PRE-SEASON RUN SIZE FORECASTS FOR FRASER RIVER SOCKEYE SALMON IN 2012

Sockeye adult spawning phase (source: DFO website).

Figure 1. Sockeye salmon distribution in the Fraser watershed (DFO GIS Division)

Context

Pre-season abundance forecasts of returning Fraser River adult Sockeye salmon in 2012 were requested by Fisheries and Oceans Canada (DFO) Fisheries Management. Forecasts are used for pre-season planning purposes and for in-season management. They are most useful early in the summer fishing season before in-season test fisheries provide adjustments for the pre-season run size estimates. Forecasts are produced by DFO as agreed under the Canada-United States Pacific Salmon Treaty. The details associated with the 2012 forecast are presented in an associated CSAS Research Document (MacDonald and Grant, 2012).

This Science Advisory Report has resulted from a DFO Canadian Science Advisory Secretariat (CSAS) Regional Peer Review (RPR). Additional publications resulting from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

SUMMARY

- Salmon forecasts are in general highly uncertain due to wide variability in annual survival rates from the egg stage to adult returns.
- For Fraser Sockeye, quantitative or qualitative indicators of survival explored to-date have not reduced forecast uncertainty and remain an active area of research.

- In the absence of indicators, Fraser Sockeye forecasts have been particularly uncertain in recent decades due to persistent declines in productivity exhibited by most stocks, with the lowest productivity on record observed for the 2005 brood year (2009 four year old and 2010 five year old returns). The subsequent 2006 (2010 four year old returns) and 2007 (2011 four year old returns) brood year stock productivities appear to have improved.
- The 2012 single forecast scenario differs from recent years forecasts that presented two scenarios: Recent Productivity (stock-specific forecasts used best performing recent productivity models evaluated only in recent low productivity periods) and Long-Term Average Productivity (stock-specific forecasts used best performing long-term average productivity models evaluated over the entire time series).
- In contrast, the 2012 forecast presents only a single forecast scenario. Under this scenario, the stock-specific forecasts were produced using either recent productivity or long-term productivity (full time series) models, selected largely based on their ability to predict a stock's true returns over its full stock-recruitment time series. Stock-recruitment data included up to the 2004 brood year.
- The 2012 forecast indicates a one in 10 chance (10% probability) the total Fraser Sockeye return will be at or below 743,000, and a nine in 10 chance (90% probability) it will be at or below 6.6 million, given that stock productivity is similar to past observations. The mid-point of this distribution (50% probability) is 2.1 million at which there is an equal chance the return will be greater or less.
- Summer Run stocks, particularly Chilko, Late Stuart and Stellako, are expected to contribute 67% to the total return forecast, whereas Early Stuart (5%), Early Summer (17%) and Late Run stocks (11%) will each contribute considerably less.
- The 2012 Fraser Sockeye forecasted return distribution falls largely (up to a three in four chance, based on past observations) below the cycle average (3.8 million). The below average return is attributed to the well below average 2008 brood year escapements for Early Summer and Late Run stocks.
- The 2012 Fraser Sockeye return has the potential to be amongst the lowest observed on this cycle if stock productivities are at the low end of past observations.
- Due to the lower 2008 escapements (which produce four year olds in 2012) relative to 2007 (which produce five year olds in 2012), the total forecasted four year old return proportion (~75%) is below average (82% average four year old proportions for all stocks combined, excluding Harrison). Expected four year old proportions range from 10% to 98%, depending on the stock.

INTRODUCTION

Overview of Past Adult Returns

The return of Fraser Sockeye has varied tremendously with some of the most extreme variations observed in recent years (Figure 2A). The 2012 cycle has the lowest average return of the four cycles of Fraser River Sockeye, with an average annual Fraser Sockeye return (1956-2008) of 3.85 million for all 19 forecasted stocks combined (see Table 1, column I for the average cycle line return for each stock. Chilko (Summer Run) has historically been the main driver of returns on this cycle line, accounting for 47% of the average total. Stellako, Weaver and Birkenhead have also contributed relatively high proportions to the cycle average, at 12%, 9% and 7% respectively. Stocks that have each comprised greater than 2% of the average return on the 2012 cycle include Early Stuart, Gates, Nadina, Pitt and Late Stuart. All remaining stocks have contributed less than 2% to the cycle average return.

Escapement in the 2007 and 2008 Brood Years

Since most Fraser Sockeye return as four year old fish after spending two winters in freshwater and two winters in the marine environment, the majority of Sockeye returning in 2012 will be recruits from eggs spawned by adults in 2008 (i.e., the brood year).

Overall, the number of effective female spawners (EFS) in the 2008 brood year (274,000 EFS) was the lowest on the 2012 cycle since 1968. For most stocks returning in 2012 (13 out of 19), brood year EFS or smolt (Chilko and Cultus) abundances were well below their time-series cycle average (1948-2004 for most stocks), including Bowron, Fennell, Gates, Pitt, Scotch, Seymour, Chilko, Cultus, Late Shuswap, Birkenhead, Portage, Harrison and Weaver (Table 1, column C). These brood year escapements, in most cases, were the lowest or amongst the lowest on record for these stocks. For the remaining six out of 19 stocks, brood year EFS abundances were close to, or above, their time series cycle average (1948-2004 for most stocks), including Early Stuart, Nadina, Raft, Late Stuart, Quesnel, and Stellako (Table 1, column C). Three Summer Run stocks (Stellako, Chilko and Late Stuart) contributed the greatest overall proportion (71%: ~ 24% each) to the total 2008 brood year EFS. The Chilliwack Lake-Dolly Varden Creek miscellaneous stock, as well as Early Stuart and Nadina contributed, on average, 4% each to the total EFS. All remaining stocks contributed less than 2% to the total EFS. Cultus Sockeye have high hatchery contributions in the fry to smolt stage that make EFS comparisons not meaningful.

Most Fraser Sockeye stocks also have a five year old component that contributes, on average, 20% to their total recruitment. For approximately half of the forecasted Fraser Sockeye stocks (Early Stuart, Bowron, Gates, Nadina, Seymour, Stellako, Late Shuswap, Cultus and Portage), 2007 brood year EFS abundances (producing the five year old returns in 2012) were below their cycle average (most time series: 1951-2003). For the other half of these stocks (Fennell, Pitt, Raft, Scotch, Chilko, Late Stuart, Quesnel, Weaver and Birkenhead), 2007 brood year EFS abundances were above, or close to, their cycle average (Table1, column D). Given this pattern in escapements for the 2008 and 2007 brood years, the five year old component may contribute more than 20% to the total return in 2012. Pitt River returns are typically comprised of a larger proportion of five year old Sockeye relative to four year olds, therefore, the 2007 brood year, which was above average, will contribute more to the total return than the 2008 brood year. Harrison has a three year old component, which contributes variable proportions to the total Harrison recruitment; this component was above average in the 2009 brood year.

Trends in Productivity and Survival Rates

In recent decades, productivity (i.e., adult returns per EFS) across all Fraser Sockeye stocks has generally declined (Figure 2B), though individual trends vary amongst stocks (Grant et al. 2010; Grant et al. 2011; Peterman and Dorner 2011). One notable exception is Harrison Sockeye, which have increased in productivity in recent years (Grant et al. 2010, 2011). The Harrison Sockeye has a unique age-structure and life-history compared to all other stocks. This stock migrates to the ocean shortly after gravel emergence (most other Sockeye rear in lakes for one to two years prior to ocean migration) and return as three and four year old fish (most other Sockeye return as four and five year olds). The declining productivity trends reached the lowest level yet observed for most stocks (Figure 2B), including Harrison, in the 2005 brood year. Subsequently, the 2006 brood year (2010 return year for most of these Sockeye) and 2007 brood year (2011 return year for most of these Sockeye) productivities were close to average for most stocks. This pattern is similarly exhibited by Chilko, typically the predominant stock of the 2012 cycle line (Figure 3B).

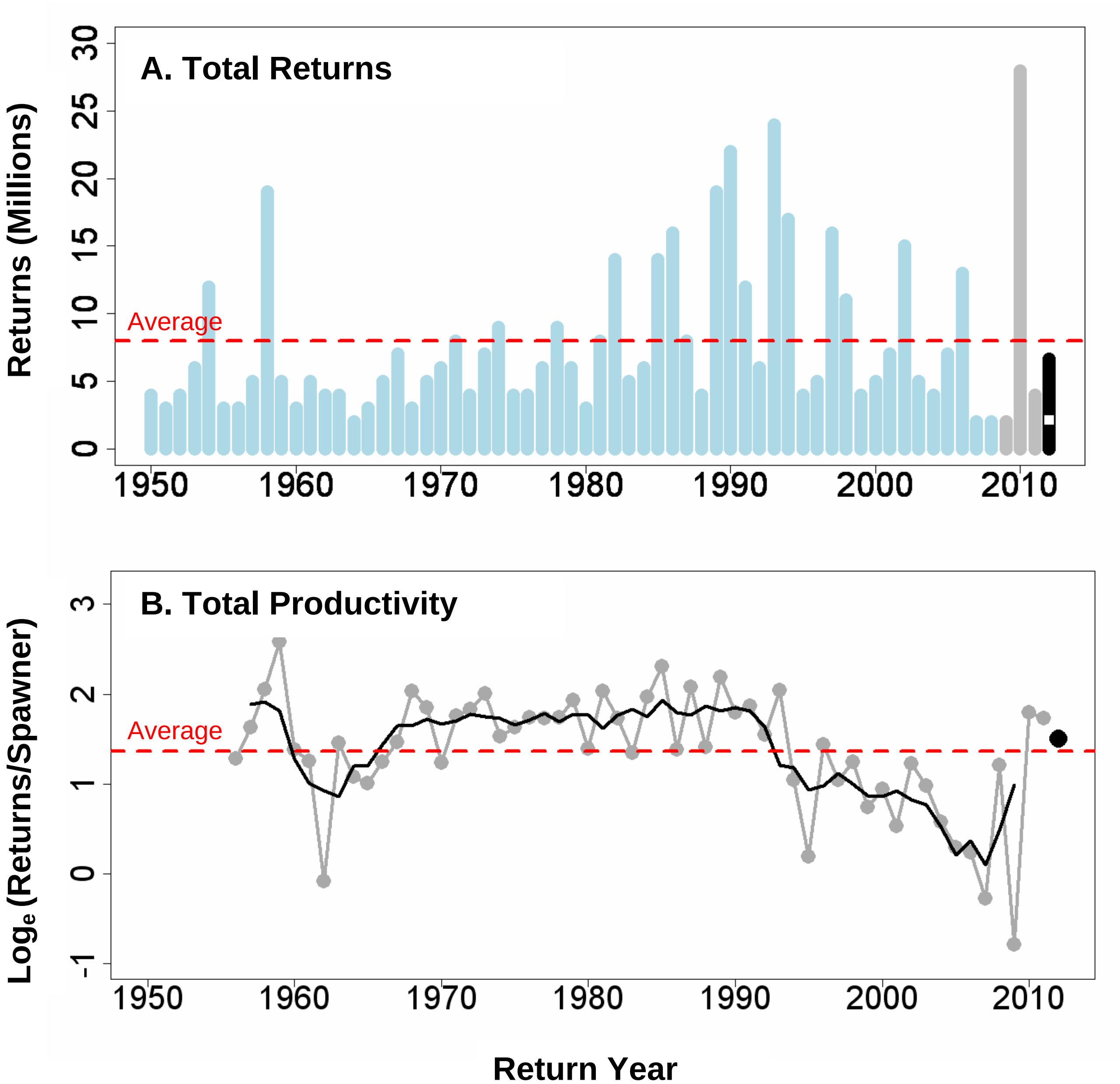


Figure 2. ***A.*** *Total Fraser Sockeye annual returns (blue bars). Grey bars from 2009 to 2010 are preliminary return data, and 2011 is the estimated in-season return only (2009-2011 return data are, therefore, subject to change). The 2012 black bar represents the maximum forecast at the 90% probability level (6.6 million), with the white square at the 50% probability level (2.1 million).* ***B.*** *Total Fraser Sockeye productivity (log*$_e$*(returns/spawner)) up to the 2011 return year. The grey line and filled circles presents annual productivity and the black line is the associated smoothed four year running average. The black dot at the end of the time series is the productivity associated with the 2012 median (50%) probability forecast. Return data for 2009 and 2010 are preliminary and for 2011 are in-season estimates only. Escapement data are provided by DFO and return data are provided by the Pacific Salmon Commission. Red dashed line in both plots is the time series average.*

Patterns in survival of Chilko Sockeye smolts migrating from their natal freshwater rearing lake suggest that the persistent declines in total Fraser Sockeye productivity are more likely due to poorer survival in the marine environment as opposed to freshwater (Figure 3A and B). In the absence of leading indicators, it is unclear whether the recent improvements in productivity will persist long-term.

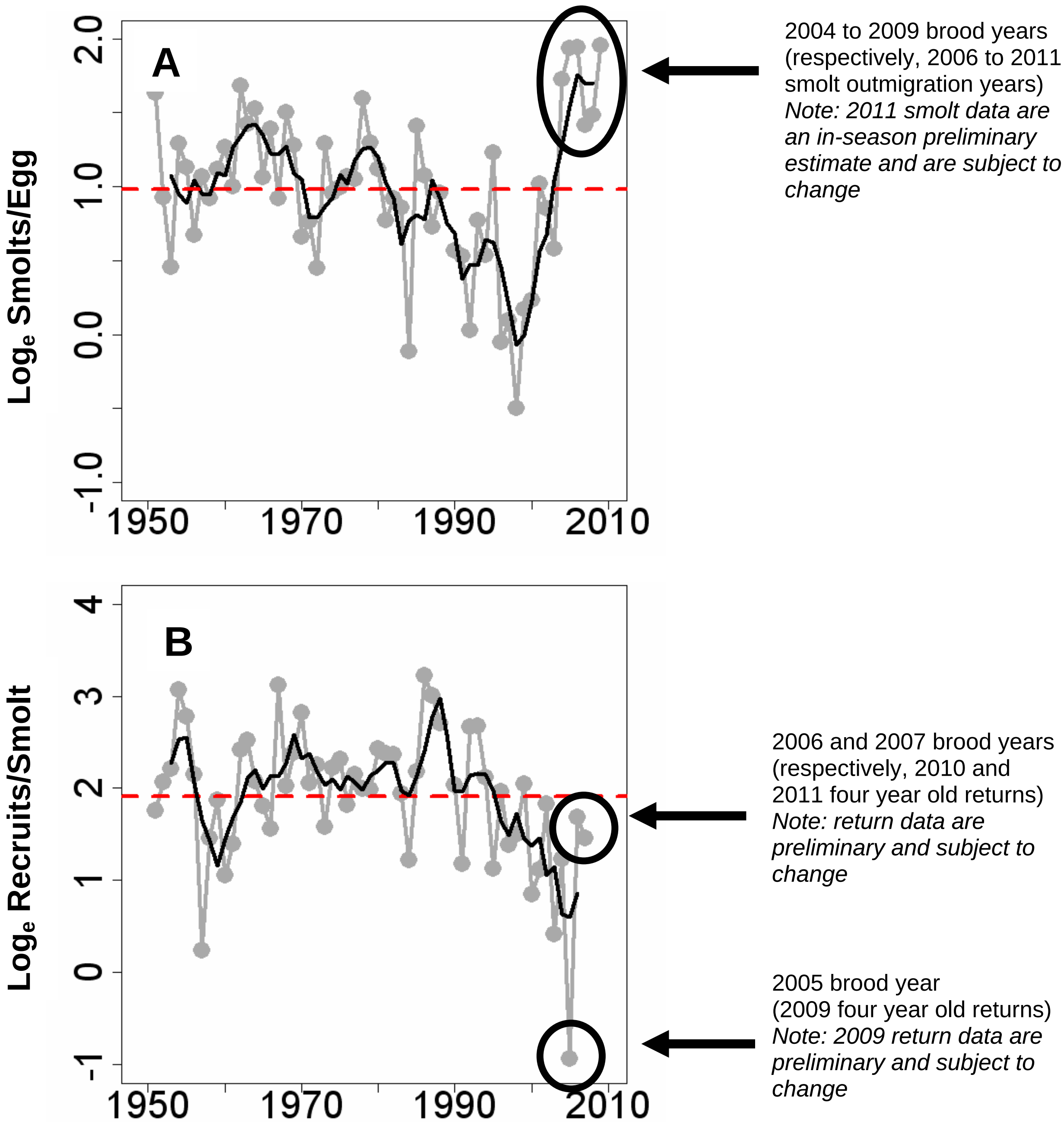


*Figure 3. Chilko River Sockeye **A.** freshwater (log$_e$ smolts per egg) and **B.** marine (log$_e$ recruits per smolt) annual survival (grey line and solid circles) and smoothed four-year running average survival (black line). Red dashed line in both plots indicate long-term average survival.*

ANALYSIS

Forecast Methods

The 2012 forecast approach follows procedures established for previous forecasts with the following exceptions:

- A single forecast scenario is presented.
- Jack-knife analysis, rather than retrospective analysis, was used to generate a time series of forecasts for the model evaluation process.
- The full suite of appropriate candidate models for each stock was evaluated using the full jackknife time series.
- Revised criteria and procedures were used in the model selection process.

The model composition for the 2012 forecast includes a mixture of models that consider both long-term productivity (RAC, TSA, MRS, RSC, power, Ricker, Ricker-cyc, Ricker-environmental covariate, power-environmental covariate, and Larkin), and recent productivity (R1C, R2C, RS1, RS2, RS4yr, RS8yr, and KF)(see MacDonald & Grant 2012 for model descriptions). The forecast model selected for each stock is provided in Tables 1 and 3. The mathematical properties of the model selected for each stock plays an important role in interpreting returns and in making inferences regarding the productivity associated with each forecast.

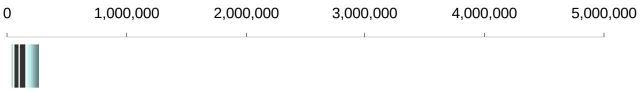
2012 Fraser Sockeye Forecasts

The 2012 forecast indicates a one in 10 chance (10% probability) that the total Fraser Sockeye return will be at or below 743,000, and a nine in 10 chance (90% probability) it will be at or below 6.6 million. The mid-point of this distribution (50% probability) is 2.1 million at which there is an equal chance of a higher or lower return (Table 1, Columns J-N). This forecast assumes that stock productivity is similar to past observations. Productivities associated with these forecasts are presented in Table 2.

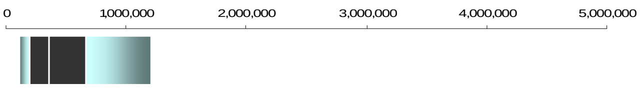
The Fraser Sockeye return forecast for 2012 is dominated by Summer Run stocks (contributing 67% to the total forecasted return) (Figure 4). In particular, Chilko (27%), Late Stuart (16%) and Stellako (11%) are expected to contribute the greatest proportions. In contrast, most Fraser Early Summer and Late Run stocks exhibited amongst the lowest brood year escapements on record in 2008, therefore, forecasts for each of these run timing groups contribute little (Early Summer: 17% and Late: 11%) to the overall 2012 Fraser Sockeye forecast (Figure 4). The Early Stuart Run contributes only 5% to the total forecast despite its average brood year escapement, given that this is a subdominant cycle year for this stock (Figure 4). The forecasted return for Cultus Sockeye, listed as ‘endangered’ by the Committee for Endangered Wildlife in Canada (COSEWIC), is smaller than the previous few years, given the lower number of outmigrating smolts observed from the brood year (2008: ~145,000 versus previous 2006 and 2007 brood years: ~400,000).

The total 2012 Fraser Sockeye forecasted return falls largely (at probability levels up to 75%) below the cycle average (3.8 million)(Table 1). If the low productivity trends of recent decades resumes for Fraser Sockeye, the 2012 return has the potential to be amongst the lowest observed on this cycle. Conversely, there is a small chance (one in four) the return could be above the cycle average, if stock productivities fall at the high end of past observations.

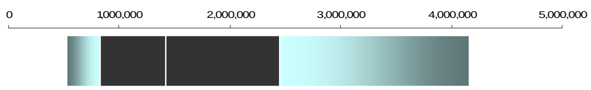
A. Early Stuart



B. Early Summer



C. Summer



D. Late Run

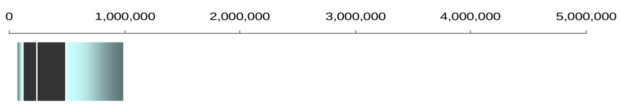


*Figure 4. Fraser Sockeye 2012 forecast probability distributions for **A**. Early Stuart; **B**. Early Summer; **C**. Summer and **D**. Late Run timing groups. These figures describe the stochastic (random) uncertainty in Fraser Sockeye forecasts as probability distributions. The width of the blue (or grey) bars represents the 10% and 90% probability levels, the width of the black bars represents the 25% to 75% probability levels, and the white line in the centre of the black bars represents the 50% probability level.*

The predicted contribution of four year old fish in the 2012 returns across all stocks (~75%) is below average (82% average four year old proportions for all stocks combined, excluding Harrison) (Table 3). The stock-specific proportion of four year olds ranged from 10% to 98%, (Table 3). For most stocks (20 out of the 25 stocks, including miscellaneous stocks), the five year old (2007) brood year escapement was greater than the four year old (2008) escapement. In particular, there were a number of stocks for which four year old brood year escapement was amongst the lowest on record, contributing to the below average overall four year old proportion.

Table 1. Fraser Sockeye forecasts for 2012 by stock and timing group at five probability levels (columns A and J to N). The forecast model selected for each stock is presented in column B. Average run sizes are presented across all cycles (H) and for the 2012 cycle (I). Brood year escapements (smolts for Chilko and Cultus) for four (2008) and five year old (2007) recruits returning in 2012 (columns C and D) are presented and colour-coded relative to their cycle average from the 1948-2004 brood years. Forecasted returns (column G), that correspond to the 50% probability level (column L), and geometric average four year old productivities $\log_e(R/EFS)$ associated with returns from the last eight (1998-2005) (column E) and last four brood years (2002-2005) (column F) are also colour-coded relative to their cycle average. Colour codes represent the following: red (< average), yellow (average) and green (> average).

A	B	C	D	E	F	G	H	I	J	K	L	M	N
Run timing group		BY (08)	BY (07)	Prod.	Prod.	Ret	**Mean Run Size**		**Probability that Return will be at or below Specified Run Size [a]**				
Stocks	**Forecast Model [b]**	(EFS)	(EFS)	(-8yr)	(-4yr)	2012	all cycles[c]	2012 cycle[d]	10%	25%	50%	75%	90%
Early Stuart	*Ricker (Ei)*	14,400	2,400	2.5	2.1		311,000	120,000	39,000	61,000	99,000	161,000	270,000
Early Summer							510,000	517,000	109,000	195,000	359,000	665,000	1,214,000
(total excluding miscellaneous)							*510,000*	*517,000*	*62,000*	*103,000*	*194,000*	*362,000*	*638,000*
Bowron	*KF*	300	1,100	2.8	2.3		39,000	27,000	1,000	1,000	2,000	4,000	6,000
Fennell	*Power*	200	6,800	4.0	3.2		25,000	34,000	5,000	7,000	12,000	20,000	32,000
Gates	*KF*	1,800	1,100	4.5	3.1		53,000	135,000	4,000	6,000	12,000	21,000	36,000
Nadina	*MRJ*	10,200	1,000	3.0	3.5		80,000	137,000	17,000	33,000	70,000	147,000	289,000
Pitt	*KF*	5,400	19,900	0.3	0.1		72,000	81,000	11,000	18,000	35,000	65,000	110,000
Raft	*Ricker (PDO)*	3,600	8,100	2.7	2.0		32,000	57,000	22,000	34,000	55,000	88,000	135,000
Scotch	*Larkin*	100	4,800	6.7	3.5		78,000	12,000	100	200	300	700	1,400
Seymour	*Ricker-cyc*	300	5,900	5.4	3.6		131,000	34,000	2,000	4,000	8,000	16,000	29,000
Misc [e]	*RS (Sc/Se)*	500	3,800				NA	NA	1,000	3,000	6,000	10,000	17,000
Misc [f]	*RS (Ra/Fe)*	200	1,000				NA	NA	1,000	2,000	3,000	6,000	13,000
Misc [g]	*RS (Ra/Fe)*	1,000	9,900				NA	NA	8,000	14,000	24,000	49,000	99,000
Misc [h]	*RS (Esum)*	19,700	1,100				NA	NA	36,000	70,000	127,000	230,000	431,000
Misc [i]	*RS (Esum)*	150	2,000				NA	NA	1,000	3,000	5,000	8,000	16,000
Summer							3,730,000	2,501,000	529,000	828,000	1,420,000	2,449,000	4,160,000
Chilko [j]	*KF (juv)*	11.8 M	25.2 M	0.02	0.02		1,350,000	1,790,000	229,000	342,000	562,000	868,000	1,274,000
Late Stuart	*Power*	57,900	4,100	2.6	2.1		560,000	187,000	92,000	166,000	338,000	730,000	1,550,000
Quesnel	*R1C*	2,500	33,800	1.0	1.0		1,358,000	57,000	17,000	33,000	67,000	137,000	261,000
Stellako	*R2C*	73,800	19,600	1.5	0.7		462,000	467,000	191,000	287,000	453,000	714,000	1,075,000
Late							3,020,000	711,000	66,000	119,000	241,000	488,000	990,000
(total exlcuding miscellaneous)							*3,020,000*	*711,000*	*62,000*	*112,000*	*228,000*	*465,000*	*950,000*
Cultus [j]	*KF (juv)*	145,300	341,000	0.02	0.02		39,000	21,000	1,000	1,000	3,000	7,000	15,000
Harrison[k]	*KF*	4,400	100,600	6.3	3.4		60,000	19,000	20,000	39,000	83,000	184,000	401,000
Late Shuswap	*Ricker-cyc*	80	32,300	2.4	0.7		2,152,000	29,000	1,000	3,000	8,000	19,000	46,000
Portage	*Larkin*	60	800	3.5	2.2		40,000	16,000	500	1,000	2,000	4,000	9,000
Weaver	*RS4yr*	600	15,800	8.8	3.9		363,000	345,000	12,000	23,000	47,000	96,000	181,000
Birkenhead	*KF*	6,800	54,300	1.6	0.9		366,000	281,000	27,000	45,000	85,000	155,000	298,000
Misc. non-Shuswap[l]	*RS (Birkenhead)*	900	2,600				NA	NA	4,000	7,000	13,000	23,000	40,000
TOTAL SOCKEYE SALMON							-	-	743,000	1,203,000	2,119,000	3,763,000	6,634,000
(TOTAL excluding miscellaneous)							*(7,571,000)*	*(3,849,000)*	*(692,000)*	*(1,104,000)*	*(1,941,000)*	*(3,437,000)*	*(6,018,000)*

a. Probability that return will be at, or below, specified projection.
b. See Grant and MacDonald (2012) for model descriptions.
c. Sockeye: 1953-2009 (depending on start of time series).
d. Sockeye: 1956-2008 (depending on start of time series).
e. Unforecasted miscellaneous Early Summer stocks (Early Shuwap stocks: S.Thompson; used Scotch/Seymour R/EFS).
f. Unforecasted miscellaneous Early Summer stocks (N. Thomson tributaries; used Raft/Fennell R/EFS).
g. North Thompson River (used Raft/Fennell R/EFS).
h. Chilliwack Lake and Dolly Varden Creek (used Early Summer R/EFS).
i. Nahatlach River and Lake (used Early Summer R/EFS).
j. Brood year smolts in columns C and D (not EFS).
k. Harrison are age-4 (column C) and age-3 (column D).
l. Unforecasted miscellaneous Late Run stocks (Harrison Lake down stream migrants including Big Silver, Cogburn, etc.; used Birkenhead R/EFS).

Definitions: BY: Brood year; BY08: brood year 2008; BY07: brood year 2007; EFS: effective female spawners; Prod. (8yr), Prod. (4yr): Productivity in age-4 recruits-per-effective female spawners in the last 8 yrs (1998-2005) or last 4 yrs (2001-2005); Ei (Entrance Island sea-surface-temperature); PDO (Pacific Decadal Oscillation).

Table 2. Geometric average four year old productivities $\log_e$(R/EFS) for each of the 19 forecasted stocks (column A) in their timing group. The average is given for four groupings of brood years: 1) up to and including 1979 (column B); 2) 1980 – 2005 (column C); 3) the most recent eight brood years (1998-2005) (column D), 4) and the most recent four brood years (2002-2005) (column E). Four year old productivities associated with the various probability levels of the 2012 forecast (based on Table 1 forecasts and escapements) are presented in columns (F) to (J). Forecast productivities are presented as R/EFS, but the $\log_e$ (R/EFS) was used to determine colour codes for columns (B) to (E) (see methods in Grant et al. 2010). Colour codes represent the following: Red (< average), yellow (average) and green (>average).

A	B	C	D	E	F	G	H	I	J
Run timing group	Early Time Series	Reference Period	Last 8 yrs	Last 4 yrs	"Long-Term Average" 2012 forecast productivities (R/EFS) for each probability level in Table 1				
Stocks	Avg R/EFS (up to 1979)	Avg R/EFS (1980-2005)	Avg R/EFS (1998-2005)	Avg R/EFS (2002-2005)	10%	25%	50%	75%	90%
Early Stuart	9.5	3.9	2.5	2.1	2.6	4.1	6.7	11.0	18.6
Early Summer									
Bowron	9.0	4.8	2.8	2.3	1.5	2.2	4.4	7.3	12.7
Fennell	20.0	4.1	4.0	3.2	6.2	10.5	19.0	34.8	57.1
Gates	17.0	7.3	4.5	3.1	1.7	3.1	6.0	11.0	19.3
Nadina	10.1	5.3	3.0	3.5	1.6	3.2	6.7	14.2	27.7
Pitt	2.6	0.6	0.3	0.1	0.1	0.2	0.6	1.4	2.5
Raft	7.9	4.5	2.7	2.0	1.6	2.8	5.2	9.2	16.4
Scotch		6.7	6.7	3.5	0.5	0.9	1.9	4.0	8.6
Seymour	10.9	5.1	5.4	3.6	2.5	3.9	7.4	13.0	23.5
Summer									
Chilko[a]	0.08	0.06	0.02	0.02	0.01	0.02	0.04	0.06	0.10
Late Stuart	11.3	7.3	2.6	2.1	1.4	2.6	5.6	12.4	26.5
Quesnel[b]	10.2	4.8	1.0	1.0	1.6	3.1	6.3	12.9	24.6
Stellako	10.1	4.5	1.5	0.7	2.3	3.5	5.4	8.6	12.9
Late									
Cultus[a]	0.05	0.04	0.02	0.02	0.00	0.01	0.02	0.05	0.10
Harrison	2.3	4.9	6.3	3.4	1.1	3.4	8.9	23.4	55.2
Late Shuswap[b]	5.9	4.0	2.4	0.7	0.0	0.0	1.2	4.8	14.5
Portage	20.9	8.8	3.5	2.2	4.8	7.9	19.0	41.3	96.8
Weaver	15.2	10.2	8.8	3.9	2.1	3.9	7.9	16.0	30.3
Birkenhead	9.4	3.0	1.6	0.9	0.6	1.2	2.7	6.0	11.9

a. Chilko and Cultus are marine survival (recruits per smolt).

b. Quesnel and Late Shuswap are cycle averages.

Table 3. Fraser River Sockeye four and five year old and total return forecasts for 2012 by stock and timing group at five probability levels. Four year old proportions (four year olds divided by the total four plus five year olds, at the 50% probability level) are presented in the final column. Yellow (grey) highlighted row is Harrison Sockeye, where five year old forecasts are actually three year olds, given this stock's unique age structure.

		Probability that actual return will be at or below specified run size															Four Year Old
Timing group/		Four Year Olds					Five Year Olds					Total					Proportions
Stock	Model	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%	10%	25%	50%	75%	90%	(at 50% p-level)
Early Stuart	Ricker (Ei)	**37,000**	**59,000**	**97,000**	**159,000**	**269,000**	**2,000**	**2,000**	**2,000**	**2,000**	**1,000**	**39,000**	**61,000**	**99,000**	**161,000**	**270,000**	**0.98**
Early Summer																	
Bowron	*KF*	0	1,000	1,000	2,000	4,000	1,000	1,000	1,000	2,000	3,000	1,000	1,000	2,000	4,000	6,000	**0.50**
Fennell	*Power*	1,000	2,000	4,000	7,000	12,000	3,000	5,000	8,000	13,000	20,000	5,000	7,000	12,000	20,000	32,000	**0.33**
Gates	*KF*	3,000	5,000	11,000	19,000	34,000	1,000	1,000	1,000	2,000	2,000	4,000	6,000	12,000	21,000	36,000	**0.92**
Nadina	*MRJ*	17,000	32,000	68,000	144,000	282,000	0	1,000	2,000	4,000	7,000	17,000	33,000	70,000	147,000	289,000	**0.97**
Pitt	*KF*	1,000	1,000	3,000	7,000	14,000	10,000	17,000	32,000	58,000	97,000	11,000	18,000	35,000	65,000	110,000	**0.09**
Raft	*Ricker (PDO)*	6,000	10,000	19,000	33,000	58,000	16,000	24,000	36,000	55,000	76,000	22,000	34,000	55,000	88,000	135,000	**0.35**
Scotch	*Larkin*	70	130	260	560	1,200	0	20	50	100	200	70	150	310	660	1,400	**0.84**
Seymour	*Ricker -cyc*	1,000	1,000	2,000	4,000	7,000	2,000	3,000	6,000	12,000	23,000	2,000	4,000	8,000	16,000	29,000	**0.25**
Misc [e]	RS	1000	2000	4000	7000	12000	0	1,000	2,000	3,000	6,000	1,000	3,000	6,000	10,000	17,000	**0.67**
Misc [f]	RS	1,000	1,000	2,000	3,000	6,000	1,000	1,000	2,000	4,000	7,000	1,000	2,000	3,000	6,000	13,000	**0.67**
Misc [g]	RS	2,000	4,000	6,000	13,000	27,000	6,000	10,000	17,000	36,000	72,000	8,000	14,000	24,000	49,000	99,000	**0.25**
Misc [h]	RS	35,000	69,000	125,000	227,000	425,000	1,000	1,000	2,000	4,000	7,000	36,000	70,000	127,000	230,000	431,000	**0.98**
Misc [i]	RS	0	1,000	1,000	2,000	3,000	1,000	2,000	4,000	7,000	12,000	1,000	3,000	5,000	8,000	16,000	**0.20**
Summer																	
Chilko	*KF(juv)*	159000	266000	441000	733000	1158000	70,000	76,000	121,000	135,000	116,000	229,000	342,000	562,000	868,000	1,274,000	**0.78**
Late Stuart	*Power*	80,000	153,000	322,000	717,000	1,535,000	13,000	13,000	16,000	13,000	15,000	92,000	166,000	338,000	730,000	1,550,000	**0.95**
Quesnel [a]	*R1C*	4,000	8,000	16,000	32,000	61,000	13,000	25,000	52,000	105,000	201,000	17,000	33,000	67,000	137,000	261,000	**0.24**
Stellako [a]	*R2C*	169,000	255,000	402,000	633,000	953,000	22,000	33,000	51,000	81,000	121,000	191,000	287,000	453,000	714,000	1,075,000	**0.89**
Late																	
Cultus	*KF(juv)*	1000	1000	3000	7000	15000	0	0	0	0	0	1,000	1,000	3,000	7,000	15,000	**1.00**
Harrison [b]	*KF*	5,000	15,000	39,000	103,000	243,000	15,000	24,000	44,000	81,000	158,000	20,000	39,000	83,000	184,000	401,000	**0.47**
Late Shuswap	*Ricker-cyc*	0	0	0	0	1,000	1,000	3,000	8,000	19,000	45,000	1,000	3,000	8,000	19,000	46,000	**0.00**
Portage	*Larkin*	0	1,000	1,000	3,000	6,000	0	1,000	1,000	2,000	3,000	500	1,000	2,000	4,000	9,000	**0.50**
Weaver	*RS4yr*	1,000	2,000	5,000	10,000	19,000	11,000	21,000	42,000	86,000	163,000	12,000	23,000	47,000	96,000	181,000	**0.11**
Birkenhead	*KF*	4,000	8,000	18,000	41,000	81,000	23,000	37,000	67,000	115,000	217,000	27,000	45,000	85,000	155,000	298,000	**0.21**
Misc. non-Shuswa	RS	2,000	3,000	6,000	11,000	19,000	2,000	4,000	7,000	12,000	21,000	4,000	7,000	13,000	23,000	40,000	**0.46**
Total		**530,070**	**900,130**	**1,596,260**	**2,917,560**	**5,245,200**	**214,000**	**306,020**	**524,050**	**851,100**	**1,393,200**	**743,000**	**1,203,000**	**2,119,000**	**3,763,000**	**6,634,000**	**0.75**

a. Age composition for non-parametric forecasts are calculated using the proportion that would be applied by a biological model.
b. Harrison are four year old (in four year old columns) and three year old (in five year old columns) forecasts.

Please note: the following footnotes are given the same letter subscript as the equivalent footnote in Table 1.
e. Unforecasted miscellaneous Early Summer Stocks (Early Shuwap stocks: S.Thompson); return timing most similar to Scotch/Seymour (Sc/Se).
f. Unforecasted miscellaneous Early Summer stocks (N. Thomson tributaries; return timing most similar to Raft/Fennell (Ra/Fe)).
g. North Thompson River .
h. Chilliwack Lake and Dolly Varden Creek (Esum).
i. Nahatlach River & Lake (Esum).
l. Unforecasted miscellaneous Late Run stocks (Harrison L.).

Source of Uncertainty

Considerable Sockeye mortality occurs in both the freshwater and marine environment throughout their life history from the egg stage to when the adults return to the Fraser watershed to spawn. Currently, Fraser Sockeye forecasts are associated with large uncertainty (i.e., wide probability distributions). In attempts to improve the predictability of Fraser Sockeye productivity, return forecasts have incorporated environmental variables, both quantitatively into forecast models (Grant et al. 2010; Grant and MacDonald 2012), and qualitatively into forecast advice (DFO 2012). However, to-date, the inclusion of environmental variables has not explained a significant portion of the variability in annual survival rates or significantly decreased forecast uncertainty. As a result, forecasts are presented as probability distributions from the 10% to 90% probability levels. Structural uncertainty in the forecast models is also explored through the comparison of stock forecasts using different top ranked models (MacDonald and Grant 2012). On-going research and workshops are recommended to explore environmental variables that could be used to explain inter-annual variability in Fraser Sockeye recruitment.

CONCLUSIONS

- For the 2012 forecast there is a one in 10 chance (10% probability) that the total Fraser Sockeye return will be at or below 743,000, and a nine in 10 chance (90% probability) it will be at or below 6.6 million, assuming stock productivity is similar to past observations. The mid-point of this distribution (50% probability) is 2.1 million (there exists a one in two chance the return will be above or below this value).
- Given the below average brood year escapements for a large number of stocks, there is a three out of four chance the 2012 returns will fall below the cycle average, assuming stock productivity is similar to past observations. There is only a one in four chance returns will be above the cycle average.
- The total four year old proportion of the 2012 forecast (~75% of the total four plus five year old forecast at the 50% probability level) is below average (82%). Four year old proportions ranged from 10% to 98% depending on the stock. This is attributed to the generally low brood year escapements of four year old versus five year old Sockeye, particularly for Early Summer and Late Run stocks.
- Model performance was evaluated for the full suite of long-term productivity (RAC, TSA, MRS, RSC, power, Ricker, Ricker-cyc, Ricker-environmental covariate, power-environmental covariate, and Larkin), and recent productivity (R1C, R2C, RS1, RS2, RS4yr, RS8yr, and KF) models across a stock’s entire stock-recruitment time series. As a result, model composition for the 2012 forecast includes a mixture of both types of models. It is important to consider the type of model being used for each stock in pre-season planning and comparisons on in-season returns to forecasts (i.e. recent productivity models tend to produce lower forecasts compared to long-term productivity models).

SOURCES OF INFORMATION

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat, Regional Peer Review Meeting on February 1, 2012 on the *Assessment of Fraser River Sockeye Salmon and Forecast 2012*. Additional publications from this process will be posted as they become available on the Fisheries and Oceans Canada Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

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