Fisheries and Oceans Canada Pêches et Océans Canada
Science Sciences

C S A S **S C C S**

Canadian Science Advisory Secretariat **Secrétariat canadien de consultation scientifique**

Research Document 2005/093 **Document de recherche 2005/093**

Not to be cited without
permission of the authors *

Ne pas citer sans
autorisation des auteurs *

Scientific advice for input to the Allowable Harm Assessment for Interior Fraser Coho Salmon

Avis scientifique à intégrer à l'évaluation des dommages admissibles pour le saumon coho du Fraser intérieur

Michael Folkes[1], Bert Ionson[2] and James R. Irvine[1]

[1]Fisheries and Oceans Canada
Science Branch, Salmon and Freshwater Ecosystems Division,
Pacific Biological Station
Nanaimo, B.C. V9T 6N7

[2] Fisheries and Oceans Canada
Fisheries Management
Vancouver, B.C.

ISSN 1499-3848 (Printed / Imprimé)

Abstract

In 2002, COSEWIC designated Interior Fraser River coho (IFC) as “endangered”. IFC could become legally listed in 2006 under the Species At Risk Act (SARA). This Working Paper was in response to a request to assess the potential for incidental harm permitting. Questions addressed in the Working Paper were: 1) What is the present/recent species trajectory? 2) What is the present/recent species status? 3) What is the expected order of magnitude/target for recovery? 4) What is the general time frame for recovery to the target? And 5) What is the maximum human-induced mortality which the species can sustain and not jeopardize survival or recovery of the species?

When IFC were assessed by COSEWIC, the rate of decline during the 3 most recent generations was ~60%, within IUCN’s endangered status criteria range. We now have 4 additional years of data during which escapements generally increased. The most recent 3 generations experienced increases ranging between 8% (North Thompson) and 132% (South Thompson). An immediate recovery goal for the Designated Unit (DU) was defined by the Interior Fraser Coho Recovery Team as exceeding a lower benchmark (three year geometric mean 20,000-25,000 wild spawners). Recent escapements for the DU exceed this benchmark, although escapements remain low relative to historical highs. Longer term (multi generation) escapement benchmarks range from 46,000 to 148,000 depending on the estimation model considered. Modelling results suggest that at current exploitations and marine survival there is less than 25% chance that spawner levels will reach one possible spawner objective of doubling by the end of three generations. It is assumed that longer recovery times will be necessary to assure higher chances of meeting target escapement levels. We cannot accurately forecast future marine survival. However, we can indicate the likely future status given differing levels of future survival. Simulation modelling suggests that, at the current exploitation rate and recent survival, the short term (2 year) probability of remaining above the survival benchmark is 90%, however the probability of remaining above that level in the longer term (3 generations) is ~50%. At the current exploitation rate and marine survival, the longer term probability of positive growth is <50%. Considering the uncertain nature of marine survival forecasting, it would be prudent to wait several more years before providing specific advice with regards to changing fisheries.

Résumé

En 2002, le COSEPAC a désigné le coho du Fraser intérieur (CFI) en tant qu'espèce « en voie de disparition ». De ce fait, le CFI pourrait être officiellement inscrit à la liste de la *Loi sur les espèces en péril* (LEP) en 2006. Ce document de travail constitue une réponse à une demande d'évaluation dommages admissibles. Les questions auxquelles répond le document sont les suivantes : 1) Quelle est la tendance actuelle / récente de l'espèce? 2) Quel est l'état actuel / récent de l'espèce? 3) Quel est l'ordre de grandeur ou l'objectif du rétablissement? 4) Quel est le délai général pour atteindre l'objectif de rétablissement? 5) Quel est le taux de mortalité causé par l'homme maximal que peut soutenir l'espèce sans que sa survie ou son rétablissement n'en soit menacé?

Quand le CFI a été évalué par le COSEPAC, le taux de déclin pour les trois générations les plus récentes avoisinait les 60 % et se situait donc dans la plage des critères applicables aux espèces en voie de disparition de l'Union mondiale pour la nature (UICN). On dispose maintenant de quatre années supplémentaires de données durant lesquelles les échappées ont augmenté d'une manière générale. Les trois dernières générations ont connu des hausses allant de 8 % (Thompson Nord) à 132 % (Thompson Sud). L'équipe chargée du rétablissement du saumon coho du Fraser intérieur a établi comme objectif immédiat de rétablissement de l'unité désignée le dépassement d'un point de référence inférieur (moyenne géométrique sur trois ans) se situant entre 20 000 et 25 000 géniteurs sauvages. Bien que les échappées demeurent faibles comparativement aux sommets historiques, les récentes échappées au sein de l'unité désignée dépassent ce point de référence. Selon le modèle d'estimation utilisé, le point de référence des échappées à long terme (multigénérationnel) s'établit entre 46 000 et 148 000. Les résultats de la modélisation révèlent qu'aux taux d'exploitation et de survie en mer actuels, les chances que les effectifs géniteurs doublent d'ici la fin de la période couvrant trois générations, sont de moins de 25 %. On assume qu'il faudra plus de temps pour assurer de meilleures chances d'atteindre les échappées cibles. Nous ne pouvons prévoir avec précision la survie future en mer, mais il est possible de déterminer la situation future probable en fonction de différents taux de survie en mer. Selon les simulations, au taux d'exploitation actuel et selon les données récentes sur la survie, la probabilité que le taux de survie à court terme (deux ans) demeure au-dessus du point de référence est de 90 % environ; toutefois, la probabilité que ce taux demeure au-dessus de ce point à plus long terme (3 générations) est de 50 % environ. Aux taux d'exploitation et de survie en mer actuels, la probabilité de croissance positive à plus long terme est < 50 %. Étant donné la nature incertaine des prévisions concernant la survie en mer, il serait prudent d'attendre plusieurs années avant de formuler un avis particulier concernant des modifications à la pêche.

Introduction

In 2002, Interior Fraser River coho salmon (IFC) were recognized as a ‘species’ under the Species At Risk Act (SARA) and designated as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (COSEWIC, 2002). The final decision for legal listing will be announced in April, 2006 (Irvine et al. 2005). If legally listed, Fisheries & Oceans Canada (DFO) will be responsible for initiating a chain of events which must take place in order to protect the species. Included in DFO’s responsibilities is the preparation of an Allowable Harm Assessment (AHA) as described by the SARA permitting framework (http://www.sararegistry.gc.ca/default_e.cfm). An AHA is intended to help define the current status of the species, targets and time frame for recovery, and the uncertainty of outcomes associated with management actions. This is the first assessment of allowable harm for Pacific salmon in Canada although Amiro (2004) recently completed a similar review for inner Bay of Fundy Atlantic salmon.

Several of the questions asked within this AHA have already been answered in published documents. As such, some questions are addressed by direct quotes (and cited) with some additional commentary where needed.

Most of the biological data in this document are from Irvine (2002)[1], but the time series has been extended by 4 years (IFCRT, 2006; J. R. Irvine, unpub. data). The survival and recovery benchmarks (objectives) are derived from the Interior Fraser Coho Recovery Team (2005) (herein described as IFCRT). The biological basis for similar benchmarks was outlined by Bradford and Wood (2004).

---

[1] When the time series of escapement data was reviewed by the IFCRT, a significant error found for one year from the North Thompson was corrected.

Data

This document relies on field derived estimates of spawner escapements for the whole IFC Designated Unit (DU). Most escapement data were collected by visual surveys of coho salmon on the spawning grounds although there is some direct enumeration at counting facilities. Prior to 1998, most visual surveys were conducted by DFO Fishery Officers. These data varied in precision and accuracy. Irvine et al. (1999a and 1999b) describe salmon escapement methodologies in more detail. In recent years, methodologies have generally improved and the spatial extent of spawner surveys has increased. Recent data for some streams has produced a time series of estimates with associated approximations of their precision. The historical data (1975 onward) were re-assessed using these recent data, thereby allowing DFO to fill in missing data and adjust older, less reliable data. Prior to 1998, reliable continuous series exist for only the North and South Thompson. Historical escapement estimates to other systems were extrapolated from the North and South Thompson using 1998-2003 proportions (Irvine, 2002; IFCRT, 2006).

Total abundance (i.e. catch plus escapement) was calculated from escapement and exploitation rate estimates. The estimation of exploitation rates are described in Simpson (2004). Methods to compute exploitation have varied during the time series. Early estimates were based on catches and escapements of coded-wire tagged coho. A DNA based approach was used during 1998-2000 when coded-wire tag data were inadequate. Specifically, stock ID by catch-area was applied to estimates of coho encounters. Since 2001, IFC exploitation rates have been estimated by the Coho Technical Committee of the Pacific Salmon Commission through methods using historical estimates of CWT recoveries and effort (Simpson, 2004).

Marine survival is represented by the Georgia Strait wild indicator marine survival data from Black Creek (Vancouver Island) and Salmon River (lower Fraser near Langley). While estimates of marine survival for IFC hatchery stocks are available, they are limited to the North and South Thompson, and are not consistently available for a sufficient number of years to be a reliable time series. Therefore, annual average marine survival rates for the two Strait of Georgia wild indicator stocks were used as a survival index for IFC (Irvine et al. 2001; Personal Communication, Kent Simpson, Fisheries & Oceans Canada; Table 3).

1. What is present/recent species trajectory?

Generational rates of decline for wild spawners computed by Irvine (2002) were ~60%, within IUCN's endangered status criteria range. Extending the time series by 4 years and re-calculating these estimates for 1994-2004 (versus 1990-2000) makes a huge difference[2]. Instead of declining, the DU increases from 8-277% with an overall mean increasing rate of about 145% (Table 1) for wild spawner escapement. Figure 1 shows the trend in returns and spawning escapement estimates experienced by the IFC from 1975 onwards.

Since 1997 exploitation rates from Canadian sources have been reduced to a level currently averaging around 3%, while the current U.S. fishery exploitation rate is approximately 10% (Personal communication, Wilf Luedke, Fisheries & Oceans Canada), (see question 6A "International"). Figure 2 presents the time series for total estimated exploitation rate on IFC.

Table 1: Rates of increase (percentages) for South and North Thompson coho salmon total wild escapement during 1994-2004. Estimates were calculated using the standard COSEWIC formula, as well as using 3 year smoothed data.

Method	South Thompson	North Thompson	Overall Mean
COSEWIC	131.5	7.9	69.7
Smoothed	383.4	157.9	270.6

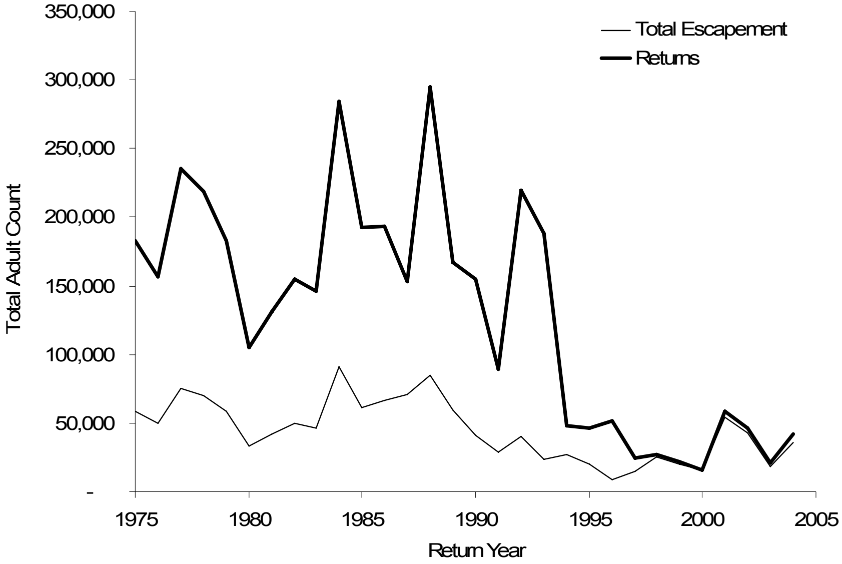


Figure 1: Estimated total returns and escapement of Interior Fraser coho.

---

[2] Preliminary escapement estimates for 2005 (~15,000) became available after these analyses were completed. Including the 2005 value would have resulted in reduced rates of increase over the 3 most recent generations.

Estimates of marine survival for IFC hatchery stocks are available (e.g. Fig. 13 in Irvine et al. 2000). Unfortunately the time series is made up of discontinuous estimates from several IFC populations. We therefore decided to follow the approach of other recent investigations and use annual average marine survival from two Strait of Georgia wild indicator stocks (Black Creek, Vancouver Island and Salmon River – lower Fraser). Considering Georgia Strait wild stock indicators, marine survival rates increased slightly since the low in 1996, but have remained low compared to the 1980's (Figure 3, Table 3). Only the North and South Thompson populations have adequate time series to estimate population growth rate changes (Figure 4). In the 23 year time series, 4 and 5 years respectively are near or below replacement (where ln(R/S)=0) for South and North Thompson respectively. Growth rate for the DU was estimated from the geometric mean R/S for North and South Thompson (Figure 5).

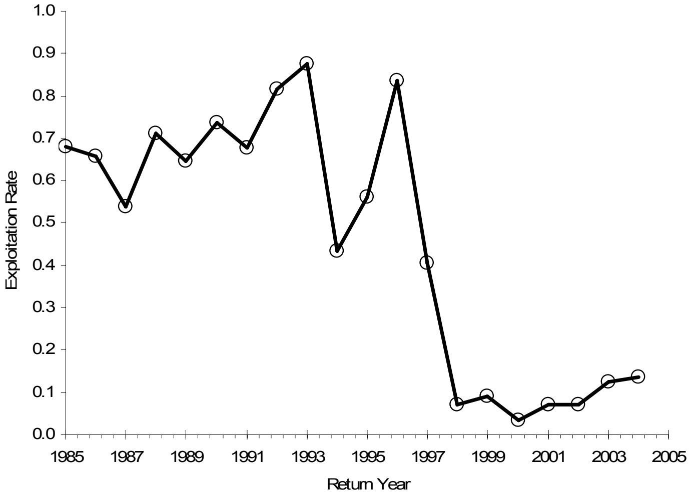


Figure 2: Estimated exploitation rates for the Interior Fraser coho salmon designated unit, 1985 – 2003. (Table 3).

Figure 3: Mean marine survival for two Strait of Georgia stocks (Black Creek, Van. Isle, and Salmon River - lower Fraser).

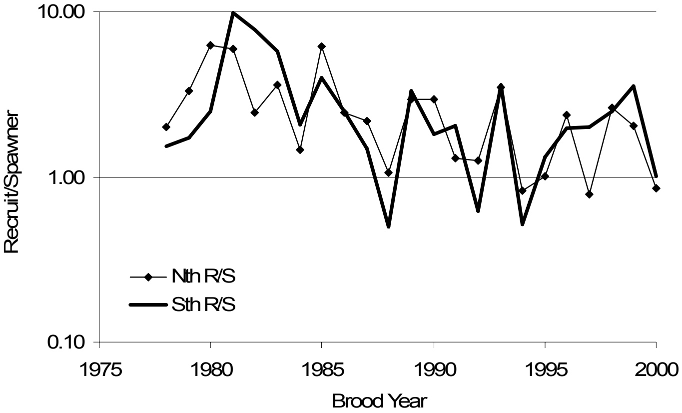


Figure 4: Recruits per spawner for North (Nth) and South (Sth) Thompson coho.

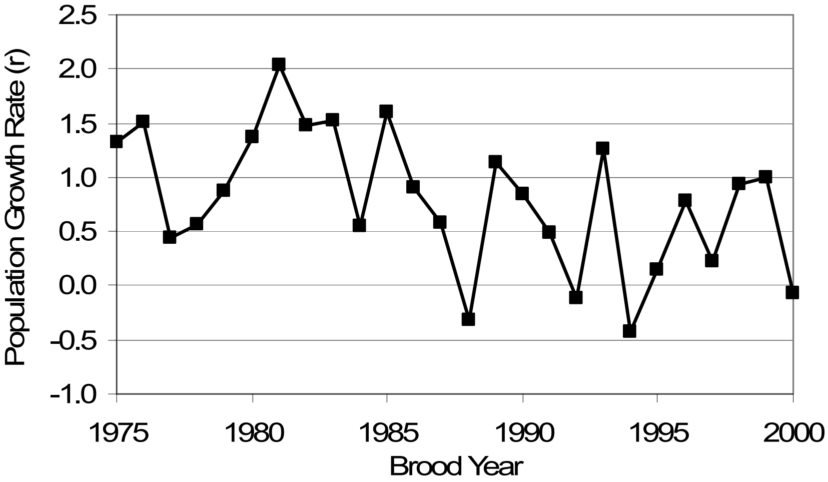


Figure 5: Population growth rate (r) estimated from combined North and South Thompson coho salmon populations for the 1975 to 2000 brood years (data updated from Irvine et al. 1999).

2. What is present/recent species status?

The present work is not intended to take the place of a detailed stock assessment. The IFC DU consists of five populations that are largely genetically distinct (Fraser Canyon, Upper Fraser, North Thompson, South Thompson, and Lower Thompson), and eleven sub-populations that were identified based on the presence of natural barriers, the influence of large lakes, and observations of spawner aggregations under differing discharge conditions IFCRT (2006). Much of the following discussion is taken from Irvine (2002) or IFCRT (2006).

Only the North and South Thompson watersheds have had reliable escapement surveys since the mid 1970's. Since 1998 the enumeration programs have been more thorough for each of the five populations. Surveys consist of either visual observations on the spawning beds or direct counting through enumeration facilities. Table 2 represents current estimates for wild-origin escapement. In assessing population status and recovery objectives, hatchery fish have been excluded from calculations presented in Irvine (2002) and the IFCRT (2006).

As mentioned previously, adequate escapement data previous to 1998 only exist for the North and South Thompson populations. Escapement estimates, before 1998, to the other three populations were extrapolated from their relative contribution in the 1998-2003 total escapements.

Most populations were at their highest levels of escapement during the mid 1980's. To de-emphasize high numbers, escapement trends were assessed using geometric means. The three year geometric mean escapement for the DU peaked during the late 1980's at just over 70,000 spawners. Geometric mean escapements between 2001 and 2004 ranged between 25,000 and 35,000.

Escapements to the DU in 2001 (54,000) and 2002 (42,000) were the highest in over a decade, ranging from 25-60% of the maximum recorded. In 2003 escapement dropped to ~18,000, with each population escaping at ~13-33% of its historical maximum. The 2004 wild escapement is ~38,000 (Table 2). The 2001-2003 population specific, geometric means suggest recent escapements are 31-46% of the maximum observed for each population.

Trends in escapement, using a three year geometric mean, are presented in Figure 6 and Figure 7. Prior to 1998 the Fraser Canyon, Upper Fraser, and Lower Thompson population trends are extrapolated from North and South Thompson. Thus their changes are uncertain. The relative abundance levels across the five populations are quite different. The North Thompson population has consistently had the largest escapement. The upper Fraser and lower Thompson have consistently had the lowest escapement. There is a great degree of uncertainty regarding escapement estimates of the upper Fraser population.

The Wild Salmon Policy (DFO 2005) commits to the identification of two benchmarks for individual units that will delineate three biological status zones (Figure 8). The lower benchmark should ensure a substantial buffer between it and a level of abundance that could lead to the unit being considered at risk of extirpation. For IFC, the lower benchmark is probably the minimum target escapement established by the IFCRT (2006). As can be seen (Figure 7), IFC are currently above this lower benchmark, and therefore we conclude that they are probably in the amber zone. The upper benchmark separating the amber and green zones has not been finalized.

The current status of fishing impacts are discussed in question 6.

Table 2: Annual total abundances and escapements of coho salmon for the Interior Fraser Designated Unit, 1975 to 2004. (IFCRT, 2006).

	Population (wild spawners)					Total	Total	Total
Year	Fraser Canyon	Upper Fraser	North Thompson	Lower Thompson	South Thompson	Wild Spawners	Spawners	Abundance
1975	9,504	5,995	27,618	4,630	10,613	58,359	58,359	182,659
1976	8,130	5,128	26,198	3,961	6,506	49,922	49,922	156,253
1977	12,260	7,733	35,220	5,972	14,096	75,281	75,281	235,624
1978	11,372	7,173	33,021	5,540	12,725	69,832	69,832	218,569
1979	9,498	5,991	22,247	4,627	15,958	58,320	58,320	182,538
1980	5,462	3,445	10,943	2,661	11,028	33,538	33,538	104,972
1981	6,836	4,312	21,265	3,330	6,235	41,979	41,979	131,391
1982	8,063	5,086	23,639	3,928	8,795	49,511	49,511	154,966
1983	7,597	4,792	21,759	3,701	8,802	46,651	46,651	146,040
1984	14,925	9,414	40,419	6,556	19,617	90,931	90,931	285,230
1985	10,084	6,360	18,546	4,475	22,016	61,481	61,481	193,294
1986	11,026	6,955	26,874	3,879	17,479	66,212	68,344	202,892
1987	11,470	7,234	27,416	5,889	18,722	70,730	80,559	175,979
1988	14,449	9,114	32,914	3,193	25,209	84,878	96,702	337,979
1989	9,918	6,256	23,701	3,207	16,196	59,277	69,714	198,624
1990	6,420	4,049	16,042	4,599	9,783	40,894	48,485	186,019
1991	4,113	2,594	11,703	5,413	4,842	28,665	33,545	105,172
1992	6,510	4,106	13,193	3,838	12,995	40,643	50,528	273,903
1993	2,193	1,383	6,192	11,034	2,631	23,434	29,381	237,165
1994	4,000	2,523	9,878	4,759	6,210	27,370	35,517	63,795
1995	3,119	1,967	8,477	2,692	4,070	20,326	22,996	53,688
1996	1,403	885	3,846	617	1,799	8,550	9,294	57,016
1997	1,846	1,165	5,457	4,214	1,970	14,652	18,675	32,180
1998	5,460	4,002	8,755	889	5,802	24,907	26,757	29,537
1999	4,096	1,397	8,801	2,068	3,306	19,668	22,597	25,844
2000	2,719	2,004	4,508	2,451	3,787	15,469	20,252	21,744
2001	5,971	6,340	22,731	5,379	13,569	53,990	61,640	67,370
2002	3,817	4,194	17,107	6,688	10,981	42,788	56,169	61,693
2003	4,552	3,117	5,537	1,699	3,332	18,236	20,745	24,558
2004	5,872	4,416	10,077	2,287	15,506	38,157	41,200	47,871

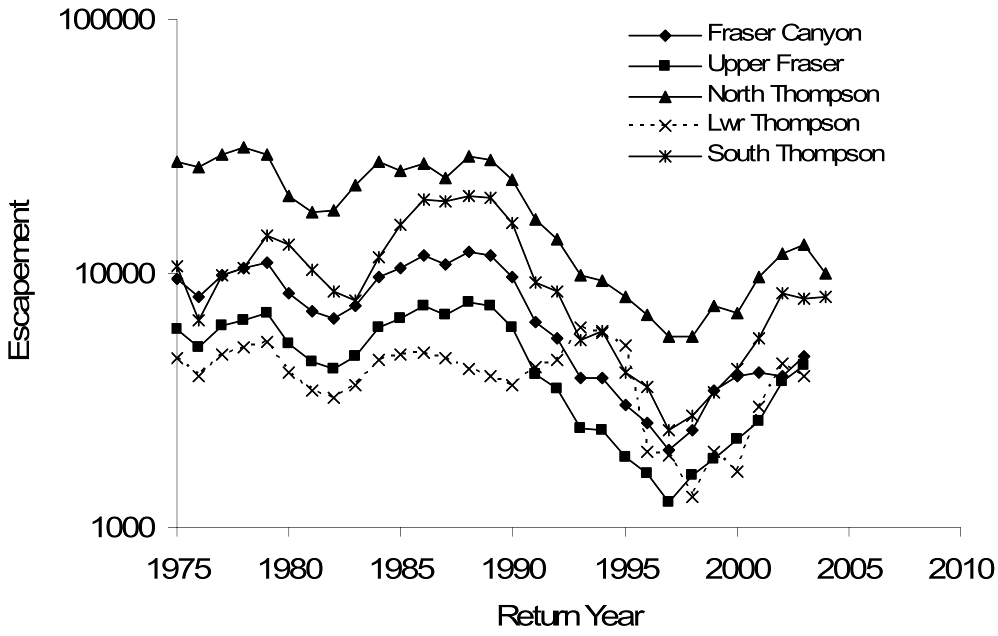


Figure 6: Trends in Interior Fraser coho salmon escapement, by population (excludes hatchery fish). Data are 3-year running geometric means plotted on a log10 scale). (IFCRT, 2006).

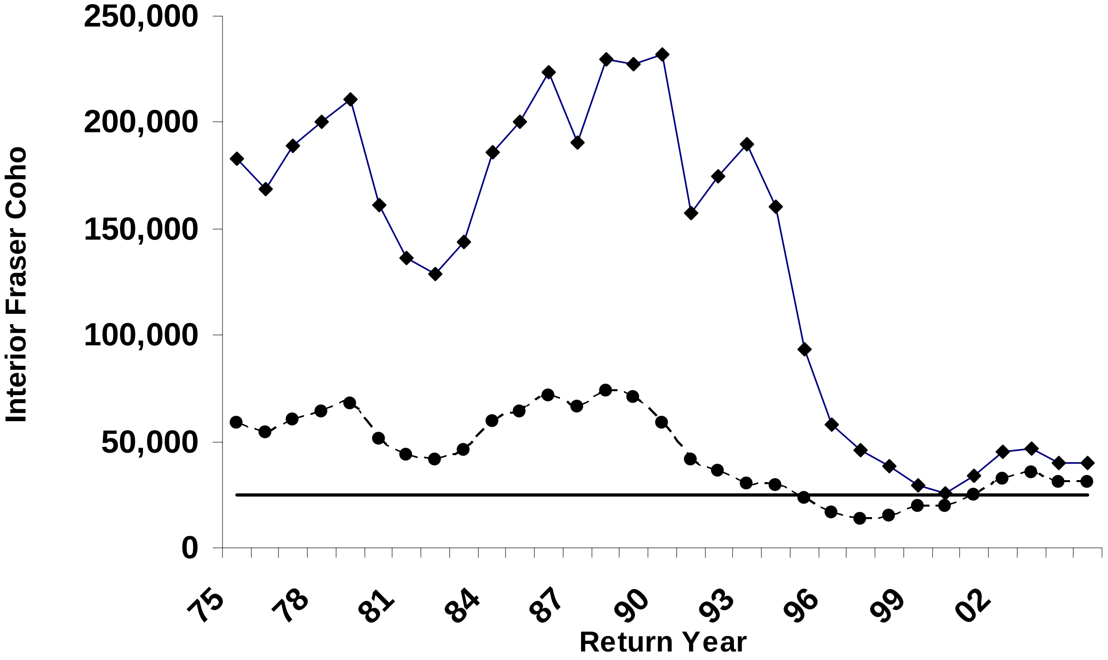
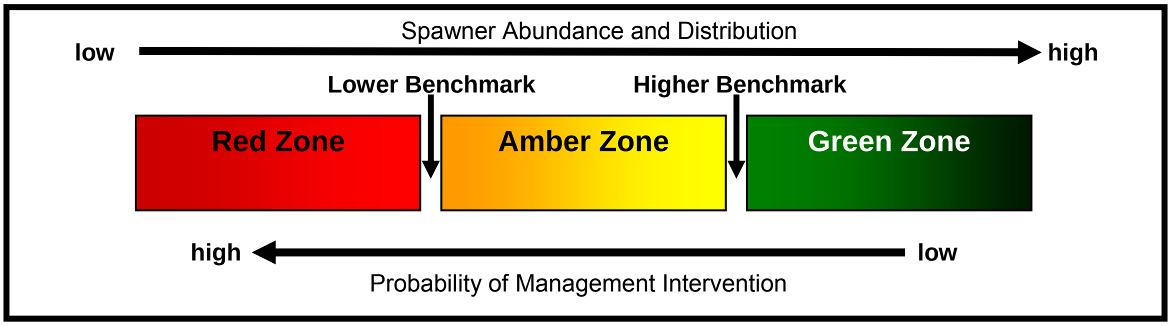


Figure 7: Trends in spawning escapement (filled circles) and total abundance (diamonds) (catch plus escapement) of naturally spawned Interior Fraser Coho (excludes hatchery fish). Data are plotted as 3-year running geometric means. Horizontal line is the provisional lower escapement benchmark that separates the red and amber zones (see Fig. 8).



.

Figure 8: . Diagrammatic representation of benchmarks and biological status zones (red, amber, and green) adapted from DFO (2005).

3. What is the expected order of magnitude / target for recovery?

The IFCRT (2006) defined two specific and one longer-term objective for the IFC:

> **“Objective 1:** The 3-year average escapement in at least half of the sub-populations within each of the five populations is to exceed 1000 naturally spawning coho salmon, excluding hatchery fish spawning in the wild. This objective is designed to provide the abundance and diversity required to satisfy the Recovery Goal.
>
> **Objective 2:** Maintain the productivity of Interior Fraser Coho so that recovery can be sustained. This objective is designed to ensure that the threats to recovery are addressed.
>
> This objective may be met by addressing the causes for the decline that were identified by COSEWIC:
>
> - Development of a harvest management plan to ensure that exploitation rates are appropriate to changes in productivity caused, for example, by fluctuations in ocean conditions.
> - Identification, protection, and if necessary rehabilitation of critical and important habitats.
> - Ensure that the use of fish culture methods is consistent with the recovery goal.
>
> **Possible Longer Term Objectives:** Over the long term it may be desirable to recover Interior Fraser Coho so that other societal objectives can be achieved. These objectives are within the scope of the recovery goal, but are beyond the mandate of the Recovery Team (see Section 3.3)”

The IFCRT (2006) gives genetic and demographic arguments for Objective 1 and Bradford and Wood (2004) more thoroughly reviewed the scientific basis for minimum viable population sizes as applicable to salmon populations.

The IFCRT (2006) analysis showed that:

> “the number of sub-populations that falls below 1,000 individuals increases significantly when aggregate DU abundance is less than 20,000 to 25,000 individuals. The analysis also suggests that when there were fewer than approximately 20,000 coho salmon spawners (3-year running geometric mean) in the DU, the recovery goal would not have been met.
>
> Thus, the historical data suggest that a level of abundance of 20,000 to 25,000 wild-origin spawners in the Interior Fraser coho salmon designated unit is required to achieve Recovery Objective 1.”

Thus a minimum tolerable level of escapement is a three year geometric mean ranging 20,000-25,000.

Escapement goals beyond the lower recovery benchmark recommended in IFCRT (2006) are likely to be policy driven. As such they would require not only a biological basis for estimation but also a socio-economic analysis that could consider, among other things, the short term costs to rebuilding (see Strategy 4 in DFO 2005). However within IFCRT (2006) six examples of long term goals were given:

- To achieve three year average escapements in all sub-populations within each of the five populations exceeding 1,000 naturally spawning coho salmon (excluding hatchery fish spawning in natural habitats).
- To recover each of the five populations to the maximum sustainable yield (MSY) abundance level, *i.e.* to the Green Zone in Figure 21.
- To recover each of the five populations to their maximum historic abundance levels.
- To recover to a level where the freshwater productive capacity within each of the five populations is optimized. A possible approach would be to estimate the maximum capacity as smolts/km and apply this to the designated unit.
- To increase adult returns so that sufficient marine origin nutrients enter each population to optimize ecosystem function.
- To recover to a level that will allow for harvesting at higher levels than are currently allowed; including, but not limited to, terminal area (i.e., in estuary or freshwater areas near natal streams) harvesting for consumptive and non-consumptive purposes.

The first example, to achieve 1000 average escapement in all subpopulations, could be estimated simply: being 11 sub-populations x 1,000 (spawners/ sub-populations) =11,000 spawners per year. Recognizing that there are strong and weak sub-populations co-migrating, this approach would result in an escapement substantially higher than 20,000. Currently, escapement assessment programs are somewhat limited in their geographic scope. Monitoring programs may not be able to deliver precise estimates of escapement for each of the eleven subpopulations. Therefore, even if management actions could protect all sub-populations to specific levels, current escapement monitoring programs might not be capable of assessing the success of management actions.

The maximum estimated escapement for IFC was 91,000 spawners in 1984 (Table 2). Three of the five populations had their maximum escapement that same year (Fraser Canyon=14,925, Upper Fraser=9,414, North Thompson=40,419). The Lower Thompson peaked in 1993 (11,034), and the South Thompson in 1988 with 25,000. The sum of these maximum escapements is 101,000 (although escapements to 2 of the 5 populations are expansions and not independent). Habitat degradation impacts on annual changes in recruitment were evaluated by Bradford and Irvine (2000). They found that rates of decline were correlated with three freshwater habitat use indices (agricultural land use, road density, and a qualitative stream habitat index). Irvine (2002) reiterated that land use in the South Thompson may be one reason for greater declines there than in the North Thompson. Escapement to the South Thompson during eight of the last ten years has been less than a fifth of the 1988 peak (25,000).

A longer term recovery target may be an escapement that would produce maximum sustainable yield. There are insufficient historical data across the coho sub-populations to estimate S_{msy} for the IFC (IFCRT, 2006). Irvine et al. (2001) and Irvine (2002) assessed female coho spawner densities for the North Thompson and suggested 24.9 females/km of accessible habitat would produce MSY. This equates to an S_{msy} of 43,000 for only the North Thompson. No estimates for S_{msy} exist for the other populations. From 1998 to 2003 the

North Thompson contributed an average of 37% of the spawners returning to the DU. Expanding the North Thompson S_{msy} of 43,000 by 1 / 0.37 gives a very crude system wide S_{msy} estimate of ~116,000 spawners. However, this approach ignores evidence of non-stationarity, differences in productivity among populations, imprecise exploitation estimates etc.

Another approach would be to develop an escapement objective based on the historical return sizes. The largest estimated return since 1975 was 295,000 in 1985 (Table 3), and 50% (or some other proportion) of this value might be a reasonable escapement objective.

Reliable estimates of escapement begin in 1975 for the North and South Thompson. For other populations, escapement data are inconsistent in availability (Irvine et al. 1999). Thus for some subpopulations escapement data are extrapolated from its relationship to North and South Thompson time series.

For North Thompson coho, Chen et al. (2002) found evidence of depensatory mortality at low spawner densities. To address concerns that freshwater density dependence be incorporated in this analysis, we estimated smolt production per spawner. Assessment of the total freshwater capacity for IFC requires the assumption that three of the populations without historical data have similar spawner-smolt recruit relationships to the combined North and South Thompson populations. This has been discussed by the IFCRT (2006). To estimate the total IFC freshwater productivity and capacity, two-parameter Ricker, Beverton-Holt, and Hockey stick stock–recruitment models were fitted to wild smolt production and natural spawner estimates (Table 3).

System wide smolt production estimates do not exist, but a smolt production index can be estimated from recruitment and marine survival.

Where:

Recruitment = Escapement / (1-Exploitation Rate)

and

Smolts = Recruitment / Marine survival

Wild smolt production was back-calculated from natural spawner estimates. However, in fitting the relationship between spawners and smolts, total natural spawners included fish of hatchery origin. Fitting a Ricker function to these data suggests a maximum total smolt production (Rmax) at 76,600 spawners (Figure 9). The maximum smolt production rate (alpha) is estimated at ~45 smolts/spawner. The linear fit is:

$\text{Ln(smolts/spawner)} = -1.29\text{x}10^{-5} \text{ x spawners} + 3.81$

Parameter	*Value*
α	45
$1/\beta$	76,600
P	<0.01
R^2	0.39

The linear fit is statistically significant, but the independent variable (spawners) explains only 39% of the variability in smolt production rate. Further, this series contains only three data points beyond the estimate of maximum production, which reduces certainty in the curve shape and the spawner level which produces the maximum smolts. However, the predicted smolt production for those three brood years is very close to the observed values (Figure 9).

To compare relative performance, models were fitted by minimized residual sum of squares. The hockey-stick model fit least well (SS=3.56) while Ricker and Beverton-Holt (BH) were similar (3.14 & 3.01 respectively). The BH fit suggests a maximum smolt production (a) of 1.7 million, and spawners at a/2 (b) equals 26,000. The smolt production curve begins to level when spawners exceed 80,000. This is similar to the to $1/\beta$ value (76,600) estimated by the Ricker fit. However the BH fit suggests a higher productivity at very low spawners with a maximum smolt production rate of 66 per spawner, while the Ricker fit is 45 smolts per spawner. The hockey stick model calculation of maximum smolt production is K=1.35 million when escapement exceeds 45,500 spawners (N*). The hockey stick productivity parameter, α, is estimated as 30 smolts per spawner. Bradford et al. (2000) used the hockey stick model to estimate the productivity parameters (smolts/female) of 14 coho streams. If we assume a 50:50 sex ratio, their estimates expand to an average α of 42.5 smolts/spawner (min=21.5, max=106). The smolt productivity estimated for IFC fits within the range of estimates from these other coho systems.

All three models have a very similar fit to the data at spawner levels less than 100,000, which is similar to the highest estimate for system capacity. Although not evaluated in the present analysis, a S-R model that assumes higher mortality at low run sizes, for example due to high predation rates or inability to find mates at low escapements (i.e. depensation, Chen et al. 2002)), would result in a lower estimate of productivity at low escapements compared to the two-parameter Ricker model. Given uncertainty and assumptions about the data inputs, the “correct” functional form of the S-R relationship cannot be reliably determined.

There is much uncertainty around the benchmarks provided in Table 4 and no concensus regarding which, if any of these values, might be an appropriate target. Spawner capacity estimates derived from the Ricker and Beverton-Holt smolt to spawner relationships were used within the modeling exercise discussed in question 5.

Table 3: Spawner, return, and smolt indices for IFC. Returns estimated from division of escapement and 1-ER. Wild smolts estimated from division of wild returns and average Georgia Strait marine survival.

	Spawning Abundance			Wild Adult Production			Marine Survival [2]			Smolt Production	
Brood Year	Wild Origin	Hatchery Origin [1]	Total Spawners In Natural Environment	Wild Escapement At Brood Year + 3	Exploitation Rate	Estimated Wild Returns From Wild Natural Spawners	Black Ck. Wild Marine Survival	Salmon Riv. (Langley) Wild Marine Survival	GS Wild MS (average of Black & Salmon)	Wild Smolt Index	$Ln\left(\frac{\text{Wild Smolt Index}}{\text{Total Natural Spawners}}\right)$ footnote 3
1975	58,359	-	58,359	69,832	68.1%	218,569	NA	NA	NA		
1976	49,922	-	49,922	58,320	68.1%	182,538	NA	NA	NA		
1977	75,281	-	75,281	33,538	68.1%	104,972	NA	NA	NA		
1978	69,832	-	69,832	41,979	68.1%	131,391	NA	NA	NA		
1979	58,320	-	58,320	49,511	68.1%	154,966	NA	NA	NA		
1980	33,538	-	33,538	46,651	68.1%	146,014	NA	NA	NA		
1981	41,979	-	41,979	90,931	68.1%	284,608	NA	NA	NA		
1982	49,511	-	49,511	61,481	68.1%	192,433	NA	NA	NA		
1983	46,651	-	46,651	66,212	65.7%	193,119	12.5%	NA	12.5%	1,539,722	33.0
1984	90,931	-	90,931	70,730	53.7%	152,835	11.5%	12.4%	12.0%	1,278,148	14.1
1985	61,481	-	61,481	84,878	71.2%	294,680	13.4%	22.9%	18.2%	1,621,953	26.4
1986	66,212	2,131	68,344	59,277	64.5%	167,059	11.5%	13.6%	12.5%	1,333,493	19.5
1987	70,730	9,829	80,559	40,894	73.7%	155,224	12.9%	13.6%	13.2%	1,173,347	14.6
1988	84,878	11,824	96,702	28,665	67.7%	88,871	8.0%	8.1%	8.1%	1,103,342	11.4
1989	59,277	10,437	69,714	40,643	81.5%	219,274	12.5%	9.8%	11.1%	1,967,783	28.2
1990	40,894	7,591	48,485	23,434	87.6%	188,241	5.4%	8.8%	7.1%	2,649,290	54.6
1991	28,665	4,880	33,545	27,370	43.3%	48,301	5.9%	10.0%	8.0%	605,492	18.1
1992	40,643	9,885	50,528	20,326	56.2%	46,364	4.5%	7.1%	5.8%	793,637	15.7
1993	23,434	5,947	29,381	8,550	83.5%	51,808	3.4%	8.2%	5.8%	894,878	30.5
1994	27,370	8,146	35,517	14,652	40.5%	24,619	4.8%	4.5%	4.6%	531,135	15.0
1995	20,326	2,669	22,996	24,980	7.0%	26,860	4.5%	2.8%	3.7%	734,003	31.9
1996	8,550	744	9,294	19,704	9.0%	21,652	1.7%	2.8%	2.2%	964,793	103.8
1997	14,652	4,024	18,675	15,469	3.4%	16,013	2.2%	6.2%	4.2%	381,843	20.4
1998	24,980	1,849	26,830	54,122	7.0%	58,196	7.4%	7.3%	7.3%	792,406	29.5
1999	19,704	2,929	22,632	42,834	7.1%	46,107	4.9%	7.1%	6.0%	764,617	33.8
2000	15,469	4,784	20,252	18,276	12.6%	20,910	3.0%	3.6%	3.3%	641,139	31.7
2001	54,122	7,654	61,776	38,157	13.5%	44,112	4.4%	4.3%	4.3%	1,021,358	16.5
2002	42,834	13,381	56,215								
2003	18,276	2,509	20,784								
2004	38,157	3,043	41,200								

[1] Before 1986 hatchery spawning in the wild was either 0 or unknown

[2] Data unavailable before 1983 for these two wild indicator systems

[3] Example calculation: Estimated wild returns from 2001 brood = 2004 wild escapement / (1-ER in 2004) = 38,157 / (1-0.135) = 44,112
Estimated wild smolts from 2001 brood = wild returns from 2001 brood / (GS wild MS for 2001 brood) = 44,112 / (0.043) = 1,021,358
Estimated wild smolt production rate from 2001 brood = Estimated wild smolts from 2001 brood / Total Spawners In Natural Environment = 1,021,358 / 61,776 = 16.5

Table 4: Various possible escapement benchmarks for IFC

Escapement Objective Approach	*Target Spawners*
Minimum tolerable (demographic & genetic)	20,000-25,000
1000 spawners in all 11 subpopulations	30,000-50,000
Maximum Historical Escapement	91,000
Smolt Capacity From Hockey Stick Spawner-Recruit	46,000
Smolt Capacity From Ricker Spawner-Recruit	77,000
Smolt Capacity From Beverton-Holt Spawner-Recruit	80,000
S_{msy} From females/km	116,000
50% of maximum return	147,500

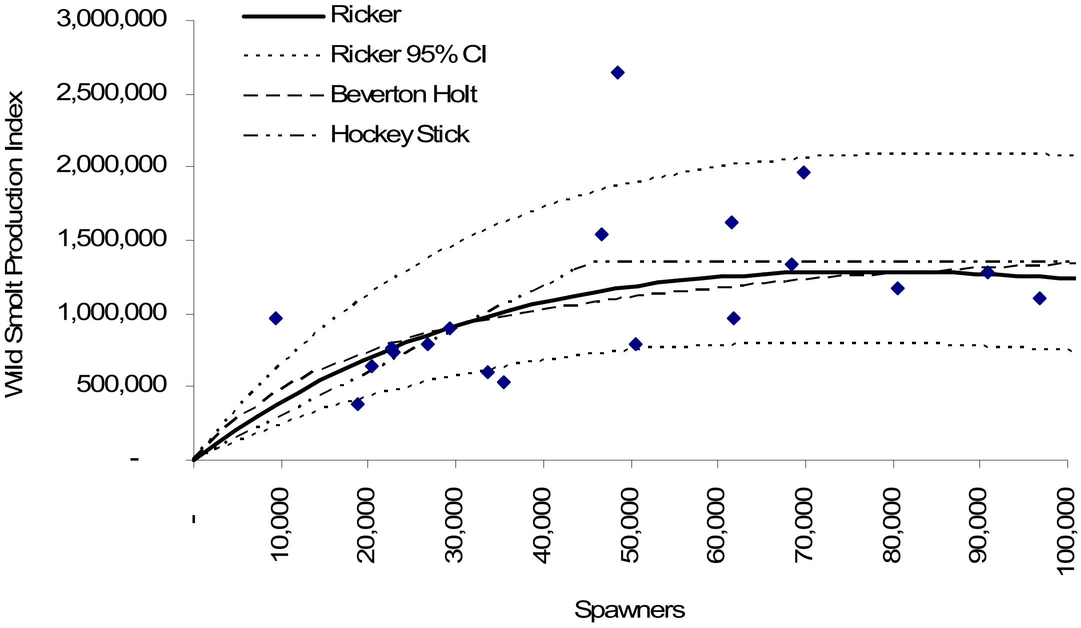


Figure 9: Ricker, Beverton-Holt, and Hockey Stick relationships between estimated wild smolt production and spawners for IFC. Dashed lines represent 95% confidence intervals for Ricker curve. Data are in Table 3.

4. What is the expected general time frame for recovery to the target?

Irvine (2002) assessed growth trajectories for North Thompson coho under three scenarios of marine survival: improved (similar to 1978-1997, R/S~3.3), average (similar to current and 1998-2000, R/S~1.5), and poor (R/S<1 as in 1998). This analysis assumed no additional habitat impacts and that fishing pressure would remain at current levels (~14%, see question 6A). Historical marine survival levels would theoretically return North Thompson coho to historical abundances within two generations. At average survival, it would likely be closer to 5-6 generations to return to higher abundance levels. At poor survival levels recruitment rates would be less than one and the population would fall toward extinction. Therefore, under current conditions of fishing and habitat impacts, the timeframe of recovery depends on marine survival.

The analysis by Irvine (2002) did not take into account variability in recruitment rates, but rather chose a fixed recruitment rate based on a relationship between marine survival and recruits per spawner. In addition, habitat loss may have reduced freshwater capacity. Routledge and Irvine (1999) found that small increases in recruitment rate variation can have a large impact on the probability of survival.

The recent (2002-2004) generational average escapement is 30,400. This is roughly half of several spawner escapement objectives presented in Table 4. The results presented in question 5 (Table 6) indicate that at current Exploitation Rate (ER) and marine survival there is less than 25% chance that spawner levels will reach one possible spawner objective of doubling (i.e. R≥2) by the end of three generations. It is assumed that longer recovery times will be necessary to assure higher chances of meeting target escapement levels. If marine survival improves beyond levels considered in this analysis, there would be a higher probability that the target escapement level could be reached in a shorter time frame. This variation has not been assessed.

As there is considerable uncertainty around future survivals, it is difficult to project with confidence the time frame for recovery. Also, what constitutes recovery has not yet been agreed upon. This issue is discussed further in question 5.

5. What is the maximum human-induced mortality which the species can sustain and not jeopardise survival or recovery of the species?

Exploitation rates that jeopardize *survival* can be defined as any level of sustained mortality that has a probability, *X*, of reducing the species to an escapement level less than the minimum benchmark of 23,000 wild spawners (three year geometric mean) (IFCRT, 2006). The rationale for this benchmark is to avoid potential negative impacts of small subpopulation sizes (<1000 wild spawners) on genetic diversity (Bradford & Wood, 2004). In requiring a 3 year mean wild escapement of 23,000 to the aggregate, it is estimated that at least half of the subpopulations within each of the five populations will have an escapement greater than 1000 (Bradford & Wood, 2004).

For the analyses presented in this report, we define exploitation rates that jeopardize *recovery* as any level of sustained mortality that has some probability, *X*, of leading to negative growth (growth rate <1) of the species.

Put in the context of allowable harm, a short term period (2 years forward) was assessed for the impacts of exploitation between starting and finishing mean escapement. An exploitation rate that reduces average escapement below the 23,000 minimal spawner objective is assumed to jeopardize survival of the species. While an exploitation rate that reduces final average escapement below the starting average is assumed to have resulted in a negative growth rate and thus jeopardized recovery of the species. To address longer term impacts, survival and recovery probabilities were also simulated over several generations (seed 3 years +9 years = 12 years total).

To assess maximum tolerable levels of human induced mortality we used a simple forward looking Monte Carlo stock-recruitment model. This model has a similar construct to one used for the Cultus Lake sockeye population viability analysis (Schubert et al. 2002, Cultus Sockeye Recovery Team, 2004). The model considers the limitations of freshwater capacity, as described in Question 3. Smolt production rates per spawner were fit to Ricker and Beverton-Holt models to consider density dependence and habitat limitations in the evaluation of rebuilding. Simulations were run separately, assuming Ricker and Beverton-Holt relationships. To consider uncertainty in the smolt recruitment relationship, residuals for the recruitment relationships were bootstrapped 250 times with replacement. Thus, 250 parameter sets of Ricker alpha, beta, sigma and Beverton-Holt a, b, sigma were included in the Monte Carlo simulations to capture uncertainty in the S-R data (Figure 10, Figure 11).

Simulations were performed with 1000 forward looking trajectories for each of the 250 stock-recruitment parameter sets, totaling 250,000 trajectories for each level of exploitation rate evaluated. Results are presented for the Ricker model and Beverton-Holt model separately.

The effect of marine survival on the unfished recruitment was assessed assuming: 1) that the recent short-term survival variation (1997-2001 brood years) is representative of the two-year permitting projection period and 2) the longer-term survival variation (1983-2001 brood years;

Table 3) is representative of the survival variation over the three-generation projection period. Marine survival is expected to have a log-normal probability distribution, thus typical values are best represented by the median, not the average. The median of the short term marine survival is 4.8%, and 6.8% for the long term series. Realistically the uncertainty in future survival rates increases with each additional year in the forward simulations given uncertain climate driven and random events. The historical Marine Survival (MS) time series is autocorrelated. The autocorrelation coefficient *r* of the marine survival rates for the 1983-2001 historical period equals 0.71 and therefore is moderately high. To simulate autocorrelative environmental effects on recruitment, an autoregressive random process (Walters and Parma, 1996) was used. The form was structured:

$m_t = m_1 e^{d_t}$, where m_t is the forecasted marine survival and

$d_t = r d_{t-1} + \omega_t$, where r is lag-1 autocorrelation =0.71

and ω_t is independent and normally distributed with mean 0 and variance equaling that of the marine survival series

However, when time=1, $\omega_1 = randnormal\left(0, \mathrm{SD} / \sqrt{\left(1 - r^2\right)}\right)$ footnote 1

[1] Personal communication, Carl Walters, University of British Columbia

An example of how well the autocorrelation of long term marine survival was simulated is rendered in the autocorrelation coefficient graph (Figure 13). The probabilities of falling below the specified escapement threshold were assessed at fixed levels of exploitation, in one percent intervals over a 0-40% range to estimate the surviving spawning escapement. For the short term trajectories, we assumed marine survival could behave in two possible ways: 1) Like Last Year (LLY, Simpson et al. 2004), or 2) random with mean and variance of recent five year marine survival. Autocorrelation was not considered in the short term trajectories. The forecasted *like-last-year* marine survival rate for 2005 returns from the 2003 brood is 4.3% with a logit transformed standard deviation of 0.477 (personal communication, Kent Simpson, Fisheries and Oceans Canada). Assuming the random seed approach, the median MS for the recent five years is 4.8%. The range of possible year one MS values, assuming LLY, is presented in Figure 12.

For the longer term (nine year) trajectories we assumed marine survival in two forms: 1) random with mean and variance of recent five year marine survival (to allow comparison with short term trajectories) and 2) random with mean and variance of full marine survival series. An autocorrelation coefficient of 0.71 was assumed in the long term simulations. The matrix of assumptions used in modeling marine survival are presented in Table 5.

All recruitment was set to occur at age 3 only. These assumptions are made with the knowledge that there are very few age 2 and 4 coho returns, which is consistent with other IFC analyses (e.g. exploitation analysis with the Fisheries Regulation Assessment Model (FRAM)).

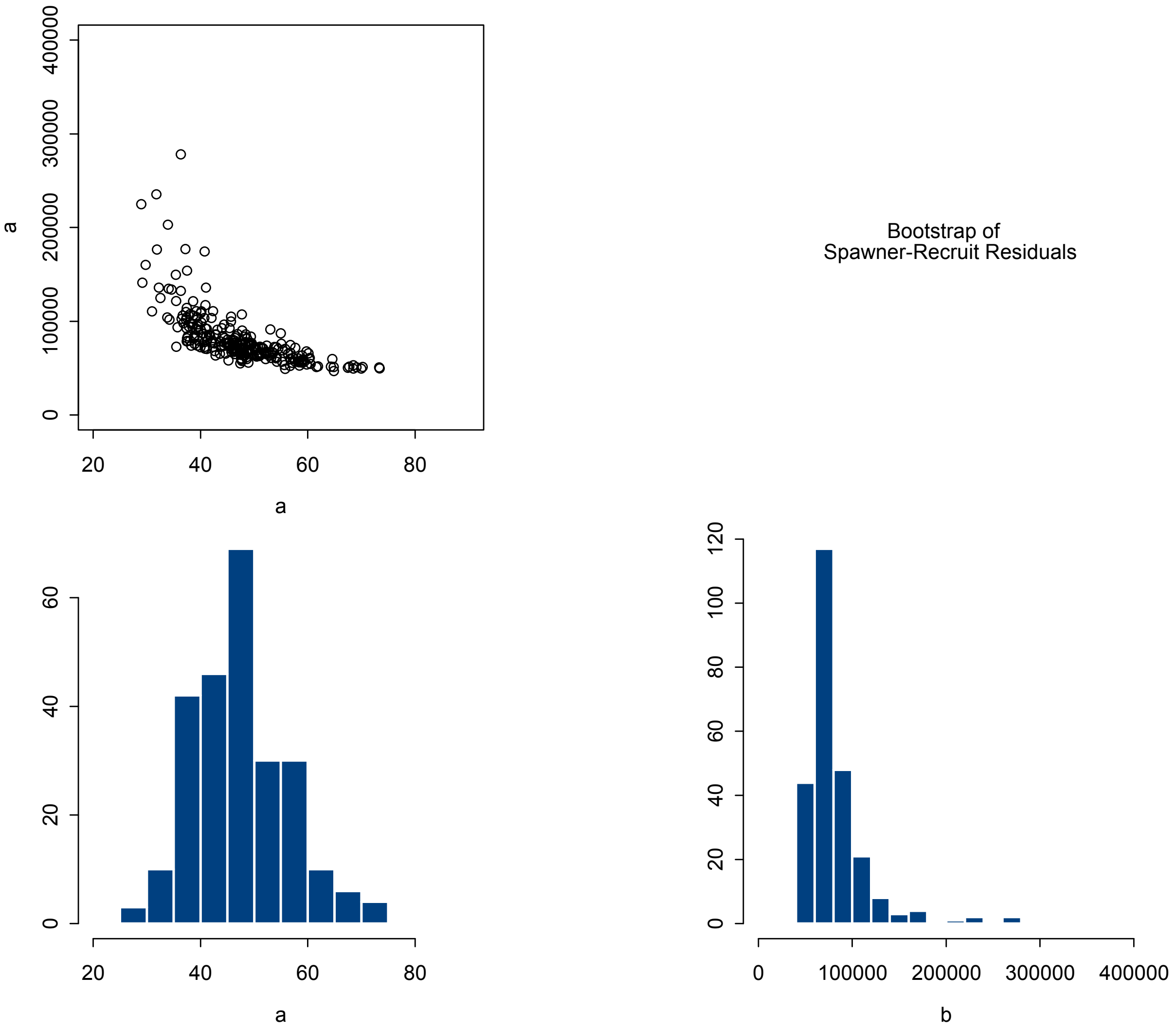


Figure 10: Bootstrap estimation of 250 Ricker alpha and beta parameters for smolt production per natural spawner in IFC.

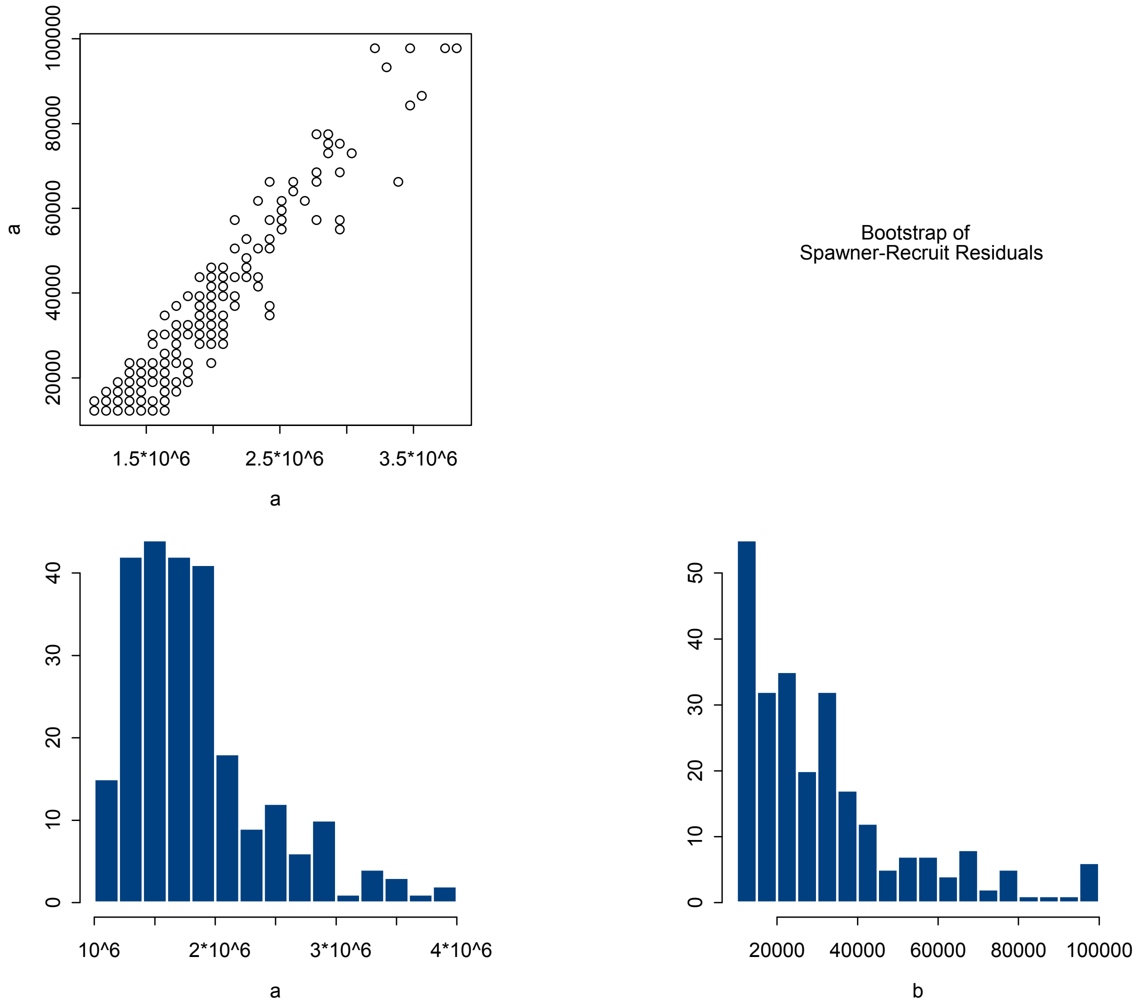


Figure 11: : Bootstrap estimation of 250 Beverton-Holt a and a parameters for smolt production per natural spawner in IFC.

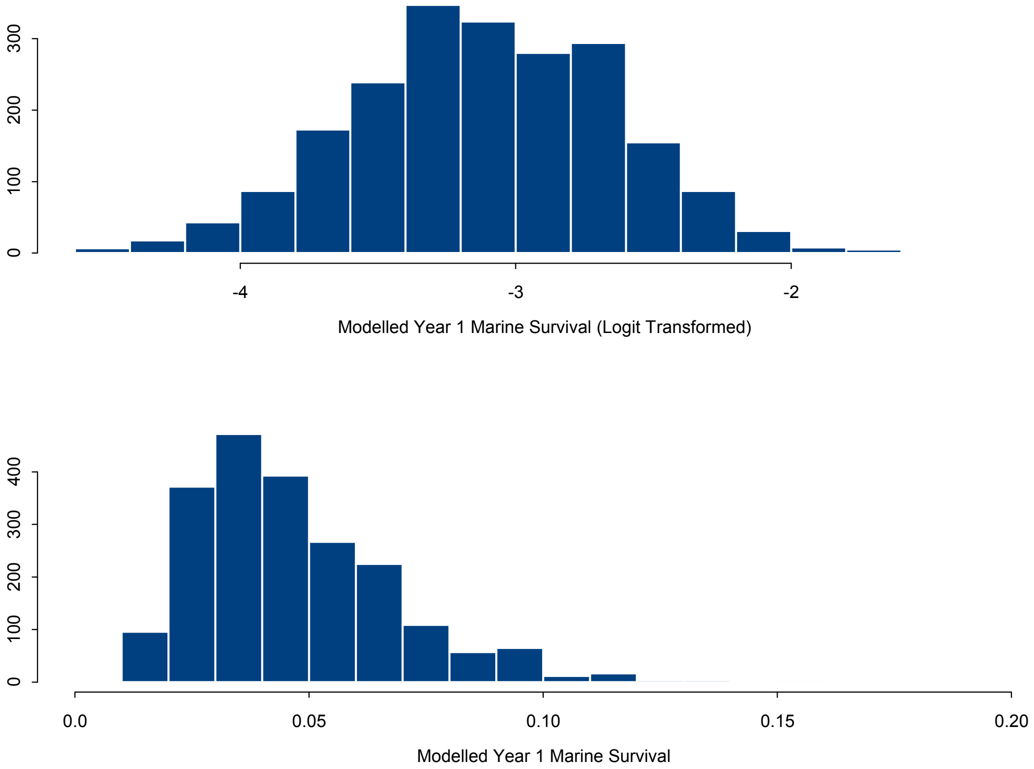


Figure 12: 2,100 values of simulated year 1 marine survival from LLY model.

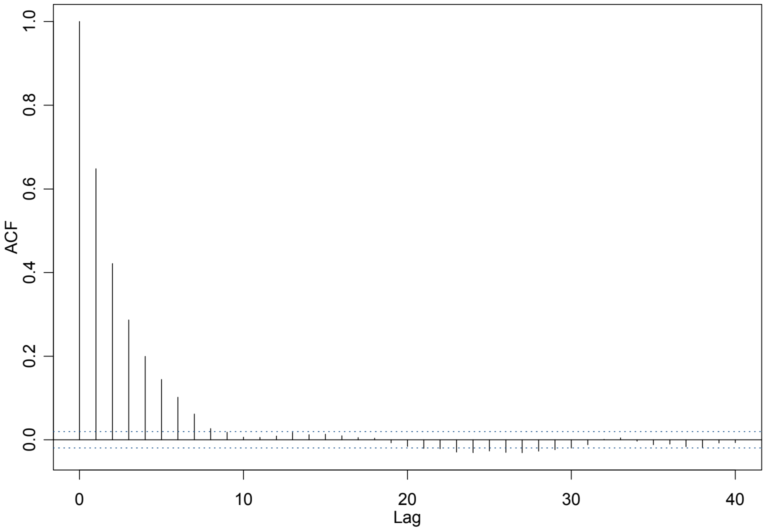
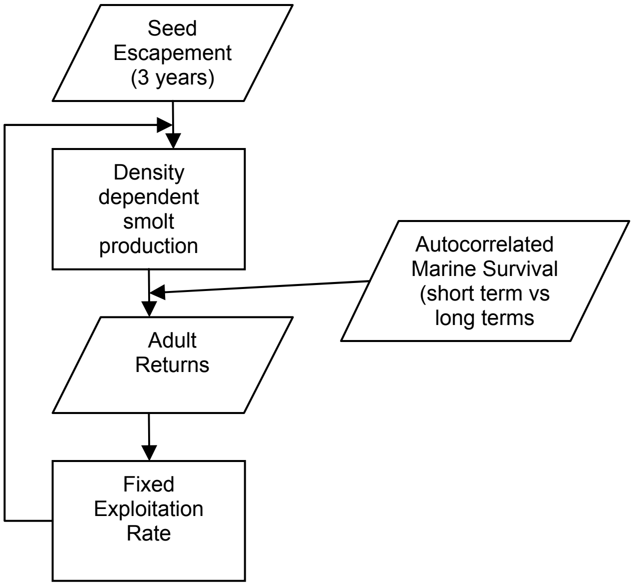


Figure 13: Autocorrelation coefficient for simulated marine survival data.

The model flow is as follows:

1. The model was seeded with individual escapements from 2002-2004.
2. Starting escapement generates a random normal estimate of smolt production from the Ricker model.
3. Returns by year is the product of smolt production and an autocorrelated marine survival
4. Escapement is the product: Returns × (1-Exploitaton Rate).
5. In the case of assessing jeopardy to growth, the three year geometric mean is calculated for the end of the period. If this amount is less than the initial escapement average or the trajectory falls below 23,000, growth was compromised.
6. Each growth trajectory, comprising of 3 years seed escapement and 2 years of forecasted returns, was iterated for 250,000 trials for each level of exploitation.



Two escapement thresholds were considered. The minimum escapement threshold to ensure survival of the DU (23,000 spawners) was described in Question 3 and used here to define jeopardizing survival. To assess jeopardy to recovery, the escapement threshold equates to the starting three year geometric mean (31,000 spawners). If the geometric mean escapement for the final three years of a simulated growth trajectory was less than 31,000 spawners, or spawners ever falls below 23,000, that trajectory had a growth rate <1. In addition, the probability of falling below initial mean escapement, at least once during trajectory, was also assessed for longer term simulations. This gives an indication if growth from current conditions is ever compromised, not just at the end of three generations.

Table 5: Matrix of conditions modelled and assumptions made regarding marine survival.

	Marine Survival Assumption	*Probability of survival (escapement not <23,000)*	*Probability of recovery (escapement not <31,000)*
Short Term	Seed using Like Last Year forecast No autocorrelation	3 seed escapement years + 2 year trajectory	3 seed escapement years + 2 year trajectory
Short Term	Seed randomly from distribution representing MS of recent five years No autocorrelation	3 seed escapement years + 2 year trajectory	3 seed escapement years + 2 year trajectory
Long Term	Seed randomly from distribution representing MS of recent five years Autocorrelation (r=0.7)	3 seed escapement years + 9 year trajectory	3 seed escapement years + 9 year trajectory
Long Term	Seed randomly from distribution representing MS of full time series Autocorrelation (r=0.7)	3 seed escapement years + 9 year trajectory	3 seed escapement years + 9 year trajectory

The probability of jeopardizing the species is calculated as follows:

$$P(\text{Jeopardizing Survival}) = \frac{\sum \text{Trajectories}_{\text{Escapement}<23{,}000}}{\sum \text{Trajectories}}$$

$$P(\text{Jeopardizing Growth}) = \frac{\sum \text{Trajectories}_{\text{Escapement}<23{,}000} + \sum \text{Trajectories}_{\text{Terminal Escapement}<30{,}400}}{\sum \text{Trajectories}}$$

RESULTS

The plots representing probability of survival and remaining above 31,000 spawners are combined in Figure 14 (Ricker model) and Figure 15 (Beverton-Holt model). The results were similar for both Ricker and Beverton-Holt. This makes sense based on the marginal differences found in the stock-recruitment fits between model types (Figure 9).

Survival probabilities

Figure 14 and Figure 15 include the probability of maintaining the species above the survival objective (wild escapement not less than 23,000) at fixed levels of exploitation. The short term plot (top left) shows probabilities assuming that MS in each year follows the either the *Like Last Year* model, or a random model. Assuming either form of MS, at current levels of exploitation (~13-14%) the probabilities of survival over the next two years remain above 85%, using either a Ricker or Beverton-Holt recruitment model.

The longer term probabilities of survival are presented in the lower left corner plots of Figure 14 and Figure 15. Assuming Ricker recruitment dynamics (Figure 14) with the assumption of long term (i.e. higher median) marine survival led to higher probabilities than recent (lower median) marine survival. Assuming a Beverton-Holt smolt recruitment model removes the highly density dependent response at high escapement levels. Looking to the bottom left plot in Figure 15 (Beverton-Holt), the assumption of MS represented by the full time series leads to higher survival probabilities than recent MS would suggest. Assuming a Beverton-Holt model, the longer term probability of survival ranges 55-75% at current exploitation rate levels. Considering the more conservative probabilities, if exploitation rates were to increase to 20%, the long term probabilities of survival drop to 50%, or a one in two chance of failing to achieve the survival objective. The short term probabilities of survival are higher, because the long term trajectories have more ‘opportunity’ to fail before the trial ends.

To reiterate, the results of these simulations suggests that the short term probability of IFC exceeding 23,000 spawners is high (≥85%) in the range of recent exploitation regimes (~13-14%) and varies little from unfished populations. In the longer term, the probability of remaining above the 23,000 threshold ranges from 57-72% at an exploitation rate of 13% and about 65-80% at zero exploitation. At the upper limit of assessed exploitation rate (40%) the long term probability of staying above 23,000 spawners ranges from 30-55%.

Recovery probabilities

Figure 14 and Figure 15 include the probability that mean escapements after three generations will be at or above initial mean escapement at fixed levels of exploitation. This is referred to as the *terminal probability* (after Akçakaya, 2002). At current exploitation rates, the short term probability of remaining above recent escapement levels ranges 62-79% for both the Ricker and Beverton-Holt relationships (Figure 14, Figure 15 top right plot). Thus, in the short term, there is better than a 1 in 2 chance that current exploitation levels may allow for growth beyond current levels. At the upper limit of simulated exploitation rate (40%), both short and longer term probabilities of maintaining growth drop below 50% (both the Ricker and Beverton-Holt relationships) or, reciprocally, there is a 1 out of 2 chance that 40% exploitation will lead to negative growth rates. Within the suggested two year time frame of an Allowable Harm Permit, if exploitation were increased to 20% there is 30-48% probability of having growth rates <1 (P(recovery)=0.52 for LLY & 0.70 for Recent MS, therefore 0.48=1.0-0.52). Considering the more conservative of the two marine survival assumptions (LLY), in the short term there is roughly a 1 in 2 chance that escapements will be less than the current average and growth will be compromised.

Interval Probabilities of Recovery

Figure 16 presents the longer term probabilities of trajectories never falling below the 31,000 benchmark at any time – not just at the end. This is referred to as the *interval probability* (after Akçakaya, 2002). Appreciably the populations go through cycles of high and low returns and that variation is not captured in the final escapement values. As a result, probabilities of dropping below the chosen benchmark, at any time, will be greater than that for final escapement. For the Ricker fit (Figure 16, top plot), assuming the full MS series, the interval probabilities are an average of 18% lower (absolute, not relative scale) than the terminal probabilities (cf, Figure 16, bottom right plot). This would suggest that based on recent escapement levels and exploitations rates, in the longer term, there is a 1 out of 2 chance (50% probability) that escapement will drop below current levels, but approximately a 68% probability that escapement will be comparable to current levels at the end of 3 generations. If we were to assume a more pessimistic marine survival (i.e. recent) and the exploitation rate were increased to 20%, there is a three out of four chance that escapement would drop below 31,000 (Figure 16, top plot) but a one in two chance that escapement after nine years will be greater than 31,000 (Figure 14, bottom right plot). Results are similar if we assume a Beverton-Holt relationship.

Thus, the probabilities to consider highly depend on the question being asked. If one is concerned with never falling below a benchmark, the interval probabilities need to be considered. If one is more concerned with long term goals, and not necessarily the population levels before the ‘period end’ then terminal probabilities should be considered. In cases of both survival and recovery, the terminal probabilities derived from the long term MS series could be overly optimistic by underestimating the number of times a trajectory might drop below the threshold. If it is true that this is an underestimate, the long term lines (square points) would drop down.

This modeling exercise was limited in terms of how it represents the dynamics of each of the 5 populations. Regarding assumptions, it does consider density dependence, habitat limitations, and both recent and long term survival. Uncertainty in the smolt recruitment relationship and marine survival is included. There is no demographic uncertainty, nor age structure, nor random catastrophic events considered. We do not have adequate data to consider freshwater capacity and productivity separately for the Fraser Canyon, Lower Thompson, and Upper Fraser populations. Thus all populations are assumed to have similar recruitment dynamics as North and South Thompson. Therefore we are limited to consider implications to the DU as a whole and not specifically each population, but this may be acceptable since COSEWIC designated the entire DU as endangered, rather than individual populations. Results are not intended to prejudice discussions about local (First Nations) or other fisheries.

Table 6: Effect of exploitation rate on probability of survival and recovery assuming a Ricker stock-recruitment relationship. The marine survival assumed in the short and is *Like Last Year* while that for the longer term is *Recent average* (see text for details). The shaded rows indicate the present fishery breakpoints by exploitation rate (see footnotes).

A. Short term (2-year) projection

Exploitation Rate (ER)	*Probability of survival (remaining above 23,000 spawners)*	*Absolute change in the probability of survival from status quo ER (13%)*	*Probability of recovery (growth beyond recent 3-year mean escapement) based on the ratio R of terminal series:initial escapement*				
			R≤0.5	*0.5< R ≤1.0*	*1.0< R ≤1.5*	*1.5< R ≤2.0*	*R >2.0*
0%	95%	4.00%	4%	36%	15%	12%	33%
10%[a]	92%	1.00%	5%	42%	15%	12%	27%
11%[b]	92%	1.00%	5%	43%	14%	11%	27%
12%	91%	0.00%	5%	43%	14%	11%	27%
13%[c]	91%	0.00%	5%	43%	14%	11%	26%
14%	90%	-1.00%	5%	44%	14%	11%	25%
15%	90%	-1.00%	5%	45%	14%	11%	24%
25%[d]	92%	1.00%	7%	52%	13%	9%	19%

B. Long-term (3-generation) projection

Exploitation Rate (ER)	*Probability of survival (remaining above 23,000 spawners)*	*Absolute change in the probability of survival from recent ER (13%)*	*Probability of recovery (growth beyond recent 3-year mean escapement) based on the ratio R of terminal series: initial escapement*				
			R≤0.5	*0.5< R ≤1.0*	*1.0< R ≤1.5*	*1.5< R ≤2.0*	*R >2.0*
0%	68%	9%	2%	45%	13%	10%	30%
10%[a]	61%	2%	3%	51%	12%	10%	25%
11%[b]	60%	1%	3%	51%	13%	10%	24%
12%	60%	1%	3%	52%	12%	10%	24%
13%[c]	59%	0%	2%	52%	12%	10%	23%
14%	58%	-1%	2%	53%	12%	10%	22%
15%[c]	57%	-2%	3%	53%	12%	10%	22%
25%[d]	49%	-10%	3%	61%	11%	8%	18%

a: US fishing only
b: no Canadian sport
c: status quo
d: next step in PST Annex Agreement

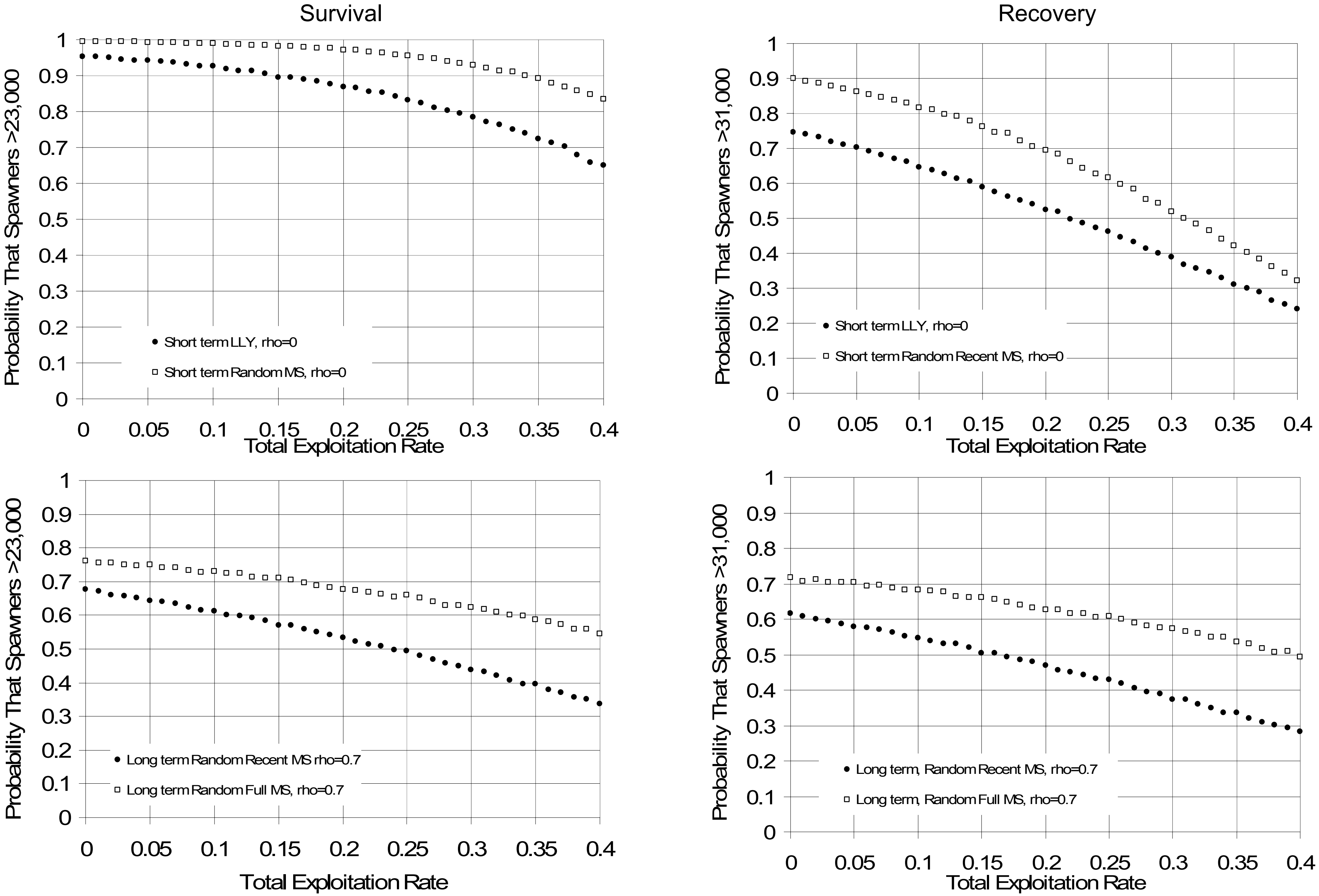


Figure 14: **Terminal probability of maintaining IFC above survival (23,000 spawners) and recovery (31,000) escapement thresholds, assuming a bias uncorrected Ricker smolt recruitment model. The top row represents short term (2 year) probabilities, the bottom row long term (9 years). The left column are probabilities of maintaining survival, the right column of maintaining escapement over 30,400 spawners. Model choice is described in the text.**

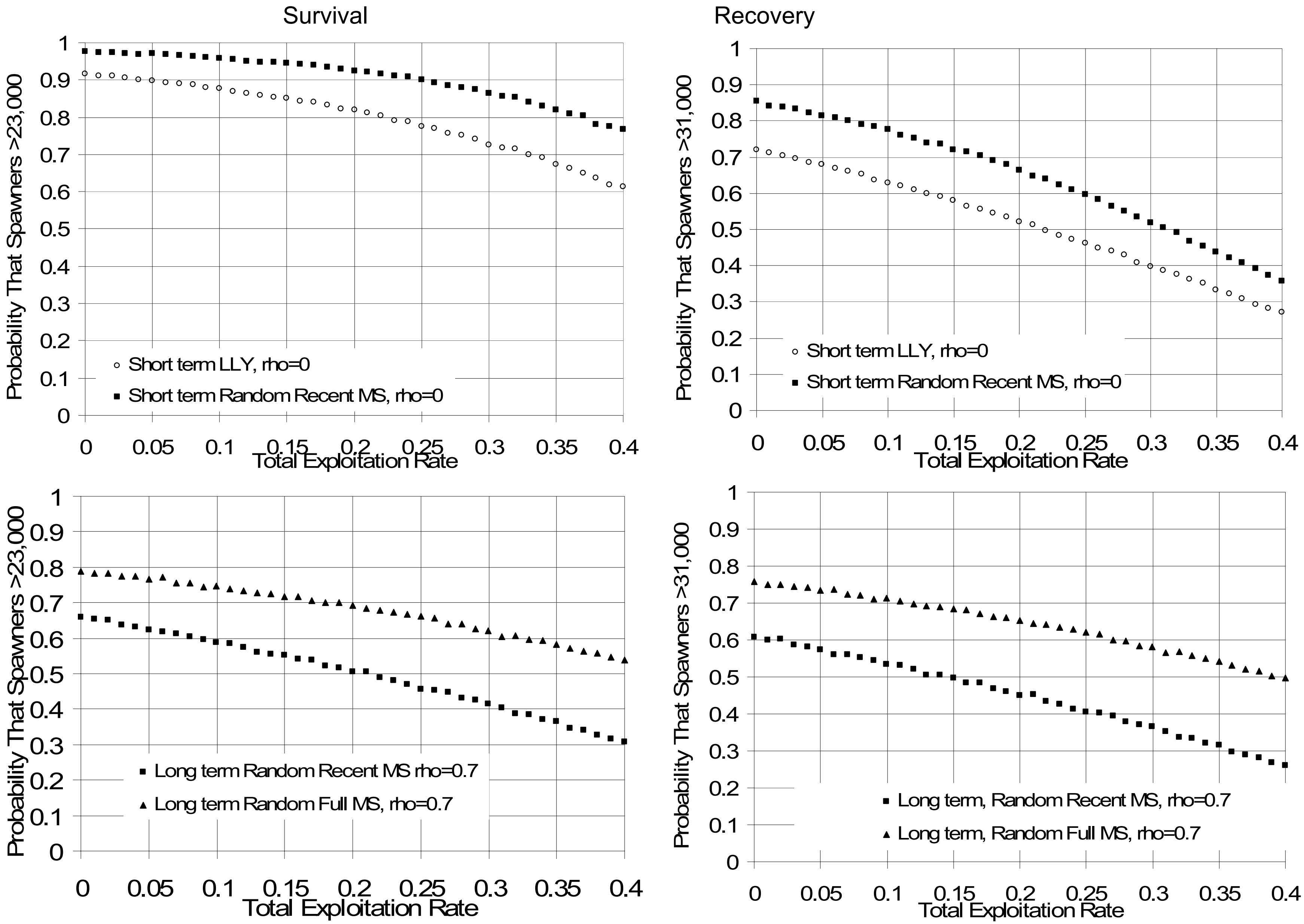


Figure 15 Terminal probability of maintaining IFC above survival (23,000 spawners) and recovery (31,000) escapement thresholds, assuming a Beverton-Holt smolt recruitment model. The top row represents short term (2 year) probabilities, the bottom row long term (9 years). The left column are probabilities of maintaining survival, the right column of maintaining escapement over 30,400 spawners. Model choice is described in the text.

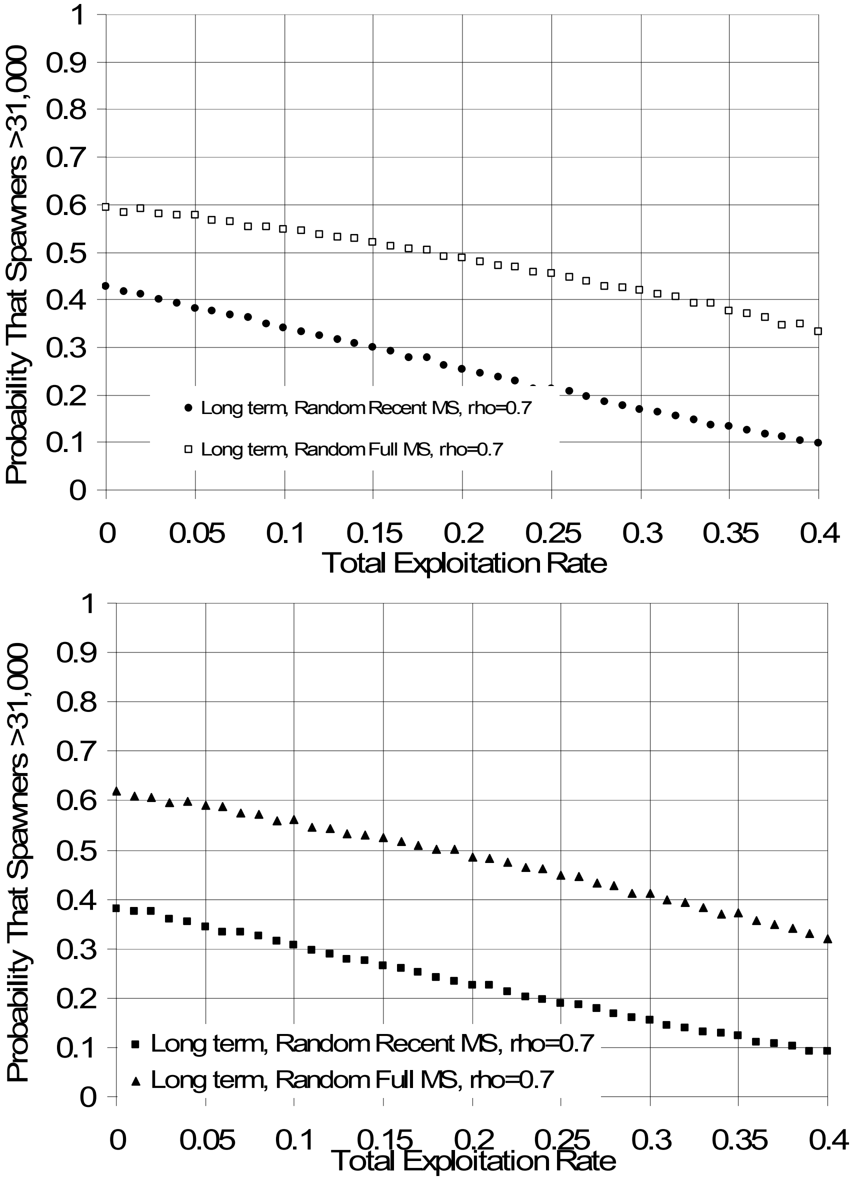


Figure 16: Interval probability of maintaining IFC above recent average escapement (31,000 spawners), for the longer time frame (9 years). The top plot assumes a Ricker smolt recruitment model, the bottom plot a Beverton-Holt model. Model choice is described in the text.

6. What are the major potential sources of mortality/harm?
6a. More specifically: Should consider, *inter alia,* and give reasons for dismissing (when appropriate) each of:

Directed fishing (with or without a quota) for a listed species—International as well as domestic fisheries

The only directed fisheries are undertaken in terminal areas by local First Nations on systems that have counting fences. Directed harvest is undertaken once the escapement reaches a specific threshold. The directed harvest is undertaken in a stepped approach (1 fish out of 10 returning fish is harvested at lower run sizes; up to 3 or 4 fish out of 10 at higher run sizes (personal communication, Elmer Fast, Fisheries & Oceans Canada). First Nation fishers undertaking directed harvests of IFC will require a permit pursuant to Section 73 of SARA if IFC are legally listed.

Bycatch in fisheries directed at other species

Except for the special circumstances noted above, there are no directed fisheries for IFC. Recent Canadian mixed stock fisheries have been managed to limit the exploitation rate of IFC to 3% or less (U.S. exploitations are ~10%). Annual assessment of fisheries undertaken in the past few years suggests that mixed stock fishery impacts have remained below 3% (personal communication, Wilf Luedke, Fisheries & Oceans Canada). Estimated impacts on these stocks from 2004 fisheries have been assessed (Draft estimated impacts on IFC stocks from the proposed 2004 Southern B.C. salmon fishing plan – unpublished Diana Dobson report – July 06, 2004). IFC are harvested as a by-catch in First Nation and recreational fisheries in southern BC targeted on sockeye and pink salmon stocks. IFC are encountered as bycatch in a broad variety of commercial fisheries in southern BC. These include troll fisheries off the West Coast of Vancouver Island, and in Johnstone Strait/Gulf of Georgia in fisheries for chinook and sockeye, gillnet fisheries in Johnstone Strait, Gulf of Georgia and Fraser River for sockeye and pink salmon and seine fisheries for sockeye and pink salmon in the Straits of Juan de Fuca and Johnstone Strait. Fishers engaged in fisheries that harvest IFC on an incidental or bycatch basis will require a permit pursuant to Section 73 of SARA.

Detrimental impacts on habitats by fishing activities

In the marine areas, salmon fishing is undertaken by net fisheries (gillnet and seine) or by trolling gear. In freshwater areas, First Nations food, social and ceremonial fishing is done by gillnetting, dipnetting or hook and line while recreational fishing is done by hook and line. None of these gear types are associated with detrimental impacts on the habitat.

Direct mortality by permitted habitat alterations (for example smolts killed in power turbines; oil & gas exploration, blasting)

Direct mortalities of coho fry and smolts have been observed through licensed water withdrawals for agricultural and domestic use. This mortality can occur directly as a result of stranding in side channels with very low volumes of water or as a result of ingestion by water extraction pumps with inadequate screening provisions (personal communication, Dean Watts, Fisheries & Oceans Canada). Indirect mortality can occur as a result of forced out-migration into less favourable environments. Licence conditions however, provide for proper screening to minimize this level of mortality and the level of mortality caused by this source is generally thought to be low. However, direct and indirect mortality associated with water extraction can be exacerbated in years of drought.

Detrimental alteration of habitats by permitted activities (for example loss of lacustrine or riverine productive capacity due to water draw-downs; gear impacts, all the "foreign materials, forces, and noises")

Agricultural activities including irrigation (water draw downs resulting in increased water temperatures), increased siltation as a result of cropping, loss of riparian vegetation through grazing are all thought to have a detrimental impact on rearing coho. Increased efforts in recent years have focused on working with the Province of B.C. and the agricultural community to reduce negative impacts associated with these activities by undertaking fencing projects and re-vegetating prime rearing areas and ensuring adequate leave strips (personal communication, Michael Flynn, Fisheries & Oceans Canada). However, these initiatives have the potential to be compromised by ongoing efforts by the province and the agricultural industry to reduce existing protective measures (personal communication, Michael Crowe, Fisheries & Oceans Canada).

Road building to support resource and urban development can have a detrimental impact on coho rearing habitat. Undersized and poorly cast culverts are responsible for restricting or eliminating passage and migration. Inadequate riparian protection on class S4-6 streams can result in negative impacts on stream reaches. The impacts of this threat can be minimized by ensuring proper leave strips, proper culvert and bridge placement and undertaking any in-stream work during the appropriate timing windows when impacts to rearing coho can be minimized (personal communication, Michael Flynn, Fisheries & Oceans Canada). Bradford and Irvine (2000) found that rates of decline were correlated with three freshwater habitat use indices (agricultural land use, road density, and a qualitative stream habitat index).

It is difficult to deal with point impacts on population aggregates like IFC. Until additional work has been conducted to assess the effects of water abstraction and other activities in freshwater, little specific guidance can be provided to habitat managers. Currently it would appear that effects in freshwater do not appear to affect the viability of IFC while they are in the amber zone. However, freshwater effects may limit the growth potential of the DU and thereby restrict its ability to recover to the green zone (Figure 8). Freshwater effects should be taken into effect in determining the total allowable harm.

Ecotourism & recreation

Ecotourism and recreation is not a significant threat to this population.

Shipping & transport & noise

Shipping, transport and noise is not a significant threat to this population

Fisheries on food supplies

Fisheries are held on some of the food sources for coho salmon. Herring fisheries in particular harvest a small portion of the standing biomass and not in quantities that would impact on the viability of coho populations.

Aquaculture; introductions & transfers

Aquaculture from fish farming activity is not thought to have a detrimental impact on IFC. However coho enhancement activities that take place both in the Interior Fraser as well as other areas in Southern BC and in the State of Washington may pose threats (IFCRT 2006).

Coho enhancement is currently being undertaken in the Interior Fraser for 3 main reasons. These include conservation enhancement of demes at low levels (3 streams), assessment enhancement where releases of marked fish provide information for assessment of exploitation and survival (4 streams) and spawning supplementation enhancement (1 stream that is being phased out).

The sources of uncertainty regarding hatchery impacts are as follows:

- Hatchery fish can create competition with wild fish when resources are limited in the marine or freshwater environment.
- Interbreeding between hatchery and wild fish may have genetic impacts on wild demes.
- Abundance of hatchery fish in a mixed stock fishery may encourage excessive fishing which may negatively affect wild populations.

The relative impact of each of these factors is unknown.

Scientific research

Scientific research takes the form of test fisheries for other species (1 or 2 gillnets in Juan de Fuca for sockeye; 1 gillnet in the Fraser River for chinook and chum salmon). Although coho are to be released, there are a limited number of mortalities as a result of the fish becoming gilled in the net. Seal predation on coho is thought to be high in some test fisheries. The number of mortalities are tracked and considered in managing fisheries within the 3% mortality ceiling (personal communication, Wilf Luedke, Fisheries & Oceans Canada).

Other scientific permits are issued with the condition of coho release. Accordingly scientific research is believed to have an insignificant impact on IFC (personal communication, Mervyn Mochizuki, Fisheries & Oceans Canada).

Military activities

There are no known military activities that impact on this stock.

International

Washington State fisheries occurring in Juan de Fuca Strait encounter IFC. U.S. assessments of mortalities associated with incidental catch in American fisheries suggest a mortality rate in the range of 7 - 10%. (personal communication, Wilf Luedke, Fisheries & Oceans Canada). This level of mortality is within the maximum range that is permitted under the Coho Annex to the Pacific Salmon Treaty.

6b. Do Canadian activities alone impact the species? For transboundary species that migrate in and out of Canadian waters, list all International activities that may impact the species.

See “International” above.

7. For those mortality/harm attributable to all human causes and contrast with that determined in Question #5.

Following is a summary of the potential impact and an estimate of the level of impact.

Name of Impact	Description	Level
Directed fishing	- fishing by First Nations in selected terminal systems	~0.3%
By-catch mortality	- fishing by First Nations, recreational and commercial fisheries in approach areas	3.0%
Detrimental impact of permitted habitat activities	- irrigation, road development to support resource development, urban development	Impact assessments very limited. Estimates of impact for specific areas available in Canadian Journal of Fisheries & Aquatic Sciences publication entitled *' Land Use, fishing, climate change, and the decline of Thompson River, B.C. coho salmon* – Mike Bradford / James Irvine (2000)
Scientific Research	- test fishing	0.5%
International	- by catch in fisheries	10.0%

REASONABLE ALTERNATIVES

It was determined there were no reasonable alternatives for each of the impacts considered.

Directed fishing – No alternatives were considered. Given the nature of this impact (only on streams where escapements met pre-determined objectives) and the nature of the government's fiduciary responsibility to First Nations, it is unreasonable to consider prohibiting this type of impact.

Bycatch mortality – No US alternatives were considered. Generally speaking, the stock appears to be recovering and the Canadian bycatch mortality rate is at a low level (<3%). Following is a table showing the various sources of bycatch mortalities (Estimated impacts on IFC stocks from proposed 2004 southern B.C. fishing plan – July 06, 2004 draft – Diana Dobson)

Fishery	**Maximum exploitation rate**
Recreational	**1.5**
Commercial	**0.8**
Test Fisheries	**0.2**
Aboriginal	**0.5**
International	**7-10**
Total	**10-13%**

Detrimental impact of permitted habitat activities

No alternatives to permitted habitat activities were considered.

Scientific Research

Because of the need to undertake scientific research activities that will ultimately improve the information base about this population, no alternatives to scientific research were considered.

International

No alternatives to the impact caused by fishing in the United States were considered. This would necessitate opening Treaty negotiations with the possibility of Canadian concessions.

FEASIBLE MEASURES TO MINIMIZE EACH OF THE IMPACTS:

Directed Fishing

Measures to minimize impact that were considered included increasing the threshold on each individual system where First Nation FSC harvest presently occurs, before a harvest opportunity would be authorized. Reducing the rate of harvest on abundance levels in excess of the minimum threshold was also considered.

It is thought these measures would have only minimal benefit as the existing FSC harvest guidelines provide a good spawning population base that could react in a very positive manner as ocean survival conditions improve.

The benefit of implementing these measures is that more spawners would be available to the population. The cost could range from increasing First Nations frustration to loss of working relationships with local First Nations and litigation. Increased levels of unaccounted harvest would also be expected to occur as a result in illegal harvest.

Bycatch Mortality:

Measures to minimize impact that were considered included closing some or all sources of bycatch mortality (detailed above).

It is thought these measures would not be effective in materially increasing the size of the spawning population because bycatch mortality levels are already very low. The benefit would be an increase in the spawning population of a few hundred fish however the cost would be significant as a result of lost fishing opportunity for First Nations, recreational and commercial fisheries on more abundant stocks, and an inability to undertake test fisheries to determine in-season abundance of other species.

Detrimental impact of permitted habitat activities:

Within the jurisdiction where IFC spawn and rear, permits are issued by the Province of British Columbia where DFO has an advisory role in the decision making process. Measures to minimize impact that were considered included the cessation of issuing permits in areas that could impact on coho spawning and rearing habitat. This would include road building and bridge construction in sensitive areas, logging near sensitive areas and water removals from coho habitat. However, it is felt that while complete cessation of these activities is not feasible, cooperative proactive actions with the Province of B.C. will be taken to develop effective provincial protection standards regarding forestry, water management, and riparian protection. The Recovery Strategy outlines further studies that are required to determine feasible actions and costs and benefits of these options (IFCRT 2006 and personal communication, Richard Bailey, Fisheries & Oceans Canada).

Three areas were recommended by the IFCRT (2006) as proposed critical habitat. These areas are:

- That portion of the Nahatlatch River above the lakes. Without this section of the Nahatlatch River, the Fraser Canyon population would lose in excess of 90% of its spawning habitat,
- The Fraser Canyon in the vicinity of the Hells Gate fishways, and
- The North Thompson River in the vicinity of Little Hell's Gate.

The potential implications of designating these areas as critical habitat have not been assessed.

Scientific Research

All scientific research activities were reviewed in 1998; test fisheries were modified to minimize impact to IFC stocks. As well, other permits that were issued to undertake studies that impacted, both directly and indirectly on IFC were reviewed and modified to reduce impacts. It is felt that the impacts from Scientific Research activities have already been minimized and there are no further steps that can be taken.

International

No feasible measures to reduce the impact of International fisheries on IFC were considered. The impact is limited by terms set out in the Coho Annex to the Pacific Salmon Treaty that considers stocks at low levels. It is not possible to quantify the potential benefits and costs of renegotiating the Annex to further reduce the impact.

Discussion

In this paper we developed a simulation model to project the possible range of annual adult recruitment for IFC, both in a two year and multi generation time frame. The model assumed future survivals would be similar to historical estimates, and that the productivity and capacity of IFC would not significantly change in the near future. Recruitment of IFC is highly sensitive to marine survival. Small improvements in marine survival could increase recruitment rates such that longer term probabilities of survival and recovery would differ greatly from values presented in this report. We did not assess the sensitivity of results to shifts in marine survival.

This report presents probabilities of survival and recovery under varying levels of exploitation. However, we did evaluate what might be considered “acceptable probabilities”. Probability tables do not indicate what impacts may be tolerable. If fisheries expand, and survival probabilities drop; would this be acceptable? This is not strictly a scientific question. Acceptable probabilities should be a function of goal importance, which can be represented by intrinsic biological and genetic values, as well as socio-economic values. For example, there might be a desire for a high probability of persistence – a short term requirement; but tolerance for some lower probability of recovery – a longer term goal. A proponent of this approach could argue that future mitigating measures might allow for reassessment of recovery. Choices are also likely driven by the values assessed in socio-economic analyses. However, it is difficult to compare two dissimilar measures (economics vs. intrinsic biological and genetic value). GSGislason (2005) assessed the socio-economic implications of legally listing IFC by using Multiple Account Evaluation. This approach identifies costs, benefits, and items having a value other than economic. However the process does not manage to quantify all values. This re-enforces the argument that identifying acceptable probability levels is difficult, and likely to vary depending on the objective (e.g. short term persistence (survival) vs. long term rebuilding (recovery)) and the relative value of objectives to other priorities (e.g. social and economic benefits and costs to society).

Assessing probabilities of survival and recovery implies these are important goals. In all likelihood the desire to achieve these goals is greater than not. If that is the case, in quantitative terms a probability for any goal must be at least 50%. At this level there is equal chance for success or failure, which is not likely acceptable when dealing with possible extirpations. A recent example of attributing a probability to a goal in salmon management occurred during the 2004 preseason planning process for Fraser sockeye fisheries. Fisheries management set an exploitation rate ceiling of 10-12% on the Cultus and Sakinaw sockeye populations with a 65% probability of remaining below that ceiling.

The choice for a higher probability of success might also be driven by returns on additional cost. If returns on investments are diminishing (i.e. additional habitat improvement or fishery reduction do not proportionally improve survival/recovery probabilities), then there could be a definable “maximum practicable probability”. In addition to achieving survival/recovery, there are various potential benefits that are assumed to be taken into consideration (e.g. fisheries on rebuilt stocks, non-consumptive benefits - including ecosystem benefits) in computing net cost. The concept is presented in the following figure although we recognize that this type of relationship may be difficult to assess.

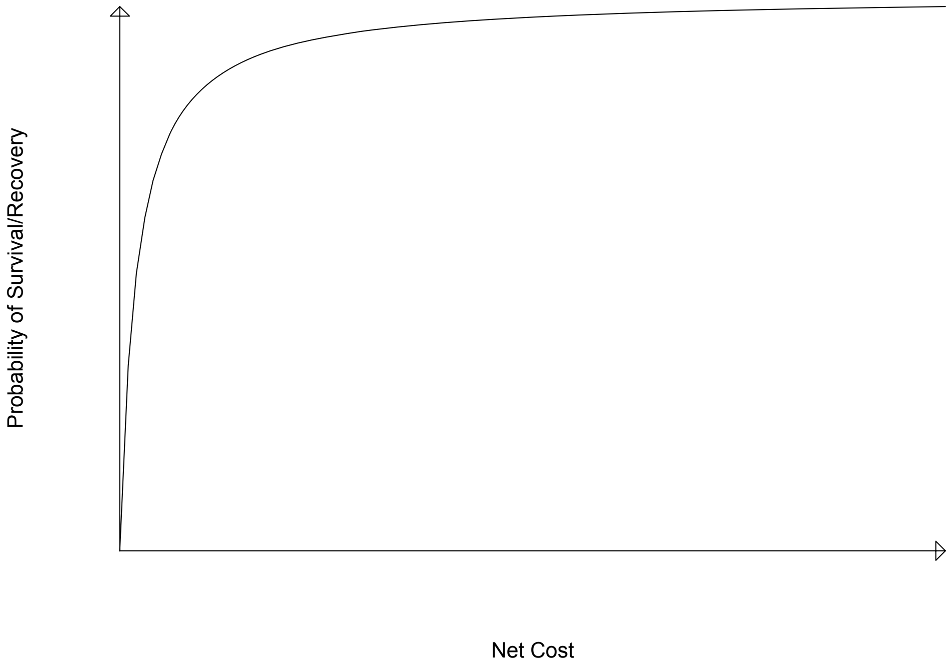


Figure 17: A hypothetical relationship between net expenditures and the probability of recovery/survival of a species at risk.

A 50% probability, when considering the survival or recovery of a species (e.g. IFC), is only appropriate if the decision maker wishes to be risk neutral. If there is a desire to be risk averse, some probability level greater than 50%, but less than 100% would be chosen. For instance, a starting point of 75% could be chosen, given that it is half way between 50% and the maximum achievable level of 100%. At a 75% probability level, success is three times more likely than failure. For the decision making process to be as objective as possible, fisheries managers should establish, *a priori*, acceptable probabilities for significant outcomes.

This document represents the first attempt at an Allowable Harm Assessment for a Pacific salmon species. The questions asked within the AHA and our approaches to answer them could be refined. Choices of acceptable probabilities will evolve as our knowledge of the system improves or priorities shift. For IFC, certainty in results is hampered by the sensitivity of adult recruitment to small changes in marine survival. Our ability to provide specific guidance on the level of harm that IFC can withstand without jeopardizing their survival and recovery is hampered by our inability to accurately forecast marine survival. Unfortunately, our ability to significantly improve marine survival forecasts is unlikely given salmons' highly dynamic nature, and likely overshadowed by fisheries management implementation error

(Peterman et al. 2000). This suggests fisheries managers should continue to be precautionary when considering future fishery options.

Finally, half of this assessment focused on a two year time frame. In order to track progress towards recovery of this species, we suggest this allowable harm assessment be repeated. Several additional years of escapement data would allow for new projections of survival and recovery probabilities. Reassessment and comparison of a species probability of improvement/decline over time may be a more robust indicator of status than traditional abundance-based methods (Staples et al. 2005).

Literature Cited

Akçakaya, H.R. 2002. RAMAS GIS: Linking spatial data with population viability analysis (ver 4). Applied Biomathematics, Setauket, New York.

Amiro, P. G. 2004. Review of Allowable Harm Permits for inner Bay of Fundy Atlantic salmon. Canadian Stock Assessment Secretariat Research Document 2004/095. Available from CSAS, 200 Kent St., Ontario, K1A 0E6, Canada, or www.dfo-mpo.gc.ca/csas.

Bradford, M. J. and J. R. Irvine. 2000. Land use, fishing, climate change and the decline of Thompson River, British Columbia, coho salmon. Canadian Journal of Fisheries and Aquatic Sciences 57:13-16.

Bradford, M J., R. Myers, and J R Irvine. 2000. Reference points for coho salmon (*Oncorhynchus kisutch*) harvest rates and escapement goals based on freshwater production. Can. J. Fish. Aquat. Sci. 57:677-686.

Bradford, M., and C. Wood. 2004. A review of biological principles and methods involved in setting minimum population sizes and recovery objectives for the September 2004 drafts of the Cultus and Sakinaw Lake sockeye salmon and Interior Fraser coho salmon recovery plans. DFO Can. Sci. Advis. Sec. Res. Doc. 2004/128. Available from CSAS, 200 Kent St., Ontario, K1A 0E6, Canada, or www.dfo-mpo.gc.ca/csas.

Chen, D. G., J. R. Irvine, and A. Cass. 2002. Incorporating Allee effects in fish stock-recruitment models and applications for determining reference points. Can. J. Fish. Aquat. Sci. 59: 242-249.

COSEWIC 2002. COSEWIC assessment and status report on the coho salmon *Oncorhynchus kisutch* (Interior Fraser population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-34 pp.

DFO (Fisheries and Oceans Canada). 2005. Canada's policy for conservation of wild Pacific salmon. Available at: http://www-comm.pac.dfo-mpo.gc.ca/publications/wsp/default_e.htm

GSGislason & Associates Ltd. 2005. Socio-economic implications of SARA: Interior Fraser coho and bocaccio. Prepared for Canadian Department of Fisheries and Oceans. Available at: http://www.dfo-mpo.gc.ca/Library/314597.pdf

Interior Fraser Coho Recovery Team. 2006. Species at risk proposed recovery strategy: coho salmon (interior Fraser River populations), *Oncorhynchus kisutch*. Fisheries and Oceans Canada.

Irvine, J. R., K. Wilson, B. Rosenberger, and R. Cook. 1999a. Stock assessment of Thompson River/Upper Fraser River coho salmon. Canadian Stock Assessment Secretariat Research Document 99/28. Available from CSAS, 200 Kent St., Ontario, K1A 0E6, Canada, or www.dfo-mpo.gc.ca/csas

Irvine, J. R., R. E. Bailey, M. J. Bradford, R. K. Kadowaki, and W. S. Shaw. 1999b. 1999 Assessment of Thompson River/Upper Fraser River Coho Salmon. Canadian Stock Assessment Secretariat Research Document 99/128. Available from CSAS, 200 Kent St., Ontario, K1A 0E6, Canada, or www.dfo-mpo.gc.ca/csas

Irvine, J. R., C. K. Parken, D. G. Chen, J. Candy, T. Ming, J. Supernault, W. Shaw, and R. E. Bailey. 2001. 2001 assessment of stock status for coho salmon from the interior Fraser River. Canadian Stock Assessment Secretariat Research Document 2001/083. Available from CSAS, 200 Kent St., Ontario, K1A 0E6, Canada or http://www.dfo-mpo.gc.ca/csas/.

Irvine, J. R., R. E. Withler, M. J. Bradford, R. E. Bailey, S. Lehmann, K. Wilson, J. Candy, and W. Shaw. 2000. Stock status and genetics of interior Fraser coho salmon. Can. Stock Assess. Secretariat Res. Doc. 2000/125. Available from CSAS, 200 Kent St., Ontario, K1A 0E6, Canada or http://www.dfo-mpo.gc.ca/csas/

Irvine, J.R. 2002. COSWIC status report on the coho salmon *Oncorhynchus kisutch* (Interior Fraser population) in Canada, in COSEWIC assessment and status report on the coho salmon *Oncorhynchus kisutch* (Interior Fraser population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. 1-34pp.

Irvine, James R., Mart R. Gross, Chris C. Wood, L. Blair Holtby, Neil D. Schubert, Peter G. Amiro. 2005. Canada's Species At Risk Act: An opportunity to protect "Endangered" salmon. Fisheries. 30(12):11-19.

Peterman, Randall M, Brian J. Pyper, Jeff A. Grout, 2000. Comparison of parameter estimation methods for detecting climate-induced changes in productivity of Pacific Salmon (*Oncorhynchus spp.*). Can. J. Fish. Aquat. Sci. 57: 181-191.

Routledge, R. D., and J. R. Irvine. 1999. Chance fluctuations and the survival of small salmon stocks. Can. J. Fish. Aquat. Sci. 56: 1512-1519.

Schubert, N.D., Beacham, T. D., Cass, A.J., Cone, T.E., Fanos, B.P., Foy, M., Gable, J.H., Grout, J.A., Hume, J.M.B., Johnson, M., Morton, K.F., Shortreed, K.S., and Staley, M.J. 2002. Status of Cultus Lake sockeye salmon (*Oncorhynchus nerka*). Canadian Science Advisory Secretariat Research Document 2002/064: 109 p.

Simpson, Kent, M. Chamberlain, J. Fagan, R. Tanasichuk, D. Dobson. 2004. Forecast for southern and central British Columbia coho salmon in 2004. Canadian Science Advisory Secretariat Research Document 2004.

Staples David F., Mark L. Taper, Bradley B. Shepard. 2005. Risk-based viable population monitoring. Cons. Biol. 19(6):1908-1916.

Walters, Carl and Ana M. Parma. 1996. Fixed exploitation rate strategies for coping with effects of climate change. Can. J. Fish. Aquat. Sci. 53: 148–158.

Acknowledgements

Many thanks to Richard Bailey, Mike Bradford, Mike Chamberlain, and Kent Simpson for their help with data and knowledge regarding the intricate details of IFC. Previous versions of this document were reviewed by Kent Simpson, Mike Bradford, Arlene Thompson and Diana Dobson, who all gave numerous constructive recommendations for improvements. Thanks also to Chuck Parken and Al Cass for putting in extensive time reading drafts and making themselves available to discuss details of the work.

Appendix 1: PSARC Request for Working Paper[3]

Date Submitted: September 30/2004

Individual or group requesting advice:
(Fisheries Manager/Biologist, Science, SWG, PSARC, Industry, Other stakeholder etc.)
Resource Management

Proposed PSARC Presentation Date: Nov 18/2004

Subject of Paper (title if developed): Allowable Harm Assessment – Thompson coho

Science Lead Author: Michael Folkes

Resource Management Lead Author: Bert Ionson

Rationale for request:
(What is the issue, what will it address, importance, etc.)
Thompson River coho have been recommended by COSEWIC for listing as "endangered" under SARA. If this stock is listed, automatic prohibitions come into effect however under certain conditions, permits may be issued that will allow low levels of impact on this stock. An allowable harm assessment framework has been developed by DFO Science and DFO Fisheries Management to determine if those conditions exist and what level of impact may be considered. The allowable harm assessment is also to be used to inform the Minister's decision about listing (specifically to identify the flexibility regarding options for fishing). Material to permit the Minister to make a listing decision has to be in Ottawa by January 20/05

Objective of Working Paper including assessment of environment/climate impacts:
(To be developed by FM, StAD, Habitat Science, HEB/Oceans, Ocean Science and Productivity)

Determine if current levels of harvest related mortality threaten rebuilding and would modest increases (from the current level of 13% to 20%) threaten rebuilding.

Question(s) to be addressed in the Working Paper:
(To be developed by initiator)

The questions as set out in the "Framework for the Department of Fisheries and Oceans to address permitting Conditions under Section 73 of SARA", namely

1. What is present/recent species trajectory?
2. What is present/recent species status?
3. What is expected order of magnitude / target for recovery?
4. What is expected general time frame for recovery to the target?

---

[3] Append to Working Paper and cc to the PSARC Secretariat following Regional Director(s) approval

5. What is the maximum human-induced mortality which the species can sustain and not jeopardise survival or recovery of the species?

6. *(a)* What are the major potential sources of mortality/harm? More specifically: Should consider, *inter alia,* and give reasons for dismissing (when appropriate) each of:

- Directed fishing (with or without a quota) for a listed species— International as well as domestic fisheries
- Bycatch in fisheries directed at other species
- Detrimental impacts on habitats by fishing activities
- Direct mortality by permitted habitat alterations (for example smolts killed in power turbines; oil & gas exploration, blasting)
- Detrimental alteration of habitats by permitted activities (for example loss of lacustrine or riverine productive capacity due to water draw-downs; gear impacts, all the "foreign materials, forces, and noises")
- Ecotourism & recreation
- Shipping & transport & noise
- Fisheries on food supplies
- Aquaculture; introductions & transfers
- Scientific research
- Military activities

(b) Do Canadian activities alone impact the species? For transboundary species that migrate in and out of Canadian waters, list all International activities that may impact the species.

7. For those factors NOT dismissed, quantify to the extent possible the amount of mortality or harm caused by each activity.

8. Aggregate total mortality/harm attributable to all human causes and contrast with that determined in Question #5.

9. To support condition (a), science and management will have to:

- Develop an inventory of all reasonable alternatives to the activities in #7, but with potential for less impact. (e.g. different gear, different mode of shipping)
- Document expected mortality/harm rates of alternate activities
- Document nature and extent of major ecosystem effects caused by the alternate activities (e.g. habitat impacts, impacts on dependent predators, etc.)
- Document expected costs and benefits of options which could be adopted, at least when options may look promising

10. To support condition (b) science and management will have to:

- Develop an inventory of all feasible measures to minimise the impacts of activities in #7
- Document the expected effectiveness of the mitigation measures for permitted activities
- Document the expected costs and benefit of options which could be applied, at least when options may look promising

11. To support condition (c), science and management will have to document:

- The expected mortality or harm for various scenarios carried over from #9 and/or #10 are below that determined in #5 and;

- The projected population trajectory under the various scenarios indicates that survival or recovery is not in jeopardy, considering cumulative sources of impact.

12. Prepare options and (where justified) recommendations regarding permits, including rationales, relevant conditions to ensure (a), (b), and (c) are covered, and performance measures. A document suitable for the Minster to enter on the SARA Public Registry should be prepared.

Stakeholders Affected:

First Nations, Recreational and Commercial

How Advice May Impact the Development of a Fishing Plan:

If current levels of fishing are thought to have a deleterious effect on the ability of this stock to rebuild, then increased levels of restrictions will be necessary in the recreational and possibly commercial fishery. If increased levels of harvest mortality can be sustained, increase flexibility in fisheries management measures can be considered.

Timing Issues Related to When Advice is Necessary:

The information is required by mid November for a late November/early December PSARC review so background material can be prepared for the mid-January deadline.

Approval as appropriate:

Regional Director Fisheries: ________________________; Date:_______________________

Regional Director Habitat: __________________________; Date:_______________________

Regional Director Science: _________________________; Date:_______________________