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Pre-COSEWIC Assessment of Interior Fraser Coho Salmon (*Oncorhynchus kisutch*)

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Foreword

This series documents the scientific basis for the evaluation of aquatic resources and ecosystems in Canada. As such, it addresses the issues of the day in the time frames required and the documents it contains are not intended as definitive statements on the subjects addressed but rather as progress reports on ongoing investigations.

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ABSTRACT

Genetically distinct Interior Fraser Coho Salmon (*Oncorhynchus kisutch*) were recognized as a Designatable Unit (DU) when their status was assessed by COSEWIC in 2002. Genetic and ecological studies revealed geographically based population structure within the Interior Fraser Coho aggregate, resulting in five Conservation Units (CUs) under Canada's Wild Salmon Policy (North, South, and Lower Thompson, Middle/Upper Fraser, and Fraser Canyon). We provide updated time series of data for escapement, total return, exploitation, productivity, size and fecundity, and distribution and summarize this information to facilitate a reassessment of the status of Interior Fraser Coho using primarily COSEWIC-based quantitative criteria. When possible, we present information for individual CUs as well. We examine major threats to Interior Fraser Coho, including threats not identified in the 2002 COSEWIC assessment. We also review previous status assessments and recovery plans.

Escapement of wild Coho Salmon to the interior Fraser River watershed declined from an average of 60,000 spawners during 1975-1988, to a low of 9,000 spawners in 1996. The most recent generational average (2009-2011, geometric mean) was 27,000. Recent generational average escapements for CUs ranged from 2,200 (Fraser Canyon) to 8,800 (North Thompson). The estimated decline in escapement for the Interior Fraser Coho aggregate for the entire time series (1975-2011) was 72%. Annual escapements to the interior Fraser River watershed have varied 8-fold during the most recent 10 years, but without any clear trend (estimated 8% decline). Rates of change in escapement for individual CUs were similar to those for the aggregate, with the exception of the Lower Thompson CU that increased 72% in escapement during the last 10 years, and the Fraser Canyon CU that decreased 58%. Limited data for several enhanced streams suggest size and fecundity of Interior Fraser Coho decreased in the 1990s, concurrent with decreasing escapement, and then increased during the 2000s. Estimated extent of occurrence (EO) was 110,000 km^2 for the Interior Fraser Coho aggregate, and ranged from 110 km^2 (Fraser Canyon) to 76,100 km^2 (Middle/Upper Fraser) for individual CUs. Area of occupancy (AO) for the Fraser Canyon CU was 32 km^2 and 14 km^2, based on 2×2 km and a 1×1 km grids, respectively. During the most recent three years, Coho Salmon were detected at 75 locations (streams) in the interior Fraser River watershed, and at one location to 30 locations within individual CUs. During 1998-2011, there was either no trend (North Thompson and Lower Thompson CUs), or a weak positive trend (South Thompson and Middle/Upper Fraser CUs and Interior Fraser Coho aggregate) in the number of locations where Coho Salmon were detected annually. The proportion of surveyed streams with Coho Salmon detected was positively correlated with escapement at both the aggregate and CU levels, with the exception of the Lower Thompson CU.

Declines in escapements and total returns of Interior Fraser Coho during the 1990s were primarily the result of declining smolt-adult survivals exacerbated by overfishing. An abrupt decrease in productivity (recruits per spawner) coincided approximately with the 1989-1990 shift in marine conditions in the North Pacific; average recruits/spawner decreased from 3.1 during 1975-1990 (return years) to 1.3 during 1991-2011. Fishing restrictions introduced in 1998 reduced average exploitation from 66% to 10%. During the most recent 10 years, productivity of the Interior Fraser Coho aggregate has been highly variable (0.3-3.0 recruits per spawner)[3], but has remained low relative to the pre-1991 period as a result of continuing poor smolt-adult survival. The aggregate has been below replacement (<1 recruit/spawner, or negative population growth) four of the last 10 years. Since the 2002 COSEWIC assessment, fishing, habitat perturbations, and climate change remain the most important threats to the long-term

[3] Erratum: September 2014. Productivity ranges corrected.

viability of the Interior Fraser Coho aggregate. Alien invasive species may be an emerging threat. The single watershed Fraser Canyon CU is particularly vulnerable due to its highly restricted EO and AO, small population size, and 58% decline in escapement during the last 10 years.

Évaluation pré-COSEPAC du saumon coho (*Oncorhynchus kisutch*) du Fraser intérieur

RÉSUMÉ

Les saumons coho (*Oncorhynchus kisutch*) du Fraser intérieur, génétiquement distincts, ont été reconnus comme formant une unité désignable (UD) lorsque le COSEPAC a évalué la situation de cette population en 2002. Les études génétiques et écologiques ont révélé que la structure de la population de saumons coho vivant dans le Fraser intérieur variait selon l'endroit. Cette diversité a mené à la création de cinq unités de conservation (UC), en vertu de la Politique concernant le saumon sauvage du Canada (Thompson Nord, Thompson Sud, basse Thompson, mi-Fraser/haut Fraser et canyon du Fraser). Nous fournissons des séries temporelles de données mises à jour sur les échappées, les montaisons totales, l'exploitation, la productivité, la taille et la fécondité. Nous résumons ensuite cette information afin de faciliter la réévaluation de la situation de la population de saumons coho du Fraser intérieur. Pour ce faire, nous utilisons essentiellement les critères quantitatifs du COSEPAC. Nous présentons aussi de l'information sur chacune des UC, lorsque c'est possible. Nous nous penchons sur les principales menaces qui pèsent sur le saumon coho du Fraser intérieur, y compris les menaces qui ne figurent pas dans l'évaluation du COSEPAC de 2002. De plus, nous passons en revue les évaluations de la situation et les plans de rétablissement précédents.

Les échappées de saumon coho vers le bassin intérieur du Fraser ont connu un déclin, passant d'une moyenne de 60 000 géniteurs de 1975 à 1988, à 9 000 géniteurs en 1996. La moyenne par génération la plus récente (2009-2011, moyenne géométrique) s'élevait à 27 000 individus. La moyenne d'échappées par génération dans les UC variait de 2 200 (canyon du Fraser) à 8 800 (Thompson Nord) échappées. La diminution des échappées au sein de la population de saumons coho du Fraser intérieur pour l'ensemble des séries temporelles (1975-2011) a été estimée à 72 %. Durant les dix dernières années, le nombre d'échappées annuelles vers le bassin intérieur du Fraser s'est multiplié par huit. Toutefois, aucune tendance claire ne ressort (déclin évalué à 8 %). Les taux de variation du nombre d'échappées dans chacune des UC avoisinaient les taux de variation pour l'ensemble de la population, à l'exception de l'UC de la basse Thompson, où les échappées ont augmenté de 72 % dans les dix dernières années, et de l'UC du canyon du Fraser, qui a connu une baisse de 58 %. Le peu de données dont nous disposons sur les cours d'eau mis en valeur tendent à indiquer que la taille et le taux de fécondité des saumons coho du Fraser intérieur ont diminué pendant les années 1990, parallèlement au déclin des échappées. Ils ont par la suite connu une augmentation dans les années 2000. La zone d'occurrence (ZO) pour l'ensemble de la population de saumons coho du Fraser intérieur a été estimée à 110 000 km^2, et variait de 110 km^2 (canyon du Fraser) à 76 100 km^2 (mi-Fraser/haut Fraser) pour ce qui est des UC individuelles. L'aire d'occupation (AO) de l'UC du canyon du Fraser était de 32 km^2 et 14 km^2. Elle a été mesurée à partir de grilles de 2$\times$2 km et de 1$\times$1 km, respectivement. Durant les trois dernières années, des saumons coho ont été trouvés à 75 emplacements (cours d'eau) du bassin intérieur du Fraser. Pour ce qui est des UC individuelles, le nombre de sites où des saumons ont été détectés variait de un à trente. De 1998 à 2011, soit il n'y avait aucune tendance annelle (UC de Thompson Nord et de la basse Thompson), soit il y avait une légère tendance à la hausse (UC de Thompson Sud, UC du mi-Fraser/haut Fraser et ensemble de la population de saumons

coho du Fraser intérieur) quant au nombre de sites où des saumons coho ont été détectés. La proportion de cours d'eau évalués où des saumons coho ont été détectés était en corrélation positive avec le nombre d'échappées, tant pour l'ensemble de la population que pour les UC individuelles, à l'exception de l'UC de la basse Thompson.

La diminution des échappées et des montaisons totales du saumon coho du Fraser intérieur pendant les années 1990 était principalement due à la baisse du taux de survie des saumoneaux-adultes, baisse accentuée par la surpêche. La productivité a connu un déclin abrupt (recrues par géniteur) qui coïncide presque avec le changement des conditions marines dans le Pacifique Nord survenu en 1989-1990. Notamment, le nombre de recrues par géniteur a diminué, passant de 3,1 de 1975 à 1990 (années de montaison) à 1,3 de 1991 à 2011. Les restrictions en matière de pêche instaurées en 1998 ont entraîné une baisse de l'exploitation moyenne, qui est passée de 66 % à 10 %. Au cours des dix dernières années, la productivité de la population de saumons coho du Fraser intérieur a fluctué de façon importante (0,3-3,0 recrues par géniteur)[4]. Toutefois, elle est demeurée faible par rapport aux années 1980 étant donné le taux de survie des saumoneaux-adultes, qui continue d'être bas. Pendant quatre des dix dernières années, le taux de fécondité au sein de la population était sous le seuil de remplacement (moins d'une recrue par géniteur, décroissance de la population). Depuis l'évaluation du COSEPAC de 2002, les menaces les plus importantes pour la viabilité à long terme de la population de saumons coho du Fraser intérieur sont la pêche, les perturbations de l'habitat et les changements climatiques. Les espèces exotiques envahissantes pourraient devenir une menace. L'UC du canyon du Fraser, comportant un seul bassin, est particulièrement vulnérable, en raison de ses ZO et AO très restreintes, de la petite taille de sa population et du déclin des échappées, qui ont diminué de 58 % au cours des dix dernières années.

[4] Erratum : Septembre 2014. Recrues par géniteur corrigé

1 BACKGROUND

In 2002, in response to concerns of the health of Fraser River Coho Salmon (*Oncorhynchus kisutch* Walbaum) in the interior of British Columbia (BC), the Committee on the Status of Wildlife in Canada (COSEWIC) assessed the status of Coho Salmon from upstream of Hells Gate in the Fraser River canyon. COSEWIC classified Interior Fraser Coho Salmon as a designatable unit (DU), chiefly because of evidence that they were genetically differentiated and substantially reproductively isolated from all other Coho Salmon (COSEWIC 2002). Relying primarily on information provided by Irvine (2002), Interior Fraser Coho were designated as endangered in May 2002 (COSEWIC 2002). Interior Fraser Coho were the second salmon DU in Canada and the first in the Pacific to be given such designation (Irvine et al. 2005). Interior Fraser Coho were identified as a unit of Coho Salmon biodiversity that had declined in abundance by approximately 60% during 1990-2000 due to decreases in smolt-adult survival, changes in freshwater habitats, over-exploitation, and possibly impacts related to hatcheries. Productivity (recruits/spawner) was sufficiently low in several years during this period that the population may not have been able to maintain replacement spawner numbers, even with a zero exploitation rate (Irvine 2002). COSEWIC was particularly concerned that if the distribution of Interior Fraser Coho became too fragmented, genetic exchange among local populations could become insufficient to ensure long-term survival. There was also a concern that if smolt-adult survivorship remained low, reductions in fishing mortality, begun by Fisheries and Oceans Canada (DFO) in 1997, could be insufficient or not maintained long enough to assure recovery.

In 2003 COSEWIC was given a legal mandate for scientific assessment of species (or DUs within a species) at risk of extinction, and Canada's new Species at Risk Act (SARA) was proclaimed. In 2004 Interior Fraser Coho were proposed for legal protection under SARA (Schedule 1 listing), based on recommendations from DFO. In 2006 the Federal Cabinet elected to not legally list Interior Fraser Coho because of concern about foregone revenues to the various fishing sectors in the event that smolt-adult survival increased significantly while the population remained listed under SARA, and because the existing Federal Fisheries Act could adequately protect the DU (Government of Canada 2006).

The status of Interior Fraser Coho Salmon has been assessed multiple times. The last detailed status assessment was in 2006 by the Interior Fraser Coho Recovery Team (IFCRT), which had a mandate to examine information gaps, recovery goals and objectives, and approaches to reach those objectives (IFCRT 2006). As well, the Pacific Salmon Commission Coho Technical Committee recently categorized the abundance status of these fish (termed a Management Unit by them) as "low" (PSC 2013). During 1998-2005, DFO assessed status in a series of peer reviews (Irvine et al. 1999a, 1999b, 2000, 2001), risk assessments (Bradford 1998; Folkes et al. 2005) and recovery potential assessments (DFO 2005a). The status of Interior Fraser Coho has not yet been assessed under DFO's Wild Salmon Policy (DFO 2005b).

The most recent guidelines for recognising DUs (dated November 2011; available at http://www.cosewic.gc.ca/eng/sct2/sct2_5_e.cfm) indicate these "should be discrete and evolutionarily significant units of the taxonomic species, where "significant" means that the unit is important to the evolutionary legacy of the species as a whole and if lost would likely not be replaced through natural dispersion". This definition has evolved considerably since the 2002 COSEWIC assessment for Interior Fraser Coho (COSEWIC 2002) and is now similar to the definition of a Conservation Unit (CU) in the Wild Salmon Policy as "a group of wild salmon sufficiently isolated from other groups that, if extirpated, is very unlikely to recolonize naturally within an acceptable time frame, such as a human lifetime" (DFO 2005b).

Throughout this document we refer to Coho Salmon from the Interior Fraser River as the Interior Fraser aggregate rather than a DU. We refer to the five major groups within the aggregate

(North Thompson, South Thompson, Lower Thompson, Fraser Canyon, and Middle/Upper Fraser) as CUs rather than populations, the term used by the IFCRT (2006). As much as possible, we provide data and evaluate status at the aggregate and CU level so COSEWIC can evaluate status at the level they determine to be appropriate.

2 OBJECTIVE

The purpose of this document is to summarize the most recently available information on Interior Fraser Coho Salmon in support of the development of an updated Status Report by COSEWIC. The scope of this document is all Coho Salmon that spawn in the Fraser River watershed upstream of Hells Gate in southern British Columbia. COSEWIC will present their results at a Species Assessment meeting expected in April 2015. In preparation, the lead agency, DFO, was tasked with preparing and presenting a Pre-COSEWIC review of Interior Fraser Coho at a Regional Advisory Process under the Canadian Science Advisory Secretariat (CSAS). Results from this process will be made available to COSEWIC to assist them with their Status Report.

3 NAME AND CLASSIFICATION

Coho Salmon is one of seven anadromous and semelparous species of Pacific salmon native to North America (Sandercock 1991). While the common name most frequently used for this species is Coho Salmon, they are sometimes referred to as silver salmon, sea trout, hooknose, or bluebacks, the latter term usually referring to small Coho Salmon caught early in their final marine year. The French common name is *saumon Coho*. Coho Salmon are an important species, contributing to catches along the Pacific coast of North America and within the Fraser River watershed.

4 MORPHOLOGICAL DESCRIPTION

Coho and other Pacific salmon can be distinguished from trout and char by the presence of 12 or more rays in the anal fin. The anal fin of juvenile Coho Salmon is sickle-shaped and its leading edge is longer than its 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. As well, black spots, when present on the caudal fin, occur usually on the upper lobe only. Sexual dimorphism develops as Coho Salmon become sexually mature. Male Coho Salmon become darker and often bright red, their upper jaw develops an elongated hooked snout, and their teeth become enlarged. Females are usually less brightly coloured and their upper jaw development is less extreme than males. More detailed descriptions of Coho Salmon are provided in Scott and Crossman (1973), Hart (1973), Pollard et al. (1997), and Sandercock (1991).

5 LIFE HISTORY CHARACTERISTICS AND BIOLOGY

Most Coho Salmon return to freshwater in the fall and spawn during fall and early winter, although 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 tend to spawn relatively late, with spawning activity peaking in mid-November, and often extending into January. All Coho Salmon die after spawning. Fry emerge from the gravel the following spring and usually reside in freshwater for a year before migrating to sea as smolts during April-June. Most Coho Salmon spend 18 months at sea before returning to freshwater in the fall and therefore have a 3-year life cycle. Variations on this general life cycle include juveniles that emigrate to sea immediately upon emergence, juveniles that reside for two years before migrating seaward, precocious males that return to spawn after only six months at sea (jacks), and multi-winter ocean residents. For Interior Fraser Coho, specifically, deviation from the dominant 3-year life history is uncommon, and there is relatively little genetic exchange among broodlines. From a scale-age sample of 2,274 fish, most (93%) went to sea in their second year, with the remainder rearing in freshwater for one or two years more; only two fish were aged as jacks, and six fish spent more than one winter at sea (Irvine et al. 1999a).

For Coho Salmon populations in general, length and weight at maturity generally ranges from 45-70 cm (fork length), and from 2-5 kg, respectively, although Coho Salmon of 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 of similar age documented by Sandercock (1991) and Weitkamp et al. (1995). Irvine et al. (1999a) reported mean post-orbital hypural lengths (sample sizes in brackets) of 42.3 cm (7,149), 45.7 cm (256), and 44.0 cm (1,853), respectively, for Coho Salmon from the North, South, and Lower Thompson River drainages. Fecundities for Interior Fraser Coho are highly variable, and generally less than those of Coho Salmon returning to lower Fraser River streams or provincial averages (Irvine et al. 1999a), which is as expected given the generally smaller sizes of the former. Female Coho Salmon are larger than males in most Interior Fraser streams, but less abundant (~45% of returns), traits characteristic of many Coho Salmon populations. In a meta-analysis of Pacific salmon survival rates, Bradford (1995) reported mean Coho Salmon egg-fry, egg-smolt, and smolt-adult survivals (prior to 1993) of 9%, 1.5%, and 9.8%, respectively, with Coho Salmon generally having higher egg-fry and smolt-adult survival, and lower egg-smolt survival than other Pacific salmon species. Weitkamp et al. (1995) documented declines in adult fish size over time for many populations of Coho Salmon. Temporal trends in size, fecundity and smolt-adult survival of Interior Fraser Coho are examined later in the document (see *Section 12.5*).

6 CLASSIFICATION AND DESIGNATION OF INTERIOR FRASER COHO

Most of British Columbia (BC) was covered by ice 15,000 years ago (Fulton 1969), after which a period of global warming began (Roed 1995). During the period of glaciation, anadromous salmon were able to exist in several glacial refugia including the lower two-thirds of the Columbia River, which was ice-free. As the ice retreated, much of the Fraser River drained through the Okanagan watershed, entering the ocean via the Columbia River. At this time, 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 postglacial 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). Thus, Interior Fraser Coho are the last 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. The Fraser Canyon remains a velocity barrier for many species of fish, resulting in a discontinuous distribution of many species and populations within species (McPhail and Lindsey 1986).

Results from earlier work documenting the genetic uniqueness of Interior Fraser Coho (Beacham et al. 2001; Irvine et al. 2000, 2001; Shaklee et al. 1999; Small et al. 1998a, 1998b) were confirmed by Beacham et al. (2011). Interior Fraser Coho are the most distinctive Coho Salmon group examined to date, with no strong genetic affinity to other Coho Salmon populations surveyed from Washington to southeast Alaska (Small et al. 1998b; Shaklee et al. 1999). Beacham et al. (2011) confirmed that Coho Salmon upstream of the Fraser River canyon (i.e. Interior Fraser) are quite distinct from those below the canyon (coancestry coefficient (F_{ST}) = 0.071). There is also evidence of adaptive differentiation in morphology and swimming performance between Interior Fraser and Lower Fraser Coho Salmon (Taylor and McPhail 1985a, 1985b).

6.1 NATIONALLY SIGNIFICANT POPULATION

Coho Salmon warrant more than one status designation. In the United States, the National Marine Fisheries Service originally proposed six[5] evolutionarily significant units (ESUs) for Coho Salmon extending from central California to southern British Columbia (Weitkamp et al. 1995). An ESU is a population or group of populations that is substantially reproductively isolated from other populations and represents an important component of the evolutionary legacy of the species (Waples 1991). Interior Fraser Coho constitute an ESU based on these criteria; they are reproductively isolated from other Coho Salmon and have a unique inland Columbia River heritage for which they are the sole remaining representative. As a sub-species of Coho Salmon, the Interior Fraser Coho aggregate also meets criteria for recognition as a COSEWIC DU (COSEWIC 2010a), and was recognized as such in 2002 (Irvine et al. 2005). Within Canada, Interior Fraser Coho are a nationally significant population that occupy ~25% of the species natural freshwater range.

6.2 POPULATION STRUCTURE

Beacham et al. (2011) examined variation at 17 microsatellite loci in their recent review of the population structure of North American Coho Salmon. Coho Salmon from the Interior Fraser River were distinct from other Coho Salmon and among the least genetically diverse of the various populations examined.

Population structure within the Interior Fraser was geographically based, aligning with the five CUs described by Holtby and Ciruna (2007) (Figure 1). Beacham et al. (2011) evaluated the distribution of genetic variation in Coho Salmon in North America using a gene diversity analysis that was structured among regions, among populations within regions, and among sampling years within populations. They found that Coho Salmon from the North Thompson River drainage clustered together in 63% of dendrograms evaluated while the clustering percentages were 36%, 92%, and 55% for the South Thompson River, lower Thompson River, and middle Fraser River regions respectively (Figure 2). Coho Salmon from the single location in the Fraser River canyon (Nahatlatch River) were distinct both from upstream populations and those of the lower Fraser River (Beacham et al. 2011).

The five CUs 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). Migration among CUs does occur, but it is sufficiently restricted to permit local adaptations to occur (Irvine et al. 2000). Genetic diversity is three to 10 times greater among CUs compared to variation among spawning groups (occupying different tributaries) within each CU. The IFCRT (2006) defined each CU (which they referred to as populations) as being demographically independent, meaning that the population dynamics of one CU would be unlikely to affect the dynamics of another (Bradford and Wood 2004).

[5] The number of Coho ESUs was increased to seven following a review in 2005 (US Department of Commerce 2005)

While further subdivision of the Interior Fraser Coho aggregate beyond the suggested five CUs does not appear warranted based on existing genetic information, each CU but one (Nahatlatch River represents the only known spawning location for the Fraser Canyon CU) occupies a vast drainage area. There are still gaps in the baseline genetic samples, particularly for spawning areas in the Middle/Upper Fraser watershed and in some of the more remote Thompson River tributaries (IFCRT 2006) It is known that migration or dispersal among spawning groups (i.e., straying) occurs at a decreasing rate with distance from the natal stream (Quinn 1993), and that the arrangement of suitable spawning habitat (e.g., inter-patch distance and connectivity) plays a central role in metapopulation dynamics, and can affect the rate of recolonization of spawning locations following local extirpation and the overall risk of extinction (Schtickzelle and Quinn 2007). To address demographic considerations and the likelihood of spatial structure within each population (CU), and to provide a framework for conservation and recovery planning, the IFCRT proposed that the Interior Fraser Coho aggregate be further delineated into 1-3 subpopulations within each population (CU), which amounted to 11 subpopulations in total (Table 1). The IFCRT delineated subpopulations based on large watersheds or lakes, the presence of partial barriers to migration, and limited genetic evidence.

Regardless of whether future work determines that the rate of gene flow among the five CUs is slow enough to warrant each CU being considered a separate DU, it is important to acknowledge that the loss of a CU would represent a loss of genetic diversity and a significant contraction in the current distribution of Interior Fraser Coho. Therefore, we recommend that conservation planning focus on the viability of each of the five CUs, not just the Interior Fraser aggregate, with additional consideration given to subpopulations, particularly isolated ones (see *Section 12.7*). This is consistent with Canada's Wild Salmon Policy. DFO is increasingly moving towards the assessment and management of CUs, which are genetically or ecologically distinct biological units (DFO 2005b).

7 HABITAT REQUIREMENTS

Since Coho Salmon spawn in freshwater and juveniles normally spend one full year there before migrating to the sea, their survival depends on having adequate habitat in freshwater as well as 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. Females generally construct nests in shallow (30-cm) areas where the gravel is less than 15-cm diameter and has good circulation of well-oxygenated water (Sandercock 1991). Low or high flows, freezing temperatures, siltation, predation, and disease can reduce egg survival. In the interior Fraser River watershed, where winters are more severe than in coastal British Columbia, there is indication that winter stream flow and temperature play a critical role in spawning site selection. Whereas average discharge is higher in winter compared to summer in coastal streams, Interior Fraser streams generally experience declining hydrographs during the fall and winter as temperatures drop below freezing at higher elevations. This creates a risk of redds dewatering and freezing if spawning occurs too early. Interior Fraser Coho have likely adapted to these conditions by spawning later in the fall and winter, and in lake-headed streams where temperatures and discharge are relatively stable. Groundwater may also play a critical role in spawning site selection. McRae et al. (2012) found that Interior Fraser Coho select spawning micro-sites with groundwater influence, presumably because groundwater moderates ambient stream temperatures. Groundwater may influence spawning distribution at larger spatial scales as well. For example, Coho Salmon spawning in the mainstems of larger streams such as the North Thompson River are often concentrated in side channels and other sites with abundant groundwater (IFCRT 2006).

Major episodes of fry dispersal include spring movements away from spawning sites (Chapman 1962; Gribanov 1948) and pre-winter movements into small tributaries and off-channel habitat (Peterson 1982). Within small streams, fry densities are generally higher in pools than in riffles. Coho Salmon fry tend to cluster in areas of suitable habitat, most frequently in small streams with gradients less than 3%. Data collected during a multi-year (2001-2011) census of juvenile Chinook Salmon (*O. tshawytscha*) and Steelhead (*O. mykiss*) in the Lower Thompson River system suggest that Coho Salmon fry reared mainly in small tributaries, and were largely absent from mainstem habitats in larger streams (Decker et al. 2012).

Structurally complex habitats (large organic debris and large substrate), and habitats with slow moving water are both necessary to ensure high overwinter survival of young Coho Salmon (Solazzi et al. 2000). Groundwater ponds and channels and other types of off-channel habitats often support large numbers of overwintering Coho Salmon fry in Interior Fraser streams (Swales and Levings 1989; Bratty 1999). Interior Fraser Coho utilize lakes less frequently than streams, but fry have been recorded in near-shore regions of lakes in the interior Fraser River watershed, including some very large lakes (e.g., Shuswap Lake, Quesnel Lake; Brown and Winchell 2004), although the extent of use and the potential productive capacity of these lakes are unknown. In the Interior Fraser, Coho Salmon fry appear to prefer lake habitats that are protected from wave action such backchannels, alcoves, and sloughs, often in close proximity to the mouths of natal streams, as opposed to exposed shorelines (Brown 2002; Brown and Winchell 2004). There is also evidence that, similar to some Interior Fraser Chinook Salmon populations (Murray and Rosenau 1989), substantial numbers of Coho Salmon fry from the Interior Fraser rear in non-natal streams for at least part of their freshwater residence. For example, large numbers of fry have been captured in side-channel habitats in the North Thompson River that do not support spawning (Scott et al. 1982; Stewart et al. 1983). In another study, DNA analysis indicated that 35% of a sample of 1,800 juvenile Coho Salmon collected during the winter from side-channel and off-channel habitat in the lower Fraser River in 2006-2007 were of Interior Fraser origin (DFO, Fraser River Chinook and Coho Salmon Stock Assessment Division, unpublished data). Identification of natal stream for individual fish (based on the analysis of microsatellite variation using the Fraser River Coho Salmon genetics baseline; Beacham et al. 2001) indicated that all five Interior Fraser CUs were represented in the sample.

Juvenile Coho Salmon from the interior migrate down the Fraser River in the spring and early summer after one year in freshwater. Tagging studies indicate that it takes from 10-16 days to migrate from the interior to the lower Fraser River (Chittenden et al. 2010). They live for an unknown time in the highly developed and constrained estuary of the Fraser River at Vancouver (Figure 1), and many appear to spend their first summer in the Strait of Georgia (Beamish et al. 2010), leaving in October/November (Chittenden et al. 2009). Interior Fraser Coho spend the remainder of their 18-month oceanic residence primarily in coastal waters (Irvine et al. 1999a, 2001). Habitat requirements of juvenile Coho Salmon in the Fraser River estuary and the Strait of Georgia are poorly understood. However, it is widely believed that early ocean residence is a critical survival period for Pacific salmon (Peterman 1987; Pearcy 1992; Downton and Miller 1998), and it has been suggested that overall year-class strength for Coho Salmon in southern BC is determined primarily during the first few months spent 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, the abundance of other juvenile salmonids, as well the presence of generally favourable ocean conditions as represented by periods of negative PDO and ENSO (Pacific Decadal and El Niño Southern Oscillation, respectively; Beamish et al. 2004; LaCroix et al. 2009; Araujo et al. 2013). A contrasting view was provided by Chittenden et al. (2010) who suggested that mortality during the downstream freshwater migration might be the primary reason for the poor status of Interior Fraser Coho. However, sample sizes were small in the Chittenden et al. study, and migration mortality could not be separated from initial handling mortality.

8 DO COHO SALMON HAVE A RESIDENCE IN THE INTERIOR FRASER?

SARA defines “residence” as “a dwelling-place, such as a den, nest or other similar area or place, that is occupied or habitually occupied by one or more individuals during all or part of their life cycles, including breeding, rearing, staging, wintering, feeding or hibernating” (Government of Canada 2004). Interior Fraser Coho have a residence in the interior Fraser River watershed based on recent scientific advice (DFO 2010) that redds (spawning nests constructed by Pacific salmon and other species) should be considered residences because they meet the following criteria: 1) individuals (not a population) make an investment (e.g., energy, time, defense) in the redd and/or invest in the protection of it; 2) the location and features of the redd contribute to the success of a life history function (i.e., breeding and rearing); 3) the redd is a central location within an individual’s larger home range, with repeated returns by the species to complete a specific life function; and 4) there is an aspect of uniqueness associated with the redd, such that if it were “damaged” the individuals would usually not be able to immediately move the completion of the life history function(s) to another place without resulting in a loss in fitness (Coho Salmon are semelparous and are therefore unable to replace a redd damaged following their death) (DFO 2010).

9 ABORIGINAL TRADITIONAL KNOWLEDGE

Aboriginal Traditional Knowledge (ATK) describes the knowledge originating with First Nations peoples pertaining to their immediate environments, and the cultural practices that build on that knowledge (Ford and Martinez 2000). Communities with a long history of resource use can acquire a deep but qualitative knowledge about the resource that they depend upon (Kurien 1998). Interior Fraser Coho 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). The Secwepemc Fisheries Commission (SFC) and the Nicola Valley Stewardship and Fisheries Authority (NWFSA) represent bands with knowledge of traditional fisheries. In addition, there are various bands not affiliated with these organizations that also possess ATK.

The use of ATK in fish and wildlife management decision-making processes is well established in other jurisdictions, but remains relatively new for Pacific salmon in British Columbia (Irvine et al. 2000). ATK pertaining to some natural resources in the Interior Fraser has been assembled (e.g., Turner et al. 2000), but no comprehensive review of ATK has been undertaken for Interior Fraser Coho or other Pacific salmon. Irvine et al. (2000) evaluated the potential for formally incorporating ATK in status assessments for Interior Fraser Coho, and concluded that while there were strong benefits in doing so, several steps would have to be completed before this were possible. These steps included the development of protocols, in cooperation with Interior Fraser First Nations, to identify the type of information sought, the way the information will be used, and the roles of DFO and Interior Fraser First Nations in collecting and interpreting the information; the creation and management of a standardized database and documentation of data sources; the establishment of protocols for evaluating ATK using the same sorts of quality control measures used to evaluate other scientific information; and protocols for integrating ATK and conventional stock assessment data in status reviews.

Although a comprehensive summary of ATK has yet to be completed for Interior Fraser Coho, the contribution of ATK to current understanding of Interior Fraser Coho, particularly their historical distribution in the interior Fraser River watershed, has been substantial. In 1998, when the DFO stock assessment program for Interior Fraser Coho was expanded (see *Section 11.1*), agency staff traveled to various First Nations communities and obtained previously unavailable information about traditional fisheries, and the historical distribution and relative abundance of Coho Salmon in local watersheds (R. Bailey, Fisheries & Oceans Canada, Kamloops, BC, personal communication, 2013). This information was then used in the selection of index streams for escapement monitoring. The ATK obtained for the Middle/Upper Fraser CU was especially valuable because the DFO had carried out relatively few assessments for Coho Salmon in that CU at that time.

10 HATCHERY PRODUCTION

Hatchery production of Interior Fraser Coho Salmon began in the late 1970s and the early 1980s for fry and smolts, respectively. Annual 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 (Regional Mark Information System Database (online database), Regional Mark Processing Center, Pacific States Marine Fisheries Commission, Portland, Oregon; available from http://www.rmpc.org.) Annual smolt releases peaked during 1999-2002 at 350,000-400,000, and declined to 200,000-250,000 in recent years. There are no large production facilities for Coho Salmon in the Interior Fraser. At the peak of production there were ~13 small enhancement projects.

The original objectives of enhancement for Interior Fraser Coho were to evaluate the effectiveness of different strategies and to assess the impact of enhanced production on natural stocks (Perry 1995; Pitre and Cross 1993). It was hypothesized that fry releases could be a useful supplementation strategy when progeny from natural spawning did not fully occupy available habitat. More recently, enhancement for Interior Fraser Coho has taken one of three forms: 1) conservation enhancement, used to protect demes that are at risk of extirpation (e.g., Salmon River); 2) assessment enhancement, where releases of CWT marked fish provide information for assessment of survival and exploitation rates and ocean distribution; and 3) rebuilding enhancement, where hatchery supplementation is used to increase escapements (IFCRT 2006). Enhancement activities are described in more detail by Irvine et al. (1999a, 2000) and the IFCRT (2006).

The majority of hatchery-origin Coho Salmon returning to the Interior Fraser spawn naturally in the wild. As a result, these first generation hatchery fish are included in escapement surveys of wild fish in enhanced streams. Prior to 1998, 21% of hatchery fry and 56% of hatchery smolts on average were marked prior to release (removal of adipose fin). After 1998, marking rates were reduced to averages of 2% and 23% for fry and smolts, respectively. Stock assessment and hatchery staff record the presence or absence of an adipose fin for live adults and carcasses that are encountered at counting fences and during hatchery brood collections or foot surveys. Based on the proportion of hatchery fish released with marks and the proportion of returning adults with marks, discrete estimates of escapement are generated for Coho Salmon that are the progeny of fish that spawned in the wild and Coho Salmon that originated from a hatchery. It should be noted, however, that the estimated proportions of hatchery-origin Coho Salmon at the CU and Interior Fraser aggregate levels that we used to estimate hatchery and wild fish escapements are biased low to some degree because hatchery fish are known to stray to unenhanced streams for which we assumed wild-origin fish contributed 100% of escapements. It should also be noted that, under the Wild Salmon Policy (DFO 2005b), some progeny of natural spawners are not “sufficiently wild” to qualify as wild salmon; the WSP defines wild salmon as having spent their entire life cycle in the wild and originating from parents that were also produced by natural spawning and continuously living in the wild. As a result, our estimates of wild Coho Salmon escapements will be biased high to some degree. Unless indicated otherwise, we assessed abundance and trends in abundance for Interior Fraser Coho based on escapements of natural-origin fish only.

11 METHODS

11.1 ESCAPEMENT DATA

We have no estimates of abundance for Interior Fraser Coho prior to the arrival of Europeans. From an analysis of commercial fishery catch records, Northcote and Burwash (1991) calculated that the average annual abundance (catch plus spawners) for Fraser River Coho Salmon in the 1920s to early 1930s was approximately 1.2 million. Assuming ~1/3 of these fish were from the Interior Fraser (derived from genetic stock ID data from commercial fisheries), the abundance of Interior Fraser Coho during this period was ~400,000. And assuming, as Northcote and Burwash did, that 50% of these fish were harvested, the annual escapement of Interior Fraser Coho was in the order of 200,000 fish. Northcote and Burwash (1991) estimated that Coho Salmon in the Fraser watershed underwent a 7.7 fold decrease between the 1920's and the period between the 1950's and the 1980's. However, they cautioned that the data for Coho Salmon data were the least reliable of those available for Pacific salmon.

For Interior Fraser Coho, the majority of escapement (number of returning adults escaping marine and freshwater fisheries and returning to natal spawning streams) estimates are derived from visual observations of adults on the spawning grounds (aerial or ground surveys; ideally incorporating multiple surveys spanning the entire period). Uncalibrated visual counts will underestimate escapement because not all spawners present are seen and because not all fish that spawn in an area are present during any one survey. In most cases, escapement estimates are derived from visual counts using either the area-under-the-curve (AUC) method (English et al. 1992), which incorporates additional information about detection probability and survey life, or the expanded peak count method where raw counts of salmon are expanded based on calibration studies where visual surveys are paired with a more accurate method such as a counting fence. Counting fences, resistivity counters and mark-recapture programs are also used in place of visual surveys on some Interior Fraser streams to provide more accurate escapement estimates.

Although escapement estimates exist for some streams in the Interior Fraser as far back as 1951, older estimates (1951-1974) are of unknown accuracy and precision. Consequently, pre-1975 estimates are of little use for analyses of changes in abundance over time. During 1975-1997 many of the tributaries within the North Thompson and South Thompson CUs were surveyed in most years. In 1984, annual escapement surveys began for four streams (Coldwater, Spius, Deadman, and Bonaparte) that represent the bulk of escapement for the Lower Thompson CU. Overall, prior to 1998, enumeration of Interior Fraser Coho spawners was sporadic and escapement estimates were often derived from observations made by DFO Fishery Officers rather than from formal surveys conducted by stock assessment staff. The former data vary considerably in precision and accuracy (Irvine et al. 1999a and 1999b provide detailed descriptions). For the Middle/Upper Fraser CU and the Fraser Canyon CU (Nahatlatch River) no reliable survey data are available prior to 1998 for the majority of streams. In 1998, as part of the recovery effort for Interior Fraser Coho, an expanded and more rigorous escapement survey program was implemented: the number of streams surveyed annually increased from an average of 56 during 1975-1997, to an average of 86 during 1998-2011; the number of surveys conducted each year for an individual stream generally increased; and more reliable methods were employed (counting fences, mark-recapture studies, and multiple surveys over time to generate AUC or calibrated peak count estimates (R. Bailey, Fisheries & Oceans Canada, Kamloops, BC, personal communication, 2013). This more comprehensive effort included surveys of streams contributing the majority of escapement for the North, South and Lower Thompson CUs, as well as regular annual surveys in the Nahatlatch River (Fraser Canyon CU), and for 10-21 streams in the Middle/Upper Fraser CU. The escapement time series for the North and South Thompson CUs that were surveyed for the longest period (1975-2011) spans 12 generations.

In the original COSEWIC assessment, Irvine (2002) summarized 1975-2001 escapement estimates for the Interior Fraser Coho aggregate (and for individual CUs where possible), and examined rates of population change during 1990-2000. To do so, it was necessary to adjust (generally upwards) estimates from earlier years when less rigorous methods were employed, and to infill estimates for unsurveyed streams and missing years (Irvine et al. 2001; Simpson et al. 2001, IFCRT 2006). In their subsequent assessment, the IFCRT, rather than using the same data as Irvine (2002), chose to reconstruct the entire time series of Coho Salmon escapements for all Interior Fraser streams for the period 1975-2003 to reflect new information (see Appendix 3 in IFCRT 2006 for a detailed description of their methods). With the exception of one stream from the North Thompson CU, the reconstructed estimates generated by the IFCRT did not differ greatly from earlier estimates used by Irvine (2002). As part of this effort, the IFCRT generated escapement estimates for the Lower Thompson (1975-1983), and Fraser Canyon, and Middle/Upper Fraser CUs (1975-1997) for earlier years when regular surveys did not occur. These escapement estimates were based on the average ratio of escapement for each CU versus the aggregate escapement for the North and South Thompson CUs during 1998-2000 (IFCRT 2006, Appendix 3). Annual escapements for the North and South Thompson CUs combined were a good predictor of escapements for the Middle/Upper Fraser CU during 1998-2011 (R^2=0.75, n=14), suggesting that this approach could provide reasonable approximations of escapement for the Middle/Upper Fraser CU for earlier years, but the same relationship was much weaker for the Fraser Canyon (R^2=0.22, n=14) and Lower Thompson CUs (1984-2011, R^2=0.07, n=28), suggesting that approximated escapements for the latter two CUs for earlier years are highly uncertain.

For this report, we used the escapement estimates reconstructed by the IFCRT for years 1975-1997. For 1998-2011, the expanded survey program meant that relatively little infilling was necessary. To infill estimates for missing years during 1998-2011 for streams that were otherwise surveyed consistently, we used a ratio method similar, but not identical, to that employed by the IFCRT (2006). For each subpopulation within a CU, we first determined which streams had a complete escapement record for 1998-2011, and then computed the total escapement for these streams for each year. Second, for stream *i* with missing years' data, we summed escapements for all years when surveys occurred and divided this value by the sum of escapements for the streams with complete records for the same years to obtain a weighted average (across years) for the ratio of escapement for stream *i* versus the total for streams with complete records. We then generated an escapement estimate for missing year *j* for stream *i* by factoring the sum of escapements for streams with complete records for year *j* by the ratio for stream *i*.

Estimates of total escapement for individual CUs and for the Interior Fraser aggregate are biased low to some degree for all years in the time series because not all Interior Fraser streams to which Coho Salmon returned were surveyed. One important source of uncertainty is the Middle/Upper Fraser CU for which the extent of distribution is not known, and relatively few streams were surveyed on an annual basis. During 2000, fishwheels were operated at two locations in the Fraser River Canyon (above and below the Nahatlatch River, the principal spawning tributary for the Fraser Canyon CU) to provide mark-recapture estimates of the total number of Coho Salmon migrating upstream (Irvine et al. 2001). These estimates were considerably higher than the corresponding estimate of total escapement to the Interior Fraser derived from surveys conducted at the terminal spawning areas, and suggest that the latter estimates were biased low by 37%-56%. Irvine (2002) adjusted estimates for the Middle/Upper CU upwards based on this apparent bias (see Table 2 in Irvine 2002). However, we did not make this adjustment because there was evidence that the mark-recapture estimates derived from the fish-wheel tagging program were positively biased to an unknown degree as a result of tag loss, tagging-induced mortality, tag misidentification, and non-representative tag application over time (Irvine et al. 2001).

11.2 EXPLOITATION

Methods used to estimate fishery exploitation (catch/(catch + escapement)) varied during the time series. From the introduction of hatchery supplementation in 1986 until 1997, exploitation rates and marine distribution for Interior Fraser Coho were estimated using mark recovery data obtained through the Mark Recovery Program operated by Fisheries and Oceans Canada (Simpson et al. 2004). Magnetic coded-wire tags (CWTs) were inserted into large numbers of hatchery-origin Interior Fraser Coho prior to their release to provide hatchery-specific marks. Recoveries of CWT marked Coho Salmon from Canadian marine and in-river (lower Fraser River mainstem) fisheries and US marine fisheries, together with estimates of total catch, were used to estimate exploitation rate and apparent marine distributions and survival (Johnson 1990 provides a detailed summary of Canadian and US coded wire tagging programs). Exploitation estimates for Interior Fraser Coho during 1975-1985 were approximated as the arithmetic average of values for 1986-1996 derived from CWT recoveries (Simpson et al. 2004).

From 1998-onward, reduced Coho Salmon abundance, restrictions on retention of Coho Salmon in commercial and sport fisheries (see *Section 12.3*), and reductions or curtailments in CWT programs meant that exploitation rates could no longer be reliably estimated from the mark recovery data (Simpson et al. 2004; Irvine et al. 2013, PSC 2013). During 1998-2000, genetic samples were collected from Coho Salmon in most fisheries annually, and Canadian (marine and in-river) and US exploitation rates on Interior Fraser Coho were derived by estimating the number of Coho Salmon encounters by catch area, and gear-specific mortality rates for fisheries occurring in those areas, and then applying estimates of the proportion of Interior Fraser Coho in those encounters based on genetic stock identification (Irvine et al. 2001; Simpson et al. 2004).

For 2001-2011, Canadian marine exploitation rates on Interior Fraser Coho were estimated using a model that scaled average exploitation rate during a baseline period (1987-1997; when exploitation rates could be reliably estimated from CWT recoveries) by the amount of fishing effort each year relative to average effort for the baseline period (Simpson et al. 2004). Similarly, United States (including Alaskan) exploitation rates on Interior Fraser Coho were estimated using their Fisheries Resource Allocation Model (FRAM; PFMC 2006), which relies on exploitation rates derived from CWT recoveries from US origin marine fisheries during an earlier based period that are scaled to reflect fishing effort in the current year relative to the baseline period. To estimate Canadian in-river (lower Fraser River) exploitation rates, total daily Coho Salmon mortalities are estimated for each fishery component as the sum of Coho taken plus the product of the number of encounters and the associated gear-specific mortality rates, and this value is multiplied by the modelled proportion of Interior Fraser Coho present in the daily catch (Simpson et al. 2004). Modelled declines over time in the proportion of Interior Fraser Coho present in the daily catch (‘decay model’) and the parameters of this decay are derived from an empirical fit of a Bayes model to DNA samples collected during 1997-1999 (Irvine et al. 2000; Simpson et al. 2004). The models described above all assume stationarity in stock distributions, but vary in the coverage of fisheries, and incorporation of release mortality and natural mortality rates. For example, the Canadian marine and Fraser River decay models assume release mortality only, while the US FRAM model assumes both release and natural mortality. Exploitation rate estimates for Interior Fraser Coho for 1975-2003 are summarized in Simpson et al. (2004). Exploitation rates for 1986-2009 are summarized by the PSC Joint Coho Technical Committee (PSC 2013). Exploitation rates reported here for 2010 and 2011 were provided by DFO Science Branch.

The reliability of exploitation rate estimates for Interior Fraser Coho from 1998 onward is uncertain for several reasons. First, the estimation models assume stationarity through time in the distribution and migration timing of Interior Fraser Coho and other Coho populations through the various fisheries. This assumption is highly uncertain given observed year-to-year shifts in the distribution of Coho Salmon between the Strait of Georgia and the west coast of Vancouver Island in the 1990s, and the difficultly in inferring inside-outside distribution changes in more recent years in the absence of directed fisheries on Coho Salmon (see Section 7). The Canadian marine exploitation and US FRAM models depend on comparisons of fishing effort in recent years versus the baseline period, but how similar fisheries in the two periods were is questionable given that during the baseline period directed fisheries on Coho Salmon occurred, whereas in recent years Coho Salmon were mainly intercepted as bycatch in fisheries targeting other species. The absence of significant directed fisheries on Coho Salmon in recent years has also meant that monitoring of fishing effort has declined, which has led to increased uncertainty in estimates of fishing effort (all models), and encounter rates and gear-specific mortality rates in the case of the Fraser in-river decay model (Simpson et al. 2004; PSC 2013). Finally, estimates of release mortality for Coho Salmon in commercial and recreational fisheries are based on data from a limited number of studies, and are also highly uncertain (PSC 2013). Mandatory release of wild Coho Salmon may also be resulting in increasing predation rates by marine mammals, particularly Harbour Seal (*Phoca vitulina)*, which can become habituated to preying on salmon released from nets and hook and line gear, but this has not been assessed. An assessment of mark-selective fisheries is planned for 2014.

11.3 BODY SIZE AND FECUNDITY

Size and fecundity data collected during regular DFO escapement surveys were too sparse and inconsistent over time to be useful for assessing temporal trends for Interior Fraser Coho (Irvine et al. 1999a). However, since the mid-1980s, size and fecundity data have been collected in a fairly consistent manner as part of brood stock collection for hatchery programs on several enhanced Interior Fraser streams. The majority of Coho Salmon sampled during these programs were wild-origin. We used these data as a proxy to assess temporal trends in mean body size (postorbital-hypural length) and fecundity (number of eggs per female). Fecundity estimates derived from these data were likely biased low to a minor degree due to the sampling method employed (see Irvine et al. 1999a).

11.4 DECLINE OR CHANGE IN ABUNDANCE

COSEWIC recommends assessing the"reduction in total number of mature individuals over the last 10 years or 3 generations (i.e., 9 years for Coho), whichever is longer" (COSEWIC 2010a). We assessed the percent change in abundance in both escapement (wild fish only) and total return (escapement + catch of wild and hatchery fish) for the most recent 10-year period (2001-2011)[6]. Change in population size was estimated for individual CUs, and for the Interior Fraser aggregate. We also estimated the change in population size (for individual CUs, and for the aggregate) for the entire 37-year time series (1975-2011). The use of multiple

[6] 11 years of data are required to estimate the change in abundance for a 10-year period.

change in abundance metrics and their interpretation in the context of ancillary information was recommended by Holt et al. (2009), and in more detailed work by Porszt et al. (2012), and in a recent process to evaluate the status of Fraser Sockeye Salmon CUs (Grant and Pestal 2012). Interpretation of status across multiple metrics can provide a more complete picture of CU status. For example, if a CU rapidly declined in abundance during an early time period and subsequently stabilized at relatively low adult numbers, status would vary markedly depending on the length of the time series used to compute the rate of change in population size.

For each time period and abundance metric (escapement and total return), we estimated rate of change using a linear time-trend model (linear regression of escapement or total return against year). Time-trend models were fit to $\log_e$-transformed escapement or total return data (smoothed using a 3-year running average) to remove the annual "noise" in salmon abundance that can obscure underlying trends (COSEWIC 2003; Grant et al. 2011). We used the coefficient value for the slope of the regression to estimate the annual intrinsic rates of change in the population (r_a). The finite rate of change per year is $1-e^{r_a}$, and the proportional change over *n* years is $1-e^{nr_a}$ (Bradford 1998).

11.5 TOTAL RETURN, PRODUCTIVITY, AND SMOLT-ADULT SURVIVAL

Total return refers to the annual number of adult Coho Salmon arriving in coastal marine areas on their return to freshwater prior to interception by fisheries (i.e. catch plus escapement). We estimated total returns for Interior Fraser Coho from estimates of total escapement (wild + hatchery) and exploitation rate, where total return = total escapement / (1-exploitation rate).

For a semelparous Pacific salmon species such as Coho Salmon, productivity is generally referred to as the number of pre-fishery adult recruits per spawner, and represents a measure of survival across the life cycle of an individual cohort. We estimated intergenerational productivity as $\ln(R_t/S_{t-3})$, where R_t is recruitment (i.e. total return) in year t, and S_{t-3} is the abundance of parent spawners (i.e. escapement) three years previous. Negative productivity estimates represent negative population growth (i.e., < 1 recruit per spawner), when a population is unable to replace itself, even in the absence of fishing.

To estimate productivity for wild Interior Fraser Coho it is necessary to include hatchery-origin Coho Salmon that spawn naturally in streams (see Section 10) as part of brood escapement (S_{t-3}) because their progeny are indistinguishable from wild adult Coho Salmon. Coho salmon (wild and hatchery-origin) that are spawned in hatcheries are not included in estimates of wild escapement. R_t is based on escapement estimates for wild adults only, which include recruits from both wild-origin parents and hatchery-origin parents that spawned in natural habitat. Our estimates of productivity are biased high to a modest degree as a result of unmarked first generation hatchery fish straying to unenhanced streams, and being included in escapement estimates for wild fish (see Section 10). Our estimates of total return and productivity are also fairly uncertain for 1975-1985 because both these parameters depend on estimates of exploitation rate, and there are no year-specific estimates of exploitation rate for this period (the mean value for a 1986-1997 base period is used to estimate exploitation rate for all years during 1975-1985; see Section 11.2).[7]

We assessed the trend in productivity over time for Interior Fraser Coho in lieu of modeling the future trajectory of the population and estimating extinction probabilities (COSEWIC Criterion E), since there is currently no consensus regarding future smolt-adult survival rates.

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[7] Erratum: September 2014. Explanation of the inclusion of hatchery origin Coho that were previously not included in brood escapement.

To illustrate the impact of fisheries exploitation on population growth for Interior Fraser Coho, we estimated “post-fishing productivity”, which we computed as $\ln(S_t/S_{t-3})$, where S_t is escapement in year t (i.e., recruitment minus catch) . The difference between productivity and post-fishing productivity represents the impact of exploitation on population growth.

In cases where data are available, partitioning productivity into pre-smolt (freshwater) and post-smolt (primarily marine) components, is helpful to determine how productivity has changed in these broad ecosystems, and to understand the mechanisms influencing survival. Estimates of smolt-adult survival for Interior Fraser Coho have been derived from CWT recovery data for several hatchery stocks in the North and South Thompson basins, but the time series of available estimates are limited and incomplete (Irvine et al 1999a). Consequently, we used smolt-adult survivals for Strait of Georgia wild indicator stocks as a surrogate for Interior Fraser Coho smolt-adult survival. This approach is supported by evidence that Coho Salmon from the two regions have similar ocean distributions, and the productivity (recruits/spawner) of Interior Fraser Coho populations is correlated with smolt-adult survival for wild Strait of Georgia Coho populations (IFCRT 2006; Beamish et al. 2010). Smolt-adult survival rates for Strait of Georgia wild Coho that appear in this document are the mean of wild Coho Salmon survivals from Black Creek (western Strait of Georgia), Salmon River (lower Fraser River) and Myrtle Creek (eastern Strait of Georgia) (data time series maintained by S. Baillie, DFO Nanaimo, and available in Supplemental Data File 2 in Irvine et al. 2013).

11.6 EXTENT OF OCCURRENCE

IUCN (2011) and COSEWIC (2010b) define extent of occurrence (EO) as “the area contained within the shortest continuous boundary drawn to encompass all the known, inferred or projected sites of present occurrence of a species, excluding cases of vagrancy”. The extent of occurrence is intended to be a metric of the geographic spread of a population, and is used to assess the degree to which it may be at risk from potential threats (de Mestral Bezanson et al. 2012). The IUCN (2011) further stipulates that for migratory species the minimum of breeding or non-breeding areas (but not both) should be used to estimate EO. For the Interior Fraser Coho aggregate, the non-breeding area includes a large area within the North Pacific Ocean, while the breeding area is much smaller, encompassing freshwater spawning and rearing habitats in the interior Fraser River watershed.

We estimated EO based on spawner distributions alone because there was insufficient information to quantify juvenile rearing distributions. We computed EO for each of the five CUs and for the Interior Fraser aggregate using the minimum convex polygon (MCP) method COSEWIC (2010b). De Mestral Bezanson et al. (2012) discuss some limitations with this for Pacific salmon, and present some alternatives. However, the MCP method is the only method prescribed in COSEWIC’s *Instructions for the Preparation of Status Report*s (COSEWIC 2010a). We estimated polygon areas (km^2) using a web-based add-in tool for Goggle Earth (http://www.earthpoint.us/Shapes.aspx), which estimates the MCP encompassing a set of points. For input data, we relied on field staff observations (locations drawn on maps or easting and northing coordinates collected with global positioning system (GPS) devices, or information collected during interviews) of the upstream extent of spawning for individual streams for 1998-2011. These data were incomplete in many cases, but were adequate for the purpose of generating MCPs to estimate EO for each CU. We were unable to assess trend in EO because spawner distribution data were not collected in a consistent and comprehensive manner from year to year, and because survey data were unavailable for the Middle/Upper Fraser and Fraser Canyon CUs prior to 1998 and for the Lower Thompson CU prior to 1984.

11.7 AREA OF OCCUPANCY

The area of occupancy (AO) is a measure of the amount of habitat occupied by a population, recognizing that the population may not occur at all locations within its EO (de Mestral Bezanson et al. 2012). As such, the AO is expected to be more closely correlated with population size than the EO. The IUCN (2011) defines AO as “the most spatially confined area essential at any stage to the survival of a population or designated unit”. For Interior Fraser Coho, this equates to spawning habitat. With the exception of the Fraser Canyon CU, we were unable to generate AO estimates because the finer-scale spawner distribution data required (i.e., linear lengths of individual stream sections were spawners are observed) were not available, as not all streams or stream reaches where spawning occurs are surveyed.

For the Fraser Canyon CU, which is encompassed within a single stream (Nahatlatch River), we computed AO using both a 2×2 km grid and a 1×1 km grid, and methods described by de Mestral Bezanson et al. (2012). Both IUCN (2011) and COSEWIC (2010b) require that the area of occupancy be assessed by overlaying the extent of occurrence of a population with a grid of 2×2 km cells and summing the area of cells in which the population occurs. COSEWIC also allows area of occupancy to be assessed using 1×1 km cells (COSEWIC 2010a), which can result in a smaller estimate of AO (de Mestral Bezanson et al. 2012), and a higher risk categorization (IUCN 2011).

11.8 NUMBER OF LOCATIONS

COSEWIC uses 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 (COSEWIC 2010a, IUCN 2011)”. De Mestral Bezanson et al. (2012) note that the number of locations is driven by the distribution of perceived threats, such that if one population is affected by different threats in different areas, then the number of locations would reflect the number of threats, whereas if an entire population experiences the same threat throughout its range, then the location number would reflect this singularity. Different definitions and interpretations of locations for a population are possible because the definition of a location is driven by perception and knowledge of threats (de Mestral Bezanson et al. 2012). Following de Mestral Bezanson et al.’s approach, we defined locations as individual streams where spawning Coho Salmon were detected, under the assumption that the threats most likely to result in long-term damage to essential freshwater spawning and rearing habitat (e.g., forest fires, landslides) would apply to watersheds associated with individual streams. Recent reviews of appropriate metrics of distribution for Pacific salmon have also treated individual streams as locations (Holt et al. 2009; Peacock and Holt 2010, 2012).

Our ability to assess the trend over time 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 in particular by the expansion of the escapement monitoring program beginning in 1998 (see *Section 11.1*). To address this, we examined the trend in the proportion of surveyed streams where Coho Salmon were detected as opposed to the trend in the absolute number of streams, and we limited our analysis to the post-1998 period (1998-2011). This analysis was conducted for individual CUs and for the Interior Fraser aggregate. It is important to note that the number of streams that had Coho Salmon detected in them will be less than the number of streams actually occupied by Coho Salmon because the probability of Coho being detected during stream surveys is less 100%. We also examined the relationship between the proportion of streams where Coho Salmon were detected and total escapement for the same period. Empirical studies have shown that the proportion of occupied spawning locations typically increases exponentially with spawner abundance until a maximum (asymptotic) occupancy is reached (Peacock and Holt 2010).

12 RESULTS AND DISCUSSION

12.1 POPULATION SIZE

Total escapements of wild Coho Salmon to the Interior Fraser were relatively stable during 1975-1988 (CV=0.27), with an average of 60,000 spawners and a peak of 91,000 spawners in 1984 (Table 2, Figure 3), and then steadily declined to a low of 9,000 spawners in 1996[8]. Escapements have fluctuated in the last decade (2002-2011), but remain several-fold lower than escapements during the earlier 1975-1988 period. The spawning population of wild Interior Fraser Coho averaged 26,000 adults (geometric mean) for the most recent generation (2009-2011, Table 1), and 23,000 adults for the most recent decade. Annual escapements of Interior Fraser Coho have varied 8-fold during the most recent decade (CV=0.57).

The North and South Thompson CUs, the two largest groups, which together accounted for an average of 60% of annual escapements (from 1998 onward when all five CUs were monitored), followed a similar trend to that described above for the Interior Fraser aggregate (Table 2, Figure 4). The Lower Thompson CU also declined in abundance during the 1990s, but to a lesser degree than the North and South Thompson CUs (Table 2, Figure 4, upper graph). The Middle/Upper Fraser CU did not exhibit any strong trends during the relatively recent period when it was monitored. Escapements to the Fraser Canyon CU during 2005-2011 were roughly 2-fold lower than those during 1998-2004 (Table 2; Figure 4). During the last decade (2002-2011), fluctuations in annual escapements to individual CUs ranged from 5-fold[9], for the Fraser Canyon CU to 8-fold for the South Thompson, North Thompson and Middle/Upper Fraser CUs, to 14-fold for the Lower Thompson CU, the latter meeting the IUCN definition of extreme fluctuation. Differences in abundance trends among the five CUs suggest that individual CUs were exposed to somewhat different environmental conditions or responded in different ways to common environmental conditions, or that both phenomena occurred (Peacock and Holt 2010). For the most recent generation, individual CUs had geometric mean escapements ranging from 2,200 for the Fraser Canyon CU (Table 1), to 8,800 adults for the North Thompson CU. These values were below the threshold for 'threatened' status for four of the five CUs (5,000 mature individuals, COSEWIC 2010a, Criterion C), and below the lower threshold of 2,500 mature individuals for 'endangered' status for the fifth CU (Fraser Canyon).

During 1986-2011, when escapements included wild as well as hatchery-origin Coho Salmon, the mean proportion of hatchery fish ranged from 0% for the Middle/Upper Fraser and Fraser Canyon CUs, to 7% and 9%, respectively, for the South and North Thompson CUs, to 35% for the Lower Thompson CU. For the Interior Fraser aggregate, the mean proportion of hatchery fish for the same period was 13% (range: 3%-27% for individual years; Table 2, Figure 3). For the most recent generation, the proportion of hatchery-origin fish in escapements was substantially lower (0%-15% among the five CUs, and 7% for the aggregate, Table 1). For wild and hatchery fish combined, geometric mean escapements to the Interior Fraser for the most

[8] Escapement survey methods were generally less intensive and accurate prior to 1998 (see *Section 11.1*).

[9] Excluding the low escapement estimate for 2006 that was influenced by poor survey conditions (see Table 2).

recent generation and for the most recent 10 years were 28,000 (Table 1) and 25,000 adults, respectively.

12.2 DECLINE OR CHANGE IN POPULATION SIZE

During the last 10 years (2001-2011), aggregate escapements of wild adult Coho Salmon to the interior Fraser River remained relatively unchanged (-9% decrease, Table 3). This was also true for three of the five CUs within (North Thompson, South Thompson and Middle/Upper Fraser, Table 3). However, there was an estimated 72% increase in adult returns to the Lower Thompson CU, despite reductions in hatchery production and corresponding reductions in the proportion of hatchery fish among returning adults during the last decade (see *Sections 10* and *12.8.5*). The Fraser Canyon CU experienced an estimated 58% decline in escapement, which lead to it having the lowest escapement of the five CUs for the most recent generation (Table 1). Prior to computing estimates for the Fraser Canyon CU, we removed the low escapement value of 84 spawners in 2006 (Table 2) because it was negatively biased by the poor surveys conditions that occurred during all surveys of the Nahatlatch River (sole spawning stream) in that year (R. Bailey, Fisheries & Oceans Canada, Kamloops, BC, personal communication, 2013). Estimates of percent population change for the most recent 10 years based on total return (escapement + catch) did not differ greatly from estimates based on escapement (Table 3), except that moderate declines in total return occurred for the South and North Thompson CUs (21% and 25%, respectively), compared to low declines for escapement (15% and 11%, respectively). These relatively small differences between escapement and total return trends is expected given the low exploitation rates during the last decade (see next section).

When we assessed changes in abundance across the entire 37-year time series, results differed substantially from those for the last 10 years. For the Interior Fraser aggregate, escapement declined by an estimated 72% during 1975-2011 (Table 3). Among the three CUs for which data were available, declines in escapement were similarly high for the South Thompson and North Thompson CUs (67% and 80% declines, respectively, Table 3), but much less for the Lower Thompson CU (38% decline), although the time series for the latter (1984-2011) was shorter. For exploited Coho Salmon populations, total return is the potential spawning size in the absence of fishing (assuming minimal en route mortality), since nearly all fish that are harvested are mature individuals returning to freshwater to spawn. Total returns of Interior Fraser Coho declined to a much greater extent than did escapements during 1975-2011, from a geometric mean of 174,000 fish during 1975-1993, to a mean of 30,000 fish for the most recent generation (Figure 3). The discrepancy between the trends for the two metrics was the result of much higher exploitation rates prior to 1998 that removed a much larger proportion of the potential adult population compared to the post-1998 period.

Threshold values (%) for assessing population decline specified under COSEWIC Criterion A (≥50% or ≥70% for endangered status, and ≥30% or ≥50% for threatened status, COSEWIC 2010a) vary depending on whether the causes of the reduction are clearly reversible, whether they are understood, and whether they have ceased. The higher threshold values apply only in cases where all three criteria are satisfied. The principle causes of the decline are understood for Interior Fraser Coho (see *Sections 12.3* and *12.8*), and they appear to be reversible given evidence that modest increases in productivity coupled with low exploitation rates has resulted in rapid population growth at both the aggregate (Figure 3, lower graph) and CU level (Figure 4, lower graph) in several years during the last decade. However, it is unclear whether Interior Fraser Coho abundance will continue to be depressed as a result of low smolt-adult survival (see *Sections 12.3 and 12.4*).

12.3 EXPLOITATION, TOTAL RETURN, AND SURVIVAL

In 1997 the DFO began implementing a series of management measures to reduce the exploitation rate on Coho Salmon populations (Irvine et al. 2001, IFCRT 2006). In 1998, unprecedented restrictions to Canadian salmon fisheries were implemented specifically to conserve Interior Fraser Coho and other depressed Coho Salmon populations in southern British Columbia. The original goal was to produce no mortality of Interior Fraser Coho. The broad distribution of Interior Fraser Coho and the sequential nature of many of the fisheries involved in their harvest meant that, for more fish to reach the spawning grounds, management measures taken in one fishery need to be complemented by measures in other fisheries (IFCRT 2006). Selective fishing techniques and a "moving window" of salmon fishing closures (i.e., closures in time and space to coincide with the presence of migrating Coho Salmon) were mandated for appropriate salmon fisheries in marine approach areas and the Fraser River mainstem. Directed commercial fisheries on Coho Salmon were curtailed except on enhanced populations in terminal areas, and non-retention of all Coho Salmon in commercial fisheries was imposed. Mark-selective regulations were introduced for recreational fisheries (only adipose-clipped hatchery fish could be retained), and retention of Coho Salmon in First Nations fisheries was only permitted for incidentally caught, non-revivable fish, or terminal fisheries targeting enhanced streams. Additional measures included a coast-wide requirement for barbless hooks, installation of revival tanks on commercial salmon fishing vessels, restriction of gill net set times to 30 minutes and a requirement for seine boats to brail and sort their catch. Measures were also taken in the United States to reduce exploitation of Interior Fraser Coho. A more detailed summary of the management measures implemented to protect Interior Fraser Coho is provided by the IFCRT (2006).

At present, the measures initiated in 1997 and fully implemented in 1998 to protect Interior Fraser Coho remain largely unchanged, with only minor modifications to allow for greater flexibility in management. The current objective is to maintain an estimated fishery-related mortality rate on Interior Fraser Coho of less than 3%[10] in Canadian fisheries. The 1999 amendments to the Pacific Salmon Treaty provide for a limit on American fishery mortality on Interior Fraser Coho of 10% while the population status remains low (see http://www.psc.org/pubs/Treaty/Treaty.pdf; PSC 2013).

Canada and US combined exploitation rates averaged 10% during 1998-2011 (range: 4%-14%, Table 2, Figure 5a). During the preceding 12-year period (1986-1997), average exploitation was nearly seven-fold higher (mean: 66%, range: 41%-88%). It is likely that the pre-1998 period of high exploitation rates for Interior Fraser Coho extended as far back as the early 1900s given the near-shore ocean distribution of Coho Salmon and the large number of fisheries in these waters historically (IFCRT 2006). Unsustainable fishing occurred in the 1990s as exploitation rates actually increased when they ought to have been reduced in response to climate-driven reductions in smolt-adult survival (see next section). Since 1998, fishery exploitation has had relatively little impact on escapements of Interior Fraser Coho, as evidenced by the nearly overlapping trend lines for total return and escapement in Figure 3.

Given the mitigating effect of reduced exploitation after 1998, the trend in total returns reflects the decline in productivity that occurred during 1975-2011 more accurately then does the trend in escapement (Figure 3).

Although freshwater habitat degradation was likely a contributing factor (see *Section 12.8.1*), the consensus is that declining smolt-adult survival was the major cause of the downward trend in productivity (Bradford 1998; Bradford and Irvine 2000; Coronado and Hilborn 1998; IFCRT

[10] Under the Pacific Salmon Treaty, Canadian fishing mortality on Interior Fraser Coho is limited to 10%.

2006, but see also Chittenden et al. 2010). We relied on the trend in smolt-adult survival estimates for Strait of Georgia wild Coho Salmon indicator stocks as a surrogate for the trend in smolt-adult survival for Interior Fraser Coho. This is supported by the fact that smolt-adult survival rates for wild Strait of Georgia Coho Salmon are a significant predictor of both productivity for Interior Fraser Coho (1986-2011, regression, R^2=0.38, P<0.0009; see next section), and smolt-adult survival for hatchery-origin Coho Salmon from a single Interior Fraser stream (Coldwater River, 1999-2009, R^2=0.50, P<0.02, Figure 5b).

Smolt-adult survival of wild Strait of Georgia Coho Salmon declined 7-fold over the available time series, from an average of 11.7% during 1986-1992 (return years), to 1.6% during 2005-2011 (Figure 5b). Since the original COSEWIC assessment in 2002 (return years up to 2000, Irvine 2002), smolt-adult survivals improved modestly during 2001-2004, but then fell below 2% in subsequent years with the exception of 2009 (3.2%). Regime shifts in marine conditions can profoundly impact ocean survival of salmon (Beamish et al. 1997, 2000; Irvine and Fukuwaka 2011). Major regime shifts occurred in the North Pacific in approximately 1976-1977 and 1989-1990 (Beamish and Bouillon 1993; Irvine and Fukuwaka 2011). Available data for Interior Fraser Coho indicates an abrupt and sustained downward shift in productivity coinciding approximately with the 1989-1990 regime shift (see next section).

12.4 PRODUCTIVITY

Productivity (ln(recruits/spawners)) of Interior Fraser Coho declined significantly from the late 1970s until present (Figure 6a). When we controlled for the effect of variation in brood abundance by plotting annual productivity against brood escapement rather than year, two distinct periods of productivity were evident (1975-1990 and 1991-2008), corresponding approximately to a 1989-1990 shift in marine conditions (Figure 6b). Productivity was considerably lower following the 1989-1990 regime shift (ANCOVA, n=34, df=1, $F\text{-}stat$=70.82[11], P<0.000001), the result of reduced smolt-adult survival (Figure 5b).

During the more recent period of low productivity there have been eight years (1995, 1997, 2000, 2003-2006, 2010; Figure 6a)[12] when productivity was less than 0 (four years in the last decade), meaning that Interior Fraser Coho were unable to replace themselves (i.e. recruits/spawner <1), even if exploitation had been zero. The fact that productivity of Interior Fraser Coho has fallen below replacement several times during the last decade indicates the potential for further declines in population size if smolt-adult survival rates remain low. There is no consensus within the scientific community about future smolt-adult survival rates for Interior Fraser Coho or Coho Salmon in general. An analysis by Folkes et al. (2005) suggests that at recent exploitation rates and smolt-adult survivals, the long-term probability of positive growth for Interior Fraser Coho is <50%. Conversely, a return to higher survivals experienced in the 1980s and early 1990s, combined with continued restrictions on fisheries would likely produce rapid increases in escapements and population rebuilding.

When we examined post-fishing productivity (ln((recruits-catch)/spawners)), it was evident that unsustainable exploitation rates occurred in 10 of 12 years during 1986-1997 when the major decline in Interior Fraser Coho abundance took place (Figure 6a). If exploitation had been sufficiently reduced, the population would have replaced itself every year during this period with the exceptions of 1991, 1995 and 1997 (Figure 6a). During 1998-2011, when restrictions were imposed on the various fisheries sectors, overall exploitation was sufficiently low (4%-13%) to

[11] Erratum: September 2014. Productivity estimate corrected.

[12] Erratum: September 2014. Productivity description corrected.

allow for positive population growth (i.e., post-fishing productivity > 0), in eight of 14 years[13]. During these years, fishing contributed to negative population growth, but the population would not have replaced itself even in the complete absence of exploitation (Figure 6a).

12.5 TRENDS IN BODY SIZE AND FECUNDITY

Reasonably consistent time series of size and/or fecundity data were available for only four enhanced Interior Fraser streams (Coldwater, Spius, Deadman, and Salmon). The Coldwater River had the longest time series, and showed a decline in mean post-orbital hyperal length and fecundity from 1988 to 1997, followed by a strong recovery from 1997 to 2011 (Figures 7 and 8), with maximum values observed in recent years. A positive trend in mean length and fecundity from the mid-1990s to 2011 was evident for the other three streams as well (Figures 7 and 8). For the Coldwater River, the minimum fecundity value observed in 1997 (1,300 eggs/female) was only 68% of the 3-year average for the beginning of the time series (1,900 eggs/female for 1988-1991) and 50% of the 3-year average for the end of the time series (2,600 eggs/female for 2009-2011). Based on marine commercial catches, the overall trend for southern British Columbia and Washington State was a decline in average body weight from the 1950s to the early 1990s, followed by a rapid rebound beginning in 1993 (Shaul et al. 2007). Although limited, the size and fecundity data for Interior Fraser Coho suggest a similar trend. Size and fecundity trends were not examined as part of the original COSEWIC status assessment for Interior Fraser Coho (Irvine 2002). The sharp decline in fecundity in the 1990s is noteworthy because it coincided with the major decline in escapement (Figure 3), and would have exacerbated the reduction in productivity at that time.

12.6 DISTRIBUTION

12.6.1 Global Range

Coho Salmon occur naturally only within the Pacific Ocean and its tributary drainage (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 9; Sandercock 1991).

In addition, Coho Salmon have been introduced to many locations including the Great Lakes. Numbers of Coho Salmon are declining throughout much of the species range and some populations have become extinct (e.g., Nehlsen 1997; Weitkamp et al. 1995; Slaney et al. 1996; Northcote and Atagi 1997). Of the seven Coho Salmon ESUs recognized in the lower United States as of June, 2012, one was listed as endangered, one as threatened, three as populations of special concern, one as undetermined, and one as not likely to become endangered.

12.6.2 Canadian range

Coho Salmon spawn and rear in most coastal streams and rivers of British Columbia. In addition Coho Salmon are also found considerable distances inland in a number of the large river systems (e.g., Fraser, Skeena, Nass, Taku; Sandercock 1991). The marine distribution of many populations including Interior Fraser Coho has been assessed using information obtained through DFO's Mark Recovery Program (MRP). In recent years this has not been possible due to limited CWT recovery data (see *Section 11.2*). Coho Salmon from the Interior Fraser have been recovered in fisheries from Alaska to Oregon, but most were gathered from commercial troll and sport fisheries operating off the west coast of Vancouver Island and in the Strait of

[13] Erratum: September 2014. Exploitation description corrected.

Georgia (Irvine et al. 1999a, 2001). Prior to 1991, large numbers of Coho Salmon remained inside the Strait of Georgia each year (Kadowaki 1997), whereas in 1991 and 1995-1997, the majority of Coho Salmon appeared to leave the Strait of Georgia and spend most of their adult lives off the west coast of Vancouver Island. Major fishery closures commencing in 1998 have made it more difficult to infer inside-outside distribution changes. Marine conditions 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).

12.6.3 Distribution within the Interior Fraser River Watershed

The Fraser River is the largest river in BC and produces more salmon than any other river in the world (Northcote and Larkin 1989). The interior Fraser River watershed is part of the Southern Mountain COSEWIC Ecological Area. Coho Salmon are widespread throughout the Thompson River system (North, South and Lower Thompson CUs; Figure 1), the largest watershed within the Fraser River system. However, their distribution in Fraser tributaries other than the Thompson is poorly understood. The Fraser Canyon CU is limited to the Nahatlatch River, a Fraser River tributary situated between Hells Gate and the Thompson River confluence. Within the Middle/Upper Fraser CU, Coho Salmon occur at least as far upstream as the Nechako River system, have been recorded in a number of other major Fraser tributaries downstream of the Nechako (e.g., Quesnel, Chilcotin, West Road (Blackwater); Figure 1), and may also occur in tributaries upstream of the Nechako (e.g., Bowron River), but their presence has not been confirmed. Coho Salmon may still be expanding their distribution in the interior Fraser River watershed after their migration past the Fraser canyon was severely impeded by large quantities of rock dumped into the river during railway construction in 1913 and a rock slide in 1914 (Ricker 1989).

Based on common landscape and geomorphologic attributes, there would appear to be an extensive amount of suitable habitat available within the Middle/Upper Fraser CU, although habitat suitability for Coho Salmon in large interior river systems is not well understood. Much of this potential habitat has limited road access, and occurs in localized patches within very large drainages. The high cost of the extensive surveys that would be required to adequately assess spawner numbers has limited recent efforts to better define current Coho Salmon distributions in these systems (R. Bailey, Fisheries & Oceans Canada, Kamloops, BC, personal communication, 2013). Moreover, the escapement monitoring program for Fraser Coho Salmon is designed to detect trends in population size rather than distribution, and effort is disproportionately allocated to those streams that account for the majority of overall escapement (Peacock and Holt 2010, 2012).

12.6.4 Extent of occurrence, area of occupancy, and number of locations

Estimated extent of occurrence (EO) was 9,900, 12,100, 10,100, and 76,000 km^2, respectively, for the North, South, and Lower Thompson, and Middle/Upper Fraser CUs (Table 1). The EO value for the Middle/Upper Fraser CU is likely an underestimate, given uncertainty about the distribution of Coho Salmon in a number of streams in this CU (see previous section). EO was much smaller (110 km^2) for the Fraser Canyon CU, which consists of a single stream (Nahatlatch River). For the Interior Fraser aggregate, EO was an estimated 110,000 km^2 (Table 1).

Due to insufficient data, we were able to estimate area of occupancy (AO) only for the Fraser Canyon CU. Estimates of AO for the Fraser Canyon CU were 36 km^2 and 14 km^2, based on 2$\times$2 km and 1$\times$1 km grids, respectively.

Number of locations is an additional distribution criterion used by COSEWIC, in conjunction with other criteria, to asses status (see COSEWIC 2010a). For the South Thompson, North

Thompson and Middle/Upper Fraser CUs, Coho Salmon spawners from the most recent generation (2009-2011) were detected at 30, 25, and 11, locations (individual streams, see *Section 11.8*), respectively (Table 1). Coho Salmon were detected in eight streams in the Lower Thompson CU, 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 (R. Bailey, Fisheries & Oceans Canada, Kamloops, BC, personal communication, 2013). Coho Salmon representing the Fraser Canyon CU spawn in a single stream (Nahatlatch River). Across the entire interior Fraser River watershed, Coho Salmon were detected in a total of 75 of the streams that were surveyed during 2009-2011.

12.6.5 Trend in the distribution of Interior Fraser Coho and relationship to abundance

We found no evidence of a declining trend in the proportion of surveyed streams with Coho Salmon detected during 1998-2011. The proportion of streams with Coho Salmon detected was quite variable among years for the Interior Fraser aggregate (Figure 10a), and for the individual CUs (Figure 11), but the data suggested either no trend (North Thompson and Lower Thompson CUs), or a weak positive trend (South Thompson and Middle/Upper Fraser CUs and the Interior Fraser aggregate). At escapement levels observed during 1998-2011 (7,000-56,000 for the aggregate, see Table 2 for escapements for individual CUs), the distribution of Coho Salmon was positively associated with escapement: at the aggregate level, total escapement explained 68% of the year-to-year variation in the proportion of streams with Coho Salmon detected (linear regression, R^2=0.68, escapements were natural log-transformed prior to analysis; Figure 10b); at the CU level, total escapement (to the CU) 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 CUs, respectively (data not shown). By contrast, there was no relationship (R^2=0.02) between the proportion of streams with Coho Salmon detected and escapement for the Lower Thompson CU, despite a strong contrast in escapement (700-9,600 spawners).

Previous studies examined trends in the presence and absence of Coho Salmon at regularly surveyed locations in the North and South Thompson CUs, and assessed the relationship between the number of locations where Coho Salmon were observed and overall escapement. Bradford (1998) found that 32% of streams in the North and South Thompson CUs that had Coho Salmon observed in them in 1988 had reached 'none-observed' status in 1997 (i.e. three generations later). This proportion declined to 18% in 1999. A preliminary assessment (based on 1975-2001 data) of the possibility of using stream occupancy to assess the status of Thompson River Coho Salmon indicated that a non-linear reduction in stream occupancy began to occur when annual escapement was reduced to about 25% of peak escapement observed during the time series (J. R. Irvine, unpublished data). Peacock and Holt (2010) also found that diversity in the spatial distribution of Coho Salmon in the South Thompson CU was positively related to escapement.

12.7 ALTERNATE APPROACHES FOR ASSESSING INTERIOR FRASER COHO

Holt et al. (2009) identified quantifiable metrics (criteria) of biological status and benchmarks for the assessment of status of Pacific salmon CUs under DFO's Wild Salmon Policy (DFO 2005b), and recommended a multi-criteria approach for assessing status that considered information on relative abundances, change in abundance over time, distribution of spawners, and fishing mortality. Under the WSP approach, status is not determined by any one metric. Instead, different metrics describe different characteristics of the status of a CU, which are then integrated into a CU status (Grant and Pestal 2012). Each WSP metric requires an upper and lower benchmark to determine status. These benchmarks delineate three status zones: Green, Amber, and Red (Figure 12). The lower benchmark represents a substantial buffer between it and a lower level of abundance (Red Zone) that could lead to a population or conservation unit (CU) being considered at risk of extirpation (DFO 2005b). A CU in the Amber Zone should be at a low risk of extirpation, can sustain fisheries, but below optimal levels. CUs in the Green Zone would not have a high probability of loss, and when CUs are maintained in this zone, maximize sustainable yields may be possible. Designated Units (DUs) listed by COSEWIC (as either threatened or endangered) would fall into the Red Zone as defined by the WSP. Grant and Pestal (2012) recently assessed the status of Fraser River Sockeye Salmon CUs using metrics and benchmarks recommended by Holt et al. (2009).

The status of Interior Fraser Coho CUs has yet to be assessed under the WSP, and no benchmarks, reference points or recovery objectives have been formally adopted for the CUs or for the Interior Fraser aggregate. The Coho Technical Committee of the Pacific Salmon Commission is currently working on WSP benchmarks and management unit reference points for Strait of Georgia Coho Salmon populations, and Fraser River management units, including Interior Fraser Coho, are tentatively scheduled for assessment in 2014-15.

As part of the original COSEWIC assessment for Interior Fraser Coho in 2002, Irvine (2002) presented preliminary upper and lower reference points (that were originally developed by Irvine et al. 2001) for the North Thompson CU, based on the number of female spawners needed per km of accessible stream habitat. The two proposed lower reference points represented the minimum escapement that the CU had recovered from previously (6.1 females/km of accessible habitat), and the theoretical 10% probability of extinction for a single brood line in one generation (4.3 females/km). The upper reference point was the estimated number of female spawners that would produce maximum sustained yield (24.9 females/km). At the time (1997-2000), the North Thompson CU was in the critical (Red) zone below the lower reference point of 6.1 females/km (Irvine et al. 2001; Irvine 2002). However, Irvine et al. (2001) identified several limitations with the data and with the approach used to develop the benchmarks, and recommended further work was needed before they could be adopted. In a separate approach, Chen et al. (2002) found evidence of depensation for the North Thompson CU at low spawner numbers and estimated a 50% extinction probability if the number of spawners dropped below ~ 5,000.

More recently, the Interior Fraser Coho Recovery Team proposed a short-term recovery objective (similar to a lower benchmark) for Interior Fraser Coho (IFCRT 2006) that addressed conservation of genetic diversity and demographic issues, and consisted of maintaining a minimum 3-year average of 1,000 naturally spawning wild Coho Salmon in at least half of the subpopulations that they identified for each of the five CUs (IFCRT 2006). This amounts to maintaining >1,000 wild adults in seven of the 11 subpopulations, or 7,000 spawners in total. Empirical analysis indicated that, on average, a total escapement of 20,000-25,000 adults would be required to meet the objective of 1,000 or more individuals in at least half of the subpopulations within each CU because the subpopulations differ in productivity and potential carrying capacity, and they would not all be expected to have the same status at any one time (IFCRT 2006). The IFCRT's benchmark of 1,000 individuals per subpopulation was based on consideration of the effective population size necessary to conserve the genetic diversity of a Pacifc salmon population with a modest amount of overlap among cycle lines (Allendorf and Ryman 2002; Waples 2002), and the results of simulation modeling for other Pacific salmon populations that suggested that starting populations larger than 1,000 individuals had a low risk of extinction and a reasonable expectation of growth providing that productivity did not remain excessively low (IFCRT 2006). The IFCRT chose to apply the criterion of 1,000 spawners at the subpopulation level, rather than at the broader CU level, despite evidence of varying degrees of interbreeding among subpopulations within CUs, and among CUs (see Section 6), because they were concerned about the large geographic area encompassed by each CU (with the exception of the Fraser Canyon CU), and the likelihood of fragmentation of individual CUs into smaller isolated groups vulnerable to Allee effects (e.g. Chen et al. 2002). The IFCRT (2006) reasoned that by ensuring that more than one subpopulation remained viable within each CU, this would provide insurance against catastrophic events, and would likely result in protection of a greater proportion of the biodiversity of the CU as a whole. This approach follows the US model for assessing ESU viability (McElhaney et al. 2000), which identified the need for genetic as well as spatial diversity. However, as noted by Bradford and Wood (2004), the IFCRT's (2006) recovery objective was not based on specific scientific criteria.

12.8 LIMITING FACTORS AND THREATS

The original COSEWIC assessment for Interior Fraser Coho in 2002 (Irvine 2002) identified excessive exploitation, degradation of freshwater habitat, climate related changes in salmon survival, and human population growth as the most important threats. These threats continue to be important and their severity and immediacy have not changed significantly since the original assessment. For example, Irvine (2002) noted that the human population in the Pacific Northwest (including British Columbia) is expected to increase by two- to seven-fold this century, and suggested that this represents a threat to Interior Fraser Coho given the overall negative relationship between human population growth and salmon abundance at a global scale (Hartman et al. 2000; Lackey 2001). Yet, the number of people living in the interior Fraser River watershed has remained relatively static since 2002 (Government of Canada 2013), although it is also expected to increase substantially over the longer term.

In the following sections, the major threats to Interior Fraser Coho are reviewed with an emphasis on new information not contained in the original COSEWIC assessment. Where possible, we have identified threats that apply to specific CUs and locations. We have also included a new category, invasive non-indigenous species, which represent an emerging threat to salmon populations in some sub-basins within the interior Fraser River watershed.

12.8.1 Freshwater habitat

Productive freshwater habitats can help sustain salmon populations during periods of adverse marine conditions (or overexploitation) because they maximize the number of smolts produced per spawner. Since most juvenile Coho Salmon spend a full year in freshwater, they are susceptible to freshwater habitat degradation. Bradford and Irvine (2000) examined the rate of decline in Coho Salmon escapements to 40 streams in the North and South Thompson CUs relative to the extent of human activity in each stream's watershed during 1988-1998. They showed that rates of decline were correlated with agricultural land use, road density, and a qualitative index of stream habitat status (Figure 13). More intensive land use may be one reason why Coho Salmon escapements to streams in the South Thompson declined at a greater rate than did escapements to streams in the North Thompson during 1975-1998 (Figure 4).

Coho Salmon habitat in the interior Fraser River watershed is far from pristine. Many valley bottoms have been logged, and subsequently used for agriculture (mainly livestock, dairy, and animal feed crops) for at least the last 50 years (Burt and Wallis 1997). This applies to all spawning streams within the Lower Thompson CU, and many spawning streams or sites within the Shuswap Lake and Middle/Lower Shuswap subpopulations (South Thompson CU), the Lower and Middle North Thompson subpopulations (North Thompson CU), and the Middle/Upper Fraser CU. In some cases, riparian vegetation has been removed, livestock have destabilized stream banks, and off-channel habitats and wetlands have been destroyed or isolated by dike construction. This has resulted in substantial reductions in the quantity and quality of spawning and juvenile rearing habitat in affected streams, lowering their carrying capacity for Coho Salmon (Brown 2002). Forest harvesting is currently occurring in the headwaters of many watersheds as well. Extensive logging within a watershed can also lead to reductions in Coho Salmon carrying capacity through degradation of the stream channel, increased summer stream temperatures, and altered seasonal hydrographs (Meehan 1992). The recent mountain pine beetle infestation in the interior Fraser River watershed has resulted in the loss of very large tracts of mature forest in important spawning drainages occupied by the South and Lower Thompson, and Middle/Upper Fraser CUs. Linear developments (e.g., highways, railways, pipelines) are another potential threat, particularly for the South Thompson, North Thompson and Lower Thompson CUs. 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 twinning of the Kinder Morgan pipeline in British Columbia represents a potential threat to the North Thompson CU and the Nicola subpopulation of the Lower Thompson CU. The Fraser Canyon CU is a unique case in that the population would lose more than 90% of its spawning habitat, and may no longer be viable if the Nahatlatch River above Frances Lake was damaged (IFCRT 2006). For the other CUs, spawning is distributed among a number of spawning streams, making them less vulnerable to localized catastrophic events.

The southern and western portions of the Thompson River watershed, which support the Lower Thompson, Nicola (Lower Thompson CU), and a portion of the Shuswap Lake subpopulations (South Thompson CU), are semiarid, and high rates of surface water withdrawal in summer for irrigation cause low flows and high water temperatures (Rood and Hamilton 1995, Walthers and Nener 2000), which can lead to increased juvenile mortality, and prevent adults from accessing 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.

In contrast to extirpated Interior Columbia River Coho Salmon, Interior Fraser Coho have not been heavily impacted by hydroelectric development. Reduced streamflows, alteration of the natural hydrograph, and smolt passage issues arising from hydroelectric developments in the Bridge and Seton watersheds have likely impacted the Middle/Upper Fraser CU, but to what degree is unclear. In the past, landslides or other natural events have resulted in blockages at critical points along the migration route of Interior Fraser Coho. Locations where blockages have occurred include Hells Gate in the Fraser River canyon, which all Interior Fraser Coho must pass on their spawning migration, Little Hells Gate in the North Thompson River, which lies downstream of all spawning locations used by the Upper North Thompson subpopulation (North Thompson CU), and the Nahatlatch Canyon of the Nahatlatch River, which lies downstream of all spawning locations for the Fraser Canyon CU (IFCRT 2006). Hells Gate and Little Hells Gate continue to act as barriers to upstream migrating Coho Salmon at certain flows (IFCRT 2006), and this may be exacerbated by reduced fish size. Given previous evidence of difficult fish passage, natural or human-induced alterations of channel morphology at these or other critical locations represent future threats to Interior Fraser Coho or subgroups within.

If juvenile Interior Fraser Coho make extensive use of non-natal rearing habitats in the lower Fraser River floodplain, as suggested by an unpublished study (see *Section 7*), then previous losses of off-channel and small stream habitat in the lower Fraser River, as a result of flood control and agricultural development, represent losses in freshwater carrying capacity for these fish. 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). Sumas Lake is one example of potential habitat for juvenile Interior Fraser Coho that has been lost. In 1924, Sumas Lake, which consisted of 3,600 ha of open water and 8,000 ha of marshland and sloughs, and may have had the potential to support 230,000 overwintering juvenile Coho Salmon (Brown 2002), was drained and converted to farmland. 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). More detailed descriptions of losses and impacts to habitat for specific Interior Fraser Coho CUs and subpopulations are collated in a series of Fraser River Action Plan (FRAP) reports (e.g., Harding et al. 1994, DFO 1998a,b), and in the final report of the Interior Fraser Coho Recovery Team (IFCRT 2006).

12.8.2 Estuary and marine habitat

Over two million people live along the lower Fraser River and, as a consequence, estuarine habitats have been severely impacted. There has been an estimated 70% to 90% loss of estuarine habitats used by juvenile Coho and other Pacific salmon in the lower Fraser River, including 99% of seasonally flooded habitats (Birtwell et al. 1988; Langer et al. 2000; Levings 2000). Water quality may also represent a threat: the Fraser River watershed drains approximately one quarter of the land area of British Columbia, and introductions from sewage, agriculture, mines and mills results in elevated levels of aluminum, iron, zinc, phosphorus, fecal coliform and turbidity in the lower river and its estuary, particularly during the spring freshet when Coho Salmon smolts from the Interior are present during their seaward migration (Chittenden et al. 2010). To what extent or duration Interior Fraser Coho utilize estuarine habitats in the lower Fraser River is not well understood. Juvenile Coho Salmon (not necessarily Interior Fraser Coho) are present in the Fraser River estuary from mid-March to mid-June (Northcote 1974). However, catch per unit effort was very low for juvenile Coho Salmon compared to that for Chinook and Chum Salmon (Levy and Northcote 1982; Levings et al. 1995), suggesting that Coho Salmon use the estuary to a lesser extent than these other species.

Although marine areas used by Coho Salmon from the Fraser River are less developed than the Fraser River estuary, there are still a variety of habitat issues within the ocean. Coho Salmon generally remain closer to the coast than most other salmon and may be more susceptible to natural and man-made changes to the marine ecosystem. However, impacts from pulp mills, sewage effluent, and fish farms are difficult to quantify. There is increasing evidence that early ocean residence is a critical survival period for Pacific salmon (Peterman 1987; Pearcy 1992; Downton and Miller 1998), but to what extent this is linked to degradation of marine habitat is unclear. For Interior Fraser Coho, degradation of estuarine and marine habitat represents a threat of unknown imminence and magnitude.

12.8.3 Climate change

Climate change is expected to have significant impacts on freshwater habitat for Interior Fraser Coho. For example, Porter and Nelitz (2009) modelled the effects of various climate change scenarios on stream temperatures and hydrology in several watersheds in the Cariboo-Chilcotin region (Middle/Upper Fraser CU), and found that, under worst-case scenarios, increased air temperatures were likely to result in significant contractions in the current range of suitable habitat for Coho Salmon during the next 80 years in most watersheds (but possible expansions in others). The Lower and South Thompson watersheds have considerably warmer climates than the Cariboo-Chilcotin, and impacts to the associated CUs (South Thompson and Lower Thompson) will presumably be more severe. Warmer temperatures will also compound the threat to Interior Fraser Coho from non-indigenous spiny-ray fishes (see *Section 12.8.6*) since these species have higher temperature preferences and thermal tolerances than Coho Salmon (Bradford et al. 2008a, 2008b; Tovey et al. 2008).

Various studies have documented the role of climate change in altering the marine ecosystem and related this to shifts 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). Recent trends in salmon abundance in the North Pacific suggest that recent climate conditions have benefited Pink and Chum Salmon, while negatively impacting Coho and Chinook Salmon (Irvine and Fukuwaka 2011). Coho Salmon may be more vulnerable to changes in climate compared to other salmon species because they have relatively long residency periods in freshwater and in near-shore areas of the Pacific Ocean, and these environments are expected to undergo a greater degree of climate-driven change compared to open ocean habitats.

There is currently much debate as to how Pacific salmon will respond to future climate change, but for Coho Salmon at least, the weight of scientific evidence and scientific opinion suggests that the overall effect will be strongly negative (e.g., Bradford 1998; Beamish et al. 1999; Lackey 2001; Irvine 2004; Healey 2011; Hartman et al. 2000; Irvine and Fukuwaka 2011). Healey (2011) recently reviewed the potential negative effects of climate change at each stage in the life cycle of Fraser River Sockeye Salmon, and his findings are highly applicable to Interior Fraser Coho. The threat of future climate change to Interior Fraser Coho is likely not imminent, but in the long-term, it represents a severe threat because: 1) smolt-adult survival of salmon is correlated with climate-induced regime shifts and inter-annual variability in sea surface temperatures and ocean currents, 2) warmer temperatures have the potential to substantially reduce usable habitat, carrying capacity and productivity in both the freshwater and marine environments, and 3) human-induced climate change will not be reversible in a reasonable time frame.

12.8.4 Harvest

Of the factors over which we have direct influence, fishery exploitation is by far the most important with respect to the conservation and recovery of Interior Fraser Coho. Fishing represents a direct threat of potentially severe magnitude to Interior Fraser Coho. For example, during several years in the 1990s fishing was responsible for the direct mortality of >80% of the total returning adult population (Figure 5a; see *Section 12.3*). In his 1998 risk assessment for Thompson River Coho Salmon, Bradford (1998) 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 (Figures 5a and 6a). During 1978-1998, estimated productivity remained above 1 recruit/spawner in every year except 1997, which would have allowed for positive population growth in the absence of fishing (Figure 6a). However, in reality, Interior Fraser Coho experienced negative population growth in 12 of 20 years during this period as a result of excessive exploitation (Figure 6a). Bradford (1998) suggested that Interior Fraser Coho Salmon escapements would have been 2-10 times greater in the late 1990s had exploitation been reduced to a sustainable levels[14] beginning in the earlier part of that decade.

By contrast, greatly reduced exploitation rates since 1998 (Figure 5a) have played a major role in halting the decline in the number of Coho Salmon returning to the Interior Fraser, despite continued low productivity (see *Sections 12.3* and *12.4*). Nevertheless, in several recent years when productivity was below replacement (<1 recruit/spawner), even relatively modest exploitation contributed to negative population growth (Figure 6a; see *Section 12.4*). Management of exploitation rates represents a conservation tool for ensuring positive

[14] See IFCRT (2006) for a detailed summary of the changes in fisheries management that were implemented to protect Interior Fraser Coho.

population growth during periods when productivity exceeds 1 recruit/spawner, and for minimizing negative population growth when it does not.

The paucity of catch data in recent years, and the resultant high uncertainty in current estimates of domestic and US exploitation rates (see *Section 11.2*) also places Interior Fraser Coho at risk, as current indices may not be sensitive enough to detect year-to-year changes in exploitation that could arise from factors such as changes in fishing regulations or fishing effort, or changes in the marine distribution and migration timing of Interior Fraser Coho. Exploitation estimates for Interior Fraser Coho are also biased low to some degree because of unmonitored terminal fisheries upstream of Hells Gate and illegal fishing, which are not accounted for in current exploitation models (L. Ritchie, Fisheries & Oceans Canada, Kamloops, BC, personal communication, 2013). Uncertainty about survival of Coho Salmon released as bycatch in fisheries targeting other salmon species, and about survival of released wild Coho Salmon in recreational fisheries where only hatchery-marked Coho may be retained are additional sources of unquantified error in exploitation rate estimates. Given substantial overlap in run-timing among the CUs, and the absence of CU-specific estimates of exploitation rate, unsustainable fishing mortality should be treated as an equal threat for all CUs within the Interior Fraser aggregate.

12.8.5 Hatchery production

In freshwater habitat, negative interactions between hatchery and wild Coho Salmon can arise in several ways. Wild Coho Salmon fry may be negatively impacted if the number of hatchery fry released in a stream exceeds the stream's carrying capacity (Fleming 2002 and references therein). As well, excessive numbers of hatchery-origin adults interbreeding with wild adults places genetic diversity and fitness of wild Coho Salmon at risk. There is a growing body of empirical evidence suggesting that progressive, intergenerational declines in fitness of wild fish can occur when hatchery fish are also present (Berejikian and Ford 2004 and references therein; Fleming 2002 and references therein). Other risks include transfer of diseases and parasites from hatchery to wild fish, and increased mortality for wild Coho Salmon that co-migrate with large numbers of hatchery fish, because the latter often attract elevated numbers of predators and fishing effort (Nickelson 2003). Since its inception in the 1980s, the scale of hatchery production of Coho Salmon in the Interior Fraser has been fairly modest relative to that in other parts of British Columbia (e.g., Strait of Georgia, Lower Fraser; see *Section 10*) and in the US Pacific Northwest (IFCRT 2006). Earlier studies (Bradford and Irvine 2000; Irvine 2002; IFCRT 2006) concluded that enhancement had had a relatively minor effect on overall population trends for the Interior Fraser aggregate, although it was noted that the Lower Thompson CU was dominated by hatchery-origin fish (60% of escapements in 1998-2000; Irvine 2002), as were several enhanced streams in the North Thompson and South Thompson CUs (IFCRT 2006). More recently, there has been a reduction in the numbers of hatchery fry and smolts released in the Interior Fraser (see *Section 10*), and this has resulted in lower proportions of hatchery fish among Coho Salmon spawning in natural habitat. For example, for the Interior Fraser Coho aggregate, the mean proportion of hatchery fish in escapements for the most recent generation (2009-2011) was 7% (Table 1) compared to 15% at the time of the original COSEWIC assessment (1998-2000, see Table 2 in Irvine 2002). The proportion of hatchery fish in escapements to the Lower Thompson CU was 5-fold lower (13%) for the most recent generation compared to 1998-2000. Enhancement efforts are currently focused on rebuilding depressed stocks and maintaining coded wire tag programs to provide smolt-adult survival and exploitation estimates based on hatchery indicator stocks (IFCRT 2006).

Negative interactions between wild and hatchery Coho Salmon can also occur in coastal and pelagic marine environments (Noakes et al. 2000). These may include competition for resources, transfer of diseases and parasites, and, in particular, 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 pose a greater risk to Interior Fraser Coho than enhancement directly 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 ~8 million for British Columbia, and ~70-80 million for British Columbia, Washington and Oregon combined (PSCSFEC 2013) during the late 1990s, and declined to ~5 million and ~50 million, respectively, for BC and for the region as a whole by 2010 (PSCSFEC 2013). Although the causal mechanisms are not well understood, there is growing evidence of negative effects of global hatchery production on the 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).

12.8.6 Invasive non-indigenous species

At a global scale, invasion of non-indigenous species is recognized 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 causes for putting freshwater fish species at risk in Canada (Miller et al. 1989; Dextrase and Mandrak 2006; Rahel et al. 2008). Region-specific assessments of distribution (Runciman and Leaf 2009) and biological risk (Bradford et al. 2008a, 2008b; Tovey et al. 2008) have been completed recently for several invasive spiny-ray fishes in British Columbia including Yellow Perch (*Perca flavescens*), Smallmouth Bass (*Micropterus dolomieu*), Largemouth Bass (*Micropterus salmoides*), Northern Pike (*Esox lucius*), Pumpkinseed (*Lepomis gibbosus*) and Walleye (*Sander vitreus*). These species have become established in British Columbia as a result of 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. Eastern Brook Trout (*Salvelinus fontinalis*), a non-indigenous salmonid, are also widely distributed in British Columbia, as a result of introductions by government agencies beginning in the 1920s (McPhail 2007), but we could find no documented examples where the introduction of this species has had significant impacts on Coho Salmon.

Yellow perch and Smallmouth Bass are the two most widely established invasive species in the interior Fraser River watershed. The presence of Yellow Perch has been confirmed in nine lakes and three streams in the South Thompson watershed (South Thompson CU; Runciman and Leaf 2009); two of the streams where Yellow Perch are established are also used by Interior Fraser Coho. Smallmouth bass are confirmed in two small lakes in the South Thompson watershed, and throughout the Beaver Creek drainage in the Quesnel River watershed (Middle/Upper Fraser CU), including six small, connected lakes and Beaver Creek itself (Runciman and Leaf 2009); Coho Salmon have been observed in the lower reaches of Beaver Creek downstream of a barrier. To date, the presence of Northern Pike or Walleye has not been confirmed in the interior Fraser River watershed, while Largemouth Bass and Pumpkinseed have both been confirmed in an isolated three-lake drainage in the South Thompson watershed (Runciman and Leaf 2009).

The risk of widespread establishment in the Thompson and Middle/Upper Fraser watersheds is considered very high for Yellow Perch and high for Smallmouth Bass based on high habitat suitability within a substantial portion of each watershed, the ability of each species to migrate considerable distances and utilize streams as well as lakes, and the proximity of established populations of each species in nearby watersheds, coupled with the risk of deliberate unauthorized introductions by anglers (Bradford et al. 2008a; Tovey et al. 2008). Despite the current absence, or near absence, of Largemouth Bass and Walleye, respectively, the risk of widespread establishment in the Thompson and Middle/Upper Fraser watersheds is considered high for these species as well based on the same factors listed for the previous two (Bradford et al. 2008b; Tovey et al. 2008). The risk of widespread establishment of Pumpkinseed and Northern Pike is estimated to be moderate, based on lower habitat suitability (Bradford et al. 2008b).

The ecological consequences (i.e., risk to the aquatic ecosystem as a whole) resulting from widespread establishment of each 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, 2008b; Tovey et al. 2008), but these studies did not specifically address the direct risk to Interior Fraser Coho. Coho Salmon are known to 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), but whether these habitats are critical for Coho Salmon is uncertain because Interior Fraser Coho appear to rear primarily in streams and off-channel habitats associated with streams (see *Section 7*). However, Smallmouth Bass, Walleye and Northern Pike commonly occupy fluvial habitats, and Largemouth Bass sometimes do as well (Bradford et al. 2008b; Tovey et al. 2008).

The direct risks to Coho Salmon from invasive spiny-ray fishes include predation (Smallmouth Bass, Largemouth Bass, Walleye, Northern Pike), competition (Yellow Perch and Pumpkinseed), and alteration of the food web (all six species). The introduction of Largemouth Bass in a shallow lake system in Oregon reduced levels of Coho Salmon for the next 15 years, with natural production of Coho Salmon becoming isolated 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 were responsible for 98% of the observed predation on juvenile Coho Salmon in the lakes. Largemouth Bass have been identified in slough and wetland habitats within the floodplain of the lower Fraser River (Tovey et al. 2008); an unpublished study suggests these habitats are used by Coho Salmon from all five Interior Fraser CUs (see *Section 7*). Similar to Largemouth Bass, Smallmouth Bass are also highly piscivorous, and are capable of heavy predation on juvenile Chinook Salmon and other salmonids (Wydoski and Whitney 2003), and, unlike Largemouth Bass, they make extensive use of clear streams and rivers (Tovey et al. 2008). There is considerable concern about the potential impacts to Coho Salmon and other salmonids if Smallmouth Bass in the Beaver Creek drainage expand their range to other areas within the Quesnel River system (Middle/Upper Fraser CU) or the 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 suggested that Northern Pike were responsible for an observed decline in escapements of Coho Salmon to that system. Bonar et al. (2005) found no evidence of significant consumption of Coho Salmon by introduced Yellow Perch and Pumpkinseed in three shallow lakes, and there was also no evidence of reduced growth rates for Coho Salmon in the presence of these two species. However, habitat preferences of both Yellow Perch and Pumpkinseed overlap substantially with that of Coho Salmon (e.g., off-channel habitat, littoral zones in small lakes, small, slow-moving streams), and there are many examples where the introduction of Yellow Perch or Pumpkinseed has led to severe declines or extirpation of other native species (Bradford et al. 2008a, 2008b; Johnson 2009).

12.9 EXISTING PROTECTION

Interior Fraser Coho were designated as endangered by COSEWIC in 2002. However, in 2006 the Federal Cabinet declined to list the population under the Species at Risk Act (SARA) because of concern about foregone revenues to the various fishing sectors in the event that smolt-adult survival increased significantly (Government of Canada 2006). Nevertheless, DFO has recognized Interior Fraser Coho as both a nationally significant population and a serious conservation concern, and has undertaken various initiatives since the late 1990s for their protection (Irvine et al. 2005). In 2005, following DFO's adoption of the Wild Salmon Policy (WSP, DFO 2005b), Holtby and Ciruna (2007) identified five separate CUs encompassing the Interior Fraser Coho aggregate. To date, the most important step taken in protecting Interior Fraser Coho has been the restrictions in Canadian salmon fisheries that began in 1997 (unprecedented at the time), were fully implemented in 1998, and remain ongoing (see IFCRT 2006 for a description of the various restrictions put in place). At the time, these actions were described as perhaps the most significant change in fisheries management ever implemented within the Pacific Region of Canada (Irvine and Bradford 2000). Reduced exploitation rates appear to have slowed the recent declining trend for the Interior Fraser Coho aggregate, despite continued low smolt-adult survival.

The Federal Fisheries Act, and in particular the Fisheries Protection Provisions have the goal of maintaining the productivity of salmon populations and their habitats (the 1986 policy will be replaced in the near future). The Federal Fisheries Act requires proposed alterations to habitat to be authorized by DFO. In British Columbia, provincial and municipal governments also regulate many land and water use activities that can affect fish populations. For example, the Provincial Water Act governs the allocation of water, water licences, and the regulation of works in streams. The Canada 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.

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Table 1. Numbers of average returning adult Coho Salmon (wild escapement and wild + hatchery escapement), and the estimated proportion of hatchery fish included in total escapements by subpopulation and Conservation Unit (CU), and for the Interior Fraser Coho aggregate during the most recent generation (geometric mean for 2009-2011). The extent of occurrence (EO) and number of locations (i.e., streams, see Section 11.8) where Coho Salmon were detected are also shown for each CU and for the Interior Fraser Coho aggregate.

Conservation Unit (CU)	Subpopulation	Escapement (wild)	Escapement (wild + hatchery)	Percent hatchery fish	Extent of occurrence (km^2)	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%	12,100	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%	9,900	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%	10,100	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%	78,000	11
Fraser Canyon	Fraser Canyon	2,158	2,158	0.0%	110	1
Interior Fraser Coho Aggregate		**26,236**	**28,105**	**6.7%**	**110,000**	**75**

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

Table 2. Summary of wild Coho Salmon escapements for individual Conservation Units (CUs) and for the Interior Fraser Coho aggregate. Escapement values shown in grey italic for the Lower Thompson, Fraser Canyon and Middle/Upper Fraser CUs are extrapolations based on observed escapements for the North and South Thompson CUs (see Section 11.1). Also shown (for the aggregate only, and by return year) are wild escapements, total escapements (wild spawners + 1st generation hatchery fish spawning in natural habitat), wild total returns (wild escapement + wild catch), total returns (total escapement + total catch), exploitation rates, and adult recruits/spawner (wild escapement/total return). Smolt-adult survival estimates are averages for Strait of Georgia wild Coho Salmon indicator stocks. Data sources and the methods used to obtain total return, exploitation and smolt-adult survival estimates are described in Section 11.3. Exploitation rates for 1975-1985 are the average of estimates for 1986-1996 (Simpson et al. 2004)[15].

	Escapement by Conservation Unit (wild fish only)					Interior Fraser Coho Aggregate					
Year	South Thomp.	North Thomp.	Lower Thomp.	Mid /Upper Fraser	Fraser Canyon	Wild escape-ment	Total escape-ment	Total return	Exploit-ation rate	Recruits / Spawner	Smolt-adult survival[1]
1975	10,613	27,618	*4,630*	*5,995*	*9,504*	58,359	58,359	182,659	68.1%		-
1976	6,506	26,198	*3,961*	*5,128*	*8,130*	49,922	49,922	156,253	68.1%		-
1977	14,096	35,220	*5,972*	*7,733*	*12,260*	75,581	75,581	235,624	68.1%		6.5%
1978	12,725	33,021	*5,540*	*7,173*	*11,372*	69,832	69,832	218,569	68.1%	3.7	9.7%
1979	15,958	22,247	*4,627*	*5,991*	*9,498*	58,320	58,620	182,538	68.1%	3.7	7.4%
1980	11,028	10,943	*2,661*	*3,445*	*5,462*	33,538	33,538	104,972	68.1%	1.4	10.1%
1981	6,235	21,265	*3,330*	*4,312*	*6,836*	41,979	41,979	131,391	68.1%	1.9	7.1%
1982	8,795	23,639	*3,928*	*5,086*	*8,063*	49,511	49,511	154,966	68.1%	2.7	4.8%
1983	8,802	21,759	*3,701*	*4,792*	*7,597*	46,651	46,651	146,014	68.1%	4.4	9.5%
1984	19,617	40,419	6,556	*9,414*	*14,925*	90,931	90,931	284,608	68.1%	6.8	9.9%
1985	22,016	18,546	4,475	*6,360*	*10,084*	61,481	61,481	192,433	68.1%	3.9	13.2%
1986	17,479	26,874	3,879	*6,955*	*11,026*	66,212	68,344	199,335	65.7%	4.1	12.5%
1987	18,722	27,416	5,889	*7,234*	*11,470*	70,730	80,559	174,073	53.7%	1.7	11.9%
1988	25,209	32,914	3,193	*9,114*	*14,449*	84,878	96,702	335,731	71.2%	4.8	18.2%
1989	16,196	23,701	3,207	*6,256*	*9,918*	59,277	69,714	196,474	64.5%	2.4	12.5%
1990	9,783	16,042	4,599	*4,049*	*6,420*	40,894	48,485	184,037	73.7%	1.9	13.2%
1991	4,842	11,703	5,413	*2,594*	*4,113*	28,665	33,545	104,001	67.7%	0.9	8.1%
1992	12,995	13,193	3,838	*4,106*	*6,510*	40,643	50,528	272,605	81.5%	3.1	11.1%
1993	2,631	6,192	11,034	*1,383*	*2,193*	23,434	29,381	236,016	87.6%	3.9	7.1%
1994	6,210	9,878	4,759	*2,523*	*4,000*	27,370	35,517	62,677	43.3%	1.4	8.0%
1995	4,070	8,477	2,692	*1,967*	*3,119*	20,326	22,996	52,454	56.2%	0.9	5.8%
1996	1,799	3,846	617	*885*	*1,403*	8,550	9,294	56,316	82.5%	1.8	5.8%
1997	1,970	5,457	4,214	*1,165*	*1,846*	14,652	18,675	31,379	40.5%	0.7	4.7%
1998	5,502	8,752	889	4,586	5,460	25,188	27,152	29,210	7.0%	1.2	3.7%
1999	3,235	8,812	1,885	1,744	4,096	19,772	22,371	24,590	9.0%	2.3	2.2%
2000	3,744	4,160	3,031	2,324	2,719	15,978	21,905	22,711	3.4%	0.9	4.2%
2001	13,264	22,733	5,379	6,346	5,971	53,693	61,408	66,101	7.1%	2.1	5.9%
2002	10,404	17,398	6,633	4,286	3,817	42,538	55,975	60,253	7.1%	2.0	5.0%
2003	3,333	5,664	1,700	3,306	4,552	18,555	21,078	24,116	12.6%	1.0	2.7%
2004	15,643	10,089	2,318	4,872	5,872	38,794	41,522	48,003	13.5%	0.7	3.7%
2005	2,088	3,957	1,787	2,282	2,513	12,637	14,064	16,164	13.0%	0.3	1.1%
2006	1,990	3,079	707	1,308	84[2]	7,158	7,798	8,608	9.4%	0.4	1.2%
2007	12,320	23,883	6,529	10,180	2,739	55,651	58,496	65,874	11.2%	1.5	1.3%
2008	6,282	3,279	2,640	1,472	1,138	14,810	16,429	18,214	9.8%	1.2	1.1%
2009	3,837	8,617	3,396	2,325	2,308	20,483[3, 16]	21,991	24,848	11.5%	3.0	3.2%
2010	8,790	10,782	9,600	5,026	1,365	35,563	37,825	42,602	11.2%	0.7	1.6%
2011	4,613	7,356	5,694	3,939	3,189	24,791	26,689	30,478	12.4%	1.7	1.3%

[1] Average of estimates for Strait of Georgia wild Coho Salmon indicator stocks.
[2] Escapement value is biased low due to poor survey conditions.
[3] Preliminary estimate, Canadian ER has not been finalized.

[15] Erratum: September 2014. Table 2 corrected to include hatchery Coho as part of brood escapement. Recruits / Spawner calculation added.

[16] Erratum: September 2014. the 2009 value for 'Wild Escapement' was originally published as 204,863. The correct value is 20,483[3], with the 3 referring to the footnote at the bottom of the table.

Table 3. Estimated percent change (negative values indicate a decline) in escapement and total return (escapement + catch) of wild Coho Salmon for the most recent 10-year period (2001-2011), and for the entire period of record (1975-2011), for five Interior Fraser Coho Conservation Units (CUs) and for Interior Fraser Coho as an aggregate. Percent change was computed based on the annual intrinsic rates of change in population size, which was derived from the slope coefficient for the regression of abundance (escapement or total return) on year (see Section 11.4). Abundance metrics were natural log-transformed and smoothed using a 3-year running average prior to computing regressions.

		Change in abundance	
Time period	Population	Escapement	Total return
2001-2011 (10-yr)	South Thompson CU	-14.6%	-20.9&
	North Thompson CU	-11.4%	-25.4%
	Lower Thompson CU	72.3%	85.0%
	Middle/Upper Fraser CU	-10.1%	-14.1%
	Fraser Canyon CU[1]	-57.5%	-66.2%
	Interior Fraser Aggregate	**-8.9%**	**-17.7%**
1975-2011 (36-yr)	South Thompson CU	-67.1%	-68.0%
	North Thompson CU	-80.2%	-81.3%
	Lower Thompson CU[2]	-38.2%	-35.6%
	Middle/Upper Fraser CU[3]		
	Fraser Canyon CU[3]		
	Interior Fraser Aggregate	**-72.1%**	**-73.0%**

[1] 2006 escapement estimate of 84 adults was excluded from the analysis (see Table 2).
[2] Escapement time series was limited to 1984-2011.
[3] Annual escapement monitoring began in 1998.

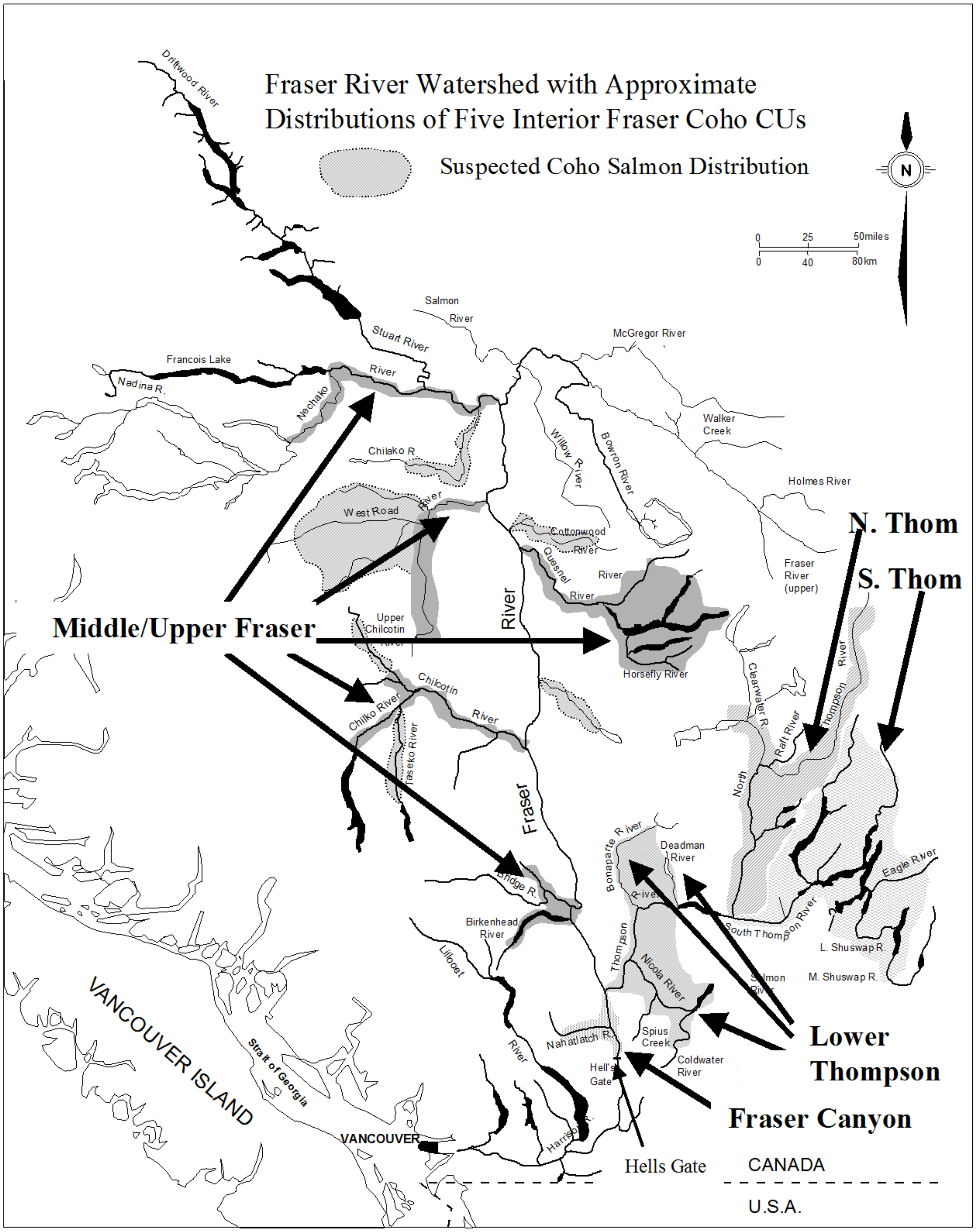


Figure 1. Approximate distribution within the Fraser River watershed of five Conservation Units (CUs) of Coho Salmon (North Thompson, South Thompson, Lower Thompson, Fraser Canyon, and Middle/Upper Fraser) within the interior Fraser River watershed (reproduced from Irvine 2002). Shaded areas represent the suspected (unconfirmed) distribution of Coho for the Middle/Upper Fraser CU, and the known (approximate) distribution for the remaining four CUs.

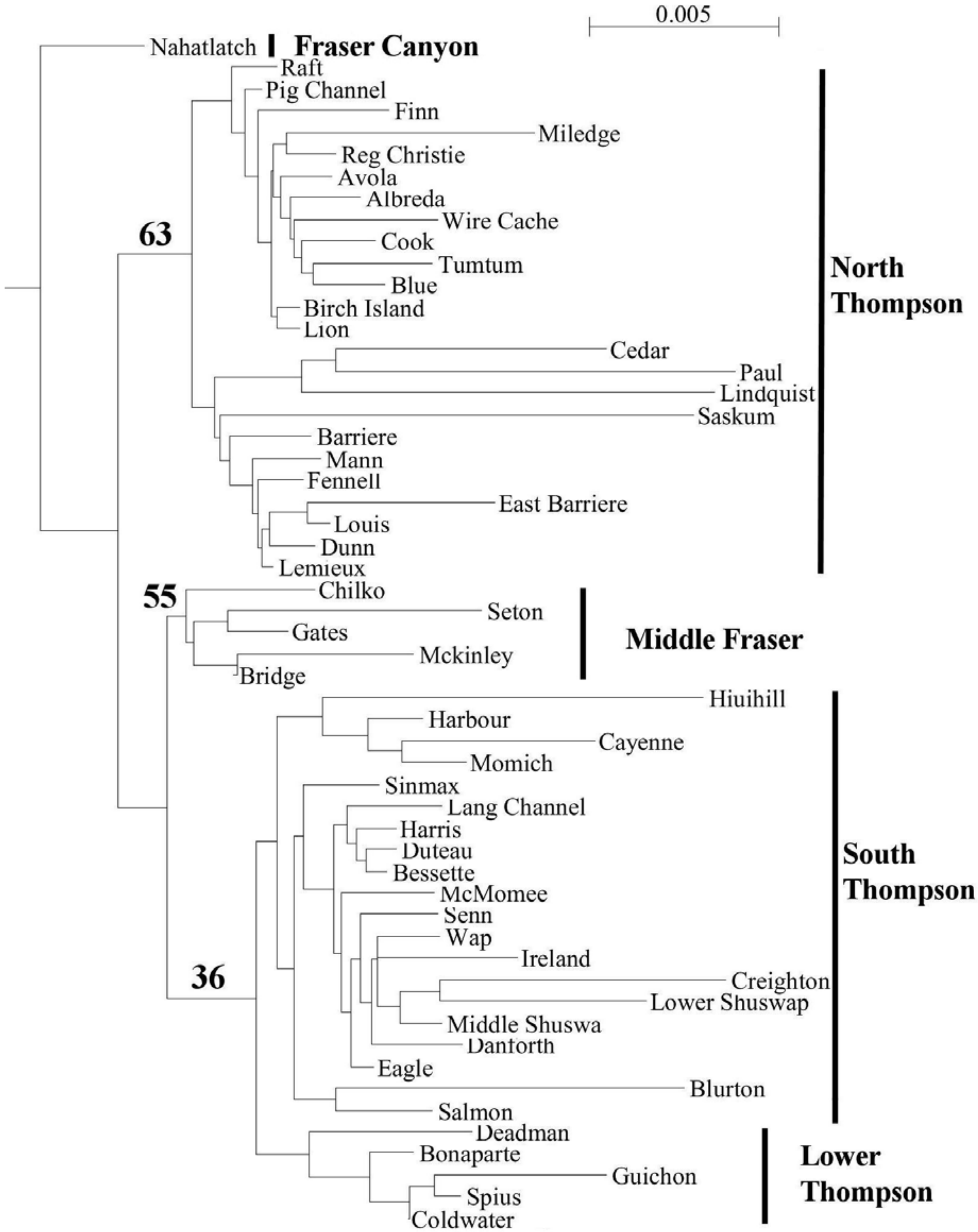


Figure 2. Neighbour-joining dendrogram of Cavalli-Sforza and Edwards (1967) chord distance for Interior Fraser River Coho Salmon populations surveyed at 15 microsatellite loci. Bootstrap values (in bold) at major tree nodes indicate the percentage of 500 trees where populations beyond the node clustered together. Figure is updated from Supplemental Figure 1 in Beacham et al. (2011); courtesy T. Beacham, DFO Nanaimo. Scale at upper right indicates coancestry coefficient (FST) values.

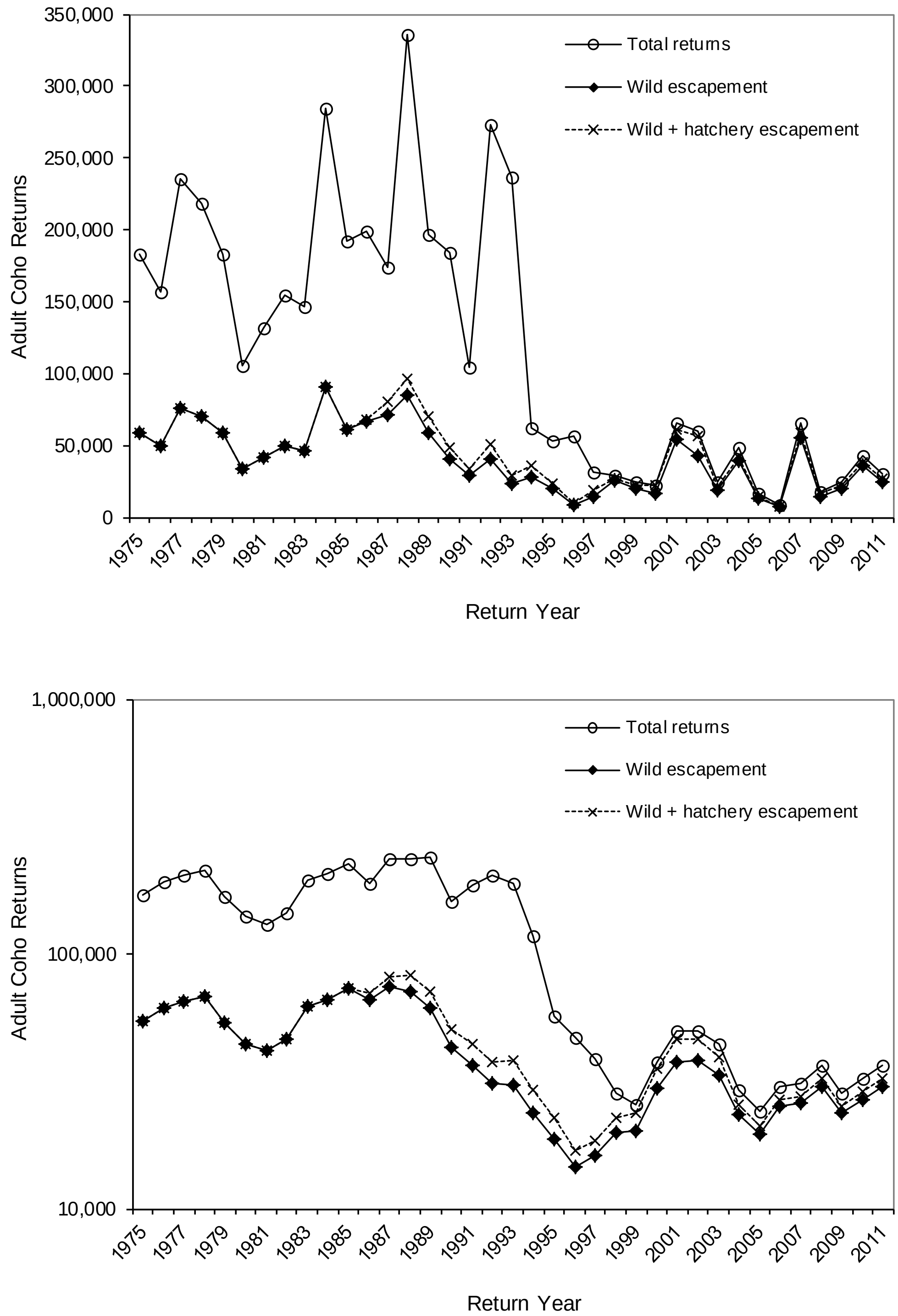
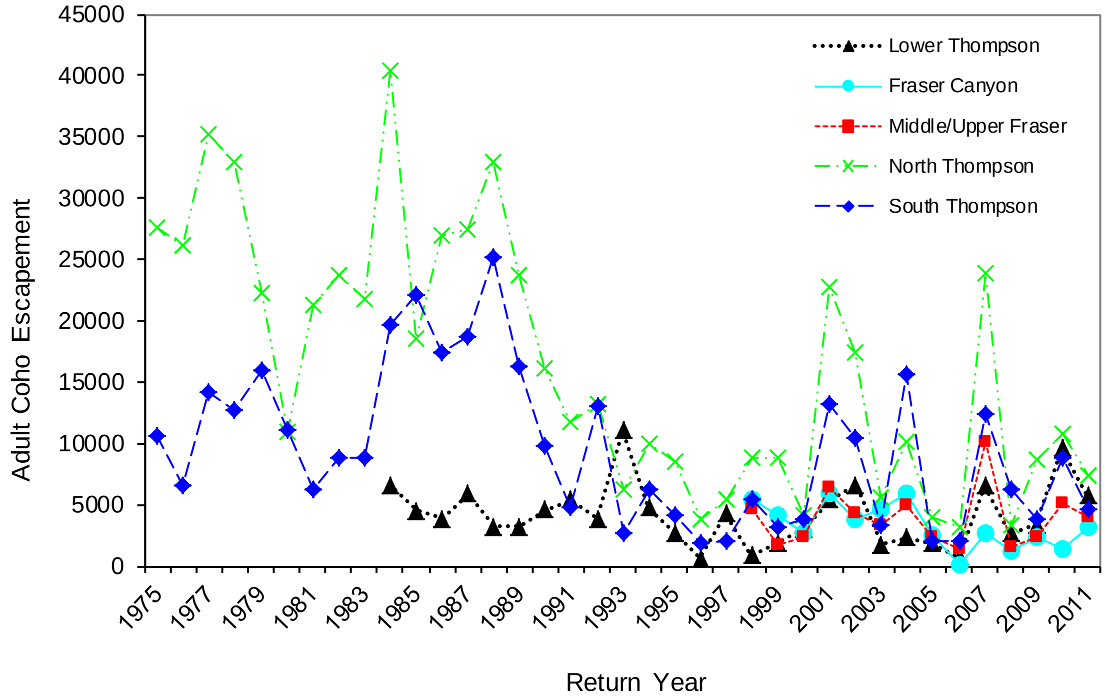


Figure 3. Reconstructed time series of wild Coho Salmon escapements and total escapements (wild + hatchery fish) and total returns (total escapement + catch) for the interior Fraser River watershed during 1975-2011 (data are provided in Table 2). The upper graph shows annual estimates; the lower graph shows the same data with escapement and total return values smoothed using a 3-year running average and plotted on a log_{10} scale. Data sources and description of the estimation methods used are provided in Sections 11.1 and 11.3.



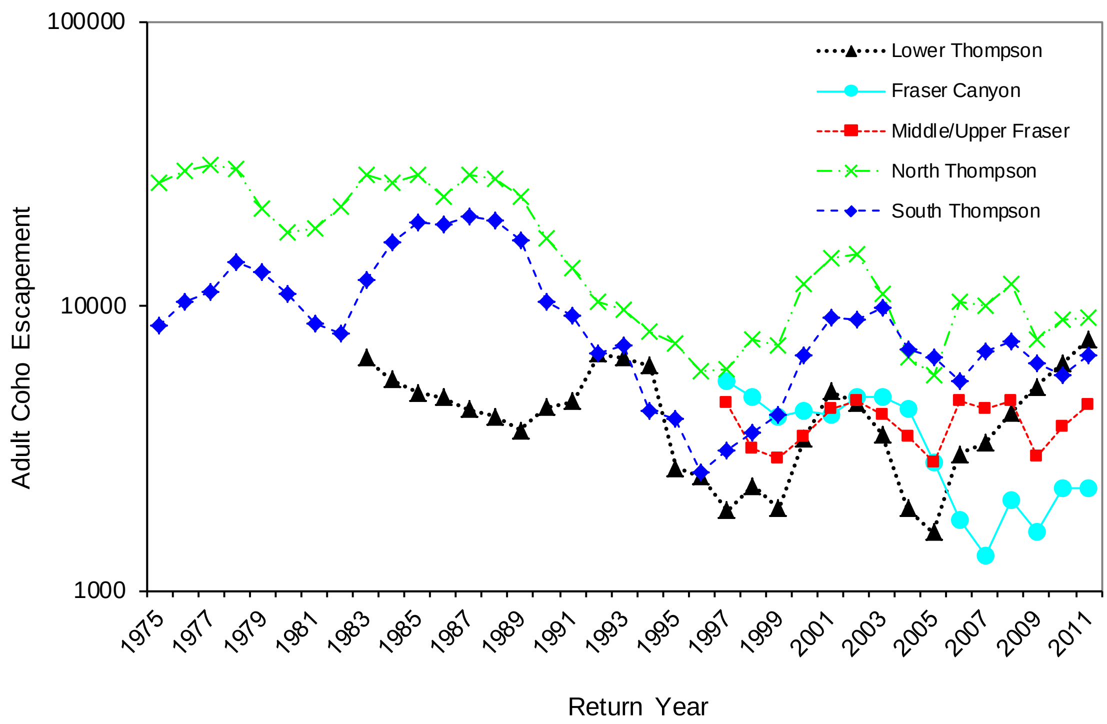


Figure 4. Reconstructed time series of wild Coho Salmon escapements for five Conservation Units (CUs) within the interior Fraser River watershed during 1975-2011 (data are provided in Table 2). The upper graph shows annual estimates; the lower graph shows the same data with abundance values smoothed using a 3-year running average and plotted on a $\log_{10}$ scale. Data sources and description of the estimation methods used are provided in Sections 11.1 and 11.3.

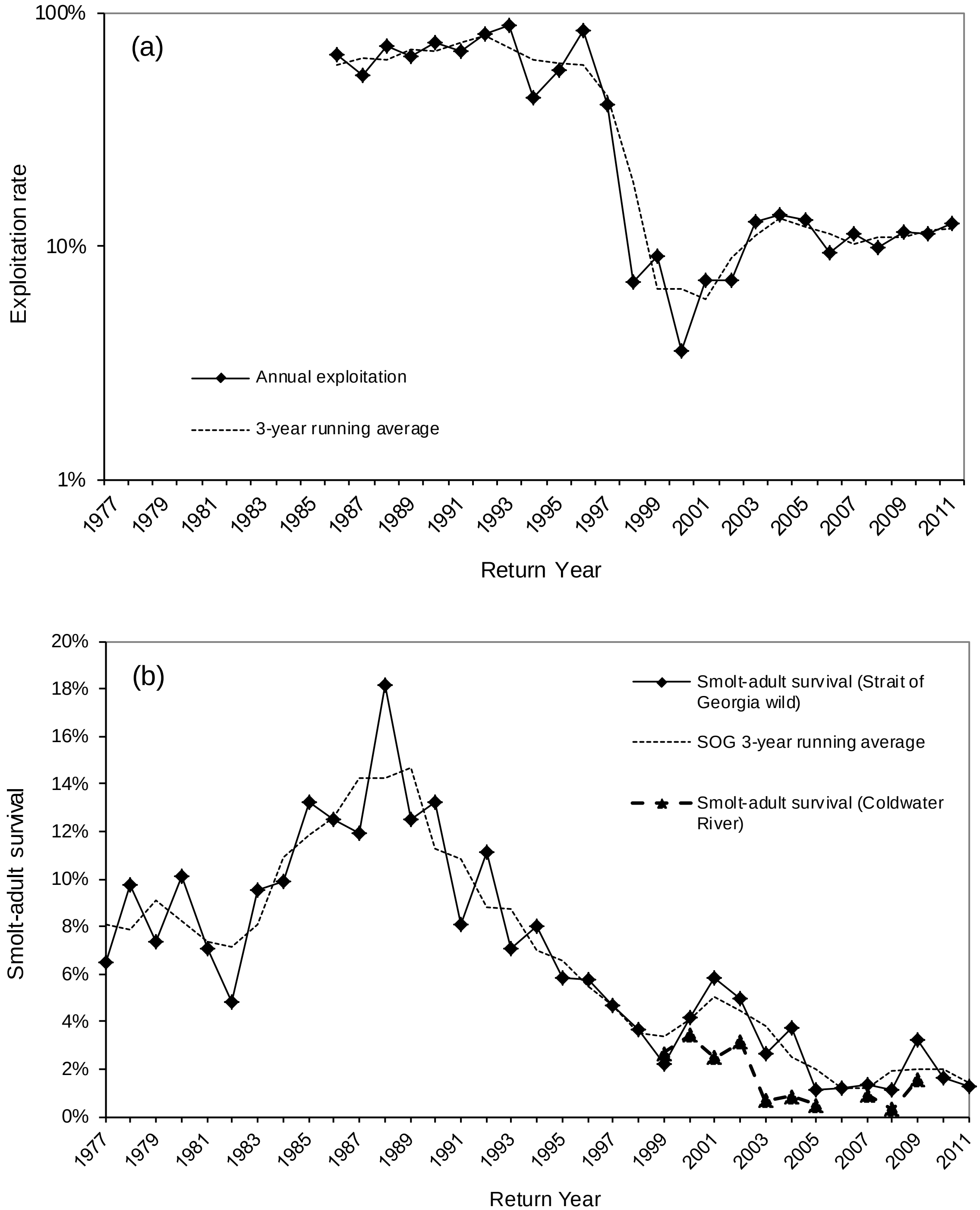


Figure 5. (a) Estimated fishery exploitation rates (plotted on a log_{10} scale) for Interior Fraser Coho during 1986-2011; (b) average of smolt-adult survival estimates for Strait of Georgia wild Coho indicator stocks (as a surrogate for Interior Fraser Coho smolt-adult survival) during 1977-2011 and for wild Coldwater River Coho Salmon (Interior Fraser) during 1999-2009. The dotted lines in each graph show smoothed values (3-year running average). Data for both graphs (except Coldwater survivals) are in Table 2.

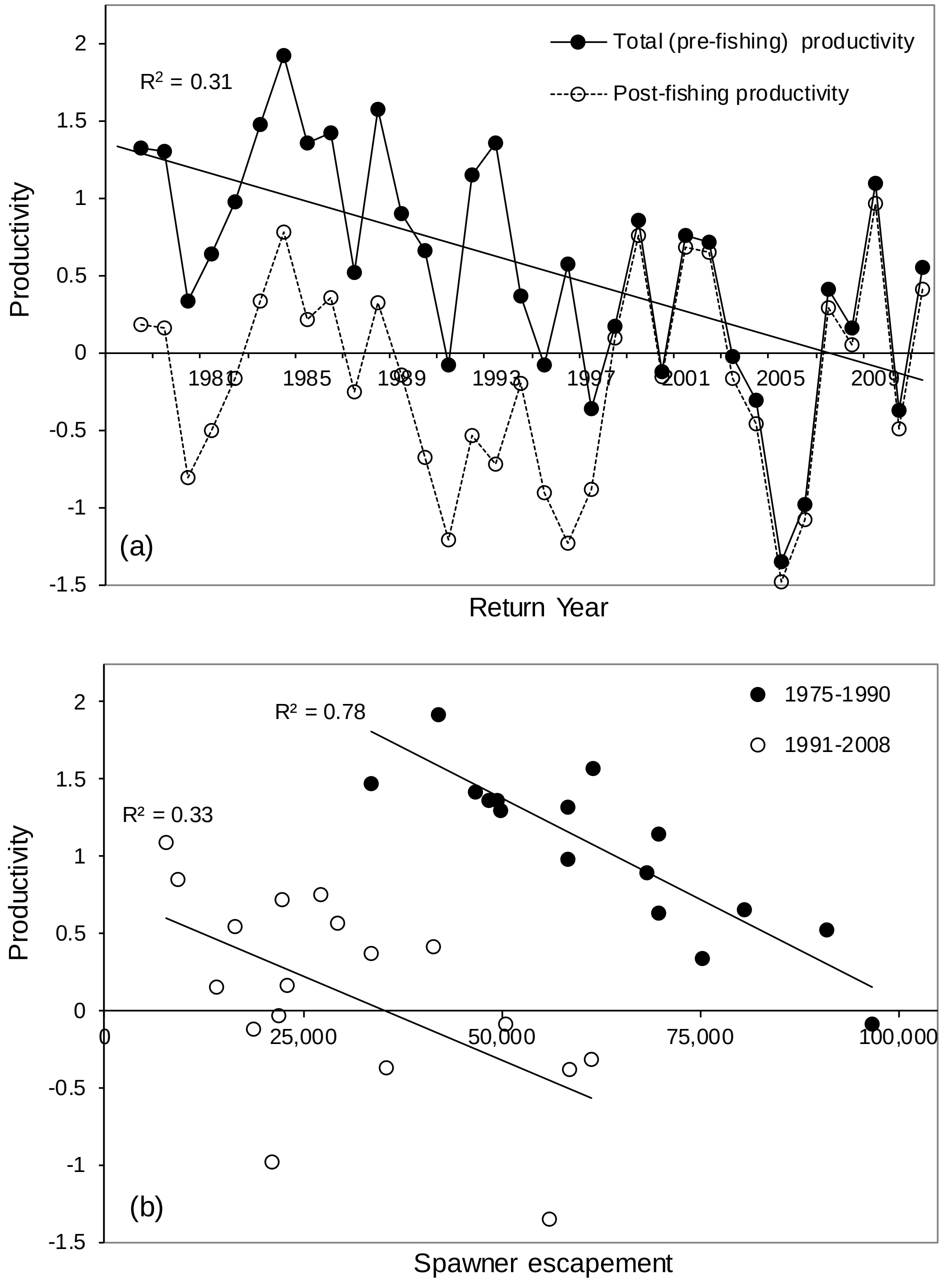


Figure 6[17]. (a) Time series (1978-2011) of estimates of total productivity (ln[recruits/spawner]) and post-fishing productivity (ln[[recruits-catch]/spawner]) for Interior Fraser Coho Salmon. Negative values represent years of negative population growth when the population is unable to replace itself (i.e., < 1 recruit per spawner), in the absence of fishery exploitation. Post-fishing productivity represents productivity with the effect of exploitation included. The difference between the two metrics represents the impact of fishing on productivity; (b) plots of total productivity versus total brood escapement for Interior Fraser Coho for two time periods: 1975-1990 (brood escapement year) and 1991-2008. The coefficient of determination (R^2) values shown indicate the log-linear regression fit for total productivity versus year (graph a), and for total productivity versus brood escapement for 1975-1990 and 1991-2008 (graph b).

[17] Erratum: September 2014. Figure 6 and caption corrected.

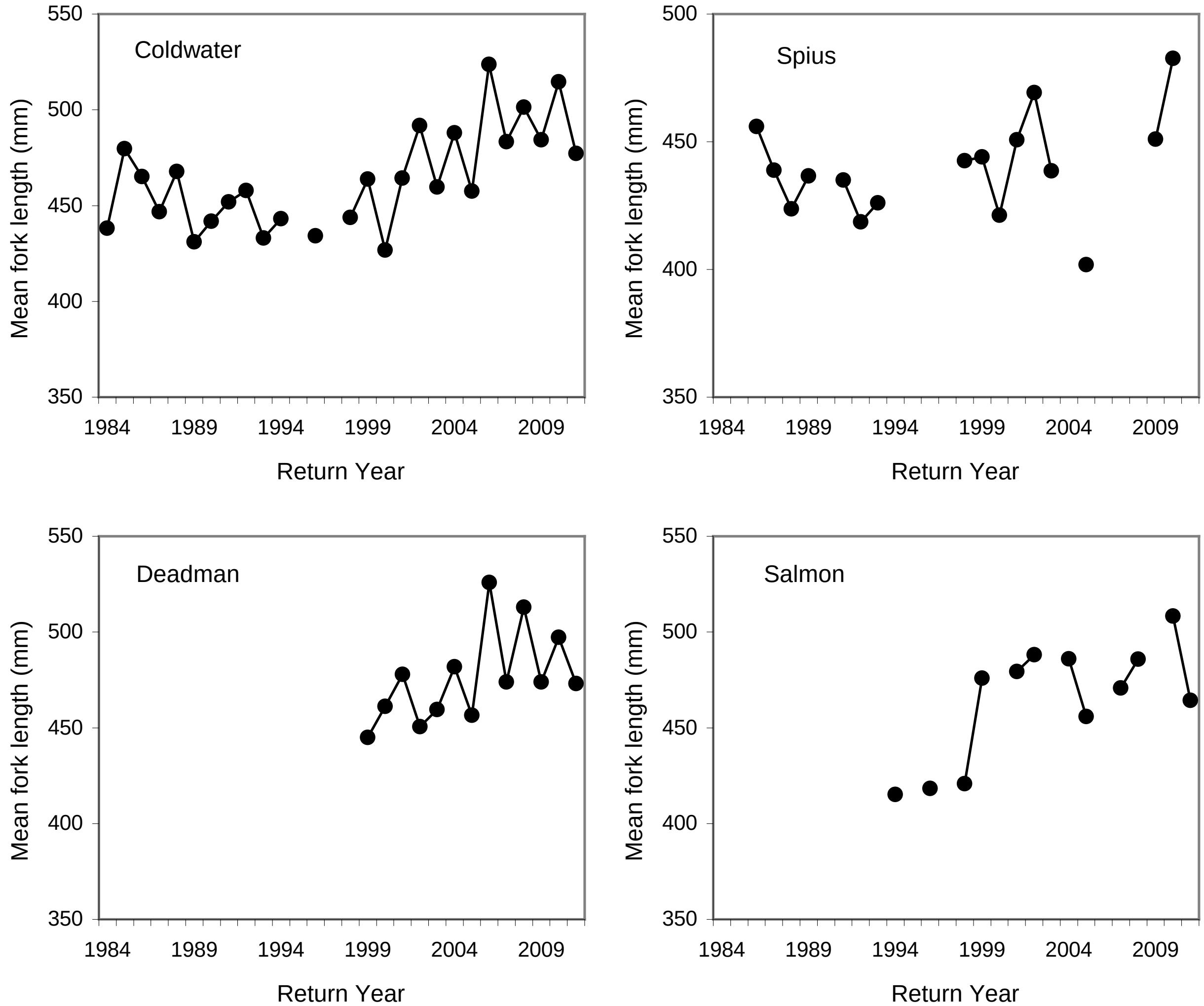


Figure 7. Mean fork lengths for samples of Interior Fraser Coho Salmon (wild and hatchery fish) collected for hatchery brood stock in four streams in the Thompson River system in various years during 1984-2011.

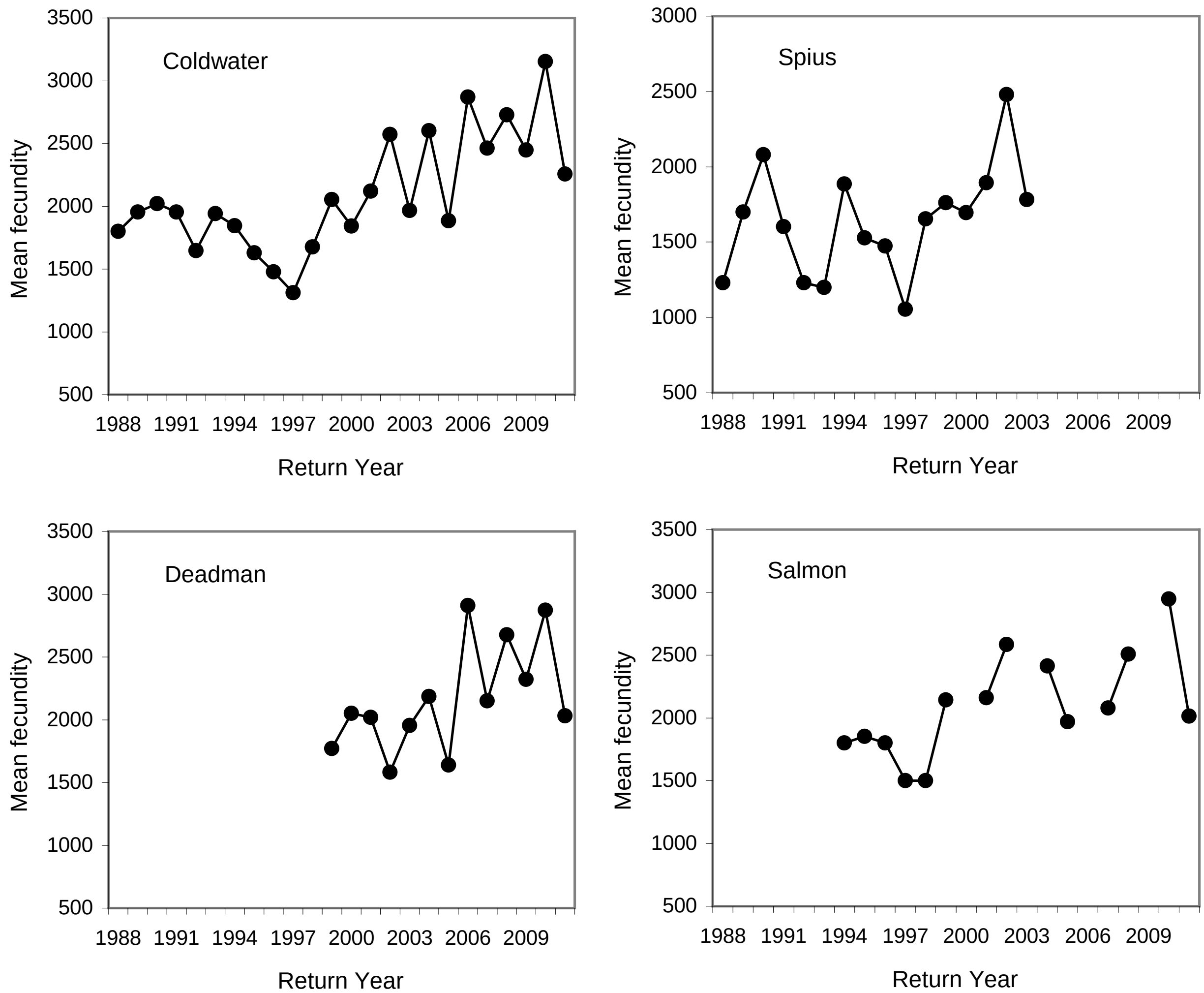


Figure 8. Estimates of mean fecundity (eggs/female) for samples of Interior Fraser Coho Salmon (wild and hatchery fish) collected for hatchery brood stock in four streams in the Thompson River system in various years during 1988-2011.

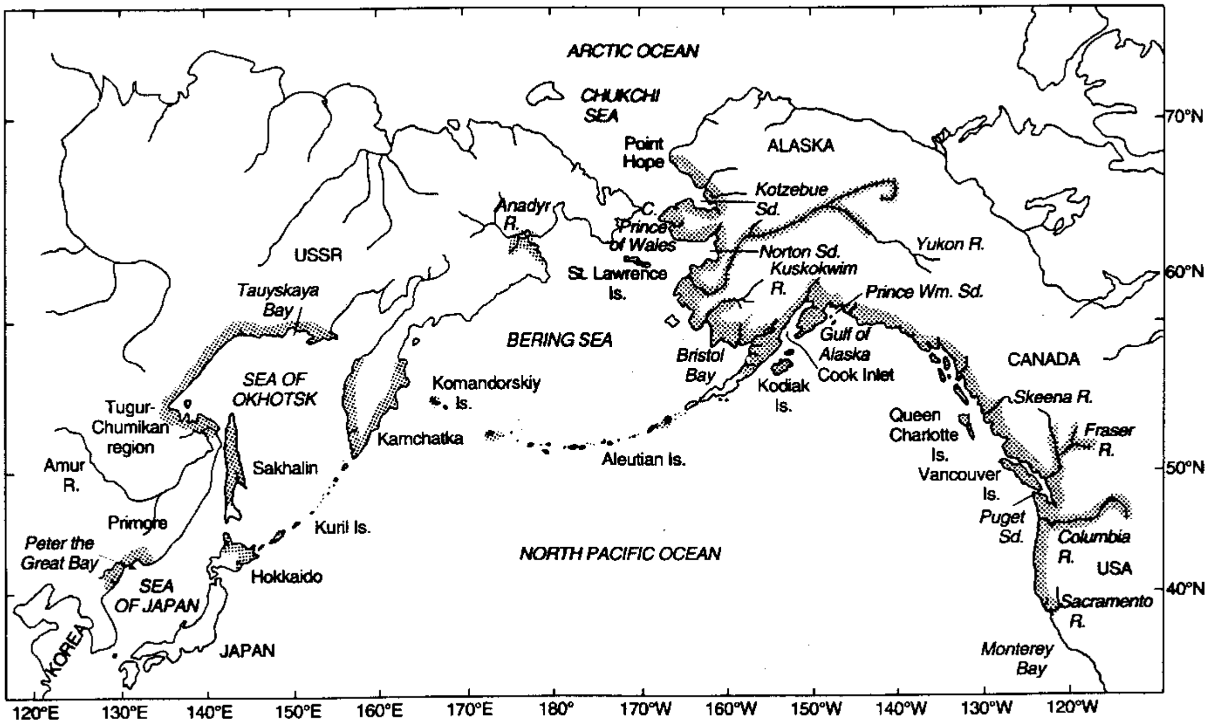


Figure 9. Approximate distribution of naturally spawning Coho Salmon globally (from Sandercock 1991).

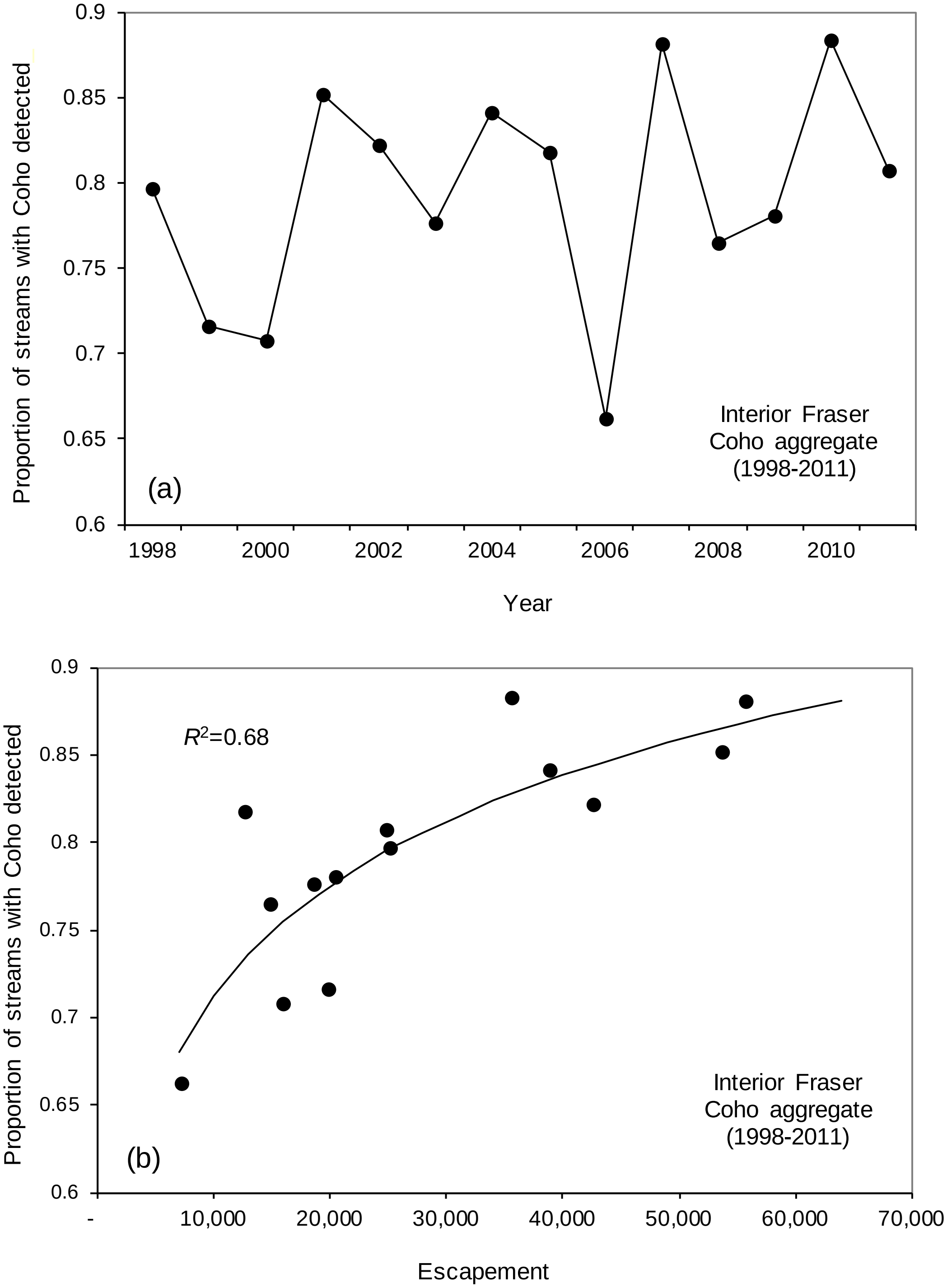


Figure 10. (a) The proportion of surveyed spawning streams in the interior Fraser River watershed where Coho Salmon were detected (detection probability is < 100%) each year during 1998-2011; (b) the relationship between the proportion of surveyed spawning streams where Coho Salmon were detected during 1998-2011 and total wild escapement for the Interior Fraser Coho aggregate. The coefficient of determination (R^2) value shown in graph b represents the log-linear regression fit.

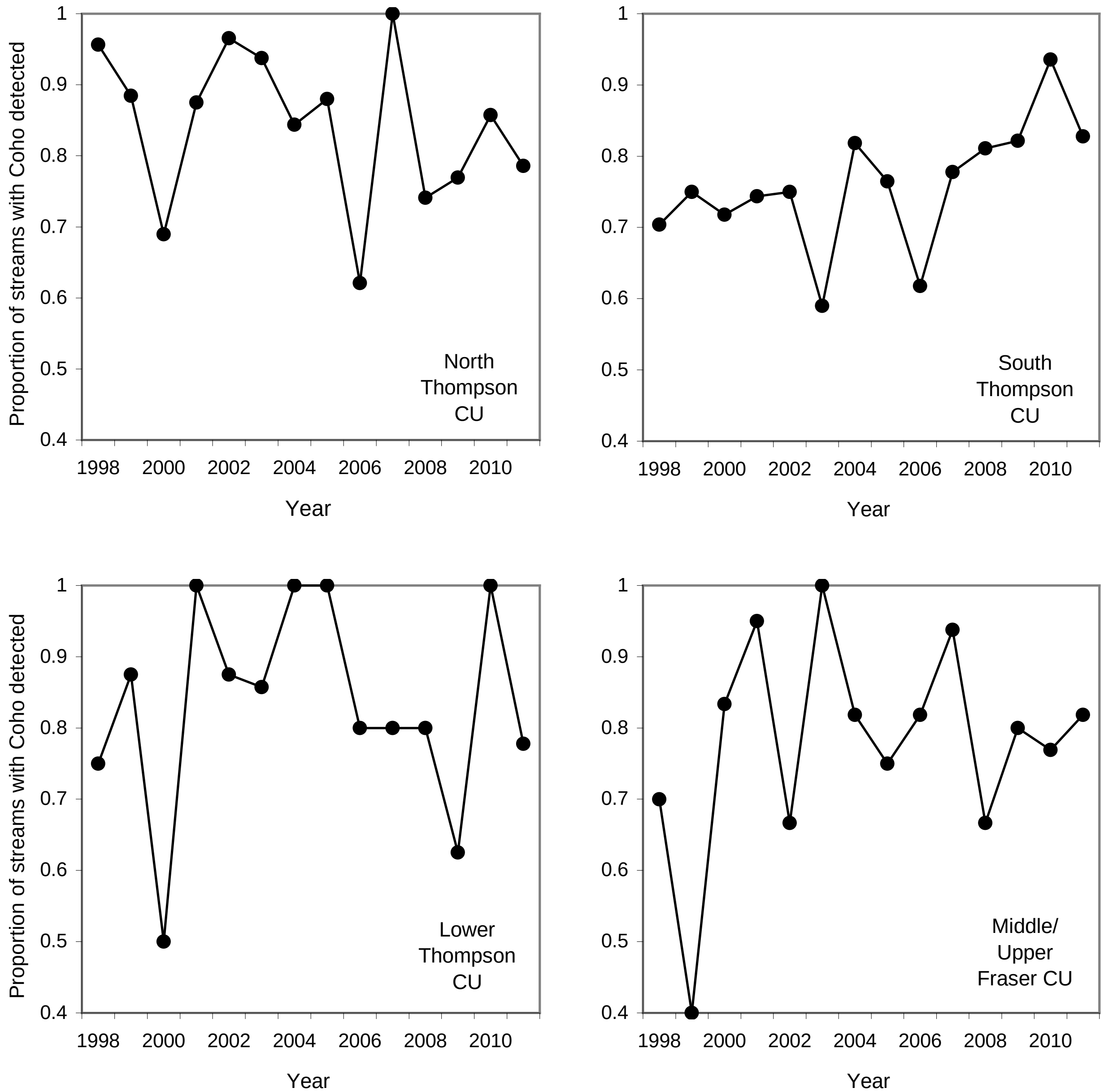


Figure 11. The proportion of surveyed spawning streams where Coho Salmon were detected (detection probability is < 100%) each year during 1998-2011 for four Conservation Units (CUs) in the Interior Fraser River watershed. The fifth CU (Fraser Canyon) consists of a single spawning stream where Coho Salmon were detected every year during 1998-2011.

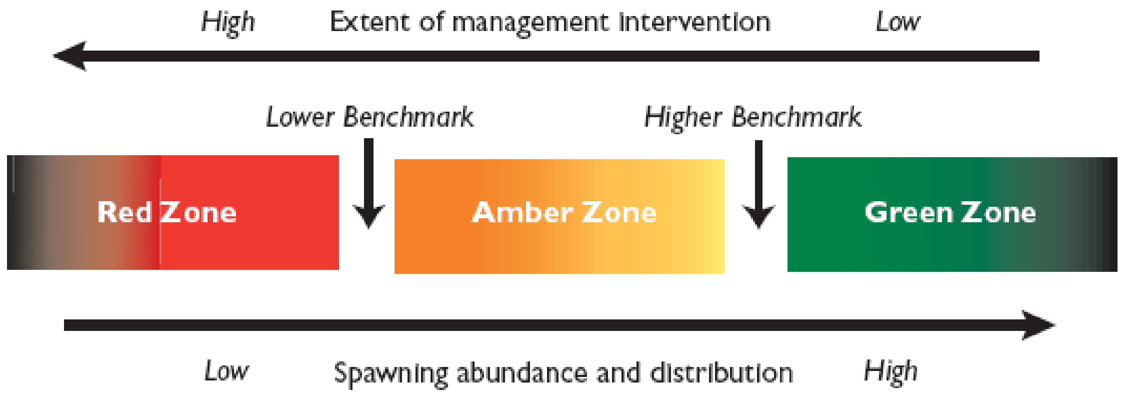


Figure 12. Diagrammatic representation of benchmarks separating three abundance status zones (red, amber, and green) for Pacific salmon under the Wild Salmon Policy (DFO 2005b). Units designated and listed by COSEWIC are in the Red Zone. Short-term recovery objectives are intended to move the unit into the Amber Zone. Longer-term objectives may move the unit into the Green Zone, an area where maximum sustainable yield (MSY) may be possible.

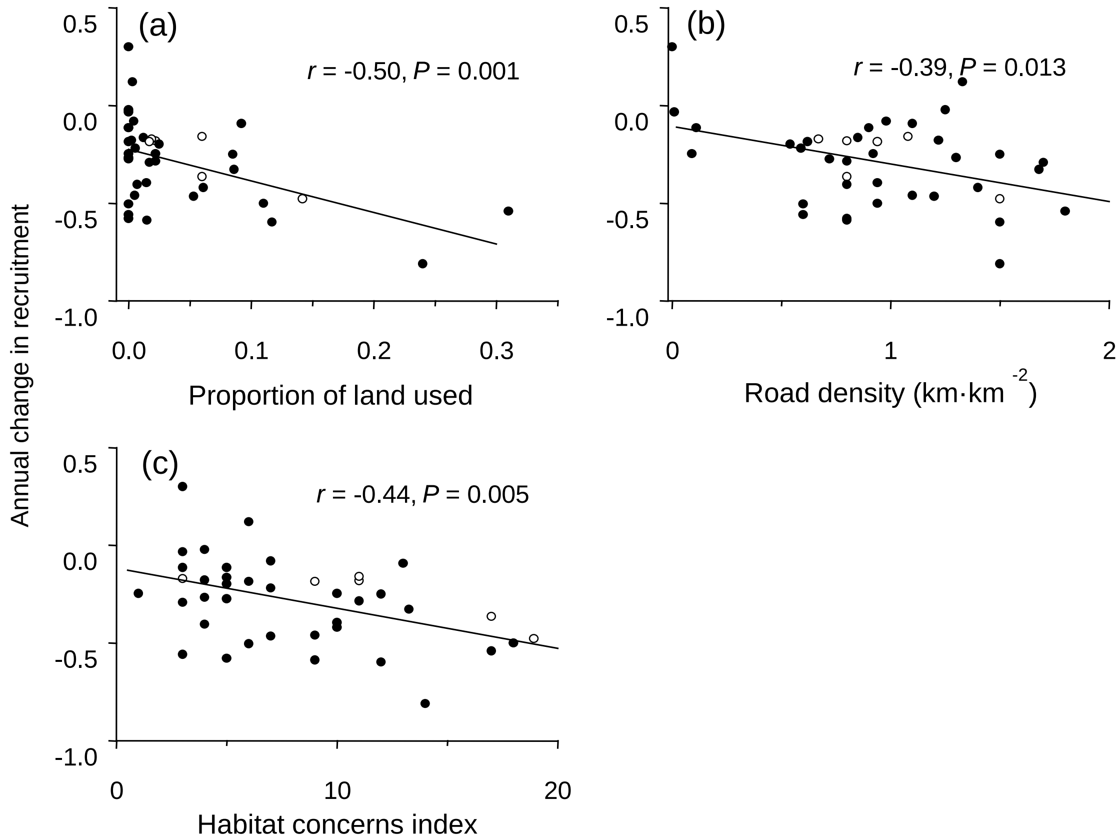


Figure 13. Correlations between three land use indices and productivity (ln(recruits/spawner)) of Coho Salmon for 40 streams in the Thompson River watershed (reproduced from Bradford and Irvine 2000). (a) Proportion of land in each catchment dedicated to agricultural or urban use; (b) density of forest, agricultural and hard surface roads in each catchment; and (c) index of habitat concerns. Open circles are streams that have had hatchery programs. Note that productivity values shown here were not derived from the same dataset as productivity values in Figure 6 (see Section 11.1).