Calibration of Visual Assessment Methods for Fraser River Sockeye Salmon *(Oncorhynchus nerka)* - Year 6

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INTRODUCTION

The enumeration of Fraser River Sockeye salmon *(Oncorhynchus nerka)* spawning escapements have historically followed a well established two-tiered protocol developed by the former International Pacific Salmon Fisheries Commission (IPSFC). An abundance threshold of 25,000 spawners determined the methodology employed, with low precision visual techniques for escapements less than 25,000, and high precision techniques (fences, hydroacoustic systems or mark-recaptures) for escapements greater than 25,000. Decreasing financial resources coupled with larger spawning escapements led to an increase in the abundance threshold from 25,000 to 75,000 spawners in 2004. As a result, visual methods are now being used to enumerate streams and populations much larger than they were historically. The standard expansion factor currently applied to visual counts to account for the consistent underestimation of live counts was developed using ground survey methods on very small, clear stream populations with relatively low (less than 25,000) spawner abundances in the Fraser River system. Its application to larger streams with larger abundances will lead to substantial negative bias in spawning estimates.

In 2014, the Southern Boundary Restoration and Enhancement Fund (SEF) funded the sixth of a multi-year calibration study to minimize bias in visually enumerated Sockeye salmon populations in the Fraser River watershed. Summaries of the first five years of the calibration study have been presented in Welch et al. 2011, Benner et al. 2012, Benner et al. 2013 and Benner et al. 2014. The following report provides a summary of the 2014 specific calibration activities as well as a summary of all calibration efforts on populations under 125,000 spawners conducted to date.

METHODS

In 2014, calibration efforts focused on five populations where high precision methodologies were employed; the Birkenhead River, Seymour River, Scotch Creek and the *Early* and *Late* Eagle River populations. Hydroacoustic imaging systems (DIDSON and/or ARIS) were employed at the Birkenhead River (DFO and Lil'wat First Nations funded) and *Early* Eagle River (DFO funded); enumeration fences were operated at Scotch Creek (Secwepmc Fisheries Commission funded) and the *Late* Eagle River (DFO funded); and a mark-recapture study was conducted at Seymour River (DFO funded).

For the purpose of calibration, low precision visual counts (live and dead) were conducted at the peak of spawn in all systems. Indices were generated for each population by dividing the respective high precision estimate by the peak visual count (live plus dead). A more detailed description of the calibration methods employed in this study is presented in Welch et al. 2011.

RESULTS

2014 CALIBRATION ACTIVITIES

Birkenhead River

One aerial survey of the Birkenhead River was conducted on September 26th with a total of 12,064 Sockeye salmon (live + dead) enumerated. The index generated from comparing the aerial count to the DIDSON estimate of 35,759 Sockeye salmon is 2.96 (Table 1).

Seymour River

One aerial survey of the Seymour River was conducted on September 9th with a total of 34,770 Sockeye salmon (live + dead) enumerated. The index generated from comparing the aerial count to the M/R estimate of 114,013 Sockeye salmon is 3.28 (Table 1).

Scotch Creek

Two aerial surveys of Scotch Creek were conducted on September 6th and 9th with a total of 23,350 and 34,860 Sockeye salmon (live + dead) enumerated, respectively. The index generated from comparing the peak aerial count to the fence estimate of 133,927 Sockeye salmon is 3.84 (Table 1).

Eagle (Early) River

One aerial survey of the *Early* Eagle River was conducted on September 6th with a total of 66,386 Sockeye salmon (live + dead) enumerated. The index generated from comparing the aerial count to the DIDSON estimate of 209,318 Sockeye salmon is 3.15 (Table 1).

Eagle (Late) River

One aerial survey of the *Late* Eagle River was conducted on October 16th with a total of 39,400 Sockeye salmon (live + dead) enumerated. The index generated from comparing the aerial count to the fence estimate of 149,970 Sockeye salmon is 3.81 (Table 1).

Table 1. Summary of low precision visual counts, high precision escapement estimates and the resulting indices at Birkenhead, Seymour and Eagle rivers and Scotch Creek, 2014.

			Low Precision		High Precision		
Stream	Size	Water Clarity	Method	Count [a]	Method	Estimate	Index
Birkenhead	Medium	Pt. Turbid	Aerial	12,064	DIDSON	35,759	2.96
Seymour [b]	Medium	Clear	Aerial	34,770	M/R	114,013	3.28
Scotch	Small	Clear	Aerial	34,860	Fence	133,927	3.84
Early Eagle [c]	Medium	Pt. Turbid	Aerial	66,386	DIDSON	209,318	3.15
Late Eagle [d]	Medium	Clear	Aerial	39,400	Fence	149,970	3.81

[a] Peak live count plus dead carcasses observed.

[b] McNomee Creek included in the M/R estimate.

[c] High precision estimate of mainstem only (above ARIS); does not include tributaries (Perry, Loftus, Yard, Crazy).

[d] High precision estimate of mainstem only (above fence); does not include Crazy Creek.

SUMMARY OF CALIBRATION EFFORTS (1988-2014)

Under current Fraser Sockeye management requirements, it is generally accepted that larger Sockeye spawning populations should not be enumerated using low precision visual methods. Calibration work conducted on all Fraser Sockeye populations to date (ranging between 167 and 491,098 spawners) generally confirms that the variability in the calibration data points (indices) increases with spawner abundance. Although the threshold for high precision methods was increased to 75,000 spawners in 2004, this summary includes populations up to 125,000 spawners as the variability within this range of abundances appears to be falling within reasonably acceptable ranges (Tables 2 and 3). Although the data is limited, indices that have been generated on populations above 125,000 spawners to date have shown much more variability indicating that visual methods may be suitable for populations up to 125,000 spawners.

Since calibration efforts began in 1988, a total of 104 calibration data points (indices) have been generated on Fraser River Sockeye salmon populations of less than 125,000 spawners (Tables 2 and 3 and Appendix 1). Of these, 71 were based on ground surveys (Table 2) and 33 were based on aerial surveys (Table 3). Of the 71 ground survey based indices, 53 were on very small sized, clear stream populations; 1 on a small sized, clear stream population; 10 on medium sized (eight clear and two partially turbid/tannic) stream populations; and 7 on large sized (five clear and two partially turbid/tannic) stream populations (Table 2). Of the 33 aerial survey based indices, 4 were on small sized (2 clear and two partially turbid/tannic) stream populations; 14 on medium sized (7 clear, 5 partially turbid/tannic and two turbid) stream

populations; 5 on large sized (3 clear and 2 partially turbid/tannic) stream populations; and 10 on extra-large sized (1 clear and 9 partially turbid/tannic) stream populations (Table 3).

Although the number of data points collected to date for most stream types is still relatively low, clear signals and trends within the data have been identified. Generally, the average index increases with stream size and water clarity (from clear to turbid) for both ground and aerial survey methods (Tables 2 and 3). The indices generated for very small, clear streams (all ground based) average 1.7 and range between 1.07 and 2.85, indicating that the use of the standard 1.8 index expansion factor is appropriate for these stream types that typically support small to moderate abundances with relatively short spawner durations. However, the larger streams (small, medium and large) with typically larger abundances and longer spawner periods reveal notably higher average indices; thus, likely often result in biased low escapement estimates when applying the standard 1.8 index.

Table 2. Summary of ground calibration surveys stratified by stream size and water clarity for Fraser Sockeye spawning populations under 125,000, 1988-2014.

Size	Water Clarity	Number of calibration surveys (n)	Average Population Estimate	Population Range	Average Index	Index Range	Standard Deviation	Coefficient of Variation
Very Small	Clear	53	9,005	167 - 38,248	1.70	1.07 - 2.85	0.38	0.22
	Pt. Turbid / Tannic	0	-	-	-	-	-	-
	Turbid	0	-	-	-	-	-	-
Small	Clear	1	122,158	-	2.31	-	-	-
	Pt. Turbid / Tannic	0	-	-	-	-	-	-
	Turbid	0	-	-	-	-	-	-
Medium	Clear	8	73,905	26,608 - 111,501	1.88	1.10 - 2.62	0.59	0.31
	Pt. Turbid / Tannic	2	35,306	14,420 - 56,192	2.42	2.17 - 2.67	0.35	0.15
	Turbid	0	-	-	-	-	-	-
Large	Clear	5	65,330	41,481 - 91,443	2.37	1.85 - 2.92	0.47	0.20
	Pt. Turbid / Tannic	2	67,022	56,006 - 78,038	2.46	2.18 - 2.74	0.40	0.16
	Turbid	0	-	-	-	-	-	-
Extra Large*	Clear	0	-	-	-	-	-	-
	Pt. Turbid / Tannic	0	-	-	-	-	-	-
	Turbid	0	-	-	-	-	-	-

*Extra Large streams not surveyed using ground methods

Table 3. Summary of aerial calibration surveys stratified by stream size and water clarity for Fraser Sockeye salmon spawning populations under 125,000, 1988-2014.

Size	Water Clarity	Number of calibration surveys (n)	Average Population Estimate	Population Range	Average Index	Index Range	Standard Deviation	Coefficient of Variation
Very Small *	Clear	0	-	-	-	-	-	-
	Pt. Turbid / Tannic	0	-	-	-	-	-	-
	Turbid	0	-	-	-	-	-	-
Small	Clear	2	102,782	83,406 - 122,158	1.89	1.26 - 2.52	0.89	0.47
	Pt. Turbid / Tannic	2	12,710	2,387 - 23,032	2.54	2.04 - 3.05	0.72	0.28
	Turbid	0	-	-	-	-	-	-
Medium	Clear	7	78,567	26,608 - 124,074	2.24	1.51 - 3.63	0.56	0.25
	Pt. Turbid / Tannic	5	57,629	13,682 - 124,148	2.87	2.13 - 3.40	0.46	0.16
	Turbid	2	49,900	28,478 - 71,322	5.80	4.17 - 7.44	2.32	0.40
Large	Clear	3	59,941	41,481 - 85,628	3.07	2.91 - 3.28	0.19	0.06
	Pt. Turbid / Tannic	2	67,022	56,006 - 78,038	2.48	2.48 - 2.49	0.01	0.00
	Turbid	0	-	-	-	-	-	-
Extra Large	Clear	1	19,345	-	2.60	-	-	-
	Pt. Turbid / Tannic	9	68,036	28,309 - 123,014	3.93	1.48 - 8.78	2.43	0.62
	Turbid	0	-	-	-	-	-	-

* Very Small streams not surveyed using aerial methods

It should be noted that the historical calibration data set was recently revised to reflect inappropriate historical stream type classifications and to remove suspected biased data points. These include changes to the 2009 and 2010 Mitchell River and 1995 Seymour River data points where the water clarity was revised from partially turbid to clear. Additionally, two data points, the 2007 Upper and Lower Horsefly River, were removed from the data set as it is believed they were likely biased due the influence of the spawning channel diversion fence on spawner behavior.

DISCUSSION

There are many factors that contribute to the development of indices, however, the main drivers relate to the observer's ability to effectively observe spawning salmon (observer efficiency) and spawner replenishment (Welch et al. 2011).

Factors such as wind, glare and shadows all influence observer efficiency, but since peak live count surveys are typically scheduled during favorable conditions, observer efficiency is largely influenced by the size (depth and width) of the stream and water clarity (Welch et al. 2011) when abundances are below 125,000 and the count is obtained at the peak of spawning

activity. As a result, observer efficiency can be sufficiently controlled for in the development of indices by categorizing streams based on these characteristics. Therefore, all Fraser Sockeye spawning streams have been classified into fifteen stream types based on size (very small, small, medium, large or extra-large) and water clarity (clear, tannic/partially turbid or turbid) for the purpose of developing stream type indices (i.e. an index developed at one location may applied to other streams within the watershed that share similar stream type criteria) (Appendix 2) (Welch et al. 2011).

In addition to stream type, indices must also be generated by survey method as counter efficiency differs considerably between ground and aerial survey methods (Welch et al. 2011). On average, aerial counts are approximately 87% of simultaneous ground counts, resulting in higher indices for aerial based surveys (Benner et al. 2013). Therefore indices must be stream type and method specific.

Unlike stream type, spawner replenishment, the other main factor in the development of indices, is more difficult to adequately address in the development of indices with the data available. While it is difficult to estimate the rate of spawner replenishment on a stream during a given year, it is recognized that the complexity of migration and spawning behavior generally increases as the population size increases, typically resulting in longer spawning periods and a higher rate of spawner replenishment. While many of the smaller Fraser River Sockeye populations typically exhibit a short, spawning and migration period many of the larger populations display multi-modal or protracted migration and spawning periods, where arrival, spawning and death occur at a relatively constant rate for an extended period of time. These patterns can be natural but more often develop from significant fishery harvests that can remove considerable portions of the run and result in a broad, flat distribution curve where live counts remain fairly constant over time. Indices in these systems will invariably be higher than those with shorter, normally distributed migration patterns with lower spawner replenishment. These patterns reaffirm that visual survey methods are inadequate for enumerating larger more complex populations.

SUMMARY

Since calibration efforts began in 1988, a total of 104 data points have been generated on populations less than 125,000 spawners by comparing visual estimates to high precision estimates throughout the Fraser River watershed. Most of this work has focused on very small sized streams, with relatively little data collected on the larger sized streams that typically support populations within the 25,000 to 75,000 range. Additional funding by the Southern Boundary and Enhancement Fund since 2007 has led to increased calibration efforts on these larger sized systems resulting in the generation of 23 data points (two small, eight medium, ten large and three extra-large) on populations less than 125,000 spawners. Although this represents significant progress towards the development of stream type and method specific indices on populations within the target abundance threshold range, significant gaps still exist.

As we continue to compile valuable calibration data throughout the Fraser watershed, indices will continue to be shaped with the expectation of decreasing error (CV). However, as outlined earlier, there are a number of confounding factors that contribute to the development of indices which can result in considerable variability within the data. It should be understood that this variability is real and not just a function of a small sample size. While the error will likely reduce in most cases as we obtain more data points, it may never reach levels considered optimal for management purposes (i.e. less than 25%).

Therefore, as calibration work continues it is recommended that the standard 1.8 index continue to be applied to all visually enumerated Sockeye stream populations until one of the following two conditions by stream type and method classification are met: i) a minimum of five data points with an error (CV) of 25% or less is obtained or ii) 10 data points have been generated. As these conditions have now been met for three stream and method specific categories, we recommend adopting the following: i) an index of 2.24 for medium, aerially surveyed clear streams (Table 3), ii) an index of 2.87 for medium, partially turbid/tannic aerially surveyed streams (Table 3) and iii) an index of 2.37 for large, clear ground surveyed streams (Tables 2).

As annual calibration opportunities are limited, continued calibration work over the long term will be required to satisfy these conditions for all stream type and method classifications. It is important that calibration efforts continue anywhere possible regardless of stream type and abundance as additional data points will continue to inform this work and refine the indices and the associated variability. Once indices are adopted and applied, it seems prudent to review and analyze all calibration activities a minimum of every 10 years to apply the most up to date and applicable data.

REFERENCES

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APPENDICES

Appendix 1. Comprehensive summary of calibrated Sockeye populations less than 125,000 in the Fraser River watershed by year and stream type characteristics, 1988-2014.

Year	Stream	Size	Water Clarity	Low Precision Visual Method	Low Precision Visual Count	High Precision Estimate Method	High Precision Estimate	Index
1988	Barriere River, upper	V. Small	Clear	Ground	15,284	Fence	26,932	1.76
1989	Stellako River	Medium	Clear	Ground	21,142	MR	43,189	2.04
1990	Forfar Creek	V. Small	Clear	Ground	7,329	Fence	13,770	1.88
1990	Gluske Creek	V. Small	Clear	Ground	7,578	Fence	11,058	1.46
1990	Scotch Creek	Small	Clear	Aerial	66,274	MR	83,406	1.26
1991	Forfar Creek	V. Small	Clear	Ground	11,083	Fence	18,522	1.67
1991	Gluske Creek	V. Small	Clear	Ground	8,321	Fence	15,294	1.84
1991	O'Ne-Ell Creek	V. Small	Clear	Ground	11,413	Fence	25,352	2.22
1991	Stellako River	Medium	Clear	Ground	42,300	MR	94,931	2.24
1992	Forfar Creek	V. Small	Clear	Ground	3,674	Fence	7,940	2.16
1992	O'Ne-Ell Creek	V. Small	Clear	Ground	3,430	Fence	8,585	2.50
1992	Stellako River	Medium	Clear	Ground	89,103	MR	97,985	1.10
1993	Stellako River	Large	Clear	Ground	46,658	MR	91,443	1.96
1994	Barriere River, upper	V. Small	Clear	Ground	3,879	Fence	5,919	1.53
1994	Forfar Creek	V. Small	Clear	Ground	3,692	Fence	4,377	1.19
1994	Gluske Creek	V. Small	Clear	Ground	1,825	Fence	3,372	1.85
1994	O'Ne-Ell Creek	V. Small	Clear	Ground	2,904	Fence	3,860	1.33
1994	Mitchell River	Medium	Pt. Turbid	Aerial	36,500	MR	124,148	3.40
1994	Seymour River	Medium	Pt. Turbid	Ground	25,866	MR	56,192	2.17
1994	Tachie River	X-Large	Tannic	Aerial	7,216	MR	42,688	5.92
1995	Bowron River	Medium	Tannic	Aerial	12,110	Fence	34,431	2.84
1995	Barriere River, upper	V. Small	Clear	Ground	4,343	Fence	11,251	2.59
1995	Forfar Creek	V. Small	Clear	Ground	12,343	Fence	16,478	1.34
1995	Gluske Creek	V. Small	Clear	Ground	8,972	Fence	15,044	1.68

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Appendix 1. Comprehensive summary of calibrated Sockeye populations less than 125,000 in the Fraser River watershed by year and stream type characteristics, 1988-2014 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Visual Method	Low Precision Visual Count	High Precision Estimate Method	High Precision Estimate	Index
1995	O'Ne-Ell Creek	V. Small	Clear	Ground	16,784	Fence	26,985	1.61
1995	Seymour River	Medium	Clear	Ground	28,509	MR	40,687	1.43
1996	Crow Creek	V. Small	Clear	Ground	433	Fence	845	1.95
1996	Barriere River, upper	V. Small	Clear	Ground	16,994	Fence	32,278	1.90
1996	Forfar Creek	V. Small	Clear	Ground	6,055	Fence	8,381	1.38
1996	Gluske Creek	V. Small	Clear	Ground	7,179	Fence	8,582	1.20
1996	O'Ne-Ell Creek	V. Small	Clear	Ground	9,527	Fence	10,772	1.13
1996	Narrows Creek	V. Small	Clear	Ground	2,409	Fence	2,846	1.18
1996	Paula Creek	V. Small	Clear	Ground	2,866	Fence	4,702	1.64
1996	Weaver Creek	V. Small	Clear	Ground	23,681	MR	38,248	1.62
1997	Forfar Creek	V. Small	Clear	Ground	5,329	Fence	10,070	1.89
1997	Gluske Creek	V. Small	Clear	Ground	7,098	Fence	11,557	1.63
1997	Stellako River	Large	Clear	Ground	22,853	Fence	55,385	2.42
1998	Eagle River (early)	Medium	Turbid	Aerial	3,827	MR	28,478	7.44
1998	Forfar Creek	V. Small	Clear	Ground	420	Fence	956	2.28
1998	Gluske Creek	V. Small	Clear	Ground	459	Fence	812	1.77
1998	Weaver Creek	V. Small	Clear	Ground	9,828	MR	28,042	2.85
1999	Forfar Creek	V. Small	Clear	Ground	1,488	Fence	1,797	1.21
1999	Gluske Creek	V. Small	Clear	Ground	1,183	Fence	1,264	1.07
1999	O'Ne-Ell Creek	V. Small	Clear	Ground	4,585	Fence	6,630	1.45
1999	Little River	X-Large	Clear	Aerial	7,432	MR	19,345	2.60
1999	Seymour River	Medium	Pt. Turbid	Ground	5,399	MR	14,420	2.67
2000	Forfar Creek	V. Small	Clear	Ground	4,144	Fence	7,315	1.77
2000	Gluske Creek	V. Small	Clear	Ground	2,877	Fence	3,936	1.37
2000	O'Ne-Ell Creek	V. Small	Clear	Ground	7,325	Fence	10,890	1.49
2000	Raft River	Medium	Clear	Ground	25,308	MR	66,292	2.62
2000	Adams River, upper	Medium	Turbid	Aerial	17,116	MR	71,322	4.17

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Appendix 1. Comprehensive summary of calibrated Sockeye populations less than 125,000 in the Fraser River watershed by year and stream type characteristics, 1988-2014 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Visual Method	Low Precision Visual Count	High Precision Estimate Method	High Precision Estimate	Index
2001	Dust Creek	Small	Tannic	Aerial	11,309	Fence	23,032	2.04
2001	Forfar Creek	V. Small	Clear	Ground	7,704	Fence	12,868	1.67
2001	Gluske Creek	V. Small	Clear	Ground	6,142	Fence	10,990	1.79
2001	O'Ne-Ell Creek	V. Small	Clear	Ground	5,881	Fence	14,010	2.38
2002	Dust Creek	Small	Tannic	Aerial	783	Fence	2,387	3.05
2002	Forfar Creek	V. Small	Clear	Ground	1,088	Fence	1,912	1.76
2002	Gluske Creek	V. Small	Clear	Ground	1,173	Fence	1,866	1.59
2002	O'Ne-Ell Creek	V. Small	Clear	Ground	1,432	Fence	2,201	1.54
2002	Seymour River	Medium	Clear	Ground	43,099	MR	111,501	2.59
2003	Gluske Creek	V. Small	Clear	Ground	611	Fence	872	1.43
2003	O'Ne-Ell Creek	V. Small	Clear	Ground	1,949	Fence	3,295	1.69
2003	Tachie River	X-Large	Tannic	Aerial	9,994	MR	28,309	2.83
2004	Forfar Creek	V. Small	Clear	Ground	706	Fence	1,003	1.42
2004	Tachie River	X-Large	Tannic	Aerial	27,706	MR	60,862	2.20
2005	Forfar Creek	V. Small	Clear	Ground	3,225	Fence	5,274	1.64
2005	Gluske Creek	V. Small	Clear	Ground	1,822	Fence	3,342	1.83
2005	Kuzkwa River	Medium	Tannic	Aerial	6,415	Fence	13,682	2.13
2005	Middle River	X-Large	Tannic	Aerial	49,636	MR	73,270	1.48
2006	Forfar Creek	V. Small	Clear	Ground	2,071	Fence	3,850	1.86
2006	Gluske Creek	V. Small	Clear	Ground	1,429	Fence	2,075	1.45
2007	Adams River, lower *	Large	Clear	Aerial	16,050	MR	52,713	3.28
2007	Adams River, lower *	Large	Clear	Ground	19,405	MR	52,713	2.72
2007	Horsefly River *	Medium	Clear	Aerial	22,405	MR	55,181	2.46
2007	Gluske Creek	V. Small	Clear	Ground	79	Fence	167	2.11
2007	Stellako River *	Large	Clear	Aerial	14,242	MR	41,481	2.91

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Appendix 1. Comprehensive summary of calibrated Sockeye populations less than 125,000 in the Fraser River watershed by year and stream type characteristics, 1988-2014 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Visual Method	Low Precision Visual Count	High Precision Estimate Method	High Precision Estimate	Index
2007	Stellako River *	Large	Clear	Ground	22,435	MR	41,481	1.85
2008	Forfar Creek	V. Small	Clear	Ground	1,667	Fence	2,608	1.56
2008	Gluske Creek	V. Small	Clear	Ground	778	Fence	1,515	1.95
2008	Tachie River	X-Large	Tannic	Aerial	21,940	MR	123,014	5.61
2009	Forfar Creek	V. Small	Clear	Ground	1,862	Fence	3,244	1.74
2009	Gluske Creek	V. Small	Clear	Ground	1,042	Fence	1,494	1.43
2009	Mitchell River	Medium	Clear	Aerial	18,950	DIDSON	45,741	2.41
2009	Stellako River	Medium	Clear	Aerial	17,566	Fence	26,608	1.51
2009	Stellako River	Medium	Clear	Ground	20,874	Fence	26,608	1.27
2009	Tachie River	X-Large	Tannic	Aerial	26,275	MR	47,452	1.81
2010	Horsefly River *	Medium	Clear	Aerial	63,187	DIDSON	124,074	1.96
2010	Mitchell River *	Medium	Clear	Aerial	38,405	MR	74,304	1.93
2011	Pitt River, upper *	Large	Pt. Turbid	Aerial	22,512	MR	56,006	2.49
2011	Pitt River, upper *	Large	Pt. Turbid	Ground	25,703	MR	56,006	2.18
2011	Stellako River *	Large	Clear	Ground	29,313	MR	85,628	2.92
2011	Stellako River *	Large	Clear	Aerial	28,490	MR	85,628	3.01
2012	Pitt River, upper *	Large	Pt. Turbid	Aerial	31,527	MR	78,038	2.48
2012	Pitt River, upper *	Large	Pt. Turbid	Ground	28,475	MR	78,038	2.74
2012	Harrison River *	X-Large	Pt. Turbid	Aerial	16,600	MR	71,002	4.28
2012	Tachie River *	X-Large	Tannic	Aerial	28,244	MR	68,568	2.43
2012	Chilliwack River, upper *	Small	Clear	Aerial	48,530	DIDSON	122,158	2.52
2012	Chilliwack River, upper *	Small	Clear	Ground	52,771	DIDSON	122,158	2.31
2013	Birkenhead River *	Medium	Pt. Turbid	Aerial	26,559	DIDSON	80,120	3.02
2013	Stellako River *	Medium	Clear	Ground	63,461	DIDSON	110,048	1.73
2013	Stellako River *	Medium	Clear	Aerial	52,530	DIDSON	110,048	2.09
2013	Tachie River *	X-Large	Tannic	Aerial	11,005	MR	97,155	8.83
2014	Birkenhead River *	Medium	Pt. Turbid	Aerial	12,063	DIDSON	35,762	2.96
2014	Seymour River *	Medium	Clear	Aerial	34,770	MR	114,013	3.28

* Funded by the Southern Boundary Restoration and Enhancement Fund (SEF)

Appendix 2. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (stream size, and/or water clarity and method may vary annually).

Population Group	Stream	Size	Water Clarity	Visual Method
Lower Fraser	Blue Creek	Very Small	Clear / Part. Turbid	Ground
	Corbold Creek	Small	Clear	Ground / Aerial
	Chilliwack River, upper (Dolly Varden Cr.)	Small	Clear	Ground / Aerial
	Depot Creek	Very Small	Clear	Ground
	Nahatlatch River	Medium	Clear / Part. Turbid / Turbid	Ground
	North Boise Creek	Very Small	Clear / Part. Turbid	Ground / Aerial
	Pitt River, upper	Large	Clear / Part. Turbid / Turbid	Ground / Aerial
	South Boise Creek	Very Small	Clear	Ground
	Upper Pitt Channel	Very Small	Clear	Ground
	Widgeon Slough	Very Small	Clear	Ground
Harrison-Lillooet	Big Silver Creek	Small	Clear	Ground / Aerial
	Birkenhead River	Medium	Clear / Part. Turbid / Turbid	Ground / Aerial
	Cogburn Creek	Small	Clear	Ground
	Douglas Creek	Small	Clear	Ground / Aerial
	Green River	Medium	Turbid	Ground / Aerial
	Harrison River	X-Large	Clear / Part. Turbid	Aerial
	Hatchery Creek	Very Small	Clear	Ground
	Miller Creek	Small	Turbid	Ground
	Pemberton Creek	Very Small	Turbid	Ground
	Poole Creek	Very Small	Turbid	Ground
	Railroad Creek	Very Small	Clear	Ground
	Sampson Creek	Very Small	Clear	Ground
	Ryan River	Medium	Turbid	Ground
	Sloquet Creek	Very Small	Clear	Ground
	Tipella Creek	Small	Part. Turbid	Ground
	Weaver Channel	Very Small	Clear	Census
	Weaver Creek	Very Small	Clear	Ground
Seton-Anderson	Bridge River	Medium	Part. Turbid / Turbid	Ground / Aerial
	Cayoosh Creek	Small	Clear	Ground / Aerial
	Churn Creek	Very Small	Clear	Ground
	Gates Channel	Very Small	Clear	Census
	Gates Creek	Very Small	Clear	Ground
	Portage Creek	Small	Clear	Ground
	Seton River	Medium	Clear / Part. Turbid	Aerial
	Yalakom River	Small	Clear	Aerial

Continued

Appendix 2. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (stream size, and/or water clarity and method may vary annually) (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
South Thompson	**Adams Lake**			
	Bush Creek	Very Small	Clear	Ground
	Cayenne Creek	Very Small	Tannic	Ground
	Momich Creek	Small	Clear	Ground
	Pass Creek	Very Small	Clear	Ground
	Upper Adams River	Medium	Part. Turbid / Turbid	Ground / Aerial
	Upper Momich Creek	Very Small	Clear	Ground
	Shuswap Lake - Main Arm			
	Adams River (lower)	Large	Clear	Ground / Aerial
	Adams Channel	Very Small	Clear	Ground
	Huihill Creek	Very Small	Clear	Ground
	Nikwikwaia Creek	Very Small	Clear	Ground
	Hlina Creek	Very Small	Clear	Ground
	Onyx Creek	Very Small	Clear	Ground
	Ross Creek	Very Small	Clear	Ground
	Scotch Creek	Small	Clear	Ground / Aerial
	Shuswap Lake - Salmon Arm			
	Canoe Creek	Very Small	Clear	Ground
	Crazy Creek	Very Small	Clear	Ground
	Eagle River (below Perry)	Medium	Part. Turbid / Turbid	Ground / Aerial
	Eagle River (above Perry)	Small	Clear	Ground / Aerial
	Gorge Creek	Very Small	Clear	Ground
	Loftus Creek	Very Small	Clear	Ground
	Perry River	Small	Part. Turbid / Turbid	Ground
	Reinecker Creek	Very Small	Clear	Ground
	Sicamous Creek	Very Small	Clear	Ground
	Tappen Creek	Very Small	Clear	Ground
	Yard Creek	Very Small	Clear	Ground
	Shuswap Lake - Seymour Arm			
	Blueberry Creek	Very Small	Clear	Ground
	Celista Creek	Small	Clear	Ground
	McNomee Creek	Very Small	Tannic	Ground
	Seymour River	Medium	Clear / Part. Turbid	Ground / Aerial
	Shuswap Lake - Anstey Arm			
	Anstey River	Small	Clear / Part. Turbid	Ground
	Hunakwa Creek	Very Small	Tannic	Ground
	Four Mile Creek	Very Small	Clear	Ground

Continued

Appendix 2. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (stream size, and/or water clarity and method may vary annually) (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
South	**Shuswap River**			
Thompson	Bessette Creek	Very Small	Clear	Ground
(cont'd)	Blurton Creek	Very Small	Clear	Ground
	Cooke Creek	Very Small	Clear	Ground
	Fortune Creek	Very Small	Clear	Ground
	Johnson Creek	Very Small	Clear	Ground
	Kingfisher Creek	Very Small	Clear	Ground
	Noisy Creek	Very Small	Clear	Ground
	Shuswap R., (Lower)	Large	Clear	Ground / Aerial
	Shuswap R., (Middle)	Medium	Clear	Ground / Aerial
	Trinity Creek	Very Small	Clear	Ground
	Tsuius Creek	Small	Clear	Ground
	Wap Creek	Small	Clear	Ground / Aerial
	South Thompson River			
	Little River	X-Large	Clear	Aerial
	South Thompson River	X-Large	Clear	Aerial
North	Barriere River	Medium	Clear	Aerial
Thompson	Barriere River, upper (Fennell Cr.)	Very Small	Clear	Ground
	Clearwater River	Large	Clear	Ground / Aerial
	Dunn Creek	Very Small	Clear	Ground
	Finn Creek	Very Small	Tannic	Ground
	Grouse (Moul) Creek	Very Small	Clear	Ground
	Harper Creek	Very Small	Clear	Ground
	Hemp Creek	Very Small	Clear	Ground
	Lemieux Creek	Very Small	Clear	Ground
	Lion Creek	Very Small	Clear	Ground
	Mann Creek	Very Small	Tannic	Ground
	North Thompson River	X-Large	Part. Turbid / Turbid	Aerial
	Raft River	Medium	Clear	Ground
Chilcotin	Chilko River	Large	Clear / Part. Turbid	Ground / Aerial
	Elkin Creek	Very Small	Clear	Ground / Aerial
	Yohetta Creek, upper	Very Small	Clear / Part. Turbid	Ground / Aerial
	Yohetta Creek, lower	Small	Part. Turbid	Ground / Aerial
Mid-Fraser	Baezaeko River	Medium	Tannic	Aerial
	Hawks Creek	Very Small	Clear	Ground
	Williams Lake River	Small	Tannic	Ground

Continued

Appendix 2. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (stream size, and/or water clarity and method may vary annually) (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
Quesnel	**Quesnel River**			
	Cariboo River, lower	Large	Clear / Part. Turbid	Aerial
	Cariboo River, upper	Large	Part. Turbid / Turbid	Aerial
	Quesnel River	Large	Clear	Aerial
	Horsefly River			
	Archie Creek	Very Small	Tannic	Ground
	Horsefly Channel	Very Small	Clear	Census
	Horsefly River	Medium	Clear	Aerial
	Little Horsefly River	Small	Clear	Ground / Aerial
	Lower McKinley Creek	Small	Clear	Ground
	Moffat Creek	Very Small	Clear	Ground
	Upper McKinley Creek	Very Small	Clear	Ground / Aerial
	Tisdall Creek	Very Small	Tannic	Ground
	Mitchell River			
	Cameron Creek	Very Small	Clear	Ground / Aerial
	Mitchell River	Medium	Clear / Part. Turbid	Aerial
	Penfold Creek	Small	Clear / Part. Turbid	Ground / Aerial
	Quesnel Lake - East Arm			
	Bill Miner Creek	Very Small	Clear	Ground
	Blue Lead Creek	Small	Part. Turbid / Turbid	Ground / Aerial
	Bouldery Creek	Very Small	Clear	Ground
	Buckingham Creek	Very Small	Clear	Ground
	Franks Creek	Very Small	Clear	Ground
	Killdog Creek	Very Small	Clear	Ground
	Lynx Creek	Very Small	Clear	Ground
	Stranger Creek	Very Small	Clear	Ground
	Summit Creek	Very Small	Tannic	Ground
	Taku Creek	Very Small	Clear	Ground
Quesnel	**Quesnel Lake - North Arm**			
	Adams Creek	Very Small	Clear	Ground
	Bowling Creek	Very Small	Clear	Ground
	Devoe Creek	Very Small	Clear	Ground
	Grain Creek	Very Small	Clear	Ground / Aerial
	Isaiah Creek	Very Small	Clear	Ground
	Junction Creek	Very Small	Clear	Ground
	Limestone Creek	Very Small	Clear	Ground

Continued

Appendix 2. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (stream size, and/or water clarity and method may vary annually) (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
Quesnel (cont'd)	**Quesnel Lake - North Arm**			
	Long Creek	Very Small	Clear	Ground
	Marten Creek	Very Small	Clear	Ground
	Roaring River	Small	Clear / Part. Turbid	Ground
	Service Creek	Very Small	Clear	Ground
	Sue Creek	Very Small	Clear	Ground
	Trickle Creek	Very Small	Clear	Ground
	Wasko Creek, lower	Very Small	Clear	Ground / Aerial
	Wasko Creek, upper	Very Small	Clear	Ground / Aerial
	Watt Creek	Very Small	Clear	Ground
	Quesnel Lake - West Arm			
	Abbott Creek	Very Small	Tannic	Ground
	Hazeltine Creek	Very Small	Tannic	Ground
	Spusks Creek	Very Small	Clear	Ground
	Tasse Creek	Very Small	Clear	Ground
	Whiffle Creek	Very Small	Clear	Ground
Early Stuart	**Driftwood River**			
	Blackwater Creek	Very Small	Clear	Ground
	Driftwood River	Medium	Clear / Part. Turbid	Aerial
	Kastberg Creek	Very Small	Tannic	Aerial
	Kotsine Creek	Small	Turbid	Aerial
	Lion Creek	Very Small	Clear	Ground / Aerial
	Porter Creek	Very Small	Clear	Ground
	Takla Lake, N.E. Arm			
	Ankwill Creek	Small	Clear	Ground / Aerial
	Bates Creek	Very Small	Tannic	Ground
	Blanchette Creek	Very Small	Clear	Ground
	French Creek	Very Small	Tannic	Ground
	Frypan Creek	Very Small	Clear	Ground / Aerial
	Lovell Creek (Forsythe Cr.)	Very Small	Clear	Ground
	Fifteen Mile Creek	Very Small	Clear	Ground
	Hudson's Bay Cr.	Very Small	Clear	Ground
	Maclaing Creek (Five Mile Cr.)	Very Small	Clear	Ground
	Shale Creek	Very Small	Clear	Ground
	Tliti Creek (Ten Mile Cr.)	Very Small	Clear	Ground
	Twenty-Five Mile Creek	Very Small	Clear	Ground
	Unnamed Creek (N. of Blanchette)	Very Small	Clear	Ground

Continued

Appendix 2. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (stream size, and/or water clarity and method may vary annually) (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
Early Stuart (cont'd)	**Takla Lake, N.W. Arm**			
	Crow Creek	Very Small	Clear	Ground
	Dust Creek	Small	Tannic	Ground / Aerial
	Hooker Creek	Very Small	Clear	Ground
	McDougall Creek	Very Small	Tannic	Ground
	Point Creek	Very Small	Clear	Ground
	Sinta Creek	Very Small	Clear	Ground
	Takla Lake, S. Arm			
	Bivouac Creek	Very Small	Clear	Ground
	Gluske Creek	Very Small	Clear	Ground
	Leo Creek	Very Small	Clear	Ground
	Narrows Creek	Very Small	Clear	Ground
	Sakeniche River	Medium	Tannic	Aerial
	Sandpoint Creek	Very Small	Clear	Ground
	Middle River			
	Baptiste Creek	Very Small	Tannic	Ground
	Forfar Creek	Very Small	Clear	Ground
	Kazchek Creek	Small	Clear	Ground
	O'Ne-Ell Creek (Kynock Cr.)	Very Small	Clear	Ground
	Van Decar Creek (Rossette Cr.)	Very Small	Clear	Ground
	Trembleur Lake			
	Fleming Creek	Very Small	Clear	Aerial
	Paula Creek	Very Small	Clear	Ground
	Sidney Creek (Felix Cr.)	Very Small	Clear	Ground
	Tarnazell Creek	Very Small	Tannic	Ground
	Tildesley Creek	Very Small	Tannic	Aerial
Late Stuart	**Stuart Lake**			
	Kuzkwa River	Medium	Tannic	Ground / Aerial
	Middle River	X-Large	Tannic	Aerial
	Pinchi Creek	Very Small	Clear	Ground
	Sowchea Creek	Very Small	Tannic	Ground
	Tachie River	X-Large	Tannic	Aerial
Nechako	Endako River	Medium	Tannic	Aerial
	Glacier Creek	Very Small	Clear	Aerial

Continued

Appendix 2. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (stream size, and/or water clarity and method may vary annually) (cont'd).

Group	Population	Size	Water Clarity	Visual Method
Nechako	Nadina Channel	Very Small	Clear	Census
	Nadina River	Medium	Tannic	Aerial
	Nechako River	Large	Clear	Aerial
	Nithi River	Small	Tannic	Ground
	Ormonde Creek	Very Small	Tannic	Ground
	Stellako River	Large / Medium	Clear	Ground / Aerial
Upper Fraser	Bowron River, lower	Medium	Clear	Aerial
	Bowron River, upper	Medium	Tannic	Aerial
	Huckey Creek	Very Small	Tannic	Aerial