

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

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

METHODS

In 2012, calibration efforts focused on five populations; the Upper Pitt, Stellako, Tachie, Harrison and Upper Chilliwack rivers. High precision mark-recapture studies were conducted at the Upper Pitt, Stellako, Tachie and Harrison rivers (DFO funded) and a high precision DIDSON (Dual Frequency Identification Sonar) study was conducted on the Upper Chilliwack River (SEF funded). A detailed description of the methods and results from the Upper Chilliwack River DIDSON spawner escapement enumeration study is provided in a supplemental report (Leaf et al. 2013, in prep). For the purpose of calibration, low precision aerial counts (live and dead) were conducted at the peak of spawn in all systems. Simultaneous ground surveys were paired with the aerial surveys at the Upper Pitt and Upper Chilliwack rivers to permit the direct comparison of the two counting methods. Indices were generated for each population by dividing the respective high precision estimate by the peak aerial count (live plus dead). A more detailed description of the calibration methods employed in this study is presented in Welch et al. 2011.

In addition to the data collected in 2012, all calibration efforts conducted and indices generated on Fraser River Sockeye salmon populations of less than 125,000 spawners from 1988 through 2012 are summarized and examined.

RESULTS

2012 CALIBRATION ACTIVITIES

Upper Pitt River

One paired aerial and ground survey of the Upper Pitt River system was conducted over a two day period from September 8th-9th with a total of 31,527 and 28,475 Sockeye salmon (live + dead) enumerated, respectively. The index generated from comparing the aerial count to the system mark-recapture estimate of 78,038 Sockeye salmon is 2.48 (Table 1). The aerial live count was 111% of the simultaneous ground count (Table 2; Appendix 3).

Stellako River

One aerial survey of the Stellako River was conducted on September 27th with a total of 52,586 Sockeye salmon (live + dead) enumerated. The index generated from comparing the aerial count to the mark-recapture estimate of 137,993 Sockeye salmon is 2.62 (Table 1).

Tachie River

One aerial survey of the Tachie River was conducted on September 21th with a total of 28,244 Sockeye salmon (live + dead) enumerated. The index generated from comparing the aerial count to the mark-recapture estimate of 68,568 Sockeye salmon is 2.43 (Table 1).

Harrison River

One aerial survey of the Harrison River was conducted on November 10th with a total of 16,600 Sockeye salmon (live + dead) enumerated. The index generated from comparing the aerial count to the mark-recapture estimate of 71,002 Sockeye salmon is 4.28 (Table 1).

Upper Chilliwack River

Two aerial surveys of the Upper Chilliwack River were conducted on August 15th and 22nd with a total of 38,551 and 48,530 Sockeye salmon (live + dead) enumerated upstream of the DIDSON, respectively. The index generated from comparing the peak aerial count (August 22nd flight of 48,530) to the total DIDSON estimate of 122,158 Sockeye salmon is 2.52 (Table 1). The aerial live counts represented 100% and 84% of the simultaneous ground counts (Table 2; Appendix 3).

Table 1. Summary of low and high precision estimates and the resulting indices at Upper Pitt, Stellako, Tachie, Harrison and Upper Chilliwack rivers, 2012.

Stream	Low Precision		High Precision		
	Method	Count ^a	Method	Estimate	Index
Upper Pitt	Aerial	31,527	M/R	78,038	2.48
Stellako	Aerial	52,586	M/R	137,993	2.62
Tachie	Aerial	28,244	M/R	68,568	2.43
Harrison	Aerial	16,600	M/R	71,002	4.28
Upper Chilliwack	Aerial	48,530	DIDSON	122,158	2.52

^a Peak live count plus dead carcasses observed

Table 2. Summary of simultaneous aerial and ground live counts at Upper Pitt and Upper Chilliwack Rivers, 2012.

Stream	Aerial Count	Ground Count	Aerial : Ground (%)
Upper Pitt	31,527	28,475	111%
Upper Chilliwack (15-Aug)*	14,200	14,191	100%
Upper Chilliwack (22-Aug)*	30,000	35,634	84%

^a Partial system count

SUMMARY OF CALIBRATION EFFORTS (1988-2012)

A summary of all calibration efforts conducted and the resulting indices generated on Fraser River Sockeye salmon populations of less than 125,000 spawners since 1988 is presented by stream size and water clarity in Tables 3 and 4 and Appendix 1. A total of 100 indices have been generated, of which, 70 are based on ground surveys (Table 3) and 30 are based on aerial surveys (Table 4). Of the 70 ground survey based indices, 53 are on very small sized, clear stream populations, one on a small sized, clear stream population, nine on medium sized (six clear and three partially turbid/tannic) stream populations and seven on large sized (five clear and two partially turbid/tannic) stream populations (Table 3). Of the 30 aerial survey based indices, four are on small sized (two clear and two partially turbid/tannic) stream populations, 12 on medium sized (five clear, five partially turbid/tannic and two turbid) stream populations, five on large sized (three clear and two partially turbid/tannic) stream populations and nine on extra large sized (one clear and eight partially turbid/tannic) stream populations (Table 4).

Table 3. Summary of ground calibration surveys stratified by stream size and water clarity for Fraser Sockeye spawning populations under 125,000, 1988-2012.

Size	Water Clarity	Number of classified streams	Ground Calibrated Streams	Number of calibration surveys (n)	Average Population Estimate	Population Range	Average Index	Index Range	Standard Deviation	Coefficient of Variation
Very Small	Clear	111	8	53	9,005	167 - 38,248	1.70	1.07 - 2.85	0.38	0.22
	Pt. Turbid / Tannic	22	-	0	-	-	-	-	-	-
	Turbid	2	-	0	-	-	-	-	-	-
Small	Clear	19	1	1	122,158	-	2.31	-	-	-
	Pt. Turbid / Tannic	9	-	0	-	-	-	-	-	-
	Turbid	3	-	0	-	-	-	-	-	-
Medium	Clear	7	3	6	73,418	26,608 - 111,501	1.98	1.10 - 2.62	0.65	0.33
	Pt. Turbid / Tannic	14	1	3	37,100	14,420 - 56,192	2.09	1.43 - 2.67	0.63	0.30
	Turbid	6	-	0	-	-	-	-	-	-
Large	Clear	6	2	5	65,330	41,481 - 91,443	2.37	1.85 - 2.92	0.47	0.20
	Pt. Turbid / Tannic	3	1	2	67,022	56,006 - 78,038	2.46	2.18 - 2.74	0.40	0.16
	Turbid	2	-	0	-	-	-	-	-	-
Extra Large*	Clear	2	-	0	-	-	-	-	-	-
	Pt. Turbid / Tannic	3	-	0	-	-	-	-	-	-
	Turbid	1	-	0	-	-	-	-	-	-

*Extra Large streams not surveyed using ground methods

Table 4. Summary of aerial calibration surveys stratified by stream size and water clarity for Fraser Sockeye salmon spawning populations under 125,000, 1988-2012.

Size	Water Clarity	Number of classified streams	Aerially Calibrated Streams	Number of calibration surveys (n)	Average Population Estimate	Population Range	Average Index	Index Range	Standard Deviation	Coefficient of Variation
Very Small*	Clear	111	-	0	-	-	-	-	-	-
	Pt. Turbid / Tannic	22	-	0	-	-	-	-	-	-
	Turbid	2	-	0	-	-	-	-	-	-
Small	Clear	19	2	2	102,782	83,406 - 122,158	1.89	1.26 - 2.52	0.89	0.47
	Pt. Turbid / Tannic	9	1	2	12,710	2,387 - 23,032	2.54	2.04 - 3.05	0.72	0.28
	Turbid	3	-	0	-	-	-	-	-	-
Medium	Clear	7	2	5	52,209	24,461 - 124,074	2.27	1.51 - 3.63	0.84	0.37
	Pt. Turbid / Tannic	14	3	5	58,461	13,682 - 124,148	2.55	1.93 - 3.40	0.59	0.23
	Turbid	6	2	2	49,900	28,478 - 71,322	5.80	4.17 - 7.44	2.32	0.40
Large	Clear	6	2	3	59,941	41,481 - 85,628	3.07	2.91 - 3.28	0.19	0.06
	Pt. Turbid / Tannic	3	1	2	67,022	56,006 - 78,038	2.48	2.48 - 2.49	0.01	0.00
	Turbid	2	-	0	-	-	-	-	-	-
Extra Large	Clear	2	1	1	19,345	-	2.60	-	-	-
	Pt. Turbid / Tannic	3	3	8	64,396	28,309 - 123,014	3.32	1.48 - 5.92	1.73	0.52
	Turbid	1	-	0	-	-	-	-	-	-

*Very small streams not surveyed using aerial methods

DISCUSSION

There are many factors affecting an observer's ability to visually count the number of spawning Sockeye salmon present during a live count survey (observer efficiency), but the main factors are believed to be the size of the stream and water clarity when the count is obtained at the peak of the spawning period and abundances are less than 125,000 (Welch et al. 2011). As presented in Welch et al. 2011, 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).

In addition to stream type, survey method must be also considered in the development of indices 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 (Appendix 3). Tables 3 and 4 summarize the stream type indices by aerial and ground survey method, respectively.

Although the number of indices generated to date for the small to extra-large stream type classifications is low (ranging from 0 to 8), the average index generally increases with stream size for both survey methods (Tables 3 and 4). 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. However, the larger streams (small, medium and large) with moderate to large abundances reveal notably higher average indices and thus, likely results in bias low escapement estimates for such populations when applying the standard 1.8 index.

SUMMARY

Since calibration efforts began in 1988, a total of 100 indices have been generated by comparing visual estimates (both aerial and ground surveys) 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 small, medium and large sized streams. As it is typically these moderately sized streams that support populations within the 25,000 to 75,000 range, future calibration activities should focus on these stream types. Additional funding by the SEF since 2007 has led to increased calibration efforts on these larger sized systems resulting in the generation of 19 indices (two small, five medium, ten large and two extra-large) on populations between 25,000 and 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 additional calibration work continues, it is recommended that the standard 1.8 index be applied to all visually enumerated Sockeye stream populations until the following two conditions by stream type and method classification are met: i.) a minimum of 10 indices have been generated and ii.) the error (CV) related to the range of indices is less than 25%. 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.

REFERENCES

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Welch, P., Benner, K. and Leaf, B. 2011. Calibration of Assessment Methods for Fraser River Sockeye Salmon (*Oncorhynchus nerka*) Spawning Populations (25,000 to 75,000). Report prepared by Fisheries and Oceans Canada for the Pacific Salmon Commission, Southern Boundary Restoration and Enhancement Fund.

APPENDICES

Appendix 1. Comprehensive summary of all calibrated Sockeye populations less than 125,000 in the Fraser River watershed by year and stream type characteristics, 1988-2012.

Year	Stream	Size	Water Clarity	Low Precision Estimate Method	Low Precision Estimate	High Precision Estimate Method	High Precision Estimate	Index
1988	Fennell Creek	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	Fennell Creek	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	Fennell Creek	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 all calibrated Sockeye populations less than 125,000 in the Fraser River watershed by year and stream type characteristics, 1988-2012 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Estimate Method	Low Precision Estimate	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	Pt. Turbid	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

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Appendix 1. Comprehensive summary of all calibrated Sockeye populations less than 125,000 in the Fraser River watershed by year and stream type characteristics, 1988-2012 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Estimate Method	Low Precision Estimate	High Precision Estimate Method	High Precision Estimate	Index
2000	Raft River	Medium	Clear	Ground	25,305	MR	66,292	2.62
2000	Adams River, upper	Medium	Turbid	Aerial	17,116	MR	71,322	4.17
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	Gluske Creek	V. Small	Clear	Ground	79	Fence	167	2.11

Continued

Appendix 1. Comprehensive summary of all calibrated Sockeye populations less than 125,000 in the Fraser River watershed by year and stream type characteristics, 1988-2012 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Estimate Method	Low Precision Estimate	High Precision Estimate Method	High Precision Estimate	Index
2007	Horsefly River	Medium	Clear	Aerial	22,405	MR	55,181	2.46
2007	Horsefly River, lower	Medium	Clear	Aerial	8,463	MR	30,720	3.63
2007	Horsefly River, upper	Medium	Clear	Aerial	13,943	Fence	24,461	1.75
2007	Stellako River	Large	Clear	Aerial	14,242	MR	41,481	2.91
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	Pt. Turbid	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	Pt. Turbid	Aerial	38,415	MR	74,322	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	24,673	MR	56,006	2.27
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

Continued

Appendix 1. Comprehensive summary of all calibrated Sockeye populations less than 125,000 in the Fraser River watershed by year and stream type characteristics, 1988-2012 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Estimate Method	Low Precision Estimate	High Precision Estimate Method	High Precision Estimate	Index
2012	Chilliwack River, upper	Small	Clear	Ground	40,201	DIDSON	122,158	3.04

Appendix 2. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method.

Population				
Group	Stream	Size	Water Clarity	Visual Method
Lower Fraser	Blue Creek	Very Small	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	Part. Turbid / Turbid	Ground
	North Boise Creek	Very Small	Part. Turbid	Ground / Aerial
	Pitt River, upper	Large	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	Part. Turbid	Ground / Aerial
	Cogburn Creek	Small	Clear	Ground
	Douglas Creek	Small	Clear	Ground / Aerial
	Green River	Medium	Turbid	Ground / Aerial
	Harrison River	X-Large	Part. Turbid	Aerial
	Hatchery Creek	Very Small	Clear	Ground
	Miller Creek	Small	Clear	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	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	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 (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
South Thompson	<u>Adams Lake</u>			
	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
	<u>Shuswap Lake - Main Arm</u>			
	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
	<u>Shuswap Lake - Salmon Arm</u>			
	Canoe Creek	Very Small	Clear	Ground
	Crazy Creek	Very Small	Clear	Ground
	Eagle River	Small / Medium	Part. Turbid / Turbid	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
	<u>Shuswap Lake - Seymour Arm</u>			
	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
	<u>Shuswap Lake - Anstey Arm</u>			
	Anstey River	Small	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 (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
South	<u>Shuswap River</u>			
Thompson (cont'd)	Bessette Creek	Very Small	Clear	Ground
	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
	Tsius Creek	Small	Clear	Ground
	Wap Creek	Small	Clear	Ground / Aerial
	<u>South Thompson River</u>			
	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	Turbid	Aerial
	Raft River	Medium	Clear	Ground
Chilcotin	Chilko River	Large	Part. Turbid	Ground / Aerial
	Elkin Creek	Very Small	Clear	Ground / Aerial
	Yohetta Creek, upper	Very Small	Clear	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 (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
Quesnel	<u>Quesnel River</u>			
	Cariboo River, lower	Large	Part. Turbid	Aerial
	Cariboo River, upper	Large	Turbid	Aerial
	Quesnel River	Large	Clear	Aerial
	<u>Horsefly River</u>			
	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
	<u>Mitchell River</u>			
	Cameron Creek	Very Small	Clear	Ground / Aerial
	Mitchell River	Medium	Part. Turbid	Aerial
	Penfold Creek	Small	Part. Turbid	Ground / Aerial
	<u>Quesnel Lake - East Arm</u>			
	Bill Miner Creek	Very Small	Clear	Ground
	Blue Lead Creek	Small	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	<u>Quesnel Lake - North Arm</u>			
	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 (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
Quesnel (cont'd)	<u>Quesnel Lake - North Arm</u>			
	Long Creek	Very Small	Clear	Ground
	Marten Creek	Very Small	Clear	Ground
	Roaring River	Small	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
	<u>Quesnel Lake - West Arm</u>			
	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	<u>Driftwood River</u>			
	Blackwater Creek	Very Small	Clear	Ground
	Driftwood River	Medium	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
	<u>Takla Lake, N.E. Arm</u>			
	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 (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
Early Stuart (cont'd)	<u>Takla Lake, N.W. Arm</u>			
	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
	<u>Takla Lake, S. Arm</u>			
	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
	<u>Middle River</u>			
	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
	<u>Trembleur Lake</u>			
	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	<u>Stuart Lake</u>			
	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 (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

Appendix 3. Summary of Sockeye salmon aerial to ground live count comparisons by stream and year in the Fraser River watershed, 2007-2012.

Stream	Year	Aerial Count	Ground Count	Aerial : Ground
Adams	2007	15,450	18,788	82.2%
Horsefly, upper*	2007	4,270	5,613	76.1%
Horsefly, lower*	2007	2,194	2,351	93.3%
Stellako	2007	10,110	12,489	81.0%
Kuzkwa*	2008	1,856	2,624	70.7%
Kuzkwa*	2008	827	942	87.8%
Stellako	2009	17,520	21,274	82.4%
Big Silver	2009	2,659	3,255	81.7%
Cameron	2009	88	130	67.7%
Upper Chilliwack*	2009	772	919	84.0%
Little Horsefly	2009	2,840	3,376	84.1%
Ankwill (1-Aug)*	2010	1,215	1,115	109.0%
Ankwill (7-Aug)*	2010	1,369	1,469	93.2%
Upper Chilliwack (13-Aug)*	2010	74	133	55.3%
Upper Chilliwack (20-Aug)*	2010	111	157	70.4%
Little Horsefly	2010	1,757	1,843	95.3%
Paula	2010	348	384	90.6%
Horsefly*	2010	511	861	59.3%
Kuzkwa*	2010	824	827	99.6%
Wasko, lower	2011	100	151	66.2%
Hazeltine	2011	36	40	90.0%
Corbold	2011	6,050	6,319	95.7%
Upper Chilliwack*	2011	363	352	103.1%
Stellako	2011	28,490	29,313	97.2%
Upper Pitt*	2011	15,215	16,510	92.2%
Kuzkwa*	2011	229	175	130.9%
Horsefly, upper*	2011	1,868	2,460	75.9%
Adams	2011	12,345	16,393	75.3%
Upper Pitt*	2012	24,265	20,846	116.4%
Horsefly, upper*	2012	51	60	85.0%
N. Boise	2012	39	41	95.1%
Nadina*	2012	290	326	89.0%
Corbold	2012	5,100	5,525	92.3%
Upper Chilliwack (15-Aug)*	2012	14,200	14,191	100.1%
Upper Chilliwack (22-Aug)*	2012	30,000	35,634	84.2%
			Average	87.2%
			SD	0.15
			CV	17.6%

*partial system count