COSEWIC
Assessment and Status Report

on the

Coho Salmon
Oncorhynchus kisutch

Interior Fraser population

in Canada

THREATENED
2016

COSEWIC
Committee on the Status
of Endangered Wildlife
in Canada

COSEPAC
Comité sur la situation
des espèces en péril
au Canada

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Coho Salmon — Photo courtesy of E. Keeley, Idaho State University.

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COSEWIC
Assessment Summary

Assessment Summary – November 2016

Common name
Coho Salmon - Interior Fraser population

Scientific name
Oncorhynchus kisutch

Status
Threatened

Reason for designation
This population experienced declines in excess of 60% in the number of mature individuals in the 1990s because of a reduction in marine survival, changes in freshwater habitats, and overexploitation, which resulted in a designation of Endangered in 2002. The population increased in abundance from 2005 to 2012 but escapement in 2014 and 2015 was very low. Marine survival rate has deteriorated. There are a number of threats to the freshwater habitat related to invasive species, drought, increased water temperatures, land use, and increased urbanization. All of these factors are suspected to cause reductions in numbers exceeding 30% over three generations including years in the recent past and the future.

Occurrence
British Columbia, Pacific Ocean

Status history
Designated Endangered in May 2002. Status re-examined and designated Threatened in November 2016.

COSEWIC
Executive Summary

Coho Salmon
Oncorhynchus kisutch

Interior Fraser population

Wildlife Species Description and Significance

Coho Salmon is one of seven species of the genus *Oncorhynchus* native to North America. Adult Coho Salmon usually weigh from 2 - 5 kg (45 - 70 cm in length) rarely exceeding 9 kg. Interior Fraser Coho Salmon are genetically unique and can be distinguished from populations in the lower Fraser River watershed and other areas of Canada. Interior Fraser Coho occupy about 25% of the range of Coho Salmon within Canada. Interior Fraser Coho Salmon constitute a single designatable unit (DU) that is genetically discrete and has significant evolutionary traits compared to other Coho populations.

Distribution

Coho Salmon are widespread throughout the Thompson River, the largest watershed in the Fraser River system. Their distribution in non-Thompson tributaries of the interior Fraser system is not well known. Coho Salmon from the interior Fraser River watershed migrate extensively in the ocean and have been recovered in fisheries from Alaska to Oregon, but most were caught off the West Coast of Vancouver Island and in the Strait of Georgia.

Habitat

The distribution of spawning habitat for Coho Salmon is usually clumped within watersheds. Juveniles tend to cluster in areas of suitable habitat in shallow gradient streams and occasionally lakes. Much of the interior Fraser watershed where Coho Salmon are found has been impacted through logging and other human disturbances and is now used for a variety of agricultural activities.

Juvenile Coho Salmon migrate down the Fraser River and spend some time in the highly developed Fraser estuary. The majority of their oceanic residence is typically spent near the coast in southern BC. The marine areas used by Interior Fraser Coho have been affected by climate-related changes that have impacted productivity and reduced the survival rate of Coho Salmon in southern BC during the last two decades.

Biology

Interior Fraser Coho Salmon return to freshwater in the fall and spawn during fall and early winter. Fry emerge from the gravel the following spring and usually remain in freshwater for a year before migrating to the ocean as smolts. The majority of Coho Salmon spend 18 months at sea before returning to freshwater to spawn and complete their 3-year life cycle.

Female Coho Salmon are larger than males in most interior Fraser systems, but slightly less abundant (~45% of returns). Interior Fraser Coho Salmon are smaller and usually produce fewer eggs than fish of the same age from other systems.

Population Sizes and Trends

Annual returns (catch + spawning escapement) averaged 161,000 without trend between 1985-1993. Returns then declined sharply and averaged 37,000 with little trend in the period 1994-2012. Escapement varied around 60,000 from 1985-1989, then declined to a low of 16,000 in 1997. This was followed by an increase to 39,000 in 2001, then another decline to 15,000 in 2005. Escapement increased again to 41,000 in 2012, but declined in the last 2 years reaching 21,000 in 2014.

Marine survival of smolts to returning adults continues to be low averaging less than 5% during the past decade, much lower than around 15% during the 1970s and 1980s. The most recent values of marine survival were the lowest seen reaching 0.1% in 2014.

Threats and Limiting Factors

Overfishing, changing marine conditions, and habitat perturbations all contributed to declines in abundance. Excessive removals occurred in the early 1990s when the impacts of fishing and concomitant declines in productivity were not yet evident to managers. Ongoing unfavourable marine conditions, disturbance of the freshwater habitat and introduction of invasive non-native species pose a continuing threat to all Interior Fraser Coho Salmon.

Protection, Status, and Ranks

Interior Fraser Coho were assessed as Threatened by COSEWIC in 2016. They were not listed under the Canadian *Species at Risk Act* but they were given added protection under the *Fisheries Act*. In the United States, Coho Salmon is considered to be endangered by extinction in one evolutionarily significant unit (ESU), threatened in two, and not likely to become endangered in only one ESU.

TECHNICAL SUMMARY

Oncorhynchus kisutch

Coho Salmon – Interior Fraser population

Saumon coho – Population de Fraser intérieur

Aboriginal Names (Name/First Nation)
sxeyqs – Secwepemcw
kwṓx̱weth – Halq'eméylem
sx̣áyqs – nłeʔkepmxc̣in
xáyeqs – Northern St̓át̓imcets
Dedzikh – Wet’suwet’en

Range of occurrence in Canada (province/territory/ocean): British Columbia, Pacific Ocean. (Fraser River watershed upstream of Hell’s Gate)

Demographic Information

Generation time (usually average age of parents in the population; indicate if another method of estimating generation time indicated in the IUCN guidelines(2011) is being used)	3 yrs
Is there an [observed, inferred, or projected] continuing decline in number of mature individuals?	Yes
Estimated percent of continuing decline in total number of mature individuals within [5 years or 2 generations]	Not Estimated
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over the last [10 years, or 3 generations].	+119% estimated based on last 10 years of escapement data -21% estimated based on entire escapement time series
[Projected or suspected] percent [reduction or increase] in total number of mature individuals over the next [10 years, or 3 generations].	Not estimated
[Observed, estimated, inferred, or suspected] percent [reduction or increase] in total number of mature individuals over any [10 years, or 3 generations] period, over a time period including both the past and the future.	Suspected reduction of > 30% because of threats in marine and freshwater habitats
Are the causes of the decline a. clearly reversible and b. understood and c. ceased?	a. No b. Yes c. No
Are there extreme fluctuations in number of mature individuals?	No

Extent and Occupancy Information

Estimated extent of occurrence (EOO)	> 20,000 km²
Index of area of occupancy (IAO) (Always report 2x2 grid value).	> 2,000 km²
Is the population "severely fragmented" i.e., is >50% of its total area of occupancy in habitat patches that are (a) smaller than would be required to support a viable population, and (b) separated from other habitat patches by a distance larger than the species can be expected to disperse?	a. No b. No
Number of "locations"* (use plausible range to reflect uncertainty if appropriate)	>> 10
Is there an [observed, inferred, or projected] decline in extent of occurrence?	No
Is there an [observed, inferred, or projected] decline in index of area of occupancy?	No
Is there an [observed, inferred, or projected] decline in number of subpopulations?	No
Is there an [observed, inferred, or projected] decline in number of "locations"*?	No
Is there an [observed, inferred, or projected] decline in [area, extent and/or quality] of habitat?	Yes, there is a decline in the quality of the marine environment inferred from a decline in the marine survival rate
Are there extreme fluctuations in number of subpopulations?	No
Are there extreme fluctuations in number of "locations"∗?	No
Are there extreme fluctuations in extent of occurrence?	No
Are there extreme fluctuations in index of area of occupancy?	No

Number of Mature Individuals (in each subpopulation)

Subpopulations (give plausible ranges)	**N Mature Individuals (average of last 3 years)**
South Thompson	5,600
North Thompson	8,100
Lower Thompson	7,500
Mid/Upper Fraser	5,400
Fraser Canyon	2,300
Total	28,900

* See Definitions and Abbreviations on COSEWIC website and IUCN (Feb 2014) for more information on this term.

Quantitative Analysis

Is the probability of extinction in the wild at least [20% within 20 years or 5 generations, or 10% within 100 years]?	Not estimated

Threats (direct, from highest impact to least, as per IUCN Threats Calculator)

Was a threats calculator completed for this species? Yes The marine survival rate has declined, fishing continues, and there are a number of threats to the freshwater habitat related to invasive species, drought, increased temperatures, land use, and increased urbanization that could result in further reductions in the number of mature individuals.

Rescue Effect (immigration from outside Canada)

Status of outside population(s) most likely to provide immigrants to Canada.	The DU exists solely in Canada
Is immigration known or possible?	No
Would immigrants be adapted to survive in Canada?	No
Is there sufficient habitat for immigrants in Canada?	Yes
Are conditions deteriorating in Canada?[+]	Yes
Are conditions for the source population deteriorating?[+]	Yes
Is the Canadian population considered to be a sink?[+]	No
Is rescue from outside populations likely?	No

Data Sensitive Species

Is this a data sensitive species? No

Status History

COSEWIC Status History: Designated Endangered in May 2002. Status re-examined and designated Threatened in November 2016.

Status and Reasons for Designation:

Status: Threatened	**Alpha-numeric codes:** A4cde
Reasons for designation: This population experienced declines in excess of 60% in the number of mature individuals in the 1990s because of a reduction in marine survival, changes in freshwater habitats, and overexploitation, which resulted in a designation of Endangered in 2002. The population increased in abundance from 2005 to 2012 but escapement in 2014 and 2015 was very low. Marine survival rate has deteriorated. There are a number of threats to the freshwater habitat related to invasive species, drought, increased water temperatures, land use, and increased urbanization. All of these factors are suspected to cause reductions in numbers exceeding 30% over three generations including years in the recent past and the future.	

[+] See Table 3 (Guidelines for modifying status assessment based on rescue effect).

Applicability of Criteria

Criterion A (Decline in Total Number of Mature Individuals): Threats in marine and freshwater habitats are suspected to cause a reduction in mature individuals of greater than 30% over three generations including years in the recent past and the future.
Criterion B (Small Distribution Range and Decline or Fluctuation): Does not meet criteria, EOO and IAO exceed limits.
Criterion C (Small and Declining Number of Mature Individuals): Does not meet criteria, population size exceeds limits.
Criterion D (Very Small or Restricted Population): Does not meet criteria
Criterion E (Quantitative Analysis): Not done.

PREFACE

The population was assessed as Endangered by COSEWIC in 2002. There had been a substantial decline in the number of mature individuals caused by reduced survival in the marine environment, overexploitation, and a deterioration in habitat quality in freshwater. While there had been a substantial reduction in fishing pressure, there was concern that this would be insufficient to stop the decline in the population.

Monitoring of the mature population, marine survival, and fishery exploitation rates has continued over the past decade. Freshwater habitat threats have also been monitored. This report provides an update on the status of Interior Fraser Coho that takes into account a considerable amount of new information accumulated over the intervening years.

The trend in mature population numbers over the past 10 years indicates the decline has stopped. While this is a positive sign for the population, there remain serious threats that could reverse the trend.

COSEWIC HISTORY

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) was created in 1977 as a result of a recommendation at the Federal-Provincial Wildlife Conference held in 1976. It arose from the need for a single, official, scientifically sound, national listing of wildlife species at risk. In 1978, COSEWIC designated its first species and produced its first list of Canadian species at risk. Species designated at meetings of the full committee are added to the list. On June 5, 2003, the *Species at Risk Act* (SARA) was proclaimed. SARA establishes COSEWIC as an advisory body ensuring that species will continue to be assessed under a rigorous and independent scientific process.

COSEWIC MANDATE

The Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the national status of wild species, subspecies, varieties, or other designatable units that are considered to be at risk in Canada. Designations are made on native species for the following taxonomic groups: mammals, birds, reptiles, amphibians, fishes, arthropods, molluscs, vascular plants, mosses, and lichens.

COSEWIC MEMBERSHIP

COSEWIC comprises members from each provincial and territorial government wildlife agency, four federal entities (Canadian Wildlife Service, Parks Canada Agency, Department of Fisheries and Oceans, and the Federal Biodiversity Information Partnership, chaired by the Canadian Museum of Nature), three non-government science members and the co-chairs of the species specialist subcommittees and the Aboriginal Traditional Knowledge subcommittee. The Committee meets to consider status reports on candidate species.

DEFINITIONS
(2016)

Wildlife Species	A species, subspecies, variety, or geographically or genetically distinct population of animal, plant or other organism, other than a bacterium or virus, that is wild by nature and is either native to Canada or has extended its range into Canada without human intervention and has been present in Canada for at least 50 years.
Extinct (X)	A wildlife species that no longer exists.
Extirpated (XT)	A wildlife species no longer existing in the wild in Canada, but occurring elsewhere.
Endangered (E)	A wildlife species facing imminent extirpation or extinction.
Threatened (T)	A wildlife species likely to become endangered if limiting factors are not reversed.
Special Concern (SC)*	A wildlife species that may become a threatened or an endangered species because of a combination of biological characteristics and identified threats.
Not at Risk (NAR)**	A wildlife species that has been evaluated and found to be not at risk of extinction given the current circumstances.
Data Deficient (DD)***	A category that applies when the available information is insufficient (a) to resolve a species' eligibility for assessment or (b) to permit an assessment of the species' risk of extinction.

* Formerly described as "Vulnerable" from 1990 to 1999, or "Rare" prior to 1990.

** Formerly described as "Not In Any Category", or "No Designation Required."

*** Formerly described as "Indeterminate" from 1994 to 1999 or "ISIBD" (insufficient scientific information on which to base a designation) prior to 1994. Definition of the (DD) category revised in 2006.

Environment and Climate Change Canada
Canadian Wildlife Service

Environnement et Changement climatique Canada
Service canadien de la faune

Canada

The Canadian Wildlife Service, Environment and Climate Change Canada, provides full administrative and financial support to the COSEWIC Secretariat.

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WILDLIFE SPECIES DESCRIPTION AND SIGNIFICANCE

Name and Classification

Coho Salmon, *Oncorhyncus kisutch* Walbaum 1792, is one of seven anadromous and semelparous species of Pacific salmon native to North America (Sandercock 1991). The scientific names derive from the Greek roots for hook (*onkos*) and nose (*rynchos*) while the species name *kisutch* is commonly used in Kamchatka and Alaska (Hart 1973). The common name for this species is Coho Salmon, but they are also referred to as silver salmon, sea trout, hooknose, or bluebacks, referring to small Coho Salmon caught early in their final marine year (Decker and Irvine 2013). The French common name is *Saumon coho*. There are additional names for Coho in local First Nations languages throughout the Interior Fraser watershed.

Morphological Description

Interior Fraser Coho and other Pacific salmon can be distinguished from trout and char in having 12 or more anal fin rays. In juvenile Coho Salmon the anal fin is sickle-shaped and the front edge is longer than the base. Adult Coho Salmon can be differentiated from other salmon by the presence of white gums at the base of the teeth in the lower jaw (Scott and Crossman 1973). When black spots occur on the tail fin they usually appear only on the upper lobe. Dimorphism develops as Coho Salmon become sexually mature with males becoming darker and often bright red, the upper jaw develops an elongated hooked snout, and the teeth become enlarged. Females are usually less brightly coloured and show lesser jaw development. Detailed descriptions of Coho Salmon are provided in Scott and Crossman (1973), Hart (1973), Pollard *et al.* (1997), and Sandercock (1991).

Population Spatial Structure and Variability

British Columbia (BC) was almost entirely covered by ice 15,000 years ago (Fulton 1969) followed by a period of global warming (Roed 1995). Anadromous salmon existed in several glacial refugia during the earlier period including the ice-free lower two-thirds of the Columbia River. As the ice retreated, much of the Fraser River drained through the Okanagan watershed, entering the ocean via the Columbia River (Decker and Irvine 2013) because the Fraser Canyon was blocked with ice near Hell's Gate (Figure 1). It was during this period that Coho Salmon (and other species) colonized the interior Fraser River watershed from a glacial refugium in the lower Columbia River watershed (Northcote and Larkin 1989). Fish entered by post-glacial lake connections in the Okanagan-Nicola area and by upper mainstem Fraser/Columbia connections. Coho Salmon in the middle and upper Columbia River watershed upstream of the Deschutes River, that may have been genetically similar to Interior Fraser Coho, are now extinct (Nehlsen 1997). Interior Fraser Coho are the only remaining representatives of this genetic group. In contrast to the inland dispersal pattern found for most Interior Fraser fish populations, many fish now found in the lower Fraser River watershed, including Coho Salmon, colonized along the coast via the sea (Decker and Irvine 2013).

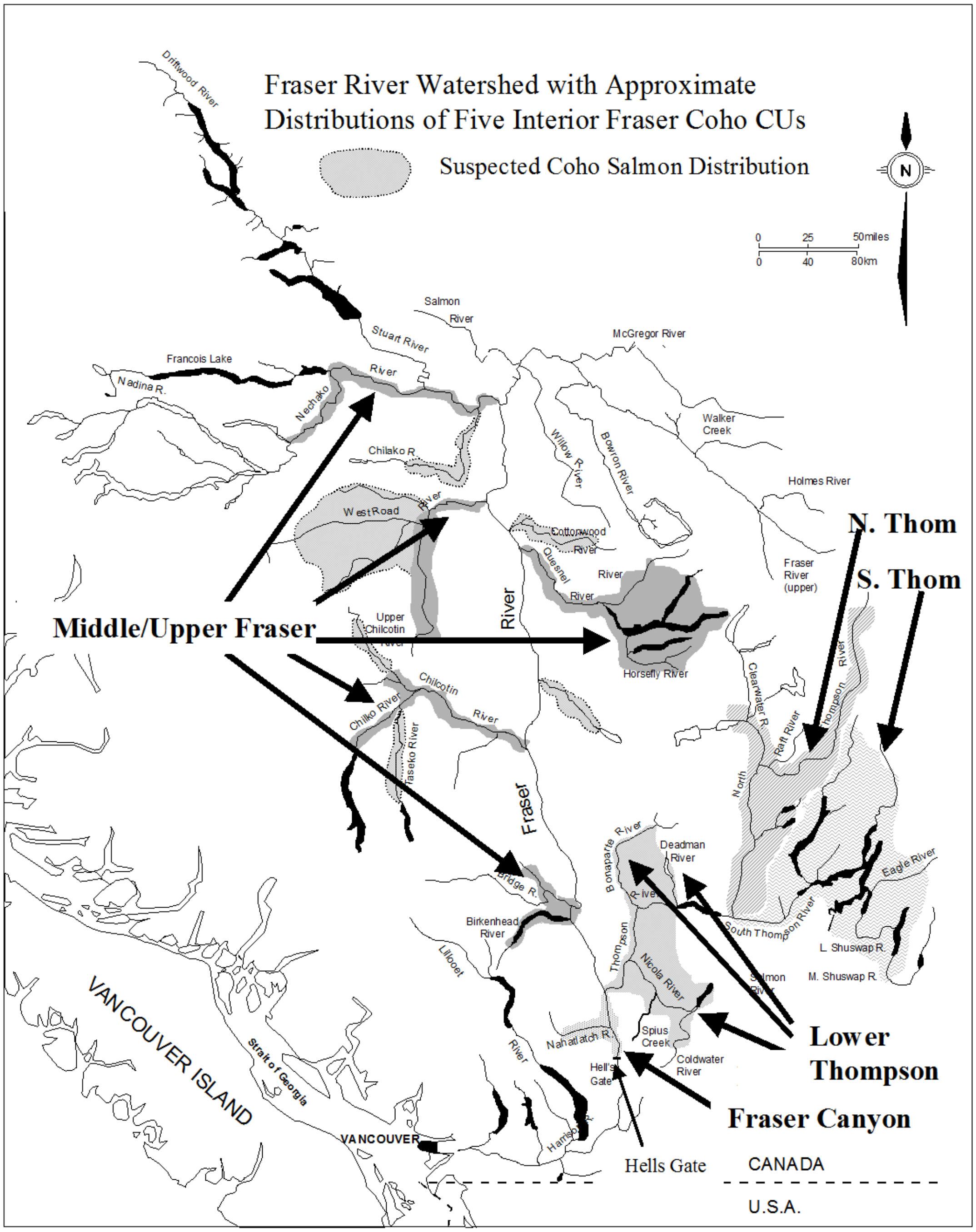

Figure 1. Approximate distribution of five Coho Salmon subpopulations (North Thompson, South Thompson, Lower Thompson, Fraser Canyon, and Middle/Upper Fraser) within the interior Fraser River DU (reproduced from Irvine 2002). Shaded areas represent the suspected (unconfirmed) distribution of Coho for the Middle/Upper Fraser, and the known (approximate) distribution for the other four subpopulations. The five subpopulations are represented by the different shadings or cross-hatchings.

Coho Salmon exhibit a high degree of spawning site fidelity and as such there are a number of genetically and ecologically distinct populations within the species. Small *et al.* (1998a,b) provide some evidence for differences within the interior Fraser River watershed. A more exhaustive analysis by Beacham *et al.* (2011) reviewed the population structure of most North American Coho Salmon by assaying 17 microsatellite loci in a gene diversity analysis that was structured among regions, among populations within regions, and among sampling years within populations. Coho Salmon from the Interior Fraser River were found to be discrete from other Coho Salmon populations and among the least genetically diverse of those examined. An updated analysis including more recent genetic data found that Coho Salmon from the North Thompson River drainage clustered together in 67% of dendrograms (Figure 2, Candy pers. comm. 2015). The samples from the South Thompson and Lower Thompson Rivers formed clusters in 64% and 100% of the replicates. The Paul Creek sample from the South Thompson was poor quality and should be disregarded (Candy pers. comm. 2015). The samples from the middle and upper Fraser River systems cluster together in 75% of dendrograms (Figure 2). Coho Salmon from the single location in the Fraser River Canyon (Nahatlatch River) were discrete both from upstream populations and those of the lower Fraser River (Beacham *et al.* 2011).

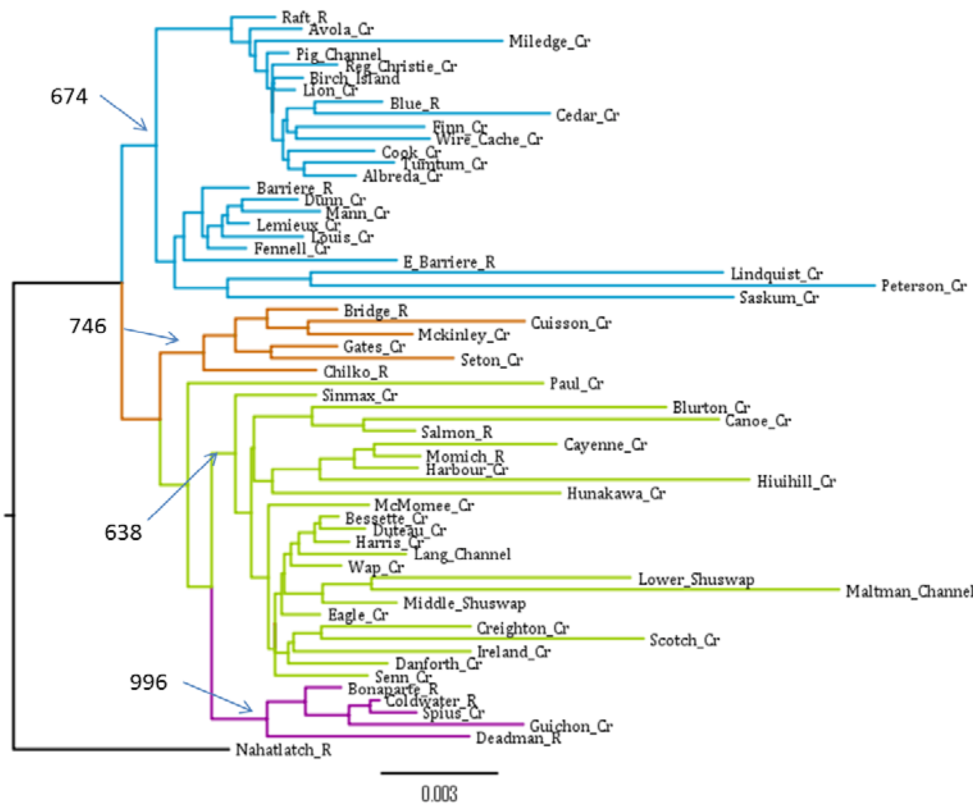

Figure 2. Neighbour-joining dendrogram of Cavalli-Sforza and Edwards (1967) chord distance for Interior Fraser River Coho Salmon populations (from top are North Thompson, Middle-Upper Fraser, South Thompson, Lower Thompson, and Fraser Canyon (Nahatlatch R)), surveyed at 15 microsatellite loci. Bootstrap values at major tree nodes denoted by arrows indicate the number of 1000 trees where populations beyond the node clustered together. (Figure courtesy J. Candy, DFO, pers. comm.)

Designatable Units

Interior Fraser Coho Salmon were assessed by COSEWIC as a single DU in 2002 (Irvine 2002). Subsequent genetic analysis indicates that subpopulations within the interior Fraser watershed are genetically discrete and reproductively isolated from all other Coho Salmon populations globally (Beacham *et al.* 2011). Interior Fraser Coho Salmon are believed to have colonized the Thompson and upper Fraser River drainages from the south from the Columbia River population (now extirpated), giving the Interior Fraser Coho a unique and significant genetic heritage (Smith *et al.* 2001). Taylor and McPhail (1985a,b) also present evidence for adaptive differentiation in morphology and swimming performance between Interior Fraser and Lower Fraser Coho Salmon. Interior Fraser Coho are smaller than fish from other populations and have also evolved a somewhat later spawn timing to coincide with interior winter hydrology whereas coastal population spawn timing is driven by fall freshets (Irvine pers. comm. 2014). Thus, Interior Fraser Coho meet COSEWIC guidelines for being a separate DU from other Coho in Canada.

Holtby and Ciruna (2007) reviewed the available genetic and ecological data for all Coho Salmon populations within British Columbia and identified five groupings within the Interior Fraser River watershed that are genetically distinct and display ecological differences and so could be considered for separate conservation units (CU) for management. The five groups correspond to the five major Coho Salmon bearing drainages within the interior Fraser River watershed; three within the Thompson River: North Thompson, South Thompson, and Lower Thompson, and two within the Fraser River: Fraser Canyon (area between the lower Fraser Canyon and the Thompson-Fraser confluence), and Middle/Upper Fraser (Fraser River and tributaries above the Thompson-Fraser confluence) (Figure 1).

COSEWIC requires that a designatable unit within a species be both reproductively discrete from other units and evolutionarily significant by way of local adaptation. Holtby and Ciruna (2007) and Candy pers. comm. (2015) (Figure 2) provide evidence for genetic discreteness among the 5 CUs. However, the evidence supporting local adaptation within these units is based on minor differences in spawn timing of less than 1 week on average (Holtby and Ciruna 2007), and is insufficient to justify recognition as separate DUs within the Interior Fraser region. Consequently, Interior Fraser Coho will be assessed as a single DU for COSEWIC purposes.

Special Significance

Coho Salmon contribute to commercial, recreational, and Aboriginal catches along the Pacific coast of North America. Coho abundance has declined throughout much of its range and some populations have become extinct (Weitkamp *et al.* 1995; Slaney *et al.* 1996; Northcote and Atagi 1997). The Interior Fraser River watershed represents 25% of the Canadian distribution of the species.

Coho Salmon continue to be an important food source for a number of First Nations in the Fraser watershed (Bennett 1973, Romanoff 1985, Prince 2002). Interior Fraser Coho Salmon return to spawn primarily within the traditional territories of the Secwepemc people (North and South Thompson and Clearwater rivers) and of the Nlaka'pmux, Sce'exmx and Okanagan people of the upper Fraser Canyon and Nicola Valley. Some Coho Salmon spawning also takes place within the traditional territories of the St'at'imc (Lillooet/Bridge River areas) and Tsilhqot'in (Chilcotin River system).

DISTRIBUTION

Global Range

Coho Salmon occur naturally only within the Pacific Ocean and its tributary drainages (Scott and Crossman 1973). Within North America, naturally spawning Coho Salmon occur in streams and rivers from California north through British Columbia to Alaska. Their distribution extends across the Bering Sea through Kamchatka to Sakhalin Island and rarely as far south as Peter the Great Bay (Figure 3; Sandercock 1991).

Coho Salmon have been introduced to many locations including the Great Lakes in North America and rivers from Maine to Maryland but there is uncertainty about the existence of any self-sustaining populations. They have also been introduced into Argentina and Chile (Scott and Crossman 1973). The DU assessed here spawns only within the Interior Fraser River watershed in British Columbia.

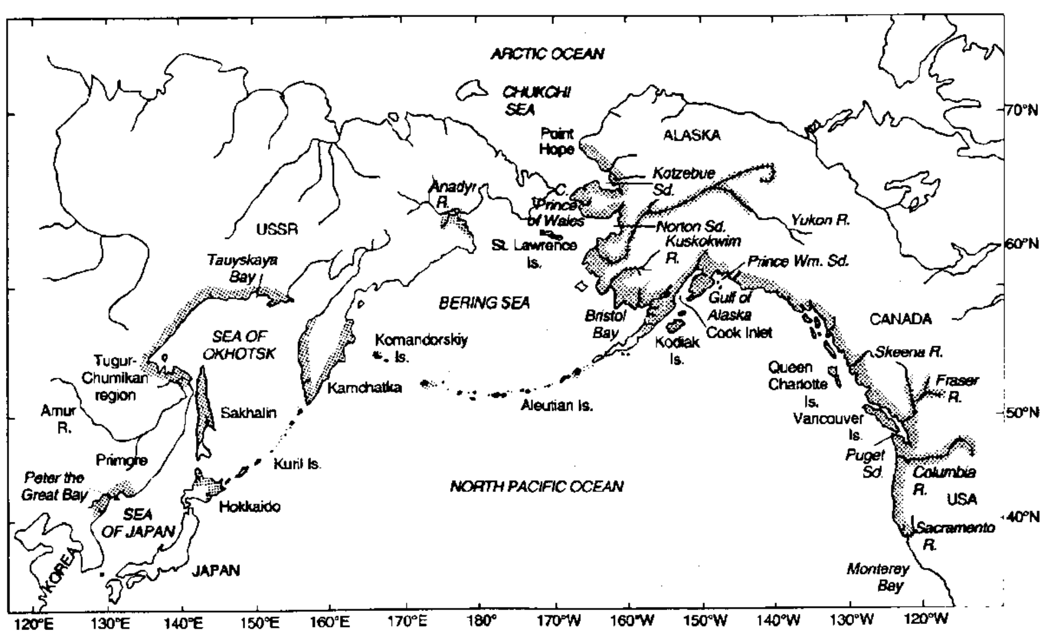

Figure 3. Approximate global distribution of naturally spawning Coho Salmon (from Sandercock 1991).

Canadian Range

Coho Salmon spawn and rear in most coastal streams and rivers of British Columbia. They are also found considerable distances inland in a number of the large river systems (e.g., Fraser, Skeena, Nass, Taku; Sandercock 1991). Tagged Coho Salmon from the Interior Fraser River have been recovered in fisheries from Alaska to Oregon, but mostly from commercial troll and sport fisheries operating off the west coast of Vancouver Island and in the Strait of Georgia (Irvine *et al.* 1999, 2001). Holtby and Ciruna (2007) report that coded wire tag returns indicated that interior Fraser Coho were mostly caught outside the Strait of Georgia. Conditions in the ocean including salinity levels, *El Niño Southern Oscillation* (ENSO) events, and climate change are known to affect the marine distribution of Coho Salmon (Pearcy 1992; Kadowaki 1997; Beamish *et al.* 1999).

Extent of Occurrence and Area of Occupancy

Coho Salmon, including Interior Fraser River populations, migrate widely in the marine environment and indications are that there is initially a northward inshore migration along the British Columbia coast to Alaska before an offshore and counter-clockwise movement through the Gulf of Alaska occurs eventually returning to the British Columbia mainland and heading towards their stream of origin (Sandercock 1991). Coho Salmon are widely distributed throughout the Thompson River system (Figure 1), the largest watershed within the Fraser River watershed (Decker and Irvine 2013). Coho Salmon distribution in Fraser tributaries other than the Thompson is poorly understood. Interior Fraser Coho are also found in the Nahatlatch River, a Fraser River tributary situated between Hells Gate and the Thompson River confluence. Within the Middle/Upper Fraser, Coho Salmon occur at least as far upstream as the Nechako River system and have been recorded in a number of other major Fraser tributaries downstream of the Nechako (e.g., Quesnel, Chilcotin, West Road (Blackwater); Figure 1) They may also occur in tributaries upstream of the Nechako (e.g., Bowron River), but their presence has not been confirmed (Decker and Irvine 2013). Coho Salmon may still be expanding their distribution in the Interior Fraser River watershed after their migration past the Fraser Canyon was severely impacted by rock dumped into the river during railway construction in 1913 and a rock slide in 1914 (Ricker 1989). Overall, the extent of occurrence exceeds 20,000 km^2 for the DU (Table 1).

The index of area of occupancy (IAO) was based on the distribution of spawning and was estimated for Interior Fraser Coho at 669 km^2 for the Fraser Canyon, 916 km^2 for the Lower Thompson, >2000 km^2 for the South Thompson, 1612 km^2 for the North Thompson, and >2000 km^2 for Middle/Upper Fraser River based on a 2$\times$2 km grid.

Table 1. Estimated average number of returning adult Coho Salmon (wild escapement and wild + hatchery escapement), and proportion of hatchery fish included in total escapements by watershed within DU, and across the DU (geometric mean for 2009-2011). The number of locations where Coho Salmon were detected is also shown for each watershed and across the Interior Fraser Coho DU (taken from Decker and Irvine 2013).

Watershed	River system	Escapement (wild)	Escapement (wild + hatchery)	Percent hatchery fish	Number of locations[1]
South Thompson	Adams River	1,174	1,174	0.0%	
	Middle and Lower Shuswap	1,757	1,757	0.0%	
	Shuswap Lake	2,398	2,531	5.2%	
	Total	5,379	5,515	2.5%	30
North Thompson	Lower North Thompson	3,476	4,236	17.9%	
	Middle North Thompson	2,450	2,450	0.0%	
	Upper North Thompson	2,600	2,600	0.0%	
	Total	8,809	9,613	8.4%	25
Lower Thompson	Lower Thompson	1,721	2,120	18.8%	
	Nicola River	3,897	4,402	11.5%	
	Total	5,704	6,701	14.9%	8
Middle / Upper Fraser	Middle Fraser	1,381	1,381	0.0%	
	Upper Fraser	1,979	1,979	0.0%	
	Total	3,584	3,584	0.0%	11
Fraser Canyon	Fraser Canyon	2,158	2,158	0.0%	1
Interior Fraser Coho DU		**26,236**	**28,105**	**6.7%**	**75**

[1] Cumulative number of unique locations with Coho Salmon detected across years during 2009-2011

Search Effort

The distribution of Coho Salmon within the entire Interior Fraser River watershed is monitored on an annual basis for the number of spawning adults. The methods used include visual surveys from land and air, mark recapture, counting fences, and video devices. With the available resources, it is not possible to survey all the streams in the entire DU each year (Decker *et al.* 2014), but it is generally accepted that they provide a reliable indicator of relative abundance. The rivers that have been observed to contain spawning Coho Salmon are presented in Appendix 2 of IFCRT (2006).

HABITAT

Habitat Requirements

Interior Fraser Coho Salmon spawn in freshwater and juveniles normally migrate to sea after one full year, so survival depends on adequate habitat both in freshwater and in the ocean. The distribution of spawning habitat for Coho Salmon is usually clumped within watersheds, often at the heads of riffles in small streams, and in side channels of larger rivers (Decker and Irvine 2013). Females generally construct nests in shallow (30-cm) areas where the rocks and gravel are less than 15-cm diameter and there is good circulation of well-oxygenated water (Sandercock 1991). Low or high flows, freezing temperatures, siltation, predation, and disease can reduce egg survival. 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 redds[1] dewatering and freezing if spawning occurs too early. Spawning occurs in the fall and winter, and in lake-headed streams where temperatures and discharge are relatively stable (Decker and Irvine 2013). Inflow of groundwater may also play a critical role in spawning site selection. 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).

Coho Salmon fry disperse from spawning sites in spring (Gribanov 1948; Chapman 1962) making pre-winter movement into small tributaries and off-channel habitat (Peterson 1982). Fry densities are generally higher in pools than in riffles in small streams and usually with gradients less than 3% (Decker and Irvine 2013). A multi-year (2001-2011) census of juvenile Chinook Salmon (*O. tshawytscha*) and Steelhead (*O. mykiss*) in the Lower Thompson River system found that Coho Salmon fry reared mainly in small tributaries, and rarely in main stem habitats in larger streams (Decker *et al.* 2013).

[1] A spawning nest created by female salmon to hold and protect eggs during incubation

After one year in freshwater, juvenile Coho Salmon from the Interior Fraser migrate down the Fraser River in the spring and early summer and enter the Strait of Georgia. Tagging indicates that it takes from 10-16 days to migrate from the interior to the lower Fraser River (Chittenden *et al.* 2010). Coho 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 (Beamish *et al.* 2010), leaving in October/November (Chittenden *et al.* 2009). Interior Fraser Coho Salmon spend the remainder of their 18-month oceanic residence primarily in coastal waters of the North Pacific (Irvine *et al.* 1999, 2001). Habitat requirements of juvenile Coho Salmon in the Fraser River estuary and the Strait of Georgia are poorly understood. The belief is that early ocean residence is a critical period for Pacific salmon (Peterman 1987; Pearcy 1992; Downton and Miller 1998), and that subsequent survival to maturity for Coho Salmon in southern BC is determined during the first few months resident in the Strait of Georgia (Beamish *et al.* 2004, 2010). Early marine survival of Coho Salmon may be influenced by numerous interacting factors including sea temperatures, the timing of ocean-entry, spring plankton blooms, food availability, predator abundance, abundance of other juvenile salmonids and generally favourable ocean conditions reflected in periods of negative Pacific Decadal Oscillation and absence of El Niño Southern Oscillation events (Beamish *et al.* 2004; LaCroix *et al.* 2009; Araujo *et al.* 2013).

Habitat Trends

Trends in habitat are discussed in detail under the section on threats.

BIOLOGY

An extensive description of the biology of Coho Salmon is provided in Sandercock (1991). Additional details are available in Scott and Crossman (1973) and Hart (1973).

Life Cycle and Reproduction

Sexually mature Coho Salmon generally return to freshwater in the fall (September/October) and spawn during a protracted period throughout the fall and early winter. Spawning can occur as early as August and as late as March in some populations (Weitkamp *et al.* 1995; Holtby and Ciruna 2007). Interior Fraser Coho Salmon tend to spawn relatively late, with spawning activity peaking in mid-November, and often extending into January. All Coho Salmon die after spawning. Females construct several redds successively moving upstream. Incubation takes 40-50 days depending on water temperature; about 15-27% of eggs survive and fry emerge from the gravel between March and July. They usually remain in fresh water for a year before migrating to sea as smolts during April-June. Most Interior Fraser Coho Salmon (90%) spend 18 months at sea returning to fresh water in the fall to complete the 3-year life cycle. Deviation from the dominant 3-year life history is uncommon, and there is relatively little genetic exchange among broodlines. Based on a 2,274 fish sample aged from scales 93% went to sea in their second year, the remainder rearing in freshwater for an additional one or two years;

only two fish were aged as jacks (precocious mature males), and six fish spent more than one winter at sea (Irvine *et al.* 1999).

Coho Salmon range in length and weight at maturity from 45-70 cm (fork length), and from 2-5 kg, although fish over 12 kg have been caught (Scott and Crossman 1973; Sandercock 1991). Jacks are usually less than 30 cm in length. Interior Fraser Coho are smaller than most Coho Salmon from other parts of the range of similar age documented by Sandercock (1991) and Weitkamp *et al.* (1995). Fecundity increases with length and latitude but generally is in the range of 1500-7000 eggs per female (Sandercock 1991). Fecundities for Interior Fraser Coho are highly variable, and generally towards the lower end of this range (1500-3200) consistent with the generally smaller sizes of these fish. Female Coho Salmon are larger than males in most Interior Fraser streams, but less abundant (about 45% of returns), traits characteristic of many Coho Salmon populations.

Dispersal and Migration

Upon emerging from the gravel Coho Salmon fry school but subsequently become territorial and smaller fish may become displaced downstream or into less desirable habitat. Downstream migration into the ocean generally occurs in the spring as yearlings but a length of 10 cm appears to be the threshold for smoltification and adaptation to saltwater conditions (Sandercock 1991). The length of residency in the estuary is unclear but some juvenile Coho Salmon may spend a few months near their natal stream before migrating offshore. Some individual Coho Salmon do not undertake extended offshore migration but spend their entire marine existence near their natal stream. Similar to other salmonids, Coho Salmon return to spawn in the river system and tributary where they were born with amazing accuracy based primarily on olfactory cues. However, homing is not exact and a small percentage (<5%) stray to other adjacent watersheds.

Interspecific Interactions

Predation on Interior Fraser Coho Salmon while they reside in freshwater is primarily from Bull Trout (*Salvelinus confluentus*), Rainbow Trout (*Oncorhynchus mykiss*), Northern Pikeminnow (*Ptychocheilus oregonensis*), and cottids (*Cottus spp.*) (G. Wilson pers. comm. 2015). Other predators include herons (*Ardea herodias*), mergansers (*Mergus merganser*), and mink (*Neovison vison*). Predators in the marine environment include Dogfish (*Squalus acanthias*) and sharks as well as Bonaparte’s (*Chroicocephalus philadelphia*) and Glaucous-winged Gulls (*Larus glaucescens*), loons (*Gavia* spp.) and marine mammals (Harbour Seals (*Phoca vitulina*), sea lions (*Eumatopias jubatus and Zalophus californianus*), and Killer Whales (*Orcinus orca*)). On entering the ocean Coho Salmon feed primarily on invertebrates but rapidly become piscivorous targeting various forage fishes (Herring (*Clupea pallasi*), Anchovy (*Engraulis mordax*), Surf Smelt (*Hypomesus pretiosus*), Sand Lance (*Ammodytes hexapterus*), Capelin (*Mallotus villosus*), and Sardines (*Sardinops sagax*)). They also feed extensively on euphausiids and occasionally squid (*Loligo* sp.). Pritchard and Tester (1943,1944) report Coho Salmon consumed rockfish (*Sebastes* sp.), Sablefish (*Anoplopoma fimbria*), myctophids, Pacific Hake (*Merluccius productus*), Saury (*Cololabis adocetus*), Walleye Pollock (*Theragra chalcogramma*), and other Coho Salmon.

POPULATION SIZES AND TRENDS

The following metrics are used in interpreting population sizes and trends:

- Escapement refers to the number of adult spawners that return to their natal stream and have ‘escaped’ any fisheries.
- Fishing rate or exploitation rate is the fraction of the adult population removed as catch. Annual fishing rates have been estimated with a number of methods over the years. They were initially estimated using a mark-recapture method of coded wire tagged hatchery bred fish. When the annual fishing rates were reduced by regulation in the mid-1990s, the estimation method was based on genetic sampling (1998-2000) and fishery modelling based on annual fishing effort (2001-present) (Decker and Irvine 2013).
- Returns refers to the number of adult salmon arriving in coastal marine areas on their return to freshwater prior to interception by fisheries. Returns are determined from estimates of escapement and fishing rate, where returns = escapement / (1-fishing rate).
- Productivity is the number of returns per spawner, and is a measure of survival of cohorts from spawning until before fishing begins. Inter-generational productivity was estimated as $\ln(R_t/S_{t-3})$, where R_t is returns in year t, and S_{t-3} is the escapement three years earlier. Productivity compensation occurs whereby productivity increases as escapement declines. This results in a concave relationship between escapement and returns, otherwise known as the stock/recruitment relationship.
- Enhancement refers to the supplementation of the population by fry or smolts that have been produced artificially in a hatchery or other enclosure.

Interior Fraser Coho Salmon are distributed in approximately 100 rivers and streams, many of them extremely remote and difficult to access. Additionally, because the spawning migration occurs over a protracted period, observing the number of spawners (escapement) in each individual system is virtually impossible. Consequently, the estimation of escapement to each stream is by necessity incomplete over the available time series and adjustments to standardize the data have been incorporated into the estimates of abundance as described below and in Decker and Irvine (2013) and Decker *et al.* (2014). However, the resulting time series of escapement estimates to each watershed is believed to accurately reflect the relative abundance of the population.

Escapement

The escapement data for Interior Fraser Coho DU compiled by Decker and Irvine (2013) have been revised and updated and provide the basis for this report (Parken pers. comm. 2015). Reliable estimates of Interior Fraser Coho escapement are available only since 1975. Between 1975 and 1997, more effort was expended to estimate Coho Salmon escapement in the North and South Thompson watersheds. Survey coverage was extended in 1984 to include several key tributaries of the Lower Thompson, as well as the Seton and Bridge tributaries of the Middle Fraser. Surveys were mainly conducted by Fisheries Officers and hatchery staff but accuracy and repeatability remains unclear. Beginning in 1998, coverage in terms of the number of systems assessed and extent of coverage within previously assessed systems increased throughout the DU. Coverage was increased to include the Nahatlatch River (Fraser Canyon) and Quesnel watersheds in the Middle Fraser; in 1999, the Chilko watershed was added. In addition, more robust methods were employed, including Area-Under-the-Curve (AUC) methodology, mark-recapture and the calculation of survey life for AUC and expansion factors for peak count estimates, based on paired assessments using high precision methods and visual surveys (Decker and Irvine 2013). The escapement estimates for 1975 to 1997 were revised by IFCRT (2006) based on calibration studies where paired assessments were conducted from 1998 to 2000. Spawner estimates from return years 1998 to 2013 were also reviewed for data quality (Parken pers. comm. 2015). Missing spawner data were common and an infilling algorithm was used to generate estimates for missing data.

Coho are semilparous with a 3-year life span giving 3 almost independent broodlines. There is a tendency for certain broodlines to dominate the total population and, in order to smooth this cyclic dominance, a 3-year running mean of the annual escapement and return values is used to describe and analyze trends. When trends are described in this report, the cited years are the mid-year of the 3-year period. This smoothing approach is commonly used for Pacific Salmon species (Grant *et al.* 2011).

The change in the number of mature individuals over the last 10 years was calculated in 2 ways: (1) based on the slope of a log linear regression for the entire time series and (2) based on the slope for the last 10 years data. The former is consistent with IUCN guidelines for widely fluctuating populations (IUCN 2011, guideline 4.5.1) and with what is suggested for Sockeye Salmon (*Oncorhynchus nerka*) by Porszt *et al.* (2011) and d'Eon-Eggertson *et al.* (2014). In both cases, the percent change in abundance over 10 years was estimated as 100*(exp(10*b)-1) where b is the slope of the respective log linear regression.

Hatchery Production

A complication to the assessment of total Coho Salmon abundance in the Interior Fraser watershed has been the introduction of hatchery fry and smolts (i.e., enhancement). Hatchery production of Interior Fraser Coho Salmon began in the late 1970s for fry and the early 1980s for smolts. Fry releases ranged from 1.5-2.5 million annually during the peak of production in the 1980s, but have remained under 400,000 since 2000 (Decker and Irvine 2013). Annual smolt releases peaked during 1999-2002 at 350,000-400,000, and declined to 200,000-250,000 in recent years. At the peak, about 13 enhancement projects were in operation. All brood stock was taken from the same subpopulations into which the progeny were released and are therefore intra-limital. The proportion of total escapement to the area in the period 1990-2004 that were of hatchery origin averaged 15.7% annually. This declined to 6.9% for the period 2005-2012 (Decker *et al.* 2014). Enhancement activities are described in more detail by Irvine *et al.* (1999, 2000) and the IFCRT (2006).

The majority of hatchery-origin Coho Salmon returning to the Interior Fraser streams spawn naturally in the wild. As a result, these first generation hatchery fish are included in escapement surveys of spawners in enhanced streams. Prior to 1998, 21% of hatchery fry and 56% of hatchery smolts on average were marked by removal of the adipose fin prior to release. After 1998, marking rates were reduced to averages of 2% and 23% for fry and smolts, respectively (Decker *et al.* 2014). Based on the proportion of marked released hatchery smolts, and the proportion of marked returning adults, estimates of escapement can be determined for Coho Salmon that are the progeny of wild spawned fish and for those of hatchery origin. However, the estimates are biased because of straying by hatchery fish and the definition of what constitutes 'wild' fish under the Wild Salmon Policy (DFO 2005).

Hatchery produced fish were considered to be a manipulated population for the purposes of this report because the brood stock was intra-limital (COSEWIC 2010, guideline 3). However, first generation hatchery origin spawners were excluded from the evaluation of quantitative criteria because it was not demonstrated that they had a net positive impact on the wildlife species.

Returns, Escapement, Fishing Rate and Productivity

Northcote and Burwash (1991) analyzed commercial fishery catch records and estimated that the average annual returns (catch plus spawners) of Fraser River Coho Salmon in the 1920s to early 1930s was approximately 1.2 million fish. Assuming about one third of these fish were from the Interior Fraser (from genetic stock ID of commercial catches), returns of Interior Fraser Coho during this period were about 400,000 fish. Assuming a 50% fishing rate they concluded that the annual spawning escapement of Interior Fraser Coho was about 200,000 fish. They further estimated that Coho Salmon in the Fraser watershed declined 7.7-fold between the 1920s and the 1950s through 1980s (reported in Decker and Irvine 2013). However, they cautioned that the data for Coho Salmon were the least reliable of those available for Pacific salmon.

Decker and Irvine (2013) and Decker *et al.* (2014) provide reconstructions of the escapement, returns, fishing rate, and marine survival rate since 1975 for Interior Fraser Coho. Parken (pers. comm. 2015) provided a revised escapement time series for 1975-2013 and Parken pers. comm. (2016) provided escapement estimates for 2014-2015 (Parken pers. comm. 2016) (Table 2). There were annual escapement estimates for the North and South Thompson subpopulations for all years since 1975. Estimates for the Lower Thompson and Middle/Upper Fraser have been available since 1984 and data for the Fraser Canyon have only been available since 1998. From 1998-2013, approximately 90% of the escapement came from subpopulations other than the Fraser Canyon. Consequently, trends in escapement, returns, fishing rate and productivity for the entire DU are described based on data from the Thompson River and the Middle/Upper Fraser River for the period 1984-2012. Trends in escapement for each subpopulation are also described.

Table 2. Summary of wild Coho Salmon escapements for subpopulations in the Interior Fraser DU (1975-2013, Parken, 2015 pers. comm., 2014-2015, Parken, 2016 pers. comm.). Also shown are estimated fishing rate, and adult recruits/spawner (wild escapement/total return). The smolt-adult (marine) survival estimates are for Strait of Georgia wild Coho Salmon indicator stocks.

Year	Escapement							
	South Thompson	North Thompson	Lower Thompson	Mid/Upper Fraser	Fraser Canyon	Fishing Rate*	Recruit/ Spawner*	Smolt Adult Survival*
1975	8,335	27,493				68.1%		-
1976	5,658	25,367				68.1%		-
1977	12,731	30,334				68.1%		6.5%
1978	11,647	32,299				68.1%	3.7	9.7%
1979	14,659	21,307				68.1%	3.7	7.4%
1980	9,579	10,936				68.1%	1.4	10.1%
1981	5,460	21,057				68.1%	1.9	7.1%
1982	7,781	23,633				68.1%	2.7	4.8%
1983	7,986	21,484				68.1%	4.4	9.5%
1984	16,946	41,396	6,808	4,726		68.1%	6.8	9.9%
1985	18,294	17,986	4,365	5,189		68.1%	3.9	13.2%
1986	16,884	30,692	4,002	1,876		65.7%	4.1	12.5%
1987	23,281	31,262	5,923	3,529		53.7%	1.7	11.9%
1988	27,552	35,039	6,059	7,940		71.2%	4.8	18.2%
1989	18,610	24,556	6,519	6,673		64.5%	2.4	12.5%
1990	10,320	17,551	8,172	2,593		73.7%	1.9	13.2%
1991	4,612	12,243	7,017	2,962		67.7%	0.9	8.1%
1992	13,565	15,929	7,976	6,193		81.5%	3.1	11.1%
1993	2,534	6,552	15,556	7,624		87.6%	3.9	7.1%
1994	4,918	14,898	10,389	1,912		43.3%	1.4	8.0%
1995	4,055	12,463	5,345	2,367		56.2%	0.9	5.8%
1996	1,373	5,923	1,854	1,183		83.5%	1.8	5.8%
1997	1,420	8,518	7,521	1,665		40.5%	0.7	4.7%
1998	5,155	9,786	2,165	4,851	5,460	7.0%	1.2	3.7%
1999	3,137	10,696	3,992	1,652	4,096	9.0%	2.3	2.2%
2000	3,307	8,054	4,739	3,920	2,719	3.4%	0.9	4.2%
2001	13,063	27,238	9,522	6,162	5,971	7.1%	2.1	5.9%
2002	10,544	22,083	16,053	4,170	3,817	7.1%	2.0	5.0%
2003	3,422	7,211	2,933	3,809	4,552	12.6%	1.0	2.7%
2004	15,850	10,661	4,304	4,760	5,872	13.5%	0.7	3.7%
2005	2,302	4,518	2,614	2,189	2,269	13.0%	0.3	1.1%
2006	2,003	3,670	1,082	1,301	1,605	9.4%	0.4	1.2%
2007	12,345	24,500	10,169	9,958	2,739	11.2%	1.5	1.3%
2008	6,688	3,849	3,800	1,464	1,138	9.8%	1.2	1.1%
2009	3,821	9,631	4,768	2,306	2,308	11.5%	3.0	3.2%
2010	8,946	12,159	12,217	4,689	2,227	11.2%	0.7	1.6%
2011	4,771	8,803	7,289	3,920	3,189	12.4%	1.7	1.3%
2012	13,303	20,058	11,559	7,127	5,134	11.3%	2.8	2.2%
2013	13,132	16,271	11,970	11,870	5,398			1.0%
2014	1,943	5,139	6,156	3,081	1,048			0.3%
2015	1,894	2,967	4,391	1,288	352			

*Taken from Table 2 in Decker *et al.* (2014).

The 3-year average returns to the Interior Fraser varied between 125,000 and 184,000 between 1985-1993 (Figure 4). Returns then declined sharply reaching a low of 22,000 in 1999. Returns increased to 41,000 in 2001 but then declined again to 17,000 in 2005. Returns increased again, reaching a 3-year average of 41,000 in 2011, the last year of available data.

The 3-year average escapement varied around 60,000 from 1985-1989 (Figure 4). Escapement subsequently declined to a low of 16,000 in 1997. This was followed by an increase to 39,000 in 2001, then another decline to 15,000 in 2005. Escapement increased again to 41,000 in 2012, but declined in the last 2 years reaching 21,000 in 2014.

The fishing rate averaged about 66% during the period 1984-1997 (Figure 5). With the realization that the number of returns and escapement were declining rapidly in the 1990s, a recovery program was initiated in 1998 and measures were implemented to reduce the fishing rate to below 13% (Decker *et al.* 2014). The fishing rate has averaged 10% since 1998.

Decker *et al.* (2014) noted two distinct periods in the stock/recruitment relationship for Interior Fraser Coho (Figure 6). Productivity per escapement was considerably higher for return years 1987-1993 than for years 1994-2012. This change corresponds approximately to a 1989-1990 change in marine conditions (Beamish and Bouillon 1993; Irvine and Fukuwaka 2011). It is also evident in annual smolt-adult survival (also referred to as marine survival) estimates for Coho Salmon indicator stocks (Figure 7). Marine survival averaged about 12% from 1984-1992, then declined to 1.1% in 2005. Since then, marine survival has averaged 1.4% and the last two available values being the lowest in the time series, 1% in 2013 and 0.3% in 2014. The trend in marine survival suggests that reduced productivity of Interior Fraser Coho Salmon is primarily a result of poor marine survival as opposed to reduced freshwater survival of smolts (Decker *et al.* 2014). With this change in marine survival, the high fishing rates in the early 1990s were unsustainable, resulting in the steep decline in returns and escapement. The reduced fishing rate has allowed some recovery in escapement. However, further recovery is unlikely and the population may well decline if the low productivity conditions prevail.

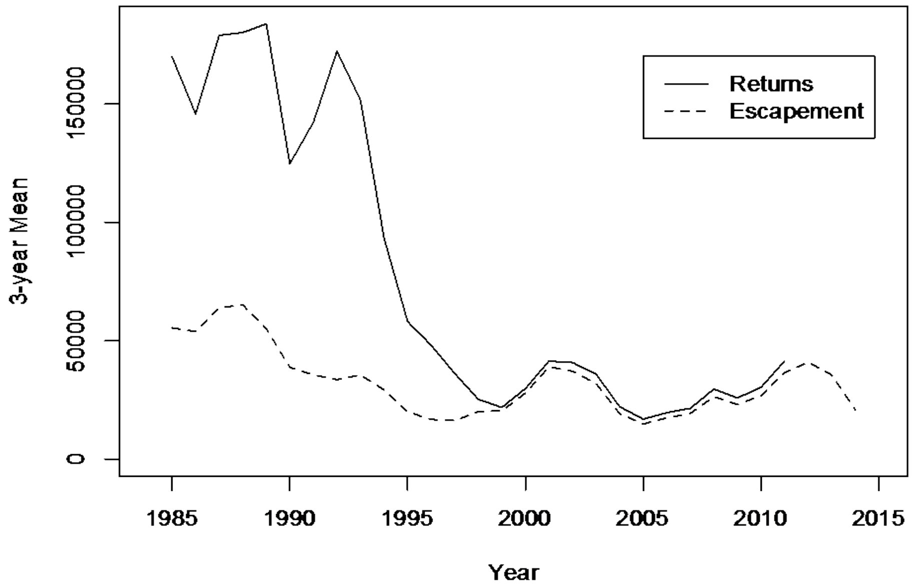

Figure 4. Three-year running mean estimates of returns and escapement for Interior Fraser Coho. Data are given in Table 2.

Figure 5. Fishery exploitation rate for Interior Fraser Coho. Data from Decker *et al.* 2014.

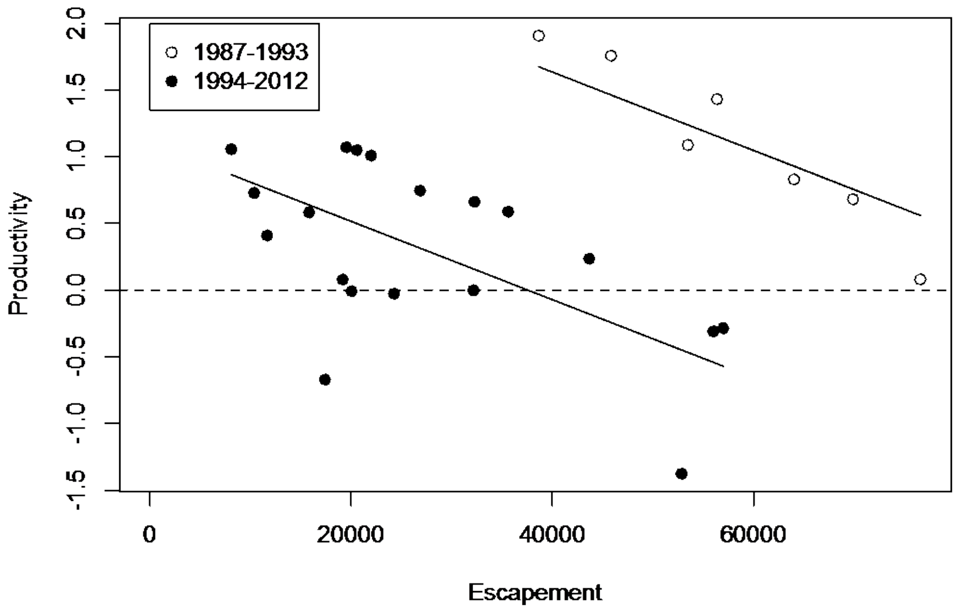

Figure 6. Productivity vs. escapement for Interior Fraser Coho showing periods of high productivity (1987-1993 return year) and low productivity (1994-2012 return year).

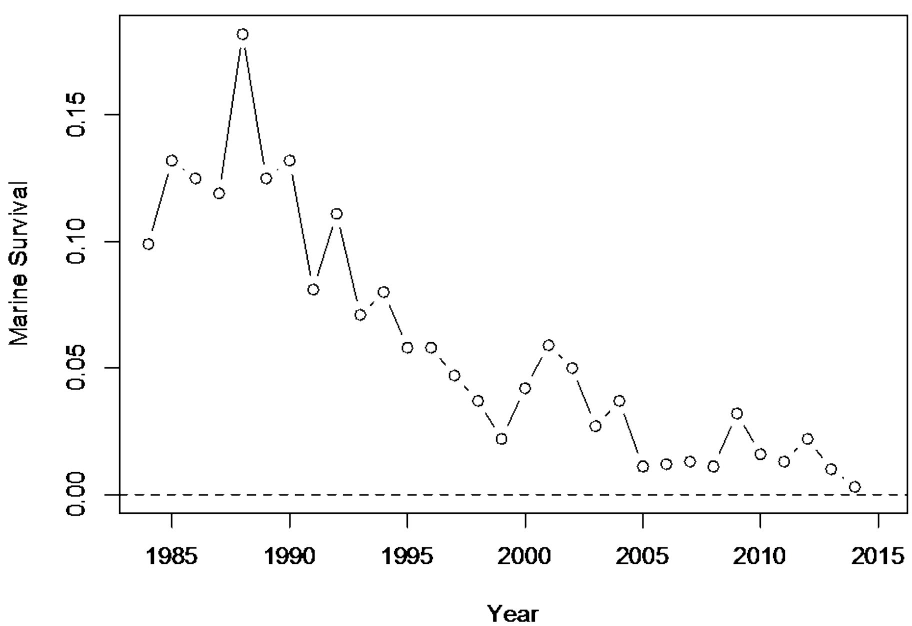

Figure 7. Estimated marine survival rate of Strait of Georgia wild Coho indicator stocks. These are assumed to be indicative of conditions experienced by Interior Fraser Coho. Data from Decker *et al*. 2014.

Rate of Change in Abundance

The 3-year average escapement to the South Thompson varied over the period 1976-2014 with peaks occurring in 1978 (13,000), 1988 (23,100), 2003 (9,900), and 2012 (10,400) (Figure 8). The most recent escapement was 5,600. The estimated slope over the entire time series was negative (-0.0247 yr^{-1}) and significant (p=0.0029). The estimated change over 10 years using the slope for the entire time series was -22%. The estimated slope for the last 10 years was positive (0.037 yr^{-1}) and non-significant (p=0.3220) (Table 3). The estimated change in abundance over 10 years using the slope from the last 10 years was +45%.

The 3-year average escapement to the North Thompson followed a similar pattern to the South Thompson with peaks in 1977 (29,300), 1987 (32,300), 2001 (19,100), and 2012 (15,000) (Figure 8). The most recent escapement was 8,100. The estimated slope over the entire time series was negative (-0.0343 yr^{-1}) and significant (p<0.0000). The estimated change over 10 years using the slope for the entire time series was -29%. The estimated slope for the last 10 years was positive (0.055 yr^{-1}) and non-significant (p=0.2691) (Table 3). The estimated change in abundance over 10 years using the slope from the last 10 years was +72%.

The escapement time series for the Lower Thompson peaked in 1993 (11,300), 2001 (10,100), and 2011 (10,400). The most recent value was 7,500. The estimated slope over the entire time series was positive (0.0019 yr^{-1}) and non-significant (p=0.8320). The estimated change over 10 years using the slope for the entire time series was +2%. The estimated slope over the last 10 years was positive (0.1515 yr^{-1}) and significant (p<0.0000). The estimated change over 10 years using the slope from the last 10 years was +355%.

The escapement time series for the Middle/Upper Fraser peaked in 1988 (6,047), 2001 (4,751), and 2012 (7,639). The most recent value was 5,400. The estimated slope over the entire time series was positive (0.0030 yr^{-1}) and non-significant (p=0.6930). The estimated change over 10 years using the slope for the entire time series was +3%. The estimated slope over the last 10 years was positive (0.0932 yr^{-1}) and significant (p=0.0110). The estimated change over 10 years using the slope from the last 10 years was +154%.

The escapement time series for the Fraser Canyon was the shortest of the 5 subpopulations and it peaked in 2002 (4,800) and 2012 (4,600). The most recent value was 2,300. The estimated slope over the entire time series was negative (-0.0471 yr^{-1}) and significant (p=0.0290). The estimated change over 10 years using the slope for the entire time series was -37%. The estimated slope over the last 10 years was positive (0.0129 yr^{-1}) and non-significant (p=0.7730). The estimated change over 10 years using the slope from the last 10 years was +14%.

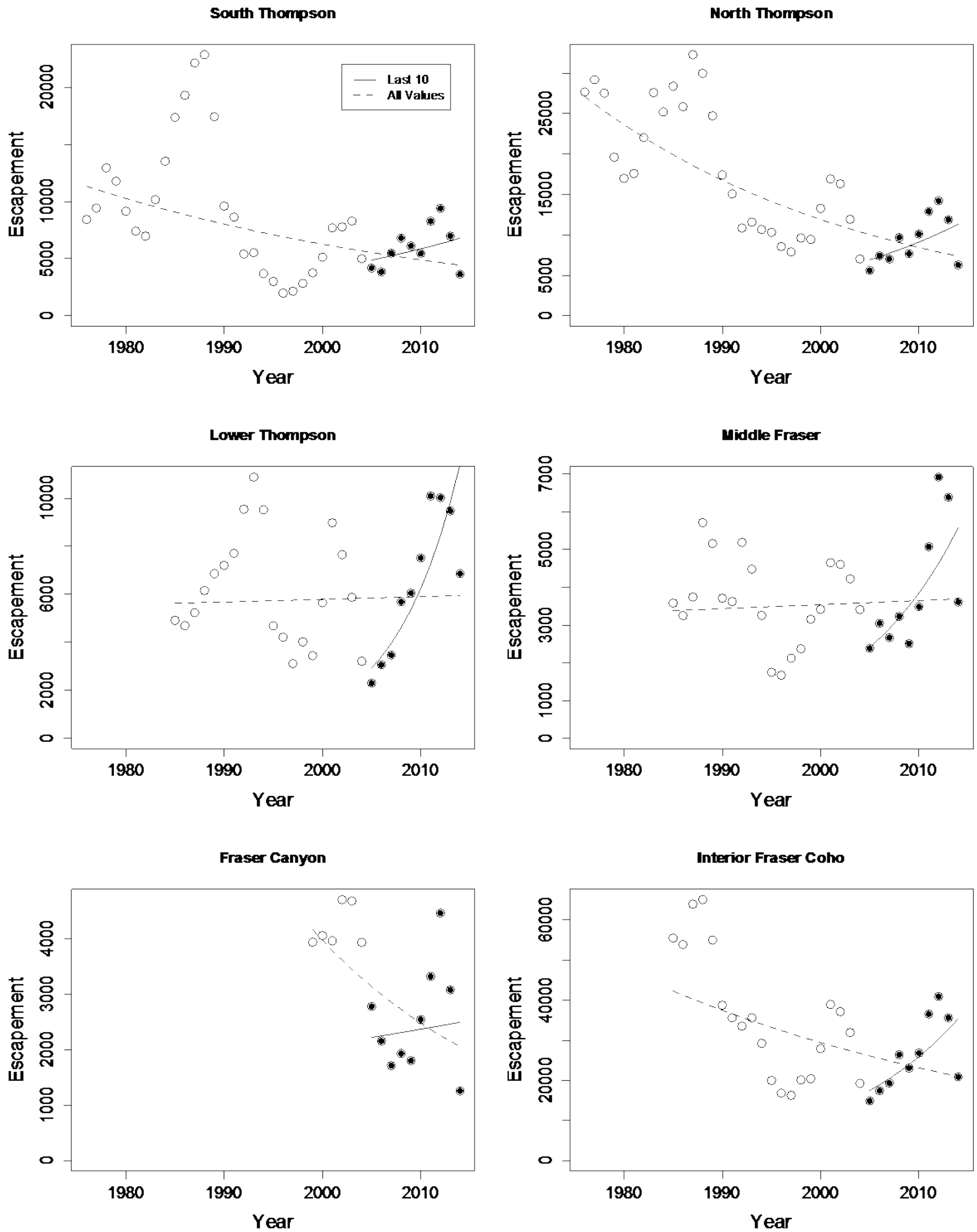

Figure 8. Trend in 3-year mean escapement of the 5 subpopulations of Interior Fraser Coho and the DU combined time series. Two log-linear regression lines are shown for each, one fit to the last 10 years (3 generations) and one fit to all values.

Table 3. Regression statistics for estimated rate of change in abundance for Interior Fraser Coho Salmon subpopulations. Two slope estimates from log-linear regressions are presented, one for the most recent 10 years (2006-2015) and one for the entire available time series. The remaining columns give the probability values of the slope estimates, the regression R^2, the number of observations in each regression, and the estimated change in abundance over a 10-year period. Values in bold and italic font are statistically significant at p<0.05.

Subpopulation	Years	Slope	Pval	R^2	Nobs	Change
South Thompson	1976-2014	***-0.0247***	0.0029	0.2163	39	***-21.9%***
	2005-2014	0.0370	0.3220	0.1222	10	44.7%
North Thompson	1976-2014	***-0.0343***	0.0000	0.5863	39	***-29.0%***
	2005-2014	0.0545	0.1240	0.2691	10	72.4%
Lower Thompson	1985-2014	0.0019	0.8320	0.0016	30	2.0%
	2005-2014	0.1515	0.0000	0.7654	10	354.7%
Middle Fraser	1985-2014	0.0030	0.6930	0.0057	30	3.1%
	2005-2014	0.0932	0.0140	0.5503	10	153.9%
Fraser Canyon	1999-2014	***-0.0471***	0.0290	0.2971	16	***-37.5%***
	2005-2014	0.0129	0.7730	0.0110	10	13.7%
Interior Fraser	1985-2014	***-0.0241***	0.0050	0.2481	30	***-21.4%***
	2005-2014	***0.0782***	0.0234	0.4941	10	***118.5%***

The escapement time series for the entire Interior Fraser DU, comprising data from the Thompson River and the Middle/Upper Fraser from 1985-2014 has three peaks in 1988 (65,600), 2001 (43,000), and 2012 (43,400). The most recent value was 26,700. The estimated slope over the entire time series was negative (-0.0241 yr^{-1}) and significant (p=0.0050). The estimated change over 10 years using the slope for the entire time series was -21%. The estimated slope over the last 10 years was positive (0.0782 yr^{-1}) and significant (p=0.0234). The estimated change over 10 years using the slope from the last 10 years was +119%.

In summary, the escapement time series in the North and South Thompson rivers and the Fraser Canyon show a long term declining trend. All three had increases in escapement in the last 10 years, but the most recent escapement was considerably lower and among the lowest values in the times series. The long term time series of escapement in the Lower Thompson and Middle/Upper Fraser showed little long term trend but a considerable increase over the past 10 years. The combined time series for Interior Fraser Coho is dominated by the North and South Thompson Rivers. It shows a long term decline in escapement but a recent increase. However, the most recent escapement value is considerably lower than the three preceding values and the marine survival rate is the lowest seen. This suggests escapement may decline further in the future..

Rescue Effect

Interior Fraser Coho Salmon are ecologically discrete and evolutionarily significant from other Canadian Coho populations (see **Designatable Units**). There is no linkage with Coho Salmon populations outside Canada. Consequently, rescue is not possible.

THREATS AND LIMITING FACTORS

Irvine (2002) identified excessive exploitation, degradation of freshwater habitat, climate related changes in salmon survival, and human population growth as the most important threats to Interior Fraser Coho Salmon. These threats continue to be important. The human population in the Pacific Northwest (including British Columbia) is expected to continue to increase in the longer term and given the negative effects on salmon abundance at a global scale (Hartman *et al.* 2000; Lackey 2001) these threats will continue to impact these populations.

Freshwater Habitat

This section informed the completion of the Natural System Modifications main threat in the IUCN Threats Calculator (Appendix 1). The threats were determined to be pervasive in scope and to have a slight severity.

Productive freshwater habitats maximize the production of smolts per spawner and can help sustain salmon populations during periods of adverse marine conditions or excessive fishing. Because juvenile Coho Salmon of the Interior Fraser spend at least a full year in freshwater, they are susceptible to freshwater habitat degradation. Bradford and Irvine (2000) found that the rate of decline of Coho Salmon escapements to 40 streams in the North and South Thompson watersheds was related to the extent of human impact during 1988-1998. Rate of decline was correlated with agricultural land use, road density, and a qualitative index of stream habitat status (Figure 9). More intensive land use may explain why Coho Salmon escapements to streams in the South Thompson declined more quickly than in the North Thompson during 1975-1998. Epp (2014) provides a detailed analysis of the impact of water withdrawal on available habitat for salmon including Coho Salmon in the South Thompson watershed.

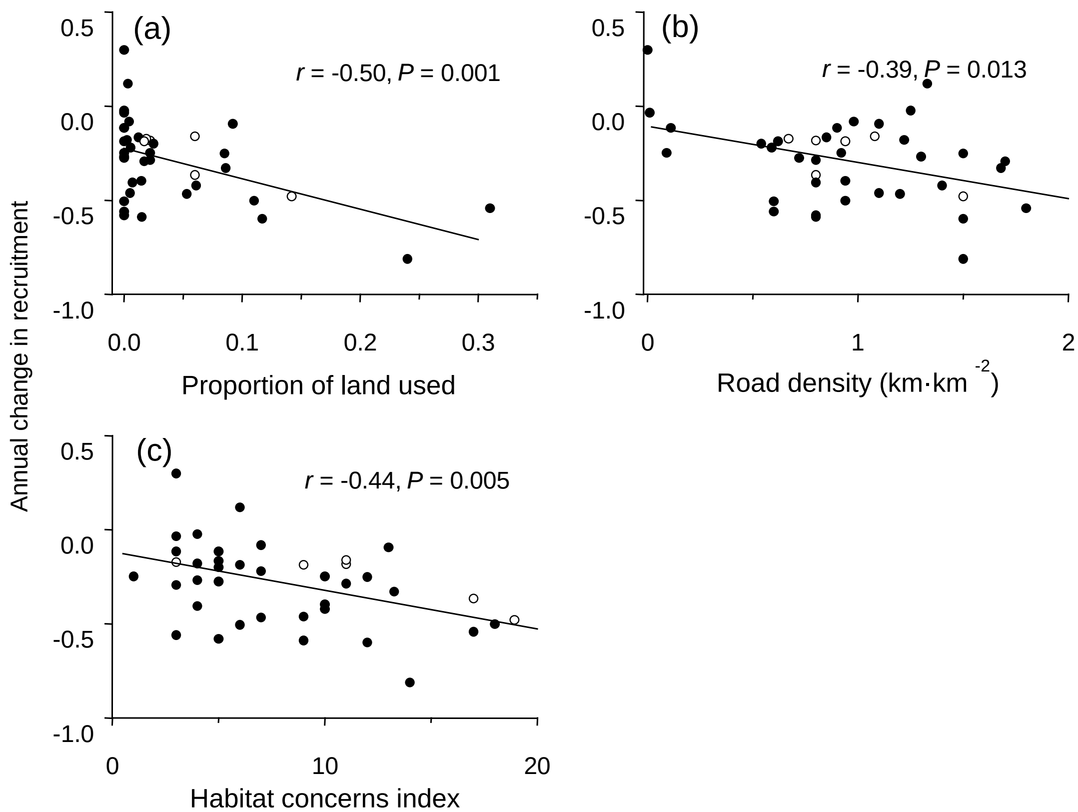

Figure 9. Correlations between three land use indices and productivity (ln(recruits/spawner)) of Coho Salmon for 40 streams in the Thompson River watershed. a) proportion of land in each catchment dedicated to agricultural or urban use; b) density of forest, agricultural and hard surface roads in each catchment; and c) index of habitat concerns. Open circles are streams that have had hatchery programs (taken from Decker and Irvine 2013).

Coho Salmon habitat in the interior Fraser River has been impacted by logging of many valley bottoms that have since supported agriculture (mainly livestock, dairy, and animal feed crops) for over 50 years (Burt and Wallis 1997). All spawning streams within the Lower Thompson watershed, and many spawning streams or sites in other systems have been impacted by this activity. Riparian vegetation has been removed, livestock have destabilized stream banks, and off-channel habitats and wetlands have been destroyed or isolated by dike construction in some locations (Brown 2002). Forest harvesting in the headwaters of many watersheds leads to degradation of the stream channel, increased summer stream temperatures, and altered seasonal hydrographs (Meehan 1992). The recent Mountain Pine Beetle (*Dendroctonus ponderosae*) infestation in the interior Fraser River watershed has resulted in the loss of large tracts of mature forest in important spawning drainages occupied by the South and Lower Thompson, and Middle/Upper Fraser subpopulations. Linear developments (e.g., highways, railways, pipelines) are another threat, particularly for the South Thompson, North Thompson and Lower Thompson. Risks to Coho Salmon from linear developments include catastrophic spills of deleterious substances (e.g., McCubbing *et al.* 2006) and habitat losses associated with stream crossings, stream channelization, erosion, and removal of riparian vegetation. The proposed expansion of the Kinder Morgan pipeline in British Columbia represents a potential threat to the North Thompson and the Nicola system within the Lower Thompson (Decker and Irvine 2013). The recent breach of the Polley Mine tailings pond and release of toxins into Quesnel Lake in the Mid/Upper Fraser watershed represents a current and potential future threat that may exist in other areas. The Fraser Canyon subpopulation could lose more than 90% of its spawning habitat, and may no longer be viable if the Nahatlatch River above Frances Lake were damaged (IFCRT 2006). The other systems are less vulnerable to localized catastrophic events because spawning is distributed among a number of spawning streams.

The southern and western portions of the Thompson River watershed, which includes the Lower Thompson and Nicola systems, and a portion of Shuswap Lake (South Thompson watershed), are semi-arid, experiencing significant surface water withdrawal in summer for irrigation resulting in low flows and high water temperatures (Rood and Hamilton 1995; Walthers and Nener 2000), leading to increased juvenile mortality, and limiting adult access to spawning habitat (Rosenau and Angelo 2003). Demand for surface water and groundwater to support urban development and agriculture is increasing in the Thompson River watershed, and represents a growing threat.

Interior Fraser Coho Salmon have not been heavily affected by hydroelectric development. However, reduced stream flow, changes to the natural hydrography, and impacts to smolt passage from hydroelectric developments in the Bridge and Seton watersheds may have impacted the Middle/Upper Fraser subpopulations to an unknown degree. Landslides or other impacts have produced blockages of Interior Fraser Coho Salmon migration routes such as at Hells Gate in the Fraser River Canyon. Little Hells Gate in the North Thompson River, downstream of all spawning locations for the Upper North Thompson, and the Nahatlatch Canyon, downstream of all spawning locations for the Fraser Canyon subpopulations (IFCRT 2006) have impacted these Coho Salmon populations as well. Hells Gate and Little Hells Gate continue to act as barriers to upstream migrating Coho Salmon at certain flows (IFCRT 2006), and may be exacerbated by reductions in fish size. Natural or human alterations of channel morphology at these or other critical locations represent future threats to Interior Fraser Coho populations.

Loss of off-channel and small stream habitat in the lower Fraser River, as a result of flood control and agricultural development, represent a reduction in freshwater carrying capacity for Interior Fraser Coho Salmon. Most of the streams in the lower Fraser River valley are classified as threatened or endangered due to draining of wetlands for agriculture and residential development, dyke construction for flood control, riparian zone degradation, and pollution (FRAP 1998; Langer *et al.* 2000; Brown 2002; Rosenau and Angelo 2005). An estimated 70% of wetland habitats have been isolated from the lower Fraser River floodplain by dyke systems (Birtwell *et al.* 1988). For example, Sumas Lake consisting of 3,600 ha of open water and 8,000 ha of marshland and sloughs, potentially supporting

230,000 overwintering juvenile Coho Salmon (Brown 2002), was drained and converted to farmland in 1924 (Decker and Irvine 2013). The rate of habitat loss likely slowed following the introduction of DFO's "no net loss" habitat policy in 1986 (Langer *et al.* 2000; Levings 2000). Detailed descriptions of impacts to habitat for specific Interior Fraser Coho subpopulations are found in Fraser River Action Plan (FRAP) reports (e.g., Harding *et al.* 1994; DFO 1998a,b), and the Interior Fraser Coho Recovery Team report (Appendix 4 of IFCRT 2006). Implications of the recent changes to the *Fisheries Act* with respect to future habitat protection are unclear.

Estuary and Marine Habitat

This section informed the completion of the Pollution main threat in the IUCN Threats Calculator (Appendix 1). The threats were determined to be pervasive in scope and to have a slight severity.

The area around the lower Fraser River is heavily populated and an estimated 70 to 90% of estuarine habitats have been lost including 99% of seasonally flooded habitats (Birtwell *et al.* 1988; Langer *et al.* 2000; Levings 2000). The Fraser River watershed drains about one quarter of the British Columbia land area and as a consequence has been heavily inundated by various pollutants including sewage, agricultural runoff, mine and mill waste resulting in elevated levels of aluminum, iron, zinc and phosphorus. As well, elevated fecal coliform and turbidity in the lower river and its estuary occur, particularly during the spring freshet when Coho Salmon smolts from the Interior Fraser are undertaking their seaward migration (Chittenden *et al.* 2010). The extent to which Interior Fraser Coho Salmon utilize estuarine habitats in the lower Fraser River is not well understood. Juvenile Coho Salmon possibly including those from all Interior Fraser watersheds are present in the Fraser River estuary from mid-March to mid-June (Northcote 1974).

Marine areas used by Coho Salmon from the Fraser River are less impacted than the Fraser estuary, but because these stocks remain closer to the coast than other salmon they may be more susceptible to natural and human-made changes to the marine ecosystem. However, localized impacts from pulp mills, sewage effluent, and fish farms are difficult to quantify. Early ocean residence has been found to be a critical survival period for Pacific salmon (Peterman 1987; Pearcy 1992; Downton and Miller 1998), but how this may be linked to degradation of marine habitat is unclear. An emerging potential new threat to Pacific salmon is the occurrence of microplastic debris in marine waters. Deforges *et al.* (2014) documented the presence of such particles in coastal BC waters. DesForges *et al.* (2015) demonstrated uptake of these particles by copepods and euphasids in the same waters and from these results estimated uptake rates by juvenile and adult Pacific salmon. The impact of microplastics on marine organisms is poorly understood at present. For Interior Fraser Coho Salmon, habitat degradation, both estuarine and marine, is a threat that is not well understood.

Climate Change

This section informed the completion of the Climate change and severe weather main threat in the IUCN Threats Calculator (Appendix 1). The threats were determined to be pervasive in scope and to have a moderate - slight severity.

Climate change is expected to have significant impacts on freshwater habitat for Interior Fraser Coho Salmon. Modelling effects of climate change scenarios on stream temperatures and hydrology in several watersheds in the Middle/Upper Fraser system showed that increased air temperatures were likely to result in significant contractions in the range of suitable habitat for Coho Salmon during the next 80 years in most watersheds (but possible expansions in others) (Porter and Nelitz 2009). The Lower and South Thompson watersheds have considerably warmer climates than the Middle/Upper Fraser, and impacts to the associated systems (South Thompson and Lower Thompson) will presumably be more severe. Warmer temperatures will exacerbate the threat from non-indigenous spiny-ray fishes that have higher temperature preferences and thermal tolerances than Interior Fraser Coho Salmon (Bradford *et al.* 2008a,b; Tovey *et al.* 2008).

The weight of scientific evidence and opinion suggests that the overall effect of climate change on Pacific salmon and Coho in particular will be negative (e.g., Bradford 1998; Beamish *et al.* 1999; Hartman *et al.* 2000; Lackey 2001; Irvine 2004; Healey 2011; Irvine and Fukuwaka 2011). The threat of future climate change to Interior Fraser Coho Salmon while not imminent, represents a future concern because: 1) smolt-adult survival is correlated with climate-induced regime shifts and inter-annual variability in sea surface temperatures and ocean currents, 2) warmer temperatures are expected to substantially reduce usable habitat, carrying capacity and productivity in both the freshwater and marine environments, and 3) human-induced climate effects will not be reversible in the short term (Decker and Irvine 2013). Irvine and Fukuwaka (2011) examined recent trends in North Pacific salmon abundance and found that changing climate conditions have benefited Pink (*Oncorhynchus gorbuscha*) and Chum (*Oncorhynchus keta*) Salmon, while negatively impacting Coho and Chinook Salmon. Coho Salmon may be more sensitive to climate change impacts because of their relatively long freshwater residency and preference for nearshore marine ecosystem, which is likely to be more affected than open ocean habitats.

Marine Survival

A number of studies have highlighted climate change impacts on marine ecosystems and the resultant reductions in smolt-adult survival for Coho and other Pacific salmon (e.g., Beamish *et al.* 1999, 2000; Coronado and Hilborn 1998; Irvine and Fukuwaka 2011). The available data for Interior Fraser Coho Salmon indicates that survival from the time of sea entry by smolts to their subsequent return as adults had declined substantially by the late 1980s (Figure 7) despite reductions in fishery removals. Warmer ocean conditions have also been associated with changes in ocean transport conditions and available food types resulting in reduced ocean survival of Coho Salmon in the northern California Current system (Bi *et al.* 2011, Losee *et al.* 2014). Marine survival remains very low with the lowest observed values in 2013 and 2014. There is no indication that conditions will improve in the near future.

Fisheries

This section informed the completion of the Biological resource use main threat in the IUCN Threats Calculator (Appendix 1). The threats were determined to be pervasive in scope and to have a negligible severity.

Fishing represents a direct and potentially severe threat to Interior Fraser Coho Salmon (Decker and Irvine 2013). During several years in the 1990s fishing was responsible for the direct mortality of >70% of the total returning adult population (Figure 5). Bradford's (1998) risk assessment for Thompson River Coho Salmon concluded that fishing mortality played a significant role in the decline of the population because exploitation was not reduced in the early 1990s to compensate for declines in productivity (Figure 6).

Reduced fishing rates since 1998 have halted the decline in the number of Coho Salmon returning to the Interior Fraser, despite continued low productivity. However, in several recent years when productivity was below replacement (< 0 in Figure 6), even modest fishing contributed to negative population growth.

Uncertainty about survival of Coho Salmon released as by-catch in fisheries targeting other salmon species or wild Coho Salmon released in recreational fisheries where only hatchery-marked Coho Salmon may be retained are additional sources of uncertainty in fishing rate estimates. Unsustainable fishing mortality is a threat for all systems within the Interior Fraser given overlap in run-timing among subpopulations, and the absence of system specific estimates of fishing rate.

Hatchery Production

This section informed the completion of the Agriculture & Aquaculture main threat in the IUCN Threats Calculator (Appendix 1). The threats were determined to be pervasive in scope and to have an unknown severity.

Interactions between hatchery and wild Coho Salmon can occur in a number of ways in the freshwater habitat. Wild Coho Salmon fry may be negatively impacted if the hatchery fry releases in a stream exceed the stream's carrying capacity (Fleming 2002). Excessive interbreeding of hatchery-origin with wild fish impacts genetic diversity and fitness of wild Coho Salmon (Berejikian and Ford 2004; Fleming 2002). Other risks include transfer of diseases and parasites from hatchery to wild fish, and increased mortality for wild Coho Salmon that co-migrate with abundant hatchery fish that attract more predators and fishing effort (Nickelson 2003). Hatchery production of Coho Salmon in the Interior Fraser began in the 1980s and has been fairly minor relative to other areas of British Columbia (e.g., Strait of Georgia, Lower Fraser) or the US Pacific Northwest (IFCRT 2006). Previous studies concluded that hatchery supplementation had a relatively minor effect on overall population trend for the Interior Fraser DU (Bradford and Irvine 2000; Irvine 2002; IFCRT 2006), but the Lower Thompson River was dominated by fish of hatchery origin (60% of escapements in 1998-2000; Irvine 2002), as were several enhanced streams in the North and South

Thompson watersheds (IFCRT 2006). Production of hatchery fry and smolts has been reduced resulting in lower proportions of hatchery fish spawning in natural habitat. The mean proportion of hatchery fish in escapements for the most recent generation (2005-2013) was 6.9% (Table 2) compared to 15.7% in 1990-2004. Hatchery efforts are now focused on rebuilding depressed stocks and maintaining coded wire tag programs to provide smolt-adult survival and fishing rate estimates using hatchery indicator stocks (IFCRT 2006).

Interactions between wild and hatchery Coho Salmon can also occur in coastal and pelagic marine environments (Noakes *et al.* 2000) and include competition for resources, transfer of diseases and parasites, and increased predation and fishing mortality for wild fish that co-migrate with large numbers of hatchery fish (Beamish *et al.* 1997). Large enhancement programs for Coho Salmon in other regions may impact Interior Fraser Coho more than enhancement within the interior Fraser River watershed. Beamish *et al.* (2008) estimated that the percentage of hatchery-reared Coho Salmon in the Strait of Georgia increased from near 0% in the early 1970s to a peak of nearly 75% in the late 1990s, and then declined to about 25% by 2006. Total production of hatchery Coho Salmon (mostly smolts) was about 8 million for British Columbia, and about 70-80 million for British Columbia, Washington and Oregon combined during the late 1990s, declining to about 5 million and 50 million, respectively, by 2010 (PSCSFEC 2013). Hatchery production of Coho Salmon throughout the eastern North Pacific appears to be negatively affecting growth and survival of wild Coho Salmon in the marine environment (Beamish *et al.* 1997; Noakes *et al.* 2000; Sweeting *et al.* 2003; Irvine and Fukuwaka 2011).

Invasive Non-indigenous Species

This section informed the completion of the Invasive & other problematic species & genes main threat in the IUCN Threats Calculator (Appendix 1). The threats were determined to be pervasive in scope and to have a slight severity.

Invasion of non-indigenous species is being recognized globally as one of the most important threats to biodiversity (Rosenzweig 2001; Rahel *et al.* 2008). Invasive fish species can permanently reduce abundance and diversity of native fishes through competition, predation, or introduction of new pathogens (Cambray 2003), and are one of the leading risk factors for freshwater fish species in Canada (Miller *et al.* 1989; Dextrase and Mandrak 2006; Rahel *et al.* 2008). Biological risk assessments (Bradford *et al.* 2008a,b; Tovey *et al.* 2008) are available for several invasive spiny-rayed fishes in British Columbia including Yellow Perch (*Perca flavescens*), Smallmouth Bass (*Micropterus dolomieu*), Largemouth Bass (*Micropterus salmoides*), Pumpkinseed (*Lepomis gibbosus*) and Walleye (*Sander vitreus*). These species have become established in British Columbia due to natural dispersal in transboundary watersheds extending into Washington or Idaho, deliberate introductions by government agencies as recently as the 1980s, and unauthorized introductions in recent years.

Yellow Perch and Smallmouth Bass are the two most widely established invasive species in the interior Fraser River watershed. Yellow Perch has been confirmed in nine lakes and three streams in the South Thompson watershed (Runciman and Leaf 2009); two of the streams are also used by Interior Fraser Coho Salmon. Smallmouth Bass are confirmed in two small lakes in the South Thompson watershed, and throughout the Beaver Creek drainage in the Quesnel River watershed, including six small, connected lakes and Beaver Creek itself (Runciman and Leaf 2009); Coho Salmon occur in the lower reaches of Beaver Creek downstream of a barrier. To date, no Northern Pike or Walleye have been confirmed in the Interior Fraser River watershed, but Largemouth Bass and Pumpkinseed have been found in an isolated three-lake drainage in the South Thompson watershed (Runciman and Leaf 2009).

The risk of widespread establishment for Yellow Perch and Smallmouth Bass in the Thompson and Middle/Upper Fraser watersheds is high based on habitat suitability within a large portion of each watershed, the ability to migrate considerable distances and utilize streams as well as lakes, and the proximity of established populations in nearby watersheds, coupled with the risk of deliberate unauthorized introductions by anglers (Bradford *et al.* 2008a; Tovey *et al.* 2008; Decker and Irvine 2013). Largemouth Bass and Walleye, which are currently absent in the Thompson and Middle/Upper Fraser watersheds, are considered to have a high risk of widespread establishment there (Decker and Irvine 2013). The risk for Pumpkinseed and Northern Pike is moderate, based on lower habitat suitability (Bradford *et al.* 2008b).

The ecological consequences resulting from widespread establishment of these six species was estimated to be moderate to high for large lakes and high to very high for small lakes (Bradford *et al.* 2008a,b; Tovey *et al.* 2008), but these studies did not specifically address the direct risk to Interior Fraser Coho Salmon. Coho Salmon often rear in both small and large lakes in the interior Fraser River watershed, usually in backchannels, sloughs and alcoves near natal streams (Brown 2002; Brown and Winchell 2004). Whether these habitats are critical for Coho Salmon is uncertain because they rear primarily in streams and off-channel habitats associated with streams. However, Smallmouth Bass, Walleye and Northern Pike commonly occupy fluvial habitats, as do Largemouth Bass occasionally (Bradford *et al.* 2008b; Tovey *et al.* 2008).

The risks to Coho Salmon from invasive spiny-rayed fishes include predation (Smallmouth Bass, Largemouth Bass, Walleye, Northern Pike), competition (Yellow Perch and Pumpkinseed), and alteration of the food web (all six species) (Decker and Irvine 2013). The introduction of Largemouth Bass in a shallow lake system in Oregon reduced levels of Coho Salmon for the next 15 years, relegating natural production of Coho Salmon to stream habitats because of bass predation in the lake (Reimers 1989). Bonar *et al.* (2005) found that of 10 non-indigenous species introduced in three shallow lakes in the Pacific Northwest, Largemouth Bass accounted for 98% of the predation on juvenile Coho Salmon. Largemouth Bass have been found in slough and wetland habitats within the lower Fraser River floodplain (Tovey *et al.* 2008). These habitats are used by Coho Salmon from the five main Interior Fraser watersheds (Decker and Irvine 2013). Smallmouth Bass are also highly piscivorous, and are capable of heavy predation on juvenile Chinook and other salmonids (Wydoski and Whitney 2003), and make extensive use of clear streams and rivers (Tovey *et al.* 2008). There is a real concern about the impact on all salmonids if Smallmouth Bass in the Beaver Creek drainage expand their range to other areas within the Quesnel River system or the greater Interior Fraser River watershed (Gomez and Wilkinson 2008). Rutz (1999) reported that Coho Salmon were common in the diet of introduced Northern Pike in off-channel and lake habitats in the Susitna River in Alaska, and caused a decline in escapements of Coho Salmon to that system. Bonar *et al.* (2005) found no significant consumption or impact on growth rates of Coho Salmon by Yellow Perch and Pumpkinseed in three shallow lakes, although habitat preferences overlap substantially (e.g., off-channel habitat, littoral zones in small lakes, small, slow-moving streams). However, there are other instances of introduced Yellow Perch or Pumpkinseed leading to declines or extirpation of other native species (Bradford *et al.* 2008a,b; Johnson 2009).

Parasites and Disease

A new and emerging concern is the potential for disease transmission or infection by sea lice of juvenile Coho Salmon as they migrate past fish farms in Johnstone Strait en route to the Pacific Ocean. Connors *et al.* (2010) found a decrease in productivity of Coho Salmon populations that were known to be exposed to sea lice near fish farms compared to those that were unexposed. More recently Krkosek *et al.* (2011) have shown that the abundance of sea lice at fish farms is negatively associated with Coho Salmon productivity. Expansion of the number and distribution of fish farms in the Johnstone Strait area is a potential threat to Interior Fraser Coho Salmon recovery.

Overall Threat

The overall threat impact scored High-Medium in the IUCN threats calculator (Appendix 1).

Number of Locations

COSEWIC applies the IUCN definition of location as “a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present.” The size of the location depends on the area covered by the threatening event and may include part of one or many subpopulations. Where a taxon is affected by more than one threatening event, location should be defined by considering the most serious plausible threat (IUCN 2011). De Mestral Bezanson *et al.* (2012) treated streams within a watershed as locations in a recent analysis of Sockeye Salmon (*Oncorhynchus nerka*). Decker and Irvine (2013) adopted the same approach for Interior Fraser Coho Salmon, assuming threats most likely resulting in long-term damage to freshwater spawning and rearing habitat (e.g., forest fires, landslides) would apply to watersheds associated with individual streams. Recent reviews of metrics of distribution for Pacific salmon also treated individual streams as locations (Holt *et al.* 2009; Peacock and Holt 2010, 2012).

The ability to assess a temporal trend in the number of streams where Interior Fraser Coho were detected was confounded by inconsistent survey effort among years (i.e., number of streams surveyed each year), and especially by the expansion of escapement monitoring beginning in 1998. Decker and Irvine (2013) addressed this by examining the trend in the proportion of surveyed streams where Coho Salmon were detected rather than in the absolute number of streams with Coho during the post-1998 period (1998-2011). The analysis was conducted for the entire Interior Fraser DU (Figure 10) and found that the number of streams where Coho Salmon were detected is less than the number of streams occupied because the detection probability during surveys is less than 100%. The relationship between the proportion of streams where Coho Salmon were detected and total escapement for the same period was also examined. Empirical studies show that the proportion of occupied spawning locations typically increases exponentially with spawner abundance until an asymptotic maximum occupancy is reached (Peacock and Holt 2010).

Decker *et al.* (2014) found no evidence of a declining trend in the proportion of surveyed streams in which Coho Salmon were observed during 1998-2011. The proportion of streams with Coho Salmon observed was variable among years for individual watersheds but suggested either no trend (North Thompson and Lower Thompson), or a weak positive trend (South Thompson and Middle/Upper Fraser). Decker *et al*. (2014) reported that at escapement levels observed during 1998-2011 (7,000-56,000 for the DU), the distribution of Coho Salmon was positively associated with escapement to the DU (total escapement explained 68% of year-to-year variation in proportion of streams with Coho Salmon detected), and at the DU level, total escapement explained 48%, 21%, 22%, and 20% of the inter-annual variation in the proportion of streams with Coho Salmon detected for the North Thompson, South Thompson, Middle/Upper Fraser and Fraser Canyon systems, respectively. However, there was no relationship (R^2=0.02) between the proportion of streams with Coho Salmon detected and escapement for the Lower Thompson, despite substantial variation (700-9,600 spawners).

It can be inferred that Interior Fraser Coho Salmon utilize the available habitats broadly across each watershed so that with increases in abundance the fish apparently spread relatively evenly over a broader area. As such, localized threats such as small oil or chemical spills are likely to impact a single or small number of locations within the DU as would other comparable habitat alterations or disruptions with the possible exception of the Fraser Canyon system which consists of a single location and could be drastically impacted by such events. Other non-specific threats such as fisheries or exposure to fish farms that would impact the DU more broadly would likely have a similar impact across all the locations within the DU. Finally, threats from invasive species are likely to have cumulative impacts in that while the initial exposure may impact a single or small number of locations within the DU, once the invader becomes established it may spread broadly throughout all the locations within the DU and potentially across watersheds to have a major impact on long-term productivity and recovery of the species.

Decker and Irvine (2013) report the number of locations in which Coho Salmon were observed. For the South Thompson, North Thompson and Middle/Upper Fraser systems, Coho Salmon spawners from recent surveys (2009-2011) were detected at 30, 25, and 11 individual streams, respectively (Table 1). Coho Salmon were detected in eight streams in the Lower Thompson, but were likely present in 10 or more streams, as several streams in the Nicola River system that likely contained spawning Coho Salmon were not surveyed during 2009-2011 (Decker and Irvine 2013). Coho Salmon representing the Fraser Canyon spawn in a single stream (Nahatlatch River). Across the entire Interior Fraser River DU, Coho Salmon were detected in a total of 75 of the streams that were surveyed during 2009-2011.

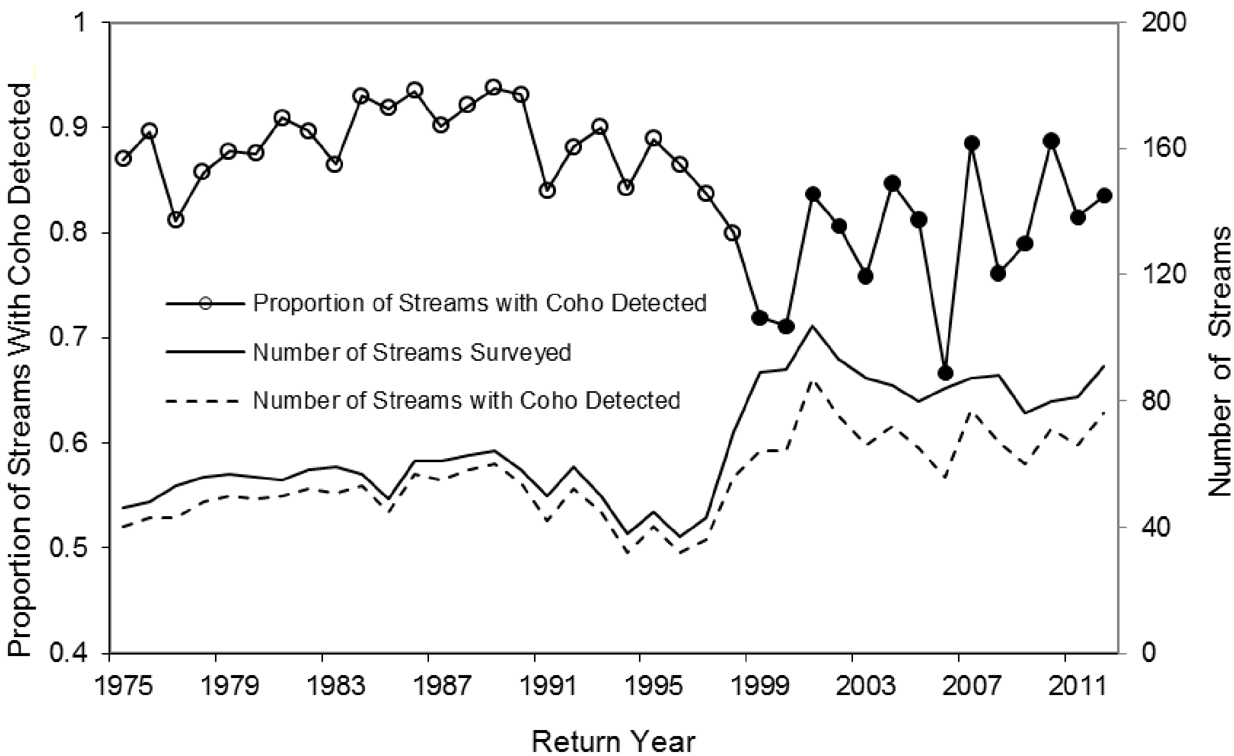

Figure 10. Trend in the number of streams in the interior Fraser River watershed where escapement surveys were conducted, and in the number of streams in which Coho Salmon were detected each year during 1975-2012 (scale shown on right vertical axis). Also shown (scale on left vertical axis) is the proportion of surveyed streams where Coho Salmon were detected each year during 1975-1997 (open circles), and during 1998-2012, following the expansion of the survey program (solid circles) (taken from Decker *et al.* 2014).

PROTECTION, STATUS AND RANKS

Legal Protection and Status

Possibly the most important step taken to date to protect Interior Fraser Coho Salmon has been the restriction on Canadian salmon fisheries that began in 1997 (unprecedented at the time), was fully implemented in 1998, and remains at this time (Appendix 5 in IFCRT 2006). The actions included having no directed fisheries on Coho Salmon and time and area closures on other species, to avoid migrating Coho Salmon in Johnstone Strait and off the west coast of Vancouver Island. Non-retention of Coho Salmon was instituted and commercial seine vessels were required to have revival boxes aboard to hold Coho Salmon prior to release and in the Fraser River only daylight gill net fishing was permitted. Irvine and Bradford (2000) described these restrictions as perhaps the most significant change in fisheries management ever implemented within the Pacific Region of Canada. Reduced exploitation rates have resulted in a modest recovery of escapements for all five major watersheds in the Interior Fraser DU, despite continued low survival of smolts to adults in the marine environment.

Interior Fraser Coho Salmon were designated as endangered by COSEWIC (2002) in 2002. In 2006 the federal Cabinet decided not to list the population under the *Species at Risk Act* (SARA) "based on uncertainties associated with changes in the marine environment and potential future socio-economic impacts on users associated with the uncertainty. Not listing provides future management flexibility related to uncertainty about marine survival and possible difficulties in recovery if marine survival worsens" (Government of Canada 2006). However, Fisheries and Oceans Canada has recognized Interior Fraser Coho Salmon as both a nationally significant population and a serious conservation concern, and undertaken various initiatives since the late 1990s for their protection and recovery (Irvine *et al.* 2005). Interior Fraser Coho Salmon were reassessed in 2016 and designated Threatened.

Habitat Protection and Ownership

The federal *Fisheries Act* was amended on June 29, 2012, to focus on protecting the productivity of recreational, commercial and Aboriginal fisheries and policies are being developed to address the changes. The federal government is focusing protection rules on real and significant threats to the fisheries and the habitat that supports them, while setting clear standards and guidelines for routine projects. The new fisheries protection provisions of the *Fisheries Act* are intended to provide for the sustainability and ongoing productivity of commercial, recreational and Aboriginal fisheries. How these changes are implemented and affect habitat protection may have significant positive impacts on interior Fraser watersheds. Additionally, British Columbia passed a new *Water Act* in 2014, and some changes will affect how the provincial and municipal governments regulate land and water use activities that can affect fish populations. For example, the regulation of groundwater is a top priority under the new legislation and could have significant effects on the interior Fraser water use provisions. The Canadian *Oceans Act* requires that Canada manage its marine resources to conserve biological diversity and natural habitats. Beyond government, there are several stewardship groups and First Nations organizations active in maintaining and enhancing fish and fish habitat within the interior Fraser River watershed (IFCRT 2006). In recent years, there has been focused enforcement to combat unscreened irrigation intakes and unauthorized water withdrawals within the interior Fraser River watershed (Decker and Irvine 2013).

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BIOGRAPHICAL SUMMARY OF REPORT WRITER(S)

Mr. Jacob (Jake) Schweigert received his B.Sc. (Honours) from the University of Toronto in 1974 and his M.Sc. (Zoology) from the University of Manitoba in 1976. Mr. Schweigert is Scientist Emeritus with Fisheries and Oceans Canada at the Pacific Biological Station (PBS), Nanaimo, British Columbia. Prior to his retirement, Mr. Schweigert was employed as a scientist with DFO since 1981 most recently as Section Head for Conservation Biology at PBS. He spent the majority of his career conducting research and stock assessment of Pacific herring and other forage species. Jake has authored or co-authored more than 30 publications in peer-reviewed scientific journals and over 70 other publications including COSEWIC stock status reports for Pacific sardine.

Appendix 1: Threats Assessment Worksheet

Species or Ecosystem Scientific Name	Coho Salmon (Oncorhynchus kisutch), Interior Fraser River population		
Element ID		**Elcode**	
Date (Ctrl + ";" for today's date):	24/08/2015		
Assessor(s):	Note that this was a trial run only and is not the final threats assessment for this wildlife species. Attendees and observers: COSEWIC Marine Fishes Specialist Subcommittee membersincluding ATK rep., status report writer Jake Schweigert, Greg Wilson (BC), Christie Whelan (DFO), Sean MacConnachie (DFO). Facilitator: David Fraser.		
References:			

Overall Threat Impact Calculation Help:

Threat Impact		Level 1 Threat Impact Counts: high range	Level 1 Threat Impact Counts: low range
A	Very High	0	0
B	High	0	0
C	Medium	1	0
D	Low	3	4
	Calculated Overall Threat Impact:	High	Medium

Assigned Overall Threat Impact:	
Impact Adjustment Reasons:	
Overall Threat Comments	

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
1	Residential & commercial development					
1.1	Housing & urban areas					
1.2	Commercial & industrial areas					
1.3	Tourism & recreation areas					
2	Agriculture & aquaculture					
2.1	Annual & perennial non-timber crops					
2.2	Wood & pulp plantations					
2.3	Livestock farming & ranching					

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
2.4	Marine & freshwater aquaculture					
3	Energy production & mining	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	
3.1	Oil & gas drilling					
3.2	Mining & quarrying	Negligible	Negligible (<1%)	Negligible (<1%)	High (Continuing)	Gravel extraction south of Mission in habitat used briefly by the species. Some rearing of juvenile Coho in Lower Fraser. There is some mitigation.
3.3	Renewable energy					
4	Transportation & service corridors	Unknown	Unknown	Unknown	Unknown	
4.1	Roads & railroads	Unknown	Unknown	Unknown	Unknown	
4.2	Utility & service lines					
4.3	Shipping lanes					
4.4	Flight paths					
5	Biological resource use	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	
5.1	Hunting & collecting terrestrial animals					
5.2	Gathering terrestrial plants					
5.3	Logging & wood harvesting					
5.4	Fishing & harvesting aquatic resources	Negligible	Pervasive (71-100%)	Negligible (<1%)	High (Continuing)	Includes fishing, bycatch and poaching. Severity negligible because the rate of take is sustainable. Assumes current management regime stays responsive to changes in fish populations.
6	Human intrusions & disturbance	Unknown	Unknown	Unknown	High (Continuing)	
6.1	Recreational activities	Unknown	Unknown	Unknown	High (Continuing)	ATVs driven in streams (possibly).
6.2	War, civil unrest & military exercises					
6.3	Work & other activities					
7	Natural system modifications	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
7.1	Fire & fire suppression	Negligible	Small (1-10%)	Negligible (<1%)	High (Continuing)	Water heated by fire; fire retardant entering waterways. See also habitat changes. Fire may also bring benefits.
7.2	Dams & water management/use	Low	Large (31-70%)	Slight (1-10%)	High (Continuing)	Run of River (hydro) projects (as barriers), but changes are above Coho habitat. Water extraction for irrigation on Thompson River. Related issues: warmer water, low productivity in riffles, sucked in when lack of exclusion devices, added pressure from poaching pipes. Flood control: see status report.

Threat		Impact (calculated)	Scope (next 10 Yrs)	Severity (10 Yrs or 3 Gen.)	Timing	Comments
7.3	Other ecosystem modifications	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Rip rap, livestock eroding banks, riparian habitat changed by fire. Change has been to more human population and less regulation.
8	Invasive & other problematic species & genes	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	
8.1	Invasive non-native/alien species	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Bass spp, Yellow Perch - eating fry (L. Thompson); expect invasive spp to expand.
8.2	Problematic native species	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Sea lice; introduction of native parasites etc. from hatcheries.
8.3	Introduced genetic material					
9	Pollution	Low	Pervasive (71-100%)	Slight (1-10%)	High (Continuing)	Severity bumped up to slight because there must be at least some cumulative impact of the unknowns.
9.1	Household sewage & urban waste water	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Includes hormones, heavy metals, microplastics
9.2	Industrial & military effluents	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Includes spills.
9.3	Agricultural & forestry effluents	Unknown	Pervasive (71-100%)	Unknown	High (Continuing)	Includes agricultural runoff and siltation from logging.
9.4	Garbage & solid waste					
9.5	Air-borne pollutants					
9.6	Excess energy					
10	Geological events	Unknown	Small (1-10%)	Unknown	Moderate (Possibly in the short term, < 10 yrs)	
10.1	Volcanoes					
10.2	Earthquakes/tsunamis					
10.3	Avalanches/landslides	Unknown	Small (1-10%)	Unknown	Moderate (Possibly in the short term, < 10 yrs)	Severity is unknown because it would depend on where it would happen.
11	Climate change & severe weather	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	Varies depending on whether events are in freshwater or marine environment.
11.1	Habitat shifting & alteration	Medium - Low	Pervasive (71-100%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	May be related to observed low marine survival.
11.2	Droughts	Medium - Low	Large (31-70%)	Moderate - Slight (1-30%)	Moderate (Possibly in the short term, < 10 yrs)	
11.3	Temperature extremes	Unknown	Pervasive (71-100%)	Unknown	Moderate (Possibly in the short term, < 10 yrs)	Please refer to status report threats section.
11.4	Storms & flooding	Unknown	Small (1-10%)	Unknown	Moderate (Possibly in the short term, < 10 yrs)	Scouring from high precipitation events. Tend to be localized.

Classification of Threats adopted from IUCN-CMP, Salafsky et al. (2008).