ASSESSMENT OF THE INTERIOR FRASER RIVER COHO SALMON MANAGEMENT UNIT

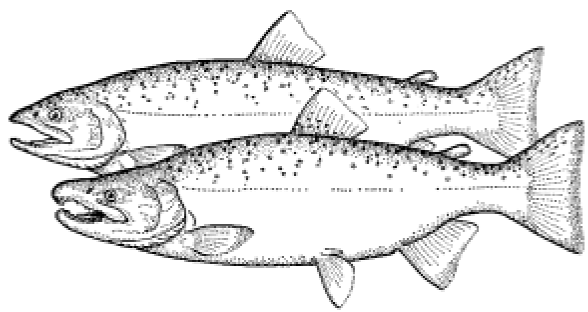


Image: Coho Salmon — provided by Fisheries and Oceans Canada, Freshwater Fishes of Canada, 1973 Fisheries Research Board of Canada, Bulletin 184, Catalogue No. FS94-184, Page 158 – line drawing of Coho Salmon.

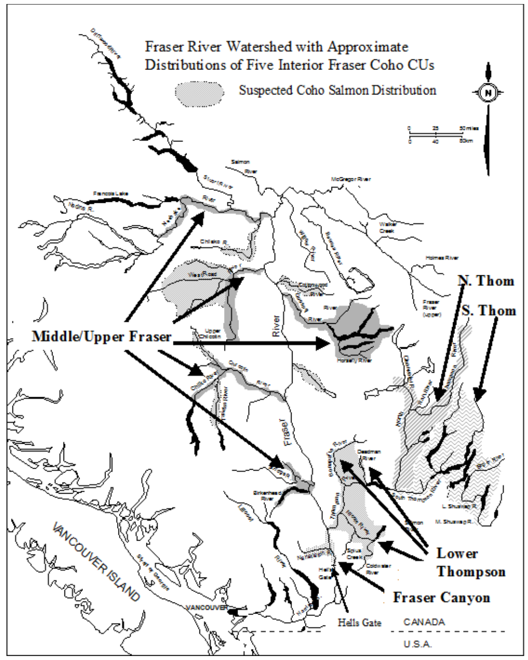


Figure 1. Distribution of 5 Interior Fraser Coho Salmon Conservation Units (N Thompson, S Thompson, Lwr Thompson, Fraser Canyon, Middle/Upper Fraser) reproduced from Irvine (2002). Shaded areas represent the suspected distribution of Coho for the Mid/Upper Fraser CU, and the distribution for the remaining 4 CUs.

Context:

Declining numbers of Interior Fraser River Coho Salmon prompted the Department of Fisheries and Oceans (DFO) to implement severe fishery management measures commencing in the 1990's. In 2002, Interior Fraser River Coho Salmon were designated as endangered by the Committee on the Status of Endangered Wildlife in Canada. In 2006, DFO published a conservation strategy outlining recovery objectives these fish.

Recent increases in spawning escapements, and potential opportunities for increased harvest of more abundant stocks and species currently constrained by measures to protect Coho Salmon, prompted a request for science advice to determine the impact of increased harvest on Interior Fraser River Coho Salmon. The assessment was to be developed in the context of recovery objectives in the 2006 Conservation Strategy document. A complete Wild Salmon Policy status assessment is planned for 2014.

This Science Advisory Report is from peer review meeting on the Interior Fraser River Coho Salmon Interim Assessment held 23-24 January, 2014. Additional publications from this meeting will be posted on the Fisheries and Oceans Canada (DFO) Science Advisory Schedule *as they become available.*

SUMMARY

- Coho Salmon in southern British Columbia, including those destined to the interior Fraser River watershed, experienced severe abundance declines in the 1990’s. DFO responded by introducing management measures to significantly reduce fishery exploitations. In 2006, DFO published a conservation strategy outlining recovery objectives for interior Fraser River Coho Salmon.
- Interior Fraser Coho Salmon were designated as endangered by COSEWIC in 2002. The Interior Fraser Coho Recovery Team (IFCRT) was established and in 2006 the Conservation Strategy for Coho salmon (*Oncorhynchus kisutch*), Interior Fraser River Populations was published (IFCRT, 2006).
- Recent improvements in Coho Salmon escapements, and the potential opportunity for increased salmon harvest of more abundant stocks and species, currently constrained by measures in place to protect Coho Salmon, led to a request for science advice to determine the impact of increased harvest on Coho Salmon originating from the Interior Fraser River management unit.
- The Interior Fraser Management Unit is comprised of five Wild Salmon Policy Conservation Units, each of which is made up of 1-3 subpopulations.
- For the most recent generation (2010-2012), aggregate wild Coho Salmon escapement to the Interior Fraser River watershed averaged 36,000 spawners, well above the short term conservation strategy recovery objective of 20,000 spawners, but below the longer term objective of 40,000 spawners.
- Two distinct periods of productivity were evident in the observed data: a higher productivity period during 1978-1993 and a lower productivity period during 1994-2012. During the current low productivity period, there have been eight years when productivity was less than one recruit/spawner; meaning that Interior Fraser Coho Salmon were unable to replace themselves, the most recent being 2010.
- Several stock-recruit models were evaluated and the Ricker model was determined to be the best model for the current period of low productivity. Using the Ricker model, closed-loop simulations were used to project the probabilities of achieving the recovery objectives set out in the Conservation Strategy (IFCRT, 2006) at various potential exploitation rates; the results formed the basis of advice to management in a decision table.
- In the current low productivity period, at existing exploitation rates of approximately 13%, the probability of achieving the short term recovery objective within 1, 2 or 3 generations is 0.65, 0.71 and 0.73, respectively. If exploitation is raised to 30%, those probabilities decrease to 0.51, 0.52 and 0.50. The probability of meeting the longer term objective is low regardless of exploitation.
- Managers should be aware that there are potentially significant sources of uncertainty with respect to estimates of fishery exploitation, escapement, stock recruitment parameters and, hence, probabilities of achieving recovery objectives. Since implementation error (variability in the ability to implement a change in exploitation), which is not captured in the models, probability estimates are likely optimistic.

BACKGROUND

During the 1990s, declines in the abundance of southern British Columbia Coho Salmon (Image), and in particular the genetically distinct Coho Salmon of the interior Fraser watershed (Figure 1), resulted in the DFO implementing fishery management measures that significantly reduced the harvest of these stocks. In 2002, the status of interior Fraser River Coho Salmon was assessed (Irvine 2002) resulting in their designation by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) as endangered (COSEWIC 2002). In 2006, DFO published a conservation strategy outlining recovery objectives for interior Fraser River Coho Salmon (IFCRT 2006) and in 2013, a pre-COSEWIC assessment was completed (Decker and Irvine 2013) to support a COSEWIC re-evaluation expected to be completed in 2015.

Recent improvements in Coho Salmon abundance, and anticipation of potential harvest opportunities for more abundant salmon stocks and species, constrained under the current measures to protect Coho Salmon, prompted a request for science advice. Fisheries Management Branch, First Nations and client groups sought information on the impacts of increased harvest on Coho Salmon originating from the Interior Fraser River Management Unit. This assessment was developed in the context of the recovery objectives outlined in the Conservation Strategy for Coho salmon (*Oncorhynchus kisutch*), Interior Fraser River Populations (IFCRT 2006). A complete Wild Salmon Policy (WSP) status assessment is planned for 2014, which will include the identification of lower and upper status benchmarks for the 5 interior Fraser Coho Salmon Conservation Units (CUs).

ASSESSMENT

The five main objectives of the assessment are provided below, along with major findings.

Objective 1: Describe the fishery management actions taken since 2006 to meet the 2006 Conservation Strategy Recovery objectives.

Actions summarized in IFCRT (2006) were updated to include information up to the 2013 fishing season. An overview follows.

Beginning in 1998, significant fishery management measures were taken in order to reduce the fishery-related mortality on southern BC Coho Salmon stocks and on Interior Fraser Coho Salmon in particular. There have been no commercial or recreational fisheries in BC targeting Interior Fraser Coho Salmon. Furthermore, for fisheries occurring in areas and dates where and when Interior Fraser Coho Salmon might be present, commercial catch has been restricted to non-retention of Coho salmon during fishing for other salmon species. Similarly, First Nations and recreational catch has been restricted to non-retention of wild Coho Salmon during fishing for other species, and during fisheries targeting hatchery-origin Coho Salmon. Retention of non-hatchery-origin Coho Salmon in southern BC has only been permitted in terminal areas where Interior Fraser Coho Salmon have been identified as being abundant through enumeration using a weir.

To reduce the incidental mortality of Coho Salmon, several mandatory selective fishing practices are currently in place for southern BC fisheries. These include: barbless hooks in all hook and line salmon fisheries, revival tanks on commercial salmon boats for recovery of fish prior to release, and brailing of catch from purse seine bunts to allow for live-sorting.

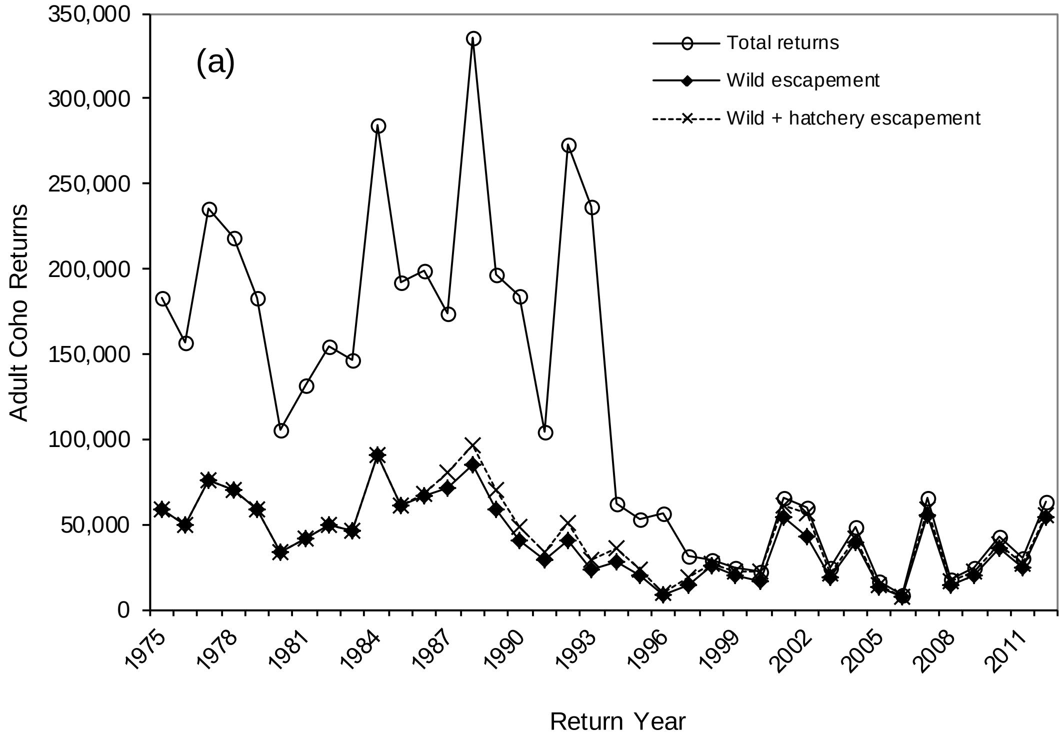
Objective 2: Quantify aggregate, population and sub-population metrics for abundance, distribution and productivity.

For the most recent generation (2010-2012), aggregate wild Coho Salmon escapement to the Interior Fraser River watershed averaged 36,000 fish geometric mean) (hereafter referred to as spawners), approximately 60% lower than escapements during 1975-1988, when the population experienced a period of relatively high and stable escapement (~59,000 spawners, Figure 2). Although escapements have been quite variable since the implementation of conservation measures in 1997-1998 (Figure 2a), a smoothed trend line (3-year running geometric mean, Figure 2b) shows a 2.5-fold increase in escapement from 1997 to 2002, followed by a decline to similarly low levels by 2005, and then an increase in escapement of similar magnitude from 2005 to 2012.

Total returns (i.e. catch plus escapement) of wild Coho Salmon to the Interior Fraser watershed for the most recent generation (geometric mean of 41,000 fish for 2010-2012) were 4-fold lower than the mean for 1975-1988 (181,000 fish). The decline in escapement over time was much less than the decline in total return because fisheries exploitation was much lower during the later period and offset the decline in survival and abundance (Figure 3a). Since 1998, reduced exploitation has resulted in relatively small differences between total return and escapement (Figure 2).

A time series plot of productivity (ln(recruits/spawners)) suggests a period of decline from 1978-2005, followed by a period of highly variable, but generally increasing productivity during 2005-2012 (Figure 3a). However, when density dependent survival is accounted for, two productivity periods (high during 1978-1993 and low during 1994-2012) are apparent (Figure 3b) During the current low productivity period, there have been eight years when productivity was less than 0 (i.e. less than 1 recruit per spawner based on pre-fishery abundance), meaning that Interior Fraser Coho Salmon were unable to replace themselves (Figure 3a).

Distributional data are difficult to interpret due to variable survey effort. It is likely that Coho Salmon were more broadly distributed in the Interior Fraser in the 1970s and 1980s than they are currently, but this cannot be verified due to lower survey effort during those early years.



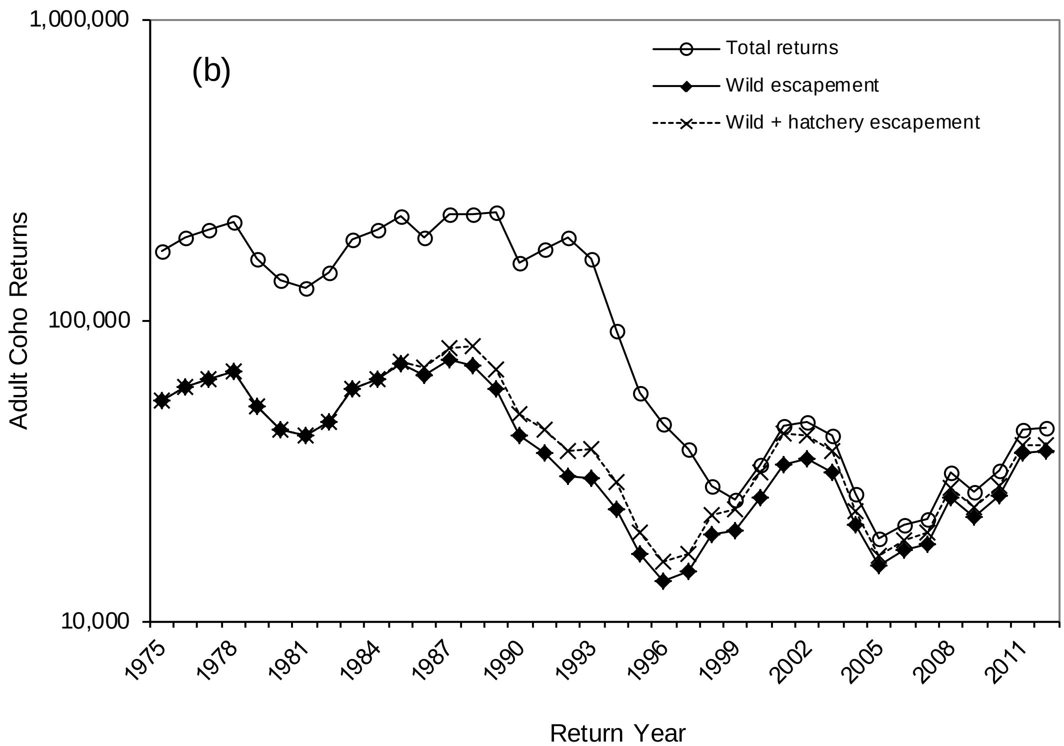


Figure 2. Reconstructed time series of wild Coho Salmon escapements and total escapements (wild + hatchery fish) and total returns (total escapement + catch) for the interior Fraser River watershed during 1975-2012). Figure 2a shows annual estimates; Figure 2b shows the same data with escapement and total return values smoothed using a 3-year running average and plotted on a $\log_{10}$ scale

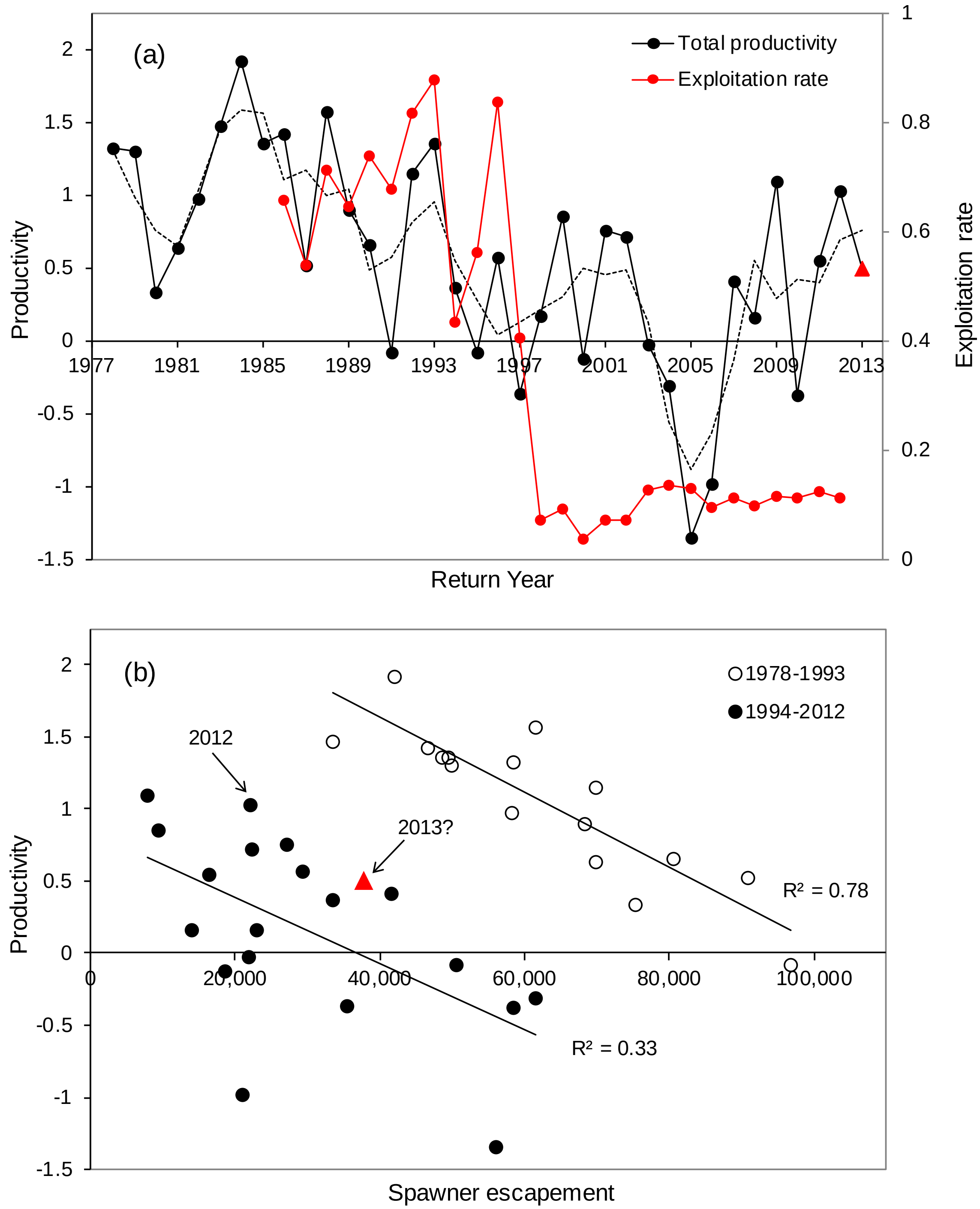


Figure 3. (a) Time series of productivity (ln[recruits/spawner]) (1978-2012) and exploitation rate estimates (1986-2012). Black dotted line shows the 3-year running arithmetic mean for productivity. Negative productivity values represent years of negative population growth when the population is unable to replace itself (i.e., < 1 recruit per spawner), even in the absence of exploitation. The preliminary estimate for 2013 appears as a solid red triangle. (b) plots of productivity versus aggregate brood escapement for 1978-1992 and 1993-2012.

Objective 3: Compare current population metrics to those outlined the 2006 Conservation Strategy recovery objectives.

As there was lack of clarity in the terms of reference about which of the 2006 IFCRT Strategy Recovery Objectives were meant to be assessed by the authors, the authors chose to assess the following two objectives:

1. IFCRT Short Term Objective 1: 3 year geometric mean escapement in at least half of the subpopulations within each of the 5 CUs to exceed 1000 natural spawners, excluding hatchery fish spawning in the wild; and,
2. IFCRT Longer Term Objective 1: 3 year geometric mean escapement in all of the subpopulations within each of the 5 CUs to exceed 1000 natural spawners, excluding hatchery fish spawning in the wild.

Based on empirical data for 1975-2012, Objective 1 was never achieved at aggregate escapement levels up to 18,000 spawners, and was always achieved at average escapements of 19,000 spawners and higher.

Prior to assessing Objective 2 above, estimates for the Lower Thompson subpopulation were removed from the analysis because of data quality concerns. Logistic regression predicted that the probability of meeting the longer term objective increased from near 0% at an aggregate escapement of 18,000, to 50% at 31,000 spawners, to 98% at 40,000 spawners.

In general, it appeared that escapements of 20,000 and 40,000 (3-year running geometric mean) would result in very high probabilities that Objectives 1 and 2 above would be met, respectively.

Since the inception of the recovery program in 1998, aggregate escapements (3-year running geometric mean) failed to meet the short-term objective (20,000 spawners) in five of 15 years (1998-99, 2005-07). However, since 2008, the short-term objective was met in every year. The longer term objective (40,000 spawners) was never met during 1998-2012. However, the 3-year running mean exceeded the longer term objective in 2012 and 2013, based on preliminary escapement estimates for 2013.

There is considerable variability among subpopulations with respect to how consistently the objective of 1,000 spawners was met during 1998-2012. For example, the Adams River and Lower Thompson subpopulations met the 1,000 spawner objective in only 33% and 67% of the years, respectively, while the Middle/Lower Shuswap, Shuswap Lake, and Middle and Lower North Thompson subpopulations met the objective every year.

Objective 4: Quantify annual exploitation rates and the level of uncertainty in these estimates.

Exploitations declined rapidly in response to changes in fishery management in the late 1990's (Figure 3a). Exploitation rate estimates for 1998-2012 are highly uncertain and likely biased low for various reasons including unreported catches and releases, and incomplete creel surveys. Multiple estimation approaches, including models that assume stationarity through time in the spatial distribution and migration timing of Interior Fraser and other Coho Salmon populations through the various fisheries are also likely to produce estimate that are biased low. (see also text in Sources of Uncertainty). Improving the accuracy and precision of Coho Salmon exploitation rates is an active area of research.

Objective 5: Estimate the probability of achieving the 2006 Conservation Strategy Recovery objectives at a range of potential exploitation rates.

Three stock recruitment models (Hockey Stick, Beverton-Holt, and Ricker) were fit to the aggregate Interior Fraser Coho Salmon wild escapement time series, both the full time series

(1975-2012) and the recent period of lower productivity (1994-2012). Since there is no evidence to suggest a departure from the current low productivity period (Figure.3b), only recruitment information from this period was used to generate advice to managers. Akaike Information Criteria (AIC) model selection criteria suggested that, for the period of lower productivity (1994-2012), the Ricker model best explained the data.

Closed-loop simulations based on the Ricker model indicated a strong trade-off between meeting the short term recovery objective and higher exploitations. For example, at current exploitation rates of approximately 15%, the probability of achieving the short term recovery objective is 0.65, 0.71 and 0.73 over 1, 2 and 3 generations, respectively. If exploitation is raised to 30%, the probability of achieving the short term objective decreases to 0.51, 0.52 and 0.50, respectively. The probability of meeting the longer term objective of 40,000 spawners at low productivity is low regardless of exploitation rate (e.g., at approximately 15% exploitation, the probability is 0.00, 0.12, and 0.17 over 1, 2, or 3 generations, while at 30% exploitation, the probability is 0.00 over 1 generation, and 0.06 or less over 2 or 3 generations).

Managers should be aware of uncertainty and potential bias in the probabilities given in Table 1. Implementation error (variability in the ability to implement a change in exploitation) is not captured in the models that generated the probabilities in Table 1. Therefore, the probabilities of achieving recovery objectives in Table 1 likely overestimate the actual probabilities (i.e., are overly optimistic) given increased uncertainty and resulting wider probability distribution of outcomes. In addition to this uncertainty in achieving target exploitation rates, uncertainty in the stock-recruitment relationship, and observed recruitment failures (recruits/spawner < 1) as recently as 2010, the potential consequences of not achieving 20,000 spawners should be recognized. The 2006 Conservation Strategy identified 20,000 spawners as a short-term objective to protect the genetic integrity of the five CUs within their geographically large spawning areas, and recommended higher targets to address longer term rebuilding objectives.

*Table 1. Results of harvest scenario analysis to determine the probability of meeting recovery objectives for the 1994 to 2012 (low) productivity period, at a given fixed exploitation rate (*ER*), for one, two, or three generations. A probability represents the percentage of times in the simulation model that the geometric mean escapement is greater than the short-term or the longer term recovery objective. Simulations were initialized with the 2010 to 2012 spawner abundance data.*

	1994-2012 (Low Productivity Period)					
	Short-term (20,000 spawners)			Longer term (40,000 spawners)		
ER	One Generation	Two Generations	Three Generations	One Generation	Two Generations	Three Generations
0%	0.75	0.84	0.87	0.00	0.23	0.31
5%	0.72	0.80	0.83	0.00	0.19	0.26
10%	0.69	0.76	0.79	0.00	0.16	0.22
15%	0.65	0.71	0.73	0.00	0.12	0.17
20%	0.60	0.66	0.67	0.00	0.09	0.13
25%	0.56	0.59	0.59	0.00	0.07	0.09
30%	0.51	0.52	0.50	0.00	0.05	0.06
40%	0.39	0.36	0.31	0.00	0.02	0.02
60%	0.15	0.07	0.03	0.00	0.00	0.00

Sources of Uncertainty

There are potentially significant sources of uncertainty with respect to estimates of fishery exploitation, escapement, and stock recruitment parameters. As well, implementation error is not included in the model.

Exploitation rate estimates for Interior Fraser Coho Salmon from 1998 onward are uncertain for several reasons. First and most significantly, the estimation models assume stationarity through time in the spatial distribution and migration timing of Interior Fraser and other Coho Salmon populations through the various fisheries. This assumption is questionable given observed year-to-year shifts in the distribution of Coho Salmon between the Strait of Georgia and the west coast of Vancouver Island in the 1990s, and the difficultly in inferring inside-outside distribution changes in more recent years in the absence of directed fisheries on Coho Salmon. The Canadian marine exploitation and US Fishery Regulation Assessment Models (FRAM) depend on comparisons of fishing effort in recent years versus the baseline period, but the assumption that current fisheries are similar to those in the baseline period is questionable, given that during the baseline period directed fisheries on Coho Salmon occurred, whereas in recent years Coho Salmon were mainly intercepted incidentally during fisheries for hatchery marked Coho Salmon and as by-catch in fisheries targeting other species. The absence of significant directed fisheries on Coho Salmon in recent years has also meant that monitoring of fishing effort on Coho Salmon has declined, which has led to increased uncertainty in estimates of fishing effort, encounter rates and gear-specific mortality. Finally, estimates of release mortality for Coho Salmon in commercial and recreational fisheries are based on data from a limited number of studies. Although it is a very important consideration, a comprehensive evaluation of uncertainty in exploitation estimates was beyond the scope of the current assessment.

There were no escapement estimates for Upper/Middle Fraser CUs during 1975-1997, or for the Lower Thompson CU during 1975-1983. Escapements to these areas were extrapolated based on ratios of abundance with other CUs during 1998-2000. For all CUs, surveys were often of limited coverage prior to 1998.

Since stock recruit model selection was based on fitting to the exploitation and escapement time series, there is uncertainty in the predictions of stock responses to harvest.

Finally, implementation error (variability in the ability to implement a change in exploitation) is not captured in the models that generated probabilities in Table 1. Estimated probabilities of achieving recovery objectives are likely optimistic.

CONCLUSIONS AND ADVICE

- Significant fishery management actions beginning in 1998 to protect Interior Fraser Coho Salmon effectively capped total (Canada and US) exploitation at approximately 13% compared to an average of 67% prior to 1998.
- The most recent 3-year geometric mean escapement (2010-2012) for the Interior Fraser Coho Salmon aggregate (36,000 wild spawners in 2012) was the largest observed since sustained harvest restrictions began in 1998. Despite modest improvements in productivity in recent years (over the last 6 years, or 2 generations), the future remains uncertain. There is no evidence of a shift from the ‘low’ productivity period that has persisted since 1994 (return year); current productivity is still well below that in the relatively high productivity period of 1978-1993 (e.g. Figure 3b).
- Generational average escapements for the Interior Fraser Coho Salmon aggregate exceeded 20,000 spawners every year since 2008, resulting in a high probability of meeting the distributional objective of 1000 spawners in half the subpopulations in each

CU (i.e. the short-term objective from IFCRT 2006). The longer term objective (>1000 spawners in every subpopulation for which an escapement of 40,000 spawners serves as a surrogate) was not met during 1998-2011, but if the preliminary escapement estimate for 2013 is included, the latter objective was reached in 2012 and 2013. Using geometric means provides more precautionary generational averages and recognizes the importance (through heavier weighting) of smaller escapements to genetic diversity.

- Based on simulations, declining population trends are predicted at exploitations exceeding 30%. Table 1 provides estimated probabilities (based on model runs) of achieving short and longer term recovery objectives for a range of exploitations. There is a strong trade-off between meeting the short-term recovery objective and higher exploitations. For example, at current exploitation rates of approximately 15%, the probability of achieving the short term recovery objective is 0.65, 0.71 and 0.73 over 1, 2 and 3 generations, respectively. If exploitation is raised to 30%, the probability of achieving the short term objective decreases to 0.51, 0.52 and 0.50, respectively. The probability of meeting the longer term objective of 40,000 spawners at low productivity is low regardless of exploitation rate (e.g., for 30% exploitation, the probability is 0 over 1 generation, and only 0.06 or less over 2 or 3 generations).
- Managers should be aware that there are potentially significant sources of uncertainty with respect to estimates of fishery exploitation, escapement, stock recruitment parameters, and hence the probabilities of achieving recovery objectives given in Table 1 and are advised to account for this in their management plans. Since implementation error, which is variability in the ability to implement a change in exploitation is not captured in the models, probability estimates are likely optimistic.
- Managers are faced with trade-offs between maximizing potential escapements of Interior Fraser Coho Salmon (to address conservation concerns associated with small populations distributed over large geographic areas at low densities), and providing increased harvest opportunities for other salmon species and stocks. Ultimately, the decision to change harvest levels will depend on consideration of current escapement, estimates of productivity and tolerance for risk, in light of recognized uncertainties and potential bias, among other factors.

OTHER CONSIDERATIONS

Assessment of the status of Interior Fraser River Coho Salmon is largely dependent on estimates of escapement and exploitation. The reliability of future status assessments as well as short-term assessments of fishing impacts on Interior Fraser Coho Salmon escapements are contingent upon a continuous time series of escapement estimates, particularly if fishing restrictions currently in place to protect Interior Fraser Coho Salmon are eased to increase fishing opportunities for other stocks and species. Increased catch monitoring and various approaches to address the uncertainty and bias in exploitation rate estimates and implementation error should also be considered to better assess the impacts of possible changes to fishing effort on Interior Fraser Coho Salmon. At higher exploitation rates, more information will be required to monitor the impacts on Interior Fraser Coho Salmon management units.

A formal WSP status assessment of Interior Fraser Coho Salmon CUs is planned for the coming winter. Identification of fishery management reference points, distinct from WSP status benchmarks, are also required for fishery planning purposes. This current assessment is not equivalent to a WSP status assessment, since it relies primarily on IFCRT recovery objectives and not WSP benchmarks.

SOURCES OF INFORMATION

This Science Advisory Report is from peer review meeting on the Interior Fraser River Coho Salmon Interim Assessment held on 23-24 January 2014. Additional publications from this meeting will be posted on the *Fisheries and Oceans Canada (DFO) Science Advisory Schedule* as they become available.

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: viii + 34 p.

Decker, A.S., and J.R. Irvine. 2013. Pre-COSEWIC Assessment of Interior Fraser Coho salmon (*Oncorhynchus kisutch*). DFO Can. Sci. Advis. Sec. Res. Doc. 2013/121. x + 57 p.

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