Chinook Strategic Planning Initiative (CSPI): DRAFT Integrated Strategic Plan (V6)

IMPORTANT NOTES ABOUT THE CURRENT VERSION:

This is the “final” draft from the 2015/2016 phase of work on the Chinook Strategic Planning Initiative.

Although it has received substantial input from the Steering and Planning Committee (SPC) and the Technical Working Group (TWG), **it is still a DRAFT**. Additional review will still be required, especially within the broader communities represented by members of the SPC. Additional work is also required in some places.

Many of the key places where additional work is required are identified directly in this document. However, the vast majority of outstanding comments and questions that require further discussion and/or further work have been removed from this document and placed in the accompanying “Questions and Considerations” document. This companion document also indicates how/where substantive changes were (or were not) made based on the feedback received from the SPC and TWG.

Given that this document is a working draft, it will receive more thorough copy editing in future stages as it approaches its final state.

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List of Acronyms and Abbreviations

Acronyms and abbreviations used in the main text of the document. Acronyms and abbreviations that appear exclusively within tables, where they have been defined for the table, or within the appendices have not been included in this list.

COSEWIC	Committee on the Status of Endangered Wildlife Species in Canada	**MCC**	Marine Conservation Caucus
CSAB	Commercial Salmon Advisory Board	**MSY**	maximum sustainable yield
CSPI	Chinook Strategic Planning Initiative	**PDO**	Pacific Decadal Oscillation
CTC	Chinook Technical Committee	**PSC**	Pacific Salmon Commission
CU	Conservation Unit	**SARA**	Species at Risk Act
CWT	coded wire tag	**SBC**	southern BC
DFO	Fisheries and Oceans Canada	**SEHAB**	Salmon Enhancement and Habitat Advisory Board
DGM	Data Generation Model	**SFAB**	Sport Fishing Advisory Board
DO	dissolved oxygen	**SFU**	Simon Fraser University
ER	exploitation rate	**SPC**	Steering and Planning Committee
ESU	Evolutionary Significant Units	**S-R**	spawner-recruit
FNFC	First Nations Fisheries Council	**TSS**	total suspended sediments
FRAFS	Fraser River Aboriginal Fisheries Secretariat	**TWG**	Technical Working Group
FSC	Food, Social and Ceremonial	**WCVI**	West Coast Vancouver Island
FW	freshwater	**WSP**	Wild Salmon Policy
HHAT	Hatchery-Harvest Analysis Tool		

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Primary Strategic Goal

Problem Statement

The poor status of many Chinook salmon populations in southern British Columbia is a matter of great concern. In some cases, stocks have been declining since the 1990s despite actions taken to reduce harvest levels. This is a broad pattern, affecting stocks in a range of geographic areas including the Fraser River, the Strait of Georgia and the West Coast of Vancouver Island. These populations are facing a number of potential challenges, including:

- depressed and/or declining spawner abundance;
- reduced and variable freshwater and marine survival rates;
- high uncertainty about future production;
- pressures on freshwater habitat;
- total mortalities associated with harvest,
- increased predation, and;
- ecosystem effects from climate changes

There are some notable exceptions, as some populations have continued to be highly productive and/or increased substantially during this period, though the predominant pattern across Conservation Units has been one of declining abundance. The decline of many southern BC Chinook populations is a significant concern for First Nations, the Canadian public, commercial and recreational fishers, and conservation groups. While the status of Chinook is a conservation concern at the level of Conservation Units, local Chinook populations are of great importance to First Nations. First Nations access to food, social and ceremonial harvest opportunities have been impacted. Harvest restrictions and closures have been implemented in the commercial and recreational fisheries.

Furthermore, the current state of knowledge is highly variable across southern BC Chinook populations, some of which have excellent information and data but many have considerable gaps in knowledge. There is a critical need to increase learning and to strengthen the knowledge base. Strategies should be deliberately structured to reduce critical uncertainties affecting management decisions, so as to adaptively improve actions over time.

Goal Statement

To restore and maintain the abundance, distribution and diversity of southern BC Chinook salmon for all that rely on them.

Overview of Document

The Integrated Strategic Plan is organized into seven sections:

- **Section 1** introduces the document, including the broader context for the plan and the scope of the current plan;
- **Section 2** summarizes the current state of knowledge about the status and trends of southern BC Chinook;
- **Section 3** describes major threats that may be contributing to the observed trends in southern BC Chinook, as well as major gaps in our knowledge about the trends, the threats, and potential management actions;
- **Section 4** outlines an objectives hierarchy, with objectives for the strategic plan and potential indicators and performance measures;
- **Section 5** identifies a comprehensive set of strategies to address the objectives, threats and knowledge gaps;
- **Section 6** provides a preliminary foundation for the implementation of the strategic plan; and
- **Section 7** briefly introduces the need for reviewing the performance of the overall plan over time.

1 Introduction

1.1 Background and Context

1.1.1 Chinook Situation

Chinook salmon are very important to British Columbia -- ecologically, economically, and socially. Unfortunately, many Chinook salmon stocks in southern BC have shown decreases in abundance, repeatedly low escapements, and/or declines in fishery catches, especially over the last fifteen years. Although a small number of stocks have continued to be highly productive and/or increased substantially during this period, the dominant pattern has been one of declines. The breadth and magnitude of these recent declines have caused broad concern among First Nations and fisheries managers as well as commercial and recreational harvesters and other groups. These concerns drive interest in implementing strategies both to halt and reverse the declines in poor-performing stocks as well as to avoid future declines in well-performing stocks. The decisions required to reverse recent trends will likely have serious consequences for those who rely on Chinook salmon returns each year to meet their social, cultural and economic needs. However, there may potentially be even more serious consequences if the necessary actions are not taken. These decisions are complex, difficult and will involve trade-offs, but the recovery of depressed stocks and the maintenance of strong stocks for southern BC Chinook could have numerous benefits for First Nations, commercial and recreational fishers, and the people of British Columbia.

Despite the implementation of recent measures by Fisheries and Oceans Canada (DFO) to reduce exploitation rates, improvements to the status of many southern BC Chinook stocks have been mixed or uncertain. The underlying causes of the poor performance of some Chinook conservation units (CUs) are unknown. However, if poor survival rates continue to persist, then it is unlikely that these initial harvest reductions alone will be sufficient for the purposes of rebuilding southern BC Chinook stocks. A more successful response will require a long-term, strategic approach. To address this challenge, the Fraser

River Aboriginal Fisheries Secretariat (FRAFS), DFO and other participants have collaborated on a strategic planning process to develop a long-term plan that is consistent with the Wild Salmon Policy. This process needs to account for the biological status of southern Chinook conservation units, their habitat and the broader ecosystem, while reflecting the diverse interests of First Nations and stakeholder groups.

There are six central challenges to the problem of assessing the southern BC Chinook situation and determining appropriate management responses. First, southern BC Chinook are not only caught in coastal BC fisheries, but also in Washington State and Alaska, thereby involving international management requirements under the Pacific Salmon Treaty. Second, there is insufficient understanding of harvest impacts in BC, including the total mortalities associated with catch and release fisheries. Third, as highlighted in the recent science workshop on southern BC Chinook, substantial scientific uncertainties exist in our fundamental understanding of the recent patterns exhibited by these stocks and the underlying processes that may be contributing to those patterns. Fourth, the interaction between Chinook and the influence and interests of humans occurs across a wide range of spatial scales (see Figure 2 and Appendix A). Individual fisheries may harvest fish from numerous CUs with similar ocean distribution patterns, common migratory habitat may be shared by multiple CUs, yet freshwater stressors or recovery actions may apply only within individual watersheds or stream reaches, thus not even applying to an entire CU. Local Chinook populations, at smaller scales than Conservation Units, are of great importance to First Nations. Fifth, until recently there were no modeling tools available for simulating management actions over many stocks, fisheries and years and evaluating the long-term consequences of management actions on wild and enhanced Chinook populations. While this situation has recently improved, much more work is required to develop, apply and test these models. Finally, there are many social and economic complexities in finding strategies which can accommodate First Nations Rights, the desire of the Canadian public for health and diverse Chinook populations, and the diverse interests across a broad group of stakeholders over a large and diverse region.

Overall, the challenge for the CSPI is to apply existing knowledge and tools to find the most effective, acceptable strategies to recovering and protecting Chinook stocks in southern BC, while recognizing the reality of substantial (and possibly increasing) constraints on the available resources (e.g., people, funding, capital) for implementing such strategies. Given substantial knowledge gaps, likely future changes in climate and the productivity of ecosystems, uncertainties in the consequences of various management actions, and complex dynamics of the entire socio-ecological system, the strategies provided by the Strategic Plan must recognize and promote the need for learning and adaptation.

1.1.2 Southern BC Chinook Salmon

Unique characteristics that distinguish Chinook salmon from other species of Pacific salmon include their large size at maturation and the wide range of strategies exhibited at all stages of their life cycle (including freshwater and marine migration timing behaviours, marine distribution patterns and morphological characteristics).

In freshwater, Chinook salmon spawning habitats can be found anywhere up to more than 1,500 kilometres upstream from their ocean entry point (Healey 1991). Freshwater rearing strategies of juvenile Chinook salmon fall into two broad categories: those that migrate to sea in their first year of life, commonly referred to as “ocean-types”, and those that migrate to sea after spending one or more years in freshwater, known as “stream-types”. Within the two major juvenile life history types, there are wide variations in the duration of freshwater residence. For ocean-types, some migrate to the estuarine environment immediately upon emerging while others reside in freshwater well in excess of 100 days. Conversely, stream-types rear in freshwater for at least a year and rearing may occur throughout the river system from headwater tributaries downstream to the lower extent of large river systems. Multiple strategies may influence the distribution of stream-type fry and parr annually (R. Bailey, unpubl. data report; Bradford and Taylor 1997). Smolting of stream-type Chinook salmon typically occurs after one year of freshwater rearing; however, in less productive environments, juveniles may remain resident for two or even three years before migration to the marine environment. The timing of emergence and subsequent length of freshwater residence then determines the seasonal timing of entry into the marine environment. Post-smoltification residence times in estuarine environments are also thought to vary from a few weeks to several months, depending on the population in question.

Between the Asian and north American-origin stocks, the oceanic distributions of Chinook salmon encompass much of the North Pacific Ocean and into the Bering Sea, and even parts of the Arctic Ocean (Healey 1991). Early marine and subsequent ocean distributions also vary considerably among populations. Estuarine residence is particularly important for ocean-types (Quinn 2005) and many studies have documented estuarine use and behaviour (e.g., Healey 1980; Sibert and Kask 1978), whereas others may begin their marine migration almost immediately upon entry into the ocean. Early marine and seasonal migrations have been investigated by Hartt and Dell (1986), Trudel et al. (2009), Beamish et al. (2010, 2012) and Tucker et al. (2011).

Several marine migration strategies are also exhibited by Chinook salmon. Marine distributions (derived from fishery encounters with coded wire tagged fish) have been examined by various authors including Sharma (2009) and Weitkamp (2010). In general, Chinook salmon either reside on the continental shelf or migrate offshore into the open waters of the North Pacific Ocean. In general, but not exclusively, stream-types are thought to rear off the continental shelf, whereas ocean-types are “shelf-residents”, remaining on the continental shelf for the duration of their ocean residence. Within those that are shelf-resident, some stocks migrate north to the Gulf of Alaska, whereas others appear to remain proximate to their point of ocean entry.

In summary, Chinook salmon have evolved a wide set of behavioural adaptations and variations in their life histories that likely spread the risk of mortality across time and space (Healey 1991), and in occupying widely varying habitats, may experience more or less favourable conditions due to the influences exerted by environmental fluctuations, both seasonally and annually.

1.1.3 Constitutional, Legal and Policy Context

Constitutional Rights

The Constitutional responsibilities to First Nations of the Crown as administered by the Governments of Canada and British Columbia are based in part on the Royal Proclamation of 1763 and the Constitution Act of 1982. As stated in the Wild Salmon Policy:

> *“Existing Aboriginal and treaty rights are recognized and affirmed in section 35 of the Constitution Act, 1982. In its 1990 decision in R. v. Sparrow, the Supreme Court of Canada held that the recognition and affirmation of existing Aboriginal rights in the Constitution Act, 1982 means that any infringement of such rights must be justified. As described in more detail in Appendix 1, DFO seeks to manage fisheries in a manner consistent with the decision of the Supreme Court of Canada in R. v. Sparrow and subsequent court decisions.” (DFO 2005, p. 2)*

The interpretation and implementation of the Aboriginal Right to fish has evolved and continues to evolve through time. The Southern BC Chinook Strategic Plan recognizes that Aboriginal Rights are involved in all aspects of this plan: harvest, habitat and enhancement (including hatcheries). The implementation of the priority is still evolving and there are significant aspects that are not fully understood.

The Wild Pacific Salmon Policy

Canada's Policy for Conservation of Wild Pacific Salmon (also known as the Wild Salmon Policy or WSP) was originally released in 2005 with the primary goal restoring and maintaining healthy and diverse salmon populations and their habitats for the benefit and enjoyment of the people of Canada in perpetuity. Since then, implementation of the WSP has been approached through an incremental 6-strategy plan, as laid out in the Policy itself. The strategies are:

Strategy 1: Standardized monitoring of wild salmon status
Strategy 2: Assessment of habitat status
Strategy 3: Inclusion of ecosystem values and monitoring
Strategy 4: Integrated strategic planning
Strategy 5: Annual program delivery
Strategy 6: Performance review

The Policy and additional details about it can be found at: http://www.pac.dfo-mpo.gc.ca/fm-gp/species-especes/salmon-saumon/wsp-pss/index-eng.html

Currently, work is being undertaken by the Department to prepare a WSP Implementation Plan which will allow alignment with changes to legislation and programs since the policy was released in 2005, such as changes to the Fisheries Act, implementation of the Fisheries Protection Program, and release of the Sustainable Fisheries Framework.

With respect to the southern BC Chinook Strategic Planning Initiative, the WSP has provided overarching guidance on the unit of assessment (Conservation Units), an approach (through work conducted under Strategy 1) for providing a standardized and objective assessment of status[1], and high-level guidance on integrated strategic planning (Strategy 4).

Species at Risk Act (SARA)

The Species at Risk Act (SARA) was enacted in 2003 "to prevent wildlife species from being extirpated or becoming extinct, and to provide for the recovery of a wildlife species that are extirpated, endangered or threatened as a result of human activity and to manage species of special concern to prevent them from becoming endangered or threatened".

If a species is listed under SARA, it is illegal to kill, harm, harass, capture, take, possess, collect, buy, sell or trade any listed endangered or threatened animal or any part or derivative of an individual. These prohibitions apply unless a person is authorized, by a permit, licence or other similar document issued in accordance with SARA, to engage in an activity affecting the listed species or the residences of its individuals. These prohibitions do not apply to species listed as being of "special concern".

Endangered, threatened, and special concern marine species in Pacific region currently listed under SARA can be found at: http://www.dfo-mpo.gc.ca/species-especes/listing-eng.htm

Committee on the Status of Endangered Wildlife Species in Canada (COSEWIC)

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was formed in 1977 to provide Canadians with a single, scientifically sound classification of wildlife species at risk of extinction. COSEWIC began its assessments in 1978 and has met each year since then to assess wildlife species.

[1] The WSP status assessment for southern BC Chinook was completed in 2014 and is currently in revision (Brown et al. 2016)

COSEWIC serves as an independent body of experts responsible for identifying and assessing wildlife species considered "at risk", and is considered to be the first step towards protecting them. Wildlife species that have been designated as threatened or endangered by COSEWIC may then qualify for legal protection and recovery under SARA. This includes development of a recovery potential assessment, increased monitoring and status re-assessments at regular intervals.

To search the full list of species identified and assessed by COSEWIC, see: http://www.cosewic.gc.ca/eng/sct1/searchform_e.cfm

To date, DFO has undertaken two pre-COSEWIC data reports to describe and summarize data available to inform a COSEWIC assessment of southern BC Chinook salmon (currently in revision[2]) and COSEWIC has contracted a status assessment of southern BC Chinook salmon [3].

International Agreements

At the international scale, bilateral (i.e., Canada and the United States) management issues pertaining to southern BC Chinook are addressed within the Pacific Salmon Treaty. Interception of Pacific salmon bound for rivers of one country in fisheries of the other has been the subject of discussion between the Governments of Canada and the United States of America since the early part of the last century. In 1985, after many years of negotiation, the Pacific Salmon Treaty was signed, setting long-term goals for the benefit of the salmon and the two countries. The Pacific Salmon Treaty is implemented by the Pacific Salmon Commission, as formed by the governments of Canada and the United States. As directed by the Treaty, the bi-lateral Chinook Technical Committee (CTC) reports annual catch and escapement data, harvest rate indices, estimates of incidental mortality and exploitation rates for all Chinook salmon fisheries and stocks harvested within the Treaty area. The CTC provides annual reports to the Pacific Salmon Commission (PSC) to fulfill this obligation as agreed by Canada and the US under Chapter 3 of the Treaty (for example, CTC 2015a, 2015b, 2015c).

1.1.4 The Southern BC Chinook Strategic Planning Initiative (CSPI)

The Strategic Plan is nested under the auspices of the Southern BC Chinook Strategic Planning Initiative (CSPI), a bilateral planning process led by First Nations and DFO, with collaboration from multiple interest groups. A DFO/First Nations bilateral steering committee oversees the overall process. The Steering and Planning Committee (SPC) is responsible for the governance of the CSPI process, as per the Terms of Reference, and providing guidance for the development of the Strategic Plan. The SPC includes representatives from First Nations, DFO, the recreational and commercial fishing sectors, and non-governmental organizations. Within the governance structure of the CSPI, the SPC also oversees the activities of the Technical Working Group (TWG), which is composed of scientists and technical experts from DFO, First Nations and other interested parties. The TWG coordinates scientific analyses to evaluate the status of Southern BC Chinook, examines causes for their decline and will continue to support the strategic planning process (e.g. developing performance indicators, analyzing options developed by the SPC, and synthesizing results to facilitate decisions by the SPC).

The overarching objective of the CSPI is:

> *"To develop an Integrated Strategic Plan that accounts for the biological status of southern BC Chinook conservation units, their habitat and the ecosystem, that addresses the causes of any declines, and identifies the management actions necessary to remedy their status where possible. This initiative will*

[2] Brown et al. 2016

[3] The date for completion and review of the status assessment is currently not defined.

depend on the collaboration of First Nations, interest groups and DFO to identify rebuilding actions related to fisheries management, salmonid enhancement and habitat restoration.

Deliverables from this process will provide guidance to annual Integrated Fisheries Management Plans, fish culture production plans, habitat restoration work plans and community partnership agreements where possible. It may also inform Pacific Salmon Treaty discussions between Canada and the United States.

This strategic plan will be developed in a manner consistent with Strategy 4 of the Wild Salmon Policy, the [DFO's] Rebuilding Guidelines of the Precautionary Approach Framework and the Species at Risk Act."

The CSPI is a unique process, as it is the first example of a Tier 2 government-to-government process where other interested parties have been invited to participate.

1.1.5 CU Summary Table

Appendix G provides a summary of some CU-level information across all the southern BC Chinook CUs, including basic life history information and indicators of selected pressures and threats.

1.2 About the Plan

This strategic plan is meant to provide high-level, strategic guidance to inform the more detailed decision-making and tactical processes occurring at smaller scales and/or within subcomponents of the entire southern BC Chinook socio-ecological system (i.e., habitat, harvest or hatchery management). The Plan represents the collective perspective of a diverse group of First Nations and interested parties and identifies a comprehensive set of strategies intended to provide benefits to Chinook populations and those that rely on them. The CSPI hopes that the Strategic Plan can provide the guidance and influence to help tactical actions and decisions being considered by other established decision-making, advisory and planning processes and bodies throughout British Columbia in support of achieving the overarching objectives for southern BC chinook.

1.2.1 Goals of the WSP, CSPI and Strategic Plan

The goals and objectives of this strategic plan are nested within other sets of goals and objectives, pertaining to the WSP and the CSPI (Figure 1 and Table 1). The detailed objectives of the Strategic Plan are described in Section 4.

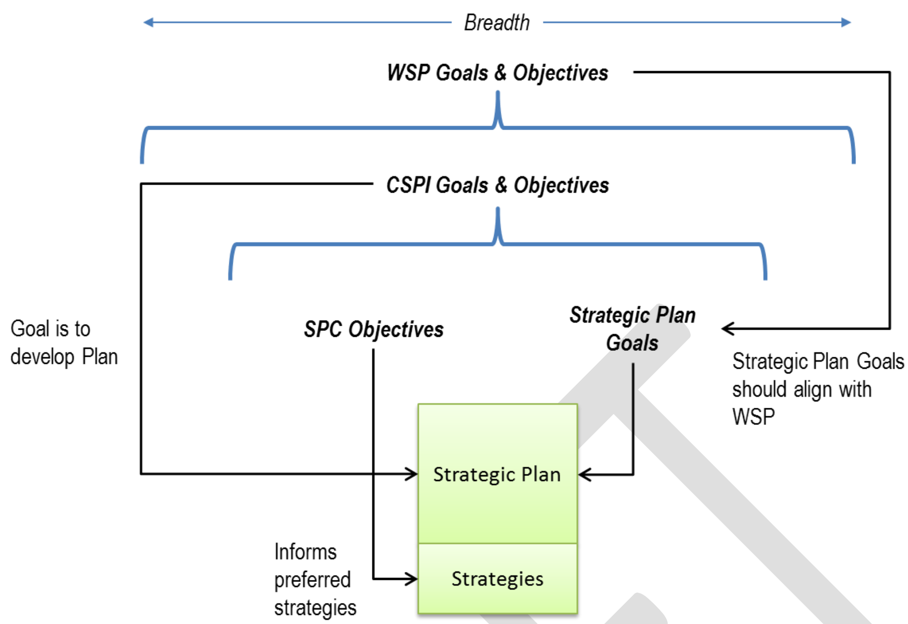

Figure 1. The goals and objectives of the strategic plan are nested within the goals and objectives of the CSPI and the Wild Salmon Policy (WSP).

Table 1. Goals and objectives associated with Wild Salmon Policy and the Chinook Strategic Planning Initiative.

Policy or Process	Goals	Objectives
WSP	Restore and maintain healthy and diverse salmon populations and their habitats for the benefit and enjoyment of the people of Canada in perpetuity.	1. Conserve the diversity, distribution and abundance of wild Pacific salmon[4] 2. Maintain habitat and ecosystem integrity 3. Manage fisheries for sustainable benefits
CSPI	Develop an Integrated Strategic Plan that accounts for the biological status of southern BC Chinook conservation units, their habitat and the ecosystem, that addresses the causes of any declines, and identifies the management strategies necessary to remedy their status where possible.	Deliverables from the CSPI process will provide guidance to annual Integrated Fisheries Management Plans, fish culture production plans, habitat restoration work plans and community partnership agreements where possible. It may also inform Pacific Salmon Treaty discussions between Canada and the United States.
Strategic Plan	To restore and maintain the abundance, distribution and diversity of southern BC Chinook salmon for all that rely on them.	Biological, social, and economic objectives (see Section 4)

1.2.2 Intended Audience

The audience for this Strategic Plan is very broad and inclusive – all parties with direct/indirect interests in sustaining robust and diverse populations of Chinook salmon and/or influence over management decisions that may potentially affect such populations. Such parties include groups within all levels of

[4] This is a broader interpretation of WSP Objective 1: "Safeguard the genetic diversity of wild Pacific salmon".

government (federal, First Nations, provincial and municipal), as well as other public and private interests.

1.2.3 Spatial and Temporal Scale

Within the aggregate of all southern BC Chinook salmon conservation units, there are numerous relevant spatial scales. Different threats, biological dynamics, and management actions operate at different scales. Figure 2 conceptually illustrates the hierarchy of spatial scales that could be considered. The present Strategic Plan focuses on identifying threats and strategies at the aggregate level and by CU group where possible. The CU groups represent one potential sub-aggregate classification, which is based on the geographic distribution of CUs during their freshwater life stages. However, other groupings are used within the Strategic Plan as necessary. For example, examination of harvest patterns and potential strategies must apply alternate aggregations of CUs because the CU groups do not represent consistent patterns of ocean distribution and may therefore be subject to entirely different sets of fisheries.

The Strategic Plan includes CU-specific information or examples in some places. However, finer spatial scales such as watershed or spawning sites are too detailed to be considered in this Plan.

The qualitative evaluation of alternative strategic directions in 2014 (Hall et al.) considered two temporal scales: short term (2 generations) and longer term (7-8 generations). Although the Strategic Plan does not presently include any quantitative modeling results, these two time frames are relevant for considering the shorter and longer term consequences of the identified strategies.

The scales at which different strategies will be implemented will vary according to specific processes through which tactical actions are selected and the specific types of actions utilized (e.g., habitat, harvest, or hatchery management actions, research and monitoring, or education and outreach activities all have different spatial and temporal scales).

The complexity of integrating multiple interacting spatial scales across CUs is conceptually illustrated in Appendix A.

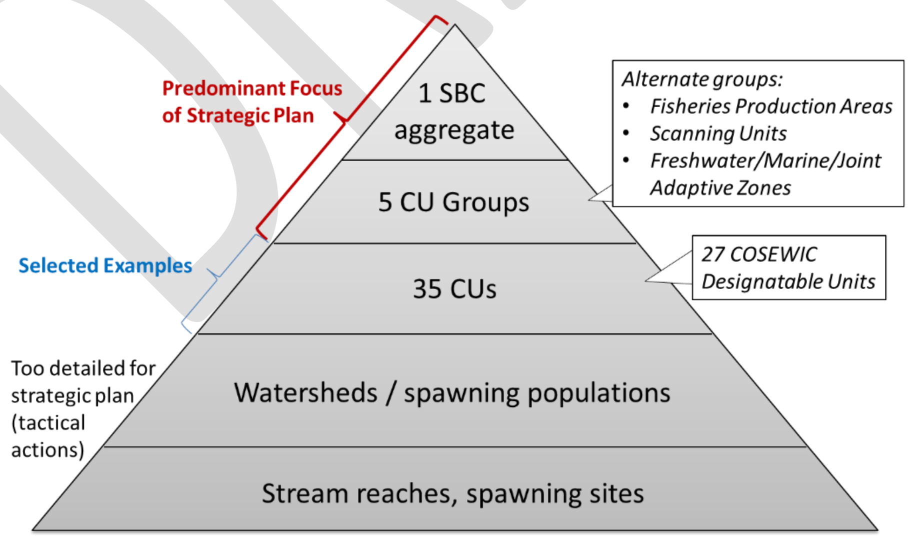

Figure 2. Multiple scales of interest with respect to southern BC Chinook salmon populations. The Strategic Plan predominantly focuses on the aggregate level and the CU group level, where feasible, plus selected CU-specific examples.

1.2.4 Strategic vs. Tactical Plans

The Strategic Plan is intended, by definition, to provide high-level, strategic direction for the improved management of Chinook salmon in southern BC. The Plan is not intended to address tactical planning or specific management actions related to harvest allocation, pre-season or in-season harvest planning, hatchery-specific production plans, watershed-specific management plans, or institution/department research planning. The details of how the strategies within the Plan could be tactically implemented cannot be specified at the level of the Strategic Plan. The Strategic Plan is intended to inform (i.e., provide guidance and direction to) multiple scales of planning processes where such tactical actions are determined, implemented and refined.

2 Status and Trends

2.1 Introduction

To help identify effective ways to conserve populations of Chinook salmon, requires an understanding of the current status and population trends for these populations. Guidance on assessment frameworks for evaluating status and trends of biological indicators for Pacific salmon is provided by: the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and Canada's Policy for Conservation of Wild Pacific Salmon (also known as the Wild Salmon Policy or WSP) (DFO 2005). The quantitative criteria established by COSEWIC can be used to delineate threatened and endangered populations (COSEWIC Table 2). Similarly, work to implement the WSP has included the development of a series of metrics and benchmarks that can be used to identify population status (Holt *et al.* 2009). Recent work within both of these frameworks has provided current evaluations of status and trends for southern BC Chinook[5]. In 2013, an independent science review panel additionally provided novel insights into the status and trends of the biological indicators for these populations (Riddell et al. 2013).

2.2 Units of Assessment: Conservation Units versus Designatable Units

Prior to the completion of quantitative assessments of status, decisions on the basic unit for analysis are required. There are 419 individual waterbodies listed in DFO's escapement database (nuSEDS) that are relevant to southern BC Chinook. These must be aggregated appropriately to ensure consistent and comparable data time series are available for analysis. As an example, data from tributaries to larger river systems are not assessed every year. It is imperative to ensure that data time series for the larger system do not "double count" the data from the various tributaries differently over time. Under the auspices of the WSP, Holtby and Ciruna (2007) introduced conservation units (CUs) as the fundamental structure which is required to preserve the genetic diversity of all Pacific populations of Chinook salmon. (The approach is similar, though not identical, to the Evolutionary Significant Units (ESUs) used in the United States.) Their work relied on a 3-pillar approach, using ecotype, life history and genetics to define CUs. A recent review of the southern BC Chinook CUs confirmed Holtby and Ciruna's initial assessment with few exceptions (DFO 2013b), re-affirming the 35 southern BC Chinook CUs. Subsequently, COSEWIC (which uses Designatable Units (DUs) as their unit of analysis) based their preliminary assessment on the list of 35 CUs, but then placed additional emphasis on genetics, ultimately resulting in the aggregation of several CUs into single DUs; as a result COSEWIC identified 27 DUs for southern BC chinook (Ma 2013).

2.3 The role of enhancement in status assessments

Populations of Chinook on the Pacific coast of Canada have been the subject of extensive enhancement efforts since the early 1970s (MacKinlay *et al.* 2004), and this was considered as part of the qualitative assessment of status and trends. Under the WSP, "wild" salmon are hatched in the wild from parents who were also born in the wild. Unfortunately at present, it is not possible to readily determine the parental origins of salmon spawned in the wild, and as such, we relied on estimates of hatchery contributions to "naturally spawned" populations (wild and hatchery salmon that spawn in the wild) as a surrogate measure of "wildness" for the population. Research being undertaken by DFO scientists aims to clarify the interpretation and quantitative assessment of hatchery-origin salmon within the context of

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[5] Brown et al. 2016 (pre-COSEWIC part 1)
Brown et al. 2016 (pre-COSEWIC part 2)
Brown et al. 2016 (WSP assessment)

the WSP status assessment process, the results of this work may inform future re-assessments of CU status[6].

2.4 Data sources for status assessments

Results from all quantitative assessments summarized here are based largely on the same data sets. Spawner abundance data up to 2012 was obtained from DFO's salmon escapement database (nuSEDS) and subjected to a wide range of data quality evaluations and treatments prior to analysis (DFO 2013a)[7]. Data issues included: varying estimate quality over time within and among time series within a CU, missing and incomplete data, and uncertain variations in aggregated estimates over time (i.e. estimates for component systems were aggregated in some years and not in others). It is important to bear in mind that many of the field programs to collect spawner abundance data began in the 1950s (or earlier) before the development of the current CU framework. Thus, some CUs are well-represented by extensive, high quality spawner abundance data while others are not. Furthermore, most CUs have historical data that have not been incorporated into nuSEDS and as such, the pre-1995 time series remains unverified in many cases (i.e. the estimate quality is unknown). Assessment techniques have also evolved over time. Overall, these facts limit the ability to interpret historical (pre-1995) spawner abundance information relative to current estimates.

Of 35 southern BC Chinook CUs, five were deemed to be "data deficient" for spawner abundance time series data. In addition, CUs had a range of enhancement activity including twelve CUs with only "low or unknown" enhancement activity, eleven CUs with only "moderate or high" enhancement activity, and seven CUs containing spawning sites with both "low or unknown" and "moderate or high" enhancement activity.

A Pacific coast-wide coded wire tag (CWT) data program is maintained for Chinook by the PSC (and operationalized through DFO and US agency CWT programs). There are 10 hatchery Chinook CWT indicator stocks included within the southern BC region. Several others from outside the southern BC region provide proxy indicator information for several southern BC Chinook CUs (though less informative than a direct indicator, proxies are still able to provide measures of relative change for associated CUs). Overall, the coast wide program coordinated by Canada and the US to recover CWTs from fishery catches and spawning returns provides information on biological measures such as fish size at release, fishery distributions, fish size at capture, and through an associated cohort reconstruction model, estimates of exploitation rates, marine survival and distributions of age at maturation (see, for example, CTC 2015a, 2015b).

Quantitative stock-recruit (S-R) analyses based on high quality field estimates are currently available for only two southern BC Chinook CUs (CK-03: Harrison[8] and CK-22: Cowichan & Koksilah[9]). S-R analyses provide estimates of intrinsic productivity and capacity for the CU, and a measure of overall survival (from spawner to recruit) for the population. Additionally, the annual PSC CTC CWT cohort reconstruction model provides updated S-R analyses for larger aggregates of stocks from southern BC (however, these cannot be partitioned into CU-specific estimates). These results are also of uncertain relevance to naturally spawning fish because many of the "model stocks" include large, temporally varying, and/or unknown fractions of hatchery fish in their estimates of ocean catch and spawning

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[6] Brown et al. 2016 (WSP Assessment)
R. Withler, DFO, Nanaimo, BC, pers. comm.
[7] Brown et al. 2016 (pre-COSEWIC; WSP Assessment)
[8] Brown et al. 2001 (unpubl. manuscript)
[9] Tompkins et al. 2005

escapement. Typically, catches and escapements resulting directly from hatchery releases are excluded from standard S-R analyses designed to assess performance of naturally-spawning fish. Despite these concerns, the model stock results tend to be positively correlated with marine survival time series derived from CWTs for stocks from within the same region (i.e. they tend to show generally similar, though not identical, time trends) (Riddell *et al.* 2013).

2.5 Results

There is general agreement across all quantitative assessments that spawner abundances of most Conservation Units (CUs) of Chinook salmon in southern BC have decreased over the most recent three fish generations (i.e. the last 12 years for CUs with a four-year average generation time). For the 19 CUs with spawning sites having "low or unknown" enhancement activity, 12 CUs showed a greater than 50% decrease in spawner abundance in the last three generations (six of these declined more than 70% and two dropped by more than 90%); two CUs showed modest increases (33-40%); and five CUs showed decreases between zero and 50%. Although trends of decreasing abundance were observed across all regions, juvenile life history types and adult return timings, Fraser and Thompson River stocks with stream-type juvenile life-history (i.e., juveniles that overwinter in rivers and go to sea as yearlings) represent the majority of those cases with decreasing spawner abundance in the last three generations (11 out of 19 non-data deficient CUs with “low or unknown” enhancement activity). Results for CUs with “moderate or high” enhancement activity are generally more variable. Of 18 CUs with “moderate or high” enhancement, seven CUs showed decreases greater than 50%, three CUs had decreases in the range of 0 to 50%, two CUs showed no significant trend (less than 3% change) and four CUs showed an increasing trend over the last three generations. For the seven CUs with both “low or unknown” and “moderate or high” enhancement activity data time series, there was generally agreement in the direction of trend, if not the magnitude, between the two data streams within any given CU. The three generation trends in abundance by CU are shown in Figure 3.

Riddell *et al.* (2013) provided a coast-wide analysis of marine survival rates for all CTC model stocks (including all available stocks to contrast with results for southern BC). The marine survival rates estimate the proportion of juveniles leaving their freshwater habitat that are still alive after their first winter at sea. Four of the five Chinook model stock groupings found in southern BC (Fraser River Late, Lower and Upper Strait of Georgia, and West Coast of Vancouver Island) indicate marine survival rates have decreased substantially from their highs in the 1970s or 1980s to lows in the 1990s and 2000s. Regions outside of southern BC also showed decreased survival rates, but in several cases, there was a temporary increase in the late 1990s and early 2000s followed by a decline. Coast-wide comparisons across all CTC Chinook salmon model stocks’ age-2 cohort marine survival rate time series show an underlying trend of shared variation from Oregon through BC, and even into some Alaskan stocks. That shared trend indicated increasing survival rates from ocean-entry year 1995 to around 2000, then decreasing until 2005, followed by a partial reversal. However, in many of the modelled stocks, there also are stock-specific sources of year-to-year variation that mask the general underlying trend (Riddell *et al.* 2013).

S-R analyses of modelled data for larger Chinook aggregates produced from the PSC Coast Wide Chinook Model show life-cycle productivities decreasing substantially over time for lower Strait of Georgia and west coast Vancouver Island Chinook salmon, but only slightly, though steadily, for the Fraser Late model stock. Other southern BC model stocks show either no trend in productivity indices, or slight increases. Numerous stocks outside of southern BC have also shown a decrease in productivity, especially since the late 1990s or early 2000s, including central and western Alaska stocks. The latter Alaskan stocks had high-quality S-R data that were not confounded by hatchery contributions (Riddell *et al.* 2013; ADF&G 2013; CTC 2015c).

Overall, southern BC Chinook stocks exhibit temporal patterns in spawner abundance, life-cycle productivity, and to a lesser extent age-2 cohort survival rates, that are shared (to varying degrees) across a large spatial area from Oregon north through to western Alaska. Thus, although it seems likely that there are large-scale processes influencing Chinook productivity, no single predominant factor can be readily identified at this time to fully account for the recent patterns and trends observed for southern BC Chinook.

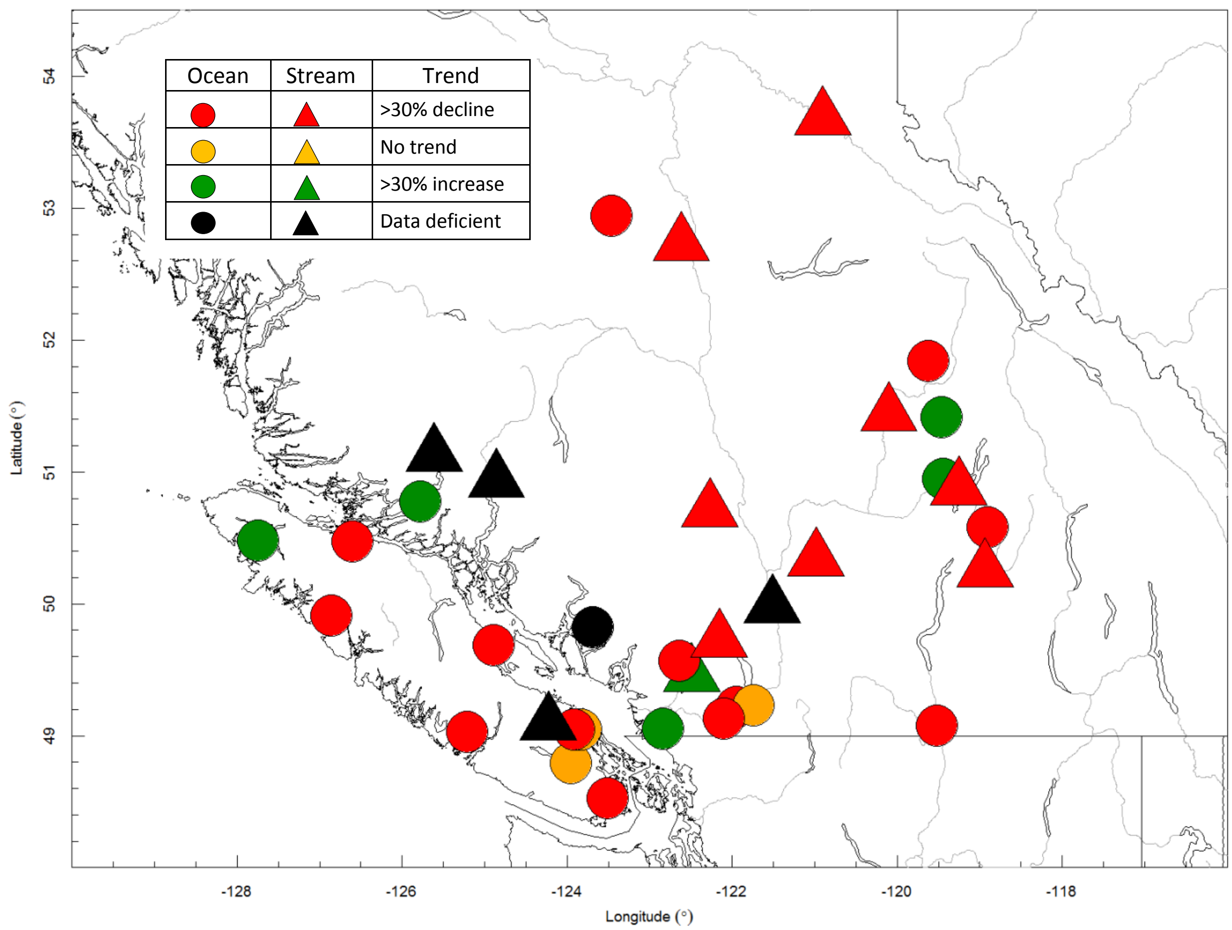

Figure 3. Three-generation trends in spawner abundance for southern BC Chinook conservation units (CUs), differentiated by ocean (circle) and stream (triangle) juvenile life history types. The number of years included in the calculation of 3 generations depends on the average age of maturity for each CU. Given that southern BC Chinook Salmon most often mature between 3 and 5 years of age (on average), the number of years used to calculate the trends illustrated here varies between 9 and 15 years (2004-2012 or 1998-2012).

3 Threats and Knowledge Gaps

3.1 Limiting Factors and Threats to Southern BC Chinook Salmon

This subsection identifies and describes the most substantial threats that are believed to be contributing to the recent declines observed across many southern BC conservation units and/or preventing recovery of depressed populations. The potential threats have been grouped into broader classes (e.g., marine habitat/ecosystem). The dominant threats within each class are briefly described and they are summarized in Table 2 (or Appendix E for a more detailed version). Although these threats are described at the scale of the entire southern BC Chinook aggregate, their relative importance and magnitude varies considerably across CUs, as illustrated by comparing the CU-specific examples described later.

Table 2. Threats to southern BC Chinook salmon.

Class and subcategory	Natural/ Human	Description of Threat	Affected Life Stage(s)	Affected subsets of CUs[1]
Climate Change – impacts on freshwater or marine ecosystems driven by climatic changes				
Water temperature (freshwater)	Natural	Most southern Chinook populations face **increasingly stressful thermal conditions** during return migrations	Returning adults	Esp. UMFR, Th, Ok
Water quantity (freshwater)		Increased vulnerability to **changes in water quantity** - climate driven changes exacerbate pressure from water extraction.	All freshwater life stages	Esp. UMFR, Th, Okanagan
Productivity	Natural	Highly likely that **climate variation and change** is influencing productivity	All, especially marine	All
Warm water predators	Natural	Increased exposure to **warm water predators** that Chinook have largely not co-evolved with.	Smolts, possibly adults in some areas	WCVI examples; potential to affect all CU's; possibly less so for far north migrating CUs
Marine Habitat – impacts on marine habitat/ecosystem quality, quantity or usage affecting marine survival rates/adult returns				
Early marine conditions	Natural	**Shared declines** in marine survival across many stocks (not all). Uncertainty about mechanisms	Juvenile, immature adults	Stocks with early or late entry timing have fared better
Early marine conditions	Natural	Changes in local and basin-scale **oceanographic conditions**.	First year of ocean residency	All
Predation	Natural	**Marine mammal predation** may affect abundance / inhibit recovery during periods of low productivity. Unlikely driver of general declines for all SBC Chinook.	Marine life stages	Esp. SoG, Johnstone Strait
Disease	Human	Disease risks from interactions with **salmon farm or aquaculture** operations	Smolts	CUs migrating by operations
Competition	Natural	**Inter-specific competition** (with other salmon species and non-salmon species)	Marine life stages	All
Estuarine Habitat – impacts on estuarine habitat conditions				
Predation	Human	Human-mediated opportunities for increased **predation by marine mammals**	Smolts	SoG
Habitat	Human	**Loss of estuarine marshes** in lower river reaches from human activity and urbanization/development pressure	Fry, smolts	All, especially Fall Chinook
Freshwater Habitat – potential loss or degradation in productivity or useable area of freshwater habitat				
Water regulation	Human	Human-induced changes in **flow and water temperatures**, exacerbated by climate change.	All freshwater life stages	VI, UMFR, Th, Ok
Didymo	Mixed	**Didymo outbreaks** – potentially contributing to reduced productivity	Eggs, fry, smolts	Esp. stream type CUs
Hydrologic Processes[2]	Mixed	**Hydrologic processes** (forest disturbance, Equivalent Clearcut Area)	All freshwater life stages	High risk: none (only BB) Mod risk: Th
Vegetation Quality[2]	Mixed	**Vegetation quality** (riparian disturbance, insect and disease defoliation)	All freshwater life stages	High risk: UMFR, Th, LSC, Ok Mod risk: WCVI
Surface Erosion[2]	Human	**Surface erosion** (road development)	All freshwater life stages	High risk: Th, LSC, WCVI, Ok Mod risk: LFR, UMFR
Fish passage/ connectivity[2]	Human	**Fish passage / habitat connectivity** (stream crossing density)	All freshwater life stages	High risk: LSC, Ok Mod risk: LFR, UMFR, Th, WCVI
Water quantity[2]	Human	**Water quantity** (water licenses)	All freshwater life stages	High risk: Th, LSC, Ok Mod risk: LFR, UMFR, WCVI/USC
Water quality[2]	Human	**Water quantity** (wastewater discharges)	All freshwater life stages	High risk: Ok, plus 5 separate CUs Mod risk: All CU groups

Class and subcategory		Natural/ Human	Description of Threat	Affected Life Stage(s)	Affected subsets of CUs[1]
	Human development footprint[2]	Human	**Human development footprint** (total land cover alterations, impervious surfaces, linear development, mining development, agricultural/rural development)	All freshwater life stages	High risk (for Linear): LSC, Ok Mod risk: UMFR, Th, LSC Mod/low: LFR, WCVI/USC
Harvest – impacts associated with fishing activities including retained catch, releases and/or gear interactions					
	Harvest mortality	Human	**Total mortalities (**e.g., bycatch, release mortality, depredation, disease, recapture, post-release predation, unauthorized harvest, other unknown/unreported removals) from **Chinook directed fisheries exceed sustainable rates** given current productivity	Adults	Unknown
Hatchery Production – impacts associated with hatchery / enhanced production of Chinook (or other salmon)					
	Genetic	Human	**Genetic risks** to wild populations from domestication selection within hatchery population and/or outbreeding effects on surrounding populations. Potential stressors on natural populations and contributions to reduced productivity/abundance include: straying into non-target systems; high enhanced contributions in target systems; lack of information relating to enhanced contribution; inability to mass mark Chinook to assist in genetic management.	Spawners	Higher risk[3]: SoG, WCVI Lower risk: LFR, Th, UMFR
	Disease	Human	Contained hatchery populations with **disease** can potentially transmit **pathogens** to wild populations in receiving waters.	Fry, smolts	Low risk: All
	Ecological	Human	Hatcheries pose five main **ecological interaction** issues related to salmon ecosystems: carrying capacity, competition, predation, disease and behavior.	Fry, smolts	Low risk: All
	Harvest pressure	Human	**Increased fishing pressure on wild stocks** due to increased hatchery production (indirect impact from hatchery production, mediated through harvest decisions).	Adult	CUs caught in mixed stock fisheries with hatchery stocks
Cumulative or synergistic interactions among threats					
	Interactions	Mixed	One or more threats or stressors acting in conjunction on a CU.	All	All

[1] Abbreviations for regional groupings: BB - Boundary Bay; LFR - lower Fraser River; LSC - lower south coast; Ok - Okanagan; SoG – Strait of Georgia; Th - Thompson River; UMFR - upper/middle Fraser River; USC - upper south coast; VI - Vancouver Island; WCVI - west coast Vancouver Island.
[2] Impact category, pressure indicators (i.e., bolded text under 'description of threat') and risk classifications are based on the southern BC Chinook salmon habitat report cards (Porter et al. 2015).
[3] "Higher risk" does not necessarily mean "high risk" – the classifications are relative not absolute (i.e., no formal definition of high, moderate and low risk categories). The CU groups have been divided into those known to have relatively higher or lower genetic risks..

Future Work:
Potential addition of information (qualitative) on the severity, extent, and frequency of each threat.

3.1.1 Freshwater Habitat

A watershed is influenced by many factors some a result of the natural landscape and some human induced. Natural landscape factors include the climate of the region and the characteristics of the watershed (physiography, lithology, watershed morphology, hydrology and vegetation) determining the ecosystems and habitats within a watershed. Human induced factors include land-use, impervious surfaces, dam impacts, water withdrawals, drainage networks, channel alterations, outfalls, vegetation management, wetland alterations, outfall discharges, introduction of exotic species, and spills or harmful discharges.

Chinook have important habitat requirements to sustain their different life history strategies in freshwater. These habitats can be divided into three inter-connected spatial dimensions: longitudinal (or riverine); lateral (or riparian); and vertical (or hyporheic) (Portland 2005). Changing the hydrology of a watershed results in changing the available habitat diversity, by disconnecting the spatial dimensions between the channel, its groundwater sources and the associated floodplain and upland habitat areas. Increasing imperviousness within a watershed can cause a net decrease in groundwater recharge (and reduce base flows) and increase surface water runoff (increased flashiness and erosion capability) (Portland, 2005).

Threats to important Chinook habitat can be a result of human activities on the landscape or landscape level factors, which rarely work in isolation.

Water Regulation

Water regulation is an entirely anthropogenic threat. Water storage structures such as dams and flow control weirs are designed to store water during periods of high runoff so that this water can be accessed for a variety of uses during periods of low flow. Uses include domestic water supply, flood control, power generation, agriculture and industrial needs such as dilution and cooling.

The threat to Chinook salmon from water regulation can take different forms. Among others:

1. Physical blockage of migration
2. Alteration of natural flow regimes
3. Increased water temperature from lake storage
4. Removal of water from natural water courses

Physical blockage of migration can be mitigated by incorporating fish ladders or bypass channels that allow adult Chinook salmon to get beyond the barrier. Similarly juvenile Chinook salmon will require a route downstream past the barrier and also measures that prevent them from entering any withdrawal structure. Alteration of flow regimes may produce a situation that isolates Chinook redds from mainstem water courses by abnormally decreasing water flows during emergence periods. Increased water temperature will advance egg and alevin development, resulting in emergence earlier than normal, placing the juveniles into habitats that may not have the food resources available yet. In addition, higher water temperatures increase the metabolism of the fish, exacerbating the requirement for food.

Geographically, the extent of water regulation is generally centred near high human population densities and areas where there is a high amount of water withdrawal for agriculture requirements, or remote power generation facilities.

The nature of water regulation is highly varied, depending on usage. Dams and power generation will normally return water back to the water course so severity is somewhat limited. Water withdrawal activities have much more serious outcomes as there is not much Chinook can do without adequate water flow and appropriate times of their life cycle. In certain circumstances, water storage and regulation can be used as a tool to mitigate the effects of potential stressors such as warm or low water, from environmental variability or climate change, although this requires tradeoffs against water availability during other periods.

Future trends are based on human population and development. Generally the human populations have increased over time, and increased the influence they have on their environment, therefore it can be assumed that Chinook salmon will continue to be negatively affected by water regulation.

Surface Erosion

Surface erosion of fine substrates is a natural process that is can be exacerbated by anthropogenic activities such as forest cover removal, road construction or general disturbance of surface material. It is often caused by abnormally high or excessive precipitation. Erosion of streamside or riparian habitats is the result of movement of water along the normal water courses. During high precipitation events surface runoff of water will also loosen rock and soil from the substrate surface and carry this material along to natural water courses. Rain on snow events and scour due to anchor ice shifting are the major forces in the interior. Those processes are greatly exacerbated by removal of streamside vegetation (cottonwoods in the southern interior), resulting in braided gravel channels and loss of pool-riffle-run structure.

This threat can affect Chinook salmon several ways. Deposition of fines and organics in potential incubation areas can mask or smother the eggs within the gravel redds; however, the selection of these areas by Chinook salmon minimizes this threat due to the slow moving water which is required for deposition of fines. On a micro scale, some deposition will still occur in sub-surface areas. A more serious threat is the deposition of these materials in rearing areas where submerged vegetation and associated aquatic benthic invertebrate communities occurs, affecting the productivity of food organisms.

Extent of impact by geographic range is highly dependent on local land use. Areas with active logging are subject to both surface and bulk erosion processes. Land gradient will also determine the impact as higher slope substrates will result in faster velocities of water, and greater erosion potential. Particularly sensitive are many interior valley floors that are comprised of alluvial gravels and cobbles resulting from glaciation. These are not resistant to erosion.

Temporal extent of impact is also dependent on localized situations. A source of sediments will continue to affect downstream water courses until the source is exhausted or resolved. Restoration to physical habitat can be difficult but does occur naturally as the annual hydraulic cycle continues to carry material downstream to areas where natural settlement occurs. This process, however, will take years to decades.

The climate change trend is for warmer, wetter winters along the coastal BC areas. This will result in higher peak winter flows as more precipitation falls as rain rather than snow, thus draining through creeks and rivers in the higher precipitation months instead of melting in spring and draining through spring and summer. In non-coastal areas the annual hydrologic flow may shift from snowmelt dominated flow regimes to winter runoff flow regimes however it is unlikely to change surface erosion patterns.

Fish Passage/Habitat

Fish passage barriers may negatively impact Chinook salmon by reducing or blocking access to spawning and rearing areas. Complete barriers can lead to reduced or fragmented species distributions, and result in dwindling populations that are increasingly genetically isolated and at greater risk of extinction

(Wofford *et al*. 2005). Fish passage barriers are a threat to southern BC Chinook salmon populations particularly in the lower south coast and Okanagan and, to a lesser degree, the Lower Fraser, southern and central Interior and the west coast of Vancouver Island.

Fish passage barriers impact Chinook salmon at varying scales and life stages. Large dams, typically constructed for hydroelectric generation, have blocked access of entire populations to their spawning grounds and effectively led to their extirpation from upstream areas. For example, almost the entire Canadian Columbia River Basin is inaccessible to Chinook salmon due to hydroelectric dams in the Columbia River, resulting in the loss of all Chinook salmon populations that once inhabited this area. Several such large dam barriers exist throughout BC. Small barriers, such as small irrigation or flood control dams, culverts, dikes, levees, floodgates and weirs, are much more widespread and reduce or block access of salmon to portions of their historical habitat. For example, channelization and dike construction can prevent access of juvenile Chinook salmon to virtually all wetland and floodplain habitats that once comprised important rearing areas, which limits the productive capacity of the system. These smaller barriers exist to varying degrees in all regions of BC that support moderate to large population clusters and agricultural activities, but Chinook CUs in the Southern Interior, lower mainland and Vancouver Island are likely most affected.

Many large hydroelectric dams are complete fish passage barriers that prevent spawners from migrating upstream. Those that do allow fish passage often lead to reduced survival of adults due to the strenuous migration through fish ladders and facilities. Impacts include delays and reduced reproductive fitness associated with dam and reservoir passage (Dauble and Mueller 1993; Geist *et al*. 2000), as well as direct and delayed mortality from fallback over dam spillways or through turbines (Dauble & Mueller 2000). The migration is also hazardous for outmigrating smolts. They must pass hydroelectric facilities on their migration to the ocean, which may lead to varying degrees of mortality from passage through the power turbines, rapid pressure changes, large forces, abrasion and turbulence. Elaborate juvenile bypass systems, as installed on the mainstem Columbia River dams, reduce mortality by guiding smolts around the power house, with survival at each dam estimated in the 93-96% range (Skalski, 2014). Nonetheless, a cumulative impact remains from passage of multiple dams.

Removal or mitigation of barriers that block fish movement can be an important tool in the recovery of fish populations, and has led to some of the largest increases in fish production compared to other restoration techniques (Scully *et al*. 1990; Roni *et al*. 2002). Furthermore, this approach can yield potential benefits (e.g. increased fish abundance and productivity) relatively quickly compared with other methods (Roni *et al*. 2002). A catchment-scale approach to mitigating fish passage barriers is likely to provide the most effective and cost-efficient means by which to enhance fish populations and overall ecological status of fluvial systems (Kemp and O’Hanley, 2010).

Water Quantity

The hydrology or freshwater flows of a watershed vary naturally depending on the climate, the characteristics of the watershed and the seasonal changes within the watershed. These variations depict the timing, magnitude and frequency of changes to flow. Change to this hydrological regime can affect critical habitat for Chinook in all three spatial dimensions. Alterations to the quantity of water, either higher high flows or lower low flows or the timing of freshets and droughts can cause migration delays, impact spawning redds and egg to fry survival, change riparian and in-stream vegetation, increase suspended sediments in the water, increase water temperature (by decreasing water depth and heating of stream substrate), change species composition within the aquatic ecosystem and change predator-prey relationships.

Issues with water quantity are thought to be increasing as more development takes place within many watersheds. The hydrology of a watershed is altered by urban development resulting in changes to the rate volume and timing of streamflow (Konrad and Booth, 2005). Imperviousness within a watershed is a measure of the surface area that no longer infiltrates water.

Threats for this factor are linked to impacts from climate change and more frequent droughts are expected over the southern BC region.

In particular, Chinook salmon from CUs located in watersheds influenced by snowmelt (rather than rain-dominated) are typically snow dominated hydrographs, with much of the total discharge resulting from winter snow accumulation and subsequent melting. Water availability is strongly influenced by land use practices that influence rate of melting, by climate change and by natural climatic variation such as phases of the PDO.

Snowpack accumulation directly influences groundwater accumulations which supply considerable input to many interior rivers, and stabilize temperatures. Groundwater abstraction may significantly impair that function.

Water Quality

Water quality is defined in terms of the chemical, physical and biological content of water. Parameters such as nutrients (nitrates and phosphates), dissolved oxygen, pH, pollutants and total suspended sediments (TSS) are measurements used to determine the quality of water. Water quality within a watershed is affected by geographic location, discharge and level of human development or industrial activity, including mining, forestry or agriculture. The Ministry of Environment is mandated to manage water bodies and has created a number of water quality objectives for various lakes and rivers that take into account the natural local water quality, uses and movement of water and waste discharges (BC MELP, 1994). These objectives are routinely monitored. The dominant drivers of water quality in the more developed regions of BC are based on cumulative effects due to land use, urbanization and human population growth. Traditionally, water quality monitoring has focused on large point source pollution as an effective means of protection but this has evolved to an integrated approach linking land-use to environmental quality supported by science based monitoring, regulatory compliance and shared stewardship (Smorong and Epps, 2014).

For Chinook, like all salmon, water quality in freshwater habitats is critical. Threats from water quality impacts can limit productivity or reduce survival. Upstream migration of pacific salmon adults are delayed at temperatures over 20 ^{0}C (McCullough, 1999) and temperatures over 12.8 ^{0}C resulted in increased mortality of females prior to spawning (Andrew and Geen, 1960). Hicks (2002) reported that average temperature exposures of 15.6-17^{0}C can lead to a reduction in reproductive success.

For dissolved oxygen (DO) the lower lethal limit is 1.6 mg/L. DO levels greater than 6.3mg/L are recommended for successful migration of anadromous salmonids (Davis, 1975). Minimum concentrations at or near saturation with temporary reductions no lower than 5mg/L were recommended for all anadromous salmonids by Reieser and Bjorn (1979) and Chapman (1988) found that any reduction of DO below saturation reduces survival.

TSS poses a significant threat to salmonids particularly egg to fry survival (from smothering of redds), reduces rearing success of juveniles and can affect return migration of adults. Sediment Levels of 509 to 1217 ppm are fatal to juveniles, levels of 500 ppm result in stress responses and levels of 100 to 300 ppm result in reduced feeding. High levels of suspended sediment can also delay upstream migration of adults (Bell, 1973 in Allen and Hassler, 1986). Suspended sediment of less than 25mg/L are suitable for salmonid habitat (Reiser and Bjornn, 1979).

Water quality threats to Chinook salmon are increasing with human population growth and development.

3.1.2 Estuarine Habitat

The near-shore environments of estuaries are unique ecological zones that host productive saltmarshes, eelgrass beds, and other shallow intertidal habitats that serve as nurseries for young salmon. Estuaries provide rearing habitat, food and refuge during a critical (and sometimes stressful) period of growth, development and osmotic acclimation to seawater. Chinook juveniles reside in estuaries from weeks to months prior to ocean migration (Neilson *et al.* 1985; Dorcey *et al.* 1978; Healey 1982). The extent of reliance depends on the specific life history types of individual populations; with ocean-type Chinook generally relying on estuaries to a greater degree than stream-type populations.

Studies on juvenile Chinook undertaken in BC and the US support the notion that the duration and quality of estuarine residency is a determinant of subsequent Chinook marine survival (Schlucter and Lichatowich 1977; Levy and Northcote 1981; MacDonald *et al.* 1988). An evaluation of 20 US estuaries by Morganson and Hilborn (2003) concluded that (fall) Chinook rearing in pristine estuaries had higher survival rates than those rearing in degraded estuaries (up to a 3 fold increase in survival between fully degraded and pristine estuary rankings). Further, estuary condition was more important for Chinook survival than it was for coho survival. Despite these findings, quantitative analyses linking Chinook survival with habitat types or other estuarine factors are sparse. As such, the mechanisms for understanding higher or lower survival within estuaries remains poorly understand.

Despite the inferred importance of estuarine habitats, their location at the mouths of rivers has predisposed them to human settlements and concomitant habitat loss from urban, industrial, agricultural, and extractive land use that affects physical habitat structure and function (**Error! eference source not found.**). In addition, estuaries near urban centers also serve as depositories for point and nonpoint sources of pollutants that affect water quality (Dexter *et al*. 1985; Varanasi *et al*. 1993).

Estuaries located near urban centers face a variety of threats associated with anthropogenic activities. In such places, significant habitat loss occurs as wetlands and other habitats have been diked off, drained, and converted for agricultural, industrial, and urban developments. In the Lower Fraser, for example, this has resulted in a loss of 70% of the rearing habitats once available to juvenile Chinook (Hoos and Packman 1974). Human activities in areas like Vancouver, Victoria, and Puget Sound are also the source of an incredible variety of contaminants including industrial chemicals, hormones, antibiotics, and central nervous system agents, to name a few (Meador *et al.* 2016). A recent study in Puget Sound estuary habitats found 29 different "contaminants of emerging concern" in tissues of juvenile Chinook, with unknown effects (Meador *et al.* 2016). Although technology has improved our ability to treat effluent, the concomitant increase in population size and the variety of chemicals used has continued to result in high contaminant loads in developed estuaries. These alterations to habitat and water quality have adverse effects that act individually, cumulatively or synergistically to increase mortality and lower survival of Chinook salmon.

Climate change and associated sea-level rise also pose a significant threat to estuary habitats across Southern BC, altering the estuarine conditions upon which juvenile and adult Chinook rely during their critical transition period. Changes in river flows and water temperatures have already begun in the Fraser and likely other systems across Southern BC, altering salinities and temperatures in the estuary (Morrison *et al*. 2002). Juvenile salmon may be negatively affected by increases in salinity during their transition to freshwater, while warming temperatures are likely to increase the susceptibility of adult

Chinook to en-route mortality. While the effects of climate change have begun, the majority of effects on Chinook and their habitats will occur in the future.

Sea-level rise will also result in changes to estuary habitats, with increased diking reducing the availability of near shore habitats, most likely replacing salt marsh with rip rap and other modified habitats. Further expansion and upgrades to flood protection structures will occur on a massive scale, with an estimated $8.8 billion in projected costs just along the tidal portion of the Lower Fraser (Delcan 2012). As salt marshes exist only in the high intertidal areas of the estuary, rising sea levels have the potential to lead to significant declines in salt marsh habitats (Sumas *et al*. 2001), areas which juvenile Chinook rely on heavily during the period prior to ocean entry.

Table 3. Primary threats to estuarine habitat.

Nature of Threat	Overarching geographic extent	Severity (e.g., how many life stages are affected)	Stability of future trend
Habitat loss/ alteration	Throughout Salish sea but greatest in highly settled areas	Strongest effect likely on ocean-type juveniles limited by available rearing habitats, but all life-history types potentially affected.	Unknown – estuarine habitat loss has been extensive in the Fraser and Puget Sound estuaries. Alterations through jetties and armoring will increase unless preventative and proactive measures are taken.
Contaminants	Greatest in urban and industrialized estuaries of Salish Sea.	Strongest effect likely on ocean-type juveniles that spend more time in estuarine waters, but could potentially extend to all types that have extended rearing in nearshore waters of the southern Salish Sea.	Stable? – Although sewage treatment may improve and regulations address some legacy pollutants, other point and non-point sources of contamination persist.
Climate change and associated sea-level rise	Important across southern BC but will lead to cumulative effects in highly settled estuaries	Changes in temperature and salinity are likely to adversely affect juvenile and adult salmon during their osmoregulatory transition period, potentially making them more susceptible to predation and pre-spawn mortality. Sea-level rise will lead to further armoring in developed estuaries like the Lower Fraser, reducing the availability of high intertidal areas which salt marshes and juvenile Chinook rely on.	Increasing –Climate change and sea-level rise are beginning to affect our hydrological cycles and oceanic conditions but the majority of the effects will be seen in the future. Although some areas have begun to prepare for sea-level rise the majority of flood protection infrastructure will be built in the future.

3.1.3 Marine Habitat

Many stocks of Chinook salmon in southern BC are currently in serious decline despite substantial reductions in fishing mortality and the implementation of several conservation and mitigation initiatives such as selective retention of hatchery fish in some areas, and numerous restoration activities (Labelle 2009; Tompkins *et al*. 2011). The current poor status of southern BC salmon stocks is constraining both domestic and international allocation and has already required closures in commercial and recreational fisheries as well as affecting food, social and ceremonial harvest opportunities for First Nations (CTC 2012). These declines may also impact on the recovery of endangered resident killer whales (*Orcinus orca*), which largely depend on an abundant supply of southern BC Chinook salmon (Ford *et al*. 2010; Hanson *et al*. 2010). It is important to note though that despite the ubiquity of these declines, some Chinook salmon stocks are currently performing well within southern BC (Tompkins *et al*. 2011; Beamish *et al.* 2012).

While the causes of Chinook salmon declines are likely multifactorial (NRC 1996; Magnusson 2001), it is generally recognized that persistently unfavourable ocean conditions and poor marine survival played a major role in these declines (Beamish *et al*. 2000, 2011; Labelle 2009). First, this is a broad pattern affecting not only populations in in southern BC, but also extends to Puget Sound, the Columbia River, California, and more recently to Alaska (NRC 1996; CTC 2012). The simultaneous decline of salmon originating from geographically-distant watersheds suggests that a common cause is affecting these stocks in the marine environment (Peterman and Dorner 2011; Kilduff *et al*. 2014, 2015). Second, these declines occurred in pristine and perturbed watersheds, as well as in river systems with and without dams (Wells *et al*. 2008). Lastly, these declines parallel trends in marine survival of hatchery indicator stocks (Beamish *et al*. 1995). This provides evidence that, in some areas, the reduction in adult returns was due to changes in ocean conditions rather than to changes in the production of salmon smolts (Beamish *et al*. 2000). Thus without an understanding of the effects of ocean conditions on the marine survival of Chinook salmon, it will be difficult to assess the success of mitigation measures and recovery strategies on salmon resources, and to provide suitable advice to fisheries managers for establishing effective harvest policies while preserving biodiversity and the productive capacity of salmon ecosystems (Kareiva *et al*. 2000; Holt 2010).

Several factors may affect salmon in the marine environment. These include: changes in 1) prey abundance, 2) the timing of prey production, 3) the timing of smolt migration, 4) smolt health, 5) the nutritional quality of their prey, 6) the abundance of predators, 7) the abundance of competitors, 8) the incidence of harmful algae, 9) pathogens and microbes infection, 10) rearing habitat quality, and 11) thermal stress, to name a few. The nature of the adaptive management strategies required to recover these populations will depend on which of these mechanisms are controlling the survival of southern BC Chinook salmon in the marine environment. However, the relative importance and cumulative effects of these factors in the overall marine survival of Chinook salmon are not well known. In addition, these factors may be compounded by climate change, and may worsen under a warming climate. Clearly, further research is required to understand how changes in climate and ocean conditions affect the viability of southern BC Chinook salmon.

3.1.4 Climate Change

Water Temperature – Freshwater

Chinook salmon depend on water temperatures within their tolerance range to survive. Elevated water temperatures in freshwater habitats are a threat to southern BC Chinook salmon populations particularly in the southern and central BC Interior, the lower mainland and southeastern Vancouver Island (Nelitz et al. 2007).

Elevated water temperatures negatively affect Chinook salmon in several ways at various life stages. Warmer winter water temperatures cause salmonid eggs to hatch sooner and may result in young that are smaller. They may emerge at a time when their insect prey base is not available (Karl et al. 2009).

Elevated temperatures during the juvenile rearing stage lead to increased fish metabolism, resulting in reduced growth if more energy is devoted to searching for food (Coutant, 1976). They may also inhibit the ability of juvenile Chinook to compete with other salmonids or warm water species for food and preferred habitats (McCullough, 1999; Hillman, 1991). If temperatures approach lethal or sublethal levels, direct mortalities of juveniles may be observed. The result of elevated water temperatures during the juvenile life stage is a reduction in productive capacity of rearing habitats. The CUs most strongly affected are those that exhibit a stream-rearing life history due to their extended freshwater rearing stage that extends through the summer low flow period when temperatures are most problematic.

Juveniles from ocean-type CUs are less susceptible because they have generally migrated to sea from their freshwater habitats prior to the summer low flow period.

During the spawning migration, high stream water temperatures affect adult Chinook salmon through higher metabolic cost of migration as well as increased susceptibility to disease and parasite infection. These factors may contribute to delayed migration and increased pre-spawn mortalities (Keefer et al. 2010; Goniea et al. 2006).

Elevated water temperatures are a result of multiple anthropogenic and natural factors. The primary anthropogenic causes include water extraction leading to low streamflows, modification of stream channels, riparian vegetation removal, waste water and drainage discharges, water impoundments, and reductions in groundwater levels (Caissie 2006). Another dominant cause is changes in air temperatures and precipitation associated with Climate Change. Above normal winter air temperatures and below normal snowfall lead to earlier and shorter duration freshets and earlier onset and longer duration summer low flow periods. During the summer, above normal air temperatures and below normal rainfall combine to result in very low streamflows, which leads to high water temperatures (IFC Recovery Team, 2006).

Water quantity

Pacific salmon are vulnerable to the effects of climate change in various degrees based on links between their distribution and exposure and the spatial variation in current and future climate regimes. A gradual increase in surface air, freshwater and sea surface temperatures are anticipated with climate change. This change in temperature will affect coastal freshwater discharge regimes and include more precipitation during the fall, winter and spring, earlier snow melt and increased freshet flows and result in overall lower flows during the summer months. These flow regime changes may effect life-history strategies of salmon (Beechie *et al.,* 2006) including adaptations of timing of spawning and fry emergence which are strongly linked to coincide with favourable river conditions and avoid high water temperatures and scouring flows (Beer and Anderson, 2001). Climate change may also effect smolt production, which has been shown to be highly correlated with annual air temperatures, winter flows, date of first fall freshet, and flow during smolt outmigration (Lawson *et al.* 2004). In particular, parr to smolt growth rates and survival indices may shift as they are closely linked to summer temperatures and minimum fall flows (Crozier and Zabel 2006; Nislow *et al.* 2004). Lower flows have also been predicted to result in potential fragmentation and loss of habitat through changes in wetted width and discharge which translates to potential changes in growth rates and age of smoltification for Chinook juveniles (Minns *et al.* 1995). Climate change may also impact smolt to adult survival indices by changing arrival timing of smolts into the estuary, which in high survival years coincides with favourable ocean conditions (spring up-welling) (Anderson and Hinrichsen 1996).

Flooding and low flow events frequency will vary across rain driven, snow-melt driven or hybrid watershed types (Whitfield et al. 2003). In coastal areas climate change is predicted to result in lower stream discharge and low amounts of rain in the summer and high discharge and heavy rainfall in the winter. For some systems on the East Coast of Vancouver Island an extended dry period in November could affect salmonid spawning by limiting migration or changing timing of migration (Hyatt, 2013). Modelling work by Leung and Qian (2003) showed that winter flooding and summer droughts would be greater in smaller watersheds within the Georgia Basin. In interior areas predictions are for earlier timing of peak flows and high discharge and snowmelt coupled with a 2 degree increase in water temperature in summer and low discharge and snow pack accumulation for winter (Wade et al. 2001; Morrison et al. 2002; Barnett et al. 2005).

Predation and Aquatic Invasive Species

Climate change can be defined as a large scale change in the Earth's weather patterns as a result of an accelerated increase of air temperature. This increase has resulted in increased ocean water temperature and changes in chemical composition, oceanic currents and precipitation patterns. As a consequence marine communities from phytoplankton up to apex predators have responded by changing population species complexes and distribution patterns. As the northern Pacific Ocean experiences warmer water conditions, marine species that are typical of tropical habitats have expanded their range northward. Southern BC Chinook populations are affected by an exposure to an increase abundance of predators such as hake, mackerel and salmon sharks.

Although range extension of freshwater based predators are limited by geography, anthropogenic activities such as releasing exotic non-native fish species, such as snakehead or yellow perch, would serve as a vector for piscivorous predators that could take advantage of warmer freshwater systems.

This range extension of salmon marine predators represents a threat to all salmonid species in southern BC. Pacific salmon are anadromous and for part of their life history, rear in marine waters from inshore to the deep ocean, depending on species and stock. This exposes all salmonid species to this threat, especially to the young fish that have recently entered marine waters.

The impact of the threat is dependent on annual sea water temperatures. Most tropical or sub-tropical predators are unable to function effectively during years when temperatures are low. Unfortunately, the trend for water temperatures is indicating that this threat will increase over time, producing a situation that allows warm water predators to continue to affect Chinook salmon in the future.

3.1.5 Hatchery Production

Although hatchery production of salmon is conducted to provide known and demonstrable benefits, it can also have the potential to negatively impact wild stocks. Biological risks to wild salmon from hatcheries exist via three main vectors: genetic, ecological and disease effects (DFO, 2013). In southern BC, wild and hatchery Chinook populations exist in close proximity to each other and can potentially interact at multiple life stages in the wild and in integrated hatchery programs.

There is evidence that interactions between hatchery and wild Chinook can result in decreased reproductive fitness and potential replacement of wild stocks (HSRG, 2014). These effects are most likely to occur in populations and CUs that are in close proximity to large scale hatchery production, but straying has been documented from distant hatcheries in Washington state into many southern BC rivers (D. Willis, pers. comm.). The primary mechanism by which hatchery practices may result in deleterious genetic effects on wild stocks in BC is outbreeding depression (via straying), although inbreeding depression and domestication of hatchery stocks can exacerbate the threat if those hatchery stocks do introgress into wild stocks.

Ecological interactions between hatchery and wild stocks are also a potential threat to southern BC Chinook. Interactions can occur within the freshwater or marine environment at multiple life stages including juveniles, feeding or spawning adults.

The third sub-category of potential threats is disease transfer from hatchery salmon to wild populations. The two primary theoretical vectors of disease transfer are downstream transmission to receiving waters from hatchery effluent, as well as direct transfer to wild salmon from hatchery fish following their release into the wild.

Empirical evidence in southern BC as well as recent scientific reviews indicate that genetic effects on wild Chinook populations from hatchery Chinook are likely the most significant threat posed by hatcheries to wild Chinook in Southern BC. Riddell et al. (2013) concluded that genetic effects from hatchery Chinook on wild populations were most likely in the West Coast Vancouver Island (WCVI) and Strait of Georgia CU groupings, due to both the relatively higher magnitude of hatchery production as well as the geographic proximity of enhanced and unenhanced systems. There is little to no direct evidence of genetic or other types of negative interactions with wild salmon in the Fraser or other non-Vancouver Island populations. Genetic analyses of some unenhanced populations on WCVI have found genetic introgression of stray hatchery fish into wild stocks at several locations (Riddell et al, 2013) although the exact magnitude of effects on fitness of wild populations is unknown. Ecological and disease effects have not been documented or confirmed in southern BC Chinook stocks, although their presence would be more likely in those areas with more extensive hatchery production on Vancouver Island. It has been hypothesized that some early marine interactions may occur in close proximity to hatchery systems following release of juveniles due to inter- and intra-specific competition in the estuary.

The degree of hatchery salmon interactions with wild populations in southern BC is currently poorly understood, although the effects are thought to be amplified on WCVI where there are many small, low productivity wild stocks in close proximity to large, productive hatchery populations. The exact mechanisms for reduced fitness in wild populations subjected to hatchery straying are unclear, but are primarily thought to occur at the adult spawner stage (HSRG, 2014). Genetic effects caused by stray hatchery fish can be variable by year, as straying can be exacerbated by environmental conditions.

Given the trajectory of stable or decreasing Chinook hatchery production in southern BC, as well as the strategies used which have shifted away from displacement releases in the past decade it is likely that the threat of negative effects on wild Chinook populations from hatchery salmon are unlikely to increase. Decreases in abundance and productivity of nearby wild stocks could increase their vulnerability to negative effects from nearby hatcheries, as could climate change-driven events that increase the susceptibility of wild stocks to external stressors.

3.1.6 Harvest

The Science Panel report describes the threat associated with harvest as follows:

> Very substantial reductions in total BC catch of Chinook salmon (originating from BC, Alaska, Oregon and Washington) occurred from 1975 to 1995; catch has been relatively steady post-1995 (Figure ST-2). More relevant to this review is a substantial decline in total coast-wide ocean catches of Chinook originating from southern BC streams (Figure H-8). Most of the decline in total catch has been attributable to reduced commercial fishery landings. Commercial landings were roughly twice sport fishery landings from 1975 to 1980, whereas today they are approximately equal (Figure H-5).
>
> Ocean distribution patterns for southern BC Chinook can be grouped into three distinct types: far-north-migrating, local-distributed, and offshore. Far-north migrating stocks contribute to Alaskan fisheries, whereas locally-distributed stocks do not. Offshore-type Chinook are vulnerable primarily as returning mature adults in coastal areas on approaches to natal streams.
>
> Total exploitation rates are the fraction of adults harvested in fisheries over a brood year's complete life span, and are computed based on CWT recovery data for indicator stocks. Total exploitation rates of southern BC Chinook stocks declined substantially over brood years 1973-1993 for both Far-north migrating and locally-distributed stock types, from an average of approximately 75% to an average of about 45%. Rates in the range of 70% to 80% are likely well above those that would have achieved maximum sustainable yield (MSY) during periods of average productivities. Total exploitation rates for all three ocean distribution types have been similar since about the 1993 brood year and have ranged from about 25% to 50%. Despite these dramatic reductions in total exploitation rates and ocean fishery

> landings, many stocks have experienced declines in spawning escapements over the past three generations.
>
> Mean CWT-based estimates of survival from release to ocean age 2, a proxy for marine survival conditions for most stocks, were relatively high for far-north-migrating and locally-distributed stock types over brood years 1973 to 1993, but since then have been much lower.
>
> The relatively long and steady period of low marine survivals that have been experienced by most southern BC Chinook stocks suggests that there has probably been a corresponding decrease in stock-specific productivities. In the Harvest section we show, for illustrative purposes, that if current stock-specific productivities have been reduced to one half of the past "average productivities", then recent exploitations rates could exceed MSY total exploitation rates that would be appropriate for many stocks currently, despite the substantial reduction from past much higher rates. If this were the case, then even the reduced exploitation rates could still be a contributing cause to the recent declines in escapements. Reductions in stock-specific productivities may not have been as great as 50%, however, and in our recommendations in the Harvest section we provide suggestions for methods that might allow more rigorous assessment of stock-specific changes in productivity from their long-term average values.
>
> \- Riddell et al. (2013, p. vi)

Managers of recreational fisheries have increasingly employed catch and release fisheries where populations of concern are present in mixed stock fisheries. Managers employ limits on the number of chinook that can be kept as well as limiting the harvest of certain sizes of chinook. The cumulative or total mortalities associated with releasing fish is not well understood. Total mortalities may include immediate mortality upon release, re-capture, depredation, predation upon disoriented fish after release, and succumbing to release related disease or injury prior to spawning. The above threats may be exacerbated by poor compliance, water temperatures, and environmental conditions.

3.1.7 CU-specific Assessments of Threats

As an example of drilling down into a finer level of detail (e.g., Section 1.2.3), some of the members of the Technical Working Group compiled and summarized the knowledge about threats to five individual CUs. The example CUs are CK-01 (Okanagan), CK-15 (Shuswap Summers 0.3), CK-17 (Lower Thompson Spring 1.2), CK-22 (Cowichan/Koksilah), and CK-31 (southwest Vancouver Island), which were chosen based on having substantial information and knowledgeable experts available to complete the work. The results are shown in Appendix F.

Although the results of these CU-specific assessments have not been interpreted in detail, two major patterns are evident when comparing to the assessment of threats across all southern BC Chinook (e.g., Table 2). First, as expected, individual threats can be specified in much finer detail (e.g., mechanisms, spatial location, temporal scale, distinction among similar threats, etc.). Second, when threats are assessed at the CU-scale, the vast majority of threats identified are freshwater and estuarine habitat stressors, with significantly less emphasis on factors during the marine component of the CU's life cycle. It appears that when examined at the scale of all southern BC Chinook salmon or CU groups (Figure 2), it is challenging to characterize unifying freshwater habitat threats because those factors are often not uniform or common across all CUs; however, when examined at the scale of individual CUs it is much easier provide detailed and nuanced characterization of such threats because it more closely aligns with the scale at which those factors operate. Alternatively, it may simply be easier to organize the specific expertise and knowledge related to freshwater/estuarine effects at the CU or watershed scale, which allows these threats to be documented in greater detail.

The CU Summary (Appendix G) also provides CU-level summary indicators for several potential threats, including freshwater habitat pressure indicators. Although much more highly aggregated than the CU specific details in Appendix F, the CU Summary (Appendix G) does provide information relevant to individual CUs rather than across all southern BC Chinook or CU groups.

3.2 Knowledge Gaps, Limitations and Data Availability

Chinook salmon exhibit tremendous biological and ecological diversity. As detailed by Riddell et al. (2013), southern BC Chinook salmon are exposed to a broad range of potential stressors and threats during different periods of their life cycle, varying in extent and duration by CU, making it difficult to disentangle the effects of different factors and unlikely that the observed patterns can be attributed to a single cause, but rather interactions among multiple variables. Combined with the socio-economic dimensions of managing habitat, harvest and hatchery production, the result is an incredibly complex socio-ecological system. Given that we have studied and managed this system for a long time, we have collected a lot of information and learned a lot relative to other species, including some other species of salmon. However, despite how much we know, there are many aspects of the system that we do not understand or do not understand well enough – much, much more remains unknown than known. Furthermore, with declining resources for monitoring and the potential for further declines, there is a risk of losing critical information currently collected (e.g., escapement and harvest monitoring).

This subsection identifies the most substantial knowledge gaps that are believed to be limiting our understanding of how potential threats are impacting southern BC Chinooks or our understanding of the most beneficial and effective strategies for halting, reversing and/or avoiding declines in Chinook.

The dominant knowledge gaps within each class are briefly described and they are summarized in Table 4 (or Appendix E for a more detailed version). Similar to the threats, the knowledge gaps have been grouped into classes. Although the identified knowledge gaps are described at the scale of the entire southern BC Chinook aggregate, their relative importance and magnitude varies considerably across CUs. Additional detail is provided for several of the knowledge gaps, as identified by the Technical Working Group.

Table 4. Knowledge gaps and uncertainties related to our understanding of southern BC Chinook salmon and the consequences of management actions and other human influences.

Class and Subcategory	Knowledge Gap	Relevance (not completed)	Affected subset of CUs (incomplete)
Status and trends			
Monitoring framework	Lack of a **comprehensive assessment and monitoring framework** (especially indicator stocks across life-history types, ecotypes, and ecosystems). Most of the other status and trends gaps are nested within this overall gap.	Critical info for stock assessment and fisheries mgt.	All
Indicator stocks	Limited number of **indicator stocks**. Highest priority gaps: Upper Fraser and mainland inlets.		Most CUs
Wild indicators	Lack of **wild indicator stocks**. However, tagging representative sample of wild fish is extremely difficult/expensive.	Separation of wild & hatchery	All
Abundance	**Quantitative abundance estimates** (cannot conduct formal stock-recruitment analyses to estimate stock-specific productivity)		Most CUs
Mortality	**Mortality rates by age-class** and annual variability		Most CUs
Productivity	Assessment of possible **temporal changes in productivity** – not possible for most stocks, which use habitat-based methods). The data necessary for S-R analyses is either incomplete or non-existent for most populations.		All
Other biometric data	In many cases, **data** on age-at-return, body size, and sex composition are inadequate for analysis		All
Marine and FW effects	Capability to **separate freshwater and marine effects** on stock recruitment and productivity		
Existing data	Validation of pre-1995 **spawner data**		All
Marine Habitat			
Survival factors	Knowledge of what is currently **limiting survival in the marine** environment		
Marine mammal predation	Possible underestimation of natural mortality due to increased **marine mammal predation**.		
Human influence on predation	How are **human-mediated changes in marine mammal** populations and behaviours leading to changes in predation		
Environmental conditions	Impacts of changes **environmental conditions** on Chinook populations. Requires substantial, long-term research programs.		
Ecosystem interactions	Limited understanding about broader dynamics of **estuarine and early marine ecosystem interactions and feedbacks** associated with both wild and enhanced Chinook stocks.		Van. Island, SoG
Salmon farms	Limited information on potential interactions and risks of **salmon farms**.		
Hatchery Production			
Risks and benefits	Clear understanding of **impacts (risks and benefits) of hatcheries** and enhanced stocks – interactions, spawning contribution, potential replacement, carrying capacity, abundance indices, harvest rates, bycatch rates, stray rates, genetics.		Esp. Vancouver Island
Effects on harvest	Better understanding of influence of changes in hatchery production on **changes in harvest levels** for different stocks or fisheries.		Van. Island
Genetic	Limited **ability to assess and monitor** enhanced contribution to return in unmarked stocks		All
Genetic - straying	Limited understanding of the extent/effect of **genetic outbreeding introgression** of hatchery stocks and other non-target stocks.		Van. Island
Genetic - straying	Limited understanding of the extent/magnitude of hatchery Chinook salmon **straying** into non-natal watersheds		Van. Island

Class and Subcategory	Knowledge Gap	Relevance (not completed)	Affected subset of CUs (incomplete)
Pathogens and Diseases			
Monitoring	**Monitoring of disease** in wild populations and estimation of impact is limited in BC.		All
Impacts of disease	The extent to which **pathogens and disease** contribute to variation in Chinook production over space and time is not known		All
Harvest			
Sustainable ERs	Are current harvest-associated total mortalities sustainable based on current productivity levels		
Catch monitoring	Need to assess current **catch and compliance monitoring across all fisheries** in marine and freshwater areas and identify the biggest gaps.[10]		
First Nations participation in catch monitoring	Concerns about **First Nations not being included in monitoring**. Some First Nations have experience or perceived an unwillingness to consider local capacity to do monitoring within their territory.		
Total mortality	Need to have better estimates of the **total mortality from fisheries** (incl. catch, bycatch, encounter rates, discards, short-/long-term release mortalities). • Is **retained catch** being accurately and completely estimated? • Is Chinook **bycatch** being accurately estimated? • Is long-term **release mortality** being accurately estimated? • Is **depredation** (forcible removal by predators of fish directly from fishing gear) being accurately estimated? • Is long-term **mortality from drop-off** from gillnets and other fishing gear being accurately estimated? • Is **compliance** being accurately estimated? • Is impact of **environmental conditions on post-release survival** being considered?		
Setting ERs	Technical basis for setting **optimal exploitation rates** is weak for many stocks. Need to consider total allowable mortality from all factors and account for changes and uncertainty in what is considered "optimal". The biggest contributing factor to this knowledge gap is the lack of S-R analyses for most populations to be able to estimate U_{MSY}.[11]		
Ecosystem-level impacts	The ecological impact of the **removal of biomass** due to harvest.		
Fishery-induced evolution	Genetic risk of modifying populations from fishing the "tails" of the distribution of run timing (i.e., "**fishery induced evolution**").		
Fishery-induced changes	Are certain harvest patterns (e.g., size, timing) contributing to **reduced productivity** for certain stocks		
Climate Change			
Various mechanisms	Incomplete knowledge of expected changes and potential impacts on different aspects of Chinook life history and habitats		All

Future Work:
Completion of the last two fields of the table.

[10] For example, 1) some CSPI participants identified gaps in freshwater catch monitoring in certain areas, and 2) participants had strongly differing views on the strength and representative of the recreational catch and compliance monitoring system.
[11] Linkage to Status and Trends knowledge gaps.

3.2.1 Assessment Monitoring

Appendix G summarizes the current state of the overall assessment program for southern BC Chinook salmon, by CU. The table illustrates whether the level of representation of each CU within the current framework is adequate, deficient or non-existent. For example, some CUs have a strong CWT hatchery indicator, multiple rivers that are assessed, and well represented in PST Chinook Technical Committee analyses, whereas there are other CUs (and even entire PST Management Units) that have no CWT indicator (often because no hatchery exists in the area), no/few rivers that are assessed, and in some cases CUs for which even the general ocean distribution pattern is unknown.

Significant gaps in the assessment of southern BC Chinook CUs are:

1) We still have CUs that are completely unrepresented within our CTC management
2) There are several PST MUs that really do not adequately represent the behaviour of the fish (i.e., Fraser Spring 5-2s include far-north migrating Birkenhead with the remainder being offshore; similar issues in Fraser Summer 5-2s; and other aggregates that include multiple run timing groups)
3) The lack of CWT indicators in the Fraser (e.g. Spring and Summer 5-2s, far-north migrating springs) and in other areas (e.g. Homathko, Klinaklini)
4) The lack of any high-precision escapement work in many areas, which means no possibility of reliably determining escapement by age and sex.

Future Work:
Further work on this section and Appendix G is currently underway.
Additionally, work is being done on a comparable appendix to identify the state of fisheries monitoring for southern BC Chinook salmon, to similarly identify strengths, weaknesses and gaps.

3.2.2 Freshwater Habitat – Ability to determine impacts of environmental conditions

The ability to understand environmental impacts on Chinook salmon within freshwater habitat is increasingly becoming important in order to identify management actions to mitigate the effects and support reproductive success. Monitoring environmental conditions increases our knowledge of how Chinook salmon utilize freshwater habitat in varying conditions. Information collected on river temperatures, migration, and reproductive success under varying and changing environmental conditions enables better management that can allow for in-season adjustments of fisheries in response to adverse effects. Collecting essential information in freshwater habitat is encouraged to close this knowledge gap to not only better manage fisheries but also to fully understand the potential impacts under varying environmental conditions.

3.2.3 Climate Change - Future Impacts

It is very possible that climate change will eventually bring Chinook habitats outside the range of previously observed environmental conditions, or so variable that adaptation is not possible. Furthermore, there could be a tipping point (or series of thresholds) that once crossed, limit the adaptive responses of Chinook and results in irreversible loss of genetic diversity and productive capacity. Partitioning observed changes in Chinook status among competing sources of variation continues to be an area primarily of speculation rather than scientific finding. Continuing to use available tools to assess (and re-assess) cumulative ecosystem impacts and to conduct scientific experiments to measure physiological responses to changing environmental conditions will help inform this work.

3.2.4 Hatchery Production

The principle knowledge gaps that exist with respect to the interactions between hatchery and wild Chinook populations in southern BC are those relating to the magnitude of changes in fitness of Chinook populations that are subject to hatchery influence (direct and indirect). Current work that is ongoing to better understand the magnitude and extent of interactions will help to inform current status, but the outcomes of this work will be needed to better characterize the risks and to inform future hatchery planning, assessment and monitoring work.

Detailed understanding of potential ecological interactions between hatchery and wild salmon populations also remains a gap. While it is generally understood there are potential interactions in the marine and freshwater environments, there are a lack of tools available to appropriately assess and manage these interactions in southern BC. Given the relatively small magnitude of southern BC hatchery Chinook production compared to that from other jurisdictions in the North Pacific, it is most likely that effects directly attributable to BC hatchery production would exist in the early marine environment, however this continues to be an area where better information is needed.

3.2.5 Harvest

The Science Panel report summarizes the knowledge gaps associated with harvest as follows:

> The limited number of indicator stocks, especially for the offshore ocean distribution type (stream-type spring Chinook), limits the level of assurance with which estimates of total exploitation rates for indicator stocks can be used to infer likely exploitation rates for untagged stocks of interest. Inconsistency in estimated total exploitation rates for Dome Creek ([hatchery chinook no longer produced]/no longer tagged) and Nicola River spring Chinook is also of concern. It is important to have at least one additional indicator stock for the offshore ocean distribution type, with a strong preference for the upper Fraser region.
>
> Quantitative abundance estimates (rather than qualitative indexes) of spawning escapements and freshwater harvests are lacking for most southern BC Chinook CUs, thereby ruling out formal stock-recruitment analyses for estimation of stock-specific productivities and assessment of possible temporal changes in productivities. Watershed and habitat-based methods for estimating productivities likely have merit, but they are less desirable than stock-recruitment analyses, in particular because they do not allow incorporation of marine survival rates as a factor that may influence recruitment production.
>
> We note the critical role that estimates of total exploitation rates and marine survival rates, based on tag recoveries of CWT releases of indicator stocks, have played in our assessment of the possibility that harvest (and also ocean environment) may be a continuing serious stressor on southern BC Chinook. It is critical that such estimates are available in the future.

- Riddell et al. (2013, p. vii)

3.2.6 Cumulative Effects

Cumulative effects are the net consequences of the aggregate stresses (both natural and anthropogenic) that determine the status and sustainability of a valued ecosystem component (Greig et al. 2003), and should ideally be assessed at the scale of ecological regions, not at the scale of individual projects (Duinker and Greig 2006). Cumulative effects were considered in the analysis of Fraser sockeye completed by the Cohen Commission (Marmorek et al. 2011), but remain one of the largest knowledge gaps in the management of Pacific salmon.

Cumulative effects on salmon populations can occur in multiple forms:

- **the total impact of a single type of stress that has occurred repeatedly over time**, possibly increasing in frequency or magnitude (e.g., the cumulative effect of water pollution in the Fraser River estuary over the past four decades). To focus management efforts, it is important to improve understanding of the relative impact of each stressor on a Chinook during the completion of its life history.
- **the total impact of a single type of stress that occurred repeatedly over space** (e.g., the cumulative effect of multiple mountain pine beetle outbreaks across the entire Fraser River watershed);
- **the total impact of many different types of stressors at one point in time or over a period of time** (e.g., the cumulative effect of changing climate, increased mammal predation, and increased harmful algal blooms). Of particular concern are stressors that could act together in a non-additive (multiplicative) fashion, causing inordinate effects when combined. The interaction of water conditions together with non-lethal fishing impacts would be an example.

Anadromous fish face a well-known set of stressors during the completion of their life cycle; these are documented in this report by (1) freshwater habitats (impacts to water flow, water temperature, water quality, and spawning conditions), (2) marine habitat (Estuarine, near shore, offshore), and (3) generalized human-induced stressors spanning both environments, including the impacts of fishing, climate change, hatchery releases and the introduction of exotic species that compete with or predate on juvenile salmonids (Figure 4).

Since some stressors can accumulate over their entire life history (Figure 4), it is very difficult to ascertain the relative contribution of different stressors to observed outcomes. The only way to tease out such relationships is by examining strong contrasts across time, space and stocks (e.g., Marmorek et al. 2011, Peterman et al. 2010), and making inferences based on correlations of stressors and responses, ideally supported by experimental evidence of cause-effect relationships. The CSPI recognizes the importance of cumulative effects, and the need for maintaining a systematic and well-designed monitoring program across all life stages to provide insights on potential cumulative effects, conducting various forms of applied research to test hypotheses regarding potential impact pathways, and periodically synthesizing all available data into an assessment of cumulative effects. The current assessment program in DFO acquires habitat and fish assessment data for the freshwater and marine portions of the life cycle, as well as gathering data on hatcheries and harvest. DFO is partnering with the Pacific Salmon Foundation and others to fill in critical information gaps regarding pathogens, the effects of aquaculture, and changes in marine habitat (e.g., Strategic Salmon Health Initiative and Salish Sea Marine Survival Project (PSF 2015)).

The management challenge is made even more complex by multiple stocks co-migrating as aggregate populations, and subjected to fisheries as well as other stresses. Maintaining a diverse portfolio of stocks has been shown to have increases the resilience of the entire aggregate population of salmon in Bristol Bay (Schindler et al. 2010). From a practical perspective, the main objectives in managing cumulative effects are to predict: (1) where and when the cumulative effects of human-induced stresses can be tolerated (and where when they cannot); and (2) where limited resources are best applied to mitigate ongoing stress.

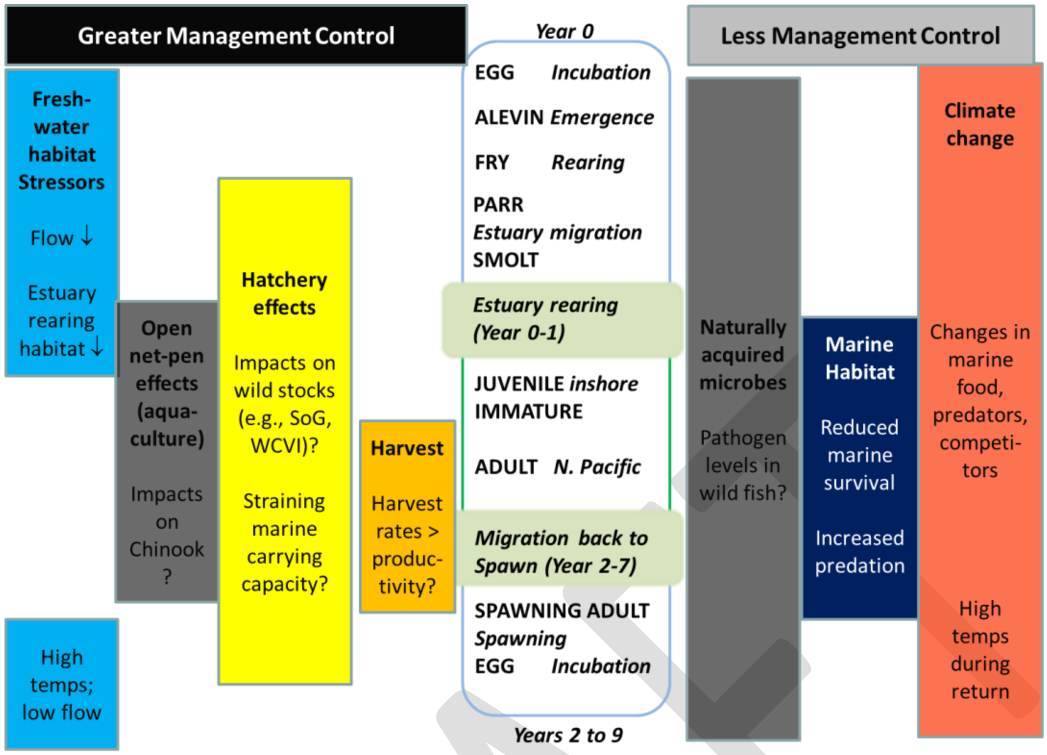

Figure 4. Conceptual illustration of the cumulative effects of different stressors affecting Chinook salmon.

4 Objectives

The SPC developed an initial set of biological, social and economic objectives at a 2-day workshop in March 2013 (Compass 2013). The TWG used a subset of these objectives in January 2014 for a *qualitative* evaluation of general *strategic directions* developed by the SPC (ESSA 2014). Table 5 builds on this and other previous work, proposing a hierarchy of objectives at 5 levels (the columns in the table): 1) objectives from the Wild Salmon Policy; 2) *fundamental* objectives (*what is desired)* developed by the SPC; 3) *means* objectives to achieve the SPC's objectives; 4) candidate indicators associated with the means objectives; and 5) candidate performance measures for each of the candidate indicators. Table 5 also indicates the class for each fundamental and means objective (i.e., biological, social, or economic) and its desired direction (i.e., increasing or decreasing). It is anticipated that Table 5 will be further refined as the strategy is implemented, particularly the indicators and performance measures, which need to be monitored and/or modelled to provide feedback on the effectiveness of the strategy in achieving the listed objectives. Indicators will vary depending on the availability of data across CUs.

Table 5. Hierarchy of objectives, indicators and performance measures proposed for the CSPI.

WSP Object.	SPC Fundamental Objectives	Proposed Means Objectives	Class	Desired Direct.	Indicator(s) / Criteria to Assess	Performance Measures (evaluations of indicators to yield insights on progress)	Source
1.	**Habitat and Ecosystem Integrity**						
Maintain habitat and ecosystem integrity	Sustain freshwater habitat carrying capacity (B5)	Increase the *quantity* of freshwater habitat (carrying capacity) in CUs where that appears to be a factor limiting freshwater production (e.g., remove barriers to allow Chinook to access high quality habitat)	Bio.	↑	S_{rep} (spawners required for replacement) and S_{msy} (spawners required for maximum sustainable yield), estimated either directly from spawner-recruit data or from GIS information on barriers and area of accessible spawning and rearing habitat (accounting for life history type). Summarized by reach, watershed or CU.	Change over time in area of accessible habitat, S_{rep} and S_{msy} due to habitat restoration actions (e.g., barrier removal) or human / natural disturbances (e.g., barrier creation)	Parken et al. 2006
		Maintain or improve the *quality* of habitat attributes that are critical to local freshwater production of Chinook salmon	Bio.	↑	Many possible habitat indicators (Nelitz 2007a, 2007b); key is to determine within each CU which ones are limiting local production of Chinook Relative levels of cumulative stress by CU, re-evaluated every 10 years.	Trends through time in key indicators limiting freshwater production within each CU or watershed Decadal changes in % of watersheds at low, moderate or high cumulative risk based on methods in Porter et al. 2013.	Nelitz et al. 2007a, 2007b Marmorek and Porter 2009 Porter et al. 2013
	Sustain salmon contribution to ecosystem health (B6)	Ensure that there are sufficient Chinook post-harvest to sustain Chinook-dependent predators	Bio.	↑	5-year average recruitment and 5-year escapement as indicators of available prey for Chinook-dependent predators	Trends over time in 5-year average recruitment and 5-year average escapement	Proposed indicator - builds on work in Nelitz et al. 2006
		Ensure that Chinook harvests are not harming Resident Killer Whale populations	Bio.	↓	Sensitivity of fecundity and population growth rate of Southern Resident Killer Whales (SRKW) to current harvest rates of Chinook salmon	Changes in the relationship between SRKW metrics and Chinook abundance indicators	Ward et al. 2013; ; Hilborn et al. 2012

WSP Object.	SPC Fundamental Objectives	Proposed Means Objectives	Class	Desired Direct.	Indicator(s) / Criteria to Assess	Performance Measures (evaluations of indicators to yield insights on progress)	Source
2.	**Conservation**						
Safeguard the genetic diversity of wild Pacific salmon	At least sustain and preferably improve overall (wild and enhanced) salmon abundance (B1)		Bio.	↑	SBC Chinook WSP integrated status paper- red, yellow, green integrated status assessment	Integrated WSP Status (# CUs in Red, Yellow, or Green category) Comparison of spawning abundance to various WSP biological benchmarks	CSAS paper in prep. -CU dashboards
	At least sustain and preferably improve wild salmon abundance (B2)		Bio.	↑			
		Ensure that total fishing mortality rates remain below level required to reach MSY	Bio.	↓	a) Total fishing mortalities (TFM) vs. TFM that would generate MSY (μ_{msy}) for indicator stocks based on *historic* productivity b) TFM vs. μ_{msy} for indicator stocks based on *current* productivity	Current TFM vs. historic productivity Current TFM vs. current productivity (see Riddell et al. 2013, which provided μ_{msy} for historic and 50% historic productivity for CDN indicator stocks)	Riddell et al. 2013
		Maintain spawner abundance above escapement goals or WSP benchmarks (where available) and/or maintain positive trend in spawner abundance	Bio.	↑	a) Time series of spawner abundance vs. escapement goal or WSP benchmarks b) Recent trends in spawner abundance	% years in which spawners exceed goals or benchmarks over last 10 years and pattern of change over time % change in spawner abundance over last 10 years	See CTC report: REPORT TCCHINOOK (15)-2, pg. 98
		Maintain stock status in green zone	Bio.	↑	a) Fraser Chinook management units b) WCVI Chinook c) Cowichan d) Others	% years objective achieved in last 10 years and pattern of change over time.	Post-season reviews
		Maintain harvest rates below harvest objectives or fishery reference points	Bio.	↓	a) Exploitation rate or total fishing mortalities vs. management objectives for specific stocks b) Actual Harvests or Total mortalities (incl. catch + releases) vs. TAC for domestic fisheries (also see international objectives)	% years actual outcomes met or exceeded in last 10 years and pattern of change over time. % Variance from targets (e.g. +/- 5% vs. +/- 50%)	Post-season reviews
	At least sustain and preferably improve salmon spawning distribution (B3)	Maintain viable numbers of Chinook spawners	Bio.	↑	Distribution of spawners across historic spawning areas	Trend through time in % of spawning areas within each CU that have viable numbers of spawners (targets TBD)	

WSP Object.	SPC Fundamental Objectives	Proposed Means Objectives	Class	Desired Direct.	Indicator(s) / Criteria to Assess	Performance Measures (evaluations of indicators to yield insights on progress)	Source
		across all historic spawning areas					
	Sustain genetic diversity (B4)	Preserve or enhance genetic diversity through hatchery programs	Bio.	↑			
		Minimize the negative impacts of enhancement on the genetic diversity of wild Chinook populations in areas of potential concern (currently Strait of Georgia (SoG) and WCVI).	Bio.	↓ (PHOS) ↑ (PNI)	Proportion of Hatchery-Origin Spawners (PHOS) Proportionate Natural Influence (PNI) (estimates the degree of influence of the hatchery environment on the mixed hatchery and natural-origin spawners)	Maintain PHOS < population-specific thresholds, and PNI > population-specific thresholds in vulnerable populations in SoG and WCVI *Note: pHOS and PNI thresholds do not currently exist*	Table Hat-1 (pg. 120) in Riddell et al. (2013); Busack et al. (2006)

WSP Object.	SPC Fundamental Objectives	Proposed Means Objectives	Class	Desired Direct.	Indicator(s) / Criteria to Assess	Performance Measures (evaluations of indicators to yield insights on progress)	Source
3.	**International – Pacific Salmon Treaty (PST)**						
Fisheries and Benefits		Maintain harvest below Total Allowable Catch(TAC) ceilings that are developed based on Aggregate Abundance Based Management (AABM)objectives according to schedule in Pacific Salmon Treaty (PST)	Bio.	↓	Maintain AABM harvests below pre-season and post-season TAC	a) Comparison of North Coast (NC) AABM harvests to . pre-season and post-season TAC b) Comparison of West Coast of Vancouver Island (WCVI) AABM harvests to pre-season and post-season TAC c) Comparison of Southeast Alaska (SEAK) AABM harvests to pre-season and post-season TAC % years objectives met in last 10 years by indicator stock, and pattern of change over time	PST Post-season Reports or CTC Reports
		Individual Stock Based Management (ISBM) objectives		↓	Canada and the United States shall limit the total adult equivalent mortality rate in the aggregate of their respective ISBM fisheries to no greater than 63.5 percent and 60 percent, respectively, of that which occurred during the 1979 to 1982 base period on the indicator stocks identified in Attachments IV and V for	% years objectives exceeded in last 10 years by indicator stock and pattern of change over time	CTC annual reports

WSP Object.	SPC Fundamental Objectives	Proposed Means Objectives	Class	Desired Direct.	Indicator(s) / Criteria to Assess	Performance Measures (evaluations of indicators to yield insights on progress)	Source
					stocks not achieving their management objectives.		

WSP Object.	SPC Fundamental Objectives	Proposed Means Objectives	Class	Desired Direct.	Indicator(s) / Criteria to Assess	Performance Measures (evaluations of indicators to yield insights on progress)	Source
4.	**First Nations**						
Fisheries and Benefits WSP Principle: Honour obligations to First Nations	At least sustain and preferably increase aboriginal FSC harvest abundance (S1)		Social	↑			
	At least sustain and preferably increase aboriginal FSC harvest distribution (S2)		Social	↑			
		Realize intended harvest opportunities for First Nations, consistent with Allocation priority that recognizes that after conservation, First Nations' FSC fisheries have priority.		↑	a) Fishery openings by area strata b) Fishing effort by area strata c) Catch vs. communal license harvest target by area (e.g. SCA, LFA, BCI)	a) Time trends in open time (hours/days) / Relative change in open time over last 10 years b) Time trends in Reported fishing effort by area strata c) Time trends in catch over last 10 years (comparison of catch with communal license harvest target) d) Average Chinook CPUE by area/year	Post-season reviews

WSP Object.	SPC Fundamental Objectives	Proposed Means Objectives	Class	Desired Direct.	Indicator(s) / Criteria to Assess	Performance Measures (evaluations of indicators to yield insights on progress)	Source
5.	**Recreational**						
Fisheries and Benefits	Maintain or enrich recreational fishery experience (S3)		Social	↑			
	Maintain or increase recreational fishery net revenue (E2)		Econ.	↑			
	Maintain or increase recreational fishery employment (E4)		Econ.	↑			
		Maintain or enhance recreational fishery opportunities while adhering to Allocation priorities for conservation and FN FSC.	Econ. Social	↑	a) Amount of fishing effort b) Wild and enhanced Chinook catch c) Chinook CPUE	a) Time trends in effort (boat days/ rod days) by area stratum b) Time trends in Chinook catch by area strata c) Time trends in CPUE (Catch/effort) by area strata	

WSP Object.	SPC Fundamental Objectives	Proposed Means Objectives	Class	Desired Direct.	Indicator(s) / Criteria to Assess	Performance Measures (evaluations of indicators to yield insights on progress)	Source
6.	**Commercial (including FN economic/demo fisheries)**						
Fisheries and Benefits	Maintain or increase commercial fishery net revenue (E1)		Econ.	↑			
	Maintain or increase commercial fishery employment (E3)		Econ.	↑			
		Maintain or enhance commercial harvest opportunities while adhering to Allocation priorities of conservation, FN FSC, and recreational fisheries.	Econ.	↑	a) Commercial Harvest b) Employment c) Income/Revenue	a) Time trends in commercial harvest by year b) Time trends in average % of commercial TAC harvested by year c) Time trends in employment and revenue	• DFO's Fishery Operations System (FOS) • Post-season reports • Policy/Economic Analysis using Provincial model

WSP Object.	SPC Fundamental Objectives	Proposed Means Objectives	Class	Desired Direct.	Indicator(s) / Criteria to Assess	Performance Measures (evaluations of indicators to yield insights on progress)	Source
7.	**Other (do not fit easily within above categories)**						
Fisheries and Benefits	Reduce management uncertainty (B7)	Show improvements over time in the achievement of biological, social and economic objectives and performance measures.	Bio.	↓	Biological, social and economic indicators listed above	Time trends in achievement of biological, social and economic performance measures.	
	Reduce management costs (E5)	Increase cost effectiveness of management as stocks recover (e.g., increasing the ratio of total returns of wild Chinook to SBC CUs to total Chinook management costs)	Econ.	↑	Chinook management costs (including monitoring, stock assessment, analysis, enforcement) Total returns of wild Chinook	Time trends in [the ratio of total returns of wild Chinook to SBC CUs] to [total Chinook management costs]	
[other]	Sustain connection with salmon (S4)	Increase the number of people involved in fishing for Chinook, in recovery of Chinook salmon populations and in watershed protection or restoration	Social	↑	# people involved in fishing for Chinook (all sectors) # people involved in local programs for recovery of Chinook salmon populations and in the protection and restoration of watersheds that support Chinook	Time trends in the number of people involved (as specified in adjacent columns)	

5 Strategies

This section presents the set of proposed strategies for achieving the objectives described in Section 4 and thus addressing the threats and knowledge gaps identified in Section 3. Where appropriate, multiple sub-strategies are nested within a single overarching strategy. The strategies are organized within the following categories:

- Marine Habitat/Ecosystem
- Freshwater habitat
- Major Projects and/or Significant Incremental/Cumulative Development
- Hatcheries and Monitoring Programs Utilizing Hatchery Indicator Stocks to Assess Status and Trends
- Harvest
- Climate Change
- Additional Monitoring to Assess Status and Trends
- Communication and Partnerships
- Formal Adaptive Management to Assess the Effectiveness of Actions

The order of the categories does not represent prioritization among the categories. Within each category, strategies and sub-strategies are organized to reflect logical sequence where appropriate.

5.1 Scope and Context

There are several important points that **must** be considered when reviewing and interpreting these strategies.

1. These strategies are not detailed, executable actions. They are intended to provide strategic direction to inform subsequent action-planning processes where the actions required to implement the strategies would be determined (e.g., within existing planning processes within different domains/regions).
2. The sub-strategies are not necessarily an exhaustive list– they are examples that support the overarching strategy.
3. The Strategic Plan is the product of a Tier 2 government-to-government process with additional multi-stakeholder input. The Strategic Plan does not represent the mandate or plan of any single organization or group. Rather, it presents a set of strategies that, if collectively and collaboratively implemented, should improve the prospects for healthy Chinook populations and sustainable use.
    a. These strategies do not reflect a commitment by any individual organization (e.g., DFO) to implement the full suite.
    b. These strategies span the mandates and jurisdictions of many different entities.
4. The strategies have not been screened by cost or feasibility of implementation. Some strategies would require very significant investment, potentially beyond realistic constraints. However, such strategies have been retained if their potential benefits would address identified threats and/or knowledge gaps.
5. Some strategies are currently addressed by existing legislation or regulations. These strategies are still relevant, however, because legislation can change and these strategies address the underlying need to maintaining (or strengthening where possible) such frameworks.
6. Some strategies may be beyond existing mandates of organizations or agencies, or outside of their usual operations. Such a gap does not diminish the importance of a strategy, but does indicate additional complexities that would need to be addressed to implement it.

Future Work:
Prioritizing and sequencing strategies. As indicated in the "scope and context" above, the product of the current phase has been a relatively comprehensive set of strategies.
Work needed to support this will include:
1. Linking the strategies to the objectives they are addressing
2. Linking the strategies to the threats and knowledge gaps they are addressing
3. Providing additional information on each strategy such as approximate timeframe, initial costs, ongoing costs, and/or other measures of feasibility.
4. Designing (and implementing) a process to assist the SPC prioritize strategies
5. Using this information to guide further components of the implementation plan.

Appendix I includes a preliminary example of #1-3 for the strategies associated with hatchery production.

5.2 Integrated Strategies to Address Threats and Knowledge Gaps and/or Achieve Objectives

❶ = Science Panel highest-level priority[12]; ❷ = SPC priority learning strategies[13]

5.2.1 Marine Habitat and Ecosystem

Strategy 1. Increase understanding of threats and limiting factors affecting juvenile survival in estuary and early marine habitats, especially in the Strait of Georgia and WCVI, and mitigate these factors where possible. ❶

1.1. Confirm or increase understanding of the location and distribution of Chinook in early marine habitats.

1.2. Study natural mortality to update assumptions used in management since the 1980s. ❶

1.3. Identify and remedy (where possible) anthropogenic threats limiting early survival or indirectly contributing to natural mortality.

1.4. If marine survival is low, apply compensatory actions within other domains

  a. Assure the best possible condition of outmigrating smolts (as addressed by freshwater strategies)

  b. Adjust harvest as appropriate

Anticipated benefits: improve the understanding, tools and effectiveness of Chinook management; develop more realistic/accurate estimates of early marine mortality

Strategy 2. Improve understanding of the prevalence and impacts of pathogens and disease on SBC Chinook, from both natural and anthropogenic sources, with particular attention to the influences of hatcheries, salmon farms and climate change.

2.1. Maintain and/or improve monitoring and reporting of pathogens and disease in hatcheries, salmon farms and natural populations.

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[12] See Riddel et al. 2013.

[13] See Hall et al. 2014.

2.2. Increase research into the dynamics of disease and potential impacts on southern BC Chinook.
2.3. If evidence suggests disease and pathogens from hatcheries and/or salmon farms are affecting southern BC Chinook, develop improved management practices.
2.4. Ensure that hatcheries and salmon farms are following best practices
2.5. If evidence pathogens and disease are negatively affecting Chinook, ensure that information on the magnitude and dynamics of the effect are integrated into management decisions within other domains, whether or not direct mitigation actions exist (e.g., effective actions may not exist)

Anticipated benefits: Improve understanding and management of a potential stressor and issue of public concern.

Strategy 3. Promote the protection of marine and estuarine habitat important to Chinook salmon and prioritize areas where restoration activities would have the greatest benefit to Chinook survival rates

3.1. Encourage strong legislation and regulation of impacts on marine and estuarine habitat, wherever possible, at all levels of government.
3.2. Communicate the importance of habitat protection and potential threats (see Communication and Partnerships).
3.3. Determine the status of estuaries and apply the estuary ranking methodology.
3.4. Identify and prioritize key estuary areas that are at risk and/or require protection.
3.5. Protect and restore rearing areas of estuaries, particularly areas frequented by multiple Chinook stocks (e.g. Fraser River).
3.6. Work with multiple levels of government and stakeholders to mitigate human activities that promote aggregations of predators (and activities that are destructive to habitat) and appear to cause high mortality of Chinook salmon in estuarine and nearshore marine areas (e.g., log booms, hatchery release practices, salmon farms, coastal developments).

Anticipated benefits: Increase survival and/or halt the decline in survival by improving habitat conditions or reducing specific threats.

5.2.2 Freshwater Habitat

Strategy 4. Promote habitat protection across all CUs[14] to support the resilience of the entire system as different types of habitat become more or less important as future conditions change in uncertain ways.

4.1. Maintain and/or strengthen legislation and regulation of impacts on freshwater habitat, wherever possible, at all levels of government.

[14] Habitat protection should not be limited to only the CUs that are currently contributing to fisheries or to only the CUs with the most significant recent declines. Maintaining the resilience of southern BC Chinook in the face of uncertain future climate/ocean regimes across all CUs requires protecting important habitat across all CUs.

4.2. Improve collaboration/coordination of existing legislation/regulations among different levels of government.
4.3. Build relationships with local government and incorporate habitat protection into local watershed planning.
4.4. Enforce existing legislation.
4.5. Communicate the importance of habitat protection and potential threats[15].

Strategy 5. Identify and remedy habitat threats within CUs, including those that have exhibited significant declines (greatest need) and those with strong local engagement in protection and restoration (greatest capacity) regardless of status and recent trends.

5.1. Develop partnerships and/or broader governance strategies to improve the coordination among the many government agencies, First Nations and community groups undertaking habitat restoration activities[16].
5.2. Identify anthropogenic threats limiting survival and/or recovery of Chinook CU's in the freshwater environment (spawning, rearing and migratory habitats)
5.3. Assess potential improvements in stock productivity and carrying capacity to identify opportunities where habitat restoration will be most effective. Communicate results to scientists working on integrated modeling across SBC CUs.
5.4. Design habitat protection and/or restoration actions, including appropriate monitoring and evaluation, prioritizing actions with the maximum benefit and/or greatest cost effectiveness
5.5. Implement actions designed to protect and restore freshwater habitat (e.g., barrier removal, protection of spawning areas, water use management to provide flow requirements for various life stages)[17].

Anticipated benefits (Strategies 4 and 5): Healthy and diverse freshwater habitats, supporting healthy and diverse Chinook populations.

Strategy 6. Integrate information on upstream migration mortality, pre-spawn mortality and reduced reproductive success into harvest planning[18]

6.1. Develop methodologies for monitoring upstream/pre-spawn mortalities and assessing relationships with river temperature, as consistent with the available information.
6.2. Determine feasibility of establishing guidelines for in-season fishing adjustments to account for upstream and pre-spawn mortality[19].
6.3. As feasible, given data availability and potential management actions, set guidelines, implement monitoring as appropriate, and apply in-season adjustments to harvest as necessary to compensate for upstream mortality and reproductive success.

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[15] Linkage to Communication and Partnerships strategies.
[16] For example, SEP-RRU, RFCPP, FHRI, FPP offsetting, PSF, etc. Linkages to Communication and Partnerships strategies.
[17] Involves engagement with other agencies and other legislation.
[18] Ultimate goal would be to achieve a similar approach, if feasible, to Fraser River Sockeye salmon.
[19] Chinook do not have the same level of data or precision of management actions as Sockeye.

Anticipated benefits: Reduce risk of overharvesting, ensure adequate spawning to sustain populations.

5.2.3 Significant Projects and/or Incremental/Cumulative Development

Strategy 7. Ensure that salmon are included as a focal area of environmental and cumulative impact assessments of significant projects with effects on Chinook salmon or multiple smaller projects[20] with a potentially significant cumulative effect

7.1. Actively engage stakeholders, as well as the Fisheries Protection Program, in environmental assessment processes of projects that could potentially affect Chinook salmon.
7.2. Develop a cumulative effects framework and assess potential effects within this structure.
7.3. Determine and prioritize actions for avoiding or reducing identified impacts to Chinook.
7.4. When existing habitat cannot be protected, mitigate or offset the loss of productive capacity, accounting for the direct, indirect and cumulative effects of the project or activity.
7.5. Require proponents of projects with potential impacts on Chinook salmon or their habitats to provide funding for research and monitoring[21]

Anticipated benefits: Reduce the risk of harm to Chinook populations and their habitats.

5.2.4 Hatcheries and Monitoring Programs Utilizing Hatchery Indicator Stocks to Assess Status and Trends

Strategy 8. Manage hatcheries in a manner that coordinates production for approved hatchery objectives (conservation, assessment, sustainable harvest opportunities, public education and community engagement, which apply to all enhanced salmon) with Chinook status and trend monitoring programs, while minimizing the risk of serious or irreversible harm to wild fish.

8.1. Follow the process, objectives, and priorities for setting enhanced production levels, considering current enhancement practices and identifying opportunities to better align production with the approved program objectives and regional monitoring requirements[22]
   a. Reduce risk of negative impacts of hatchery practices on wild stocks
   b. Maintain or increase practices that have demonstrated benefits consistent with the prioritized established objectives[23].
   c. Identify high level production priorities by CU, CU group or Management Unit for further investigation and analysis of risk and benefit

[20] Many smaller projects do not require EAs but may incrementally contribute to significant cumulative effects.
[21] Especially where direct avoidance, mitigation, and/or compensation cannot be achieved.
[22] See DFO 2012a.

[23] DFO 2012a, 2013a.

8.2. Review existing monitoring programs which are based on hatchery stocks, and supplement, modify or maintain as necessary to develop and implement an effective, integrated network of hatchery indicator stocks, across life-history types, ecotypes, and ecosystems, providing information of sufficient quality for sound management decisions.

   a. Maintain existing hatchery CWT indicators where they still provide important information. ❷
   b. Review hatchery CWT indicators to assess where they are most useful. ❷
   c. Identify and prioritize Chinook ecotypes[24] that do not have indicator stocks (e.g., Upper Fraser springs, possibly other Upper/Middle Fraser and/or Thompson stocks, Mainland inlets) and/or have inadequate information for sound management decisions.
   d. Add additional CWT hatchery stock(s) to address major knowledge gaps. ❷

8.3. Assess the direct and indirect risks of hatchery and enhancement[25] practices on the spawning and rearing success of wild populations[26]. ❷

   a. Assess potential effects (genetic, ecological, disease) on wild fish of hatchery fish spawning in the natural environment.
   b. Assess potential effects (genetic, ecological, disease) on wild fish of hatchery fish rearing in the natural environment.

8.4. Assess the benefits (both direct and indirect) of hatchery production to the provision of harvest opportunities, stock rebuilding, and genetic conservation of salmon populations.

   a. Assess how changes in hatchery production affect changes in harvest levels in different stocks and fisheries. ❷
   b. Use available tools (e.g., Hatchery-Harvest Analysis Tool (HHAT)) to explore the short and long-term consequences of changes in hatchery production (e.g., changes in harvest rates, abundance indices, bycatch rates, weak stock management), especially in terms of impacts on wild populations.
   c. Improve available tools for evaluating the interactions between hatchery production and fisheries.

8.5. Given existing knowledge about the status, trends, threats and knowledge gaps for each CU, CU group or aggregate, determine the level of precaution, risk aversion, and urgency with which production adjustments should be pursued.

   a. If risks to fisheries, assessment or rebuilding are considered to outweigh risks to conservation (risk aversion with respect to production objectives is strongest), proceed with conducting additional analyses and thoroughly explore tradeoffs before deciding upon and implementing any adjustment in production levels (i.e., consider available outputs from 8.4).

[24] Life-history strategy, adult run timing and geographic area.
[25] Including all forms of enhancement.
[26] See DFO risk management frame work for enhancement (DFO 2013a).

b. If risks to conservation are considered to outweigh risks to fisheries, assessment or rebuilding (risk aversion with respect to conservation objectives), proceed with implementing changes in production levels based on the best available information and monitoring the effects of these actions to the extent possible.
c. Prioritize opportunities to increase higher value and lower risk hatchery production to support conservation, First Nations, recreational and commercial objectives[27].

8.6. Assess the benefits and risks of new hatchery production, as guided by the above sub-strategies, considering identified priorities and objectives, tradeoffs and integration with the existing system.

Anticipated benefits: Better alignment of hatchery production with approved hatchery objectives and regional monitoring requirements, an improved monitoring program, and increased learning about the effects of hatchery practices.

5.2.5 Harvest

Strategy 9. Ensure fisheries are managed in a manner that supports recovery of Chinook CU's that have shown declines and supports sustainable harvest, firstly to provide for First Nations' Section 35 Aboriginal Right to fish, then for other sectors.

Strategy 10. Control harvest to ensure that fishing related mortality does not exceed sustainable removal rates based on current productivity.

10.1. The determination of appropriate harvest actions must explicitly consider the tradeoffs between collecting more information and taking immediate action. The following two sub-strategies represent two ends of a spectrum. The most appropriate approach along this spectrum should be based on existing knowledge about the status, trends, threats and knowledge gaps for each individual CU, CU group or aggregate, and consider potential biological, social and economic impacts [28]:
a. Conduct analyses before taking additional harvest actions (i.e., implement Sub-strategies 10.2, 11.1 then and 10. 3)
b. Take immediate action based on the best available information (i.e., implement Sub-strategy 10.3)

[27] See Section 4, Objectives.
[28] 10.1a and 10.1b are fundamentally different strategic approaches – they represent the two opposing ends of a spectrum (i.e., learn-then-act vs. act-then-learn). Therefore for a particular CU, CU group or aggregate, the application of one approach precludes the other. The SPC did not have consensus on either approach or the framing of the strategy as two distinct options. This strategy require further work to develop guidance or establish a process for deciding the most appropriate approach under different circumstances.

10.2. Assemble all available data and analyses to evaluate sustainable harvest levels representative of as many CUs as possible, including:

a. Recent exploitation rates
b. Total mortalities associated with all fishing activities
c. Harvest distribution data (e.g., stock identification from DNA sampling)
d. Age-specific total mortalities in fisheries
e. Current productivity
f. Marine survival rates
g. U_{MSY} and S_{MSY} and S_{max} based on current conditions
h. Escapement goals (where they exist)
i. Comparisons of current exploitation rates with U_{MSY}
j. Comparisons of spawner levels with S_{MSY} and S_{max}
k. Trends in total abundance

10.3. Design harvest management actions with explicit consideration of conservation objectives for all CUs, including appropriate monitoring and evaluation to assess performance.

a. After conservation, harvest management actions must consider the order of harvest allocation priorities and protection of that priority.
b. Incorporate catch composition through DNA analysis.

10.4. Informed by the best available information, reduce harvest impacts by fishery management unit to support positive generational growth of populations at risk (e.g., CUs showing >30% decline over 3 generations and/or remaining at depressed levels of abundance, such as Fraser River stream 5.2's) or populations where evidence indicates overexploitation relative to current productivity, so as to contribute to achieving conservation objectives across CUs.

Strategy 11. Develop an integrated model to evaluate effects of fishery- (including gear, size limit, etc.), place-, and time-specific changes in harvest. ❷

11.1. Use available and recently developed tools (e.g., DGM and HHAT) to evaluate the potential outcomes of changes in harvest for each CU, stock, or CU group, including the following steps:

a. Collect the data necessary to utilize and apply the tools (e.g., DGM and HHAT are data limited)
b. Considering a full range of uncertainties, explore the short and long term consequences of changes in harvest to recover CUs that have shown serious declines.
c. Assess and review outcomes across time, region, First Nation, and fishery sector, explicitly accounting for uncertainty.
d. Evaluate the implications of alternative management strategies for meeting conservation and sustainable use objectives (e.g., R_{max} type of strategy, strategies that allow buffers or otherwise account for uncertainty (e.g., climate change impacts), alternate metrics for CUs in risk, recovery ERs).

11.2. Conduct retrospective analyses of past harvest strategies and decisions, to understand how well past actions worked.

Strategy 12. Conduct appropriate monitoring and evaluation to fully assess fishery related mortalities for Chinook salmon.

12.1. Account for total fishery mortalities for Chinook by providing accurate and timely reporting of retained catch (including bycatch and incidental catch) and released fish, and any associated biological sampling requirements (e.g., DNA sampling, CWTs[29], mark rates, encounter rates, discards, short and long term release mortalities[30]). ❷

12.2. Implement the *Strategic Framework for Fishery Monitoring and Catch Reporting in the Pacific Fisheries*[31] and apply DFO's risk assessment tool (and other tools, as beneficial) to assess risks within Chinook fisheries. Mitigate risks or address gaps where required.

12.3. Develop methods to account for other sources of fishing related mortality (e.g. depredation, drop-out from gear, ghost fishing, release mortality, etc.) and compliance.

NEW PROPOSED Strategy XX. Apply fishery management tools as a means to reduce potential risks from hatchery production (Strategy 8), such as hatchery straying.

- **XX.1**. Explore opportunities to better take advantage of harvestable hatchery surplus to meet FSC needs then other sectors' needs.

Anticipated benefits (Strategies 9-12): Improved alignment of fishing mortality with current stock productivity to support improved status and trends of Chinook populations in many CUs, while allowing sustainable harvest.

5.2.6 Climate Change

Strategy 13. Assess (simulate/model) the potential impacts of climate change on SBC Chinook[32].

13.1. Complete retrospective analyses to assess the relationships between changes in climate and changes in Chinook survival and abundance over the last few decades.

13.2. Complete forward simulations to evaluate the potential impacts of predicted changes on SBC Chinook.[33]

13.3. Develop and implement an experimental design for monitoring and assessing the impacts of climate change on SBC Chinook.

[29] Linkages to Strategy 8 and 15 -

[30] Linkage to Strategy 14 – higher water temperatures may increase release mortality rates.

[31] DFO 2012b.

[32] Disentangling the impacts of climate change from the effects of other factors is very difficult and may not be possible given the extent and precision of the available data.

[33] E.g., Nelitz et al. (2009a, b)

Strategy 14. Identify and consider opportunities to mitigate the effects of climate change on southern BC Chinook salmon where possible.

14.1. Identify potential threats to SBC Chinook that result from the interacting influences of climate change and human actions (e.g., decreases in water availability due to the combined effects of changing temperatures, altered patterns of precipitation and increased consumption of water in regions with growing human populations).

14.2. Identify and prioritize management actions to mitigate the effects of identified threats.

14.3. Develop climate change adaptation[34] plans and tools (within collaborative partnerships).

14.4. Evaluate and implement alternative management strategies that allow for greater uncertainty[35].

Anticipated benefits (Strategies 13-14): Greater chances of having Chinook persist and recover despite the effects of climate change.

5.2.7 Additional Monitoring to Assess Status and Trends

Strategy 15. Develop a network of indicator stocks to represent wild chinook management units using best available tools and methods. Integrate the data from the network of hatchery indicator stocks (covered in Strategy 8) with potential wild indicators and biometric data to better provide information of sufficient quality for sound management decisions.

15.1. Add indicators to represent wild stocks.[36]

a. Identify wild stocks with greatest need for an indicator.
b. Assess the feasibility of establishing an indicator, given best available tools and methods.
c. Implement tagging and monitoring as necessary.

15.2. Fill key gaps in existing monitoring[37], to provide the information required to estimate current productivity to be able to assess sustainable levels of harvest.

15.3. Implement additional monitoring of key performance measures.

a. Include data on age-at-return, body size, and sex composition in annual monitoring.

15.4. Assess data collection within the context of prospective priorities – e.g., in 20 years, which stocks are the highest priority to have collected 20 years of spawner-recruit data[38].

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[34] Climate change adaptation encompasses human actions that can be taken to mitigate or compensate for the direct and/or indirect impacts of climate change on southern BC Chinook

[35] Linkage to Strategy 11.1d.

[36] Note that CWT indicator programs for wild stocks are extremely expensive and very difficult to implement. It is likely going to continue to be most feasible to use hatchery produced Chinook, though there may be exceptions where wild stocks can be tagged.

[37] See Appendix H – Assessment Summary for Southern BC Chinook

[38] This strategy must be forward-looking – conducting rigorous analyses for run reconstruction and estimating productivity require about 20 years of data.

Strategy 16. Review and incorporate historic information into current data sets for maximum benefit

16.1. Complete validation of Chinook spawner data collected prior to 1995.

16.2. Pull together all spawner-recruit data into a central repository.

16.3. Use spawner-recruit data wherever it exists[39] to develop the best estimates of productivity.[40]

Strategy 17. WSP Implementation: Monitor CU status and progress toward abundance / recovery objectives and WSP benchmarks.

Anticipated benefits (Strategies 15-17): Better informed fish management decisions and increased probability of CU persistence and recovery.

5.2.8 Communication and Partnerships

Strategy 18. Develop a communication plan to improve communication and education among all stakeholders and interested parties.

18.1. Increase understanding of Chinook status, threats and potential mitigation of these threats, demonstrating how multiple actions can improve productivity, survival and recovery.

18.2. Increase understanding of existing strategies and processes for managing, monitoring and assessing threats.

18.3. Target outreach to those outside salmon circles, especially decision-makers and stakeholders in domains outside of DFO (e.g., land use management, water management, agencies reviewing development proposals).

a. Consider how other legislation interacts with Chinook issues (e.g., Water Sustainability Act)

18.4. Involve governments, including First Nations governments, harvesters, environmental groups, and community interests in the planning and conduct of Chinook recovery initiatives.

Strategy 19. Promote and encourage local and regional partnerships.

19.1. When establishing new partnerships, consider applying the framework established in the Cowichan Watershed to guide engagement, while recognizing that each situation may differ

a. Identify potential partners, especially those with overlapping or conflicting mandates.

b. Improve communication among potential partners, connecting competing or non-communicating groups[41].

c. Develop objectives and governance processes.

19.2. Identify opportunities to coordinate efforts locally - make efficient use of limited resources and avoid spending money on work that is unnecessary, of limited benefit or is a low collective priority.

19.3. Strive to align local and regional strategies.

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[39] E.g., Nicola and Lower Shuswap

[40] Linkage to Strategy 10 – these analyses are needed for more populations in order to be able to determine harvest levels that are sustainable with respect to current productivity.

[41] Connection with Strategy 18

Strategy 20. Consider First Nations Traditional and Ecological Knowledge at the local and regional scales.

20.1. Identify opportunities to incorporate Aboriginal Traditional Knowledge into existing analyses and/or planning processes.

20.2. Develop and implement protocols for use of and for the sharing of Aboriginal Traditional Knowledge.

Anticipated benefits (Strategies 18-20): More comprehensive actions across multiple stakeholders and where required, First Nations, to preserve and recover Chinook CUs; more constituencies speaking and acting on behalf of Chinook.

5.2.9 Formal Adaptive Management to Assess the Effectiveness of Actions

Strategy 21. Apply the principles of formal Adaptive Management[42] to the implementation of strategies, in order to determine the effects of management actions, increase learning and reduce critical uncertainties.

21.1. Develop Adaptive Management approaches in consultation with First Nations and other interested parties.

21.2. Identify critical uncertainties in the effects of management actions that could be resolved through formal Adaptive Management

21.3. Identify hypotheses to be tested and design and implement formal Adaptive Management experiment(s) for the selected management actions.

21.4. Implement, monitor, evaluate and adjust management actions as per the Adaptive Management plans developed.

Anticipated benefits: Stronger evidence for evaluating and adjusting management actions.

[42] Adaptive Management principles include: identifying critical uncertainties; predict the estimated effects of different actions; intentionally structure the design of actions to maximize learning; develop an explicit plan for how info is collected and interpreted; include triggers to adjust action is performance is poor; and engage stakeholders throughout the process of developing the design.

5.3 Summary of Strategies in an Adaptive Management Framework

The strategies described in this plan can be summarized in terms of the 6-step cycle of adaptive management (Figure 5): assess, design, implement, monitor, evaluate and adjust. Figure 5 groups the 9 sets of strategies described in Section 5 into 8 categories[43]. Common themes which run across multiple life history stages and strategic management domains are grouped together in Figure 5. For example, an improved understanding of threats and potential remedies has relevance to the management of freshwater and marine habitats, harvest and hatcheries, and also needs to also consider climate change as well as cumulative effects. While not all actions are expected to be implemented using a *rigorous* adaptive management approach with a formal experimental design, it is intended that all actions in the strategy will be implemented with an adaptive management *mindset*, so that learning and adjustment becomes a strong principle in the ongoing implementation of the CSPI strategy.

An adaptive management "mindset" includes:

- embracing uncertainty and focus on those that have the most influence on decision making;
- encouraging diverse and collaborative processes for resolving uncertainties;
- having absolute clarity around their fundamental management objectives;
- using 'systems thinking' as a way to analyze complex social-ecological systems;
- adopting scientifically rigorous approaches for developing and testing hypotheses;
- viewing policies, decisions, or actions as 'treatments' that need to be tested;
- making a commitment to monitoring, learning, and adjusting their actions;
- treating failures, mistakes, and surprises as opportunities for learning;
- building on small successes before scaling up; and
- sharing insights and findings with others in a clear and transparent way.

[43] "Additional Monitoring to Assess Status and Trends" and "Formal Adaptive Management to Assess the Effectiveness of Actions" have been combined for the summary figure.

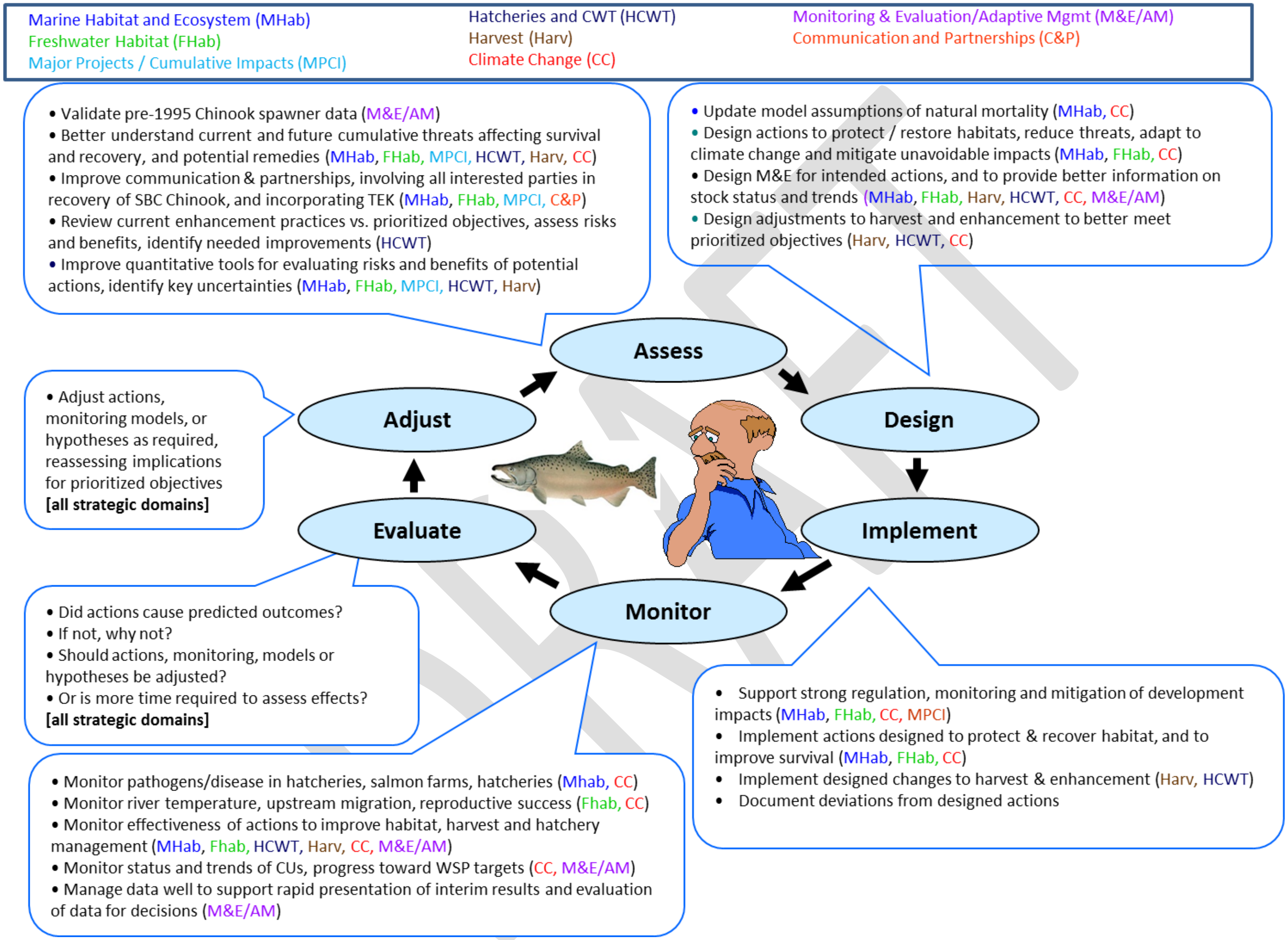


Figure 5. Summary of the CSPI strategy in the form of an adaptive management (AM) cycle. The cycle begins with "Assess". Subsets of the strategy are shown in the blue box at top, with coloured codes that appear in the AM cycle wherever applicable. Other abbreviations: CWT= Coded Wire Tag; FNs = First Nations; M&E = Monitoring and Evaluation; SBC = Southern BC; TEK = Traditional Ecological Knowledge.

6 Plan Implementation

Future Work:
This section represents a proposed general structure and some key principles for implementation. It represents a starting point.

The development of a more detailed implementation plan will require its own process. Prior to developing such a process, there needs to be time for FRAFS, DFO and other participants to 1) review the existing draft in further detail with their respective constituencies, and 2) to reflect on how the existing process has worked and what is required going forward. Ultimately, both implementation and the development of the implementation plan need to be collaborative, bilateral processes.

In this context, the present draft represents an important (but not final) milestone in the larger process of developing and implementing an integrated strategic plan for southern BC Chinook salmon.

6.1 Process of Implementing the Strategic Plan

Implementation is the crux of all planning efforts. The management of harvest, hatcheries and habitat involves many entities and existing processes, at a variety of spatial scales, some of which are listed in Table 6. Successful implementation of the southern BC Chinook strategic plan will require both a widespread understanding of the strategy, a commitment to its implementation, and integration of strategic content across multiple scales, entities and processes. To achieve this, SPC and TWG members (supported by DFO) should:

a. Review the plan with their respective organizations
b. widely distribute the draft plan and a summary presentation of its content to key entities (including those listed in Table 6);
c. present the draft plan to all key entities and processes that are critical to its implementation;
d. establish <u>bidirectional</u> flows of information with these key entities and processes;
e. find contact persons within these key entities and processes who will act as both champions for the draft plan, and 2-way conduits of information;
f. monitor both the implementation of the plan and its effectiveness, using the indicators and performance measures described in Section 4;
g. provide annual updates on progress of the strategy to key entities and processes; and
h. review and update the plan as required, or at least every 5 years.

Table 6. Examples of Organizations, Processes, Regulations and Plans by which the draft Chinook strategy could be implemented and integrated. Hyperlinks are provided to further explain some of the items in this table.

Scale	Harvest	Hatchery	Habitat
National and International	Pacific Salmon Treaty (PST) (CAN/US/FNs/US Tribes); Pacific Salmon Commission Treaties with FNs PSC Chinook Technical Committee	PSC Chinook Technical Committee PSC Chinook Technical Committee	BC Fish Protection Act (CAN) Section 35 of the Fisheries Act (CAN/FN) Climate Change Adaptation (CAN) Columbia River Treaty International Joint Commission
		Wild Salmon Policy Species at Risk Act	
Provincial and Regional	Integrated Fisheries Management Plans (IFMP) Integrated Harvest Planning Committee Fraser River Aboriginal Fisheries Secretariat (FRAFS) First Nations Fishery Council (FNFC) Commercial Salmon Advisory Board Sportfish Advisory Board	SEP Production Planning Framework (DFO 2012a), Biological Risk Management Framework (DFO 2013a), Operational Guidelines, and Best Management Practices	BC Water Sustainability Act BC Riparian Areas Regulation BC Forest Range and Practices Act BC Environmental Protection Division BC Hydro Water Use Plans
		Science Branch of DFO Salish Sea Marine Survival Project (Pacific Salmon Foundation) Strategic Salmon Health Initiative (Genome BC)	
Sub-Regional	Fraser Chinook Management Plan WCVI Chinook Management Plan		Coastal Plans (CAN/BC/FN) Regional District Plans Protected Area Plans including Marine Protected Areas (MPAs), Rockfish Conservation Areas (RCAs). Southern Strait Georgia National Marine Conservation Area Reserve (NMCAR) Fraser Basin Council Fraser River Estuary Management Plan
Local (CU, First Nations, Watershed)	Local Fish Harvest Plans FRAFS Forum on Conservation and Harvest Planning First Nations fishery plans Areas 23 and 25 round tables Cowichan Harvest Round Table Sport fishing closures in Georgia Strait and other areas	Local Production Plans (DFO) UFFCA/DFO TWG on Summer 5_2 indicator stock ONA/SFC Shuswap River Hatchery operations ONA/CRITFC Okanagan Chinook	Land use plans Watershed Plans Water Use plans (BC, local) Official Community Plans Flood management plans Industry plans (e.g., forest management plans, mining plans, run of river hydro) Strategic Engagement Agreements: - Stó:lo Nation - Tsilhqot'in National Government

Abbreviations: CAN=Canada; CEDP = Community Economic Development Program; CRITFC = Columbia River Inter-Tribal Fish Commission; DFO = Fisheries and Oceans Canada; FNs = First Nations; ONA = Okanagan Nation Alliance; PSC = Pacific Salmon Commission; SEP = Salmon Enhancement Program; SFC = Secwepemc Fisheries Commission; TWG = technical working group; UFFCA = Upper Fraser Fisheries Conservation Alliance; WCVI = West Coast Vancouver Island.

Future Work:
There is a need to identify critical, key partners within the table above.

6.2 Timeline and Priorities

Table 7 provides a draft timeline for implementation of the plan over the next 20 years (until the year 2035), organized into 5-year time periods, which are approximately the lifespan of one generation of Chinook salmon. This draft timeline requires further discussion amongst the SPC and TWG, as well as other entities who could be involved in implementation. The draft set of proposed activities listed in Table 7 are expected to continue beyond 2035, but 20 years provides a reasonable planning horizon. It is hoped that implementation of the plan will lead to substantial recovery of Chinook populations over this 20-year time period. The timeline in Table 7 makes the following assumptions:

- Networking to publicize the draft plan and develop networks among key entities (task 1) could begin immediately in 2016; Table 6 provides a starting list of such entities.
- Integration of the plan's strategies into the activities of key entities can also begin immediately (task 2) and would continue over the duration of the plan.
- It could take until 2018 to operationalize and finalize some of the actions under the plan (task 3), with intensive analytical (TWG) and policy (SPC) activities conducted over 2016 and 2017, and then repeated at the end of each 5-year period to support a detailed review of the plan.
- The final plan would be widely distributed and publicized in 2018 (task 4) to each of the partners developed under task 1.
- Implementation of recommended actions (task 5) could begin immediately for some actions in 2016, but for other actions would need to await the completion of analyses under task 3.
- Intensive efforts would ideally occur during 2016-2018 to set up the monitoring, research and evaluation infrastructure to support the plan, and would then continue for the next 20 years (task 6), providing the key performance measures (Table 5) needed for adjustments to the plan every 5 years using an adaptive management approach.
- Annual updates of key indicators and performance measures could be provided to all of the partners involved either directly or indirectly with implementation of the plan (task 7), and could be presented at an annual symposium, ideally synchronized with the Salish Sea project.
- A review of the plan could occur every 5-years (including in 2020), and could involve an intensive set of analytical (TWG) and policy (SPC) activities, leading up to an expanded annual symposium.

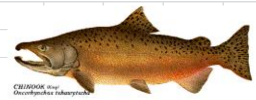
6.3 Resources

The structure of the CSPI (SPC and TWG) has worked well over the last 3 years, with constructive and respectful dialogue, and dedicated work, on many challenging issues. It would be prudent to maintain this structure until these parties agree to an alternative structure. Technical staff and resources have been very stretched over the last 3 years within all CSPI entities, which has led to delays in moving forward with various data assembly, assessment and modelling activities that are required to analyze alternative proposed actions. For successful implementation of this plan, it is essential to not only develop partnerships (strategies 18-20) but also to increase the capacity of participating entities to accomplish the tasks identified in the strategy. This increased capacity would ideally be established across multiple entities, including DFO, First Nations, fisheries organizations, academic institutions and non-government entities.

7 Performance Review

As described in Section 6, it is proposed that there be annual reports on progress, generated by the Technical Working Group (or its future successor), using the indicators and performance measures described in Table 5, presented at an annual symposium open to all partners. In addition, there will be an intensive review and adjustment of the plan every 5 years, based on trends in these indicators and performance measures, as well as other relevant information from ongoing research activities, changes in the Pacific Salmon Treaty, etc. These 5-year reviews will involve an intensive period of analytical and policy activities, as shown in the Table 7 timeline; they will form a high level cycle of adaptive management. In addition, the strategy envisions the design and implementation of formal adaptive management experiments for particular harvest, hatchery and habitat actions, as described under the strategies in Section **Error! Reference source not found.**.

Table 7. Draft proposed timeline for implementation of Southern BC Chinook Strategic Plan. This is only a preliminary draft that will require further discussion.




TASK	1st generation of Chinook					2nd generation of Chinook					3rd generation of Chinook					4th generation of Chinook				
Year →	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
1. Networking to publicize draft plan, develop partnerships	High	High	High																	
2. Integrate plan into key processes and entities	High	High	High	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
3. Analytical tasks to operationalize actions under the plan[1]	High	High	Low		High					High					High					High
4. Distribution, presentation and publication of final plan			High																	
5. Implement plan's harvest, habitat and hatchery actions	Low	Low	High	High	High	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
6. Monitoring, research and evaluation to support plan	High	High	High	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
7. Annual updates on progress	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦	♦
8. 5-year reviews and updates of the plan					5-year review					5-year review					5-year review					5-year review

High Intensity
Low intensity
5-year review and updates of plan
♦ Annual updates on progress & symposium

[1] Includes various analytical tasks to better understand the impacts and benefits of alternative harvest, habitat and hatchery actions. More intensive analytical tasks will be repeated every 5 years as part of the 5-year review.

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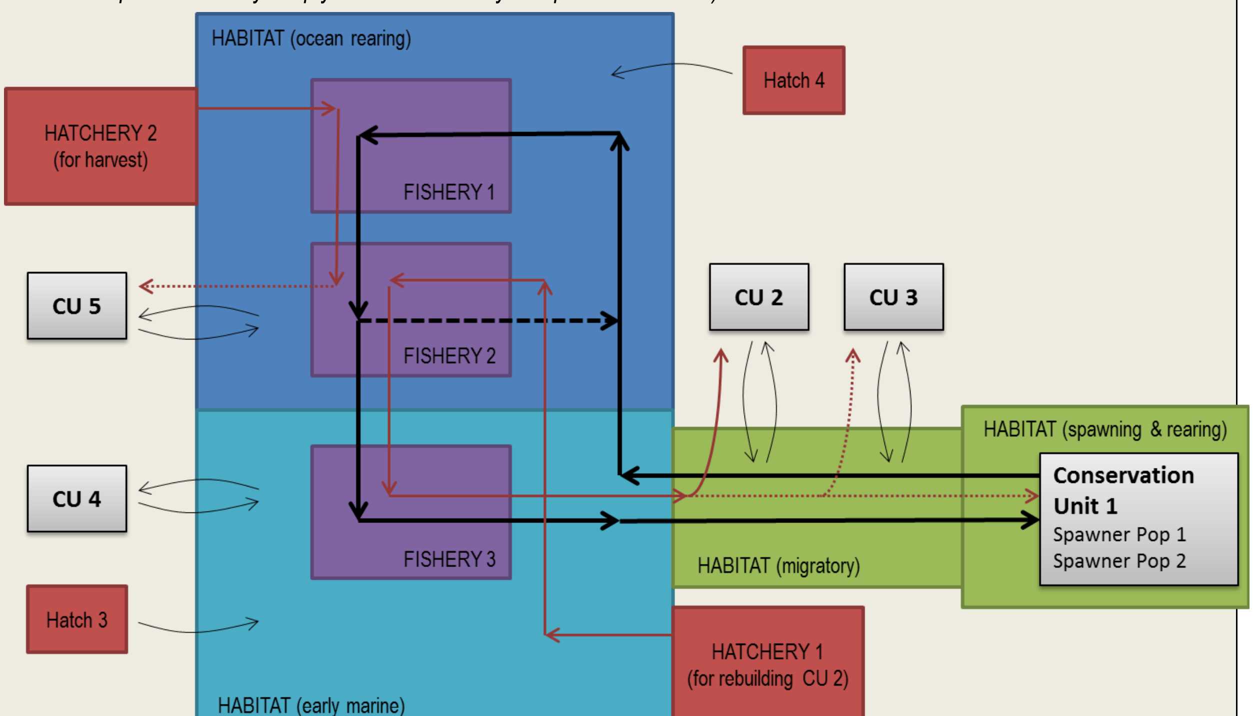
Appendix A. The complexity of interacting spatial scales

The diagram and text below conceptually describes the complexity of integrating multiple spatial scales across multiple CUs and multiple influences.

Issue of Spatial Scale. *It is necessary to have multiple spatial scales for planning. The actions that affect SBC Chinook occur over very different spatial scales that are not fully nested within each other. For example, freshwater habitat and ecosystem related planning typically has a local scope whereas fisheries planning is focused on major watersheds and coastal areas.*

1. *The conceptual diagram below attempts to represent the spatial complexity and many-to-many relationships among the influences of habitat, fisheries, and hatcheries:*
2. *The diagram focuses on a single Conservation Unit (CU1) for which we need to develop a plan.*
3. *The migratory life cycle of fish from CU1 is shown with black arrows.*
4. *These fish move through many habitat zones (FW rearing, FW migratory, early marine, ocean rearing, back through FW migratory to FW spawning).*
5. *The CU fish may be intercepted by multiple fisheries, potentially by the same ocean fisheries over multiple years.*
6. *Hatchery 1 is producing fish for rebuilding CU 2, which are also intercepted by similar fisheries, and have spawners that sometimes stray into nearby CUs (incl. CU 1).*
7. *Hatchery 2 is producing fish for harvesting in two of the fisheries that also intercept CU 1 fish.*
8. *Other hatcheries also produce fish that interact in the system (they have been represented very simply but may also have similarly complex dynamics to first two).*
9. *There are other CUs, each experiencing similarly complex system with the same types of interactions (but not the same permutations) with habitats, fisheries, hatcheries and other CUs. The other CUs in the diagram are represented very simply but have similarly complex interactions).*



The "take home message" of the diagram is that it would not be possible to develop a fully-integrated CU-specific plan for a single CU in isolation of the interdependencies throughout the rest of the system. Identifying internally cohesive, externally independent sub-units of the SBC Chinook population that can be used for planning across all management actions is not feasible. It is necessary for planning to occur at multiple spatial scales, as appropriate for each layer in the system, while still recognizing the cumulative effects of the aggregate.

Appendix B. Southern BC Chinook Salmon Biological and Ecological Background

Future Work:
This appendix has not been written, although the outline (not included) has been substantially developed. The outline for this section was developed during earlier and has been by the SPC and TWG.

The purpose of this appendix is to provide the biological context of the plan – i.e., a summary of the biology and ecology of southern BC Chinook salmon. This would include addressing such topics as:

1. Basic description
2. Distribution
3. Habitat needs and trends
4. Biology: life cycle and life history types; predation; physiology; migration; interactions
5. Ecological role

Appendix C. Management of Southern BC Chinook Salmon

Future Work:
This appendix has not been written, although the outline (not included) has been substantially developed. The outline for this section was developed during earlier and has been by the SPC and TWG.

The purpose of this appendix is to provide the management context of the plan – i.e., a summary of how Chinook salmon and their habitat are currently managed. This would include addressing such questions as:

1. How do we manage Chinook salmon right now?
2. How have we managed Chinook in the past and/or what changes have been made? (where relevant to understanding the current situation)
3. Who is involved in the management of Chinook habitat, harvest and hatcheries (i.e., entities, mandates, responsibilities)?
4. What are some of the key management challenges going forward?
5. How have the resources available for managing Chinook could give general indication of trends in resources for management

Appendix D. Analytical Models and Tools

Modelling work is proceeding along a parallel track to the development of the strategic plan. Models are expected to inform in-depth discussion and analysis of specific management actions that could be considered at a later date. Active work has been progressing during 2015-16 on three tools:

- Bocking decision tree
- Data Generation Model (DGM)
- Harvest Hatchery Analysis Tool (HHAT)

The Bocking decision tree is a flowchart intended to provide a step-wise approach to evaluating different options being considered for the recovery of Southern BC Chinook stocks. It was originally proposed by Bob Bocking during the March 2015 SPC/TWG workshop and has since been further reviewed and revised by the TWG.

The Data Generation Model (DGM) is a modelling tool developed by the PSC Joint Chinook Technical Committee (CTC) designed to evaluate the potential effects of different harvest management strategies on Chinook populations. The DGM can account for Chinook production dynamics for any number of Chinook populations and fisheries (entirely user-defined) and a range of different fishery regulations over time to explore potential effects on Chinook recovery, harvest, etc. At present, the DGM is still in development stages, though some preliminary testing has been completed. TWG members have been working on parameterizing the model and developing a base case for comparison with alternatives.

The Hatchery-Harvest Analysis Tool (HHAT) is for strategic hatchery production planning, which has been under development over the past couple years. One of the key outcomes is the ability to examine the effects on fisheries of alternative production scenarios. The HHAT could address two key recommendations of the Southern BC Chinook Strategic Planning process (Hall et al. 2014):

- “Using CWT indicators to represent all production, develop an updated hatchery production model based on recent years CWT-derived survival and catch distribution data (2009-2012) to be able to quantitatively assess the potential impacts of increases, decreases and shifts in hatchery production to the contributions to specific fisheries”
- Assess how changes in hatchery production affect changes in harvest levels in different stocks and fisheries. [SPC priority learning strategy]

The first results from preliminary application of the tool were presented at the February 2016 SPC/TWG workshop. Although only preliminary and coarse, the results proved informative for discussions and improved understanding regarding the complex interactions between hatchery production levels and fishery outcomes.

Appendix E. Detailed Threats and Knowledge Gaps Tables

E.1 Detailed Threats Table

Potential Threat	Subcategory	Natural or Human-Controlled	General	e	f	g	Affected Life Stage(s)	Affected CU groups
Climate Change – impacts on freshwater or marine ecosystems driven by climatic changes								
Climate Change	Water temperature (freshwater)	Natural	Most southern Chinook populations have faced **increasingly stressful thermal conditions** during return migrations in recent decades. **Higher temperatures** in Fraser River. Many summer run Chinook migrate during peak temperature, exposed to increasingly stressful temperatures				Returning adults	Esp. Upper/Mid Fraser River, Thompson, Okanagan
Climate Change	Water quantity (freshwater)		Increased vulnerability to changes in water quantity - climate driven changes exacerbate pressure from water extraction. Impacts on groundwater recharge related to changing snow pack in snowmelt dominated systems.				Returning adults; juveniles (eggs – smolts)	Esp. Upper/Mid Fraser River, Thompson, Okanagan
Climate Change	Productivity	Natural	Numerous and interconnected pathways. Highly likely that **climate variation and change** has been a factor influencing productivity in the past and will have increasing impacts in the future.				All, especially marine	
Climate Change	Warm water predators	Natural	Increased exposure to **warm water predators** (e.g. mackerel, Humboldt squid, marine mammals) associated with abnormally warm ocean conditions. Chinook salmon have largely not co-evolved with these predators.				Juvenile – smolt; possible adult predation in some areas (e.g. Sea Lions from further south?)	WCVI examples; potential to affect all CU's; possibly less so for far north migrating CUs
Marine Habitat – impacts on marine habitat/ecosystem quality, quantity or usage affecting marine survival rates/adult returns								
Marine Habitat	Early marine conditions	Natural	**Shared declines** in marine survival across many stocks (not all). Uncertainty about exact mechanisms (e.g. prey availability, competition, physical conditions, predation etc.)				Juvenile, immature adults	Stocks with early or late entry timing have fared better
Marine Habitat	Early marine conditions	Natural	Changes in local and basin-scale **oceanographic conditions**.				First year of ocean residency	
Marine Habitat	Predation	Natural	**Marine mammal predation** may affect abundance / inhibit recovery during periods of low productivity. Unlikely driver of general declines for all SBC Chinook since 1995; however, evidence of predation threats contributing to declines of specific CUs (e.g. Cowichan, Puntledge). Substantial increases in Transient KW with potential interactions with to seal dynamics (may have responded to increased seal abundance and/or be displacing seals further north). Observations of resident seals found further back into inlets than ever before, seals resident in freshwater (also natural), and sea lions found in new areas. Predation on outmigrating juveniles and returning adults. Depredation directly from fishing gear.				Marine life stages	Especially in Strait of Georgia, Johnstone Strait
Marine Habitat	Disease	Human	Increased disease risks due to interactions with **salmon farm or aquaculture** operations				Smolts?	??
Marine Habitat	Competition	Natural	**Inter-specific competition** (with other salmon species and non-salmon species)					

Potential Threat	Subcategory	Natural or Human-Controlled	General	e	f	g	Affected Life Stage(s)	Affected CU groups
Estuarine Habitat								
Estuary/FW	Predation	Human	Human activities that **enhance opportunities for marine mammals** to prey on juvenile Chinook (e.g. lights on bridges or fish farms, haul out areas such as log booms, etc.)				smolts	Strait of Georgia
Estuary/FW	Habitat	Human	**Loss of estuarine marshes** in lower river reaches from human activities/development and urbanization/development pressures (e.g. dredging, diking, drainage, industrial activities, port activities)-See Colin Levings work. Loss of critical transition habitats (e.g., Lower Fraser, Squamish River and many others). Much of the estuarine habitats in south coast and Strait of Georgia are mostly occupied by log booming (much research/literature).				Fry, smolts	All, especially Fall Chinook; .
Freshwater Habitat – potential loss or degradation in productivity or useable area of freshwater habitat								
Freshwater habitat	Water regulation	Human	Human-induced changes in **flow and water temperatures** (water quantity). Linkage to climate change impacts which can moderate or exacerbate threat.				Eggs, fry, smolts, returning adults, spawners	Vancouver Island, Upper/Mid Fraser, Thompson, and Okanagan
Freshwater habitat	Didymo	Human/ Natural	Broad landscape changes (e.g. increased nitrogen loading either from atmosphere or human activity) leading to **didymo outbreaks** – potential factor contributing to reduced productivity.				Eggs, fry, smolts	Stream type CUs
reshwater habitat	Hydrologic Processes[1]	Human/ Natural	Indicators: Forest disturbance, Equivalent Clearcut Area				All freshwater life stages	High risk: none (only BB) Mod risk: Thompson
Freshwater habitat	Vegetation Quality[1]	Human/ Natural	Indicators: Riparian disturbance, Insect and disease defoliation				All freshwater life stages	High risk: U/M Fraser, Thompson, Lower South Coast, Okanagan Mod risk: WCVI
Freshwater habitat	Surface Erosion[1]	Human	Indicators: Road development				All freshwater life stages	High risk: Thompson, Lower South Coast, WCVI, Okanagan Mod risk: Lower Fraser, U/M Fraser
Freshwater habitat	Fish passage / habitat connectivity[1]	Human	Indicators: Stream crossing density				All freshwater life stages	High risk: Lower South Coast, Okanagan Mod risk: Lower Fraser, U/M Fraser, Thompson, WCVI
Freshwater habitat	Water quantity[1]	Human	Indicators: Water licenses				All freshwater life stages	High risk: Thompson, Lower South Coast, Okanagan Mod risk: Lower Fraser, U/M Fraser,

Potential Threat	Subcategory	Natural or Human-Controlled	General	e	f	g	Affected Life Stage(s)	Affected CU groups
								WCVI/Upper South Coast
Freshwater habitat	Water quality[1]	Human	Indicators: Wastewater discharges				All freshwater life stages	High risk: Okanagan, plus 5 other CUs across groups Mod risk: All CU groups
Freshwater habitat	Human development footprint[1]	Human	Indicators :Total land cover alterations, impervious surfaces, linear development, mining development, agricultural/rural development				All freshwater life stages	High risk: Lower South Coast, Okanagan (for Linear) Mod risk: U/M Fraser, Thompson, Lower South Coast Mod/low: Lower Fraser, WCVI/Upper South Coast
Harvest – impacts associated with fishing activities including retained catch, releases and/or gear interactions								
Harvest	Harvest mortality	Human	**Total mortalities (**e.g., bycatch, release mortality, depredation, disease, recapture, post-release predation, unauthorized harvest, other unknown/unreported removals) from **Chinook directed fisheries exceed sustainable rates** given current productivity				Adults	
Harvest	Harvest mortality	Human	Decreasing escapements with stable/decreased ER suggests possibility that **total mortality may exceed sustainable rates** (e.g., esp. if total mortality is greater than reported mortality). Need to consider total fishing mortalities including from all retention and releases. Several sources of mortality are not captured such as depredation, by-catch in other fisheries (e.g. Bering Sea Pollock fishery).				Adults	
Harvest	Removals	Human	**Unreported / unknown removals** (including by-catch in fisheries not included in total mortality tables, depredation, unauthorized/unreported harvest)				Adults	All
Hatchery Production – impacts associated with hatchery / enhanced production of Chinook (or other salmon)								
Hatchery production	Genetic	Human	**Genetic risks** to enhanced and surrounding wild populations generally are believed to result from domestication selection within the hatchery population and/or outbreeding effects on surrounding populations. Potential stressors on natural populations and contributions to reduced productivity and potentially to declines in abundance include: • straying into non-target systems • high enhanced contributions in some target systems • lack of information relating to enhanced contribution • inability to mass mark Chinook to assist in genetic management		M	M	Spawners	Higher risk: Strait of Georgia, WCVI Low: Lower Fraser, Thompson, U/M Fraser
Hatchery production	Disease	Human	Contained hatchery populations with **disease** can potentially transmit **pathogens** to wild populations in receiving waters.	L	L	L	Fry, smolts	Low risk: All

Potential Threat	Subcategory	Natural or Human-Controlled	General	e	f	g	Affected Life Stage(s)	Affected CU groups
Hatchery production	Ecological	Human	Hatcheries pose five main **ecological interaction** issues related to salmon ecosystems: carrying capacity, competition[44], predation, disease and behavior.	L	L	L	Fry, smolts	Low risk: All
Hatchery production	Harvest pressure	Human	Increased hatchery production for harvest objectives can lead to increased fishing on mixed stocks and therefore increased pressure on wild stocks (indirect impact from hatchery production, mediated through harvest decisions).					
Hatchery production		Human	**High proportion of hatchery-origin spawners** (pHOS) exceeds Columbia criteria. (>0.2 in 50% of past 15 years; CTC). Lack of data on straying and genetics. Unlikely significant negative effect, but uncertain.					Thompson River
Cumulative or synergistic interactions among threats								
Interaction Effects		Human/ Natural	One or more threats or stressors acting in conjunction on a CU. Many examples.				All	All

Future Work:
Columns 'e', 'f', and 'g' are place holders for information (qualitative) on the severity, extent, and frequency of each threat. Preliminary values have been provided for a few threats but this information is incomplete.

[44] Includes interspecific interactions with other hatchery production releases (e.g. chum, coho). For example, Chum hatchery releases compete for food but are timing of release is ahead of Chinook

E.2 Detailed Knowledge Gaps Table

Area	**Subcategory** (incomplete)	**Knowledge Gap**	**Relevance** (not completed)	**CU Group** (incomplete)
Status and trends				
Status and trends	Monitoring / assessment framework	Lack of a **comprehensive monitoring framework**: • high-precision network of indicator stocks across life-history types, ecotypes, and ecosystems • extensive and intensive monitoring programs • additional layer of monitoring (e.g., migration) Most of the other knowledge gaps associated with status and trends are connected to this overall gap.	Critical info for stock assessment and fisheries mgt. (e.g., cohort-specific ERs, allows forecasts)	
Status and trends	Indicator stocks	Limited number of **indicator stocks** (10 current indicators stocks for 35 CUs). Highest priority gaps (areas/ecotypes with no representation): Upper Fraser (5.2 springs and summers) and mainland inlets. Other important gaps: Lower Fraser (e.g., Birkenhead is likely remnant of more broadly distributed life-history type), middle Shuswap		Numerous (esp. offshore ocean distribution)
Status and trends	Wild indicators	Lack of **wild indicator stocks**. However, tagging representative sample of wild fish is extremely difficult/expensive (may need surrogate hatchery for info assessment).	Separation of wild and hatchery stocks	
Status and trends	Abundance	**Quantitative abundance estimates** (cannot conduct formal stock-recruitment analyses to estimate stock-specific productivity)		Most CUs/ stocks
Status and trends	Mortality	**Mortality rates by age-class** and annual variability		
Status and trends	Productivity	Assessment of possible **temporal changes in productivity** – not possible for most stocks, which use habitat-based methods). The data necessary for S-R analyses is either incomplete or non-existent for most populations.		All
Status and trends		In many cases, **data** on age-at-return, body size, and sex composition are inadequate for analysis		All
Status and trends		Capability to **separate freshwater and marine effects** on stock recruitment and productivity		
Status and trends	Existing data	Validation of pre-1995 **spawner data**		All
Marine Habitat				
Marine habitat	Survival factors	Knowledge of what is currently **limiting survival in the marine** environment		
Marine habitat	Marine mammal predation	Possible underestimation of natural mortality due to increased **marine mammal predation**. Need information on the interaction of marine mammals with Chinook in mainland inlets, Discovery Islands, etc. Observations of seals and what they are eating should be reported. Marine mammals are intelligent and adaptable, so it will be difficult to fully understand predation dynamics without better understanding behaviour (e.g., to understand annual variability vs. average consumption rates). Important at local scales and specific case-studies, but lower priority at larger scale.		
Marine habitat	Human influence on predation	To what extent are human actions influencing predation, through changes in the abundance, distribution and/or behaviours of marine mammals.		
Marine and FW	Environmental conditions	Ability to determine impacts **environmental conditions** on Chinook. Requires substantial, long-term research programs.		
Hatchery	Ecosystem interactions	Limited understanding about **estuarine and early marine ecosystem interactions and feedback** with respect to both wild stocks and hatchery production. Have some tools but don't understand broader dynamics.		Van. Island, SoG

Area	Subcategory (incomplete)	Knowledge Gap	Relevance (not completed)	CU Group (incomplete)
Marine habitat	Salmon farms	Limited information on potential interactions and risks of **salmon farms**. Given knowledge on Sockeye and lack of info on Chinook, salmon farms could be considered a threat until shown otherwise.		
Hatchery Production				
Hatchery	Risks and benefits	Clear understanding of **impacts (risks and benefits) of hatcheries** and enhanced stocks – interactions, spawning contribution, potential replacement, carrying capacity, abundance indices, harvest rates, bycatch rates, stray rates, genetics. Vancouver Island is highest concern due to highest levels of production by far.		Esp. Vancouver Island
Hatchery	Effects on harvest	Better understanding needed of how changes in hatchery production affect **changes in harvest levels** in different stocks and fisheries (progress being achieved with HHAT)		
Hatchery	Genetic	Limited **ability to assess and monitor** enhanced contribution to return in unmarked stocks		All
Hatchery	Genetic - straying	Limited understanding of the extent and effect of **genetic outbreeding introgression** of hatchery stocks and other non-target stocks.		Van. Island
Hatchery	Genetic - straying	Limited understanding of the extent and magnitude of hatchery Chinook salmon **straying** into non-natal watersheds		Van. Island
Hatchery		Potential influence of enhancement on natural populations in Lower Fraser is highly uncertain given lack of data on key metrics		Lower Fraser
Pathogens and Diseases				
Pathogens		**Monitoring of disease** in wild populations and estimation of impact is limited in BC. Monitoring had been largely non-existent until more recently. Strategic Salmon Health Initiative (SAR 2309) has been collecting samples of wild and hatchery fish, across all species, testing for all diseases.		All
Pathogens		The extent to which **pathogens and disease** contribute to variation in Chinook production both between populations and over time is not known		All
Harvest				
Harvest	Sustainable ERs	Are current harvest-associated total mortalities sustainable based on current productivity levels		
Harvest	Catch monitoring – overall	Overall need to identify where the biggest **gaps in catch data** are. There is a lack of knowledge about where fish in caught in certain locations are coming from and/or lack of knowledge about the numerous places fish from certain stocks are being caught. Need for assessment of current catch monitoring across all fisheries. Report cards on catch monitoring across all fisheries – bias, precision, underreporting, etc.		
Harvest	Freshwater catch monitoring	There are gaps in freshwater catch monitoring (includes First Nations' and recreational fisheries). There are big gaps in catch information for freshwater fisheries on Vancouver Island, whereas freshwater First Nations fisheries in the Fraser are highly monitored and collect lots of data.		
Harvest	Recreational catch monitoring	There is considerable uncertainty and disagreement among stakeholders and participants on the **strength and representativeness of recreational catch monitoring**. The recreational catch monitoring program includes estimates of encounters, catches and releases from creel surveys and voluntary CWT head collection. The creel survey and First Nations survey augment primary data from the test fishery to provide good estimates of catch. DFO participants stated that the creel survey is statistically sound and provides decent estimates. Some other participants question the geographic representation within the creel survey program. These concerns may reflect gaps in monitoring and/or gaps in communication and education about the existing approaches.		
Harvest	First Nations participation in catch monitoring	Concerns about **First Nations not being included in monitoring**. First Nations have repeatedly offered to contribute to monitoring in other regions (e.g., other coastal, Van Island) but have been turned down. Some First Nations have perceived an unwillingness to consider local First Nations capacity to do monitoring within their territory. Partnerships and collaboration could help First Nations achieve more comprehensive monitoring (across all sectors) within their respective territories.		

Area	**Subcategory** (incomplete)	**Knowledge Gap**	**Relevance** (not completed)	**CU Group** (incomplete)
Harvest	Total mortality	Need to have better estimates of the **total mortality from fisheries** (incl. catch, bycatch, encounter rates, discards, short-/long-term release mortalities). • Is **retained catch** being accurately and completely estimated? • Is Chinook **bycatch** being accurately estimated? • Is long-term **release mortality** being accurately estimated? Release mortality includes short- and long-term mortality (including predation after release) from catch and release or releases due to fish not meeting regulations. We have a good understanding of mortality within 24 hrs, but lack of understanding of long-term release mortality. Releases could be added to reporting requirements or requests where not already included. • Is **depredation** (forcible removal by predators of fish directly from fishing gear) being accurately estimated? Depredation is very tangible to fishers and appears to be a more significant problem that currently reported. Losses from predators are not (consistently) reported in FSC, recreational and commercial fisheries. • Is long-term **mortality from drop-off** from gill-nets and other fishing gear (injury and infection) being accurately estimated? • Is **compliance** being accurately estimated? • Is impact of **environmental conditions on post-release survival** being considered?		
Harvest	Setting ERs	Technical basis for setting **optimal exploitation rates** is weak for many stocks. Need to consider total allowable mortality from all factors and account for changes and uncertainty in what is considered "optimal". The biggest contributing factor to this knowledge gap is the lack of S-R analyses for most populations to be able to estimate U_{MSY}.[45]	Adults	
Harvest	Ecosystem-level impacts	The ecological impact of the **removal of biomass** due to harvest.		
Harvest	Fishery-induced changes	Genetic risk of modifying populations from fishing the "tails" of the distribution of run timing (i.e., "**fishery induced evolution**").		
Harvest	Fishery-induced changes	Are certain harvest patterns (e.g., size, timing) contributing to reduced productivity for certain stocks		
Climate Change				
Climate change		Do not have full knowledge of changes that will happen and potential impacts on different aspects of Chinook life history and habitats		All

[45] Linkage to Status and Trends knowledge gaps.

Appendix F. Examples of CU-specific Identification of Threats

The following five tables each identify major threats for an example individual CUs. These examples were developed by members of the Technical Working Group. The particular example CUs selected represent an opportunistic sample (i.e., CUs for which there is substantial knowledge and TWG members with time to dedicate to the exercise). These CUs are not meant to provide a representative sample across all regions, ecotypes, run timings, and life-history types. The five example CUs include (in order of their tables):

1. CK-01 Okanagan
2. CK-15 Shuswap Summers 0.3
3. CK-17 Lower Thompson Spring 1.2
4. CK-22: Cowichan/Koksilah
5. CK-31 SWVI (Somass system only)

CK-01: Okanagan

Potential Threat	Subcategory	Natural or Human	Potential Severity	Extent of Threat	Frequency	Affected Life Stage(s)	Affected Populations	Specific Concern / Comments
Climate Change								
Climate Change	Water temperature and change in hydroperiod	Human/ Natural	High (Moderate) - Increasing	Freshwater migration, freshwater residence.	Annual	fry, smolts, adults	All	Water temperatures often reach upper tolerance limits for salmon in the mainstem Okanagan River and tributaries, as well as the Columbia River on return migration of spawners. Metabolically, certain life stages may see a marginal positive gain, thus the High/Moderate rating.
Climate Change	Pathogens	Human/ Natural	Moderate - Increasing	Freshwater migration, freshwater residence.	Annual	adults	All	Increased incidence of pathogens (e.g., BKD) during years with high water temperatures and low flows, leading to prespawn mortality.
Climate Change	Forest Fires	Human/ Natural	Low - Increasing	Freshwater migration, freshwater residence.	Annual	fry, smolts, adults	All	Increasing droughts and forest fires can lead to increases in sediment supply and changes in the hydrograph.
Habitat Degradation								
Habitat Degradation	Channelization	Human	High - Stable	Almost all freshwater areas used	Annual	egg, alevin, fry, smolts, spawners	All	Almost the entire Okanagan River has been channelized and diked since the 1950s, leading to significant loss of mainstem river channel, sidechannels and floodplain habitat. The remaining channel lacks complexity and suitable spawning gravel. Approximately 91% of juvenile rearing habitat has been lost compared to historical conditions. It is likely that little usable summer habitat remains in the channelized sections of the Okanagan main channel due to lack of complexity and suitable habitat, in combination with high water temperatures. Restoration projects are under way.
Habitat Degradation	Flow Regulation	Human	Moderate (mainstem) - High (tributaries) - trend Stable	Almost all freshwater areas used	Annual	egg, alevin, fry, smolts, spawners	All	Dams were installed at the outlet of all mainstem lakes for water storage and flow regulation, and in most tributaries for water storage, leading to an unnatural thermal regime (elevated water temperature). Flow regime likely plays a key role in survival of smolts through the river, the dams, and through the estuary.
Habitat Degradation	Water Allocation	Human	High - Increasing	Freshwater migration, freshwater residence.	Annual	fry, smolts, adults	All	Water temperatures often reach upper tolerance limits for salmon in the mainstem Okanagan River and tributaries, as well as the Columbia River on return migration of spawners. Extremely low flows are often observed in tributary streams, leading to lack of accessible habitat and high water temperatures.
Habitat Degradation	Dam Construction	Human	High - Stable	All freshwater areas used.	Annual	spawners, egg, alevin, fry	All	Construction of dams for water storage and flow regulation in the first half of the 20th century has blocked access to significant portions of the former range of Okanagan Chinook, including portions of the mainstem Okanagan river, tributaries, Skaha and Okanagan Lakes. Access was provided recently above two dams (McIntyre and Skaha), with the current upstream extent at the south end of Okanagan Lake.
Habitat Degradation	Hydroelectric Development	Human	Low (adults), High (smolts) - Variable	Entire freshwater outmigration route	Annual	smolts, returning adults	All	Smolts and adults pass 9 hydroelectric dams in the Columbia River on their migration to and from sea. Smolt mortality at each dam ranges from 5% to 15%, and survival to the mouth of the Columbia is estimated at 43% (2006 COSEWIC Assessment). Mortality likely varies by year. Adult survival is estimated at 80-85% (2006 COSEWIC Assessment). Concerns include impacts from TGP and delayed mortality, increased predation.
Habitat Degradation	Pollution	Human	Moderate - High - Stable	entire migration route but particularly in Lower Columbia and estuary	Annual	fry, smolts and adult migrants	All	Pollution from industry and agriculture along the Columbia River and in the estuary. Increasing level of cyanobacteria from nutrification in Osoyoos Lake.
Habitat Degradation	Channel Modifications	Human	High - Stable	Columbia River Estuary	Annual	smolts	All	Loss of wetland and side channel habitat to development in the Lower Columbia River Estuary has been extensive. This has resulted in a switch in primary production in the estuary from a macrodetritus-based source to a microdetritus-based source, which has lowered the productivity of the estuary (Bottom et al. 2005)
Predation								
Predation	Predation by Exotic species	Human	High (fry), Low-Moderate (smolts) - High - stable	freshwater rearing and migration habitat to the Columbia River estuary	Annual	fry and smolts	All	Introduction of a number of piscivorous alien fish species (e.g. walleye, northern pike, less so largemouth and smallmouth Bass, perch,) are preying on Chinook juveniles. The delay of out-migrants associated with lower flows and delays at dams can increase mortality.
Predation	Predation by Native Species	Natural	High - Increasing	freshwater rearing and migration habitat in the Columbia River estuary	Annual	fry and smolts, adults	All	Native piscivorous fish species (e.g. pikeminnow) are preying on Chinook juveniles. The delay of out-migrants associated with lower flows and delays at dams can increase mortality. Flow regulation along the columbia river and habitat modifications to warmer, less complex habitats likely facilitated the proliferation of these species. Also high predation in the Lower Columbia (McNary-Bonneville) and estuary by seabirds that are increasing in numbers (Fresh et al. 2005). Avian predators consumed 10 to 30 percent of the total estuarine salmonid smolt production in 1997. Estuary survival of smolts is estimated at approx. 65%. Also predation on juveniles and adults by pinnipeds.
Harvest								
Harvest	Marine	Human	High	Marine residence and migration	Annual	Adults	All	Total mortalities associated with harvest are uncertain. The retained catch by all sectors averaged 61% over last decade. Increase to just under 80% for last year with data (2013). Biggest impacts are traditionally in marine commercial fisheries but harvest in-river in FN and sport fisheries has increased in recent years
Harvest	Freshwater	Human	Moderate -	Marine residence and migration	Annual	Adults	All	Also unknown component of poaching
Hatchery Production								
Hatchery Production	High Enhancement in US Col. R.	Human	Moderate / High - Stable	entire migration route, particularly in Lower Columbia and estuary	Annual	smolts to returning adults	All	Large numbers of hatchery Chinook are released into the Columbia River in the US annually. These fish may adversely impact Okanagan stocks by competition for food resources and habitat, as well as through the large-scale fisheries directed at these hatchery fish. Adult residualization and mini-jacks of hatchery Chinook increasing.

CK-15: Shuswap Summers 0.3

Potential Threat	Subcategory	Natural or Human	Potential Severity	Extent of Threat	Frequency	Affected Life Stage(s)	Affected Populations	Specific Concern / Comments
Harvest								
Harvest	Freshwater	Human	Moderate - stable	Freshwater spawning migration	Annual	Spawners	All	Total mortalities associated with harvest are uncertain.. Retained catch all sectors averaged 52% over last decade. Severity is high, extent is entire CU, Frequency is annual, Pressure is stable.
Harvest	Marine	Human	Moderate - variable	Marine residence and migration	Annual	Adults	All	Total mortalities associated with harvest are uncertain. Retained catch by all sectors averaged 52% over last decade. Severity is high, extent is entire CU, Frequency is annual, Pressure is stable.
Harvest	Marine	Natural	?	Marine migration through nearshore areas	Annual	Adults and sub-adults	All	High predation on Chinook from killer whale (spring stocks concentrated in southern resident kw diets; northern residents timing might not align): See Hansen et al; John Fores, Graham Ellis -Harbor seals and sea lions potentially high predation levels
Climate Change								
Climate Change	Water temperature (FW)	Human/ Natural	Moderate - Increasing	Freshwater migration, freshwater residence.	During some years	egg, alevin, fry, smolts, adults	All	Water temperatures can reach upper tolerance limits for salmon in the Middle and Lower Shuswap Rivers, as well as the Fraser River on return migration of spawners. Observed prespawn mortality in Lower Shuswap (temps, affected by density of Chinook and sockeye eg., stress). Deep cold holding pools have become rare in some areas of this CU. Juveniles are less susceptible due to ocean-type life history and relatively limited freshwater rearing.
Climate Change	Water temperature (marine)	Human/ Natural	Moderate - Increasing	All	Annual	early marine though returning adult	All	Throughout marine residence. Increased energetic demand, reduced quality and quantity of food. Increased threat from warm-water predators
Climate Change	Acidity	Human Induced	Unknown - likely increasing due to fossil fuel use	All	Annual	early marine through returning adult	All	Ocean acidification associated with fossil fuel use
Hatchery								
Hatchery Production	High Enhanced component	Human	Moderate - stable	All life stages in Middle Shuswap River	Annual	egg, alevin, fry, smolts, adults	Middle Shuswap (1 of 2)	The hatchery component of middle Shuswap is 50-60% and productivity (Return per spawner) much less than Lower Shuswap. Natural production is extremely low there but causes unclear (Hydroelectric Operation?).
Freshwater Habitat								
Habitat Degradation	Hydroelectric Development	Human	Low? - Increasing	Spawning habitat within 500 m of Wilsey Dam, Middle Shuswap River	Annual	egg, alevin, fry	Middle Shuswap (1 of 2)	Interception of gravel at Wilsey Dam has let to coarsening of substrate outside the preferred range for Chinook within approx. 500 m of the dam. This is an area that is typically heavily used by Middle Shuswap Chinook spawners.
Habitat Degradation	Hydroelectric Development	Human	Low - Stable	Spawning habitat downstream of Wilsey Dam, Middle Shuswap River	Annual	egg, alevin, fry	Middle Shuswap (1 of 2)	Alteration of thermal regime and incubation temperatures by 2 dams (Sugar Lake Dam, 30 km upstream and Wilsey Dam, immediately upstream [run of river])
Habitat Degradation	Hydroelectric Development	Human	Moderate - Increasing	Spawning and adult holding habitat in the Middle Shuswap River	Annual	spawners, egg, alevin, fry	Middle Shuswap (1 of 2)	Dredging of fine sediment from the forebay of Wilsey Dam planned for spring 2016. Sediment will be pumped into the river below the dam. Concern over infilling of holding pools.
Habitat Degradation	Hydroelectric Development	Human	High - Stable	Middle Shuswap River	Annual	spawners, egg, alevin, fry	Middle Shuswap (1 of 2)	Construction of Wilsey Dam in the 1930 blocked access to 30km of river upstream with abundant high quality Chinook spawning habitat. Spawning below occurs only within a few km of the dam; redd superimposition observed at times
Habitat Degradation	Forestry	Human	Moderate - stable	throughout freshwater residence	Annual	all freshwater life stages	All	Alterations to flow regimes. Loss of riparian cover, loss of channel stability and complexity, siltation; often exacerbated by agricultural removal of riparian cover
Habitat Degradation	Road Development	Human	moderate - stable	Variable	Annual; Throughout FW residence	All FW life stages	All	Lots of logging in the area. Also, highway runs adjacent for some stretches.
Habitat Degradation	Permitted waste water discharge	Human	Unknown	Lower Shuswap River downstream of Enderby	Annual; Throughout FW residence	All FW life stages	Lower Shuswap (1 of 2)	Enderby Treated Effluent Discharge permitted into Lower Shuswap downstream of Enderby.
Habitat Degradation	Sedimentation	Human/ Natural	High - Increasing	Spawning and adult holding habitat in the Middle Shuswap River	Annual	spawners, egg, alevin, fry	Middle Shuswap (1 of 2)	Sedimentation of deep holding pools in the Middle Shuswap River has increased over the past ~5 years. In 2015, only one pool was used by holding Chinook; all others were observed to be too shallow. This issue may be exacerbated in future years by bulk sediment releases during the proposed dredging works (see above). The source of sediment is unknown but suspected to be in the tributary Bessette Creek.
Habitat Degradation	Riparian Disturbance	Human	High - Increasing	riparian area, freshwater rearing habitat, spawning habitat	Annual	egg, alevin, fry, and smolts	All	Riparian zone damage from channelization and clearing has degraded instream habitat by reducing cover, LWD inputs, and increasing fine sediment deposits. Habitat complexity is very low in the Lower Shuswap downstream of Enderby. Restoration projects are underway in some limited areas.
Habitat Degradation	Channelization, Riparian Disturb, Low Streamflows Flows	Human	High - Increasing	freshwater rearing areas	Annual	fry and smolts	All	Migrating fry and smolts are known to use the lower reaches of tributary streams as well as off-channel areas for rearing. Many of those tributaries and off-channel areas are in agricultural areas and have been heavily modified by infilling, channelization, diking, riparian disturbance, and water withdrawals, leading to uniform, sandy-bottom channels with high water temperatures. These areas are now either inaccessible to rearing Chinook, or are of lower value and favour coarse fish species (e.g., pikeminnow, redside shiners, carp), that may compete with and prey upon juvenile Chinook. Further, stranding of fry in flooded pastures is a concern where dikes exist.
Habitat Degradation	Agricultural Activities	Human	Moderate - Increasing	freshwater rearing areas	Annual	fry and smolts	All	Runoff from agricultural areas introduces nutrients mainly to small tributary streams but likely also the mainstem Lower and Middle Shuswap River. In small tributaries and side channels, this leads to excessive growth of aquatic macrophytes and associated water stagnation and highly fluctuating DO and pH (fish kills observed in some areas).
Habitat Degradation	Channel Modifications	Natural	Moderate - Increasing	freshwater rearing areas	Annual	fry and smolts	Middle Shuswap (1 of 2)	Off-channel rearing areas are partially or fully cut off from main channel flows by channel migration, leading to decreased flows and increased weeds. Off-channel access needs to be maintained. Restoration projects under way in some areas.
Habitat Degradation	Channel Modifications	Human	High - Increasing	entire migration route but particularly in Lower Fraser and estuary	Annual	smolts	All	Extensive diking and elimination of off-channel rearing habitats along the migration route of smolts (e.g., seasonally flooded habitats thorughout the Lower Fraser e.g., sumas lake, Nicomen Slough, Seabird Island, estuary near Vancouver Airport). Sidechannels were cut-off due to diking or completely eliminated.

Potential Threat	Subcategory	Natural or Human	Potential Severity	Extent of Threat	Frequency	Affected Life Stage(s)	Affected Populations	Specific Concern / Comments
Habitat Degradation	Pollution (Lower Fraser and Estuary)	Human	Moderate - trend unknown	entire migration route but particularly in Lower Fraser and estuary	Annual	smolts and adult migrants	All	Pollution from industry and agriculture along the Lower Fraser and in the estuary (e.g., airport chemical run-off from de-icing)
Predation								
Predation	Predation by exotic species	Human	Low - Increasing	freshwater rearing habitat	Annual	fry and smolts	All	Introduction of piscivorous alien fish species (Largemouth Bass) are preying on Chinook juveniles
Predation	Predation by Native Species	Natural	Low - Stable	Throughout Middle Shuswap River	Annual	eggs, fry	Middle Shuswap (1 of 2)	Anecdotal information suggests increasing population of Mountain Whitefish that may be preying on Chinook eggs and juveniles
Marine Habitat								
Food Availability	Reduced Prey Items	Natural	Moderate - Increasing	Marine	Most years	sub-adults, adults	All	Increasing marine water temperatures changes prey items from high lipid large zooplankton to smaller, low lipid zooplankton. Likely a moderate effect on productivity, on offshore migrant CU populations, occurs most years and threat is increasing over last 100 years
Habitat Degradation	Pollution	Human	Moderate - Increasing	Strait of Georgia	Annual	smolts / early marine	All	Acidification, urbanization, higher pollution levels in Strait of Georgia. Severity is moderate, extent is entire CU population, frequency is annual, threat is increasing with growing human population.
Food Availability	Reduced Prey Items	?	High - Stable	Strait of Georgia	Annual	smolts / early marine	All	Decreased Chinook prey items such as eulachon and herring. Causative factor unknown, but will affect survival of Chinook in early marine stage. Severity is high, Extent is entire CU, Frequency is likely annual and Change may be stable at this point.
Food Availability	Reduced Prey Items		?	Strait of Georgia	Annual	smolts / early marine	All	Strait of Georgia late ocean entry. Oceanic zooplankton community large decadal variability of amount and composition. Summer zooplankton dominated by smaller copepods and euphausiids but trade-off between these surface nutrient supply modulated by stratification. Variation in bloom timing (short phyto blooms at spring neap frequency).
Habitat Degradation	Pollution (Marine)	Human	low - stable	Variable	Annual During estuarine and marine residence	early marine through returning adult	All	Marine threats due to increasing tanker traffic with oils and LNG

CK-17: Fraser River Spring 1.2

Potential Threat	Sub-category	Natural or Human	Potential Severity	Extent of Threat	Frequency	Affected Life Stage(s)	Affected Populations	Specific Concern / Comments
Climate Change								
Climate Change	Water temperature (marine)	Natural (??)	moderate-increasing	All	throughout marine residence	early marine through returning adult	All	Throughout marine residence. Increased energetic demand, reduced quality and quantity of food. Increased threat from warm-water predators
Climate Change	Water temperature (FW)	Natural (? human-induced)	high - increasing	All	Summer period during FW residence	0+ parr	All, those rearing in tributary streams likely more vulnerable	
Climate Change	Acidity	Human induced	Unknown - likely increasing	All	throughout marine residence	early marine through returning adult	All	Ocean acidification associated with fossil fuel use
Climate Change	Drought	Natural (??)	high - increasing	All	Throughout FW residence, possible impact in-redd due to reduced groundwater availability	0+ parr	All	Main impact linked to temperature in summer and reduced quality and quantity of rearing habitats. If groundwater impacted, reduced GW availability may reduce thermal buffering of GW, resulting in decreased egg to fry, loss of summer thermal refugia, decreased availability of overwinter GW habitats
Habitat Degradation								
Habitat Degradation	Forestry	Human Controlled	moderate - stable	All	Throughout FW residence	All FW life stages	All	Alterations to flow regimes. Loss of riparian cover, loss of channel stability and complexity, siltation; often exacerbated by agricultural removal of riparian cover
Habitat Degradation	Urban development	Human Controlled	moderate-high - increasing on Nicola	Variable	Throughout FW residence	All FW life stages	Nicola and Coldwater most	"Sustainable growth……"
Habitat Degradation	Pollution (FW)	Human Controlled	moderate-high - stable	Variable	Throughout FW residence	All FW life stages	All but Coldwater River very vulnerable to road-related pollutants; others to agricultural run-off	Highway pollution, agricultural runoff. Coldwater and Louis many be vulnerable to petro-chemical spills with pipeline development
Habitat Degradation	Pollution (Estuary)	Human Controlled	moderate - trend unknown.	Variable	During estuarine residence	early marine	Pollution in Fraser estuary associated with industrial activities, and GVRD sewage, runoff etc	Very vulnerable life stage and much habitat has been lost due to industrial development, booming grounds. GVRD sewage discharge and other impacts to Fraser Estuary (well documented)
Habitat Degradation	Pollution (Marine)	Human Controlled	low - stable	Variable	During estuarine and marine residence	early marine through returning adult	All but Coldwater River very vulnerable to road-related pollutants; others to agricultural run-off	Marine threats due to increasing tanker traffic with oils and LNG
Habitat Degradation	Road development	Human Controlled	moderate - stable	Variable	Throughout FW residence	All FW life stages	All but some more vulnerable. Coldwater and Bonaparte very vulnerable to all linear development	Lots of roads in Nicola, Coldwater and along Louis. Deadman and Spius less vulnerable
Habitat Degradation	Mining development	Human Controlled	Unknown	All	Throughout FW residence	All FW life stages	Unaware of any proposals currently	
Habitat Degradation	Water allocation	Human Controlled	high - increasing	All	Throughout FW FW residence, possible impact in-redd due to reduced groundwater availability	0+ parr, returning adults	All. Nicola, Coldwater and Louis likely most vulnerable	Major issue in southern interior associated with urbanization, agriculture and other point source removals
Habitat Degradation	Permitted waste water discharge	Human Controlled	Unknown	All, especially sewage discharge into Nicola	Throughout FW residence	All FW life stages	Nicola. Not sure about permitted discharge into others	Merritt sewer
Habitat Degradation	Riparian disturbance	Mostly human Controlled	high - increasing	Bonaparte, Louis, Nicola, Coldwater, Deadman. Less in upper Spius and upper Coldwater	Throughout FW residence	All FW life stages	Bonaparte, Louis, Nicola, Coldwater, Deadman. Less in upper Spius and upper Coldwater	Agriculture is primary culprit with linear development and forestry also contributing
Habitat Degradation	Agricultural/ Rural development	Mostly human Controlled	high - increasing	Bonaparte, Louis, Nicola, Coldwater, Deadman. Much less in Spius	Throughout FW residence	All FW life stages	Bonaparte, Louis, Nicola, Coldwater, Deadman.	Agriculture is primary culprit, frequently associated with removal of riparian cover leading to bank instability and loss of channel stability and loss of LWD recruitment
Harvest								
Harvest	Freshwater	Human Controlled	Moderate, stable	All	Annual on return migration	Returning adults	All, later returning more vulnerable than pre-freshet	FN and rec fisheries in Lower Fraser and terminally
Harvest	Marine	Human Controlled	Moderate, variable	All	Annual on return migration	Returning adults	All, later returning more vulnerable than pre-freshet	WCVI troll, entrance recreational fisheries

CK-22: Cowichan/Koksilah

Potential Threat	Subcategory	Natural or Human	Potential Severity	Extent of Threat	Frequency	Affected Life Stage(s)	Affected Populations	Specific Concern / Comments
Climate Change								
Climate Change	Water levels	Natural	Low	All	Annually	fry emergence	All populations	High water scour of redds
Climate Change	Water levels	Natural/ Human	Low	All Spawning Habitat	3 in 10 years	fry emergence	All population in low water years where spawn is in lower river	Chum overspawn
Climate Change	Water levels	Natural	Low/V.Low	20% of spawning area	1 in 10 years	fry emergence	20% of population that spawns below Skutz Falls	Dewatering of redds and reduced incubation survival
Climate change	water levels	Natural/Human	Lack of Information	All of river	3 in 10 years	Freshwater residency	All populations	Stranding in isolated off-channel habitat and tributaries with rapid decreases in flow
Climate Change	water levels	Natural	High	All of river	Annually	Freshwater residency	All populations	insufficient flow to provide access and sustain quality/quantity of seasonally available OC habitat and mainstem rearing habitat between March/May
Climate Change	Water Temperature	Natural/Human	low	lower river	Annually	Freshwater residency	Fry	High water temps combined with low DO
Climate Change	Water levels	Natural	low	All of river	Annually	Freshwater residency	fry	Higher high flows that prematurely displace juveniles downstream and reduce overall fry survival
Habitat								
Habitat Degradation	Water Quality	Natural	High	All spawning habitat	Annually	egg, alevin, fry	All populations if spawn if more than average of 25% spawning occurs downstream of Sandy Pool	High Suspended Sediment
Habitat Degradation	Water Quality	Natural	Low	All Spawning habitat	Annually	egg, alevin, fry	All population, 75% generally spawn above eroding clay banks	High Suspended Sediment
Habitat Degradation	Freshwater	Human	Moderate	70% of Lower river rearing	Annually	Freshwater residency	High amount of population affected	Loss of access to historic tributary and off-channel habitat due to diking
Habitat Degradation	Freshwater	Human	High	Lower river	Annually	Freshwater residency	All populations	Loss of high quality rearing habitat
Habitat Degradation	Estuary	Human	Lack of Information	All estuary	Annually	smolt	Potentially high - gap in information	Decreasing freshwater flows
Habitat Degradation	Food supply	unknown	unknown	moderate	Annually	Freshwater residency	Fry	Lack of suitable food supply
Habitat Degradation	Water Quality	Human	Lack of Information	lower river	Annually	Freshwater residency	fry	Heavy metal concentrations
Habitat Degradation	Estuarine habitat	Human	high	All estuary	Annually	Smolting, estuarine residence	All populations	lack of good quality estuarine interface habitat for smolts
Habitat Degradation	Estuarine habitat	Human	lack of information	All estuary	unknown	Smolting, estuarine residence	All populations	Decreased water quality and reduced fry survival due to ballast dumping, industrial discharge and sewage effluent in the estuary
Habitat Degradation	Estuary	Human	Lack of Information	All estuary	unknown	Smolting, estuarine residence	All populations	available food supply and rearing capacity of Cowichan estuary due to competition with invasives
Habitat Degradation	Lower River	Natural/Human	Moderate	lower river	3 in 10 years	freshwater entry	Some of population is affected	aggradation of sediments creates a migration barrier in lower Cowichan mainstem during summer and early fall period.
Habitat Degradation	fish passage	Human	Moderate	All of lower river	Annually	upstream migration	All population in Cowichan River	Loss of safe migration route through lower mainstem due to channelization, loss of habitat complexity and instream cover features
Habitat Degradation	Refuge habitat	Natural	Moderate	middle and upper reaches of mainstem Cowichan	Annually	upstream migration	most of fall population	Availability of good quality refuge habitat in close proximity to spawning habitat
Habitat Degradation	Water Temperature	Natural/Human	moderate	all CU except earlies holding in Lake	Annually	upstream migration	All fall populations and earlies holding in the river	High water temperatures in lower river/estuary during late summer/early fall migration period can increase migration mortality and sublethal stress.
Habitat Degradation	Water Quality	Human	Low	lower river	Annually	upstream migration	Affects Cowichan/Koksilah portions of CU	poor water quality conditions during late summer/early fall migration (coliforms, deleterious substances)
Habitat Degradation	Water Quality	Natural	Moderate	All spawning habitat	Annually	spawning	Affects all CU	High suspended sediment loads can reduce spawning habitat quality by compacting gravel
Habitat Degradation	Spawning Habitat	Natural	Low	All spawning habitat	Annually	spawning	All populations except upper watershed spawners	Lack of sufficient natural gravel recruitment to mainstem spawning habitat
Habitat Degradation	Spawning Habitat	Natural	unknown	All spawning habitat	Annually	spawning	All populations	Availability of a sufficient quantity of good quality spawning habitat
Habitat Degradation	Invasive Species	Human	unknown	All of river	Annually	all life stages in freshwater	All populations	Colonization of invasive species
Barrier	fish passage	Human	high	Moderate extent - specific to Cowichan Lake access for fry	Annually	Freshwater residency	Early-run population and fall run fish that spawn in upper tributaries	Limited juvenile passage at Cowichan Lake fishway, tributary culverts
Barrier	fish passage	Natural	high	80% of spawning habitat	Annually	upstream migration	Some of population is affected	Limited access through Skutz Falls and possibly Marie Canyon
Barrier	fish passage	Human	Moderate	lower river	Annually	upstream migration	most of fall population	Potential delay in migration due to counting fence
Predation	Freshwater	Natural	Moderate	All	Annually	fry emergence	All populations egg to fry survival	Predation by birds and fish
Predation	Freshwater and estuary	Natural	Lack of Information	All parts of river and estuary	Annually	Freshwater residency	All populations; 50% loss of hatchery fry	Predation of fry by brown trout, river otters, pinnepeds, birds, etc.
Predation	Estuary	Natural	lack of information	All estuary	unknown	Smolting, estuarine residence	All populations	predation of smolts in estuary by pinnipeds
Predation	Estuary	Natural	High	Estuary and Lower River	3 in 10 years	freshwater entry	All population in low water years	Predation of adults in estuary and lower river by pinnipeds
Harvest								
Harvest	Marine	Human	high	All ocean rearing	Annually	Deep-water marine	All populations	over harvest in commercial and recreational fishery
Harvest	Freshwater	Human	Moderate	Lower river	Annually	freshwater entry	All populations	harvest in FNs fishery

CK-31: SWVI (Somass system only)

Potential Threat	Subcategory	Natural or Human	Potential Severity	Extent of Threat	Freq.[46]	Affected Life Stage(s)	Affected Populations	Condition	Specific Concerns / Comments
Habitat									
Environmental conditions	Water flow	Human	Low	Spawning habitat	3	egg, alevin	Upper River	data gap	Low water flows that dewater redds. Competing human uses.
Environmental conditions	Water flow	Natural/Human	Very Low	Spawning habitat	2	egg, alevin	All populations	Increasing	More frequent and higher peak flows over winter can scour/disturb redds. Influences include climate change and herring.
Environmental conditions	Water flow	Natural	Very Low	River / tributaries	1	fry	Stamp, Somas, Sproat	Unknown	Increased stranding in isolated off-channel habitat and tributaries with decreases in flow
Environmental conditions	Water flow	Natural/Human	Low	Tributaries	3	fry	Great Central	Stable	Increased stranding in isolated off-channel habitat and tributaries with decreases in flow. Influences include logging activity.
Environmental conditions	Water flow	Natural/Human	Moderate	River / tributaries	3	fry, smolt	All populations	Stable	High flows
Environmental conditions	Water quality		Very Low	Lower river	3	Adults	All populations	Increasing	Limited or delayed access due to conditions such as water temperature, DO, or flow
Environmental conditions	Water quality	Natural/Human	Low	Estuary/lower riv.	3	Adults	All populations	Increasing	High water temperatures during late summer/early fall migration period. Influences include climate change and forest cut rate.
Environmental conditions	Water quality	Natural/Human	Very Low	Estuary	1	Adults	All populations	Increasing	Poor conditions during the late summer/early fall migration period (low DO, coliform levels, deleterious substances). Influences include natural and pollution.
Environmental conditions	Water quality	Human	High	Lower River	5	fry, smolt	All populations	Increasing/data gap	Poor water quality (temperature, TSS, DO, pH, hardness, supersaturation)
Water quality			Unknown	Estuary		smolt	All populations	Unknown	Mortality or reduced fitness resulting in failure to smolt
Habitat degradation	Urban/indust. dev't	Human	Very High	Estuary	5	smolt	All populations	information gap	Low early marine survival due to lack of food and reduced water quality
Habitat degradation	Urban/indust. dev't	Human	Very High	Estuary	5	smolt	All populations	Increasing	Loss of good quality foreshore, estuarine and nearshore habitat
Habitat degradation	River bed		High	Spawning habitat	4	egg, alevin	Lower river and tributaries	Stable/data gap	Egg mortality due to abundant and right size gravel
Habitat degradation	River bed		Very Low	Spawning habitat	2	egg, alevin	Upper Stamp	Unknown	Egg mortality due to abundant and right size gravel
Habitat degradation	River bed		Very High	Spawning habitat	5	egg, alevin	All populations	information gap	Gravel quality and quantity
Habitat degradation	Urban dev't and channelization	Human	Very High	Lower River	5	fry, smolts	All populations	Stable	Lack of in-stream complexity and riparian complexity.
Habitat degradation	Urban dev't	Human	High	Estuary	4	smolt	All populations	Stable	Loss of suitable habitat
Habitat degradation	Aggradation	Natural/Human	Very Low	Lower River	1	Adults	All populations	Unknown	Creating a migration barrier during summer and early fall periods. Influences include logging activities.
Habitat degradation	Sedimentation	Human	High	Spawning habitat	5	egg, alevin, fry	All populations	Increasing/data gap	High suspended sediment loads
Habitat degradation	Invasive species	Human	Very Low	Spawning habitat	1	egg, alevin, fry	Upper River	Unknown	Feeding by invasive koi
Habitat degradation	Pollution	Human	Moderate	Estuary	3	smolt	All populations	Stable	Decreased water quality
Habitat degradation		Natural/Human	Very Low	Lower River	1	Adults	All populations	Unknown	Loss of safe migration route due to channelization, loss of habitat complexity, and instream cover features
Habitat degradation				River		fry			Lack of suitable habitat
Food availability			Moderate	River	4	fry, smolt	All populations	Increasing/data gap	Lack of food
Disturbance	Invasive species		Very Low	Spawning habitat	1	Egg, Alevin	Upper river	Unknown	Redd disturbance
Anthropogenic Disturb.		Human	Very Low	Spawning habitat	4	Adults	All populations	Increasing	Disturbance to spawning activity
Anthropogenic Disturb.		Human	Very Low	Spawning habitat	1	Egg	Upper river	Unknown	Redd disturbance
Anthropogenic Disturb.		Human	Very Low	River	1	fry, smolts	All populations	Unknown	Mortality or fitness impacts
Anthropogenic Disturb.		Human	Very Low	Estuary	1	smolt	All populations	Unknown	Mortality or reduced fitness from disturbance
Other salmon species	Chum	Natural	Very Low	Spawning habitat	1	Egg		Unknown	Chum overspawn that disturbs chinook redds
Competition	Invasive species		Very Low	Lower river	1	fry, smolt	All populations	Unknown	Competition with aquatic invasive species
Competition / predation	Invasive species		Very Low	Estuary	1	smolt	All populations	Unknown	Competition and predation by aquatic invasive species
Predation	Pinnipeds	Natural/Human	Low	Estuary/lower riv.	4	Adults	All populations	Increasing	Safe holding habitat in estuary and lower river during good flow regimes. Influences include channelization and urban development.
Predation	Pinnipeds	Natural/Human	Moderate	Estuary/lower riv.	4	Adults	All populations	Increasing	During low water, high temperature, and tide related. Influences also by urban development and channelization, and natural ecosystem factors.
Predation		Natural	Very Low	Spawning habitat	5	Adults	All populations	Unknown	Predation on spawning grounds
Predation	Other species	Natural	High	River	4	fry, smolts	All populations	Stable/information gap	Mortality as a result of high levels of predation
Predation	Other species	Natural	High	Estuary		smolt	All populations	Stable	Predation of smolts in the estuary
Predation	Other fish species	Natural	Very Low	Spawning habitat	4	Egg, Alevin	Upper river	Increasing	Predation by sculpins, trout, pike minnow, cutthroat, crayfish, etc.

[46] Temporal Frequency: how often in 10years will this happen? (1 rarely to 5 frequent)

Potential Threat	Subcategory	Natural or Human	Potential Severity	Extent of Threat	Freq.[46]	Affected Life Stage(s)	Affected Populations	Condition	Specific Concerns / Comments
Harvest									
Fisheries management	Enumeration	Human	Low	River	4	Adults	All populations	Stable	Delays in upstream migration due to fishways, blockages, counting fences, etc.
Fisheries management	Enforcement	Human	Low	River	5	Adults	All populations	Stable/information gap	Unauthorized fishing
Hatchery Production									
Hatchery impacts	Competition	Human	High	River	5	fry	All populations	Stable/data gap	Competition with hatchery fry
Pathogens and Disease									
Disease		Natural/Human	Low	River	2	fry, smolt	All populations	Stable	Mortality of fitness impacts. Influences include hatchery and natural environment.
Disease				Estuary					Mortality of fitness impacts

Appendix G. CU Summary Table

Area	CU Index	CU Name	Adult Run Timing	Major Juvenile Type	# Time Series for Analysis [1]	Status	CWT Indicator Stock [strong] *[weak]*	Ocean distrib. pattern	Total Exploitation (avg 1999-2011)	Top 2 Fisheries (avg 1999-2011)	Panel: ER > Adj E_{MSY} [1]	Habitat pressure – # of watersheds by cumulative risk rating (Full CU) [2] High	Mod	Low	Habitat pressure (% high/mod watersheds) [2] FULL CU	Spawning	Mod/high enhancement
Fraser River Conservation Units																	
Fraser-Lower	CK-03	LFR-fall	Fall	ocean	1	▼	**Harrison**	Local	35%	**11%** in WCVI troll, **5%** in SoG sport		11	1	2	**86%**	**100%**	
	CK-04	LFR-spring[2]	Spring	stream	1	▲	*(Dome)*					9	11	29	*40%*	**75%**	□[3]
	CK-05	LFR-UPITT	Summer	stream	1	▼	*(Dome)*					5	7	17	*41%*	**75%**	
	CK-06	LFR-summer	Summer	stream	1	▼	*(Dome)*					23	29	68	*43%*	**79%**	
	CK-07	Maria	Summer	ocean	1	◄►	*Shuswap*					1	0	0	**100%**	**100%**	■
	CK-9008	(P)HatchX-LFR	Fall	ocean	1	▼	**Chilliwack**	Local	30%	**6%** in WCVI troll, **6%** terminal sport							■
Fraser-THOM	CK-13	STh-0.3	Summer	ocean	4 (1)	▲	*Shuswap*					137	56	21	**90%**	**100%**	
	CK-14	STh-1.3	Summer	stream	2	▼	*(Dome)*					40	18	19	**75%**	**92%**	■
	CK-15	STh-SHUR	Summer	ocean	2	?	**Shuswap**	Far North	**52%**	**10%** NBC sport, **7%** NBC troll	**YES**	33	15	1	**98%**	**100%**	■
	CK-16	STh-BESS	Summer	stream	4	?	*Nicola*					14	2	0	**101%**	**100%**	
	CK-17	LTh	Spring	stream	6 (3)	▼	**Nicola**	Offshore	33%	**6%** terminal FN net, **5%** Nicola mouth sport		191	59	8	**97%**	**100%**	■
	CK-18	NTh-spr	Spring	stream	2	▼	*(Dome)*					36	17	27	66%	**100%**	
	CK-19	NTh-sum	Summer	stream	5	▼	*(Dome)*					73	30	30	**78%**	**80%**	
	CK-82	Adams-upper	Summer	ocean	1	◄►	*(Dome)*					5	11	16	50%	66%	
Fraser-Upper	CK-08	NAHAT	Spring	stream	1	?	*(Dome)*					5	9	20	*41%*	57%	
	CK-09	Portage	Fall	stream	1	▼	*(Dome)*					10	3	9	59%	**80%**	
	CK-10	MFR-spring	Spring	stream	12 (7)	▼	*(Dome)*					409	266	338	66%	**80%**	
	CK-11	MFR-summer	Summer	stream	6 (2)	▼	*(Dome)*					221	135	99	**79%**	**87%**	
	CK-12	UFR-spring	Spring	stream	27 (6)	▼	**(Dome)**	Offshore	**69% (to 2006)**	**40%** term. FN net, **12%** Juan de Fuca sport	**YES**	163	132	213	58%	**76%**	□[3]
Coastal Conservation Units																	
GS+OK	CK-01	OK[3]	Summer	stream	1	▼	*SUM (Col. R. Summers)*					17	7	1	**96%**	n/a	
	CK-02	BB	Fall	ocean	1	▲	*NSF (Puget Sound)*					8	0	0	**100%**	**100%**	■
	CK-20	SC+GStr[4]	Fall	ocean	6 (14)	?	*Big Qualicum*					35	25	117	*34%*	*36%*	
	CK-21	Goldstr	Fall	ocean	1	▼	*Cowichan*					2	0	0	**100%**	**100%**	■
	CK-22	CWCH-KOK	Fall	ocean	1 (4)	◄►	**Cowichan**	Local	**65%**	**27%** SoG sport, **9%** WCVI troll	**YES**	19	6	5	**83%**	**75%**	■
	CK-23	NanR-spr	Spring	stream	1	?	*Puntledge*					2	2	4	50%	*33%*	
	CK-83	midEVI-sum	Summer	ocean	2 (1)	▼	**Puntledge**	Far North	29%	**10%** SoG sport, **7%** NBC sport		27	22	22	**82%**	**84%**	■
	CK-25	midEVI-fall	Fall	ocean	2 (2)	◄►	**Nanaimo**		**47%**	**24%** SoG sport, **6%** term. comm. net	**YES**	11	3	8	64%	**100%**	■
	CK-27	QP-fall	Fall	ocean	4 (2)	▼	**Big Qualicum**	Far North	40%	**9%** SoG sport, **8%** NBC sport		28	3	23	58%	**100%**	■
WCVI/NEVI/USC	CK-28	SC+SFj[5]	Fall	ocean	10	▲	*Big Qualicum*					7	10	131	*12%*	*26%*	■
	CK-29	NEVI	Fall	ocean	5 (1)	▼	**Quinsam**	Far North	41%	**15%** NBC sport, **4%** SoG sport		61	53	42	73%	**100%**	■
	CK-31	SWVI	Fall	ocean	20 (20)	▼	**Robertson**	Far North	**56%**	**13%** term. comm. net, **11%** term. sport	**YES**	51	46	50	66%	60%	■
	CK-32	NoKy[6]	Fall	ocean	21 (3)	▼	*Robertson*					37	27	22	74%	**100%**	■
	CK-33	NWVI	Fall	ocean	2 (2)	▲	*Robertson*					18	8	0	**90%**	**83%**	■
	CK-34	HOMATH	Summer	stream	0	?	*Atnarko*					0	16	23	*8%*	*25%*	
	CK-35	KLINA	Summer	stream	1 (1)	?	*Atnarko*					4	35	39	*17%*	n/a	

[1] See Riddell et al. (2013)

[2] From southern BC Chinook salmon habitat report cards (Porter et al. 2015)

[3] In the 2013 analyses,C K-04 and CK-12 fell within the definition of "moderate-high" enhancement but would likely be considered "unknown-low" because enhancement activity stopped just over 3 generations ago.

Appendix H. Assessment Summary for Southern BC Chinook

This table provides a summary of the current state of assessment monitoring for southern BC Chinook across all CUs. A stoplight approach is used for qualitative ratings – in general, green indicates the program elements are established and adequate, yellow indicates that program elements are in place but inadequate, and red indicates that the program elements are either not in place at all or completely inadequate (details for the thematic classification of each field are included below the table). PST CTC Mgt. Unit – Pacific Salmon Treaty Chinook Technical Committee management units. DU - Designatable Unit (i.e., the unit used in the COSEWIC status assessment).

	PST CTC Mgt. Unit	Proposed DU Name	CU	Conservation Unit Name	Life History	Ocean Distribution	CWT Indicator	Rivers with type 1 or 2 escapement	Rivers with escapement	Rivers Assessed	Total Rivers	Draft WSP Status[2]	Forecast	Comments
Inside - Fraser River	Fraser Late	BC Lower Fraser River Ocean Fall	CK-03	CK_Lower Fraser River_FA_0.3	Ocean (Immediate)	Local	Harrison R	1	1	1	1	GREEN (p)	Y	Harrison River
			CK-9008	Fraser-Harrison fall transplant_FA_0.3	Ocean (Immediate)	Local	Chilliwack/ Vedder R.	0	1	1	1	TBD	Y	Chilliwack/Harrison Chinook transplanted
	Fraser Spring 1.3	BC Lower Fraser River Stream Spring	CK-04	CK_Lower Fraser River_SP_1.3	Stream	Far north migrating (Birkenhead)	None	0	0	1	3	DD*	N	Birkenhead, Ryan and Green. 1980's Birkenhead tags mostly recovered in SEAK troll. *CU status should be re-evaluated after review of enhancement level definition
		BC Middle Fraser River Stream Spring (FRCany+GStr)	CK-08	CK_Middle Fraser-Fraser Canyon_SP_1.3	Stream	Offshore	None	0	0	0	1	DD	N	Nahatlatch River, presumed offshore, sporadic escapement work with Sox program
		BC Middle Fraser River Stream Spring (MFR+GStr)	CK-10	CK_Middle Fraser River_SP_1.3	Stream	Offshore	None	0	0	10	19	RED	N	Mid Fraser springs
		BC Upper Fraser River Stream Spring	CK-12	CK_Upper Fraser River_SP_1.3	Stream	Offshore	None	0	0	18	26	RED	N	Upper Fraser springs
		BC North Thompson Stream Spring	CK-18	CK_North Thompson_SP_1.3	Stream	Offshore	None	0	0	1	8	RED	N	North Thompson springs. Many systems not surveyable due to glacial turbidity. Blue surveyed some years, Finn Creek is type 5 survey in reality
	Fraser Spring	BC South Thompson Stream Summer	CK-16	CK_South Thompson-Bessette Creek_SU_1.2	Stream	Offshore?	None (Nicola?)	0	0	4	4	RED*	N	Lots of issues with relationship between Bessette stocks and Mid Shuswap. *CU definition should be reviewed
		BC Lower Thompson Stream Spring	CK-17	CK_Lower Thompson_SP_1.2	Stream	Offshore	Nicola R	3[3]	1[4]	6	8	RED	N	Well covered with Nicola (MR), Deadman and Bonaparte (resistivity counts). Nicola CWTs
	Fraser Summer 1.3	BC Lower Fraser River Stream Summer	CK-05	CK_Lower Fraser River-Upper Pitt_SU_1.3	Stream	Unknown[5]	None	0	0	1	1	DD	N	Upper Pitt poorly understood, due to glacial turbidity. Count is on one clear tributary. Distribution unknown. Unknown if escapement in Blue Cr. Is an index of return to Upper Pitt
			CK-06	CK_Lower Fraser River_SU_1.3	Stream	Unknown[5]	None	0	0	2	9	DD	N	Chilliwack summers, Lillooet summers. Difficult to enumerate other than Chilliwack and smaller systems like Big Silver
		BC Middle Fraser River Stream Fall	CK-09	CK_Middle Fraser River - Portage_FA_1.3	Stream	Offshore?	None	0	0	1	1	RED	N	Strange genetics. Does not fit with rest of mid Fraser. May be from different ancestry. Distribution inferred but uncertain. Small population.
		BC Middle Fraser River Stream Summer	CK-11	CK_Middle Fraser River-SU_1.3	Stream	Offshore	Chilko R (proposed)	1	1[6]	9	16	AMBER	N	Stuart, Taseko, Cariboo difficult to assess due to turbidity. Some DIDSON at Taseko. MR at Chilko, and work to develop indicator.
		BC South Thompson Stream Summer	CK-14	CK_South Thompson_SU_1.3	Stream	Offshore	None (Chilko?)	1[7]	0	2	4	RED / AMBER	N	Poorly understood group. Not clear if Chilko would be appropriate indicator.
		BC North Thompson Stream Summer	CK-19	CK_North Thompson_SU_1.3	Stream	Offshore	None (Chilko?)	0	0	5	6	RED	N	Barriere, North Thompson, Clearwater, Mahood etc.
	Fraser Summer 0.3	BC Lower Fraser River Ocean Summer	CK-07	CK_Maria Slough_SU_0.3	Ocean (90 day)	Far north migrating	None (Lwr Shuswap)	0	0	1	1	TBD	N	Maria Slough
		BC South Thompson Ocean Summer	CK-13	CK_South Thompson_SU_0.3	Ocean (90-150-day)	Far north migrating	None (Lwr Shuswap)	0	4	4	4	GREEN	N	Largest returns in Interior currently. Not currently feasible to run type 1 or 2 project on these stocks
			CK-15	CK_Shuswap River_SU_0.3	Ocean (90-150-day)	Far north migrating	Lower Shuswap R	1[8]	2	2	3	TBD	N	Lower and Mid Shuswap
			CK-82	CK_Upper Adams River_SU_x.x	Ocean?	Far north migrating?	None (Lwr Shuswap)	0	0	0	1	DD	N	Remnant of two recolonization attempts. Broodstocks were Finn Creek (Upper North Thompson Spring 1.3) and Lower Shuswap (Shuswap Summer 0.3)

	PST CTC Mgt. Unit	Proposed DU Name	CU	Conservation Unit Name	Life History	Ocean Distribution	CWT Indicator	Rivers with type 1 or 2 escapement	Rivers with escapement	Rivers Assessed (2015)[1]	Total Rivers	Draft WSP Status[2]	Forecast	Comments
Inside	Unrepresented	BC Southern Mainland - Boundary Bay Ocean Fall	CK-02	CK_Boundary Bay_FA_0.3	Ocean	Local?	None Nooksack?, Samish?	0		0	3	TBD	N	
Inside	Unrepresented	BC South Coast - Georgia Strait Ocean Fall	CK-20	CK_Southern Mainland-Georgia Strait_FA_0.x	Ocean	Far north migrating?	None (Big Qualicum?)	1		1	15	DD	N	
Inside	Unrepresented	BC East Vancouver Island Stream Spring	CK-23	CK_East Vancouver Island-Nanaimo_SP_1.x	Stream	Local?	None	0		0	1	DD	N	
Inside	Unrepresented	BC East Vancouver Island Ocean Summer	CK-83	Vancouver Island-Georgia Strait_SU_0.3	Ocean	Far North Migrating	Puntledge Summers	0		4	4	TBD	N	Includes Cowichan Summers however we are unclear whether these are a separate population from the Cowichan Falls at this time. Also includes Chemainus Summers which also may not be a separate timed population
Inside	Lower Georgia Strait (LGS)	BC East Vancouver Island Ocean Fall	CK-21	CK_East Vancouver Island-Goldstream_FA_0.x	Ocean	Local?	Cowichan	1		1	1	TBD	N	
Inside	Lower Georgia Strait (LGS)	BC East Vancouver Island Ocean Fall	CK-22	CK_East Vancouver Island-Cowichan & Koksilah_FA_0.x	Ocean	Local	Cowichan	1		2	3	TBD	N	
Inside	Lower Georgia Strait (LGS)	BC East Vancouver Island Ocean Fall	CK-25	CK_East Vancouver Island-Nanaimo & Chemainus_FA_0.x	Ocean	Local	None (was Nanaimo)	0		2	2	TBD	N	
Inside	Lower Georgia Strait (LGS)	BC East Vancouver Island Ocean Fall	CK-27	CK_East Vancouver Island-Qualicum & Puntledge_FA_0.x	Ocean	Far North Migrating	Big Qualicum	0		4	6	TBD	N	
Inside	Upper Strait of Georgia (UGS)	BC South Coast - Southern Fjords Ocean Fall	CK-28	CK_Southern Mainland-Southern Fjords_FA_0.x	Ocean	Far North Migrating	Phillips				25	DD	N	
Inside	Upper Strait of Georgia (UGS)	BC East Vancouver Island Ocean Fall (EVI + SFj)	CK-29	CK_East Vancouver Island-North_FA_0.x	Ocean	Far North Migrating	Quinsam				14	RED	N	
Inside	Upper Strait of Georgia (UGS)	BC Southern Mainland Ocean Summer	CK-34	CK_Homathko_SU_x.x	Ocean	Far North Migrating	None	0			2	DD	N	
Inside	Upper Strait of Georgia (UGS)	BC Southern Mainland Stream Summer	CK-35	CK_Klinaklini_SU_1.3	Stream	Far North Migrating	None	0			2	DD	N	Fishwheel program produced successful mark-recapture in KlinaKlini in early 2000's. Glacially turbid systems with substantial returns, currently under-assessed.
Outside	West Coast Van. Isl. (WCVI)	BC West Vancouver Island Ocean Fall (South)	CK-31	CK_West Vancouver Island-South_FA_0.x	Ocean	Far North Migrating	Robertson	1		34	49	RED	Y	Stamp falls has counters on the Somas River. Out of the 34 assessed, each system was surveyed at least once. Enumeration Class Type 5 or better: Somass River, Ash River, Gracie Creek, Taylor River, Drinkwater Creek, McBride Creek, Tranquil Creek, San Juan River, Nitinat River, Clemens Creek, Nahmint River, Sarita River, Toquaht River, Bedwell River, Cypre River, Megin River.
Outside	West Coast Van. Isl. (WCVI)	BC West Vancouver Island Ocean Fall (Nootka & Kyuquot)	CK-32	CK_West Vancouver Island-Nootka & Kyuquot_FA_0.x	Ocean	Far North Migrating	None (Robertson)	1		24	43	RED	Y	MR at the Burman River. Out of the 24 assessed, each system was surveyed at least once. Enumeration Class Type 5 or better: Burman River, Leiner River, Kaouk River, Conuma River, Tahsis River, Tlupana River, Artlish River, Malksope River, Tahsish River, Espinosa Creek, Gold River, Little Zeballos River, Oktwanch River, Zeballos River, Kauwinch River.
Outside	West Coast Van. Isl. (WCVI)	BC West Vancouver Island Ocean Fall (North)	CK-33	CK_West Vancouver Island-North_FA_0.x	Ocean	Far North Migrating	None (Robertson)	0		3	10	TBD	Y	Systems assessed are Marble, Colonial, and Cayeghle. Note: Colonial Creek was thought to be Utluh Creek. Utluh Creek should be removed from the files as it doesn't produce fish at all.

[1] Estimate of Type-5 or better. [2] Brown et al. 2016 (WSP Assessment). [3] Nicola MR; Bonaparte and Deadmas resistivity counts but no biosampling. [4] Uncertain if Nicola ages and sex reflect wild escapements at other sites. [5] Far north migrating? Likely far north due to ancestry. [6] Would be green if test fishery ages are reasonably represented. [7] Salmon River at Salmon Arm broodstock and enumeration fence. [8] Lower Shuswap. Sometimes do MR at Mid Shuswap if funding available.

Thematic classification key:

	PST CTC Management Unit	Life History	Ocean Distribution	CWT Indicator
Green	Unit is homogenous (1 life history type and single marine distribution)	Known	Known from tags, or strong genetic evidence	CWT indicator in CU that represents CU well in terms of distribution and maturation
Yellow	Unit is not homongenous (i.e., differences in life history or run timing)		Inferred by tags or genetics	No indicator in CU but one in neighbouring CU that represents indicator well in terms of ocean distribution
Red	Not represented within the CTC management framework at all	Unknown	Unknown	No existing, appropriate indicator

Appendix I. Strategies – Linkages to Objectives, Threats, and Gaps, Time Frame and Costs

As referenced in Section 5.1, this Appendix provides an example of adding supplemental information and linkages to the strategies. The table identifies the linkages between strategies/sub-strategies and the relevant objectives, threats and knowledge gaps being addressed and provides estimates of the approximate timing and costs. This example is limited to the strategies associated with hatchery production; however, the intent is to provide this information for all the strategies. Such information will be helpful to the SPC for prioritizing and/or sequencing strategies within the currently comprehensive set of strategies.

PLEASE NOTE: this example was developed prior to the final revisions to the strategies associated with hatchery production (i.e., the wording and organization of some of the strategies has changed, so the strategies in this table no longer perfectly align with Section 5), therefore it should be considered as an ***illustrative*** example only.

Sub-strategy		Objective Addressed	Threats/Knowledge Gaps Addressed	Time Frame	Initial Cost	Cost/yr
8.1 Follow the process, objectives, and priorities for setting enhanced production levels, considering current enhancement practices and identifying opportunities to better align production with the approved program objectives and regional monitoring requirements (DFO 2012a)						
8.1a	Identify high level production priorities by CU, CU group or Management Unit for further investigation and analysis of risk and benefit	B2	Hatchery-genetic Hatchery-ecological	1-2 yrs	?	N/A
8.1b	Reduce risk of negative impacts of hatchery practices on wild stocks, in areas where such impacts have been demonstrated or are strongly suspected.	B1, B3, B4, S1, S2, E1, E2, B7	Indicator stocks	5-10yrs	?	Tradeoff costs †
8.1c	Maintain or increase practices that have demonstrated benefits consistent with the prioritized objectives established above (DFO, 2012, 2013).	B1, B3, B4, S1, S2, E1, E2, B7		1-2 yrs	?	?
8.2 Review existing monitoring programs which are based on hatchery stocks, and supplement, modify or maintain as necessary to develop and implement an effective, integrated network of hatchery indicator stocks, across life-history types, ecotypes, and ecosystems, providing information of sufficient quality for sound management decisions.						
	Maintain existing hatchery CWT indicators where they still provide important information.	B7	Sustainable ERs Setting ERs Estimates of ERs	Short term (>1yr)	N/A	~$1M
8.2b	Review hatchery CWT indicators to assess where they are most useful.	E5	Sustainable ERs Setting ERs Estimates of ERs	Short term (>1yr)	-	-
8.2c	Identify and prioritize Chinook ecotypes that do not have indicator stocks (e.g., Upper Fraser springs, possibly other Upper/Middle Fraser and/or Thompson stocks, Mainland inlets).	B7	Sustainable ERs Setting ERs Estimates of ERs	1-2 yrs	N/A	N/A
8.2d	Identify and prioritize Chinook ecotypes that have inadequate information for sound management decisions.	B7	Sustainable ERs Setting ERs Estimates of ERs	1-2 yrs		

Sub-strategy		Objective Addressed	Threats/Knowledge Gaps Addressed	Time Frame	Initial Cost	Cost/yr
8.2e	Add additional CWT hatchery stock(s) to address major knowledge gaps. ❷	B7	Sustainable ERs Setting ERs Estimates of ERs	5-10yrs	~$250K	~$300K
Assess the direct and indirect risks of hatchery and enhancement practices on the spawning and rearing success of wild populations (DFO 2013a). ❷						
8.3a	Assess potential effects (genetic, ecological, disease) on wild fish of hatchery fish spawning in the natural environment	B1, B2, B4	Hatchery Production -Genetic -Ecological -Disease	1-10yrs	~$150K	$100K
8.3b	Assess potential effects (genetic, ecological, disease) on wild fish of hatchery fish rearing in the natural environment	B1, B2, B4	Hatchery Production -Genetic -Ecological -Disease	1-10yrs	~$150K	$100K
8.4. Assess the benefits (both direct and indirect) of hatchery production to the provision of harvest opportunities, stock rebuilding, and genetic conservation of salmon populations.						
8.4a	Assess how changes in hatchery production affect changes in harvest levels in different stocks and fisheries ❷	S1, S2, E2, E3, E5	Hatchery Production -Effects on harvest	1-2 yrs	~$30K	N/A
8.4b	Use available tools (e.g., Hatchery-Harvest Analysis Tool (HHAT)) to explore the short and long-term consequences of changes in hatchery production (e.g., changes in harvest rates, abundance indices, bycatch rates, weak stock management), especially in terms of impacts on wild populations.	B1, B2, S1, S2, E2, E3, E5	Hatchery Production -Effects on harvest	1-2 yrs	?	?
8.4c	Improve available tools for evaluating the interactions between hatchery production and fisheries.	B7 (and others above)	Hatchery Production -Effects on harvest	1-2 yrs	~$100K	~$40K
Given existing knowledge about the status, trends, threats and knowledge gaps for each CU, CU group or aggregate, determine the level of precaution, risk aversion, and urgency with which production adjustments should be pursued.						
8.5a	If risks to fisheries, assessment or rebuilding are considered to outweigh risks to conservation (risk aversion with respect to production objectives is strongest), proceed to conduct analyses and thoroughly explore tradeoffs before deciding upon and implementing any adjustment in production levels	B1, B3, S1, E1, E2		1-10yrs	Tradeoff costs	Tradeoff costs
8.5b	If risks to conservation are considered to outweigh risks to fisheries, assessment or rebuilding (risk aversion with respect to conservation objectives), proceed directly to 8.6, implementing production level changes based on the best available information and monitoring the effects of these actions to the extent possible.	B1, B3, B4		1-10yrs	Tradeoff costs	Tradeoff costs
8.5c	Prioritize opportunities to increase higher value and lower risk hatchery production to support Objectives 2, 4-6.			1-10yrs		

† No implementation cost, likely tradeoff cost