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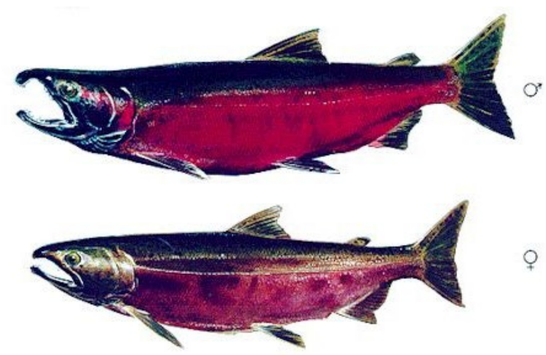
RECOVERY POTENTIAL ASSESSMENT – INTERIOR FRASER COHO (*ONCORHYNCHUS KISUTCH*)



Coho Salmon adult spawning phase. Fisheries and Oceans Canada website.

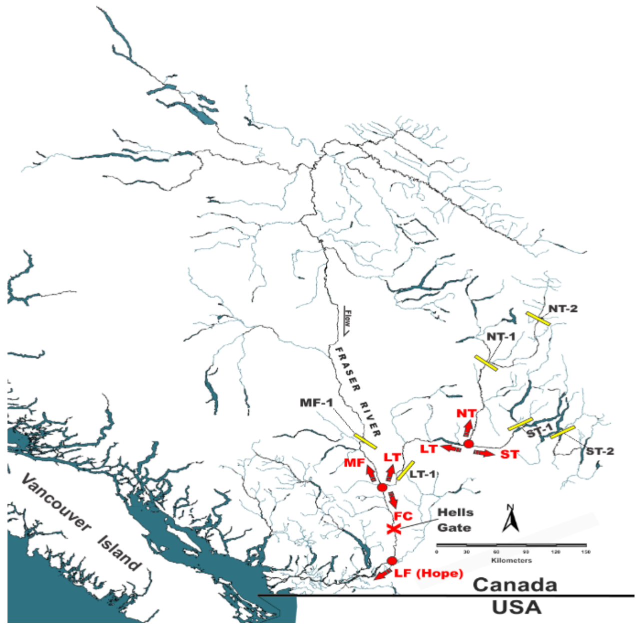


Figure 1. The Fraser River and its major tributaries that make up the IFC DU. The five Conservation Units within the DU are North Thompson (NT), South Thompson (ST), Lower Thompson (LT), Fraser Canyon (FC), and Middle Fraser (MF).

Context:

The Interior Fraser population of Coho Salmon was designated as Endangered in May 2002 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The status was re-examined and designated Threatened in November 2016. However, recent escapement and smolt-to-adult survival were very low and suspected to cause reductions in numbers exceeding 30% over three generations.

DFO Science was asked to complete a Recovery Potential Assessment (RPA) to provide science advice to inform the potential addition of Interior Fraser population of Coho to Schedule 1 of the Species at Risk Act (SARA). The advice in the RPA may be used to inform both scientific and socio-economic aspects of the listing process, development of a recovery strategy and action plan, and to 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 the Interior Fraser population of Coho.

This Science Advisory Report is from the May 22-24, 2019 regional peer review on Recovery Potential Assessment – Interior Fraser Coho (Oncorhynchus kisutch). Additional publications from this meeting will be posted on the [Fisheries and Oceans Canada (DFO) Science Advisory Schedule](#) as they become available.

October 2019

SUMMARY

- Interior Fraser Coho (IFC) are the Designatable Unit (DU) of Coho Salmon (*Oncorhynchus kisutch*) that spawns in the Fraser River watershed upriver from Hells Gate in British Columbia.
- IFC were designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) in 2002; however, they were not subsequently listed under the *Species at Risk Act* (SARA). COSEWIC reassessed the status of IFC in 2016 and revised the designation from Endangered to Threatened.
- Productivity was considerably higher during 1987-1993 (“historic” regime) than during 1994-2017 (“current” regime) return years; lowered smolt-to-adult survival was a major driver that reduced average productivity since return year 1994. The 3-year running average pre-fishery returns in the historic regime varied between 153,000 and 227,000 with an overall average of 199,000, while the current regime pre-fishery returns varied between 21,000 and 70,000 with an overall average of 38,000.
- Coho Salmon habitat (spawning ground, nursery, rearing, food supply, migration, and other areas) research has mostly been conducted in coastal river systems, which have different hydrological characteristics compared to the interior river system used by IFC.
- Redds, the spawning nests constructed by Pacific salmon and other species, meet the definition of a “residence” under SARA.
- IFC reside in the river systems of the BC interior where hydrological regimes are highly influenced by temperature extremes, snowpack and associated melt-water supply. This results in a different timing for spring freshet events when compared to rain-dominated coastal streams. The varying ability for juvenile IFC to access tributaries, side channels and isolated pools influences their behaviour and habitat use.
- The three highest ranked anthropogenic threats to IFC include modifications to catchment surfaces, linear development, and agricultural and forestry effluents. Several other threats including fishing, dams and water management/use, introduced genetic material, household sewage and urban waste water, and industrial and military effluents, were ranked as low-medium.
- The COSEWIC threats calculator utilized for this assessment integrates the additive cumulative impact of all threats and assessed the overall threat impact as High-Very High. Climate change is anticipated to exacerbate the impact of many anthropogenic and natural threats.
- A quantitative analysis of a dataset including natural-origin escapements from 1998-2016 was used to recommend a DU-level recovery target. The recommended recovery target for IFC is a 3-year geometric mean abundance of 35,935 natural-origin spawners within a 10 year timeframe.
- The probability that IFC will reach the DU recovery target was explored using stock-recruitment models and forward simulation. The results showed that the probability of reaching the recovery target in 10 years under current conditions is equally likely to reach the target as to not reach it. However, there is high uncertainty in the population trajectory projection (the 80% uncertainty interval spanned -29% to +29%).
- The simulation results showed that recovery of natural-origin IFC is unlikely (≤33%) under decreased smolt-to-adult survival conditions, regardless of the exploitation rate. Increased

smolt-to-adult survival, however, increased the probability of recovery to a greater degree than decreasing the exploitation rate.

- IFC recovery is possible if human-induced mortality is minimized given current environmental conditions and variability, and if impacts from the identified threats are also mitigated. If the recent smolt-to-adult survival pattern continues and the models are correct, the population trajectory is most likely to be positive or stable at a zero exploitation rate and recovery may eventually occur. At an exploitation rate of ≤ 6% at current smolt-to-adult survival, model simulations indicated meeting the recovery target in 10 years was likely (≥ 66% chance) but not very likely (≥ 90% chance).
- Although not quantified here, there is a de facto human induced mortality rate on juvenile IFC in freshwater that is non-fisheries related. Therefore, impacts to freshwater environments should also be seriously considered in addition to exploitation rate when considering allowable harm.

INTRODUCTION

Rationale for Recovery Potential Assessment

After the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses an aquatic species as Threatened, Endangered or Extirpated, Fisheries and Oceans Canada (DFO), as the responsible jurisdiction for aquatic species under the *Species at Risk Act* (SARA), undertakes a number of actions to support implementation of the Act. Many of these actions require scientific information on the current status of the species, threats to its survival and recovery, and the species' potential for recovery. Formulation of this scientific advice has typically been developed through a Recovery Potential Assessment (RPA) following the COSEWIC assessment. This timing allows for the consideration of peer-reviewed scientific analyses into SARA processes, including the decision whether or not to list a species on Schedule 1, and during recovery planning if the species is listed.

Interior Fraser Coho Salmon (*Oncorhynchus kisutch*), hereafter, IFC, belongs to the Salmonidae family and spawns (reproduces) in the Fraser River watershed upriver from Hells Gate in British Columbia. Interior Fraser Coho Salmon are genetically unique, representing a single Designatable Unit (DU), and can be genetically distinguished from populations in the lower Fraser River watershed and other areas of Canada. Interior Fraser Coho Salmon occupy about 25% of the freshwater range of Coho Salmon within Canada.

The status of IFC has been assessed multiple times in the recent past by both COSEWIC and DFO. In 2002, IFC were assessed as Endangered by COSEWIC; however, they were not subsequently listed under SARA. In response to the Endangered COSEWIC status, DFO assembled the Interior Fraser Coho Recovery Team (IFCRT), and a comprehensive conservation strategy was published in 2006 (IFCRT 2006). COSEWIC reassessed IFC and revised the status from Endangered to Threatened in 2016 (COSEWIC 2016), recognizing that the population had increased in abundance during 2005 to 2012. The existence of high (historic) and low (current) productivity regimes is an important aspect of considering recovery and risks from threats that was highlighted in the pre-COSEWIC document (Decker and Irvine 2013) and is summarized again in this RPA. In 2014, an interim assessment (Decker et al. 2014) was finalized after a peer review process to assess IFC in the context of the IFCRT recovery objectives (IFCRT 2006). Also in 2014, IFC were assessed under the Wild Salmon Policy (WSP) framework, which assessed the DU as five Conservation Units (CU) (DFO 2015). Three of the CUs were determined to be “Amber” WSP status and two were “Amber/Green” WSP status, in the context that “the status was solely based on the abundance of spawners relative to the potential to produce recruits given current environmental conditions"[1]. The most recent analysis of IFC was in 2018, which was done to discuss IFC in the context of the Pacific Salmon Treaty and to suggest management reference points (Korman et al. 2019). A COSEWIC DU report for all Coho Salmon in Canada is currently being developed and should also be considered once available.

Biology, Abundance, Distribution and Life History Parameters

Coho Salmon is one of five species of Pacific salmon native to North America that spend their adult life in the sea and return to freshwater to spawn once before dying. Sexually mature Coho Salmon generally return to freshwater in the fall and spawn during a protracted period throughout the fall and early winter. Like most salmon, IFC use olfactory cues to migrate towards their natal watershed; however, due to the variable hydrology in the interior, IFC have a much higher straying rate between tributaries within the same CU compared to coastal Coho Salmon. Interior Fraser Coho Salmon tend to spawn relatively late, with spawning activity peaking in mid-November, and often extending into January. Females construct several redds, successively moving upstream. Incubation of Coho Salmon eggs generally takes 40-50 days depending on water temperature; anywhere from 0-74% of eggs survive and fry emerge from the gravel between March and July.

Juvenile Coho Salmon use and travel through large areas of freshwater, estuarine, and marine habitats. Upon emerging from the gravel, coastal Coho Salmon fry can become territorial, with smaller fish displaced downstream or into less desirable habitat. Unlike coastal Coho Salmon, however, there is little evidence of territorial behaviour in the parr life stage for IFC. Data collected during a multi-year (2001-2011) survey in the lower Thompson River system suggest that IFC fry rear mainly in small tributaries, and are largely absent from mainstem habitats in larger streams. Some of the juvenile Coho Salmon collected during the winter from side-channel and off-channel habitat in the lower Fraser River during a DFO study were of interior Fraser River origin.

Eighty-eight percent of IFC complete a 3-year life cycle with the remaining 12% completing a 4-year life cycle on average. Less than 1% of returning IFC were aged as younger than 3 years old or older than 4 years. Since deviation from the dominant 3-year life history is uncommon there is relatively low genetic exchange among broodlines in most years.

Due to their genetics and geographic separation, IFC are separated into five WSP Conservation Units within the DU; the five CUs are North Thompson, South Thompson, Lower Thompson, Fraser Canyon, and Middle Fraser (Figure 1). The IFCRT (2006) also identified 11 subpopulations within the five CUs, which have been assessed by DFO in follow-up management planning activities (Decker et al. 2014). It is important to note that the COSEWIC report refers to the CUs as subpopulations, which are referred to as populations in other IFC documents (Table 1). This report will use the term "subpopulation" to refer to delineations within CUs in alignment with the IFCRT approach.

[1] Unpublished document. Wild Salmon Policy Biological Status Assessment for Conservation Units of Interior Fraser River Coho Salmon (*Oncorhynchus kisutch*). Parken, C.K. and 20 co-authors. CSAS Working Paper 2013SAL12.

Table 1. Overview of terminology used in different reports with equivalent interpretation (i.e. in the same Delineation Level). For example, all terms used in the 1st Sub-level refer to the 5 major divisions shown in Figure 2. DU = Designatable Unit. MU = Management Unit. CU = Conservation Unit. IFCRT = Interior Fraser Coho Recovery Team. COSEWIC = Committee on the Status of Endangered Wildlife in Canada. PST = Pacific Salmon Treaty. WSP = Wild Salmon Policy.

Delineation Level	IFCRT / Pre-COSEWIC	PST / WSP	COSEWIC
Broadest (e.g. all systems upstream of Hells Gate)	DU	MU	DU
1st Sub-level (e.g. all systems part of the North Thompson River)	CU	CU	Subpopulation
2nd Sub-level (e.g. systems upstream of the Blue River confluence with the North Thompson River)	Subpopulation	Subpopulation	(no reference of)

There are more than 11,775 km of stream habitat within the known range of IFC and of this total approximately 7,019 km are accessible to migrating IFC. These are assumed to be minimum estimates because smaller tributaries are not captured in the estimates. Although IFC utilization of the upper Middle Fraser CU is poorly understood, it is important to note that over two-thirds of the stream area accessible to IFC lies in the upper portions of the Fraser River. The populations for which most data exists, those in the Thompson River drainage, occupy less than one-third of the area accessible to IFC. The lack of records on the presence of IFC in many parts of the upper Middle Fraser CU is a major knowledge gap.

Lowered smolt-to-adult survival was a major driver that reduced productivity of IFC and is likely inhibiting the DU's ability to recover to historic levels. Decker et al. (2014) noted two distinct periods in the stock-recruitment relationship for IFC (Figure 2a) that are likely driven by a reduction in smolt-to-adult survival since return year 1994. A shift is evident in annual smolt-to-adult survival estimates for IFC hatchery-indicator stocks, with survival in the current regime being much lower than before the regime shift (Figure 2b). Productivity was considerably higher during 1987-1993 ("historic" regime) than during 1994-2017 ("current" regime) return years.

Estimated exploitation rates (total Canada and US) also determine pre-fishery abundances and are essential in defining the number of fish that return to the spawning grounds. The exploitation rate averaged 66% from 1984-1997 (Figure 2c). With the realization that the number of pre-fishery returns and escapement were declining rapidly in the 1990s, measures were implemented beginning in 1998 to reduce the exploitation rate to below 13% (Decker et al. 2014).

The 3-year running geometric average pre-fishery returns in the historic regime varied between 153,000 and 227,000 with an overall average of 199,000, while the current regime pre-fishery returns varied between 21,000 and 70,000 with an overall average of 38,000 (Figure 2d). The average natural-origin escapement was 2.2 times greater in the historic regime compared to the current regime. The 3-year running geometric average escapement in the historic regime varied between 36,000 and 74,000 with an overall average of 57,000. The 3-year running average escapement in the current regime varied between 17,000 and 43,000 with an overall average of 26,000.

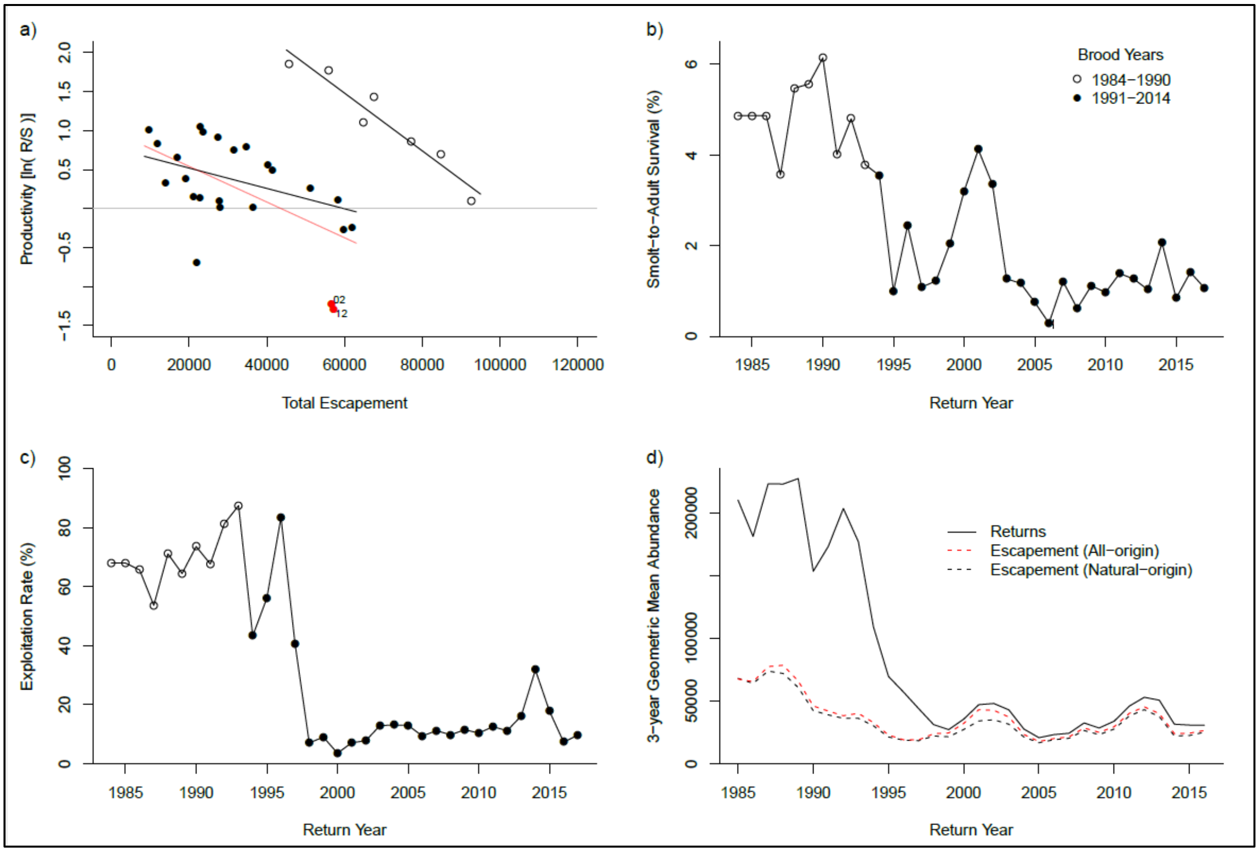


Figure 2. Productivity versus total abundance (a), smolt-to-adult-survival (b), exploitation rate of adipose present pre-fishery returns (c), and 3-year geometric running mean abundance of pre-fishery returns (black solid), total escapement (red dashed), and natural-origin escapement (black dashed) for Interior Fraser Coho Salmon that spans two distinct regimes (d). Brood years 1984-1990 are open circles, which coincides with the historic regime, and 1991-2013 are filled circles, which coincides with the current regime. In (a), the black lines represent the relation between productivity and total escapement; R2 = 0.93 and 0.19 for the historic and current regimes, respectively, with $p < 0.05$ for each model. The two red points are influential points from brood years 2002 and 2012. The red line is the current regime slope with the influential points included. This figure assumes all fish are age 3 to make recent years comparable to years prior to 1998 when scale-age data is scarce or absent.

Population trajectories for IFC were calculated from the slope of natural-log linear regressions of 3-year running arithmetic average total pre-fishery returns and natural-origin spawners. The trajectories were calculated over two time periods: the entire time series (long-term trend, 1984 to 2016), and the last 10 years (recent trend, 2007 to 2016) and reported as the percent change over 10 years.

The population trajectory in pre-fishery returns was negative for the DU (and all five CUs individually) when estimated from the long-term trend. When estimated from the recent trend, the DU and two CUs had positive trajectories in pre-fishery returns (Lower Thompson, Middle Fraser) and three had negative trajectories (Fraser Canyon, North Thompson, South Thompson). However, the 95% confidence interval for all CUs in the recent term crossed zero, suggesting large uncertainty in the recent trend pre-fishery return trajectories. Therefore, it appears that the population may still be declining when considering the longer data series, while there is larger uncertainty in the trajectory when only considering the recent data.

The DU and most of the CU population trajectories in natural-origin spawner abundance were negative when estimated from the long term trend. The DU and two CUs were estimated to be positive from the recent trend. The DU and three of the CUs had 95% confidence intervals that crossed zero for calculations from the long-term trend. The DU and all CUs had 95% confidence intervals that crossed zero for calculations from the recent trend, indicating large uncertainty in the direction of the population trajectory. Similar to the pre-fishery returns results, it appears that the spawning population may be declining when considering the longer data series, while there is larger uncertainty in the trajectory when only considering the recent data.

Given the mitigating effect of reduced exploitation after 1998, the trend in total pre-fishery returns reflects the impacts from the decline in productivity that occurred after 1989 (brood year) more accurately than the trend in natural-origin spawners.

Estimates of important life-history parameters at the DU level are presented in Table 2. In most cases, the most up-to-date and consistent data for the current productivity regime is used; this includes data from 1998 until present, when available. Data are from DFO stock assessment with the exception of fecundity data provided by the DFO Salmon Enhancement Program. There are several sources of uncertainty and underlying assumptions in many of the estimates. Consult the Research Document[2] resulting from this process for details.

*Table 2. Average estimates of life-history parameters at the DU level with the standard deviation (SD) of the estimates and data timeframe. Average estimates are from point estimates across years, weighted by sample size if available. *Note that this is 1 SD above and below the mean from a log-normal distribution.*

Parameter (measurement)	Estimate	SD	Data Timeframe
Age at Maturity (Percent Age 3)	88.3	1.3	2000-2017
Generation Time (Years)	3.12	0.018	2000-2017
Sex Ratio (Percent Males)	49.1	5.5	1998-2017
Fecundity (Eggs per Female from hatchery brood-stock)	2315	523	1998-2018
Smolt to Adult Survival (Percent from hatchery smolts)	1.0	0.7-1.6*	2000-2013
Harvest Mortality/ Exploitation Rate (Percent)	12.5	5.7	1998-2017
Recruits per Spawner (age distribution corrected)	1.3	0.7	1998-2013
Spawners per Spawner (age distribution corrected)	1.15	0.64	1998-2013

ASSESSMENT

Habitat and Residence Requirements

The definition of habitat for IFC includes spawning grounds and nursery, rearing, food supply, migration, and any other areas on which the population depends, directly or indirectly, to carry out their life processes. This broad definition means that essentially anywhere that IFC are found is considered to be Coho Salmon habitat. Much of the available research on habitat use by Coho Salmon has been conducted in coastal river systems, which have significantly different hydrological characteristics from the interior river system used by IFC. Groundwater supply is

[2] Arbeider, M., Ritchie, L., Braun, D., Jenewein, B., Rickards, K., Dionne, K., Holt, C., Labelle, M., Nicklin, P., Mozin, P., Grant, P., Parken, C., and Bailey, R. Interior Fraser Coho Salmon Recovery Potential Assessment. DFO Can. Sci. Advis. Sec. Res. Doc. (in revision)

important for the survival of eggs during the winter and for maintaining adequate water flow for fry during the summer.

Spawning and egg incubation habitat: Spawning takes place over a wide variety of habitats and the overall abundance of spawning habitat is not generally thought to be limiting. Winters are severe in the interior Fraser River watershed and winter stream flow and temperature may play a critical role in spawning site selection (Decker and Irvine 2013). Interior Fraser streams also generally experience declining discharges during the fall and winter as temperatures drop below freezing at higher elevations creating a risk of dewatering and freezing of spawning sites if spawning occurs too early. McRae et al. (2012) found that groundwater moderates ambient stream temperatures and Interior Fraser Coho select spawning micro-sites with groundwater influence. Groundwater also appears to influence spawning distribution at larger spatial scales with fish congregating in side channels with abundant groundwater off the main stems of larger streams such as the North Thompson River (IFCRT 2006). Therefore, features that may affect the hydrology of groundwater may also indirectly influence important habitat properties for Coho Salmon.

Fry and juvenile rearing habitat: Juvenile IFC reside in the river systems of the BC interior where hydrological regimes are highly influenced by temperature extremes, snowpack and associated melt-water supply. The hydrological regime results in a different timing for spring freshet events when compared to rain-dominated coastal streams. Fry emergence from spawning sites corresponds with the periods of high discharge during spring freshets, and fry likely colonize the flooded habitats that are created. Groundwater ponds and channels and other types of off-channel habitats often support large numbers of overwintering Coho Salmon fry in interior Fraser streams. Interior Fraser Coho use lakes less frequently than streams, but fry have been recorded in near-shore regions of lakes in the interior Fraser River watershed, including some very large lakes (e.g., Shuswap Lake, Quesnel Lake). The varying ability for juvenile IFC to access tributaries, side channels and isolated pools influences their behaviour and habitat use. As noted prior, IFC are also known to rear in lower Fraser River tributaries.

Out migration and ocean rearing habitat: Typically after one year in freshwater, juvenile IFC migrate down the Fraser River in the spring and early summer. They remain in the highly developed estuary of the Fraser River at Vancouver for an unknown period and many spend their first summer in the Strait of Georgia, leaving in October/November. They spend the remainder of their 18-month oceanic residence primarily in coastal waters of the North Pacific but specific habitat properties are not quantified.

Adult freshwater migratory habitat: Adult IFC require waters of sufficient depth and velocity in order to access holding and spawning areas within the drainage. In addition, water temperature must be within an acceptable range. Under certain conditions, water velocities in the Fraser River near Hells Gate in the Fraser Canyon, and in the area referred to as Little Hells Gate in the North Thompson River can restrict upstream passage of IFC.

Freshwater habitat distribution: IFC spawn upstream of Hells Gate in the Fraser Canyon and are widespread throughout the Thompson River watershed and Fraser watershed north of the Thompson River confluence (Figure 1). Their distribution in the Middle Fraser and Fraser Canyon areas are less well known. Coho Salmon are known to occur as far upstream as the Nechako River in the upper Fraser area, but there are several major upper Fraser watersheds where IFC presence is probable though not yet confirmed.

Marine distribution: Specific marine habitat properties for IFC are largely unknown, but the marine distribution of habitat is thought to be primarily along the coast of British Columbia. Smolts enter the Fraser River estuary and then use the Strait of Georgia during their initial months. Just under half (on average) of adult size IFC caught are found along the Vancouver

Island Continental Shelf. Nearly half of IFC caught are in the Strait of Georgia, Puget Sound and Juan de Fuca Strait. However, the full marine range of IFC is unknown because fishing does not occur in all parts of the Northeastern Pacific, and only hatchery-origin individuals have been used to create the distribution information.

Spatial configuration constraints: Reduced stream flow, changes to the natural hydromorphology, and impacts to smolt passage from hydroelectric developments in the Bridge and Seton watersheds may have impacted the Middle Fraser CU to an unknown degree. Hells Gate and Little Hells Gate continue to act as barriers to upstream migrating Coho Salmon at certain river levels (IFCRT 2006). Loss of off-channel and small stream habitat in the lower Fraser River, as a result of flood control and agricultural development, represent a likely reduction in freshwater carrying capacity for IFC.

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 species, would be considered residences under this definition in the event of listing as Threatened under SARA.

Threats and Limiting Factors to Survival and Recovery

Anthropogenic Threats

This report 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 2014): 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. In this case, IFC are the "wildlife species at risk".

The threat categories reported here are based on the unified classification system used by COSEWIC when assessing status of wildlife species (COSEWIC 2012). The threat classification system was used to define broad categories of threats. The final assessment of those threat categories follows DFO (2014) guidance to the extent possible in the context of limited data and information on threats to IFC within Canadian waters. For IFC, a working group assessed threats to IFC using a COSEWIC threats calculator tool that was modified and expanded to improve the applicability to salmonids. Then the information and rankings from the initial COSEWIC-style assessment by the working group were used to convert the assessment into the DFO (2014) standardized assessment method.

Modifications to catchment surfaces, linear development, and agricultural and forestry effluents were identified as the three highest ranked anthropogenic threats to IFC (Table 3). Several other threats were identified as low-medium threat risk, among them were fishing-related threats. The low-medium threat risk for fishing-related threats was primarily due to the uncertainty around estimates of fishing encounters and post-release mortalities. The fishing-related threats result from fisheries occurring in both Canada and the US.

Modifications to catchment surfaces result from activities/events such as forestry, forest fires, agriculture, and urban and industrial development. The impacts associated with these include: altered stream temperature and flow regimes from vegetation clearing or increases in impervious surfaces. The impacts of forest fires are similar to forestry in how they alter flow and temperature regimes, but their impacts can be worse since wildfires do not follow forestry management rules and can remove all vegetation, including riparian vegetation.

Linear development includes straightening and channelization of streams, often modifying natural landscapes with riprap, dykes, culverts, bridges, and floodgates, which are associated with the protection of agricultural, industrial, and urban development. These modification can make the habitat less “desirable” for Coho Salmon due to changes in cover from predators and stream velocity. 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).

Agricultural and forestry effluents include sediment, large woody debris, nutrients, and various toxic chemicals. Forest fires may exacerbate impacts of effluents and forest fire management can also result in the introduction of additional toxic chemicals; these threats were included in the threat level of this category because it does not fit well into any of the other categories. Fine sediments have direct impacts by reducing egg survival through decreasing oxygen circulation, and by preventing fry from emerging from redds. Changes in course sedimentation can result in stream habitats shifting from pools to riffles, and increased landslide frequency. Nutrient loading from fertilization of agricultural lands and forestry replanting, or feces from livestock that enriches effluent may also impact juvenile salmon and their habitat. Higher than natural nutrient levels can cause eutrophication and create hypoxic zones in stagnated water that likely prevent juvenile salmon from using those habitats.

Cumulative Impacts

The abundance and productivity of salmon populations is related to changes in climate, which may impact both ocean and freshwater habitats. Climate driven changes in ocean current patterns have profound effects on coastal productivity by influencing the availability of nutrients along the continental shelf. There are no known region-specific ocean climate change projections for IFC, but there is evidence that areas where IFC rear in the ocean may be affected or even buffered from some climate change impacts. Some region-specific climate change projections exist for the interior Fraser River that suggest IFC may benefit in some regions but will likely be negatively impacted in many others. Increasing river temperatures in particular may create a migratory bottleneck in the lower Thompson River for IFC. There is currently much debate as to how Pacific salmon will respond to future climate change, but for Coho Salmon, the weight of scientific evidence suggests that the overall effect will be strongly negative within the 21st century. The threat of future climate change to IFC is imminent and it represents a severe threat in the long-term.

Large enhancement programs for Coho and other salmon in other regions may pose a risk to IFC, which may exacerbate several natural limiting factors or other threats. In addition to competition for resources, hatchery salmon may increase transfer of diseases and parasites, and increase predation and fishing mortality for wild fish that co-migrate with the large numbers of hatchery fish in the ocean.

Cumulative impacts are the combined impact of past and present human activities and natural process interacting. Unlike impacts from specific development activities, cumulative impacts occur over an extended period of time and as a result of a combination of a variety of activities. The COSEWIC threats calculator (COSEWIC 2012) assessment of IFC captured the additive cumulative impact of all threats assessed. The calculator ranked the overall threat impact as High-Very High, which suggests that the IFC population may decline between 10-100% in the next 10 years due to the cumulative impact of the threats identified if additional mitigation is not implemented. Climate change is anticipated to exacerbate the impact of many anthropogenic and natural threats.

Table 3. DFO threats assessment for Interior Fraser Coho Salmon. Note that categories are a slight modification of the COSEWIC Categories. Refer to DFO (2014) for detailed description of each factor level in the table. The bracketed number following the Threat Risk ranking represents the Causal Certainty rank. Examples are not inclusive of all threat aspects.

Threat	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent	Examples
Modifications to Catchment Surfaces	Known	Medium-High	High	Medium-High (2)	Historical/ Current/ Anticipatory	Continuous	Extensive	removal of forest and vegetation, and creation of impervious surfaces resulting in modified hydrological regimes
Linear Development	Known	Medium	High	Medium (2)	Historical/ Current/ Anticipatory	Continuous	Extensive	reducing habitat complexity through channelization, rip-rapping
Agricultural & forestry effluents	Known	Medium	High	Medium (2)	Historical/ Current/ Anticipatory	Continuous	Extensive	additional sedimentation resulting from removal of vegetation
Fishing (Commercial; Food, Social, and Ceremonial; Recreational)	Known	Low-Medium	Very High	Low-Medium (1)	Historical/ Current/ Anticipatory	Recurrent	Extensive	adult mortality resulting from direct and indirect fishing mortality
Dams & water management/use	Known	Low-Medium	High	Low-Medium (2)	Historical/ Current/ Anticipatory	Continuous	Extensive	groundwater extraction for agricultural use; large and small hydroelectric dams
Introduced genetic material	Known	Low-Medium	High	Low-Medium (2)	Historical/ Current/ Anticipatory	Recurrent	Narrow	influence of hatchery-origin fish interbreeding with natural-origin fish
Household sewage & urban waste water	Known	Low-Medium	Medium	Low-Medium (3)	Historical/ Current/ Anticipatory	Continuous	Extensive	pollution from combined sewer outfalls, such as micro-plastics, heavy metals, hormones
Industrial & military effluents	Known	Low-Medium	Medium	Low-Medium (3)	Historical/ Current/ Anticipatory	Continuous	Extensive	pollution from operational effluent, stored waste, and accidental spills
Science Activities	Known	Low	High	Low (2)	Historical/ Current/ Anticipatory	Recurrent	Narrow	stock assessment (test fishery, mark-recapture) and academic research

Threat	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent	Examples
Mining & quarrying	Known	Low	Medium	Low (3)	Historical/ Current/ Anticipatory	Recurrent	Restricted	primarily placer mining that occurs in-river
Fire & fire suppression	Known	Low	Medium	Low (3)	Historical/ Current/ Anticipatory	Recurrent	Restricted	direct heating from fires; ditch digging and water scooping
Invasive Plants Modifying Habitat	Known	Low	Medium	Low (3)	Historical/ Current/ Anticipatory	Continuous	Narrow	Cheatgrass growing in floodplains
Livestock farming & ranching	Likely	Low	Low	Low (4)	Historical/ Current/ Anticipatory	Recurrent	Restricted	cattle directly crushing redds
Roads & railroads	Known	Low	Low	Low (4)	Historical/ Current/ Anticipatory	Recurrent	Narrow	maintenance, widening, and construction of bridges directly in river
Utility & service lines	Known	Low	Low	Low (4)	Historical/ Current/ Anticipatory	Recurrent	Narrow	maintenance, widening, and construction of utility (e.g. pipelines) directly in river
Shipping lanes	Known	Low	Low	Low (4)	Historical/ Current/ Anticipatory	Recurrent	Extensive	dredging, primarily in the lower Fraser River
Invasive non-native/alien species	Known	Unknown	Medium	Unknown (3)	Historical/ Current/ Anticipatory	Continuous	Extensive	primarily invasive fishes that are predators of juvenile IFC
Introduced Pathogens and Viruses	Unknown	Unknown	Medium	Unknown (3)	Anticipatory	Continuous	Narrow	Piscine Orthoreovirus, Heart and Skeletal Muscle Inflammation
Recreational Activities	Likely	Unknown	Low	Unknown (4)	Historical/ Current/ Anticipatory	Recurrent	Restricted	ATVs, other off-road vehicles, horses directly crushing redds

Table 4. Natural limiting factors assessed in the DFO threats assessment and calculator framework for Interior Fraser Coho Salmon. The Threat Risk of a natural limiting factor is assumed to be Low unless there are external anthropogenic factors that are exacerbating the effects of a natural limiting factor. Refer to DFO (2014) for detailed description of each factor level in the table. The bracketed number following the Threat Risk ranking represents the Causal Certainty rank.

Limiting Factor	Likelihood of Occurrence	Level of Impact	Causal Certainty	Threat Risk	Threat Occurrence	Threat Frequency	Threat Extent	Notes
Varying Ocean Conditions	Known	Medium-High	Very High	Medium-High (1)	Historical/ Current/ Anticipatory	Continuous	Extensive	exacerbated by climate change; historic evidence of possible impacts
Varying Freshwater Conditions	Known	Medium-High	High	Medium-High (2)	Historical/ Current/ Anticipatory	Continuous	Extensive	exacerbated by climate change that shifts temperature and flow
Competition	Known	Medium	Medium	Medium (3)	Historical/ Current/ Anticipatory	Continuous	Extensive	exacerbated by hatchery-origin Coho Salmon
Predation	Known	Medium	Medium	Medium (3)	Historical/ Current/ Anticipatory	Continuous	Extensive	exacerbated by hatchery-origin Coho Salmon
Avalanches/ landslides	Likely	Low-Medium	High	Low-Medium (2)	Historical/ Current/ Anticipatory	Recurrent	Narrow	exacerbated by forestry and climate change
Biological & Physiological Limits	Known	Low	Very High	Low (1)	Historical/ Current/ Anticipatory	Continuous	Extensive	semelparous, fecundity and thermal constraints
Native Parasites & Pathogens	Known	Unknown	Low	Unknown (4)	Historical/ Current/ Anticipatory	Continuous	Extensive	data deficient on disease transmission rates; may be exacerbated by hatchery fish

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 2014). 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 (Table 4) unless there are other factors that are exacerbating natural levels of variation or impacts to a population. As almost all of the natural limiting factors are affected by anthropogenic induced climate change or landscape level development, they are intertwined with existing threats and impacts.

Recovery Targets

The IFCRT (2006) suggested IFC recovery objectives based on ecological and conservation theory that would maintain the viability and diversity of naturally spawning Coho Salmon within the interior Fraser River watershed. They included the aspect of delineated subpopulations within each CU. The IFCRT "long-term target" was that the 3-year geometric average of natural-origin escapement in all of the subpopulations within each of the five CUs is to exceed 1,000 Coho Salmon. The 3-year mean represents average abundance per generation (three consecutive years in the case of IFC) and is used to smooth out annual variations and influences from both dominant and sub-dominant brood lines that may exist. This leads to a more precautionary approach and ensures that recovery status does not change on the basis of a single large annual return. Since the 11 subpopulations likely have different productivities and capacities, the aggregate DU abundance that meets the subpopulation target is expected to be greater than 11,000 (the sum of 1,000 per the number of subpopulations) on average. The IFCRT originally suggested that the DU target be 40,000 based on a qualitative assessment of historic data. A more quantitative analysis of historic data to determine what the DU level target could be is reported here.

The quantitative analysis used a dataset including natural-origin escapements from 1998-2016. For the purpose of this analysis, natural-origin returns are defined as first generation Coho Salmon spawning in natural rivers. Estimation of natural-origin returns was conducted by removing the estimated enhanced contribution of adipose-absent and adipose-present hatchery returns from total returns. Adipose clip rates were determined during field programs and applied to total return to estimate adipose-absent contribution; however, adipose-present returns required further classification as natural- or hatchery-origin. The hatchery return of adipose-present IFC was estimated from survival rates, for the life stages between release and adult, and exploitation rates for adipose-present fish. Smolt-to-adult survival rates were estimated using mark recovery data for coded-wire tag release stages and data from the Mark Recovery Program database. Enhanced contribution from adipose-present hatchery IFC returns was then removed from the total adipose-present returns to estimate natural returns. This method has been detailed in section 2.1.4 of Parken et al.[1]. As used in this report, “smolt-to-adult survival” includes measures of total mortality occurring over the life stages of outmigration as smolts to the estuary, marine migration and residence, and the upriver migration as adults.

The DU recovery target for IFC is recommended as a 3-year geometric mean abundance of 35,935 natural-origin spawners. The IFCRT long-term target did not include a “time-bound” component that is a requirement of the “SMART” approach (DFO 2011); so the default minimum ten years (which encompasses 3 generations) is used for this assessment. Projecting further than 10 years is not recommended because there are only 16 years of stock-recruitment data available to create parameter estimates and variance. Other recovery targets could be considered; however, any models and all targets should be reviewed as more data become available or as environmental conditions that affect underlying population dynamics, such as productivity or survival, change.

The probability that IFC reach the DU recovery target was explored using stock-recruitment models and forward simulation. The same three model forms used in the most recent evaluation framework for assessing Coho Salmon reference points (Korman et al. 2019) were used here. The simulation results from each model were combined and given equal weight. The decision to use an equal weight model averaged approach should be considered as expert opinion rather than based on strict statistical criteria.

After the escapement for each model's trials were combined, three population performance metrics were calculated.

1. **Final success**: the final 3-year geometric mean escapement at the DU was calculated for each trial and was assigned a value of one for successfully meeting or exceeding the target of 35,935 or assigned a zero for failing. Final success is reported as the proportion of simulation trials that were successful (Figure 3).
2. **Proportion of positive trajectories**: The percent change in abundance was calculated over 10 years for each trial. If a population's percent change was positive, it was assigned a value of one. The proportion of positive trajectories is reported.
3. **Percent change**: From the calculation above, the median percent change over 10 years was calculated as well as the 10th and 90th quantiles to represent the 80% uncertainty interval. The percent change provides context of the possible magnitude of the trajectory and captures additional uncertainty better than the simple proportion of trials metrics.

At the current average exploitation rate (ER) and smolt-to-adult survival, the proportion of final success in trials was 41%. The proportion of positive trajectories was 50%. The median percent change in 10 years was 0% with the 80% uncertainty interval spanning -29% to 29%.

These results show that the probability of reaching the recovery target in 10 years under current conditions is "about as likely as not" (i.e., equally likely to reach the target as to not reach it). There is potential for the population to remain stable (neither decrease nor increase). However, there is high uncertainty in this trajectory projection.

The interior Fraser River watershed is large and difficult to assess in the context of freshwater habitat requirements and supply. The impact of several threats, particularly climate change, may change the suitability of habitat both annually and seasonally. The impacts of landscape modifications on habitat supply are also difficult to quantify. Additionally, the information regarding coastal Coho Salmon populations is not directly transferable due to their behavioural differences. The result is that the elements associated with assessing habitat requirements and supply represent a notable knowledge gap in the context of IFC.

Following the same simulation methods reported earlier, the average smolt-to-adult survival and exploitation rate values were varied to approximate different future productivity and mortality scenarios. Each combination of smolt-to-adult survival and exploitation rate was simulated for 500 trials using each model form, with each trial projecting 10 years into the future. The results indicate that there is a strong pattern that higher smolt-to-adult survival and lower exploitation rate result in a higher proportion of simulations meeting the recovery target and a positive trajectory for the IFC population (Table 4). The recovery of natural-origin IFC is unlikely under decreased smolt-to-adult survival conditions, regardless of the exploitation rate. Increased smolt-to-adult survival increased the probability of recovery to a greater degree than decreasing the exploitation rate (Figure 4). It is important to note that, although the simulation and assessment did not explicitly address changes in habitat, factors that affect egg-to-smolt survival will affect recovery potential.

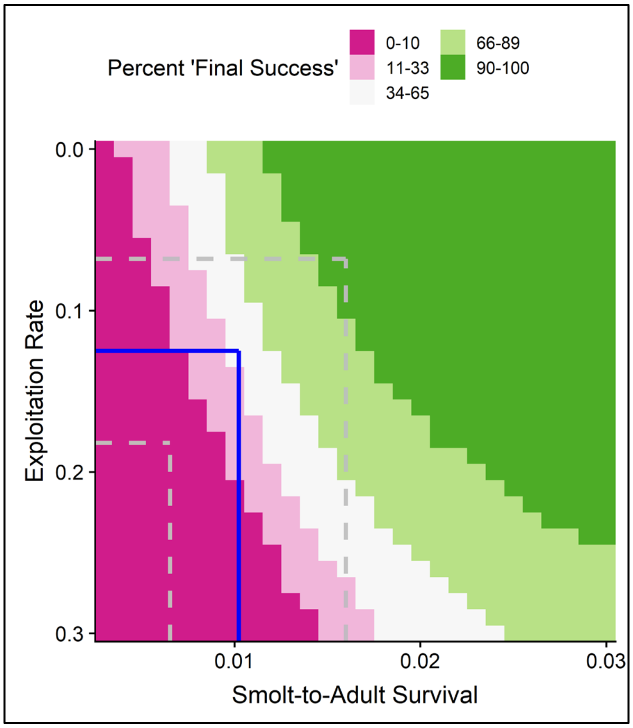


Figure 3. Proportion of model-averaged Monte Carlo simulation results where the final 3-year geometric mean abundance was ≥ 35,935 ('Final Success'). The blue lines intersect at the current smolt-to-adult survival and exploitation rate averages. The gray dashed lines represent one standard deviation above and below each factor's average.

Table 4. Summary of the proportion of trials that met the recovery target in the final 3-year geometric mean abundance (Final Success) over a range of exploitation rates (ER) and smolt-to-adult survival rates. Values represent the average of the three equally weighted model's simulation results.

ER	**Smolt-to-Adult Survival**													
	0.3%	0.5%	0.7%	0.9%	1.0%	1.1%	1.3%	1.5%	1.7%	1.9%	2.1%	2.3%	2.5%	3.0%
0%	8%	18%	45%	72%	81%	87%	95%	98%	99%	100%	100%	100%	100%	100%
1%	7%	17%	41%	68%	79%	85%	94%	97%	99%	99%	100%	100%	100%	100%
2%	7%	16%	38%	65%	76%	82%	92%	97%	99%	99%	100%	100%	100%	100%
3%	6%	14%	35%	63%	73%	82%	90%	97%	99%	99%	100%	100%	100%	100%
4%	5%	13%	32%	60%	72%	79%	90%	95%	98%	99%	99%	100%	100%	100%
5%	5%	11%	28%	57%	68%	76%	88%	94%	97%	99%	99%	100%	100%	100%
6%	5%	10%	26%	54%	66%	74%	86%	94%	97%	98%	99%	99%	100%	100%
7%	4%	9%	21%	51%	63%	72%	85%	92%	96%	98%	99%	99%	99%	100%
8%	3%	8%	19%	47%	60%	70%	83%	91%	95%	98%	99%	99%	99%	100%
9%	3%	6%	17%	42%	56%	66%	81%	89%	94%	97%	98%	99%	99%	100%
10%	2%	6%	15%	39%	52%	64%	78%	88%	93%	96%	98%	99%	99%	100%
11%	2%	5%	12%	33%	47%	61%	76%	84%	92%	95%	98%	99%	99%	99%
12%	2%	4%	11%	29%	43%	57%	73%	83%	91%	94%	96%	98%	99%	99%
13%	1%	4%	9%	26%	40%	52%	70%	82%	88%	93%	96%	97%	98%	99%
15%	1%	2%	7%	19%	31%	43%	64%	77%	85%	91%	94%	95%	97%	99%
20%	0%	1%	2%	7%	11%	20%	42%	60%	72%	79%	86%	89%	92%	96%
30%	0%	0%	0%	0%	1%	1%	4%	14%	27%	41%	52%	62%	68%	80%

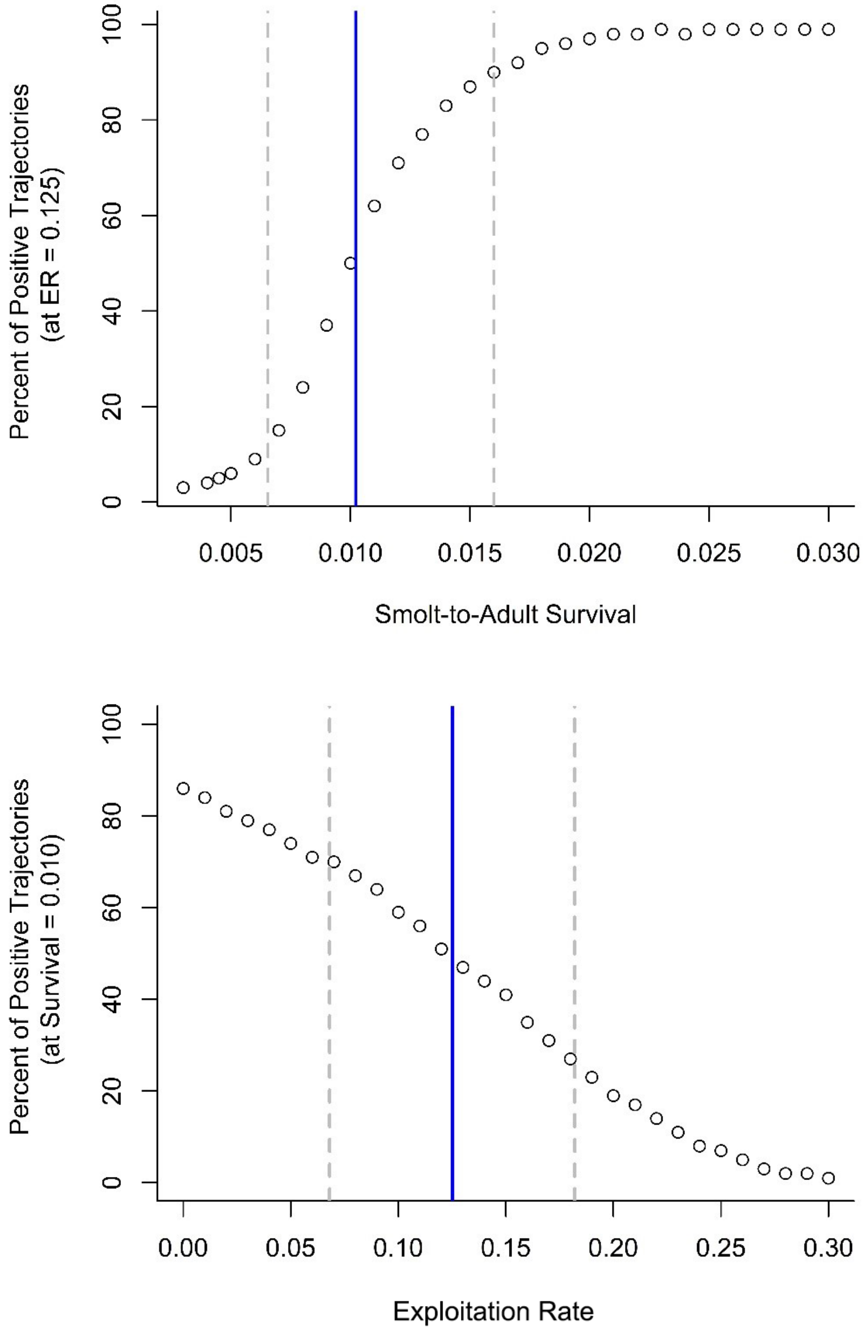


Figure 4. Incremental change in proportion of positive trajectories in simulations across smolt-to-adult survival (top) and exploitation rates (bottom) when the other metric is held at the current average. Blue line indicates the current average of each metric and the gray dashed lines are one standard deviation away

Scenarios for Mitigation of Threats and Alternatives to Activities

Due to the complexity of the IFC life history, a number of the key factors contributing to IFC productivity and survival are managed across many levels of government. IFC productivity and survival depends on cool, clean, connected waterways, as well as intact groundwater sources, and riparian and off-channel habitats spanning thousands of kilometres of stream length and flowing through a myriad of land titles (private, commercial, governmental) and activities (urban development, mining, forestry, agriculture, ranching, fishing, recreation). To be effective, the mitigation of risk to habitat supporting IFC productivity requires implementation of clear and effective legislation and regulations, policy and best practice documents to address threats, and supported by monitoring and enforcement of mandated measures.

This section discusses both specific and broad mitigation strategies including threats to IFC from development, fishing, hatcheries, and water management. Most of the mitigation activities and processes suggested below would also improve productivity and survival.

- Threats to IFC from activities related to modifying catchment area (such as forestry, agriculture, ranching, mining, and urban development) can be addressed by planning to minimize the cumulative hydrological effects of deforestation and riparian disruption in any given watershed.
- After the dramatic decline in southern BC Coho Salmon productivity in the early to mid-nineties, fisheries impacting IFC were eliminated or significantly restricted by 1998 (Interior Fraser Coho Recovery Team 2006). Fisheries planning is currently conducted based on information that may no longer be representative of IFC, e.g. migration timing or routes (Pacific Salmon Commission 2013). A better understanding of how decisions, and changes to fisheries management actions, impact recent IFC exploitation is required to continue to effectively manage IFC within the current fisheries framework. Reducing uncertainty in fishery mortality estimates, and greater enforcement to curtail unlawful fishing activity would help to improve the accuracy of fisheries planning and maintain fisheries impacts within an appropriate overall exploitation rate.
- Measures to monitor returning populations for proportion of natural influence, hatchery stock timing and size influences on natural populations, would improve the ability to mitigate threats associated with hatchery activity. Mitigation measures around hatcheries are outlined well in the literature (Withler et al. 2018), which also highlights their capacity to act as conservation tools and a mitigation measure for depleted stocks.
- There is growing recognition in BC's regulatory framework of the importance of aquifer sources to environmental needs. Section 55(4) of the *Water Sustainability Act* now clarifies that government has the discretion to consider environmental flow needs when adjudicating both new and per-existing groundwater use. Though the *Water Sustainability Act* change to licence ground water is a step forward, there is still work required to incorporate current ground water wells into the regulatory framework, meter all extraction activities, and create water allocation regimes that include planning for fish-water requirements. Active water management for the objective of buffering migratory or juvenile salmonids from low flows or high temperatures is also a possible mitigation activity.

Allowable Harm Assessment

IFC recovery is possible if human-induced mortality is minimized given current environmental conditions and variability, and if impacts from the identified threats are also mitigated. If the recent smolt-to-adult survival pattern continues and the models are correct, the population trajectory is most likely to be positive or stable at zero exploitation rate and recovery may eventually occur. However, under the Pacific Salmon Treaty (2019), the United States, as the intercepting Party, shall not be required to reduce its impact on IFC below a 10% exploitation rate. Therefore achieving a zero exploitation rate is not expected regardless of fishery actions taken by Canada.

At an exploitation rate of ≤ 6% at current smolt-to-adult survival, model simulations indicated meeting the recovery target in 10 years was likely[3] (≥ 66% chance) but not very likely (≥ 90% chance). In order to support recovery, the practice of minimizing exploitation rates on IFC should continue.

Although not quantified here, there is a de facto human induced mortality rate on juvenile IFC (and likely adult migrants) in freshwater that is non-fisheries related. Population growth of anadromous salmon is known to be particularly sensitive to changes in egg-to-smolt survival and juvenile life stages are all sensitive to habitat quality; therefore, impacts to freshwater environments should also be seriously considered in addition to ER when considering allowable harm and overall recovery potential.

Sources of Uncertainty

- There are considerable knowledge gaps concerning freshwater and marine habitat distribution for IFC. The Fraser River watershed covers a very large area and IFC habitat use has not been thoroughly studied. Therefore, some information reported here is based on what is known generally regarding Coho Salmon habitat use and IFC freshwater distribution has been inferred from this. Similarly, IFC marine distribution is inferred from limited information on IFC specifically and Coho Salmon generally.
- There are some issues associated with the IFC dataset that need to be considered when extrapolating results from model fitting and forward simulation. The major issue is that models that are used to estimate ER follow several assumptions that are known to likely be in error but for which there is currently no better alternative. The models do not calculate error in their estimates; therefore, any back-calculation of recruitment from escapement is inherently uncertain and may be in error.
- Typically there is a limited number of fish samples for analyses. For example, the age at maturity data and generation time is based on scale aging methods from scales collected from post-spawning adults. There are generally few scale samples collected per CU per year and not every CU-year has data.
- At the time of the regional peer review meeting when this report was produced, the major land slide near Big Bar on the Fraser River was not known to DFO nor its impacts on migratory salmon investigated. The majority of IFC spawn in areas below the Big Bar slide site but one subpopulation (Upper Middle Fraser) spawns above the slide. The suggested recovery target was based on maintaining 1000 or more natural-origin spawners in all subpopulations. Therefore, the recovery target would likely not be met if the Big Bar slide acts as an impediment to IFC migration to the Upper Middle Fraser subpopulation.

[3] The International Panel of Climate Change adopted several risk/certainty categories that are now widely used to categorically describe probabilities of scenarios occurring. Very likely ≥ 90%, Likely ≥ 66%, About as likely as not 33-66%, Unlikely ≤ 33%, Very Unlikely ≤ 10%.

Research Recommendations

- The observed concerns in the stock-recruitment model residuals and in the quality of the data may be improved with subsequent and dedicated research. Several suggestions for future research are:
    - Improve estimates of exploitation rates, fishing encounters and post-release mortality and the uncertainty around estimates.
    - Include compounding uncertainty in the data (i.e. escapement and recruitment) so that the true uncertainty in the model may be representative. An errors-in-variables model may also be beneficial if measurement error was quantified for either ER or escapement.
    - Investigate additional or alternative covariates to describe unexplained variability, issues associated with the use of time series data, and trends in productivity. Alternative covariates may include but are not limited to: hatchery contribution, smolt production, and various freshwater environmental covariates.
    - Continue collecting spawner abundance, ER, and biological data to increase the length of the dataset. Increased contrast, particularly at higher spawner abundances, would improve parameter estimation (e.g. around carrying-capacity) and allow for additional covariates. Increased scale sampling effort across both number of systems and in the number of samples would bolster confidence in age-based recruitment reconstruction.
    - Explore alternative model types, e.g. state-space models or partial hierarchical models, because not all CUs may have the same degree of covariance (e.g. opposite trends in productivity) or may be affected by different processes. Additional comparisons with less complex models may also be insightful.
- Future assessment of the supply of suitable habitat and habitat use, including the investigation of density-dependent processes, would benefit from collaboration between DFO Science, DFO Fish and Fish Habitat Protection Program, and the Province of BC, as well as individuals who have compiled information in the Community Mapping Network database.

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SOURCES OF INFORMATION

This Science Advisory Report is from the May 22-24, 2019 regional peer review on Recovery Potential Assessment – Interior Fraser Coho (*Oncorhynchus kisutch*). 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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