

**Calibration of Visual Assessment Methods for
Fraser River Sockeye Salmon (*Oncorhynchus nerka*) - Year 9**

May 2018

Paul Welch and Andrew Grant

**Fisheries and Oceans Canada
Fraser River Stock Assessment
985 McGill Place
Kamloops, BC
V2C 6X6**

Report Prepared For:

**Pacific Salmon Commission
Southern Boundary Restoration and Enhancement Fund
600-1155 Robson Street
Vancouver, BC.
Canada V6E 1B5**

TABLE OF CONTENTS

LIST OF TABLES.....	iii
LIST OF APPENDICES	iii
INTRODUCTION.....	4
METHODS.....	4
RESULTS.....	5
2017 CALIBRATION ACTIVITIES	5
<i>Stellako River</i>	5
<i>Tachie River</i>	5
<i>Harrison River</i>	5
<i>Aerial to Ground Counts</i>	6
CALIBRATION ACTIVITIES (1988-2017)	6
SUMMARY.....	10
REFERENCES.....	11
APPENDICES	12

LIST OF TABLES

Table 1. Summary of low precision visual counts, high precision escapement estimates and the resulting indices at Stellako, Tachie, and Harrison rivers, 2017.	5
Table 2. Summary of aerial to ground comparison surveys by stream for Fraser Sockeye salmon spawning populations, 2017.	6
Table 3. Summary of ground calibration surveys stratified by stream size and water clarity for Fraser Sockeye salmon populations, 1988-2017.	7
Table 4. Summary of aerial calibration surveys stratified by stream size and water clarity for Fraser Sockeye salmon populations, 1988-2017.	7
Table 5. Summary of ground calibration surveys by stream for Fraser Sockeye salmon populations, 1988-2017.	8
Table 6. Summary of aerial calibration surveys by stream for Fraser Sockeye salmon populations, 1988-2017.	9
Table 7. Summary of aerial to ground comparison surveys by stream size for Fraser Sockeye salmon spawning populations, 2002-2017.	9

LIST OF APPENDICES

Appendix 1. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2017.	13
Appendix 2. Summary of aerial to ground comparison surveys by specific streams for Fraser Sockeye salmon populations, 2002-2017.	19

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 (IPSF). 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, sonar 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 abundances much larger than they were historically. The standard expansion factor of 1.8 currently applied to visual counts to account for the consistent underestimation of live counts was developed on very small, clear stream populations with relatively small (less than 25,000) spawner abundances in the Fraser River system. Its application to larger streams with larger abundances commonly leads to substantial negative bias in spawning estimates.

In 2017, the Southern Boundary Restoration and Enhancement Fund (SEF) funded the ninth of a ten year calibration study to minimize bias in visually enumerated Sockeye salmon populations in the Fraser River watershed through the development of stream type and method specific indices. Summaries of the first eight years of the calibration study have been presented in Welch et al. 2011, Benner et al. 2012, Benner et al. 2013, Benner et al. 2014, Benner et al. 2015, Benner et al. 2016 and Welch et al. 2017. The following report provides a summary of the 2017 specific calibration activities as well as a summary of all calibration data collected by DFO since 1988.

METHODS

In 2017, calibration efforts focused on three populations representing three unique stream types where high precision spawning escapement enumeration projects were implemented; the Stellako River (medium clear), Tachie River (extra-large tannic) and Harrison River (extra-large clear). A hydroacoustic imaging system (DIDSON) was employed at the Stellako River, while mark-recapture studies were conducted at the Tachie and Harrison rivers.

Low precision ground and/or aerial visual counts (live and dead) were conducted at the peak of spawn in all river populations. Expansion factors (indices) were generated for each population by dividing the respective high precision estimate by the peak visual count (live plus dead). In addition, simultaneous ground surveys were paired with aerial surveys at a number of locations throughout the Fraser Watershed to permit the direct comparison of the two counting methods. A more detailed description of the calibration methods and stream-type classifications for all Fraser Sockeye spawning populations are presented in Welch et al. 2011.

In addition to the data collected in 2017, all calibration data collected by DFO on Fraser Sockeye populations from 1988-2017 are examined and summarized.

RESULTS

2017 CALIBRATION ACTIVITIES

Stellako River

One paired aerial and ground survey of the Stellako River was conducted on September 28th with a total of 48,204 and 65,109 Sockeye salmon (live + dead) enumerated, respectively. The indices generated from comparing the aerial and ground counts to the sonar estimate of 91,294 (above sonar) Sockeye salmon are 1.89 and 1.40, respectively (Table 1).

Tachie River

Two aerial surveys of the Tachie River were conducted on September 20th and 26th with a total of 33,485 and 47,665 Sockeye salmon (live + dead) enumerated, respectively. The index generated from comparing the peak aerial count on September 26th to the mark-recapture estimate of 114,676 Sockeye salmon is 2.41 (Table 1).

Harrison River

One aerial survey of the Harrison River was conducted on November 7th with a total of 5,270 Sockeye salmon (live + dead) enumerated. The index generated from comparing the aerial count to the mark-recapture estimate of 49,983 Sockeye salmon is 9.48 (Table 1).

Table 1. Summary of low precision visual counts, high precision escapement estimates and the resulting indices at Stellako, Tachie, and Harrison rivers, 2017.

Stream	Stream Size	Water Clarity	Low Precision		High Precision		Index
			Method	Count ^a	Method	Estimate ^b	
Stellako	Medium	Clear	Aerial	48,204	Sonar	91,294	1.89
Stellako	Medium	Clear	Ground	65,109	Sonar	91,294	1.40
Tachie	Extra Large	Tannic	Aerial	47,665	MR	114,676	2.41
Harrison	Extra Large	Clear	Aerial	5,270	MR	49,983	9.48

^a Peak live count plus dead carcasses observed.

^b Estimates do not include live spawners below the sonar site, which is negligible.

Aerial to Ground Counts

Simultaneous aerial to ground counts occurred at 12 locations from August 8th to November 7th in 2017 (Table 2).

Table 2. Summary of aerial to ground comparison surveys by stream for Fraser Sockeye salmon spawning populations, 2017.

Stream	Date	Stream Size	Water Clarity	Aerial Count ^a	Ground Count ^a	Aerial / Ground ratio
Blue Lead	23-Sep	Small	Part. Turbid	96	113	0.85
Chilliwack (Upper)	16-Aug	Medium	Clear	2,020	2,706	0.75
Chilliwack (Upper)	23-Aug	Medium	Clear	789	1,020	0.77
Corbold	10-Sep	Small	Clear	3,835	3,771	1.02
Dust	08-Aug	Small	Tannic	46	90	0.51
Frypan	08-Aug	V. Small	Clear	104	171	0.61
Harper	12-Sep	V. Small	Clear	15	22	0.68
Harrison	07-Nov	X-Large	Clear	5,137	2,337	2.20
Horsefly, upper	12-Sep	Medium	Clear	14,648	12,228	1.20
Kuzkwa	20-Sep	Medium	Tannic	1,925	2,511	0.77
North Thompson	19-Sep	X-Large	Part. Turbid	3,013	1,651	1.82
Stellako	28-Sep	Medium	Clear	48,204	64,822	0.74

^a Counts may only represent a portion of the stream

CALIBRATION ACTIVITIES (1988-2017)

Since calibration efforts began in 1988 a total of 136 calibration data points (indices) have been generated on Fraser River Sockeye salmon populations (Appendix 1). Of these, 84 were based on ground surveys and 52 were based on aerial surveys. The vast majority of ground calibrated systems are from streams that have been categorized as very small with water clarity categorized as clear (Table 3); whereas, the number of aerial calibrated systems has focused primarily on medium and extra-large sized streams with either clear or partially turbid/tannic water clarity (Table 4).

Table 3. Summary of ground calibration surveys stratified by stream size and water clarity for Fraser Sockeye salmon populations, 1988-2017.

Size	Water Clarity	Number of calibration surveys (n)	Average Population Estimate	Average Index	Index Range	Standard Deviation	Coefficient of Variation
Very Small	Clear	53	9,005	1.70	1.07 - 2.85	0.38	0.22
	Pt. Turbid / Tannic	0	-	-	-	-	-
	Turbid	0	-	-	-	-	-
Small	Clear	0	-	-	-	-	-
	Pt. Turbid / Tannic	0	-	-	-	-	-
	Turbid	0	-	-	-	-	-
Medium	Clear	21	94,919	2.13	1.10 - 4.21	0.82	0.38
	Pt. Turbid / Tannic	2	35,306	2.42	2.17 - 2.67	0.35	0.15
	Turbid	0	-	-	-	-	-
Large	Clear	6	325,207	4.11	2.22 - 9.04	2.57	0.63
	Pt. Turbid / Tannic	2	67,022	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 typically not surveyed using ground methods

Table 4. Summary of aerial calibration surveys stratified by stream size and water clarity for Fraser Sockeye salmon populations, 1988-2017.

Size	Water Clarity	Number of calibration surveys (n)	Average Population Estimate	Average Index	Index Range	Standard Deviation	Coefficient of Variation
Very Small *	Clear	0	-	-	-	-	-
	Pt. Turbid / Tannic	0	-	-	-	-	-
	Turbid	0	-	-	-	-	-
Small	Clear	0	-	-	-	-	-
	Pt. Turbid / Tannic	2	12,710	2.54	2.04 - 3.05	0.72	0.28
	Turbid	0	-	-	-	-	-
Medium	Clear	16	76,629	2.30	1.23 - 3.34	0.64	0.28
	Pt. Turbid / Tannic	7	76,698	3.37	2.84 - 4.90	0.70	0.21
	Turbid	2	49,900	5.80	4.17 - 7.44	2.32	0.40
Large	Clear	2	100,441	6.63	3.28 - 9.97	4.73	0.71
	Pt. Turbid / Tannic	2	67,022	2.48	2.48 - 2.49	0.01	<0.01
	Turbid	0	-	-	-	-	-
Extra Large	Clear	5	160,399	6.00	2.30 - 11.88	4.39	0.73
	Pt. Turbid / Tannic	16	154,844	3.70	1.48 - 10.32	2.66	0.72
	Turbid	0	-	-	-	-	-

* Very Small streams not surveyed using aerial methods

From 1988 to 2017, the average index generally increases with stream size and water clarity (from clear to turbid) for both ground and aerial survey methods. Indices generated for very small, clear streams (all ground based) average 1.7 and range between 1.07 and 2.85 with a Coefficient of Variation (CV) of 0.22 (Table 3), while larger stream sizes (i.e. small, medium, large and extra-large) reveal notably higher average indices and higher variability (CV ranging between <0.01 to 0.73) (Tables 3 and 4). The highest variability is associated with streams categorized as large clear, extra-large clear and extra-large partially turbid/tannic. This high variability can be linked to a few streams within each group, as outlined in Tables 5 and 6. Streams displaying a CV greater than 0.50 include the Eagle, Adams (lower), Harrison, Middle, and Tachie rivers.

Table 5. Summary of ground calibration surveys by stream for Fraser Sockeye salmon populations, 1988-2017.

Size	Water Clarity ^a	Stream	Number of calibration surveys (n)	Average Population Estimate	Average Index	Index Range	Standard Deviation	Coefficient of Variation
V. Small	Clear	Barriere (Upper)	4	19,095	1.94	1.53 - 2.59	0.46	0.24
	Clear	Crow	1	845	1.95	-	-	-
	Clear	Forfar	17	7,080	1.67	1.19 - 2.28	0.30	0.18
	Clear	Gluske	17	5,485	1.61	1.07 - 2.11	0.28	0.17
	Clear	Narrows	1	2,846	1.18	-	-	-
	Clear	O'Ne-ElI	10	11,258	1.73	1.13 - 2.50	0.47	0.27
	Clear	Paula	1	4,702	1.64	-	-	-
	Clear	Weaver	2	33,145	2.23	1.62 - 2.85	0.88	0.39
Medium	Clear / Pt. Turbid / Tannic	Seymour	4	55,700	2.21	1.43 - 2.67	0.57	0.26
	Clear	Stellako	18	98,607	2.11	1.10 - 4.21	0.86	0.41
	Clear	Raft	1	66,292	2.62	-	-	-
Large	Clear	Adams (Lower)	6	325,207	4.11	2.22 - 9.04	2.57	0.63
	Pt. Turbid / Tannic	Pitt (Upper)	2	67,022	2.46	2.18 - 2.74	0.40	0.16

^a Water Clarity can differ on an annual basis in some systems

Table 6. Summary of aerial calibration surveys by stream for Fraser Sockeye salmon populations, 1988-2017.

Size	Water Clarity ^a	Stream	Number of calibration surveys (n)	Average Population Estimate	Average Index	Index Range	Standard Deviation	Coefficient of Variation
Small	Pt. Turbid / Tannic	Dust	2	12,710	2.54	2.04 - 3.05	0.72	0.28
Medium	Clear	Upper Chilliwack	2	89,080	2.93	2.52 - 3.34	0.58	0.20
	Clear	Horsefly	2	89,628	2.21	1.96 - 2.46	0.35	0.16
	Clear	Stellako	8	77,613	2.09	1.23 - 3.01	0.69	0.33
	Clear	Kuzkwa	1	13,682	2.13	-		
	Clear	Seymour	1	114,013	3.28	-		
	Clear / Pt. Turbid / Tannic	Mitchell	3	81,398	2.58	1.93 - 3.40	0.75	0.29
	Pt. Turbid / Tannic	Birkenhead	3	50,773	3.63	2.96 - 4.90	1.10	0.30
	Pt. Turbid / Tannic	Bowron	1	34,431	2.84	-		
	Pt. Turbid / Tannic	Nadina	1	16,667	3.32	-		
	Pt. Turbid / Tannic / Turbid	Eagle (<i>Early</i>)	2	118,898	5.30	3.15 - 7.44	3.03	0.57
	Turbid	Adams (Upper)	1	71,322	4.17	-		
Large	Clear	Adams (Lower)	2	100,441	6.63	3.28 - 9.97	4.73	0.71
	Pt. Turbid / Tannic	Upper Pitt	2	67,022	2.48	2.48 - 2.49	0.01	0.00
Extra Large	Clear	Little	2	218,068	2.45	2.30 - 2.60	0.21	0.09
	Clear / Pt. Turbid / Tannic	Harrison	6	143,325	7.05	2.63 - 11.88	3.95	0.56
	Pt. Turbid / Tannic	Middle	2	177,371	2.29	1.48 - 3.11	1.15	0.50
	Pt. Turbid / Tannic	Tachie	11	148,062	3.40	1.61 - 8.83	2.34	0.69

^a Water Clarity can differ on an annual basis in some systems

Since 2002, a total of 77 independent aerial to ground visual comparisons have been completed on all stream sizes throughout the Fraser watershed (Appendix 2). Aerial to ground ratios generally increase with stream size; however, the data reveals similar results amongst the moderately sized (small, medium and large) streams (Table 7).

Table 7. Summary of aerial to ground comparison surveys by stream size for Fraser Sockeye salmon spawning populations, 2002-2017.

Stream	N	Aerial / Ground ratio ^a
Very Small	12	0.71
Small	17	0.81
Medium	35	0.82
Large	8	0.82
X-Large	5	2.61

^a Aerial Proportion (i.e aerial count divided by ground count).

SUMMARY

A total of four calibration surveys comparing low precision visual estimates to high precision (sonar or mark-recapture) estimates were conducted in 2017. Of these, two (1 aerial, 1 ground) were conducted on a medium, clear system (Stellako River), one on an extra-large, clear system (Harrison River) and one on an extra-large, tannic system (Tachie River). Additionally, simultaneous aerial to ground counts were conducted at 12 locations to compare the two counting methods.

Since 2007, with funding through the Pacific Salmon Commission Southern Boundary Enhancement and Restoration Fund (SEF) a total of 35 low to high precision calibration data points have been generated on Fraser Sockeye populations up to 125,000 spawners. It is anticipated that calibration opportunities will exist in 2018 representing the tenth and final year of this work funded through the SEF. A final comprehensive report summarizing all calibration efforts through 2018 with recommendations will be provided to the SEF in the spring of 2019.

Although 2018 may represent the final year of SEF funding for this work, DFO will strive to opportunistically conduct calibration work into the future to continue to address gaps, refine the data and ultimately improve the accuracy of Fraser Sockeye spawning escapement estimates.

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APPENDICES

Appendix 1. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2017.

Year	Stream	Size	Water Clarity	Low Precision	Low Precision Visual Count	High	High ^a Precision Estimate	Index
				Visual Method		Precision Estimate Method		
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
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-El 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-El 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	Medium	Clear	Ground	46,658	MR	91,443	1.96
1994	Adams River, lower	Large	Clear	Ground	289,040	MR	676,624	2.34
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-El 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	Adams River, lower	Large	Clear	Ground	170,346	MR	378,952	2.22
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

Continued

Appendix 1. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2017 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Visual Method	Low Precision Visual Count	High Precision Estimate Method	High ^a Precision Estimate	Index
1995	Gluske Creek	V. Small	Clear	Ground	8,972	Fence	15,044	1.68
1995	O'Ne-El 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
1995	Stellako River	Medium	Clear	Ground	75,611	Fence	126,743	1.68
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-El 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	Middle River	X-Large	Tannic	Aerial	90,598	MR	281,472	3.11
1997	Stellako River	Medium	Clear	Ground	22,853	Fence	55,385	2.42
1997	Tachie River	X-Large	Tannic	Aerial	251,926	MR	491,098	1.95
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	Adams River, lower	Large	Clear	Ground	93,320	MR	380,869	4.08
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

Continued

Appendix 1. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2017 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Visual Method	Low Precision Visual Count	High Precision Estimate Method	High ^a Precision Estimate	Index
1999	O'Ne-El 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
1999	Stellako River	Medium	Clear	Ground	38,867	MR	136,105	3.50
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-El 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
2000	Tachie River	X-Large	Tannic	Aerial	229,427	MR	368,966	1.61
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-El 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-El 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	Adams River, lower	Large	Clear	Ground	73,880	MR	313,913	4.25
2003	Gluske Creek	V. Small	Clear	Ground	611	Fence	872	1.43
2003	O'Ne-El 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

Continued

Appendix 1. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2017 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Visual Method	Low Precision Visual Count	High Precision Estimate Method	High ^a Precision Estimate	Index
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	Clear	Aerial	6,415	Fence	13,682	2.13
2005	Middle River	X-Large	Tannic	Aerial	49,636	MR	73,270	1.48
2005	Tachie River	X-Large	Tannic	Aerial	104,532	MR	185,889	1.78
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
2006	Little River	X-Large	Clear	Aerial	180,953	MR	416,790	2.30
2006	Stellako River	Medium	Clear	Ground	44,997	Fence	146,035	3.25
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 *	Medium	Clear	Aerial	14,242	MR	41,481	2.91
2007	Stellako River *	Medium	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
2008	Stellako River	Medium	Clear	Ground	75,026	MR	159,749	2.13
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	Harrison River	X-Large	Pt. Turbid	Aerial	116,891	MR	307,373	2.63
2009	Mitchell River	Medium	Clear	Aerial	18,950	Sonar	45,741	2.41
2009	Stellako River	Medium	Clear	Aerial	17,566	Fence	26,298	1.51
2009	Stellako River	Medium	Clear	Ground	20,874	Fence	26,298	1.27

Continued

Appendix 1. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2017 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Visual Method	Low Precision Visual Count	High Precision Estimate Method	High ^a Precision Estimate	Index
2009	Tachie River	X-Large	Tannic	Aerial	26,275	MR	47,452	1.81
2010	Horsefly River *	Medium	Clear	Aerial	63,187	Sonar	124,074	1.96
2010	Mitchell River *	Medium	Clear	Aerial	38,405	MR	74,304	1.93
2010	Stellako River	Medium	Clear	Ground	48,016	Fence	202,358	4.21
2011	Adams River, lower	Large	Clear	Ground	16,393	MR	148,169	9.04
2011	Adams River, lower	Large	Clear	Aerial	14,860	MR	148,169	9.97
2011	Pitt River, upper *	Large	Pt. Turbid	Aerial	22,512	MR	56,006	2.49
2011	Pitt River, upper *	Large	Pt. Turbid	Ground	25,737	MR	56,006	2.18
2011	Stellako River *	Medium	Clear	Ground	29,313	MR	85,628	2.92
2011	Stellako River *	Medium	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 *	Medium	Clear	Aerial	48,530	Sonar	122,158	2.52
2012	Stellako River	Medium	Clear	Aerial	52,586	MR	137,993	2.62
2012	Stellako River	Medium	Clear	Ground	91,877	MR	137,993	1.50
2013	Birkenhead River *	Medium	Pt. Turbid	Aerial	26,559	Sonar	80,121	3.02
2013	Harrison River	X-Large	Clear	Aerial	67,090	MR	250,117	3.73
2013	Stellako River *	Medium	Clear	Ground	63,461	Sonar	109,220	1.72
2013	Stellako River *	Medium	Clear	Aerial	52,530	Sonar	109,220	2.08
2013	Tachie River *	X-Large	Tannic	Aerial	11,005	MR	97,155	8.83
2014	Birkenhead River *	Medium	Pt. Turbid	Aerial	12,064	Sonar	35,759	2.96
2014	Eagle River (early)	Medium	Pt. Turbid	Aerial	66,378	Sonar	209,318	3.15
2014	Seymour River *	Medium	Clear	Aerial	34,770	MR	114,013	3.28

Continued

Appendix 1. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2017 (cont'd).

Year	Stream	Size	Water Clarity	Low Precision Visual Method	Low Precision Visual Count	High Precision Estimate Method	High ^a Precision Estimate	Index
2015	Stellako River *	Medium	Clear	Aerial	68,244	Sonar	101,215	1.48
2015	Stellako River *	Medium	Clear	Ground	64,736	Sonar	101,215	1.56
2015	Harrison River *	X-Large	Pt. Turbid	Aerial	11,218	MR	115,715	10.32
2016	Birkenhead River *	Medium	Pt. Turbid	Aerial	7,439	Sonar	36,439	4.90
2016	Chilliwack River, upper *	Medium	Clear	Aerial	16,783	Sonar	56,002	3.34
2016	Harrison River *	X-Large	Clear	Aerial	5,536	MR	65,758	11.88
2016	Nadina River *	Medium	Tannic	Aerial	5,023	Sonar	16,672	3.32
2016	Stellako River *	Medium	Clear	Aerial	22,672	Fence	27,774	1.23
2016	Stellako River *	Medium	Clear	Ground	22,121	Fence	27,774	1.26
2017	Harrison River *	X-Large	Clear	Aerial	5,270	MR	49,983	9.48
2017	Stellako River *	Medium	Clear	Aerial	48,204	Sonar	91,294	1.89
2017	Stellako River *	Medium	Clear	Ground	65,109	Sonar	91,294	1.40
2017	Tachie River *	X-Large	Tannic	Aerial	47,665	MR	114,676	2.41

^a Projects that were enumerated using sonar or traditional weirs do not include fish that were observed spawning downstream of the fences.

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

Appendix 2. Summary of aerial to ground comparison surveys by specific streams for Fraser Sockeye salmon populations, 2002-2017.

Stream	Year	Stream Size	Water Clarity	Aerial Count	Ground Count	Aerial / Ground Ratio
Anstey River	2002	Small	Part. Turbid	3,710	10,855	0.34
Eagle River - Lower (below Perry)	2002	Medium	Part. Turbid	17,538	31,470	0.56
Eagle River - Upper (above Perry)	2002	Small	Clear	2,675	3,867	0.69
Kuzkwa River	2005	Medium	Tannic	3,019	3,784	0.80
North Thompson River	2006	X-Large	Part. Turbid	3,800	970	3.92
Adams River (Lower)	2007	Large	Clear	15,450	18,788	0.82
Horsefly River	2007	Medium	Clear	6,464	7,964	0.81
Stellako River	2007	Medium	Clear	10,110	12,489	0.81
Forfar Creek	2008	V. Small	Clear	767	1,956	0.39
Kuzkwa River	2008	Medium	Tannic	1,856	2,624	0.71
Kuzkwa River	2008	Medium	Tannic	827	942	0.88
O' Ne-Ell Creek	2008	V. Small	Clear	2,109	4,303	0.49
Big Silver Creek	2009	Small	Clear	2,659	3,255	0.82
Cameron Creek	2009	V. Small	Clear	88	130	0.68
Chilliwack River (Upper)	2009	Medium	Clear	772	919	0.84
Little Horsefly River	2009	Small	Clear	2,840	3,376	0.84
Stellako River	2009	Medium	Clear	17,520	21,274	0.82
Ankwill Creek	2010	Small	Clear	1,215	1,115	1.09
Ankwill Creek	2010	Small	Clear	1,369	1,469	0.93
Chilliwack River (Upper)	2010	Medium	Clear	185	290	0.64
Horsefly River	2010	Medium	Clear	511	861	0.59
Kuzkwa River	2010	Medium	Tannic	824	827	1.00
Little Horsefly River	2010	Small	Clear	2,154	2,117	1.02
Paula Creek	2010	V. Small	Clear	348	384	0.91
Adams River (Lower)	2011	Large	Clear	12,345	16,393	0.75
Chilliwack River (Upper)	2011	Medium	Clear	363	352	1.03
Corbold Creek	2011	Small	Clear	6,050	6,319	0.96
Hazeltine Creek	2011	V. Small	Tannic	36	40	0.90
Horsefly River	2011	Medium	Clear	1,868	2,460	0.76
Pitt River (Upper)	2011	Large	Part. Turbid	15,215	16,510	0.92
Stellako River	2011	Medium	Clear	28,490	29,313	0.97
Wasko Creek (Lower)	2011	V. Small	Clear	50	76	0.66
Chilliwack River (Upper)	2012	Medium	Clear	35,200	40,201	0.88
Chilliwack River (Upper)	2012	Medium	Clear	14,200	14,191	1.00
Corbold Creek	2012	Small	Clear	5,100	5,525	0.92
Horsefly River	2012	Medium	Clear	51	60	0.84
North Boise Creek	2012	V. Small	Part. Turbid	39	41	0.95
Pitt River (Upper)	2012	Large	Part. Turbid	29,706	27,539	1.08
Stellako River	2012	Medium	Clear	52,586	89,325	0.59
Adams River (Lower)	2013	Large	Clear	37,898	65,593	0.58
Corbold Creek	2013	Small	Clear	5,865	6,360	0.92
Kazchek Creek	2013	Small	Clear	680	942	0.72
Kuzkwa River	2013	Medium	Tannic	1,675	1,781	0.94
North Boise Creek	2013	V. Small	Part. Turbid	430	706	0.61
Pitt River (Upper)	2013	Large	Part. Turbid	12,183	16,434	0.74

Continued

Appendix 2. Summary of aerial to ground comparison surveys by specific streams for Fraser Sockeye salmon spawning populations, 2002-2017 (cont'd).

Stream	Year	Stream Size	Water Clarity	Aerial Count	Ground Count	Aerial / Ground Ratio
Stellako River	2013	Medium	Clear	52,530	63,461	0.83
Seymour	2014	Medium	Clear	15,750	16,870	0.93
Adams River (Lower)	2015	Large	Clear	1,110	1,292	0.86
Dust Creek	2015	Small	Tannic	113	163	0.69
Harper Creek	2015	V. Small	Clear	26	28	0.93
Horsefly River	2015	Medium	Clear	7,433	5,864	1.27
Kuzkwa River	2015	Medium	Tannic	180	232	0.78
Little River	2015	X-Large	Clear	78	80	0.98
Stellako River	2015	Medium	Clear	67,218	63,710	1.06
Adams River (Lower)	2016	Large	Clear	15	18	0.83
Dust Creek	2016	Small	Tannic	7	13	0.54
Kazchek Creek	2016	Small	Clear	22	24	0.92
Kuzkwa River	2016	Medium	Tannic	588	591	0.99
Nadina River	2016	Medium	Tannic	2,875	6,201	0.46
Stellako River	2016	Medium	Clear	22,355	21,804	1.03
Summit Creek	2016	V. Small	Clear	16	21	0.76
Harrison River	2016	X-Large	Clear	5,343	1,290	4.14
Nadina River	2016	Medium	Tannic	3,858	6,490	0.59
Chilliwack River (Upper)	2016	Medium	Clear	14,390	19,880	0.72
Chilliwack River (Upper)	2016	Medium	Clear	12,465	17,115	0.73
Blue Lead Creek	2017	Small	Part. Turbid	96	113	0.85
Chilliwack River (Upper)	2017	Medium	Clear	2,020	2,706	0.75
Chilliwack River (Upper)	2017	Medium	Clear	789	1,020	0.77
Corbold Creek	2017	Small	Clear	3,835	3,771	1.02
Dust Creek	2017	Small	Tannic	46	90	0.51
Frypan Creek	2017	V. Small	Clear	104	171	0.61
Harper Creek	2017	V. Small	Clear	15	22	0.68
Harrison River	2017	X-Large	Clear	5,137	2,337	2.20
Horsefly River	2017	Medium	Clear	14,648	12,228	1.20
Kuzkwa River	2017	Medium	Tannic	1,925	2,511	0.77
North Thompson	2017	X-Large	Part. Turbid	3,011	1,645	1.83
Stellako River	2017	Medium	Clear	48,204	64,822	0.74