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RECOVERY POTENTIAL ASSESSMENT FOR SOUTHERN BRITISH COLUMBIAN CHINOOK POPULATIONS, FRASER AND SOUTHERN MAINLAND CHINOOK DESIGNATABLE UNITS (1, 6, 13, AND 15)

Chinook Salmon adult spawning phase. Image credit: Fisheries and Oceans Canada

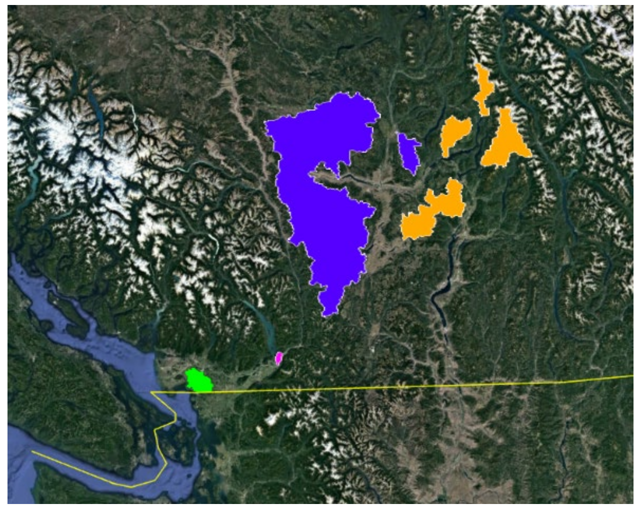

Figure 1. Map of Southern BC showing the natal areas of the 4 Designatable Units (DU). DU 1 is green, DU 6 is pink, DU13 is orange, and DU 15 is blue.

Context:

Four Designatable Units (DU) of southern British Columbia (BC) Chinook Salmon that spawn in the Fraser River drainage and Southern Mainland of BC were designated as either Threatened or Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2020. DFO Science was requested by the DFO Species at Risk Program to undertake a Recovery Potential Assessment (RPA) for four populations (DUs 1, 6, 13, 15) to provide science advice on the potential addition of these populations to Schedule 1 of the Species at Risk Act (SARA). The advice from the RPA will be used to inform both scientific and socio-economic aspects of the listing process, development of a recovery strategy and action plan, support decision-making with regards to the issuance of permits or agreements, and the formulation of exemptions and related conditions. The advice generated via this process will update and/or consolidate any existing advice regarding these populations of southern BC Chinook Salmon.

This Science Advisory Report is from the February 22-24, 2022 regional peer review on the Recovery Potential Assessment – Southern BC Chinook Salmon – Four Designatable Units. Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

SUMMARY

- Southern British Columbian Chinook (SBCC) Designatable Units (DU) were assessed by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in November 2020. Of those in the Fraser River and Southern British Columbia (BC) mainland, one was designated as *Threatened* and three were designated as *Endangered*. Abundances of these Chinook salmon DUs have declined or remained at a low level since the COSEWIC assessment. The assessed DUs are:
  - Southern Mainland Boundary Bay, Ocean, Fall – Boundary Bay (DU1)
  - Lower Fraser (LFR) River Ocean Summer – Maria Slough (DU6)
  - South Thompson (STh) Stream Summer 1.3 (DU13)
  - Lower Thompson (LTh) Stream Spring 1.2 (DU15)
- All four DUs have experienced high levels of hatchery enhancement which is why they were not included in COSEWIC (2019, 2020) and DFO (2020, 2021).
- Redds, the spawning nests constructed by Pacific salmon and other fish species, meet the definition of a "residence" under the *Species at Risk Act* (SARA).
- The COSEWIC threats calculator was used to assess 33 ongoing and future threats limiting the population recovery of each DU over the next three generations. Natural systems modifications, climate change and severe weather were the highest ranked threat categories for these four DUs. Invasive and problematic species, pollution, and agriculture and aquaculture, and biological resource use were ranked high for two of the four DUs.
- The overall threat ranking for all DUs was Extreme based on their number and severity. This ranking suggests that a decline of 71-100% is anticipated over the next 3 generations or 10 years, unless threats are mitigated.
- Climate change is anticipated to negatively impact all DUs including through interactions with other threats. Habitat shifting and alteration has occurred and will continue to occur through changes to physical and biological processes in both marine and freshwater environments. Predicting future changes in salmon productivity and abundance is challenging in the current era of rapidly changing conditions, as there is significant uncertainty in both the future state of natural environments, and the ability to mitigate anthropogenic effects.
- Natural systems modification was ranked a medium-high or high threat risk for all DUs largely due to pervasive water management and anthropogenic land-based ecosystem modifications related to agriculture, forestry, resource extraction, and linear/urban development activities.
- Two recovery targets were proposed for each of the four DUs:
  - A **survival** target that approximates conditions such that a DU would not be characterized as *Endangered* or *Threatened* by COSEWIC.
  - A **recovery** target at which the DU would no longer be considered to be at risk under COSEWIC guidelines.
- Each target consists of two benchmarks: generational average wild spawner abundance and the three-generation trend in wild spawner abundance. Additionally, genetically-based

targets associated with hatchery impacts on wild populations should align with targets recommended by DFO (2018a).

- There were insufficient data to conduct forward projections of population trajectories for these four DUs. However, given the number and severity of threats facing these DUs, it is unlikely that they will reach either their survival or recovery targets in three generations under current conditions.
- Some data to assess relative population abundances exist, but productivity could not be monitored for all of the DUs. Data limitations with absolute abundance and exploitation rate estimates, basic demographic attributes of spawning populations, and the inability to estimate hatchery contributions of Chinook Salmon existed in all but one system.
- A list of mitigation measures was developed to address identified threats. These measures may increase survival or productivity but information was not available to assess their efficacy, nor their potential to increase the probability of meeting the recovery targets. A mitigation survey provided expert opinion on the relative importance of mitigations for recovery of each DU.
- These DUs are at great risk based on the threats assessment and the qualitative assessments of population trajectories. **Further harm may continue to jeopardize recovery and survival. Therefore, to promote the survival and recovery of these DUs, it is recommended that all future and ongoing human-induced harm should be prevented.** It is important to note that some activities in support of survival or recovery could result in harm but may have a net positive effect on the population and should be considered.

INTRODUCTION

Rationale for Recovery Potential Assessment

Subsequent to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assessing an aquatic species as *Threatened, Endangered* or *Extirpated*, Fisheries and Oceans Canada (DFO) undertakes several actions required to support implementation of the *Species at Risk Act* (SARA). Many of these actions require scientific information on the current status of the wildlife species, threats to its survival and recovery, and the feasibility of recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) within a designated timeframe following the COSEWIC assessment. This timing enables the consideration of peer-reviewed scientific analyses into SARA processes including recovery planning.

In November 2020, COSEWIC assessed the status of 12 of 28 Chinook Salmon DUs in southern BC (COSEWIC 2020), four of which are evaluated in this RPA. These four DUs were considered to have received hatchery supplementation over the past three generations or were previously considered by DFO to have insufficient data for assessment. This assessment led to the status assignment of 3 DUs as *Endangered* and 1 as *Threatened* (Table 1). The three Endangered DUs are Maria Slough (DU6), the South Thompson (STh) Stream Summer 1.3 (DU13), and Lower Thompson Stream (LTh) Spring 1.2 (DU15) while Boundary Bay (DU1) was designated as Threatened. The RPA addresses the 22 elements outlined in the Terms of Reference for completion of RPAs for Aquatic Species at Risk (DFO 2014a), which include:

- SBCC biology, abundance, distribution and life history parameters (Elements 1 –3);
- descriptions of SBCC habitat and residence requirements at all life stages (Elements 4-7);

- assessment and prioritization of threats and limiting factors to the survival and recovery of SBCC (Elements 8-11);
- proposed recovery targets for SBCC DUs (Elements 12-15);
- scenarios for mitigation of threats and alternatives to activities (Elements 16-21); and,
- an allowable harm assessment to evaluate the maximum human-induced mortality and habitat destruction that the species can sustain without jeopardizing its survival or recovery (Element 22).

Table 1. Rationale for COSEWIC status designation listing for Southern British Columbian Chinook (SBCC) Designatable Units (DU) covered in this RPA, and their relation to fisheries Management Units (MU) and Wild Salmon Policy Conservation Units (CU).

Management Unit (MU)	Conservation Unit (CU)	Designatable Unit (DU)	COSEWIC Status	Reasoning for Status
Spring 4_2	CK-17 Lower Thompson	DU15 – Lower Thompson Stream Spring	Endangered	From 2013-2018, the number of mature individuals steeply declined and marine survival has been low since 2000. Deforestation, wildfires, habitat destabilization, agricultural water withdrawal and climate change induced disruption to water quality are continuing threats to this population and exacerbated by a relatively long freshwater residence.
Summer 5_2	CK-14 South Thompson 1.3	DU13 - South Thompson Stream Summer 1.3	Endangered	This summer run of Chinook has declined and is projected to continue declining. Water levels, agricultural runoff, pollution, and modified freshwater habitats are continuing threats to this population and are emphasized due to a relatively long freshwater residence.
Summer 4_1	CK-07 Maria	DU6 – Lower Fraser River Ocean Summer (Maria Slough)	Endangered	This summer run of Chinook spawning at a single site (Maria Slough) has declined. In 2018, failed water control structures and low water levels prevented spawners from accessing the spawning site. Declines in water quality and quantity and freshwater and marine habitat quality are continuing threats to this population.
Fall 4_1	CK-02 Boundary Bay	DU1 – Boundary Bay Ocean Fall	Threatened	Hatchery releases, which are ongoing and have included fish from other populations, have allowed the total population size to increase while threatening the genetic integrity of the remaining wild fish. This fall run of Chinook spawning in Boundary Bay drainages occurs in highly altered marine and freshwater habitats. Low marine survival, bycatch, and fish culture effects are continuing threats to this population.

Biology, Abundance, Distribution, and Life History Parameters

Chinook Salmon are the largest Pacific salmon species and have an anadromous life cycle that uses both freshwater and ocean habitats. Chinook Salmon spawn in the late-summer and fall, yet their return to freshwater precedes spawning by days to several months depending on migration distances and hydrological conditions required to access terminal spawning areas.

SBCC populations are designated as spring, summer, or fall return populations depending on the time in which more than 50% of spawners pass through the lower Fraser River or, in the case of Boundary Bay (DU1), through the Little Campbell River fence during their return migration. All return timing groups are represented by DUs assessed in this RPA (Table 2).

Table 2. Run and migration timing descriptions for the SBCC DUs assessed in this RPA.

Run timing designation	Migration timing	Fraser River Chinook DUs
Spring	≥ 50% of the spawners pass through the lower Fraser River by July 15th	DU15 LTh-Spring
Summer	≥ 50% of the spawners pass through the lower Fraser River between July 15th and August 31st	DU6 LFR-Summer (Maria) DU13 STh-Summer
Fall	≥ 50% of the spawners pass through the Little Campbell River fence after August 31st	DU1 Boundary Bay-Fall

During spawning, female Chinook construct several redds in succession upstream, depositing a group of eggs in each that are fertilized by one or more males. After spawning, all adult Chinook die. The duration of egg incubation depends on the intra-gravel water temperature, ranging from one to six months, after which the alevins emerge from eggs into the gravel. The behaviour of juvenile Chinook salmon then falls into one of two life history “types”; stream type or ocean type. Generally, Chinook fry emerge from gravel and remain in freshwater for one or more years (stream type; DUs 13 & 15) or migrate to the sea within five months of emergence (ocean type; DUs 1 & 6).

Estimating the number of spawners at the DU level presents a challenge for the DUs assessed in this RPA. Absolute abundance estimates of spawners are difficult to assess when populations within a DU occur over such a broad geographic range (i.e. DUs 13 and 15) and high quality spawner estimates are not available for the DUs that occupy a limited geographic reach (i.e., DUs 1 and 6). This challenge requires that spawner estimates be considered approximations of relative abundance for the purposes of the RPA. An update of the COSEWIC (2020) assessment of trends of abundance for these four DUs shows that trends continue to decline for DUs 6, 13, and 15 and continue to increase for DU1 (Figure 2). However, it is not currently possible to separate hatchery from wild Chinook in DU1 as external marking of hatchery-produced smolts ceased after brood year 2014 and adult fish have not been sampled for hatchery origin. Thus, the more recent returns are a combination of hatchery and wild. Trends were assessed on two timeframes, with the first representing the trend in abundance over the entire dataset (coloured), and the second being the trend in abundance over the last three generations (black). It should be noted that COSEWIC and the DFO Wild Salmon Policy (WSP) consider wild Chinook to be the offspring of parents who were born in the natural environment. Therefore, trends in abundance for all DUs are presented for both hatchery and wild fish combined as data were not available to quantify wild spawners for these DUs.

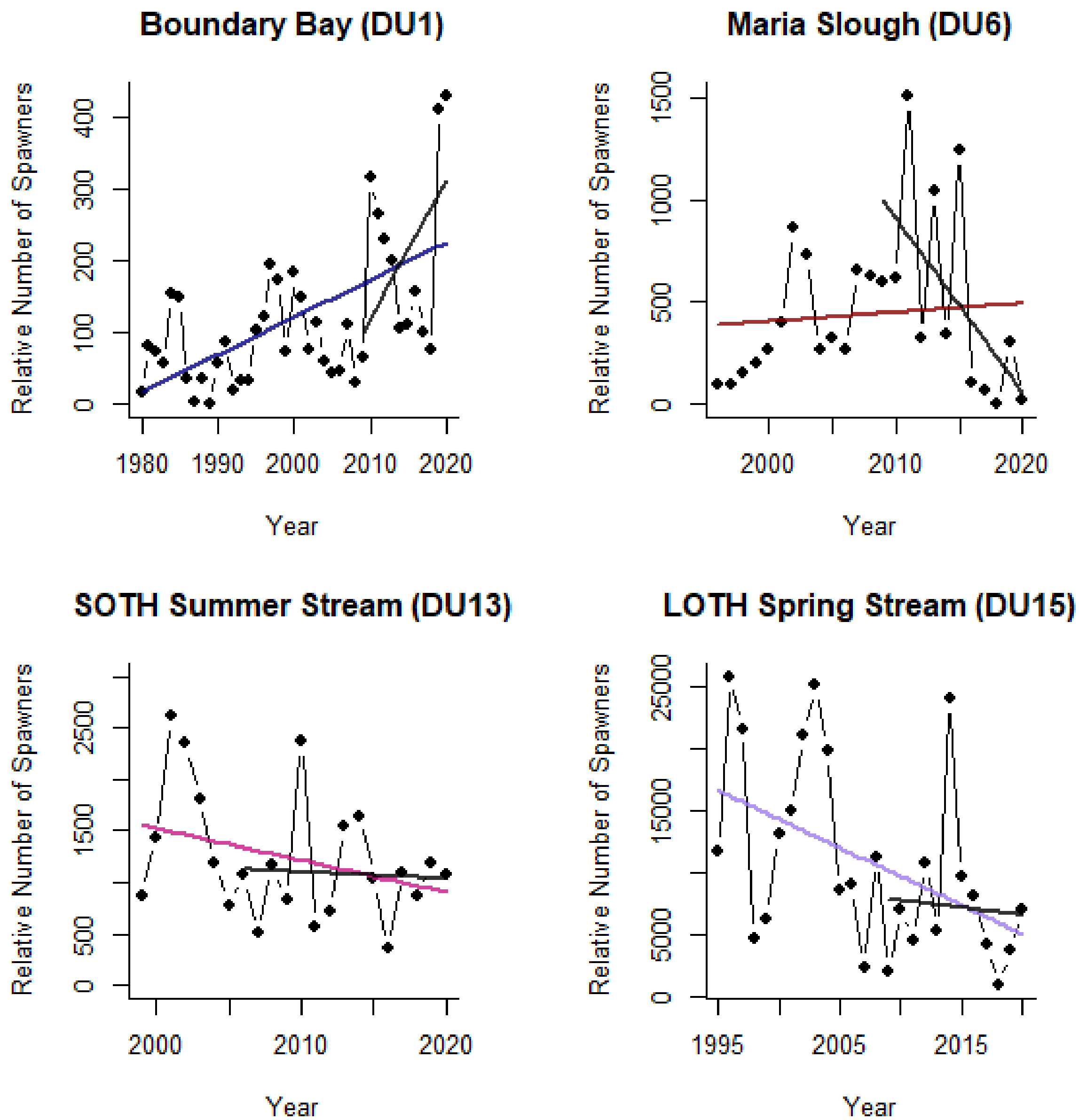

Figure 2. Time series trend in relative escapement with two estimates of the rate of change in escapement through time (coloured) rate of change over the entire time series and (black) rate of change over the last three generations.

ASSESSMENT

Habitat and Residence Requirements

Chinook Salmon use a diverse range of habitats throughout their life cycle. Ocean-type and stream-type Chinook Salmon generally use different freshwater and ocean habitats during the year, and exhibit different smolt and adult migration timing. Much of the variation in freshwater habitat use can be linked to differences in the hydrology of the spawning habitat and the nearby stream network. Coastal streams and rivers with rain-dominated hydrology support ocean-type Chinook Salmon that typically migrate to the ocean in their first year of life, whereas interior watersheds with snow-dominated hydrology support stream-type individuals that overwinter for one year or more in freshwater, with some exceptions. Differences in habitat use and conditions between ocean- and stream-type Chinook Salmon are reviewed below and based on previous summaries of Chinook habitat (Healey 1991; Brown 2002; COSEWIC 2019; Brown et al. 2019).

Spawning and egg incubation habitat: The habitat required for Chinook Salmon to carry out reproduction, including spawning and incubation, occurs in a range of different systems from small streams to large rivers. Females generally select spawning sites that have good circulation of well-oxygenated water (Healey 1991). Specific habitat features associated with Chinook Salmon spawning locations are the areas upstream of riffles, pool tail-outs especially below log jams, and on the upstream side of large gravel dunes in large rivers. These habitats are particularly important because they are associated with higher subsurface flows relative to other habitats.

Fry and juvenile rearing habitat: Chinook Salmon fry are most often found in habitats with small substrate, relatively low velocity, and shallow depth. They are most often observed in main river channels and are found less often in off-channel habitat; however, juvenile Chinook Salmon commonly rear in small non-natal streams throughout the Fraser and Yukon rivers (Murray and Rosenau 1989; Scrivener et al. 1994). Brown (2002) provides a comprehensive review of the freshwater rearing habitat required for Chinook Salmon, in both coastal and interior British Columbia watersheds.

Outmigration and rearing habitat: Ocean-type SBCC from the lower Fraser and Boundary Bay encounter snowmelt-induced river levels in May, June, and July and may use seasonal river flows as a queue to begin downstream emigration. After one year in freshwater, juvenile stream-type Chinook Salmon from the interior and lower Fraser systems migrate downstream in the spring and early summer and enter the Strait of Georgia. Tagging studies indicate that it takes hatchery Chinook smolts from the Nicola watershed between 3.4 and 19.2 days (median) to travel from interior release sites to the mouth of the Fraser River. Similar data are not available for wild smolts, nor smolts from other interior DUs. Chinook Salmon require productive estuarine and nearshore marine habitats. Nearly all SBCC spend the first few months and longer in the Salish Sea and tend to remain within 200 to 400 km of the Fraser River for the first year at sea, irrespective of life history type.

Adult freshwater migratory habitat: SBCC migrate variable distances to reach natal spawning streams and some DUs experience significantly different thermal and flow conditions depending on the location and timing of their adult return to freshwater. During spawning migrations, SBCC require water of optimal temperature and sufficient velocity and depth to access spawning grounds, and hydrological conditions can limit or impede migration and affect survival.

Freshwater habitat distribution: SBCC spawn throughout the Fraser River drainage and Boundary Bay, and are present in the Fraser River mainstem and all its major accessible tributaries (Figure 1). SBCC distribution throughout the drainage is based on surveys of adult spawners and juveniles. For rearing juvenile SBCC, distributional surveys have been primarily limited to inventories conducted to plan forestry activities or other industrial activities, and additional surveys based on a structured survey study design are a knowledge gap.

Marine distribution: The marine distribution of SBCC can differ between populations with different life history strategies; however, the full extent of their marine distribution is not well understood due to insufficient tagging and sampling to adequately characterize all their rearing locations in the North Pacific. In general, ocean-type Chinook Salmon tend to spend most of their time in the marine environment along the coastal shelf between BC and Alaska while stream-type Chinook Salmon spend their first summer, fall and winter in the Salish Sea, before migrating off the coastal shelf or northward along the continental shelf to Alaska and other parts of the North Pacific to feed and mature prior to migrating back to freshwater. Juvenile salmon surveys conducted over a decade show that all four DUs are detected in the Salish Sea over the summer period, and most are detected moving northward through Johnstone Strait in their first fall/winter at sea. There is some evidence that the Lower Fraser stream-type fish are far-north migrants and rear on the continental shelf, while interior stream-type SBCC perform extensive offshore migrations as far north as the Bering Sea.

Spatial configuration constraints: SBCC as a whole have not been heavily affected by hydroelectric development, with a few exceptions on tributaries due to an absence of dams on the mainstem of the Fraser and Thompson rivers. Hells Gate in the Fraser River canyon can be a barrier at certain flows for Chinook Salmon migrating upstream, although fishways alleviate most passage issues. Seadams at the mouth of the Serpentine and Nicomekl rivers limited anadramous fish passage to low tide outflow periods; however, the degree to which sea dams affect upstream migration and smolt outmigration has not been quantified.

Flood control and agricultural development, particularly in the lower Fraser River and Boundary Bay, have led to a loss of off-channel connectivity and stream and riparian habitat. The loss of floodplain connectivity has likely reduced the freshwater carrying capacity for those DUs with life histories that rely on these areas for rearing. Large-scale development within the floodplains of for agricultural and residential development, as well as dike construction and channel confinement, have caused wetlands to be drained, riparian zones to be degraded, and the aquatic systems to be polluted.

Concept of residence: SARA defines “residence” as “a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating”. Redds, the spawning nests constructed by Pacific salmon and other fish species, are considered residences under this definition in the event of listing as Threatened, Endangered or Extirpated under SARA.

Threats and Limiting Factors to Survival and Recovery

This RPA follows the definition of threats found in the “Guidance on Assessing Threats, Ecological Risk and Ecological Impacts for Species at Risk” Science Advisory Report (DFO 2014b). This definition states: a threat is “any human activity or process that has caused, is causing, or may cause harm, death, or behavioural changes to a wildlife species at risk, or the destruction, degradation, and/or impairment of its habitat, to the extent that population-level effects occur”. For the purpose of this report, SBCC are considered to be the “wildlife species at risk”.

The threat categories used for the assessment are based on the unified classification system used by COSEWIC when assessing status of wildlife species (COSEWIC 2012). This threat classification system was used to define broad categories of threats, and the final threat assessment follows DFO guidance to the extent possible in the context of limited data and information on threats to SBCC within Canadian waters. For SBCC, and to inform this RPA, a working group assessed threats in the Autumn of 2021 using a COSEWIC threats calculator tool prior to the Regional Peer Review. The information and rankings from the initial COSEWIC-style assessment by the working group were then used to convert the assessment into the DFO standardized assessment method. Threat rankings are presented in Table 2.

Table 3.Overall threat ranking for assessed SBCC DUs. Note this table displays the cumulative threat ranking of the multiple threat categories contained in each of the overarching major threat categories provided in the table.

COSEWIC Major Threat Category	DU1	DU6	DU13	DU15
Residential and commercial development	Unknown	Low	Low	Low
Agriculture and aquaculture (Hatchery competition)	Medium-High	Medium-High	Low-Medium	Low-Medium
Energy production and mining	NA	Low-Medium	Low-Medium	Low-Medium
Transportation and service corridors	Negligible	Low-Medium	Low-Medium	Low-Medium
Biological resource use (Fishing)	Medium-High	High	Low	Low-Medium
Human intrusions and disturbance	Negligible	Negligible	Negligible	Low
Natural systems modifications (Water management, ecosystems modifications)	High	Medium-High	Medium-High	High
Invasive and other problematic species and genes	High	Low-Medium	Low-Medium	Medium-High
Pollution (From all sources and threats)	Medium-High	Medium	Medium	High
Geological events (Landslides)	Unknown	Unknown	Low	Unknown
Climate change and severe weather (Shifting habitats)	Low-High	Low-High	High	High
OVERALL THREAT RANKING	Extreme	Extreme	Extreme	Extreme

Anthropogenic Threats

Climate change and natural systems modifications were the highest rank threats among DUs. Climate change is expected to negatively impact all SBCC DUs through shifting habitat conditions in both marine and freshwater environments. In addition, the occurrence of extreme weather events such as droughts, heat waves, storms and floods as happened in 2021 are also projected to increase in frequency with the changing climate, all of which have significant negative implications for SBCC. North Pacific Ocean surface temperatures have been steadily increasing and are projected to continue increasing, threatening SBCC through shifts in zooplankton distribution, ocean productivity and nutrient availability, metabolic requirements, pathogenic virulence, and intensification of predation by other species. Marine heatwaves compound the threat from changing ocean conditions and include “The Blob” between 2013-

2016 which caused unprecedented shifts in marine ecosystems along the Pacific coast of North America, and the more recent "Northeast Pacific Marine Heatwave of 2019" which has the potential to be as strong as the former event. Climate change-induced impacts within freshwater include changes in snowpack accumulation, groundwater availability and discharge regimes that affect the quantity, quality, availability, and temperature of freshwater rearing and spawning habitats for SBCC.

Ecosystem modifications that alter catchment surfaces or increase impervious surfaces can have significant effects on stream temperatures and flow regimes. These activities include water extraction, forestry, wildfires, and development from agricultural, industrial, and residential sectors. Impacts of wildfires are similar to forestry as they alter flow and temperature regimes, however, subsequent salvage logging operations can further destabilize watersheds. Changes to flow regimes may lead to timing mismatches with the availability of seasonally inundated habitats that are critical to SBCC growth and survival. Linear development includes straightening and channelization of streams, often modifying natural landscapes with riprap, dikes, culverts, bridges, and floodgates, which are associated with the protection of agricultural, industrial, and urban development. These modifications render habitat less suitable for juvenile Chinook Salmon. Additionally, there is often an associated reduction in the overall amount of habitat after channelization due to a reduction in stream length and isolation from rearing habitats (e.g., side channels, off-channel habitat, ponds, and wetlands).

Impacts of biological resource use, such as fisheries varied among the DUs discussed in this RPA. Of the four DUs discussed, only DU15 has code wire tag (CWT) indicator stock data available to assess fishing impacts. Due to a lack of data specific to DU1, the Samish River CWT indicator stock was used as a proxy for fishing related information. The Samish data indicate that the most impacts would occur in marine recreational fisheries in Southern British Columbia. A relatively high number of fish are also removed from the spawning grounds for hatchery broodstock in this DU. The abundant Lower Shuswap CWT indicator stock was used as a proxy for DU6 as they are considered in the same management unit and comigrate through the Fraser River. This suggests that fishing related impacts in the lower Fraser River and marine environment could be high for this small, single site DU. Additionally, it is likely that this DU holds in the Fraser mainstem prior to conditions in Maria Slough becoming favourable which would increase their susceptibility to recreational and First Nations fisheries. Unfortunately, DU13 does not have any data that are available as a proxy for measuring fisheries impacts; however, the review of recent management actions to reduce fishing pressure on Spring and Summer stream type Chinook suggests that these measures have been successful in reducing exploitation rates. Fishing impacts for DU15 are also quite low due to these management measures and exploitation rates average around 26.5%.

Natural Limiting Factors

Natural limiting factors are defined as “non-anthropogenic factors that, within a range of natural variation, limit the abundance and distribution of a wildlife species or a population” (DFO 2014b). Natural limiting factors or processes may be exacerbated by anthropogenic activities and can then become a threat. By default, a natural limiting factor would be scored as having a “Low” Threat Risk in the calculator unless there are other factors that are exacerbating natural levels of variation or impacts to a population. Almost all of the natural limiting factors are affected by anthropogenic-induced climate change or landscape-level human activities. Natural limiting factors are intertwined with existing threats and impacts, and for SBCC, include: the biological and physiological limits of Chinook Salmon; predation of Chinook Salmon at all life stages; and inter/intra-specific competition in both marine and freshwater environments.

Recovery Targets

For all SBCC DUs considered in this report, both a survival and recovery target were proposed and used in this RPA (Table 3). The survival target is aimed at reaching a COSEWIC status of Special Concern, whereas the recovery target represents a benchmark of recovery or a status of Not at Risk. This approach is consistent with DFO advice on setting SARA recovery targets (DFO 2011). These targets were generated using the habitat model (Parken et al. 2008) which utilizes existing stock recruit relationships where data are not limited and correlates them to the amount of available habitat for each Chinook life history type. This relationship can then be used to make inferences about stock-recruit relationships in data-limited systems. However, it should be noted that the model creates absolute abundance targets while the data on the DU level for this RPA is relative abundance.

These DUs were designated Threatened and Endangered by COSEWIC largely due to small population sizes and declines in spawner abundances. Accordingly, minimum abundance targets were included as these DUs currently have historically low estimates of relative abundance and the percent change requirements will not adequately support recovery. The spawner level required to achieve the number of spawners at maximum sustainable yield (S_{msy}) within one generation (S_{gen}) was selected for the survival abundance target as this metric has performed well in evaluations under scenarios with varying productivity (Holt 2009; Holt and Bradford 2011) and is consistent with the WSP abundance lower benchmark. The recovery abundance target was set to 85% of S_{msy}, to correspond with the abundance component of WSP green status for Chinook Salmon. These abundance benchmarks are evaluated as a generational average abundance of wild spawners. For DUs with an S_{gen} or S_{msy} less than 1,000 spawners, the target was increased to 1,000 to ensure COSEWIC criterion D would be exceeded.

For this RPA, recovery targets are set for a number of wild spawners but current assessments of status are based on all fish who spawn in the wild including hatchery reared individuals as robust estimates of the level of impact of hatchery programs on these DUs do not exist to parse wild from hatchery spawners in abundance estimates. In order to address this issue going forward, it is also recommended that all hatchery practices should align with guidelines set out in DFO 2018a for minimizing genetic risks from enhancement.

Table 4. Survival and recovery targets for each DU assessed.

DU	DU Short Name	Survival Targets		Recovery Targets	
		Abund.	% Change Requirement	Abund.	% Change Requirement
DU1	Boundary Bay-Fall	1,000	Positive population growth	1,780	Positive population growth
DU6	LFR-Summer (Maria)	1,000	Positive population growth	1,000	Positive population growth
DU13	STh-Stream-Summer	1,326	Positive population growth	3,351	Positive population growth
DU15	LTh-Stream-Spring	4,038	Positive population growth	16,627	< 30% decline

Scenarios for Mitigation of Threats

SBCC use an extensive and diverse range of habitats throughout their life cycle, with considerable variability in habitat use and migration timing between populations. This variability places some DUs at greater risk than others, particularly for stream-type variants that rear in freshwater for one or more years (DUs 13 and 15). There is also considerable inter-annual variability within the freshwater and marine environments that affect the severity of the suite of threats and limiting factors on spawning success. Further to this, many of the threats identified in the Threats Section of the RPA are extremely difficult to mitigate due to the many interrelated physical, biological, and chemical processes involved in large ecosystems. The combination of these factors poses many challenges for mitigation planning and creates a large amount of uncertainty associated with quantifying the effectiveness of mitigation measures once they are employed. There is also currently insufficient data to quantify DU-level benefits from individual mitigation activities for all DUs, which greatly limits our ability to prioritize mitigation activities by both their importance to SBCC recovery and by their feasibility to maximize use of resources. For these reasons, prioritization of mitigations was not attempted and an overview of potential options was provided instead (Table 4). However, a survey about the relative importance of mitigation measures was completed by the subject matter experts who attended the threats workshop, which is summarized in Figures 3 - 6. This was added to the RPA to identify the potentially most impactful mitigation measures as determined by the expert opinion available at the threats workshop.

Table 5.General mitigation strategies to address threats to SBCC.

COSEWIC Major Threat Category	Threat Category Description	Possible Pathway(s)	Possible Mitigation Options	Notes
Residential and commercial development	• Footprints of residential, commercial, and recreational development	• Loss or degradation of habitat	• Manage ongoing and future development in the context of salmon habitat requirements, mandate and monitor compensatory works for loss of habitat • Proper catchments for the filtration of runoff • Adequate riparian and flood plain set backs • Installation of non-impervious surfaces • Water smart planning • Properly sizing culverts or choosing to install bridge structures • Land-use planning exercises	-
Agriculture and aquaculture	• Footprints of agriculture, horticulture, and aquaculture • Competitive interactions with hatchery fish	• Loss or degradation of habitat • Competition	• Manage ongoing and future activities/development in the context of salmon habitat and ecosystem requirements, mandate and monitor compensatory works for loss of habitat and ecosystem function • Transition to closed containment aquaculture • Reduce hatchery production, align hatchery programs with DFO (2018a) genetically-based targets for enhanced Chinook populations • Livestock watering stations installed in areas away from watercourses • Re-establishment and maintenance of riparian buffers • Water smart planning • Proper crop choices for climate • Adoption of Environmental Farm Plans	• Refer to Environmental Farm Plan and other related policies. • Note that there is a large amount of surplus hatchery production outside of the Fraser River; the Chilliwack River Hatchery is a notable exception.
Energy production and mining	• Footprints and extraction activities from mining (e.g. gravel extraction, placer mining, etc.).	• Loss or degradation of habitat	• Manage ongoing and future activities/development in the context of salmon habitat requirements, mandate and monitor compensatory works for loss of habitat	-

COSEWIC Major Threat Category	Threat Category Description	Possible Pathway(s)	Possible Mitigation Options	Notes
Transportation and service corridors	• Footprints from roads, railroads, utility and service lines, and shipping lanes	• Loss or degradation of habitat	• Manage ongoing and future activities/development in the context of salmon habitat requirements, mandate and monitor compensatory works for loss of habitat • Use salmon-friendly stream crossings (e.g., free span bridges, baffles, etc.), upgrade old passages (e.g., hanging culverts)	-
Biological resource use	• Logging and wood harvest in riparian areas, transport of logs via rivers • Fishing	• Loss or degradation of habitat • Direct and indirect mortality	• Update/improve forestry policy in the context of protecting and restoring salmon habitat and riparian areas, managing the time and abundance of log booms in river, monitor and enforce water quality requirements for salmon health • Development and adherence to thresholds at an appropriate spatial scale. • Riparian setbacks written into regulations that are adequate for the protection of fish and fish habitat, and salmon ecosystems • Greater involvement of regulators during forest harvest planning • Better guidance from governments and professional associations for forestry professionals including but not exclusive to: hydrologists, geomorphologists, engineers, biologists and foresters. • Consideration of cumulative effects of forestry • Strategic decommissioning and rehabilitation of forestry roads. • Strategic replanting, species selection and thinning of new forests (to provide for climate change resilience and mitigate for increased water usage by young trees). • Integrated and transparent planning for forestry operations in watersheds that are worked both by single forestry entities and where multiple forestry companies are operative. • Adoption of First Nations forest and watershed principles into forestry planning.	Fishing effects are transboundary and are associated with mixed stocks and mixed species

COSEWIC Major Threat Category	Threat Category Description	Possible Pathway(s)	Possible Mitigation Options	Notes
			• Review of the laws and regulations governing forestry activity in BC by a joint BC and DFO panel to determine the current framework's ability to protect fish and fish habitat under the Fisheries Act. • Manage the time and abundance of log booms in river, monitor and enforce water quality and effluent targets around booms • Precautionary fisheries management, increased monitoring and enforcement, minimize fisheries related mortality (direct and incidental), education on identification of salmonids and conservation concerns	
Human intrusions and disturbance	• Recreational activities (e.g., ATVs in streams, jet boats, etc.)	• Loss or degradation of habitat • Direct and indirect mortality • Alteration of behaviour	• Manage access (e.g. infrastructure) to water and allowable activities (e.g. regulations) over time and space, increased monitoring and enforcement • Increased education on interacting with streams and salmon	-
Natural systems modifications	• Fire and fire suppression • Dams and water Management • Modifications to catchment surfaces, forestry, and linear development	• Loss or degradation of habitat • Direct and indirect mortality • Alteration of behaviour	• Update/improve forestry policy in the context of conserving watershed functions that support salmon; mandate, monitor, and manage reforestation and restoration activities (including managing for mature forest characteristics) • Use strategic treatments such as thinning, forest floor clearing/ burning to prevent large fires • Manage ongoing and future development of water resources to ensure river flows that lead to positive population productivity, increase monitoring and enforcement of surface and ground water, specifically with salmon biological requirements as targets, including river flows in August for stream-type Chinook (juveniles and adults) • Decommission or remove dams, increase, monitor, and maintain fish passage infrastructure for adults and juveniles (fishways, fish ladders, etc.) • Adaptively manage water in the face of climate change and increased variability	-

COSEWIC Major Threat Category	Threat Category Description	Possible Pathway(s)	Possible Mitigation Options	Notes
			• Manage ongoing and future linear developments by imitating more natural waterways, reconnecting off-channel habitat, removing or restoring old developments, and set and monitor water quality and sediment targets • Consider the impacts of cumulative effects in decision making	
Invasive and other problematic species and genes	• Aquatic invasive species (AIS), introduced pathogens and viruses, problematic native species (e.g., pinnipeds, parasites, and disease), interbreeding with hatchery-origin fish	• Loss or degradation of habitat • Alteration of behaviour • Predation and competition • Increased prevalence of infection • Reduced genetic diversity and natural selection forces	• Removals of AIS, prevention of introduction through increased monitoring for new and of existing AIS populations, increased enforcement and education surrounding introductions of AIS • Monitoring and treatment of pathogens in aquaculture, transition to land-based aquaculture and increased treatment of aquaculture effluent and effluent associated with fish processing plants, implement and monitor predator control measures • Reductions in log booms in lower Fraser and estuary that serve as haul-out sites for pinnipeds • Monitor hatchery and wild genetics and implement responsive hatchery planning, mark and tag hatchery fish to identify stock-specific contributions and out-of-basin strays, minimize hatchery production, sample river spawners to measure fish origins from hatcheries	Pinniped populations have increased due to protection of marine mammals began in the 1980s; research is required on the efficacy and direct applicability of predator controls
Pollution	• Introduction of exotic and/or excess materials or energy from point and nonpoint sources, including nutrients, toxic chemicals, and/or sediments from urban, commercial, agricultural, and forestry activities	• Altered behaviour and physical condition due to hormone and developmental que mimics, gene regulation, and other toxicities, potentially reducing survival and resilience	• Manage ongoing and future activities/developments that contribute to pollution, improve domestic, industrial/agricultural and storm water management and monitoring, increase enforcement of best practices for water quality and effluent management • Removal or remediation of contaminated sediments	-

COSEWIC Major Threat Category	Threat Category Description	Possible Pathway(s)	Possible Mitigation Options	Notes
Geological events	• Avalanches and landslides	• Stop or reduce passage • Increased mortality associated with passage	• Increase, monitor, and maintain fish passage infrastructure for adults and juveniles (e.g., fishways, replace culverts with bridges, etc.) • Proactively identify areas that are at risk of landslides that could result in passage impediments, and implement regular monitoring to decrease mitigation response times to initiate mitigation activities	-
Climate change and severe weather	• Freshwater and marine habitats shifting, and increasing frequency of severe weather events (e.g., droughts, floods, temperature extremes, etc.)	• Loss or degradation of habitat • Direct and indirect mortality • Exacerbate impacts from other threats	• Follow guidelines from the recent Paris Accord and International Panel on Climate Change reports • Proactively manage habitats and populations so that they are resilient and may adapt to future changes • Modernize water management for consistency with changing climate and stream hydrology to rejuvenate Chinook production (beyond sustenance at current low abundance)	Adaptive management is required for all mitigation activities in the context of climate change and the increased frequency of severe weather events

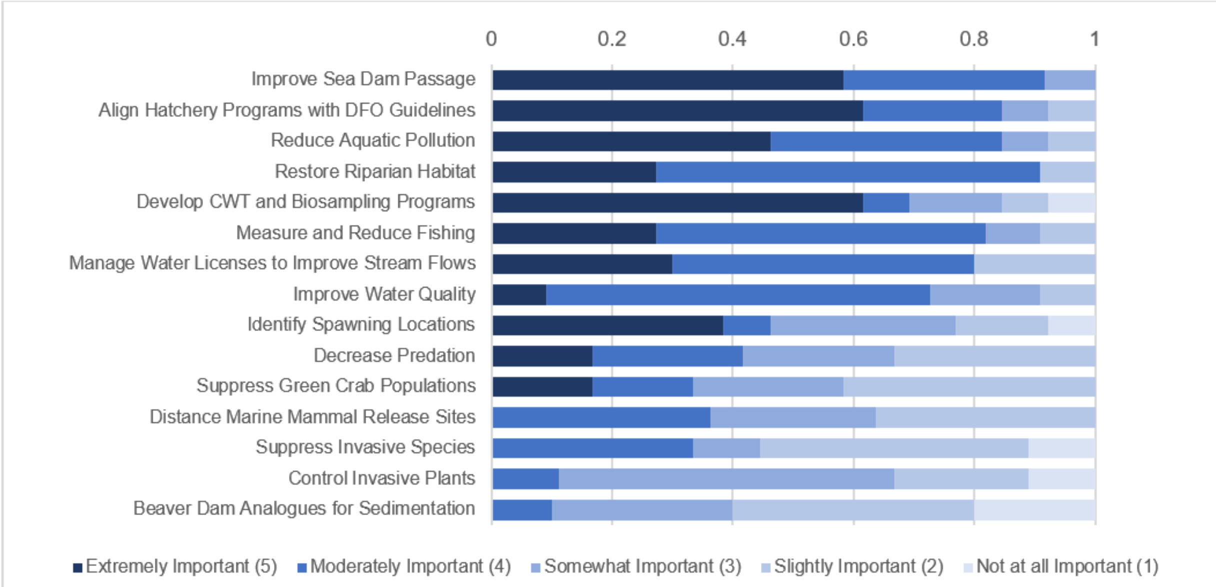

Figure 3. Proportion of mitigation survey responses for each measure, ordered by weighted averages (top=highest) for DU1

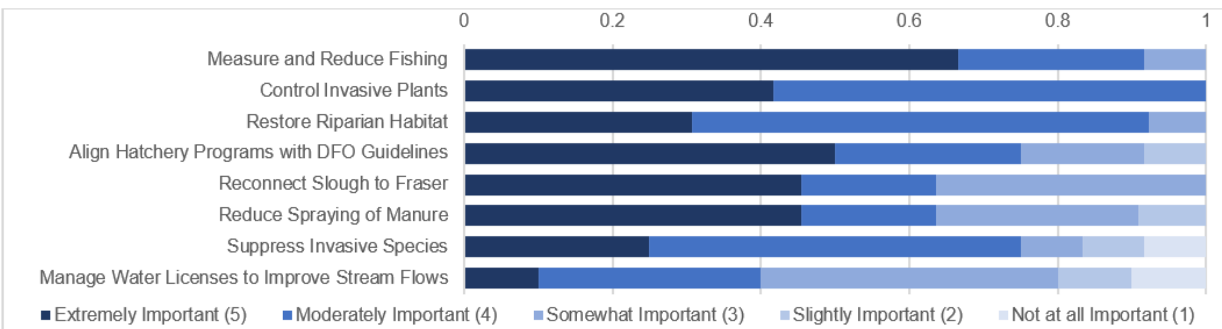

Figure 4. Proportion of mitigation survey responses for each measure, ordered by weighted averages (top=highest) for DU6

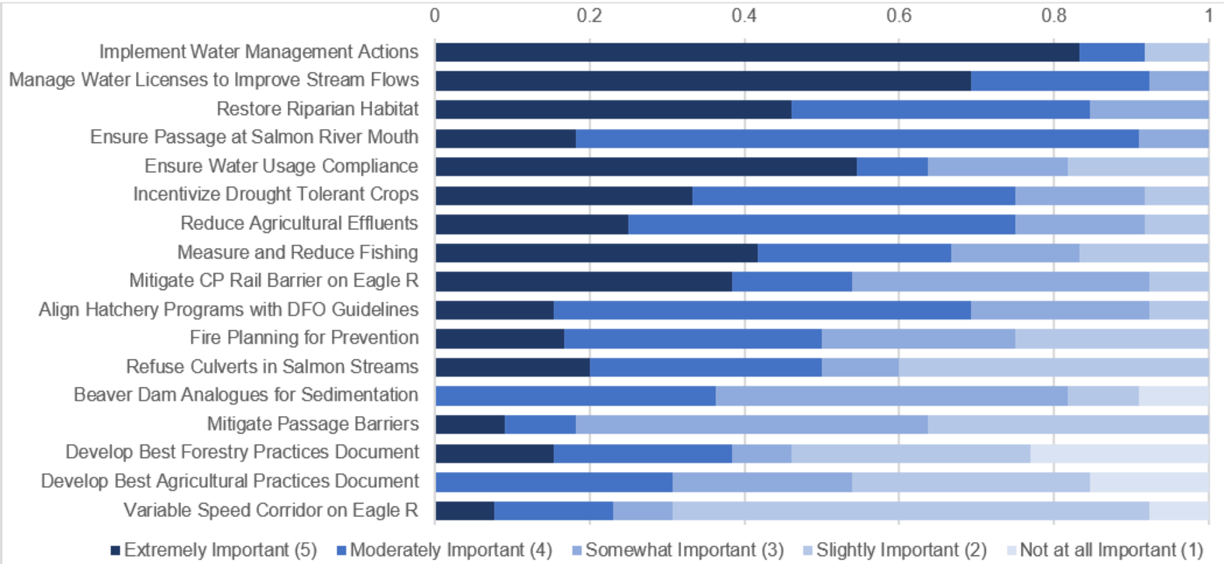

Figure 5. Proportion of mitigation survey responses for each measure, ordered by weighted averages (top=highest) for DU13

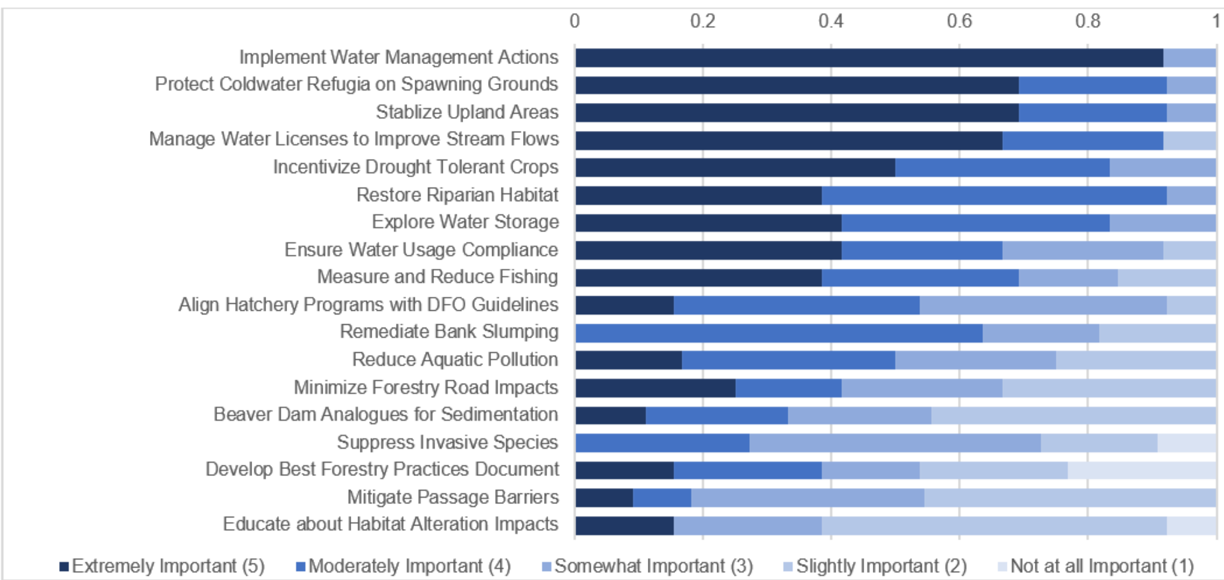

Figure 6. Proportion of mitigation survey responses for each measure, ordered by weighted averages (top=highest) for DU15

Allowable Harm

Quantitative forward projections are not reliable nor robust for the four DUs due to the uncertainty that stems from the quality of the relative escapement data and lack of reliable exploitation estimates. Therefore, the allowable harm assessment is based on the threats assessment from Element 8, recent trends in relative abundance (Element 2), and the possible future trajectory of these populations based on qualitative assessments. The results of the threats workshop indicated that all DUs were considered to be at High or Extreme risk, due to the severity and number of threats that each of the DUs are facing. Alleviating many of these threats may be difficult given the widespread nature of these threats, especially as many are exacerbated by climate change, posing a risk of extinction for these DUs within the next three generations.

There is considerable uncertainty about the future trajectory of these populations but based on the threats assessment and the qualitative assessment of population trajectories, these populations are at great risk. Based on this information, a precautionary approach is suggested unless sufficient increases in generational average abundances and trends in abundances are confirmed due to mitigation measures or changes in natural conditions. **Further harm may continue to jeopardize recovery. Therefore, to promote the survival and recovery of these DUs, it is recommended that all future and ongoing human-induced harm should be prevented.** It is important to note that some activities in support of survival or recovery could result in harm but may have a net positive effect on the population and should be considered.

For DU 6, there is additional concern due to the limited area of the spawning habitat and a single, small population.

For DU 15, there is additional concern due to the increased threat risk from landscape level changes throughout the watershed due to the number, size and intensity of recent forest fires and floods.

Sources of Uncertainty

- There are significant knowledge gaps surrounding the freshwater and marine habitat distribution of these four DUs. SBCC freshwater distribution spans a large geographical area within the Fraser River and Boundary Bay watersheds and most of this habitat has not been comprehensively studied. Furthermore, the marine distribution of SBCC is poorly known due to a lack of tagging and tag recovery programs for these DUs; as a result, some of the distribution information reported in this RPA is inferred from limited data which contributed to limitations achieved by the threats assessment.
- Although a basic understanding of the freshwater and marine biology of SBCC exists, for most DUs there is insufficient information on key population vitality attributes, such as egg-to-fry survival, important details of freshwater habitat use, productivity, stock-recruit data, and freshwater and marine survival information.
- Knowledge gaps exist for the impacts of fisheries (both targeted and non-targeted at Chinook) for the majority of DUs. A population within DU15 has a long-standing time series of CWT data; however, much of the fisheries information uses proxies for the remaining DUs within the assessment.
- There are significant gaps in our current knowledge of the distributions of invasive species, and their potential effects on SBCC in both marine and freshwater environments.
- There are a multitude of pollution sources impacting these DUs, yet there is limited available information on the lethal and sublethal effects of these contaminants on Chinook Salmon in both marine and freshwater environments.
- Competition between wild and hatchery salmon is expected to have a negative effect on these DUs but the magnitude of this impact is uncertain.
- Uncertainty also exists regarding the degree of genetic influence of hatchery salmon on wild Chinook Salmon and the adverse influence on fitness. Data are also insufficient to distinguish wild and hatchery fish on the spawning grounds for all but one population.
- Uncertainty about the number of spawners in each DU (both in terms of bias and precision, and changes to these over time) and the unknown proportion and origins of hatchery fish

need to be considered when comparing abundance data to quantitative benchmarks as benchmarks and data may not be directly comparable.

- Estimates of suitable habitat availability and inferred productivities create uncertainties within survival and recovery targets generated from the habitat model, which is based on a meta-analysis of Chinook populations from Oregon to Alaska.
- There is considerable uncertainty about the efficacy of mitigation measures identified in Table 2 in furthering the survival and recovery at the DU level.

OTHER CONSIDERATIONS

- Climate change observed at the global scale and local scale has contributed to unprecedented environmental conditions in the Pacific Ocean (e.g., heat waves) and to freshwater habitats (e.g., November 2021 flooding in Southern BC), and these new conditions can have unforeseen, and yet unknown, synergistic implications to the survival and productivity of Chinook Salmon. For example, warmer water temperatures can increase fish stress and also facilitate the transmission of pathogens and disease; reduced river flows, when adult Chinook are staging to spawn, can also facilitate the transmission of pathogens and disease.
- The current distribution and abundance of Chinook Salmon within DU1 and DU6 has been affected by the practices of non-Indigenous settlers for more than a century, which massively transformed the rivers and landscape for economic benefits. Since the 1980s, salmon restoration involved transplanting hatchery fish among populations and across DUs. However, there was a limited understanding of historic Chinook distribution. Knowledge of the indigenous people in relation to the historic distribution of Chinook prior to the arrival of non-indigenous settlers could help guide the recovery and restoration of both DUs.
- Considering the advice of DFO (2018b), conservation hatchery programs are those conducted for the persistence and recovery of populations imperiled by low abundance and threats to productivity; and are managed and informed by scientific and fish culture subject matter experts. For conservation hatchery programs, the genetic risk of reduced diversity and extirpation due to small population size may exceed the genetic risk of domestication associated with a high level of hatchery production in the early stages of a conservation hatchery program. For these populations, hatchery production should be undertaken as part of a broader recovery program in which the factors leading to low abundance are addressed. The hatchery program itself should be designed as a staged process in which the initially high level of hatchery production decreases throughout the process of population recovery to ultimately achieve genetically-based enhancement targets that align with recovery of the DU.

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SOURCES OF INFORMATION

This Science Advisory Report is from the February 22-24, 2022 regional peer review on the Recovery Potential Assessment – Southern BC Chinook Salmon – Four Designatable Units. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule as they become available.

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MPO. 2022. Évaluation du potentiel de rétablissement des populations de saumon chinook du sud de la Colombie-Britannique, unités désignables du Fraser et du sud de la partie continentale (1, 6, 13 et 15). Secr. can. des avis. sci. du MPO. Avis sci. 2022/035.