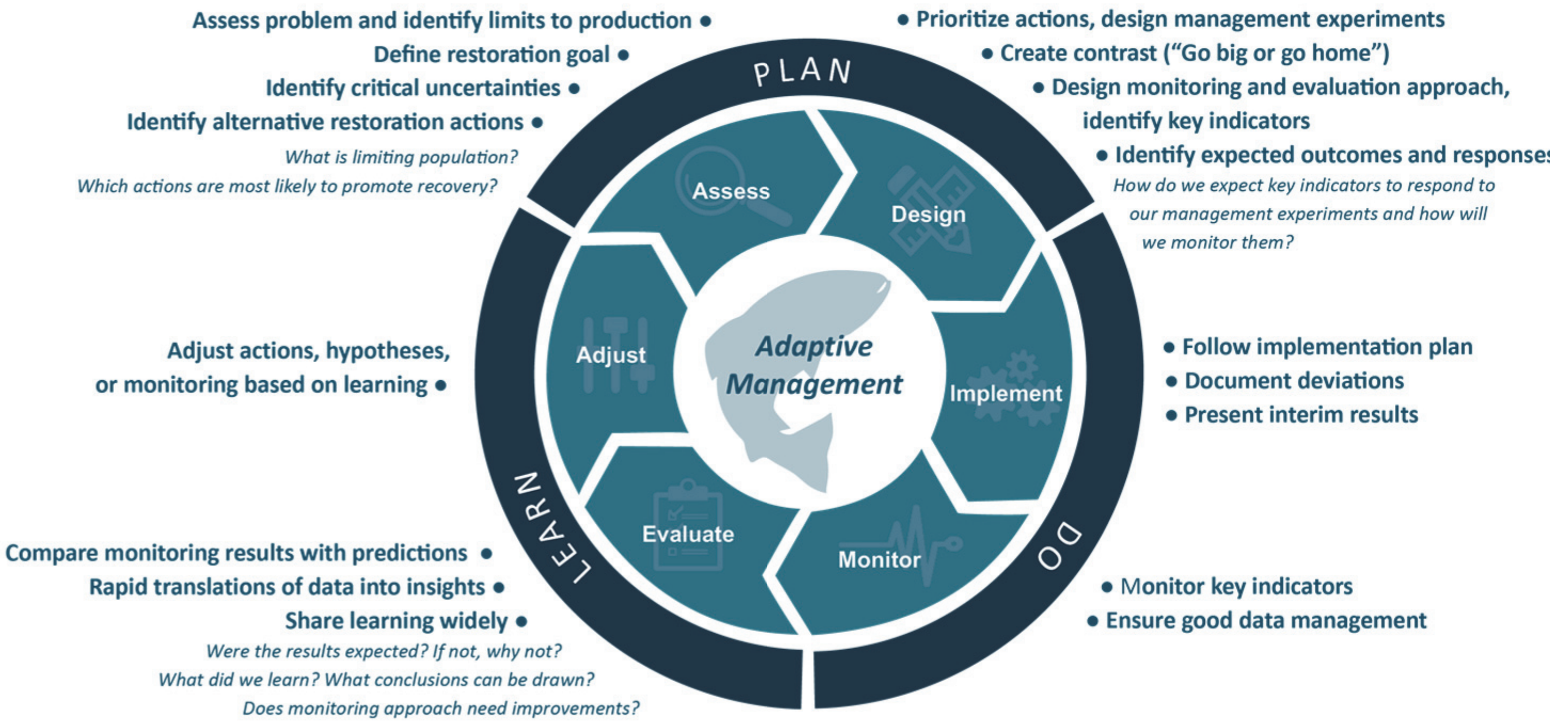


Figure 6: The six stages of the Adaptive Management cycle adapted for stock restoration activities. The bolded texts are actions associated with each stage, the italicized texts are examples of questions associated with each action

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Appendix A: Limiting factors tables

Yukon River North Main Stem

Table A1: Limiting factors table for Chinook from the North main stem of the Yukon River detailing current knowledge about the nature of potential limiting factors as well as their severity, extent, frequency and direction of change by life stage.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Egg deposition, incubation	Short-term climatic/hydrologic variation resulting in dewatering/freezing/reduction of flow through redds. Effects of sediment inputs from land instability and placer mining, sands/silts filling redds post egg deposition resulting in reduced egg-to-fry survival.	Locally variable, varying from catastrophic to no effects.	Climatic/hydrological effects will affect all spawning areas. Natural sediment inputs will affect all areas. Effects of placer mining on spawning is limited to the Klondike River, particularly downstream of Flat/All gold Creeks.	Climatic/meteorological effects are constant and unpredictable. These include, either directly or indirectly, high and low waters, sediment release and transfer, and variation around poorly defined trends. Sediment releases from placer mining will depend on the price of gold.	River flows appear to be more variable, and effects of low- and high water periods are expected to increase. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing. Releases of sediment from placer mining appear to be increasing due to new areas being mined. Overall, stress on this life stage is probably increasing.
Fry emergence	Short-term climatic/hydrologic variation in severity and timing of spring breakup, resulting in fry being exported from rivers or isolated in pools/back channels in flood plains.	Export of emergent fry has not been measured. Stranding is variable.	All spawning areas	Some degree of export and stranding expected in all years; high degree in early and violent ice off episodes	Export of and stranding of emergent fry are thought to be increasing.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Rearing	Short-term climatic/hydrologic variation resulting in reduced quantity of habitat in low water years and decreased quality of habitat (low water temperatures, limited food supply) in high water years. Displacement of fry from rearing areas at high flows. Effects of sediment inputs from land instability and placer mining results in sands/silts/clays filling streams and reducing available food organisms. Obstructions to upstream migration from beaver dams in non-glaciated portion of the watershed. NOTE that YR NMS provides rearing habitat to fry from most or all upstream Yukon River Chinook Salmon stocks.	Locally and temporally variable, from catastrophic to no effects. Low flows and warmer water temperatures are thought to have less severe effects than high flows and related low water temperatures on habitat quantity/quality. Effects of placer mining may be locally/temporally profound and are otherwise related to the concentration of sediment and duration of discharge. Obstruction of upstream migration may result in decreased growth at the end of the first summer of life.	Rearing habitat is widespread and includes spawning areas, migration routes and portions of all non-spawning tributaries. Climatic/hydrological effects will affect all rearing areas. Sediment inputs from natural/semi-natural landslides, active layer detachments following forest fires, and slope deflations will affect all rearing areas. Placer mining is widespread and effects of sediment inputs or stream bank/bed modification and stability are correspondingly widespread. Obstructions to upstream fry migration by beaver are generally limited to river floodplain areas (including low gradient tributaries crossing the floodplain, disrupted valley bottoms and non-glaciated areas. Note that fry produced in this watershed may rear in all downstream waters.	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be episodic and short duration. Sediment from placer mining tends to be constant and of longer duration, extending from months through years. Obstruction of fry migration to rearing habitats on flood plains is ongoing, but is uncommon in unglaciated areas.	Flows appear to be more variable, and effects to rearing fry are expected to increase. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing. Sediment releases from placer mining appear to be increasing as new areas are mined. Obstructions to upstream migration by beaver are flow dependent, and most severe during extended low flow periods.
Over-wintering	Short-term climatic/hydrologic variation results in decreased high quality ground water discharges into overwintering areas following low water summers. Climate change-related increased discharges of low quality ground water into over wintering habitats from melting permafrost decreases survival. Reduced quantity/quality of overwintering habitats resulting from natural- or placer mining associated fine sediment deposition on	Locally and temporally variable, from catastrophic to no effects. Kills of overwintering fry due to poor water quality have been recorded. Potential overwintering areas have been observed to be choked with sediment from upstream landslides and placer mining. Upstream migration to prime overwintering habitats has been obstructed by beaver dams. Removal of most or all fry from an isolated overwintering area by mink has been observed.	Overwintering habitat is limited in this Watershed. Much of the land surface was not glaciated. Precipitation and snowmelt drain quickly. Winter stream flows from unglaciated areas are very low in volume and tend to be anoxic and high in total dissolved solids. Short-term climatic/hydrological effects will affect most overwintering areas. Sediment from natural sources and placer mining tends to be greatest in the unglaciated areas and may have only a small effect on the overall amount of overwintering	Climatic/meteorological effects are constant and unpredictable. Climate change related low quality ground water discharges are ongoing. Sediment from natural sources tends to be of short duration and from placer mining to be of long duration, extending from years through decades. Beaver dams on ground water fed channels may persist for extended periods, obstructing multiple year classes of fry from	Flows appear to be more variable, and effects to overwintering fry are expected to increase. Climate change related discharges of low quality ground water into overwintering areas are expected to increase. Effects of sedimentation are expected to remain relatively constant. The beaver population is probably at the carrying capacity of their habitats and effects (on a Watershed basis) will remain constant, albeit effects will vary locally. There is insufficient

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	preferred cobble/rubble stream bottoms. Obstruction of access by fry to overwintering habitats by beaver dams. Increased risk of predation from mammalian predators when fry are concentrated in small overwintering areas. NOTE that YR NMS provides overwintering habitat to fry from most or all upstream Chinook Salmon stocks.		habitat. Beaver are numerous in flood plain areas, and dams on ground water fed channels may persist for extended periods, obstructing multiple year classes of fry from access to overwintering areas. Mink and otter are numerous along floodplains of larger rivers and pose a high risk to concentrations of juveniles.	access to overwintering. Frequency of predation is variable, and depends on population size of predators - may be affected by the price of furs/energy of trapper.	information to be able to determine changes in predation.
Smolting, estuarine residence	Changes in the timing of ice break up leading to mismatch between outmigration timing (which can be driven by timing of ice breakup) and prey availability during early marine life. Short-term climatic/hydrologic variation resulting in low spring water temperatures and delayed out-migration of overwintered yearlings.	Locally and temporally variable.	May affect all yearling salmon.	Though variable, the timing of ice break up has been getting earlier over time. Recent water temperature monitoring initiatives may provide insight to the frequency of cooler than normal springs.	All indications are that the timing of ice break up will continue to be earlier and earlier in the spring. Negative effects of lower water temperatures are probably declining due to climate change and trend to warmer, earlier springs.
Juvenile and sub-adult marine	Changing oceanographic conditions and increased abundance of other Pacific salmon species leading to reduced food in the ocean and increased competition (either directly or indirectly) for available resources.	Unknown, likely to be significant but temporally variable.	All salmon within the watershed.	Oceanographic influences are constant but their effects are unpredictable.	Unknown.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Freshwater entry, upstream migration	Short-term climatic/hydrologic variation resulting in low water/warm water conditions in the Yukon River in Alaska associated decreased fitness in returning adults and an increased risk of parasitism and disease.	Severity of decreased fitness or increases in parasitism can vary from no measurable effect to death. Severity may be less for YR NMS Watershed due to shorter adult migration routes and cool or cold spawning river temperatures.	All upstream migrating salmon in- or through this watershed.	The condition of adults is not monitored. Recent water temperature monitoring initiatives may provide insight to the frequency of low water/warm water years. Acquired knowledge and results of the present monitoring initiative may allow prediction to determine frequencies of warm water events over extended periods.	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability.
Spawning	Short-term climatic/hydrologic variation resulting in episodic extreme high flows during the spawning period and reduced stock productivity. Channel instability resulting in constantly changing spawning locations. Sediment from natural sources and placer mining degrading spawning habitats. Lack of fitness related to thermal stress or increase parasitism resulting in decreased spawning success.	Locally and temporally variable. There is a higher risk of catastrophic flows as none of the spawning rivers in this Watershed are lake buffered, and an entire year class may be lost in a single flood event. Constant changing of spawning locations may result in spawning in sub-optimal locations. Sections of spawning rivers may be sediment so heavily that no spawning occurs for years or decades. Decreased fitness or increases in parasitism may result in pre-spawn mortality, partial spawn, or reduced egg to fry survival.	All spawning rivers in this Watershed.	Frequency of flood events on mid-sized or larger watersheds could be determined from WSC hydrometric monitoring.	Flows appear to be more variable, and water temperatures are expected to also be more variable. Channel instability is not monitored but is expected to increase. Effects are expected to increase but there will be significantly inter-annual or longer variability.

Stewart River

Table A2: Limiting factors table for Chinook for the Stewart River watershed detailing current knowledge about the nature of potential limiting factors as well as their severity, extent, frequency and direction of change by life stage

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Egg deposition, incubation	Short-term climatic/hydrologic variation resulting in dewatering/freezing/reduction of flow through redds. Effects of sediment inputs from land instability and placer mining, sands/silts filling redds post egg deposition resulting in reduced egg-to-fry survival. Effects of water management of existing hydro electrical developments. Effects of past and present quartz mining.	Climatic/hydrologic and sediment effects are locally variable, varying from catastrophic to no effects and are most pronounced in spawning rivers with limited lake storage/buffering. Hydro effects may result in some redds being lost. Release of metals and process chemicals from quartz mining and milling may result in lethal or chronic effects to eggs or alevins.	Climatic/hydrological effects will apply to all spawning areas. Natural sediment inputs will affect all areas. Placer mining sediments are limited to the Mayo River and the McQuesten River drainage, particularly the South McQuesten. Existing hydro is limited to Mayo River. Effects of quartz mining are concentrated in the South McQuesten drainage.	Climatic/meteorological effects are constant and unpredictable. These include, either directly or indirectly, high and low waters, sediment release and transfer, and variation around poorly defined trends. Sediment releases from placer mining will depend on the price of gold. Effects of hydro are annual and depend on water management.	River flows appear to be more variable, and effects of low- and high water periods are expected to increase. Episodic releases of sediment from deep seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing, with increased effects. Releases of sediment from placer mining appear to be stable but subject to the price of gold. Effects of the Mayo hydro has increased over the last two decades. Effects of quartz mining have declined over the last 30 years. Overall, stress on this life stage is probably increasing.
Fry emergence	Short term climatic/hydrologic variation in severity and timing of spring breakup, resulting in fry being exported from rivers or isolated in pools/back channels in flood plains.	Export of emergent fry has not been measured. Stranding is variable.	All spawning areas	Some degree of export and stranding expected in all years; high degree in early and violent ice off episodes.	Export of and stranding of emergent fry are thought to be increasing.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Rearing	Short-term climatic/hydrologic variation resulting in reduced quantity of habitat in low water years, decreased quality of habitat (low water temperatures, limited food supply) in high water years. Displacement of fry from rearing areas at high flows. Effects of sediment inputs from land instability and placer mining results in sands/silts/clays filling streams and reducing available food organisms. Release of toxic materials from quartz mining development and operations. Obstruction of upstream migration in natal or non-natal streams by beaver- or hydro electrical dams. NOTE that each rearing stream or river provides rearing habitat to fry from most or all upstream Chinook Salmon stocks and that fry produced in this Watershed may rear in streams located outside of it. .	Locally and temporally variable, from catastrophic to no effects. Low flows and warmer water temperatures are generally thought to have less severe effects than high flows and related lower water temperatures on habitat quantity/quality. Effects of natural sedimentation and related channel responses or those caused by placer mining may be locally/temporally profound and otherwise are related to the concentration of sediment and duration of discharge. Releases of toxic materials from quartz mining development or operation limited to potential chronic effects. During dry years or multiples thereof beaver activity may result in Chinook fry being denied access to much or most high quality habitat, causing decreased growth and fitness following the first summer of life.	Rearing habitat is widespread and includes spawning areas, migration routes and portions of all non-spawning tributaries. Climatic/hydrological effects will apply to all rearing areas. Sediment inputs from natural/semi-natural landslides, active layer detachments following forest fires, and slope deflations will affect all rearing areas. Quartz mining development is widespread in the Watershed. Placer mining is widespread and effects of sediment inputs or stream bank/bed modification and stability are correspondingly widespread. Obstructions to upstream fry migration by beaver are widespread, and by hydro are presently limited to the Mayo River above the Wareham dam. Note that fry produced in this Watershed may rear in all downstream waters.	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be episodic and short duration. Sediment from placer mining tends to be constant and of longer duration, months through years. Obstruction of fry migration to upstream rearing habitats is most common during dry years and particularly during multi-year droughts. Effects of quartz mining development may persist for years and decades. Rearing takes place in so many streams of such different hydrological characteristics that only coarse resolution relationships with meteorological or hydrometric data can be derived. Effects of existing hydro are variable and on-going	Flows appear to be more variable, and effects to rearing fry are expected to increase as a result. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing. Sediment releases from placer mining depend on the price of gold. Effects of quartz mining development are probably stable or possibly declining due to new technology. Obstructions to upstream migration by beaver will trend with local stream flows and social acceptance of control. Effects of existing hydro increased after the Mayo project was joined to the Yukon Grid.
Over-wintering	Short-term climatic/hydrologic variation may result in decreased high quality ground water discharge into overwintering areas following low water summers. Climate change-related increased discharges of low quality ground water into over wintering habitats from melting permafrost decreases survival. Reduced quantity/quality of overwintering	Locally and temporally variable, from catastrophic to no effects. Kills of overwintering juveniles may occur due to poor water quality or insufficient quantity. Potential overwintering areas may be choked with sediment from upstream landslides and placer mining. Upstream migration to prime overwintering habitats may be obstructed by beaver dams. Releases of toxic materials from	Overwintering habitat is considered widespread. Short-term climatic/hydrological effects will apply to most overwintering areas. Sediment from natural sources will periodically reduce the capacity of most overwintering areas, while placer mined creeks will have reduced capacity to overwinter fry. Quartz mining development is widespread in the Watershed. Beaver are numerous and dams on	Climatic/meteorological effects are constant and unpredictable. Climate change related low quality ground water discharges are ongoing. Sediment from natural sources tends to be of short duration and from placer mining tends to be of long duration, extending from years through decades. Effects of quartz mining development	Flows appear to be more variable, and effects to overwintering fry are expected to increase. Climate change related discharges of low quality ground water into overwintering areas are expected to increase. Effects of sedimentation are expected to remain relatively constant. Effects of quartz mining development are probably stable or possibly increasing as older workings thaw

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	habitats resulting from natural- or placer mining associated fine sediment deposition on preferred cobble/rubble stream bottoms. Release of toxic materials from quartz mining development and operations. Obstruction of access by fry to overwintering habitats by beaver dams. Increased risk of predation from mammalian predators when fry are concentrated in small overwintering areas. NOTE that each rearing stream or river provides overwintering habitat to fry from most or all upstream Chinook Salmon stocks, and that fry produced in this Watershed may overwinter outside of it.	quartz mining development or operation are generally related to chronic effects. Concentration of overwintering fry in small areas may result in high mortality from predatory mammals.	ground water fed channels may persist for extended periods, obstructing multiple year classes of fry from access to overwintering areas. Mink and otter pose a high risk to concentrations of juveniles.	may persist for years and decades. Beaver dams on low gradient or ground water fed channels may persist for extended periods, obstructing multiple year classes of fry from access to overwintering. Dams on higher gradient streams most frequent during low water years or droughts. Frequency of predation variable, and depends on population size of predators - may be affected by the price of furs/energy of trapper.	and release heavily contaminated waters. The beaver population is probably at the carrying capacity of their habitats and effects (on a Watershed basis) will remain constant, albeit effects will vary locally. There is insufficient information to be able to determine changes in predation.
Smolting, estuarine residence	Changes in the timing of ice break up leading to mismatch between outmigration timing (which can be driven by timing of ice breakup) and prey availability during early marine life. Short-term climatic/hydrologic variation resulting in low spring water temperatures and delayed out-migration of overwintered yearlings.	Locally and temporally variable.	May affect all yearling salmon.	Though variable, the timing of ice break up has been getting earlier over time. Recent water temperature monitoring initiatives may provide insight to the frequency of cooler than normal springs.	All indications are that the timing of ice break up will continue to be earlier and earlier in the spring. Negative effects of lower water temperatures are probably declining due to climate change and trend to warmer, earlier springs.
Juvenile and sub-adult marine	Changing oceanographic conditions and increased abundance of other Pacific salmon species leading to reduced food in the ocean and increased competition (either	Unknown, likely to be significant but temporally variable.	All salmon within the watershed.	Oceanographic influences are constant but their effects are unpredictable.	Unknown.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	directly or indirectly) for available resources.				
Freshwater entry, upstream migration	Short term climatic/hydrologic variation resulting in low water/warm water conditions in the Yukon River below the mouth of the Stewart , associated decreased fitness in returning adults and an increased risk of parasitism and disease. Fraser Falls may be a partial obstruction during low water/warm water years. Migration into and up smaller, lake dominated streams may be obstructed by beaver during low water years or droughts. Upstream migration in the Mayo River is obstructed by the Wareham Lake dam and affected by the Mayo B dam.	Severity of decreased fitness or increases in parasitism can vary from no measurable effect to death. Obstruction and delays at Fraser Falls expected to result in decreased spawning success and use of alternate spawning areas (i.e., Watson Creek). Obstruction of migration by beaver may result in loss of one or more year classes and possibly extirpation of the stock in small, lake dominated tributaries.	The mainstem Stewart River has tended to be relatively cool during upstream migration. Spawning streams with limited lake storage such as the McQuesten are expected to have colder waters lake dominated streams. Small, lake dominated streams that are vulnerable to obstruction by beaver include Janet Creek, Ollie Creek and possibly Emerald and Pleasant Creek.	The condition of adult Yukon River Chinook is not monitored. Recent water temperature monitoring initiatives may provide insight to the frequency of low water/warm water years. Acquired knowledge and results of the present water temperature monitoring network may allow prediction and back casting to determine frequencies over extended periods. The effects of the Mayo Hydro-electrical project are ongoing.	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability. Effects of obstruction can be modified through monitoring and beaver management. Effects of the Mayo Hydro-electrical project are thought to have increased.
Spawning	Short-term climatic/hydrologic variation resulting in episodic extreme high flows during the spawning period in non-buffered screams resulting in reduced stock productivity, or extreme low flows in smaller streams resulting in inadequate velocities and depth of flow for spawning adults and potentially high temperatures in lake dominated streams. Lack of fitness related to thermal stress or increased parasitism resulting in decreased spawning success. Sediment from natural sources and placer mining degrading	Locally and temporally variable. A significant portion of the spawning stock for a river may be lost in a single flood event or as a result of very low flows, associated high water temperatures and delays in spawning. Decreased fitness or increases in parasitism may result in pre-spawn mortality, partial spawn, or reduced egg to fry survival. Sections of spawning rivers may be sedimented so heavily that spawning cannot occur for years or decades. Water management effects may result in reduced spawning success.	Non-buffered stream such as the McQuesten will be most vulnerable to high water events. Small streams such as Janet Creek and Watson Creek will be vulnerable to low water effects. Water management effects are limited to the Mayo River.	The condition of adult Yukon River Chinook is not monitored. Frequency of flood events on mid-sized or larger watersheds could be determined from WSC hydrometric monitoring. Smaller and more isolated spawning streams are less easy to determine as individual streams have not been monitored or characterized. Water management effects in the Mayo River are ongoing.	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability. Effects of the Mayo Hydro-electrical project are thought to have increased.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	spawning habitats. Effects of flow reductions/increases below the Mayo Hydro electrical dam during spawning periods.				

White River

Table A3: Limiting factors table for Chinook from the White River watershed detailing current knowledge about the nature of potential limiting factors as well as their severity, extent, frequency and direction of change by life stage

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Egg deposition, incubation	Short-term climatic/hydrologic variation resulting in dewatering/freezing/reduction of flow through redds. Effects of sediment inputs from land instability, sands/silts filling redds post egg deposition resulting in reduced egg-to-fry survival.	Climatic/hydrologic and sediment effects are locally variable, from catastrophic to no effects and are most pronounced in spawning rivers with limited lake storage/buffering.	Climatic/hydrological effects will apply to all spawning areas. Natural sediment inputs will affect all areas.	Climatic/meteorological effects are constant and unpredictable. These include, either directly or indirectly, high and low waters, sediment release and transfer, and variation around poorly defined trends.	River flows appear to be more variable, and effects of low- and high water periods are expected to increase. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing, with increased effects. Overall, stress on this life stage is probably increasing.
Fry emergence	Short-term climatic/hydrologic variation in severity and timing of spring breakup, resulting in fry being exported from rivers or isolated in pools/back channels in flood plains	Export of emergent fry has not been measured. Stranding is variable.	All spawning areas.	Some degree of export and stranding expected in all years; high degree in early and violent ice off episodes.	Export of and stranding of emergent fry are thought to be increasing.
Rearing	Short-term climatic/hydrologic variation resulting in reduced habitat quantity in low water years, decreased habitat quality (low water temperatures, limited food) in high water years, and displacement of fry from rearing areas at high flows. Effects of sediment inputs from land instability results in sands /silts /clays filling streams and reducing available food. Obstruction of upstream migration by beaver dams.	Locally and temporally variable, from catastrophic to no effects. Low flows and warmer water temperatures are thought to have less severe effects than high flows and related lower water temperatures on habitat quantity/quality. Effects of natural land instability or placer mining may be profound. During dry years or multiples thereof beaver activity may result in Chinook fry being denied access to much or most high quality habitat, causing decreased growth	Rearing habitat is widespread and includes spawning areas, migration routes and portions of all tributaries to the Donjek downstream of the Kluane River. Climatic/hydrological effects will apply to all rearing areas. Sediment inputs from natural landslides, active layer detachments following forest fires, and slope deflations will affect all rearing areas. Obstructions to upstream fry migration by beaver are widespread.	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be episodic and short duration. Obstruction of fry migration to upstream rearing habitats is most common during dry years and particularly during multi-year droughts.	Flows appear to be more variable, and effects to rearing fry are expected to increase as a result. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing. Obstructions to upstream migration by beaver will trend with local stream flows and social acceptance of control.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	NOTE that each rearing stream provides habitat to fry from most or all upstream stocks.	and fitness following the first summer of life.			
Over-wintering	Short-term climatic/hydrologic variation may result in decreased high quality ground water discharge into overwintering areas following low water summers. Climate change-related increased discharges of low quality ground water into overwintering habitats from melting permafrost decreases survival. Reduced quantity/quality of overwintering habitats resulting from natural fine sediment deposition on preferred cobble/rubble stream bottoms. Obstruction of access by fry to overwintering habitats by beaver dams. Increased risk of predation from mammalian predators when fry are concentrated in small overwintering areas. NOTE that each rearing stream or river provides overwintering habitat to fry from most or all upstream Chinook Salmon stocks.	Locally and temporally variable, varying from catastrophic to no effects. Kills of overwintering juveniles may occur due to poor water quality or insufficient quantity. Potential overwintering areas may be choked with sediment from upstream landslides. Upstream migration to prime overwintering habitats may be obstructed by beaver dams. Concentration of overwintering fry in small areas may result in high mortality from predatory mammals.	Overwintering habitat is widespread and includes spawning areas, migration routes and portions of all tributaries to the Donjek downstream of the Kluane River. Short-term climatic/hydrological effects will apply to most overwintering areas. Sediment from natural sources will periodically reduce the capacity of most overwintering areas. Beaver are numerous in flood plain areas and low gradient streams. Dams on ground water fed channels may persist for extended periods, obstructing multiple year classes of fry from access to overwintering areas.	Climatic/meteorological effects are constant and unpredictable. Climate change related low quality ground water discharges are ongoing. Sediment from natural sources tends to be of short duration. Beaver dams on low gradient- and ground water fed channels may persist for extended periods, obstructing multiple year classes of fry from access to overwintering. Dams on higher gradient streams most frequent during low water years or droughts. Frequency of predation variable, and depends on population size of predators - may be affected by the price of furs/energy of trapper.	Flows appear to be more variable, and effects to overwintering fry are expected to increase. Climate change related discharges of low quality ground water into overwintering areas are expected to increase. Effects of sedimentation are expected to remain relatively constant. The beaver population is probably at the carrying capacity of their habitats and effects (on a Watershed basis) will remain constant, albeit effects will vary locally. There is insufficient information to be able to determine changes in predation.
Smolting, estuarine residence	Changes in the timing of ice break up leading to mismatch between outmigration timing (which can be driven by timing of ice breakup) and prey availability during early marine life. Short-term climatic/hydrologic variation resulting in low spring water temperatures and delayed out-	Locally and temporally variable.	May affect all yearling salmon.	Though variable, the timing of ice break up has been getting earlier over time. Recent water temperature monitoring initiatives may provide insight to the frequency of cooler than normal springs.	All indications are that the timing of ice break up will continue to be earlier and earlier in the spring. Negative effects of lower water temperatures are probably declining due to climate change and trend to warmer, earlier springs.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	migration of overwintered yearlings.				
Juvenile and sub-adult marine	Changing oceanographic conditions and increased abundance of other Pacific salmon species leading to reduced food in the ocean and increased competition (either directly or indirectly) for available resources.	Unknown, likely to be significant but temporally variable.	All salmon within the watershed.	Oceanographic influences are constant but their effects are unpredictable.	Unknown.
Freshwater entry, upstream migration	Short term climatic/hydrologic variation resulting in low water/warm water conditions in the Yukon River in Alaska, associated decreased fitness in returning adults and an increased risk of parasitism and disease. The White and Donjek Rivers are heavily sedimented during upstream migration, placing additional stress on upstream migrating adults. Entry to, and migration up, Tincup Creek, the sole lake headed spawning stream, may be obstructed by beaver during low water years or droughts.	Severity of decreased fitness or increases in parasitism can vary from no measurable effect to death. Sediment levels in the White and Donjek could delay stressed adults and reduce spawning success. Obstruction of migration by beaver in Tincup Creek could result in loss of one or more year classes and possibly extirpation of the stock	All Chinook will be affected by increased water temperatures in the Yukon River downstream of the mouth of the White River. Effects of high sediment levels will be greatest for the Tincup Creek and Kluane River stocks due to the length of migration. Only the Tincup Creek stock is vulnerable to obstruction by beaver.	The condition of adult Yukon River Chinook is not monitored. Frequency of past periods of low water/warm water could be derived from meteorological or hydrometric archives. Sediment levels in the White and Donjek Rivers are probably related to stream flow, and could be derived from Water Survey of Canada data. Beaver have not dammed Tincup Creek in the recent past, but could do so at any time.	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability. Effects of potential obstruction of Tincup Creek can be modified through monitoring and beaver management.
Spawning	Short-term climatic/hydrologic variation resulting in episodic extreme high flows during the spawning period in non-buffered streams resulting in reduced stock productivity. Lack of fitness related to thermal stress or increased parasitism resulting in decreased spawning success.	Locally and temporally variable. A significant portion of the spawning stock for a river may be lost in a single flood event. Decreased fitness or increases in parasitism may result in pre-spawn mortality, partial spawn, or reduced egg to fry survival.	The Nisling- and Khorasan River stocks are vulnerable to extreme high flows. Decreased fitness related to increases in water temperature in downstream migration routes will apply to all spawning stocks	The condition of adult Yukon River Chinook is not monitored. The Nisling- and Kluane Rivers are monitored by the WSC. Frequency of past periods of high water could be derived from meteorological or hydrometric archives. Tincup Creek is not monitored.	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability.

Pelly River

Table A4: Limiting factors table for Chinook from the Pelly River watershed detailing current knowledge about the nature of potential limiting factors as well as their severity, extent, frequency and direction of change by life stage.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Egg deposition, incubation	Short-term climatic/hydrologic variation resulting in dewatering/freezing/reduction of flow through redds. Effects of sediment inputs from land instability and placer mining, sands/silts filling redds post egg deposition resulting in reduced egg-to-fry survival. Effects of past and present quartz mining.	Climatic/hydrologic and sediment effects are locally variable, varying from catastrophic to no effects and are most pronounced in spawning rivers with limited lake storage/buffering. Release of metals and process chemicals from quartz mining and milling may result in lethal- or chronic effects to eggs or alevins.	Climatic/hydrological effects will apply to all spawning areas. Natural sediment inputs will affect all areas. Effects of quartz mining on spawning areas include the temporary extirpation of the Anvil and Rose Creek stocks by the Faro Mining Complex, and potential effects to Blind Creek.	Climatic/meteorological effects are constant and unpredictable. These include, either directly or indirectly, high and low waters, sediment release and transfer, and variation around poorly defined trends. Quartz mining depends on global metal prices and degree of government subsidization of the industry.	River flows appear to be more variable, and effects of low water periods are expected to increase. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing, with increased effects. Discharges of toxic materials from the Faro Mine have decreased, but is a result of government care and maintenance and therefore vulnerable. Overall, stress on this life stage is probably increasing.
Fry emergence	Short-term climatic/hydrologic variation in severity and timing of spring breakup, resulting in fry being exported from rivers or isolated in pools/back channels in flood plains	Export of emergent fry has not been measured. Stranding is variable.	All spawning areas	Some degree of export and stranding expected in all years; high degree in early and violent ice off episodes	Export of and stranding of emergent fry are thought to be increasing.
Rearing	Short-term climatic/hydrologic variation resulting in reduced quantity of habitat in low water years, decreased quality of habitat (low water temperatures, limited food supply) in high water years. Displacement of fry from rearing areas occurs at high flows. Effects of sediment inputs from land instability results in sands/silts/clays filling	Locally and temporally variable, from catastrophic to no effects. Low flows and warmer water temperatures are thought to have less severe effects than high flows and related lower water temperatures on habitat quantity/quality. Effects of natural sedimentation and related channel responses may be locally/temporally profound and otherwise are related	Rearing habitat is widespread and includes spawning areas, migration routes and portions of all non-spawning tributaries. Climatic /hydrological effects will apply to all rearing areas. Sediment inputs from natural/semi-natural landslides, active layer detachments following forest fires, and slope deflations will affect all rearing areas. Quartz mining development is widespread	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be episodic and short duration. Effects of mining development and abandonment may persist for years and decades. Obstruction of fry migration to upstream rearing habitats is most common during dry	Flows appear to be more variable, and effects to rearing fry are expected to increase as a result. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing. Effects of quartz mining development are probably stable or possibly declining due to new

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	streams and reducing available food organisms. Effects of deleterious substances released from abandoned or developing quartz mines. Obstruction of upstream migration in natal or non-natal streams by beaver dams. NOTE that each rearing stream or river provides rearing habitat to fry from most or all upstream Chinook Salmon stocks and that fry produced in this Watershed may rear in streams located outside of it.	to the concentration of sediment and duration of discharge. Releases of toxic material from quartz mining development and abandonment are probably limited to chronic effects. During dry years or multiples thereof beaver activity may result in Chinook fry being denied access to much or most high quality habitat, causing decreased growth and fitness following the first summer of life.	in the watershed but most is at a low level of intensity. The Faro Mine poses a potential threat to rearing in Rose Creek, Anvil Creek and the mixing zone in the Pelly River. Obstructions to upstream fry migration by beaver are widespread. Note that fry produced in this Watershed may rear in all downstream waters.	years and particularly during multi-year droughts. Effects of quartz mining development and abandonment may persist for years and centuries. Rearing takes place in so many streams of such different hydrological characteristics that only coarse resolution relationships with meteorological or hydrometric data can be derived.	technology, while those from the abandoned Faro mine are controlled by the Government of Canada. Obstructions to upstream migration by beaver will trend with local stream flows and social acceptance of control.
Over-wintering	Short-term climatic/hydrologic variation may result in decreased high quality ground water discharge into overwintering areas following low water summers. Climate change-related increased discharges of low quality ground water into over wintering habitats from melting permafrost decreases survival. Reduced quantity/quality of overwintering habitats resulting from natural fine sediment deposition on preferred cobble/rubble stream bottoms. Release of toxic materials from quartz mining development and operations. Obstruction of access by fry to overwintering habitats by beaver dams. Increased risk of predation from mammalian predators when fry are concentrated in small	Locally and temporally variable, from catastrophic to no effects. Kills of overwintering juveniles may occur due to poor water quality or insufficient quantity. Potential overwintering areas may be choked with sediment from upstream landslides. Releases of toxic materials from quartz mining development or operation are generally related to chronic effects. Upstream migration to prime overwintering habitats may be obstructed by beaver dams. Concentration of overwintering fry in small areas may result in high mortality from predatory mammals.	Overwintering habitat is considered widespread. Short-term climatic/hydrological effects will apply to most overwintering areas. Sediment from natural sources will periodically reduce the capacity of most overwintering areas. Quartz mining development is widespread in the Watershed, and includes the Faro Mining Complex, which releases toxic materials into Rose Creek, Anvil Creek and possibly Blind Creek. Beaver are numerous and dams on ground water fed channels may persist for extended periods, obstructing multiple year classes of fry from access to overwintering areas. Mink and otter pose a high risk to concentrations of juveniles.	Climatic/meteorological effects, are constant and unpredictable. Climate change related low quality ground water discharges are ongoing. Sediment from natural sources tends to be of short duration. Beaver dams on low gradient or ground water fed channels may persist for extended periods, obstructing multiple year classes of fry from access to overwintering. Effects of quartz mining development and abandonment may persist for years to centuries. Dams on higher gradient streams are most frequent during low water years or droughts. Frequency of predation variable, and depends on population size of predators - may be affected by the price of furs/energy of	Flows appear to be more variable, and effects to overwintering fry are expected to increase. Climate change related discharges of low quality ground water into overwintering areas are expected to increase. Effects of sedimentation are expected to remain relatively constant. Discharges of toxic materials from the Faro Mine have decreased, but is a result of government care and maintenance and therefore vulnerable. The beaver population is probably at the carrying capacity of their habitats and effects (on a Watershed basis) will remain constant, albeit effects will vary locally. There is insufficient information to be able to determine changes in predation.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	overwintering areas. NOTE that each rearing stream or river provides overwintering habitat to fry from most or all upstream Chinook Salmon stocks, and that fry produced in this Watershed may overwinter outside of it. .			trapper.	
Smolting, estuarine residence	Changes in the timing of ice break up leading to mismatch between outmigration timing (which can be driven by timing of ice breakup) and prey availability during early marine life. Short-term climatic/hydrologic variation resulting in low spring water temperatures and delayed out-migration of overwintered yearlings.	Locally and temporally variable.	May affect all yearling salmon.	Though variable, the timing of ice break up has been getting earlier over time. Recent water temperature monitoring initiatives may provide insight to the frequency of cooler than normal springs.	All indications are that the timing of ice break up will continue to be earlier and earlier in the spring. Negative effects of lower water temperatures are probably declining due to climate change and trend to warmer, earlier springs.
Juvenile and sub-adult marine	Changing oceanographic conditions and increased abundance of other Pacific salmon species leading to reduced food in the ocean and increased competition (either directly or indirectly) for available resources.	Unknown, likely to be significant but temporally variable.	All salmon within the watershed.	Oceanographic influences are constant but their effects are unpredictable.	Unknown.
Freshwater entry, upstream migration	Short term climatic/hydrologic variation resulting in low water/warm water conditions in the Yukon River downstream of the mouth of the Pelly and in the Pelly River itself. This period/distance of thermal stress may be associated with decreased fitness in returning adults and an increased risk of parasitism and disease. Entry	Severity of decreased fitness or increases in parasitism can vary from no measurable effect to death. Obstruction of entry due to channel characteristics may result in larger fish not being able to enter spawning streams. Obstruction of migration upstream in spawning rivers by beaver may result in loss of one or more year classes and possibly extirpation of the stock.	Temperatures in the mainstem Pelly River exceed levels of concern in warmer summers. Spawning streams with limited lake storage, such as Blind- and Anvil Creek are expected to have colder waters than lake dominated streams. Large adult salmon have been observed having difficulty entering the Earn River during low Pelly River flows. Small spawning streams, such as	The fitness of adult Yukon River Chinook is not monitored. Recent water temperature monitoring initiatives and WSC data may provide insight to the frequency of low water/warm water years. Acquired knowledge and results of the present water temperature monitoring network may allow	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability. Effects of obstruction can be modified through monitoring and beaver management.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	into and up smaller streams, including but not limited to those that are lake dominated may be obstructed during low water/warm water years either due to channel characteristics or beaver activity.		Mica and Needle Rock Creeks and the Glenlyon River are numerous in the watershed and the effects of obstruction of entry and upstream migration may be correspondingly severe.	prediction and back casting to determine frequencies over extended periods	
Spawning	Short-term climatic/hydrologic variation resulting in episodic extreme high flows during the spawning period in non-buffered streams causing reduced stock productivity, or extreme low flows in smaller streams resulting in inadequate velocities and depth of flow for spawning adults. Sediment from natural sources degrading spawning habitats. Lack of fitness related to thermal stress throughout the upstream migration or increased parasitism resulting in decreased spawning success.	Locally and temporally variable. A significant portion of the spawning stock for a river may be lost in a single flood event or as a result of very low flows, associated high water temperatures and delays in spawning. Sections of spawning rivers may be sedimented so heavily that spawning cannot occur for years or decades. Decreased fitness or increases in parasitism may result in pre-spawn mortality, partial spawn, or reduced egg to fry survival.	Non-buffered streams such as Anvil and Blind Creeks will be most vulnerable to high water events. Small streams such as such as Mica and Needle Rock Creeks and the Glenlyon River will be vulnerable to low water effects.	Frequency of flood events on mid-sized or larger watersheds could be determined from WSC hydrometric monitoring. Smaller and more isolated spawning streams are less easy to determine as individual streams have not been monitored or characterized.	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability.

Yukon River Mid Main Stem

Table A5: Limiting factors table for Chinook from the mid main stem of the Yukon River detailing current knowledge about the nature of potential limiting factors as well as their severity, extent, frequency and direction of change by life stage.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Egg deposition, incubation	Short-term climatic/hydrologic variation resulting in dewatering/freezing /reduction of flow through redds. Long term trends to lower annual flows in some spawning streams. Effects of sediment inputs from land instability and placer mining, sands/silts filling redds post egg deposition resulting in reduced egg-to-fry survival. Effects of quartz mining development.	Climatic/hydrologic and sediment effects are locally variable, varying from catastrophic to no effects and are most pronounced in spawning rivers with limited lake storage /buffering. Releases of toxic substances from existing quartz mining is at worst limited to chronic effects on incubating eggs.	Climatic/hydrological effects will apply to all spawning areas. Natural sediment inputs will affect all areas. Effects of placer mining sediments are limited to the Big Creek and South Big Salmon River spawning stocks. Long-term trend to lower stream flows most noticeable in the Nordenskiold River drainage. Quartz mining activities are widespread on the west side of the Yukon River throughout the Watershed, although generally at a low level of intensity.	Climatic/meteorological effects are constant and unpredictable. These include, either directly or indirectly, high and low waters, natural sediment release and transfer, and variation around poorly defined trends. Sediment releases from placer mining will depend on the price of gold.	River flows appear to be more variable, and effects of low water periods are expected to increase. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing, with increased effects. Releases of sediment from placer mining appear to be stable but subject to the price of gold. Quartz mining is currently in decline in this watershed.
Fry emergence	Short-term climatic/hydrologic variation in severity and timing of spring breakup, resulting in fry being exported from rivers or isolated in pools/back channels in flood plains.	Export of emergent fry has not been measured. Stranding is variable.	All spawning areas.	Some degree of export and stranding expected in all years; high degree in early and violent ice off episodes.	Export of and stranding of emergent fry are thought to be increasing.
Rearing	Short-term climatic/hydrologic variation resulting in reduced quantity of habitat in low water years, decreased quality of habitat (low water temperatures, limited food supply) in high water years, and displacement of fry from rearing areas at high flows. Effects of sediment inputs from land instability and placer mining results in sands/silts/clays filling	Locally and temporally variable, from catastrophic to no effects. Low flows and warmer water temperatures are thought to have less severe effects than high flows and related lower water temperatures on habitat quantity/quality. Effects of natural sedimentation and related channel responses or those caused by placer mining may be	Rearing habitat is widespread and includes spawning areas, migration routes and portions of all non-spawning tributaries. Climatic/hydrological effects will apply to all rearing areas. Sediment inputs from natural/semi-natural landslides, active layer detachments following forest fires, and slope deflations will affect all rearing areas. Placer mining is	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be episodic and short duration. Sediment from placer mining tends to be constant and of longer duration, extending from months through years. Obstruction of fry migration to upstream rearing habitats is	Flows appear to be more variable, and effects to rearing fry are expected to increase as a result. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing. Sediment releases from placer mining appear to be increasing as new areas are mined. Effects of

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	streams and reducing available food organisms. Effects of toxic materials released from developing or operating quartz mines. Obstruction of upstream migration in natal or non-natal streams by beaver dams. NOTE that each rearing stream or river provides rearing services to fry from most or all upstream Chinook Salmon stocks and that fry produced in this Watershed may rear in streams located outside of it.	locally/temporally profound and otherwise are related to the concentration of sediment and duration of discharge. Releases of toxic material from quartz mining development and abandonment are probably limited to chronic effects. During dry years or multiples thereof beaver activity may result in Chinook fry being denied access to much or most high quality habitat, causing decreased growth and fitness following the first summer of life.	specific to a limited number of tributaries and effects of sediment inputs or stream bank/bed modification and stability are correspondingly limited. Obstructions to upstream fry migration by beaver are widespread. Note that fry produced in this Watershed may rear in all downstream waters.	most common during dry years and particularly during multi-year droughts. Effects of quartz mining development may persist for years and decades. Rearing takes place in so many streams of such different hydrological characteristics that only coarse resolution relationships with meteorological or hydrometric data can be derived.	quartz mining development are probably stable or possibly declining due to new technology. Obstructions to upstream migration by beaver will trend with local stream flows and social acceptance of control.
Over-wintering	Short-term climatic/hydrologic variation may result in decreased high quality ground water discharge into overwintering areas following low water summers. Reduced quantity/quality of overwintering habitats resulting from natural- or placer mining associated fine sediment deposition on preferred cobble/rubble stream bottoms. Effects of toxic materials released from developing or operating quartz mines. Obstruction of access by fry to overwintering habitats by beaver dams. Increased risk of predation from mammalian predators when fry are concentrated in small overwintering areas. NOTE that each rearing stream or river provides overwintering habitat to fry from most or all upstream	Locally and temporally variable, from catastrophic to no effects. Kills of overwintering juveniles may occur due insufficient quantity of water. Releases of toxic material from quartz mining development and abandonment are probably limited to chronic effects. Potential overwintering areas may be choked with sediment from upstream landslides and placer mining. Upstream migration to prime overwintering habitats may be obstructed by beaver dams. Concentration of overwintering fry in small areas may result in high mortality from predatory mammals.	Overwintering habitat is considered widespread. Short-term climatic/hydrological effects will apply to most overwintering areas. Sediment from natural sources will periodically reduce the capacity of most overwintering areas, while placer mined creeks will have reduced capacity to overwinter fry. Quartz mining development is widespread in the Watershed and includes one operating mine. Beaver are numerous and dams on ground water fed channels and low gradient sections of stream may persist for extended periods, obstructing multiple year classes of fry from access to overwintering areas. Mink and otter pose a high risk to concentrations of juveniles.	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be of short duration and from placer mining tends to be of long duration, extending from years through decades. Effects of quartz mining development may persist for years and decades. Beaver dams on low gradient or ground water fed channels may persist for extended periods, obstructing multiple year classes of fry from access to overwintering. Dams on higher gradient streams most frequent during low water years or droughts. Frequency of predation variable, and depends on population size of predators - may be affected by the price of furs/energy of	Flows appear to be more variable, and effects to overwintering fry are expected to increase. Effects of sedimentation are expected to remain relatively constant. Effects of quartz mining development are probably stable or possibly declining due to new technology. The beaver population is probably at the carrying capacity of their habitats and effects (on a Watershed basis) will remain constant, albeit effects will vary locally. There is insufficient information to be able to determine changes in predation.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	Chinook Salmon stocks, and that fry produced in this Watershed may overwinter outside of it.			trapper.	
Smolting, estuarine residence	Changes in the timing of ice break up leading to mismatch between outmigration timing (which can be driven by timing of ice breakup) and prey availability during early marine life. Short-term climatic/hydrologic variation resulting in low spring water temperatures and delayed out-migration of overwintered yearlings.	Locally and temporally variable.	May affect all yearling salmon.	Though variable, the timing of ice break up has been getting earlier over time. Recent water temperature monitoring initiatives may provide insight to the frequency of cooler than normal springs.	All indications are that the timing of ice break up will continue to be earlier and earlier in the spring. Negative effects of lower water temperatures are probably declining due to climate change and trend to warmer, earlier springs.
Juvenile and sub-adult marine	Changing oceanographic conditions and increased abundance of other Pacific salmon species leading to reduced food in the ocean and increased competition (either directly or indirectly) for available resources.	Unknown, likely to be significant but temporally variable.	All salmon within the watershed.	Oceanographic influences are constant but their effects are unpredictable.	Unknown.
Freshwater entry, upstream migration	Short-term climatic/hydrologic variation resulting in low water/warm water conditions in the Yukon River downstream of the northern boundary of the Watershed, associated with decreased fitness in returning adults and an increased risk of parasitism and disease. Migration into- and up smaller, lake dominated streams may be obstructed by beaver during low water years or droughts.	Severity of decreased fitness or increases in parasitism can vary from no measurable effect to death. Obstruction of migration by beaver may result in loss of one or more year classes and possibly extirpation of one or more stocks,	Temperatures in the Yukon River are not monitored. All returning Chinook will be subject to the effects of temperatures during the upstream migration. Small(er) rivers and streams will be vulnerable to obstruction by damming. These include Tatchun Creek, Northern Creek, the Nordenskiold upstream of Kirkland Creek, Kirkland Creek, Incised Creek, and Walsh Creek.	The condition of adults is not monitored. Recent water temperature monitoring initiatives may provide insight to the frequency of low water/ warm water years. Acquired knowledge and results of the present water temperature monitoring network may allow prediction and back casting to determine frequencies over extended periods	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability. Effects of obstruction can be modified through monitoring and beaver management.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Spawning	Short-term climatic/hydrologic variation resulting in episodic extreme high flows during the spawning period in non-buffered streams resulting in reduced stock productivity, or extreme low flows in smaller streams resulting in inadequate velocities and depth of flow for spawning adults. Long term trends to lower annual flows in some spawning streams. Sediment from natural sources and placer mining degrading spawning habitats. Lack of fitness related to thermal stress or increased parasitism resulting in decreased spawning success.	Locally and temporally variable. A significant portion of the spawning stock for a river may be lost in a single flood event or as a result of very low flows, associated high water temperatures and delays in spawning. Sections of spawning rivers may be sedimented so heavily that spawning cannot occur for years or decades. Decreased fitness or increases in parasitism may result in pre-spawn mortality, partial spawn, or reduced egg to fry survival.	All spawning Chinook will be subject to short-term climatic/hydrologic variation, including the periodic effects of elevated water temperatures during their upstream migration. Small(er) rivers and streams, and particular lake dominated streams may have water temperatures approaching or exceeding levels of concern during the normal spawning period. These include Tatchun Creek, the Nordenskiold, Kirkman Creek, Incised Creek, and Walsh Creek. The Klusha creek stock has been extirpated due to low water levels and related effects.	Frequency of flood events on mid-sized or larger watersheds could be determined from WSC hydrometric monitoring. Smaller and more isolated spawning streams less easy to determine as individual streams have not been monitored or characterized.	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability.

Teslin River

Table A6: Limiting factors table for Chinook from the Teslin River watershed detailing current knowledge about the nature of potential limiting factors as well as their severity, extent, frequency and direction of change by life stage.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Egg deposition, incubation	Short-term climatic/hydrologic variation resulting in dewatering/freezing /reduction of flow through redds. Some spawning streams are very cold during high water/cool water years. Effects of sediment inputs from land instability and placer mining, sands/silts filling redds post egg deposition resulting in reduced egg-to-fry survival.	Climatic/hydrologic and sediment effects are locally variable, varying from catastrophic to no effects and are most pronounced in spawning rivers with limited lake storage/buffering. Some spawning rivers appear to have barely enough thermal energy to incubate eggs through to emergence.	Climatic/hydrological effects will apply to all spawning areas. Natural sediment inputs will affect all areas. Data on water temperatures is sparse, but Rose River had only 1096 degree days in 2012, or 96 DD more than generally accepted DD to emergence. Placer mining effects are limited to Sidney Creek.	Climatic/meteorological effects are constant and unpredictable. These include, either directly or indirectly, high and low waters, sediment release and transfer, and variation around poorly defined hydrometric or stream temperature trends. Placer mining activity reflects the price of gold.	River flows appear to be more variable, and effects of low- and high water periods are expected to increase. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing, with increased effects. Placer mining effects are minor. Overall, stress on this life stage is probably increasing.
Fry emergence	Short-term climatic/hydrologic variation in severity and timing of spring breakup, resulting in fry being exported from rivers or isolated in pools/back channels in flood plains	Export of emergent fry has not been measured. Stranding is variable.	All spawning areas.	Some degree of export and stranding expected in all years; high degree in early and violent ice off episodes	Export of and stranding of emergent fry are thought to be increasing.
Rearing	Short-term climatic/hydrologic variation resulting in reduced quantity of habitat in low water years, decreased quality of habitat (low water temperatures, limited food supply) in high water years. Displacement of fry from rearing areas occurs at high flows. Effects of sediment inputs from land instability results in sands/silts/clays filling streams and reducing abundance of available food organisms. Obstruction of	Locally and temporally variable, from catastrophic to no effects. Low flows and warmer water temperatures are thought to have less severe effects than high flows and related lower water temperatures on habitat quantity/quality. Effects of natural- and placer mining sedimentation and channel responses may be locally/temporally profound and otherwise are related to the concentration of sediment and duration of discharge. During dry	Rearing habitat is widespread and includes spawning areas, migration routes and portions of all non-spawning tributaries. Climatic/hydrological effects will apply to all rearing areas. Sediment inputs from natural/semi-natural landslides, and active layer detachments following forest fires will affect all rearing areas. Obstructions to upstream fry migration by beaver are widespread. DNA analysis have identified Teslin River fry as the sub-dominant	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be episodic and short duration. Sediment from placer mining tends to be constant and of extended duration. Obstruction of fry migration to upstream rearing habitats is most common during dry years and particularly during multi-year droughts. Rearing takes place in so many streams of	Flows appear to be more variable, and effects to rearing fry are expected to increase as a result. Episodic releases of sediment from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing. Obstructions to upstream migration by beaver will trend with local stream flows and social acceptance of control.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	upstream migration in natal or non-natal streams by beaver dams. NOTE that each rearing stream or river provides rearing habitat to fry from most or all upstream Chinook Salmon stocks and that fry produced in this Watershed may rear in streams located outside of it.	years or multiples thereof beaver activity may result in Chinook fry being denied access to much or most high quality habitat, causing decreased growth and fitness following the first summer of life.	population in non-natal streams and spawning rivers in the Yukon River North Mainstem in 2009, 2012 and 2013 implying significant downstream movement by this stock.	such different hydrological characteristics and over such an extended distance (i.e., at least as far as the US/Canadian border) that only coarse resolution relationships with meteorological or hydrometric data can be derived.	
Over-wintering	Short-term climatic/hydrologic variation may result in decreased high quality ground water discharge into overwintering areas following low water summers. Reduced quantity/quality of overwintering habitats resulting from natural fine sediment deposition on preferred cobble/rubble stream bottoms. Obstruction of access by fry to overwintering habitats by beaver dams. Increased risk of predation from mammalian predators when fry are concentrated in small overwintering areas. NOTE that each rearing stream or river provides overwintering habitat to fry from most or all upstream Chinook Salmon stocks, and that significant numbers of fry produced in this Watershed overwinter outside of it.	Locally and temporally variable, from catastrophic to no effects. Kills of overwintering juveniles may occur due to poor water quality or insufficient quantity. Potential overwintering areas may be choked with sediment, denying its use by fry. Upstream migration to prime overwintering habitats may be obstructed by beaver dams. Concentration of overwintering fry in small areas may result in high mortality from predatory mammals.	Overwintering habitat is considered widespread. Short-term climatic/hydrological effects will apply to most overwintering areas. Sediment from natural sources will periodically reduce the capacity of most overwintering areas. Beaver are numerous. Dams on ground water fed channels or low gradient stream reaches may persist for extended periods, obstructing multiple year classes of fry from access to overwintering areas. Mink and otter pose a high risk to concentrations of juveniles. The condition of downstream overwintering habitats is important to this stock due to significant movement out of the Watershed.	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be of short duration. Beaver dams on low gradient or ground water fed channels may persist for extended periods, obstructing multiple year classes of fry from access to overwintering. Dams on higher gradient streams are most frequent during low water years or droughts. Frequency of predation variable, and depends on population size of predators - may be affected by the price of furs/energy of trapper.	Flows appear to be more variable, and effects to overwintering fry are expected to increase. Effects of sedimentation are expected to remain relatively constant. The beaver population is probably at the carrying capacity of its habitats and effects (on a Watershed basis) will remain constant, albeit effects will vary locally. There is insufficient information to be able to determine changes in predation.
Smolting, estuarine residence	Changes in the timing of ice break up leading to mismatch between outmigration timing (which can be driven by timing of ice breakup) and prey availability	Locally and temporally variable.	May affect all yearling salmon.	Though variable, the timing of ice break up has been getting earlier over time. Recent water temperature monitoring initiatives may provide insight	All indications are that the timing of ice break up will continue to be earlier and earlier in the spring. Negative effects of lower water temperatures are probably

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	during early marine life. Short-term climatic/hydrologic variation resulting in low spring water temperatures and delayed out-migration of overwintered yearlings.			to the frequency of cooler than normal springs.	declining due to climate change and trend to warmer, earlier springs.
Juvenile and sub-adult marine	Changing oceanographic conditions and increased abundance of other Pacific salmon species leading to reduced food in the ocean and increased competition (either directly or indirectly) for available resources.	Unknown, likely to be significant but temporally variable.	All salmon within the watershed.	Oceanographic influences are constant but their effects are unpredictable.	Unknown.
Freshwater entry, upstream migration	Short-term climatic/hydrologic variation resulting in low water/warm water conditions in the Yukon River downstream of the mouth of the Teslin River and in the Teslin River itself. This period/distance of thermal stress may be associated with decreased fitness in returning adults and an increased risk of parasitism and disease. Entry into and up smaller, lake dominated streams may be obstructed during low water/warm water years either due to channel characteristics or beaver activity.	Severity of decreased fitness or increases in parasitism can vary from no measurable effect to death. Obstruction of migration upstream in spawning rivers by beaver may result in loss of one or more year classes and possibly extirpation of the stock.	Temperatures in the mainstem Teslin River exceed levels of concern in warmer summers. Spawning streams with limited lake storage are expected to have colder waters than lake dominated streams. Small, lake dominated streams are present in the watershed and the effects of obstruction of entry and upstream migration may be of concern. These streams include the Swift River (north), Hundred Mile Creek (tributary to Nisutlin) and Tlingit Creek.	The condition of adult Yukon River Chinook is not monitored. Recent water temperature monitoring initiatives and WSC data may provide insight to the frequency of low water/warm water years. Acquired knowledge and results of the present water temperature monitoring network may allow prediction and back casting to determine frequencies over extended periods	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability. Effects of obstruction can be modified through monitoring and beaver management.
Spawning	Short-term climatic/hydrologic variation resulting in episodic extreme high flows during the spawning period in non-buffered streams resulting in reduced stock productivity, or extreme low flows in smaller streams	Locally and temporally variable. A significant portion of the spawning stock for a river may be lost in a single flood event or as a result of very low flows, associated high water temperatures and delays in spawning. Sections of spawning	All spawning Chinook will be subject to short-term climatic/hydrologic variation, including the periodic effects of elevated water temperatures during their upstream migration. Small(er) rivers and streams, and particular lake	Frequency of flood events on mid-sized or larger watersheds could be determined from WSC hydrometric monitoring. Smaller and more isolated spawning streams are less easy to determine as	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	resulting in inadequate velocities and depth of flow for spawning increased risk of predation. Sediment from natural sources and placer mining degrading spawning habitats. Lack of fitness related to thermal stress throughout upstream migration or increased parasitism resulting in decreased spawning success.	rivers may be sedimented so heavily that spawning cannot occur for years or decades. Decreased fitness or increases in parasitism may result in pre-spawn mortality through exhaustion or predation, partial spawn, reduced egg to fry survival.	dominated streams may have water temperatures approaching or exceeding levels of concern during the normal spawning period. These include, but may not be limited to, the Teslin River North- and South mainstem, Hundred Mile Creek, and the Morley River.	individual streams have not been monitored or characterized.	

Yukon River South Mainstem

Table A7: Limiting factors table for Chinook from the South main stem of the Yukon River detailing current knowledge about the nature of potential limiting factors as well as their severity, extent, frequency and direction of change by life stage.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Egg deposition, incubation	Short-term climatic/hydrologic variation resulting in dewatering/freezing/reduction of flow through redds, or eggs being deposited in sub-optimal habitats at extreme low flows. Long term trends to lower annual flows in some spawning streams. Effects of sediment inputs from naturally occurring instability, with sands/silts filling redds post egg deposition resulting in reduced egg-to-fry survival. Effects of hydroelectric development, and specifically the conversion of the Yukon River to a reservoir above the Whitehorse Rapids and Lewes River dams. Effects of beaver damming spawning streams after egg deposition has occurred, and specifically the conversion of stream to pond.	Climatic/hydrologic and sediment effects vary locally, from catastrophic to no effects. Effects of extreme high flows are most pronounced in spawning rivers with limited lake storage/buffering. Small spawning streams are most subject to extreme low flows. Conversion of rivers to reservoirs or streams to ponds may result in stock reduction or extirpation.	Climatic/hydrological effects will apply to all spawning areas. Natural sediment inputs will affect all areas. Spawning streams subject to the effects of very low flows include M'Clintock River (above the mouth of Michie Creek), Michie Creek and Wolf Creek. The Yukon River spawning stock above Miles Canyon has been extirpated by the Whitehorse Rapids Hydro Dam due to backwater effects on spawning areas. Post spawn conversion of streams to ponds and back flooding of redds has occurred on Michie Creek.	Climatic/hydrological effects are constant and unpredictable. These include, either directly or indirectly, high and low waters, sediment release and transfer, and variation around poorly defined hydrometric and water temperature trends.	River flows appear to be more variable, and effects of high and low water periods are expected to increase. Episodic releases of sediment from deep seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing, with increased effects. The existing Yukon Energy Corporation facilities and operations have extirpated the Yukon River Chinook spawning stock above Miles Canyon.
Fry emergence	Short-term climatic/hydrologic variation in severity and timing of spring breakup, resulting in fry being exported from spawning streams or the Watershed.	Export of emergent fry has not been measured. Stranding is variable.	All spawning areas	Some degree of export is expected in all years, with increasing proportion of total Watershed production during more severe freshets.	Insufficient information to speculate.
Rearing	Short-term climatic/hydrologic variation resulting in reduced quantity of habitat in low water years, decreased quality of	Locally and temporally variable, from catastrophic to no effects. Low flows and warmer water temperatures are thought to have	Rearing habitat is currently widespread within the Watershed and includes spawning areas, migration routes and portions of all	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be	Flows appear to be more variable, and effects to rearing fry are expected to increase as a result. Episodic releases of sediment

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	habitat (low water temperatures, limited food supply) in high water years. Displacement of fry from rearing areas occurs at high flows. Competition with hatchery fry may occur early in the growth season. Land instability results in sands/silts/clays filling streams and reducing abundance of available food organisms. Obstruction of upstream migration occurs in natal or non-natal streams by beaver dams. Abstraction of water from rearing stream for irrigation is an emerging issue. NOTE that each rearing stream or river provides rearing services to fry from most or all upstream Chinook Salmon stocks and that fry produced in this Watershed may rear in streams located outside of it.	less severe effects than high flows and related lower water temperatures on habitat quantity/quality. Effects of natural- and sedimentation and channel responses may be locally/temporally profound and otherwise are related to the concentration of sediment and duration of discharge. During dry years or multiples thereof beaver activity may result in Chinook fry being denied access to much or most high quality habitat, causing decreased growth and fitness following the first summer of life. Demand for irrigation is greatest during dry years and may dry up rearing streams.	non-spawning tributaries. Climatic /hydrological effects will apply to all rearing areas. Sediment inputs from natural/semi-natural landslides, active layer detachments following forest fires, and slope deflations will affect all rearing areas. Obstructions to upstream fry migration by beaver are widespread. Competition with hatchery fry is limited to M'Clintock River and Michie Creek. Potential conflicts with agriculture are focussed in the Takhini River drainage. Note that fry produced in this Watershed may rear in all downstream waters.	episodic and short duration. Obstruction of fry migration to upstream rearing habitats is most common during dry years and particularly during multi-year droughts. Release of hatchery fry occurs annually. Threats from irrigation are greatest during low water years or multi-year droughts. Rearing takes place in so many streams of such different hydrological characteristics and over such an extended distance (i.e., at least as far as the US/Canadian border) that only coarse resolution relationships with meteorological or hydrometric data can be derived.	from deep-seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing. Obstructions to upstream migration by beaver will trend with local stream flows and social acceptance of beaver control. The Yukon dry-land agricultural land quantum is increasing, with a consequent increase in risk to Chinook rearing habitat. Releases of artificially propagated fry have increased with the Fox Creek Stock Restoration Project, although at little apparent effect on natural stocks.
Over-wintering	Short-term climatic/hydrologic variation may result in decreased high quality ground water discharge into overwintering areas following low water summers. Reduced quantity/quality of overwintering habitats resulting from natural fine sediment deposition on preferred cobble/rubble stream bottoms. Obstruction of access by fry to overwintering habitats by beaver dams. Increased risk of predation from mammalian	Locally and temporally variable, from catastrophic to no effects. Kills of overwintering juveniles may occur due to poor water quality or insufficient quantity. Potential overwintering areas may be choked with sediment, denying it's use by fry. Upstream migration to prime overwintering habitats may be obstructed by beaver dams. Concentration of overwintering fry in small areas may result in high mortality from predatory mammals.	Overwintering habitat is currently considered widespread within the Watershed. Short-term climatic/hydrological effects will apply to most overwintering areas. Sediment from natural sources will periodically reduce the capacity of most overwintering areas. Beaver are numerous. Dams on ground water fed channels or low gradient stream reaches may persist for extended periods, obstructing multiple year classes of fry from access to overwintering areas. Mink	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be of short duration. Beaver dams may persist for extended periods. Frequency of predation variable, and depends on population size of predators - may be affected by the price of furs/energy of trapper.	Flows appear to be more variable, and effects to overwintering fry are expected to increase. Effects of sedimentation are expected to remain relatively constant. The beaver population is probably at the carrying capacity of its habitats and effects (on a Watershed basis) will remain constant, albeit effects will vary locally. There is insufficient information to be able to determine changes in predation.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	predators when fry are concentrated in small overwintering areas. NOTE that each rearing stream or river provides overwintering habitat to fry from most or all upstream Chinook Salmon stocks, and that significant numbers of fry produced in this Watershed may overwinter outside of it.		and otter pose a high risk to concentrations of juveniles. Note that fry produced in this Watershed may rear in all downstream waters.		
Smolting, estuarine residence	Changes in the timing of ice break up leading to mismatch between outmigration timing (which can be driven by timing of ice breakup) and prey availability during early marine life. Short-term climatic/hydrologic variation resulting in low spring water temperatures and delayed out-migration of overwintered yearlings.	Locally and temporally variable.	May affect all yearling salmon.	Though variable, the timing of ice break up has been getting earlier over time. Recent water temperature monitoring initiatives may provide insight to the frequency of cooler than normal springs.	All indications are that the timing of ice break up will continue to be earlier and earlier in the spring. Negative effects of lower water temperatures are probably declining due to climate change and trend to warmer, earlier springs.
Juvenile and sub-adult marine	Changing oceanographic conditions and increased abundance of other Pacific salmon species leading to reduced food in the ocean and increased competition (either directly or indirectly) for available resources.	Unknown, likely to be significant but temporally variable.	All salmon within the watershed.	Oceanographic influences are constant but their effects are unpredictable.	Unknown.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Freshwater entry, upstream migration	Short-term climatic/hydrologic variation resulting in low water/warm water conditions in the Yukon River downstream of the confluence with the Teslin River. This period/distance of thermal stress may be associated with decreased fitness in returning adults and an increased risk of parasitism and disease. Entry into and up smaller, lake dominated streams may be obstructed during low water/warm water years either due to channel characteristics or beaver activity. Delays by migrating fish caused by the Whitehorse Rapids Dam, particularly during warm water/low water years.	Severity of decreased fitness or increases in parasitism can vary from no measurable effect to death. Obstruction of migration upstream in spawning rivers by beaver may result in loss of one or more year classes and possibly extirpation of the stock. Delays at the Whitehorse Rapids dam have been associated with pre-spawn mortality in warm/low water years.	Temperatures in the mainstem Yukon River above Whitehorse approach levels of concern in warmer summers. Spawning streams with limited lake storage such as Wolf Creek are expected to have colder waters lake dominated streams. Small, lake dominated streams are present in the watershed and the effects of obstruction of entry and upstream migration may be of concern. These streams include the Ibex River, the Mendenhall River, McIntyre Creek, Wolf Creek and Michie Creek.	Effects on adult fitness are not monitored. Recent water temperature monitoring initiatives and WSC data may provide insight to the frequency of low water/warm water years. Parasites (*icthyophonus*) were investigated during the last warm water/low water period. Acquired knowledge and results of the present water temperature monitoring network may allow prediction and back casting to determine frequencies over extended periods	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability. Effects of obstruction can be modified through monitoring and beaver management. The operation of the Whitehorse Rapids Fishway may mitigate the entry of returning Chinook if the operators are skilled.
Spawning	Short term climatic/hydrologic variation resulting in episodic extreme high flows during the spawning period in non-buffered streams resulting in reduced stock productivity, or extreme low flows in smaller streams resulting in inadequate velocities and depth of water for spawning adults and increased risk of predation by mammals. Sediment from natural sources and placer mining degrading spawning habitats. Lack of fitness related to thermal stress throughout the upstream migration or increased parasitism resulting in	Locally and temporally variable. A significant portion of the spawning stock for a river may be lost in a single flood event or as a result of very low flows, associated high water temperatures and delays in spawning. Sections of spawning rivers may be sedimented so heavily that spawning cannot occur for years or decades. Decreased fitness or increases in parasitism may result in pre-spawn mortality through exhaustion or predation, partial spawn, reduced egg to fry survival.	All spawning Chinook will be subject to short-term climatic/hydrologic variation, including the periodic effects of elevated water temperatures during their upstream migration. Small(er) rivers and streams, and particular lake dominated streams may have water temperatures approaching or exceeding levels of concern during the normal spawning period. This includes but may not be limited to Michie Creek and the Mendenhall River.	Frequency of flood events on mid-sized or larger watersheds could be determined from WSC hydrometric monitoring. Smaller and more isolated spawning streams are less easy to determine as individual streams have not been monitored or characterized. Effects of back watering from the Whitehorse Rapids hydro dam are ongoing.	Flows appear to be more variable, and water temperatures are expected to also be more variable. Effects are expected to increase but there will be significantly inter-annual or longer variability.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	decreased spawning success. Back water effects from the Whitehorse Rapids Hydro dam.				

Porcupine River

Table A7: Limiting factors table for Chinook from the Porcupine River detailing current knowledge about the nature of potential limiting factors as well as their severity, extent, frequency and direction of change by life stage.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Egg deposition, incubation	Short-term climatic/hydrologic variation resulting in dewatering/freezing/reduction of flow through redds. Effects of sediment inputs from land instability, particularly sands/silts filling redds post egg deposition resulting in reduced egg-to-fry survival.	Locally and temporally variable, from catastrophic to no effects.	Climatic/hydrological effects will affect all spawning areas. Sediment inputs will affect all areas.	Climatic/meteorological effects, constant and unpredictable. Sediment from natural sources, episodic releases from landslides, slope instability following forest fires and thermokarst has greatest effect on spawning rivers, and the few constant releases will have the least.	River flows appear to be more variable, and effects of low water periods are expected to increase. Episodic releases of sediment from deep seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing, with increased effects. Overall, stress on this life stage is probably increasing.
Fry emergence	Short-term climatic/hydrologic variation in severity and timing of spring breakup, resulting in fry being exported from rivers or isolated in pools/back channels in flood plains	Export of emergent fry has not been measured. Stranding is variable.	All spawning areas	Some degree of export and stranding expected in all years; high degree in early and violent ice off episodes	Export of and stranding of emergent fry are thought to be increasing.
Rearing	Short-term climatic/hydrologic variation resulting in reduced quantity of habitat in low water years, decreased quality of habitat (low water temperatures, limited food supply) in high water years, and displacement of fry from rearing areas at high flows. Effects of sediment inputs results in sands/silts/clays filling streams and reducing available food organisms. Use of non-natal streams by Porcupine River Chinook Salmon has not been confirmed.	Locally and temporally variable, from catastrophic to no effects. Low flows and warmer water temperatures are thought to have less severe effects than high flows and related low water temperatures on habitat quantity/quality.	Rearing habitat is less well investigated than in other Canadian rivers, and use of non-natal streams has not been confirmed. Climatic/hydrological effects will affect all rearing areas. Sediment inputs from natural/semi-natural landslides, active layer detachments following forest fires, and slope deflations will affect all rearing areas.	Climatic/meteorological effects are constant and unpredictable. Sediment from natural sources tends to be episodic and short duration.	Flows appear to be more variable, and effects to rearing fry are expected to increase. Episodic releases of sediment from deep seated landslides, surface slips following forest fires, and permafrost related slope deflation appear to be increasing.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
Over-wintering	Short-term climatic/hydrologic variation results in decreased high quality ground water discharge into overwintering areas following low water summers. Climate change-related increased discharges of low quality ground water into over wintering habitats from melting permafrost. Reduced quantity/quality of overwintering habitats resulting from natural- or placer mining associated fine sediment deposition on preferred cobble/rubble stream bottoms. Obstruction of access by fry to overwintering habitats by beaver dams. Increased risk of predation from mammalian predators when fry are concentrated in small overwintering areas.	Locally and temporally variable, from catastrophic to no effects. Kills of overwintering fry due to poor water quality have been recorded. Potential overwintering areas have been observed to be choked with sediment from upstream landslides and placer mining. Upstream migration to prime overwintering habitats has been obstructed by beaver dams. Removal of most or all fry from an isolated overwintering area by mink has been observed	Overwintering habitat may be limited in this Watershed. Most of the land surface was not glaciated. Precipitation and snowmelt drain quickly. Winter stream flows from unglaciated areas are very low and tend to be anoxic and high in total dissolved solids. Short-term climatic/hydrological effects will affect most overwintering areas. Sediment from natural sources may have only a small effect on the overall amount of overwintering habitat. Mink and otter along floodplains of larger rivers and pose a high risk to concentrations of juveniles.	Climatic/meteorological effects are constant and unpredictable. Climate change related low quality ground water discharges are ongoing. Sediment from natural sources tends to be of short duration and from placer mining of long duration, extending from years through decades. Frequency of predation variable, and depends on population size of predators - may be affected by the price of furs/energy of trapper.	Flows appear to be more variable, and effects to overwintering fry are expected to increase. Climate change related discharges of low quality ground water into overwintering areas are expected to increase. Effects of sedimentation are expected to remain relatively constant. There is insufficient information to be able to determine changes in predation.
Smolting, estuarine residence	Changes in the timing of ice break up leading to mismatch between outmigration timing (which can be driven by timing of ice breakup) and prey availability during early marine life. Short-term climatic/hydrologic variation resulting in low spring water temperatures and delayed out-migration of overwintered yearlings.	Locally and temporally variable.	May affect all yearling salmon.	Though variable, the timing of ice break up has been getting earlier over time. Recent water temperature monitoring initiatives may provide insight to the frequency of cooler than normal springs.	All indications are that the timing of ice break up will continue to be earlier and earlier in the spring. Negative effects of lower water temperatures are probably declining due to climate change and trend to warmer, earlier springs.
Juvenile and sub-adult marine	Changing oceanographic conditions and increased abundance of other Pacific salmon species leading to reduced food in the ocean and	Unknown, likely to be significant but temporally variable.	All salmon within the watershed.	Oceanographic influences are constant but their effects are unpredictable.	Unknown.

Life stage	Nature of factor/threat	Severity	Extent	Frequency	Change
	increased competition (either directly or indirectly) for available resources.				
Freshwater entry, upstream migration	Short-term climatic/hydrologic variation resulting in low water/warm water conditions in the Yukon River in Alaska associated decreased fitness in returning adults and an increased risk of parasitism and disease.	Severity of decreased fitness or increases in parasitism can vary from no measurable effect to death.	Not monitored, but possibly high during low water/warm water years as upstream migration occurs during maximum day length periods.	Effects on fitness not monitored. Recent water temperature monitoring initiatives may provide insight to the frequency of low water/warm water years. Parasites (icthyophonus) were investigated in the US during the last warm water/low water period. Acquired knowledge and present water temperature monitoring network may allow prediction and back casting to determine frequencies over extended periods	Effects are expected to increase due to Climate Change, but the rate of change will be obscured in inter-annual or longer variability.
Spawning	Short-term climatic/hydrologic variation resulting in episodic extreme high flows during the spawning period and reduced stock productivity. Lack of fitness related to thermal stress or increase parasitism resulting in decreased spawning success.	Locally and temporally variable. There is a higher risk of catastrophic flows as none of the spawning rivers in the Watershed are lake buffered, and an entire year class may be lost in a single flood event. Decreased fitness or increases in parasitism may result in pre-spawn mortality, partial spawn, or reduced egg to fry survival.	Not monitored, but possibly low due to cool temperatures in spawning rivers	Frequency of flood events on mid-sized or larger watersheds could be determined from WSC hydrometric monitoring.	Effects are expected to increase due to Climate Change, but the rate of change will be obscured in inter-annual or longer variability.

Appendix B: Restoration actions and objectives tables

Little Salmon Carmacks First Nation (Carmacks)

TableB1: Summary notes from meetings with Little Salmon Carmacks First Nation in July of 2015. See Section 5.1 for further details.

Objectives	• Increase overall salmon abundance. • Sustain cultural connection; have fish camps come alive again, passing skills and traditional knowledge down to next generations.
Chinook observations	• Fish have been smaller and there has been a decline in numbers, extremely noticeable since about a decade ago.
Limiting factors	• Concerns with placer mining in Big Creek watershed; some LSCFN members are not convinced that placer creek spawning grounds will ever go back to how they once were. • Concerns with placer mining in upper Nisling (Nansen, Victoria Creek, Klaza River area). • Lots of mining development in nearby tributaries is still proposed. There are big placer operations happening currently in Big Creek. At Williams Creek, there is a mine ready to open. At the mouth of the river at Big Creek, sediment has been built up very high. • The barge at Minto Mine reaches right across the river. • Jet boats are constantly ripping up and down the river from the Casino project (http://www.casinomining.com/project/). • Ocean fishing. • Concern over the use of acid-generating rocks in salmon spawning grounds in the area- this was a big deal a few years ago when bridge on Tachun Creek was rebuilt; stabilising rocks came from Minto mine site. There was also a second creek in LSCFN's traditional territory (potentially called 13 mile South), which was reinforced with riprap. There was a third area by Little Fox Lake where riprap was once used too; once the origin of rock for these projects was determined, it was a major red flag for LSCFN. Tatchun Creek is a major salmon spawning ground. LSCFN doesn't know whether the rock is acid generating or not and don't know if it's being monitored. • Pressures on the Tatchun Creek area: there is a public boat launch, a popular recreational fishery, land use conflicts, DFO use for the Salmon in the Schools project egg take from Tatchun, Yukon College electroshocking fishery site (LSCFN objected to this out of Tatchun Creek), a mistreated fish camp by the public, etc. At one point, DFO also had a weir in Tatchun Creek without letting Little Salmon Carmacks First Nation know. • Climate concerns: Up some creeks, there is warmer water, ice is no longer feeding creeks, and varying silt levels have been observed.

Past restoration activities	• Has been some beaver dam removal on the Tatchun, Nordenskjold and at Braeburn Lake about a mile up from the campground. • Beaver dam removals on Klusha Creek. By 2001, had completed breaching dams up to Twin Lakes. That fall observed salmon spawning up to nearly Twin Lakes. • In July 2014 some LSCFN and RRC members did a stream walk at Tatchun Creek to assess that troublesome beaver dam that was mentioned. They had started trying to do a pilot project on baseline data to count spawning salmon. They assessed the creek; noticed a lot of large pike and merganser ducks eating small fry. • Some willow planting has occurred through MERG (Mining Environment Research Group- I think now called MPERG- Mining and Petroleum Environment Research Group) in the Big Creek watershed area 10-15 years ago; this was seen by LSCFN as a successful project. • Since 1999, have had salmon return to Cash Creek near Nordenskjold, near Division Mountain. • The Habitat Conservation Stewardship Programme was well-received and worked well in Carmacks. Al was involved and can elaborate further on this initiative, which included signage, camps etc.
Proposed or potential restoration activities	• At Tatchun Creek, there are some concerns about salmon not migrating past a large beaver dam. LSCFN wouldn't go intervene there because they need more information about breaching dams properly. For example, if fry are in the area, they don't want to flood them out. There is an opportunity for more education and training in this area. • Increased watershed planning, water quality assessments, look into programs with insects as an indicator of creek health. • A useful tool would be an evaluation of Yukon Chinook restoration projects, examining what's worked and what has not.
Chinook population(s)	• Tatchun, Mica, Nordenskjold were mentioned. • Seymour Creek is also a significant creek. There was a placer operator near the mouth, but restoration activity was great there and the area was restored really well ecologically. We don't want anyone to return there again for a while since it *has* been restored so well.
Key uncertainties	• Lack of data in the region; they don't have several years of baseline data collection, no data on predator to fry ratios. • Not enough studies are being done on impacts of mining, dams, etc. More work needs to be done on metal leaching, specifically copper leaching. When metal levels are increased in tributaries, there are concerns that this disturbs the olfaction of migrating salmon. Concerns with Minto Mine water license and use of riprap in Tatchun Creek were of concern (http://www.yukon-news.com/news/mine-waste-rock-in-creek-raises-concerns/). • A temperature-related change is a key uncertainty.

Selkirk First Nation (Pelly Crossing)

Table B2: Summary notes from meetings with the Selkirk First Nation in July of 2015. See Section 5.1 for further details.

Objectives	• Chief and Council and Selkirk's Lands department stressed that managing salmon must occur with traditional knowledge at the forefront. TK used to always be at the forefront when speaking about management. Everything is limiting First Nation rights and interests. TK is extremely important and Selkirk First Nation wants TK to be at the forefront of management. • Improve overall salmon abundance. • Ensure that cultural fisheries, stewardship and outreach are incorporated into stock restoration initiatives. • Most important: sustain cultural connection with salmon and continue to fish whenever possible on Pelly stocks.
Chinook observations	• Numbers are down, the fish are smaller. In the 80s, caught around 24 fish a day. • Females with big eggs come at the end of the run and that 15 % of Canadian stock is Pelly River stock.
Limiting factors	• Think it is not First Nation harvest that is causing decline. They said they really don't know what is causing population decline. • The Pollock fishery was mentioned and the possibility this is taking away from a food source for Chinook. • Are hatchery fry disturbing natural fry, removing a food source for them? • No major habitat issues around Pelly they can think of that would decrease numbers as much as they have, • Warming waters. • Lots of seagulls fishing for fry at the mouth of the Pelly River. • From the mouth of Mica Creek to Tatelman Lake is important area for them. The creek at the mouth of Tatelman is drying up. • Pelly River is the most important to them. There are some beaver dams there that may be an issue. • They said salmon are swimming by the mouth of Micah Creek and instead going to Sheldon Lake. • Towhata Lake, where whitefish originally lived is now all weeded in.
Past restoration activities	• There was lots of monitoring work done in the early 1990s by Paul Sparling and by Laberge Environment- they were assessment reports, where they went into creeks and determined if intervention required- most were R&E projects.

Proposed or potential restoration activities	• Selkirk FN is very keen to take action and get going on a stock restoration project. They are tired of talking and ready to become action-based. They are keen to get started and want some direction. Elder showed up at the meeting, noted she would be keen to share her traditional knowledge with YSSC if it would benefit stock restoration. This was only the very beginning and the very first meeting on this issue, and that he plans to have several other community gatherings and discussions about this. Selkirk's Chief and Council, as well as members of their Land department and RRC were in attendance. • Stream enhancement. • Bringing back traditional beaver hunts (specifically looking at removing beaver dams at Grayling Creek very soon). • Salmon hatchery considerations? Want more info on this. • Sonar station on the Pelly River? • They are not keen on feasibility studies, etc. They are keen to get action going. • Keen to set traps for beavers if needed.
Chinook population(s)	• Pelly River is the most important to them. • From the mouth of Mica Creek to Tatelman Lake is important area for them.
Key uncertainties	• Lack of data. • Since can't fish, lack of knowledge of current catch composition

First Nation of Na-Cho Nyak Dun (Mayo)

Table B3: Summary notes from meetings with the Na-Cho Nyak Dun First Nation in July of 2015. See Section 5.1 for further details.

Objectives	• Biggest objective is just to increase overall salmon abundance: "People just want more fish. They just want to be able to go fishing again; they're not talking about genetic diversity, etc." • Want to increase wild stocks. • The cultural aspect is extremely important to NND. Want to be able to fish to renew their culture, not have their fish camps empty.
Chinook observations	• DFO has the majority of statistics and data here. • As a kid, they would catch hundreds of fish between 3 to 4 families at the fish camp her family attended. The last time they attended fish camp was four years ago, and they caught around 4 fish. It just wasn't worth it with the expenses of gas, food, etc. for the weekend to catch so few. The size has dropped significantly. There are pictures from 30-40 years ago, when salmon caught were nearly the size of people.
Limiting factors	• Big concerns with placer mining at McQuesten River, Haggart Creek. At Haggart Creek, there is quartz and placer mining happening. Haggart Creek flows into the McQuesten River; close to the confluence of the McQuesten and the Stewart, significant proposals are in for placer mining, some of which have recently been approved. • Beaver dams may be preventing adult spawners from returning to some of their spawning grounds. • Yukon Energy dam in the Mayo River is an issue. Some winters, flooding occurs and they then have to excavate a channel, which may interrupt gravel for salmon spawning.
Past restoration activities	• Hatchery Release Program at Lower May River below Yukon Energy's dam- there is a rearing channel Yukon Energy put in there for salmon. • 20 or 30 years ago, a community member said they did an egg take and then released them. • Refer to DFO for any past projects.
Proposed or potential restoration activities	• Looking at doing some hatchery work at Upper Mayo River, above the dam. This is currently in the planning stages; want this project to coincide and be in alignment with egg take incubation and release program. Eggs would be incubated at NND and at JV Clark School in Mayo. • Mentioned a new form of incubation they are interested in hearing more about that allows fish to incubate in-stream. • NND is currently testing to find a good site for a Sonar system, funded by the Yukon River Panel. Between August 6 and 14, they will be testing sites on the Stewart River (similar to what they have done on the Porcupine River) with EDI Environmental Dynamics. The goal is to have a sonar system there permanently. They are doing this because there is currently no data on how many salmon are migrating up the Stewart River.

Chinook population(s)	• Stewart River, Haggart Creek, 17 mile and Frasier Falls (those are the most accessible areas for NND folk). • Janet, McQuesten, Mayo tributaries also of importance. • They noted that Yukon Development Corporation is currently looking at another hydro project at Fraser Falls.
Key uncertainties	• Lack of data. • "We at NND haven't changed anything. We have been doing the same thing for years. We want proof that stopping fishing is having some sort of impact because thus far, we haven't seen that stopping harvesting has made any sort of difference to stock numbers. We have good habitat, good water, we aren't fishing; there is no local reason we can think of as to what would have decreased stock numbers, other than placer mining impacts in local streams." • It would be helpful to know if anyone is studying the health of fish coming through; are there any poisons in their bodies? • We can't think of anything else it could be.

Carcross Tagish First Nation (Carcross)

Table B4: Summary notes from meetings with the Carcross Tagish First Nation in July of 2015. See Section 5.1 for further details.

Objectives	• Haven't been salmon in these tributaries for a long time. Objective would be to get some salmon back in these systems, period, and to reactivate cultural connection to salmon.
Chinook observations	• Major decrease in abundance of salmon. Changes have been observed in this region mainly since Yukon River dams were put in: the Lewes dam has caused a lot of river problems. Its 1922 construction caused a loss of muskrats as well as a loss of salmon. Also the 1958 Whitehorse Rapids Dam construction (http://www.hougengroup.com/yukon-history/yukon-nuggets/whitehorse-rapids-dam/) and 1969 rebuild of Lewes River dam have been disruptive.
Limiting factors	• Construction of the two dams. • Two big flood events; septic tanks popping out of ground. • How creosote is having an effect from leakage nearby. • Fuel dumps along the Alaska Highway potentially. • Not cold winters like used to have- could this be affecting overwintering juveniles?
Past restoration activities	• No fish, so no restoration activities. • Looking at flow regimes on Pennycook- data loggers in use.
Proposed or potential restoration activities	• Just received funding from the Pacific Salmon Foundation to undertake traditional knowledge with elders this summer, to discuss traditional salmon knowledge in CTFN's traditional territory.
Chinook population(s)	• McClintock River and Michie Creek.
Key uncertainties	• Lack of data and lack of knowledge of composition of catches since haven't fished for a long time.
Key contacts	• Lawrence Ignace- Director, Heritage, Lands and Natural Resources: 867-821-4251 ext. 8222, lawrence.ignace@ctfn.ca

Ta'an Kwäch'än Council (Whitehorse)

Table B5: Summary notes from meetings with the Ta'an Kwäch'än Council in July of 2015. See Section 5.1 for further details.

Objectives	• None discussed.
Chinook observations	• Lower numbers, smaller males, overall size decreased, within last two decades.
Limiting factors	• Our salmon are just not getting to their spawning grounds. • Just guessing reasons: overharvest, climate change, fleets in ocean (Chinook bycatch) • In 2010, since regulations on bycatch enacted, should start to see increase since not fishing. Would think would see more fish coming back to spawning grounds, but we aren't. And also, with fishermen along the Alaskan side taking less fish and with smaller net sizes, but still is not reflected in numbers returning.
Past restoration activities	• Fox Creek- hatchery project since 2006/07. Incubating fish in McIntyre Hatchery, releasing at Fox Creek. Fox Creek chosen because known to be salmon there historically but citizens hadn't seen them there in 50 years. Once TKC learned of McIntyre hatchery program, partnered up with EDI Environmental Dynamics, determined what to do in 2006/07. This project is now in its last stage, its 8th year. (http://www.yukon-news.com/business/first-salmon-return-to-fox-creek/ http://www.cbc.ca/news/canada/north/chinook-salmon-returning-to-yukon-s-fox-creek-1.1863813) • Fry release programs and temperature monitoring in various other tributaries in TKC traditional territory.
Proposed or potential restoration activities	• If Fox Creek proves to be unsuccessful as a hatchery release site, would like to explore other tributaries for hatchery projects. Recognising a lot of other First Nations have asked a lot of questions about our program, happy to assist with education for other First Nations interested in hatchery programs. • May be interested in opportunities around Hootalinqua or 30 mile.
Chinook population(s)	• McClintock • Michie Creek • Croucher Creek
Key uncertainties	• Lack of data. • Haven't been able to fish, so don't know what catch composition would be.

Tr'ondëk Hwëch'in (Dawson City)

Table B6: Summary notes from phone call with the Tr'ondëk Hwëch'in in July of 2015. See Section 5.1 for further details.

Objectives	• Improve overall salmon abundance • Improve wild salmon abundance • Improve salmon spawning distribution • Sustain genetic diversity • Sustain salmon contribution to ecosystem health • Increase aboriginal FSC harvest abundance • Improve aboriginal FSC harvest distribution • Ensure that cultural fisheries, stewardship and outreach are incorporated into stock restoration activities
Chinook observations	• From 80s, population started to decline, size started to decrease. These changes have been more and more prevalent in last few years; sex ratio skewed with more males. Elders said jacks have always been present (there is a name for Jacks in Hän language) but they are more prolific now.
Limiting factors	• Because of Commercial fishing, some have pointed at commercial fishermen at 40 mile (late 70s, 80s and early 90s); commercial fishermen having deeper nets than they were supposed to. A number of elders feel that contributed to decline in size and numbers. • Strong feeling that Alaskan subsistent harvest gets a lot of fish for dog teams (factor present in the past). • People are concerned with marine environment on the whole and with activities such as high-impact trawling. • Ocean productivity; is there enough fish as a food source for Chinook in the Bering Sea? • Could the nuclear power plant incident in Fukushima be linked? • Climate Change; changing temperatures and chemistry. • Some may attribute placer mining, but people feel placer mining has changed quite a bit. e.g. Up Bonanza Creek, was muddy years ago, and today it's running clear in the height of placer mining season. • Jetboating up the Klondike….years ago, some local community members visited a community on Lower Yukon River through the Yukon River Intertribal Watershed Exchange. In this community, jetboating was prohibited on the river due to being salmon spawning grounds. After hearing that, some TH Members are concerned about the impact of jetboating stirring up the river near Dawson.

Past restoration activities	• In 2003/04, TH was involved with a bank stabilization project for rearing habitat on the banks of the Klondike River. • There was sonar project on the Klondike River that Brian Mercer ran. • There was a screw trap on the main stem to identify timings for juvenile smolt departures (10+ years ago). • Tix Tanner (DFO Biologist) had an instream incubation project on the Klondike…don't think it worked out well, but there was some study on it.
Proposed or potential restoration activities	• This year there will be broodstock taken off the Klondike. • TH has proposed further feasibility work for a potential hatchery. An application is for R and E support. • Will continue to discuss stock restoration options with DFO. • There are some TH citizens that would like to move forward with some form of artificial propagation (broodstock would be from Klondike river. Study pointed out that Klondike was best to get broodstock from).
Chinook population(s)	• Klondike River, Candida was notable spawning grounds, 40 mile was in the past (but heavy placer mining last number of decades; good rearing habitat for juveniles but not sure for spawning), Stewart, not sure about the 60 mile- don't know of any fish camp up there.
Key uncertainties	• Haven't been able to put finger on what are limiting factors for Chinook population. • Is habitat a limiting factor? We don't really know because we haven't had the numbers passing through to be able to tell.

Kwanlin Dun First Nation (Whitehorse)

TableB7: Summary notes from review of documents provided by Kwanlin Dün First Nation in August of 2015. See Section 5.1 for further details.

Objectives	• Salmon are of paramount importance to KDFN culture. Being able to fish again (increased abundance of fish) and sustaining cultural connection to salmon is the objective. • Ensure that cultural fisheries, stewardship and outreach are incorporated into stock restoration activities: "We need to pass a real strong resolution to try and get our word into these management and committee boards that do speak about the fish and wildlife".
Chinook observations	• Lower numbers and fish not running where they used to anymore. Similar observations to other First Nations.
Limiting factors	• Text from *King Salmon River M'Clintock River Watershed Management Planning and Michie Creek Chinook Salmon Field Investigations 2003:* I. Concerns, Issues and Risks to Salmon: • Elders' Concerns ○ Decline in fish numbers- many talked about how they can no longer fish salmon. There are not enough salmon. ○ Whitehorse dam and its effect on fish- the Elders talked about how the construction of the Whitehorse dam had affected the numbers of salmon coming through. They remember their parents talking about the decline in numbers. ○ Whitehorse Fish Ladder- the Elders consider the fish ladder structure to be an unnatural way for the salmon to bypass an obstacle such as the dam. They are concerned that it puts additional stress on the fish, and as a result, the fish are arriving at M'Clintock in poorer shape than if there were no obstacle. This affects quality of the fish for eating. ○ Whitehorse Fish Hatchery- tags and fin clipping- Elders are concerned about the tags the hatchery puts on the fish. Elders talked about how people they know who have been alarmed seeing the fins cut off the fish. They indicated they didn't have enough information to understand what the hatchery is doing by cutting off fins and attaching tags, and if it has an effect on fish. ○ Whitehorse Hatchery- mix of wild and hatchery stocks. There was discussion about the effect of releasing hatchery fish into the wild system and interfering with nature. There is concern about the mixing of the stocks, although the practice of seeding a stream with a female's eggs was traditionally practiced to make salmon go back to a certain stream. They also indicated they didn't have enough information about what the hatchery was doing. ○ Overfishing- Elders are concerned about overfishing. They believe that some people are taking too much fish- more than they need. ○ Changes experienced by dam and highway- people were affected in many ways. ○ Lack of respect for the camps and equipment- they reported 'tourists' wrecking their things. In the past, they could leave cabins open and gear in the bush with an understanding it would be respected. Now they find things get taken. ○ Lower water levels; the Elders notice the water level in the M'Clintock is lower. They are concerned about how that affects fish. ○ Boundaries and having to get permission- in the past they could fish anywhere and everything was shared. Now you have to get permission from another First Nation. Kwanlin Dun has to go to another First Nation's Traditional Territory to fish. ○ Kitty Smith told a story about some electronic device killing salmon, just like driftwood.

	• Terrain Hazards and the Spawning Area:
	  ○ Michie Creek spawning grounds lie in narrow valley- susceptible to permafrost thaw and forest fires...reduction in vegetation by fire reduces insulation cover of soil...leads to soil instabilities and landslides. Early 2000s landslide documented on north-facing hill slope above Michie Creek spawning area. Impacts of a large landslide on spawning area could be severe, lead to siltation of creek. If slide large enough, Al Von Finster said could dam up creek entirely.
	• Potential risks to Salmon from Current and Potential Future Land Use Activity:
	  ○ In M'Clintock Valley and Marsh Lake area, increase in year-round residents, proximity to Whitehorse and easy access by existing roads and trails has led to increase in rec activities in many watershed parts, including known Chinook spawning areas:
	    ▪ potential siltation of spawning areas as result of vehicles crossing waterbodies.
	    ▪ increased use of jet boats; possible juveniles be sucked into jets during downstream salmon migration. Also, erosion in mid and late summer concern as wake that washes up on shore causes fine sediments to become suspended in water, increasing turbidity of the river; resulting limitation in sunlight can reduce plant growth and invertebrate populations, thereby reducing salmon's food supply.
	  ○ Agricultural use in area; risk of fertilizers leaching into M'Clintock River or Michie Creek, (D. Murray, personal communication, Oct. 2003). Effects of erosion have been minimised by ensuring setback distances from streams and waterbodies.
	  ○ Effects of fire suppression activities- could create more environmental damage than fire itself (D. Milne, personal communication, Nov. 2003). E.g., Building of fire guards, heavy equipment use, dropping of aerial retardants and foam. Proven that fire-fighting chemicals are very toxic to fish.

Past restoration activities	• KDFN has conducted several studies to understand salmon resources in their Traditional Territory. For past 17 years, Yukon River Panel funding has allowed for various restoration related activities on Michie and M'Clintock, such as juvenile capture, stock assessment, monitoring of water quality/health, some obstruction removal (of beaver dams) and creek walks. • See ' 2014 Michie Creek Monitoring Project' prepared by Nick de Graaf and KDFN: assessment of migratory habitat in Michie Creek to ensure that adult salmon were not obstructed and the monitoring of stream flows and temperatures in the primary Chinook salmon spawning area in upper Michie Creek.

Proposed or potential restoration activities	• As per *Geis Too'e: King Salmon River M'Clintock River Watershed Management Planning and Michie Creek Chinook Salmon Field Investigations 2003, I.*
	• *Recommendations for Next Steps: 2004/2005*:
	  ○ identify potential land uses in KDFN rural blocks in watershed
	  ○ additional assessment of potential risks to salmon from human and natural disturbances
	  ○ additional consideration of numbers of fish returning, escapement, and KDFN's Basic Needs Allocation under the UFA to examine ways in which the numbers of fish returning to the M'Clintock can be increased
	  ○ identify actions for addressing potential risk factors, such as:
	    -KDFN policies for land uses
	    -fire management plan
	    -KDFN resolutions to General Assembly regarding salmon
	  ○ growth trial in hatchery to mimic sizes found in nature.

	○ continued stewardship activities monitoring and removing beaver dam and logjams. ○ assessment of Byng Creek to describe habitat and map redds. ○ genetics and the need to explore the availability of using historic scale structures for DNA to compare with other stocks including Robert Service Way population. ○ JCS diet and benthic studies in Michie Creek after hatchery plantings.
Chinook population(s)	• M'Clintock Watershed • Michie Creek • Marsh Lake

Teslin Tlingit Council (Teslin)

Table B8: Summary notes from meeting with Teslin Tlingit Council in August of 2015. See Section 5.1 for further details.

Objectives	• Increase wild salmon abundance (leery of hatchery solutions and impacts that could have on wild stocks, such as hatchery salmon outcompeting wild salmon when they're young and other concerns that came out of a stock restoration workshop in Whitehorse last year): it was mentioned by a TTC citizen, "If going to hatchery enhancement projects, we have to be committed forever. That's a concern for TTC." • Reinvigorate a cultural connection with salmon (TTC Citizen has said, "Last time I was at fish camp, I was a boy. I'll be 60 next year. Some of our youth have never experienced fish camps in their lives.") TTC has been flying in Sockeye salmon from the Taku River to keep the fish culture somewhat alive, but it's not the same and the flown-in fish are more difficult to dry (more fat on them than Teslin Chinook).
Chinook observations	• Lower numbers • More males • Smaller fish • Used to put net in for a couple nights, then 5 day closure, then put net back out. Haven't fished in 17 years, so unsure of composition of catches today.
Limiting factors	• No major local impacts they can think of, but in brainstorming, the following were mentioned: ○ Wonder about some of the high waters Teslin has recently been getting in recent years and if that could have some impacts; some years, major flooding, concerns about beaver dams, but people don't think beaver dams are as big of an issue as they were in the past; they do make a barrier, but you still see fry above the dam, so they're getting over it somehow. Lots of beaver dams that were once problems are now washing themselves away with recent high waters in recent years. ○ Climate change impacts on water levels a concern ○ Warming waters
Past restoration activities	• TTC does temperature monitoring, measures ice thickness • In 2003 there was project with EDI- they did a compilation of mapping related to Chinook salmon in the area: Went to the traditional territory and documented species in it, determined if Chinook are spawning or rearing in certain areas, if there were freshwater species in those areas, etc. • Salmon in the Schools program is important. • Past beaver dam removal: Unsure if past beaver dam removal has been successful or not since they didn't monitor or have data of how many salmon were there beforehand. This relates to a capacity issue within TTC to go back and look through past restoration projects. • Culverts have been fixed up in the past to allow salmon migration and that made a difference

Proposed or potential restoration activities	• Starting in August 2015, TTC has partnered with EDI as a Yukon River Panel project to undertake stock restoration preparatory work: EDI will be traveling into TTC traditional territory to do an update to 2003 compilation of salmon mapping. They will try to determine if streams are suitable for in-stream incubation (if TTC can help wild stocks without operating a hatchery). They want to determine what the limiting factors are. • TTC sees no point in putting in money and capacity until the limiting factors of stock restoration in their region are determined.
Chinook population(s)	• All areas of Teslin watershed
Key uncertainties	• So many stock restoration activities have happened over the years, but there is a lack of capacity at TTC to go back through the data and a lack of monitoring to answer "was that restoration action effective?" • Reiterate the point that TTC has been very busy in regards to stock restoration.

Appendix C: Inventory of past restoration and enhancement actions in the Canadian portion of the Yukon River Watershed

Table C1: Brief summary of past restoration and enhancement actions undertaken in the Canadian portion of the Yukon. When available Yukon River Panel R&E fund project numbers are provided. For additional details on the types of actions described see Sections 5.1-5.8.

Action	Watershed / Chinook population(s)	Type of action	Summary of Actions	Other
1	Yukon River, North Main-Stem: Klondike River Sub-Watershed		**1990 to 2004:** The Yukon River Commercial Fishers Association (YRCFA) and Tr'ondëk Hwëch'in partnered together on R&E projects on the North and South Klondike. From **1992 to 1995** tagged juveniles were released to the Klondike River.	DFO and the YG library system may have additional documents. Around 2009, Roberta Joseph with the Tr'ondëk Hwëch'in (TH) led an initiative to conduct a feasibility study for a Chinook hatchery in their traditional territory. In 2015, Natasha Ayoub with TH submitted a proposal for R&E funding for a conservation hatchery training institution coordinator. CRE-106-16N
2	Yukon River, North Mainstem: Germaine Creek		**2003:** Soil Bioengineering Demonstration Project. Site was assessed by private consultants, planning took place in late 2003, live staking conducted in 2004. Site monitored systematically until 2006, and then at a reduced frequency and level of detail until 2013.	CRE-87N-03 to CRE-87-06
3	Stewart River Watershed: South McQuesten River		**2001 and 2002:** Nacho Nyak Dun (NND) used hand tools to excavate a channel to provide passage around the 200+ meter long Haggart Creek Log Jam.	**2008:** Monitoring was completed and the new channel remained effective. CRE-30-01
4	Stewart River Watershed: Mayo River		Hatchery built at what is now the Wareham Lake Power Generating Station and produced fry for release into the Mayo river in 1991 and 1992. Hatchery was then abandoned.	The program was initiated in the late '80's by the Mayo Renewable Resource Council and the Stewart Valley Salmon for the Future Society. Funding was provided largely by YTG/Canada Economic Development Agreements.
5	Stewart River Watershed: Mayo River		Groundwater fed channels were excavated in 2004 and annual monitoring was completed in 2008.	There is current interest in establishing a hatchery facility on the Mayo River below the Wareham dam to restore Chinook on the Mayo River.

Action	Watershed / Chinook population(s)	Type of action	Summary of Actions	Other
6	Stewart River Watershed: Fraser Falls		There is a possible natural barrier when the water is under certain levels. Enhancing passage through construction/excavation of a fishways has been a topic of discussion for decades. In **2010**, the community was consulted and the majority rejected any modification to the falls.	CRE-119N-10
7	Yukon River Mid Main-Stem Watershed: LSCFN Traditional Territory		**2000:** The Little Salmon Carmacks First Nation (LSCFN) conducted a Beaver Management Workshop and determined which creeks should be managed for the benefit of salmon, including Tatchun and Klusha creeks	
8	Yukon River Mid Main-Stem Watershed: Tatchun Creek		**2000, 2001, 2002, 2003:** LSCFN and DFO have repeatedly breached beaver dams. Obstruction monitoring and management is required annually to ensure migratory adult access upstream	CRE-03-00, CRE-13-01 to CRE-35N-03
9	Yukon River Mid Main-Stem Watershed: Tatchun Creek		**1991 to 2012**: Eggs harvested from the creek nose-tagged fry were released	
10	Yukon River Mid Main-Stem Watershed: Nordenskiold River		**2000 to 2004:** Beaver obstructions were managed	CRE-16-00, CRE-16-01, CRE-55-02 and CRE-55-03
11	Yukon River Mid Main-Stem Watershed: Klusha Creek		**1996 to 2004:** Beaver obstructions were managed.	**1999:** Detailed mapping by LSCFN and Yukon Conservation Society **2001:** Successful salmon spawning. **2004:** Stream had dried and the stock was considered to be extirpated. CRE-35-04
12	Pelly River Watershed: watershed level		**2000:** Selkirk First Nation (SFN) conducted the Pelly Beaver Management Workshop; Decision made to maintain salmon access to Towhata Lake; Obstruction management occurred.	
13	Pelly River Watershed: Willow Creek		**1998 and 1999:** Assessment took place. **2000:** SFN's Pelly Beaver Management Workshop decision made to maintain juvenile salmon access to the rapids.	

Action	Watershed / Chinook population(s)	Type of action	Summary of Actions	Other
14	Pelly River Watershed: Needle rock Creek		**1999:** Obstruction management became the focus following a stock & habitat assessment by SFN	
15	Teslin River Watershed: Swift River (north)		**2001:** Assessment coincided with obstruction management for spawning Chinook	CRE-35-01
16	Teslin River Watershed: Deadman Creek		**2001:** Assessments have coincided with obstruction management and stock restoration studies	
17	Teslin River Watershed: Deadman Creek		**2015:** TTC have identified Deadman Creek as a candidate for stock restoration; R&E proposal submitted for 2016: *Deadman Creek Chinook Salmon Restoration Pilot Project and In-Stream Egg Incubation Trial.*	JTC/YRP feedback on 2016 proposal recommends Morley for stock restoration. CRE-18-16
18	Yukon River South Main-Stem Watershed: Fox Creek	 	*Ta'an Kwäch'än Fox Creek Salmon Restoration Project* **1997 to 1998:** Pre-assessment. **2006 to 2008:** Pre-assessment. **2008:** Plan prepared and permits acquired; Brood stock acquired from the Whitehorse Rapids Fishway; Eggs incubated at Whitehorse Rapids Fish Hatchery (early) and McIntyre Creek Fish Hatchery (remainder of incubation period). **2009 to present (2015):** Fox Creek stocked with fry	**2015:** Plan ends, evaluation and renewal is under discussion. CRE-16-97, CRE-54N-06, CRE-52N-07 and CRE-54-14.
19	Yukon River South Main-stem Watershed: Takhini River		**1990 to 2008:** Eggs were harvested from the Takhini river, incubated at the McIntyre Incubation Facility, and nose-tagged fry were released into the Takhini River. **Goal:** Stock Restoration and limited assessment of returning adults. Releases summarized in JTC report, some fry produced were planted in Flat Creek (tributary to Takhini) with limited numbers returning to the creek.	McIntyre Creek Incubation Facility in Whitehorse is a separately augmented project for stock restoration and enhancement. CRE-15-98, CRE-65-02 to CRE-65-12
20	Yukon River South Main-Stem Watershed: McIntyre Creek		**1989:** Inception of the McIntyre Creek Incubation Facility. Site of eyed egg incubation for the present Fox Creek Restoration Project. Produced fry for Takhini, Flat and Tatchun Creek augmentation projects	Spring fed facility; Has been used for education, outreach, rehabilitation of prisoners from the Whitehorse Correctional Center and natural stock augmentation. CRE-15-98, CRE-65-02 to CRE-65-14

Action	Watershed / Chinook population(s)	Type of action	Summary of Actions	Other
21	Yukon River South Main-Stem Watershed: McIntyre Creek	Unintended consequence of an industrial activity	**Mid-1950s:** Fish Lake outflow was diverted to Porter Creek and thence to Lower McIntyre Creek after which the Chinook Salmon population in McIntyre Creek developed organically (no releases of fry).	
22	Yukon River South Main-Stem Watershed: McIntyre Creek		Obstruction monitoring and, as required, management has to be conducted annually to ensure the adults can ascend the creek.	
23	Yukon River South Main-Stem Watershed: McIntyre Creek		**2005:** A berm was constructed to reduce the risk of the McIntyre Creek flowing through a contaminated site. **2014:** Plans were prepared for additional works	
24	Yukon River South Main-stem Watershed: Wolf Creek		**1984 to present:** Annual fry release from Whitehorse Rapids Fish Hatchery. **Objective:** Restoring a poorly documented Chinook Salmon population.	**Results:** Low returns, creek now stocked during a public release to raise public awareness. Release numbers low.
25	Yukon River South Main-stem Watershed: Wolf Creek		Obstruction monitoring and, as required, management conducted annually to ensure the adults can ascend the creek. **2003 & 2006:** The Whitehorse Rapids Fishway Staff, The Yukon Fish and Game Association and local residents monitored the creek and conducted obstruction management	Local residents breach beaver dams to allow upstream migration during at least some years. CRE-64N-03 and CRE-64N-06
26	Yukon River South Main-stem Watershed: Wolf Creek		**Late 1980s:** A stream side, surface water fed incubation box was installed but failed due to frazil ice blocking the inlet pipe	
27	Yukon River South Main-stem Watershed: Wolf Creek		**Barrier to upstream migration**: Adult Chinook were unable to migrate upstream past a sheet pile wall below the Alaska Highway Crossing during low flows **1986**: A weir-and-pool fishway was constructed but failed relatively quickly. **1997/1998 to present:** An off-channel concrete fishway was constructed in 1997 and completed in 1998. It requires significant annual maintenance to operate effectively. (RE-22-97)	

Action	Watershed / Chinook population(s)	Type of action	Summary of Actions	Other
28	Yukon River South Main-stem Watershed: Yukon River above Wolf Creek		**2006 to present:** Fry releases from the Whitehorse Rapids Fish Hatchery. **Goal:** to restoring a major spawning group. **Monitoring results**: Inconclusive	**1880s:** First documented major spawning group. CRE-134N-10 and CRE-16-14.
29	Yukon River South Main-stem Watershed: M'Clintock River and Michie Creek		**1984 to Present (2015):** Fry releases commence from the Whitehorse Rapids Fish Hatchery. **Goal:** maintaining the Yukon River Chinook Salmon above the Whitehorse Rapids dam. **Other fry release sites:** Byng Creek, a tributary of Michie Creek below Michie Lake; Fox Creek, a tributary of Michie Lake; Judas Creek, the main stem Yukon and in the M'Clintock River downstream of the falls. Mitigation for Whitehorse Rapids Hydro Project.	Other fry release sites were used In an attempt to reduce the risk of exceeding the capacity of Michie Creek when the hatchery capacity was ~400K. Fry were released to Wolf and Michie Creeks and to the Yukon River main stem and M'Clintock River (below the falls).
30	Yukon River South Main-stem Watershed: M'Clintock River		Chinook fry stocked in the M'Clintock River below the falls in anticipation of a fishway being constructed following the signing of the Yukon River Salmon Agreement. **Outcome:** Stocking ceased due to the R&E fund not being able to support the expense of construction and maintenance of the proposed fishway.	
31	Yukon River South Main-stem Watershed: M'Clintock River		**1999:** Monitoring and obstruction management was first conducted. **2001 to present:** Continuous/annual monitoring and obstruction management**.**	Kwanlin Dun First Nation (KDFN) has shown much interest in the M'Clintock River. KDFN developed a watershed plan for the M'Clintock River. CRE-19-01, CRE-50-02 to CRE-50-07, and CRE-51N-07 to CRE-51-14

Appendix D: Inventory of past stock and habitat assessment action in the Yukon.

Table D1: Brief summary of past stock and habitat assessment actions undertaken in the Canadian portion of the Yukon. When available Yukon River Panel R&E fund project numbers are provided.

Watershed / Chinook population(s)	Summary of Actions	Other
Yukon River - Canadian portion	**1999:** Traditional information on salmon was gathered; Archival information on salmon was gathered.	CRE-17-98
Yukon River North Main-Stem Watershed & lower Stewart: watershed level	**1997:** Archival information on salmon was gathered.	CRE-05-97
Yukon River North Main-Stem Watershed: watershed level	**2006 to present (2015)**: The DDRRC has conducted a Community based Stream Stewardship Program.	CRE-06-06 to CRE-06-15
Yukon River North Main-Stem Watershed: Coal Creek	**2002:** Stock and Habitat assessment conducted.	CRE-08-02
Yukon River North Main-Stem Watershed: Fifteen Mile River	**1997:** Stock and Habitat assessment conducted.	
Yukon River North Main-Stem Watershed: Twelve Mile (Chandindu) River	**1998 to 2004:** An enumeration weir was operated to determine whether the stock was large enough to support an egg take and out-plant program as part of a region-wide stock restoration program.	CRE-01-98, CRE-01-99, CRE-13-02, CRE-13-03 and CRE-13-05
Stewart River Watershed: watershed level	**1993:** Local information gathered.	
Stewart River Watershed: McQuesten River	**1998:** Stock restoration plan started by NND which included investigating potential ground water incubation sites along the Silver Trail and Klondike Highways). **2003:** A second plan was developed.	CRE-01-97 and CRE-20-02
Stewart River Watershed: Crooked Creek	**1997 and 1998:** Stock & habitat assessment conducted by Stewart Valley Salmon for the Future Society.	CRE-01-97 and CRE-31-98
Stewart River Watershed: Mayo River	**Late 1980's:** Mayo Renewable Resource Council and the Stewart Valley Salmon for the Future Society initiated a program to restore Chinook salmon stocks in the Stewart River Watershed.	
Stewart River Watershed: Mayo River	A feasibility study for a Chinook enumeration fence on the Mayo River was prepared, and the fence operated for at least one year.	
Stewart River Watershed: Mayo River	**2003:** Chinook rearing habitat downstream of the Mayo Hydro was assessed. **2004:** Groundwater fed channels were excavated. **2008:** annual monitoring was completed.	CRE 19N-03 to CRE 19N-08

Watershed / Chinook population(s)	Summary of Actions	Other
Stewart River Watershed: Janet Creek	**1996:** Stock and habitat assessment conducted by Stewart Valley Salmon for the Future Society in 1996.	
Stewart River Watershed: Ollie Creek - tributary to the Hess River	**2002:** Stock and Habitat assessment conducted by private individual**.**	CRE-39-02
White River Watershed: watershed level	**2002, 2003 & 2004:** Local, traditional and scientific/technical information was collected.	CRE-44-02, CRE-53N-03 and CRE-58-03
White River Watershed: Nisling River	**1998:** Stock and habitat assessment conducted by White River First Nation (CRE-34-98).	
White River Watershed: Tincup Creek	**2000, 2001:** Stock and habitat assessment was conducted by the Kluane First Nation.	White River First Nation. CRE-11-00 & CRE-33-01
White River Watershed: Snag Creek	**2001:** Stock and habitat assessment conducted by White River First Nation. No salmon were found.	White River First Nation. No salmon were found. CRE-25-02
White River Watershed: Upper White River	**2001:** Stock and habitat assessment conducted by White River First Nation. No salmon were found.	White River First Nation. No salmon were found. CRE-44-02
Yukon River Mid Main-Stem Watershed: watershed level	**2010:** Local, traditional and scientific/technical information was collected by Little Salmon/Carmacks First Nation.	CRE-141N-10
Yukon River Mid Main-Stem Watershed: Tatchun Creek	**1997 to 1999:** Stock and habitat assessment was conducted by a private contractor. Activities included a fish counting fence, juvenile trapping and habitat assessment.	CRE-34-98 and CRE-03-99
Yukon River Mid Main-Stem Watershed: Nordenskiold River	**1999 to 2003:** Stock and habitat assessment in the upper river was conducted by the Champagne and Aishihik First Nation.	
Pelly River Watershed: watershed level	**1980's through 1990's:** Water quantity/quality testing took place in the vicinity of Pelly Crossing to determine whether a ground water fed incubation facility could be constructed.	
Pelly River Watershed: watershed level	**2002:** An assessment of tributaries of the lower Pelly and Macmillan Rivers was conducted in 2002.	CRE-27-02
Pelly River Watershed: watershed level	**2000:** Selkirk First Nation conducted a Beaver Management Workshop to determine which creeks should be managed for the benefit of the salmon and which should not.	Selkirk First Nation
Pelly River Watershed: watershed level	**2005-2007:** The Selkirk Renewable Resources Council conducted a Community based Stewardship Program.	The Selkirk Renewable Resources Council CRE-31N-05 to CRE-31-07
Pelly River Watershed: Mica Creek	**2001 and 2002**: Low flows were monitored and assessed.	Laberge Environmental Services. 2002. Overwintering Habitat (Low Flow) Survey Mica Creek and Willow Creek – Pelly River Tributaries, March 2002. Prepared for Selkirk First Nation. 8 p and Appendices. CRE-09-01 and CRE-28-02
Teslin River Watershed: Teslin River (downstream of Johnson's Crossing.)	**1997:** Assessment of habitat in Chinook rearing tributaries.	CRE-08-97

Watershed / Chinook population(s)	Summary of Actions	Other
Teslin River Watershed: Nisutlin River and Teslin Lake	**1998:** Assessment of habitat in Chinook rearing tributaries.	CRE-20-98
Teslin River Watershed: Swift River (north)	**2001:** Assessment coincided with obstruction management for spawning Chinook.	CRE-35-01
Teslin River Watershed: Deadman Creek	**2001:** Assessments have coincided with obstruction management and stock restoration studies.	
Yukon River South Main-stem Watershed: watershed level	**2004:** Local/traditional and scientific/technical information for the Ta'an Kwachan Traditional Territory collected	Ta'an Kwäch'än Council CRE-93N-04
Yukon River South Main-stem Watershed: watershed level	**2006-2012:** Ta'an Kwäch'än conducted a community stewardship program.	Ta'an Kwäch'än Council CRE-54N-06 to CRE-54-12
Yukon River South Main-stem Watershed: watershed level	**2002 and 2003:** City of Whitehorse commissioned a fish GIS data base and restoration plan for the City of Whitehorse in 2002, and a detailed plan in 2003.	City of Whitehorse
Yukon River South Main-stem Watershed: Takhini River	**1998:** The Mendenhall River and downstream tributaries were assessed. **2002 and 2003:** The upper Takhini River and tributaries to Kusawa Lake were assessed by Champagne and Aishihik First Nations.	Champagne and Aishihik First Nation CRE-15-97 CRE-54-02 CRE-54-03
Yukon River South Main-stem Watershed: Wolf Creek	**1998:** A counting fence was operated in the lower creek to enumerate returning. adults	Provided a good evaluation for outplants. CRE-27-98
Yukon River South Main-stem Watershed: Michie Creek	**1998 and 1999:** The Yukon Fish and Game Association operated a counting fence on Michie Creek.	CRE-27-98 CRE-02-99).
Yukon River South Main-stem Watershed: Monkey Creek, tributary to Marsh Lake	**1998:** Habitat assessment.	CRE-06-98

Appendix E: Backgrounder: Beaver and Salmon in the Canadian Sub-Basin of the Yukon River.

Prepared by: Al von Finster.

Introduction

Beaver (*Castor canadensis*) co-occupy salmon ranges in North America. Interactions between beaver and salmon at any specific location depend on the species of salmon present and their behaviour. The behaviour of different populations of salmon reflect local or regional adaptations to latitudinal and elevational locations and related geomorphological, hydrological and climatic conditions. The present and past effects of human activities are also considerations. This backgrounder will be geographically confined to the YRCSB and the Chinook salmon and fall chum Salmon (*O. keta*) occupying it. It focuses on specific types of streams where beaver activities may negatively affect the upstream migration of these salmon, their spawning success and productivity of habitats. The historical and current context is provided, followed by the salmon species and their specific vulnerabilities. The background is concluded with an account of the past management of obstructions in the YRCSB and a proposed Obstruction Management Protocol.

Historical Context

Beaver, salmon and people have co-occupied the YRCSB since the recession of ice at the end of last glacial period. Beaver were dispersed across the landscape as small, sedentary colonies. The salmon and the people were migratory. Salmon were generally trapped at fish camps. Wildlife, including beaver, were harvested annually in the areas surrounding fish camps. Simply stated, salmon fed the people and the people ensured that the salmon could return to, and ascend, their spawning streams.

Large-scale fur trapping and trading in the YRCSB began after the international beaver fur market collapsed in 1843. The depletion of beaver characteristic of much of North America did not occur. There were no competing landscape-level land uses such as cattle ranching or crop based agriculture in the YRCSB. Beaver are legally considered a fur bearer. Since 1952 only the holder of the trapping concession on which they reside can kill beaver. The market for beaver pelts collapsed in the 1950s. Beaver populations in the YRCSB probably exceeded pre-contact levels by 1980 and have remained high.

Current Context: Reconciliation of Scientific vs Local/Traditional Knowledge

Many of the effects of beaver on salmon are difficult to investigate scientifically, in part as science is most effectively conducted in controlled environments. The YRCSB is an uncontrolled environment: the small(er) spawning streams are unregulated; the annual precipitation and resulting stream flow is variable; the annual distribution of beaver and intensity of their effects are uncertain; and salmon returns to specific spawning streams small enough to be vulnerable to the effects of beaver cannot be predicted. There are currently no long-term salmon stock assessment programs on streams vulnerable to the effects of beaver.

Funding cycles lock scientific researchers into study plans designed far in advance of the field work required to collect data. At best these plans are based on past environmental conditions and biological responses to them. The conditions during the period when the data collection is actually conducted may be significantly different than the assumed conditions. The Scientific community is generally composed of graduates from mid latitude institutions. They tend to default to the knowledge developed in, and relevant to the geographical areas in which they received their education. Current mid-latitude Scientific/Technical perspectives on beaver are that the mammal is a positive influence on fish and fish habitat.

Local Knowledge of the effects of beaver on salmon is based on observations not directly related to a systematic scientific evaluation. Local Knowledge may include direct observations by First Nation, Territorial or Federal government field staff, independent consultants or citizens. Most local information supports the position that beaver dams can obstruct the upstream migration of fish, including salmon.

Traditional Knowledge is the property of the First Nation holding it, and may include both observational information and the interpretations of the oral record incorporated into Traditional Law. Yukon First Nations have been supportive of beaver management in streams supporting valuable populations of migratory fish, inferring that the activity is in accordance with Traditional Knowledge and Law.

Salmon Species and Vulnerabilities

As noted in the Introduction, the YRCSB is considered to only support populations of Chinook salmon and Fall Chum Salmon. This simplifies assessment of the potential effects of beaver dams on salmon. Both species are addressed below.

Chinook Salmon

<u>Adults</u>

Adult Yukon River Chinook salmon ascend and spawn in streams and rivers. Watershed areas vary from over 100,000 km^2 to less than 400 km^2. Populations using larger watercourses are not vulnerable to beaver dams regardless of hydrological conditions. Adults using the smallest streams are vulnerable to disruption under virtually all hydrological conditions. Populations using intermediate sized watercourses may be vulnerable during seasonal - or multi -year (drought) low flow conditions. During severe droughts watercourses with drainage areas in excess of 3000 km^2 may be dammed by beaver. In 1999, for example, beaver were able to dam the Nordenskiold River above the mouth of Klusha Creek which denied access to the upper about 80 km of river. This included two of the three primary Chinook spawning areas along the river.

Certain small(er) streams support large populations and high densities of adult Chinook Salmon. These streams tended to have had fish camps at, or near, their mouths in the past. An example is the Tatchun River, a tributary to the Mid-Yukon Mainstem near Carmacks. In 1997 a total of 1198 adult were enumerated at a counting fence near the mouth. Spawning occurs in a ~5,000 meter reach of the creek between the Klondike Highway bridge and the outlet of Tatchun Lake. The creek is nominally 6 meters wide, giving a calculated density of one adult for every 25 m^2 of stream bottom.

The greatest effect beaver dams have on adult Chinook salmon is the obstruction of upstream migration, particularly during low - water/clear - water/warm - water conditions in small(er) streams. When most severe, significant portions of the preferred spawning habitat may be inaccessible: an example of this occurred in 2010, when a large dam on the Tatchun River obstructed the upper ~4.1 km of the ~5 km spawning area.

A second effect on adult Chinook salmon is the conversion of spawning streams to beaver ponds. Chinook do not spawn in the still waters of beaver ponds. Eggs in salmon redds that become backwatered after spawning occurs will not develop into fry. A beaver dam built in the early summer of 2015 in the Tatchun River backwatered about 350 meters of prime spawning habitat. The river did not flow over the crest of the beaver dam, but instead crossed the forest floor as overland flow. The river did not substantially return to its channel until ~150 meters downstream of the beaver dam. The total effect of this single beaver dam was to remove ~10% of the total spawning habitat of the Tatchun River.

A third effect is limited to creeks and rivers that flow from lakes. Beaver dams located at the lake outlets can result in storage of significant volumes of water. These dams are likely to remain in place for long periods as a consequence of the lake buffering high flow events. When the dams do fail, they tend to do so catastrophically and result in an outwash flood. An example of this is Janet Creek, a small spawning stream entering the Stewart River above Mayo. Janet Lake, from which it flows, has a surface area of ~15 km^2, or 15,000,000 m^2. The lake outlet is subject to periodic beaver damming. Failure of a 1.5 m high dam at the lake outlet would result in the rapid release of 22,500,000 m^3 of water. This has happened in the past: results of floods in the lower valley include a large log bridge that was lifted from its abutments, carried downstream and deposited beside the creek.

Juveniles

Many or most young-of-year Chinook leave the streams they were born in, move downstream into larger rivers and then enter non-natal streams to rear and overwinter. Young-of-year Yukon River Chinook salmon have only ~90 to ~130 days to feed and build up fat reserves to last them through the winter. It is important that they have unobstructed access to as much habitat as possible.

The primary effect of beaver dams on young-of-year Chinook is to obstruct or delay the upstream migration in these non-natal streams. Some young-of-year Chinook will be able to ascend over (or through) most dams, and most Chinook will be able to ascend over some dams. Multiple dams on a stream will have a cumulative effect on the upstream migration of juveniles. A large concentration of young-of-year Chinook immediately below any beaver dam will provide adequate evidence that the dam is an obstruction. Young-of-year Chinook captured above a beaver dam and pond that are significantly larger than those captured below the dam is evidence that the dam has been an obstruction for a considerable period of time.

Fall Chum Salmon

Yukon River Fall Chum salmon spawn from September to October in ground water discharge areas in back channels, side channels or main channels of large rivers. These areas are sometimes referred to as “upwelling” areas. Juveniles migrate to the sea very early, generally at - or around annual ice out flow.

The only negative effect of beaver dams on Fall Chum is to obstruct entry into spawning areas in ground water fed sloughs-and blind side channels. Fall Chum Salmon appear to have little ability to ascend over even a small beaver dam. In the Kluane River a ground water fed side channel that had been used annually by 2000+ spawning Chum was dammed in the late 1980s. No Chum were subsequently observed spawning upstream of the dam.

Management of the effects of beaver dams on salmon in the YRCSB

As a general statement, activities to manage the effects of beaver dam obstructing Yukon River Salmon must take place in a legal manner and receive the appropriate social license. The activities should also be cost effective and conducted in the most efficient manner possible.

Methods of managing the effects of beaver on salmon in most mid-latitude areas (BC, US West Coast) are based on not removing beaver from the problem area. These methods include a variety of structures to reduce the potential for beaver to dam a specific section of creek, or to provide upstream passage of targeted species of salmon or other fish over - or through a specific dam. Of importance, there is a greater human population, a correspondingly greater density of interests, and significantly more financial resources and community investment in aquatic systems in mid-temperate areas than in the north. This is a critical consideration: any structure placed in the creek will incur expenses to design, operate, maintain, monitor and rebuild. Costs to permit/license/authorize structures and to satisfy environmental assessment requirements may be several times the actual cost of the structure. The use of structures to managing the effects of beaver should only be considered if a long term financial commitment can be made by the proponent to take responsibility for the structure over its designed life and to decommission it at the end of that life.

In the YRCSB the main means of managing the effects of beaver on adult salmon after the signing of the Yukon River (Interim) Salmon Agreement was to breach those dams which were obstructing the upstream migration of adult salmon or posed a reasonable risk of doing so. Most beaver management projects were conducted by First Nations and explicitly included the removal of beaver from specific streams. There was considerable discomfort within the predominantly Whitehorse resident environmental and bureaucratic communities regarding the concept of removal of beaver for the benefit of fish. American technical members of the Yukon River Joint Technical Committee reviewing Restoration and Enhancement Fund applications and providing advice to the Yukon River Panel were generally from the US Pacific West Coast and imported their beliefs regarding fish-beaver interactions from there. A significant administrative burden was placed on any organization applying for funding for beaver management projects, as there was an expectation that the effects of each dam would be assessed to scientific standards leading to a decision would be made regarding what action to take. A plan would then be drafted and guide intervention. The results of the intervention would be monitored, an evaluation would be conducted and a report would be prepared to scientific standards. This was beyond the capacity of applicants.

The Interim agreement ended in 1997. The Yukon River Salmon Agreement was signed on December 4, 2002. The intervening period allowed DFO Salmon Enhancement Program staff an opportunity to modify existing DFO Habitat and Enhancement Branch evergreen Beaver Management Guidelines. Draft Obstruction Management Protocols were introduced in 2004, then tested and evaluated in 2005. This included applying the draft Protocols to Yukon River Panel funded stream stewardship projects. The proponents filled in an evaluation form after their project was completed. The Draft Protocols were referred to agencies likely to conduct beaver dam removal projects or to be involved in regulating the projects. Issues identified by parties in the evaluation were addressed, and the Protocols were implemented in 2006.

Concurrently, effort was expended by Yukon River Salmon Enhancement Program staff to educate US Federal and Alaska State employees in salmon and beaver interactions in the high, dry interior lands of the YRCSB. A period of relative stability in the US and Alaskan membership of the JTC allowed their concerns to be largely addressed and the Protocols accepted.

In April of 2007, the Protocols were presented to the Panel. The Protocols were to have been included in the contracts for applicable Restoration and Enhancement Fund projects funded in that year. The Yukon River Panel severed its relationship with the long-term Executive Secretary shortly after April 2007 and DFO assumed the role of Executive Secretary. Use of the Obstruction Management Protocol was not made a contractual obligation in 2007 or succeeding years. The Protocol continued to be offered to applicants until the 2010 funding year, but its use was voluntary.

An updated Protocol is detailed in the following section for consideration as a guidance tool for future projects. Updates to the Protocol generally address technological advances such as the development of digital cameras, smart phones and much wider availability of GPS. Note that the Protocol addresses only Obstruction Management, as this is the most pressing need. It does not address back flooding of productive spawning habitat or outburst flooding resulting from lake outlet beaver dam failure.

Obstruction management on small, productive and vulnerable Yukon River Chinook salmon spawning streams

Chinook in the Yukon River Canadian Sub-Basin spawn in a wide variety of stream sizes. These include a number of small streams. Certain of these small streams support significant spawning populations and are vulnerable to beaver damming at almost all flows. A larger number of streams are vulnerable under seasonal low flows or during multi-year low flow periods (droughts). The dams may obstruct the upstream migration of Chinook salmon to their preferred spawning locations or delay the migration. As the Chinook are at the end of a very long upstream migration, obstruction or delay could result in pre-spawn mortality due to exhaustion or predation. It could also result in adults spawning in lower quality habitats downstream.

There is no program or process to identify streams at risk of obstruction, although some streams have a known history of obstruction due to beaver dams. There is no process to classify streams to determine those which would deliver the greatest return on investment should an obstruction monitoring and intervention program be considered.

The Yukon Salmon Sub-Committee is well placed to manage a program to conduct annual monitoring and obstruction management on a small number of Chinook spawning streams. The streams would be identified and assigned priorities on the basis of an identification and classification processes. Funding provided by the Yukon River Panel could be topped up annually after receipt of the report detailing the preceding year's activities.

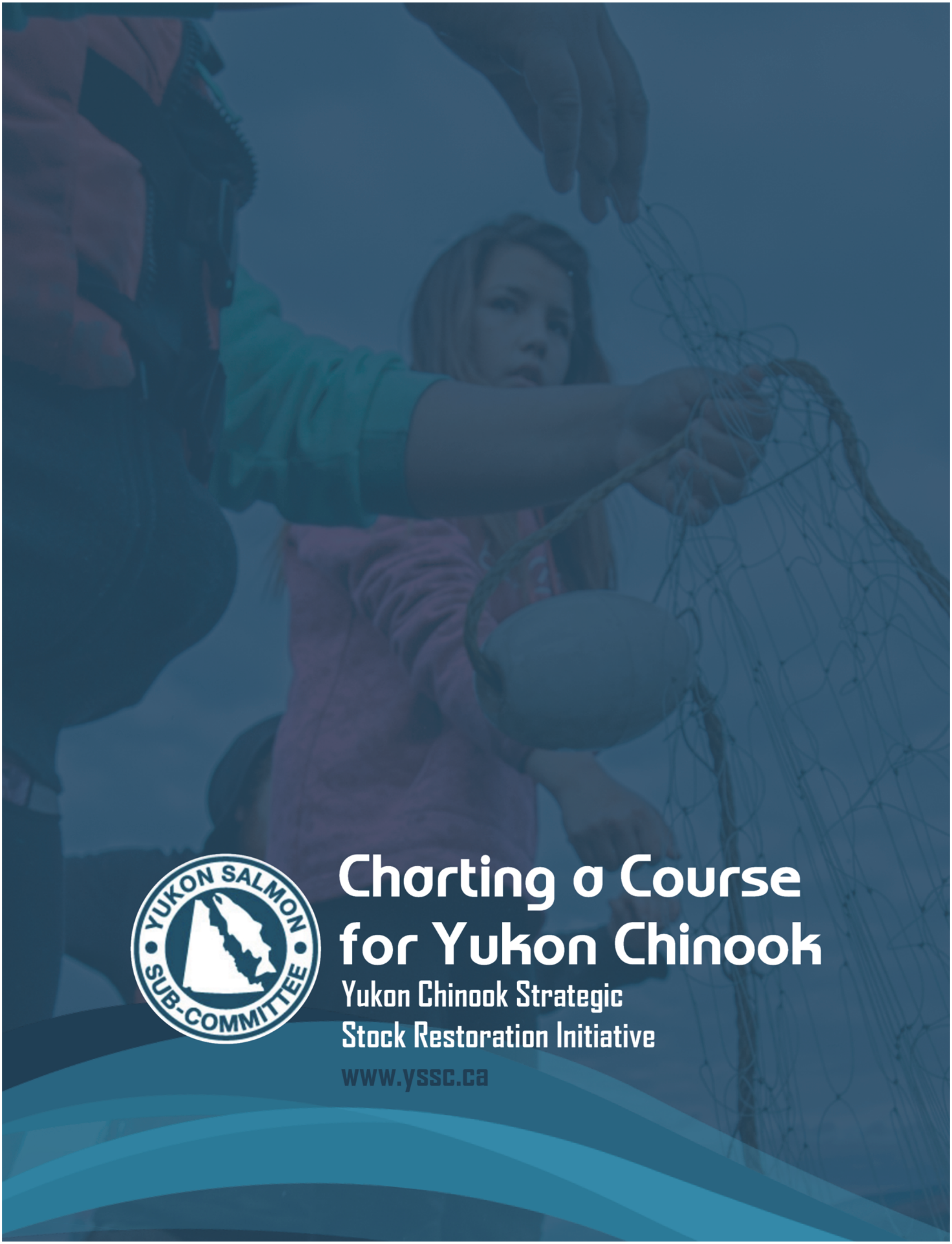
As a first action, spawning streams potentially at risk would be identified on the basis of watershed characteristics and areas. Streams with significant lake buffering and limited watershed areas would be at most risk and those with no lake buffering and large watershed areas above the limits of known spawning would be at least risk. The risk of seasonal or multi-year low water periods would be factored in. Existing information and knowledge would then be accessed to determine which streams had sufficient information for planning processes and which did not. Those streams at apparent high risk for which little information exists regarding present or past beaver activities could be field inventoried.

The next step would be to develop a classification process to determine which streams would provide a justifiable return on investment if obstruction management were to take place. Streams with small spawning populations would rank lower than those with large spawning populations; those that are easily and inexpensively accessed would be rated higher than those that were remote and expensive to access.

The final step in program design would be to develop a standardized reporting format. This would contribute to the development of a data base of obstructions. It would also assure the Panel that the funds had been expended appropriately and support the continuation of the Program.

Once the classification process was completed, the program would be operational. Timing of monitoring flights would have to be determined in consultation with DFO and possibly other agency staff. Flights could be timed immediately prior to the expected entry of the Chinook to the spawning streams or at some point after the salmon had entered. If a stream is observed to be obstructed a decision could be made to intervene through breaching the dam and complementary methods. Capable persons would be hired to do this through casual hire, preferably through local First Nations but potentially otherwise.

The field staff would be provided with a GPS, digital camera and a clipboard with the standardized form. The form would be designed to capture important information and to allow the field staff to enlarge on their observations should they wish to do so. The information gathered would be the basis of the annual report to the Panel.



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