Calibration of Visual Assessment Methods for
Fraser River Sockeye Salmon *(Oncorhynchus nerka)* - Year 10

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Paul Welch and Brian Leaf

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

LIST OF APPENDICES

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, 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 escapements based on live counts was developed based on ground (foot) surveys of very small, clear streams with relatively small Sockeye spawning populations (i.e., less than 25,000). Its application to larger streams with larger spawner abundances commonly leads to substantial negative bias in escapement estimates.

In 2018, the Southern Boundary Restoration and Enhancement Fund (SEF) funded the tenth and final year of a multi-year calibration study that had an objective of minimizing bias in visually enumerated Sockeye salmon populations in the Fraser River watershed. Summaries of the first nine years of the calibration study are summarized 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, Welch et al. 2017 and Welch et al. 2018. This final report provides the results of the 2018 specific calibration activities as well as a summary of all calibration results obtained since 1988.

METHODS

In 2018, calibration efforts focused on nine populations where high precision spawning escapement enumeration projects were implemented: the Adams, Birkenhead, Eagle, Harrison, Little, Seymour, Stellako, and Nadina rivers, and Scotch Creek. Hydroacoustic imaging systems (DIDSON/ARIS) were used at the Birkenhead, Eagle, Nadina and Stellako rivers, while mark-recapture studies were conducted at the Adams, Harrison, Little and Seymour rivers. Lastly, a fish weir (fence) was used at Scotch Creek.

Low precision ground and/or aerial visual counts (live and dead) were conducted at the peak of spawning activity for each population. Expansion factors (indices) were generated for each population by dividing the high precision estimate by the respective peak visual count (live plus dead). For a subset of the nine populations (Seymour, Harrison, Stellako and Little rivers) both ground and aerial counts were conducted to facilitate comparison of the resultant expansion factors for the two methods. Stream characteristics for all Sockeye populations in the Fraser River watershed are summarized in Appendix 1 and a more detailed description of the calibration methods employed in this study are presented in Welch et al. 2011.

In 2017 and 2018, an Unmanned Aerial Vehicle (UAV) (i.e., 'drone') was included as a third visual count method for calibration purposes. This initial work was intended primarily as a feasibility study to determine if it was possible to visually enumerate spawning Sockeye salmon using UAVs and under what conditions (e.g., weather, overhead vegetation, stream size and character, etc.). UAV surveys in 2017-2018 were limited to specific spawning reaches of several of the nine streams mentioned above (Seymour, Stellako, Middle Shuswap and Little rivers).

In addition to the data collected in 2018, this report provides a summary of all calibration work completed by DFO for Fraser Sockeye populations from 1988-2018. This includes a summary of mean expansion factor (indices) values (and related statistics) for specific categories of streams based on size and water clarity that have been generated using all calibration data collected to date.

RESULTS

2018 CALIBRATION ACTIVITIES

Early Summer Runs

Nadina River

One aerial survey of the Nadina River (including the Nadina artificial spawning channel) was conducted on September 16th with a total of 123,964 Sockeye salmon (live + dead) enumerated. The index generated from comparing the aerial count to the sonar estimate of 177,194 Sockeye salmon is 1.43 (Table 1).

Scotch Creek

One aerial survey of Scotch Creek was conducted on September 8th with a total of 22,777 Sockeye salmon (live + dead) enumerated. The index generated from comparing the aerial count to the fence estimate (above fence only) of 81,169 Sockeye salmon is 3.56 (Table 1).

Seymour River

Paired aerial and ground surveys of the Seymour River were conducted on September 8th with a total of 37,730 and 75,846 Sockeye salmon (live + dead) enumerated, respectively. The indices generated from comparing the aerial and ground counts to the mark-recapture estimate of 119,462 (not including McNomee) Sockeye salmon are 3.17 and 1.58, respectively (Table 1).

Summer Runs

Harrison River

Paired aerial and ground surveys of the Harrison River were conducted on November 10th with a total of 4,520 and 1,655 Sockeye salmon (live + dead) enumerated, respectively. The indices generated from comparing the aerial and ground counts to the mark-recapture estimate of 15,177 Sockeye salmon are 3.36 and 9.17, respectively (Table 1).

Stellako River

Paired aerial and ground surveys of the Stellako River were conducted on September 29-30th with a total of 91,008 and 79,640 Sockeye salmon (live + dead) enumerated, respectively. The indices generated from comparing the aerial and ground counts to the sonar estimate of 176,904 (above sonar) Sockeye salmon are 1.94 and 2.22, respectively (Table 1).

Late Runs

Adams River - Lower

One ground survey of Adams River was conducted on October 22nd with a total of 181,880 Sockeye salmon enumerated. The index generated from comparing the ground count to the mark-recapture estimate of 535,564 Sockeye salmon is 2.94 (Table 1).

Birkenhead River

One ground survey of Birkenhead River was conducted on September 18-19th with a total of 4,727 Sockeye salmon enumerated. The index generated from comparing the ground count to the sonar estimate of 15,066 Sockeye salmon is 3.19 (Table 1).

Eagle (Late) River

One aerial survey of Eagle River was conducted on October 16th with a total of 78,495 Sockeye salmon enumerated. The index generated from comparing the aerial count to the sonar estimate (above sonar) of 179,736 Sockeye salmon is 2.29 (Table 1).

Little River

Paired aerial and ground surveys of the Little River were conducted on October 24th with a total of 51,480 and 53,100 Sockeye salmon enumerated, respectively. The indices generated from comparing the aerial and ground counts to the mark-recapture estimate of 127,386 Sockeye salmon are 2.47 and 2.40, respectively (Table 1).

Table 1. Summary of low precision visual counts, high precision escapement estimates and the resulting indices for Nadina, Scotch, Seymour, Harrison, Stellako, Adams (Lower), Birkenhead, Eagle (Late) and Little rivers in 2018.

			Low Precision		High Precision		
Stream	Stream Size	Water Clarity	Method	Count [a]	Method	Estimate	Index
Nadina	Medium	Tannic	Aerial	123,964	Sonar	177,194	1.43
Scotch	Small	Clear	Aerial	22,777	Fence	81,169 [b]	3.56
Seymour	Medium	Clear	Aerial	37,730	MR	119,462	3.17
Seymour	Medium	Clear	Ground	75,846	MR	119,462	1.58
Harrison	Extra Large	Clear	Aerial	4,520	MR	15,177	3.36
Harrison	Extra Large	Clear	Ground	1,655	MR	15,177	9.17
Stellako	Medium	Clear	Aerial	91,008	Sonar	176,904 [b]	1.94
Stellako	Medium	Clear	Ground	79,640	Sonar	176,904 [b]	2.22
Adams (Lower)	Large	Clear	Ground	181,880	MR	535,564	2.94
Birkenhead	Medium	Pt. Turbid	Ground	4,727	Sonar	15,066 [b]	3.19
Eagle (Late)	Medium	Clear	Aerial	78,495	Sonar	179,736 [b]	2.29
Little	Extra Large	Clear	Aerial	51,480	MR	127,386	2.47
Little	Extra Large	Clear	Ground	53,100	MR	127,386	2.40

[a] Peak live count plus dead carcasses observed.

[b] Estimates do not include live spawners below the sonar or fence site, which is negligible.

Aerial to Ground Counts

Simultaneous aerial and ground counts occurred at 10 locations from August 10th to November 10th in 2018 (Table 2). These paired aerial-ground counts were conducted in conjunction with high precision assessments in some cases (see above), as well as for several other streams where no high precision assessment occurred.

Table 2. Comparison of simultaneous aerial and ground survey live and dead counts by stream for Fraser Sockeye salmon spawning populations, 2018.

Stream	Date	Stream Size	Water Clarity	Aerial Count [a]	Ground Count [a]	Aerial / Ground ratio
Chilliwack (Upper)	20-Aug	Medium	Clear	610	1,200	0.51
Corbold	1-Sep	Small	Part. Turbid	1,101	1,551	0.71
Corbold	6-Sep	Small	Part. Turbid	1,579	1,904	0.83
Dust	10-Aug	Small	Tannic	399	489	0.82
Harrison	10-Nov	X-Large	Clear	4,520	1,655	2.73
Kuzkwa	15-Sep	Medium	Tannic	1,220	2,719	0.45
Little	24-Oct	X-Large	Clear	51,480	53,100	0.97
North Thompson	26-Sep	X-Large	Part. Turbid	1,759	1,346	1.31
Stellako	29-Sep	Medium	Clear	91,185	79,640	1.14
Seymour	8-Sep	Medium	Clear	36,880	75,846	0.49
South Thompson	24-Oct	X-Large	Clear	242	247	0.98

[a] Counts may only represent a portion of the stream

CALIBRATION ACTIVITIES (1988-2018)

Since calibration efforts began in 1988 a total of 149 calibration data points (indices) have been generated on Fraser River Sockeye salmon populations based on comparisons of visual counts to escapement estimates derived from high precision assessments (Appendix 2). Of these, 90 were based on ground surveys and 59 were based on aerial surveys. The vast majority of calibration data points derived from ground surveys are from streams that have been categorized as very small with water clarity characterized as clear (Table 3; Appendix 3); whereas, data points derived from aerial surveys are primarily from medium and extra large-sized streams with either clear or partially turbid/tannic water clarity (Table 4).

Table 3. Summary of mean calibration factors for ground-based counts stratified by stream size and water clarity for Fraser Sockeye salmon populations, 1988-2018.

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	23	99,551	2.11	1.10 - 4.21	0.79	0.37
	Pt. Turbid / Tannic	3	28,559	2.68	2.17 - 3.19	0.51	0.19
	Turbid	0	-	-	-	-	-
Large	Clear	7	355,258	3.94	2.22 - 9.04	2.38	0.60
	Pt. Turbid / Tannic	2	67,022	2.46	2.18 - 2.74	0.40	0.16
	Turbid	0	-	-	-	-	-
Extra Large	Clear	2	71,281	5.78	2.40 - 9.17	4.79	0.83
	Pt. Turbid / Tannic	0	-	-	-	-	-
	Turbid	0	-	-	-	-	-

Table 4. Summary of mean calibration factors for aerial-based counts stratified by stream size and water clarity for Fraser Sockeye salmon populations, 1988-2018.

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	1	81,169	3.56	-	-	-
	Pt. Turbid / Tannic	2	12,710	2.54	2.04 - 3.05	0.72	0.28
	Turbid	0	-	-	-	-	-
Medium	Clear	19	89,587	2.32	1.23 - 3.34	0.62	0.27
	Pt. Turbid / Tannic	8	89,260	3.13	1.43 - 4.90	0.95	0.30
	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	7	134,936	5.12	2.30 - 11.88	3.90	0.76
	Pt. Turbid / Tannic	16	154,844	3.70	1.48 - 10.32	2.66	0.72
	Turbid	0	-	-		-	-

* Very Small streams typically not surveyed using aerial methods

From 1988 to 2018, the average index generally increases with stream size and water clarity (from clear to turbid) for both ground and aerial-based counts. 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: <0.01 to 0.83) (Tables 3 and 4). The highest variability is associated with streams categorized as large clear, extra-large clear and extra-large partially turbid/tannic. High variability (CV > 0.5) can be linked to a few streams within each group (Eagle, Adams (lower), Harrison, Middle, and Tachie rivers; Tables 5,6).

Table 5. Summary of ground survey-derived mean calibration factors by individual stream for Fraser Sockeye salmon populations, 1988-2018.

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-Ell	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	Pt. Turbid / Tannic	Birkenhead	1	15,066	3.19	-	-	-
	Clear / Pt. Turbid / Tannic	Seymour	5	68,452	2.09	1.43 - 2.67	0.57	0.27
	Clear	Stellako	19	102,723	2.12	1.10 - 4.21	0.83	0.39
	Clear	Raft	1	66,292	2.62	-	-	-
Large	Clear	Adams (Lower)	7	355,258	3.94	2.22 - 9.04	2.38	0.60
	Pt. Turbid / Tannic	Pitt (Upper)	2	67,022	2.46	2.18 - 2.74	0.40	0.16
Extra Large	Clear	Little	1	127,386	2.40	-	-	-
	Clear / Pt. Turbid / Tannic	Harrison	1	15,177	9.17	-	-	-

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

Table 6. Summary of aerial survey-derived mean calibration factors by individual stream for Fraser Sockeye salmon populations, 1988-2018.

Size	Water Clarity [a]	Stream	Number of calibration surveys (n)	Average Population Estimate	Average Index	Index Range	Standard Deviation	Coefficient of Variation
Small	Clear	Scotch	1	81,169	3.56	-	-	-
	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	9	88,645	2.07	1.23 - 3.01	0.64	0.31
	Clear	Kuzkwa	1	13,682	2.13	-	-	-
	Clear	Seymour	2	116,737	3.22	3.17 - 3.28	0.08	0.02
	Clear	Eagle (*Late*)	1	179,736	2.29	-	-	-
	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	2	96,933	2.37	1.43 - 3.32	1.34	0.57
	Pt. Turbid / Tannic / Turbid	Eagle (*Early*)	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	3	187,840	2.46	2.30 - 2.60	0.15	0.06
	Clear / Pt. Turbid / Tannic	Harrison	7	125,018	6.52	2.63 - 11.88	3.87	0.59
	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 88 aerial to ground visual count comparisons have been completed for 32 individual streams broadly distributed across the Fraser Watershed, and representing all five stream size categories (Appendix 4). Ratios of aerial to ground counts generally increase with stream size. However, the data reveal similar results amongst the moderately sized (small, medium and large) streams (Table 7).

Table 7. Summary of mean aerial to ground count ratios for simultaneously conducted aerial and ground surveys, stratified by stream size, for Fraser Sockeye salmon spawning populations for 2002-2018.

Stream	N	Aerial / Ground ratio [a]
Very Small	12	0.71
Small	20	0.81
Medium	39	0.81
Large	8	0.82
X-Large	9	2.03

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

SUMMARY

Calibration work completed in 2018 provided 13 new calibration data points: seven for aerial survey counts, and six for ground survey counts. Of these, one was obtained for an aerial survey on a small, clear stream (Scotch Creek), five (3 aerial, 2 ground) for medium/clear streams (Eagle, Seymour and Stellako rivers), two (1 aerial, 1 ground) for medium/partially turbid/tannic streams (Birkenhead and Nadina rivers), one for a large, clear stream (Adams River-lower) and four (2 aerial, 2 ground) for extra-large, clear streams (Harrison and Little rivers). Additionally, simultaneous aerial to ground counts were obtained for 10 streams.

The 2018 field season represents the tenth and final year of a SEF funded calibration study to minimize bias in visually enumerated Sockeye salmon populations in the Fraser River watershed. During this time frame, calibration efforts on all sized systems resulted in the generation of 67 indices (48 funded by the SEF). Although this represents significant progress towards the development expansion factors for specific stream types and assessment methods, and, in some cases, specific streams, significant gaps still exist.

Originally, it was anticipated that the standard 1.8 index would continue to be applied to all visually enumerated Sockeye stream populations until the completion of the 10 year calibration study. Following that it was hoped that new stream type indices would be adopted and a retroactive escapement analysis would be conducted, contingent on the criteria that escapements to individual streams would only be reassessed if they fell within a stream size/water clarity/assessment method strata having either a minimum of five data points with an error (CV) of 25% or less or having a total of 10 or more data points. These conditions have now been met for three of the strata: medium-sized/clear/ground survey, medium-sized/clear/aerial survey, and extra-large/partially turbid/aerial survey. The mean expansion factor values for these three strata are 2.1, 2.3, and 3.7, respectively (Tables 3,4).

Moving forward, it is recommended that continued analysis be conducted that examines incorporating additional parameters, such as stream discharge, on an annual basis. For example, data from Stellako River suggests that there is a fairly strong relationship between discharge and the resulting index created from the live counts. During years of high stream flows it would be prudent to apply an index that incorporates the difficulties related to counting conditions during high water flows compared to those experienced during low flow years.

Even though the 10 year SEF funded calibration study is complete, Fraser River Stock Assessment will continue to collect and compile calibration data throughout the Fraser watershed, to increase sample sizes for the various calibration strata, with the expectation of improving the precision of the mean calibration factor values, and further refining the classification strata as well. However, as outlined in previous calibration report summaries, there are a number of factors related to weather and environmental conditions, physical stream characteristics and Sockeye behaviour that can contribute to high levels of variability in expansion factor values developed for aerial and ground survey counts. It should be

understood that this variability is real and not just a function of a small sample size. While the error may reduce in some cases as we obtain more data points, it may never reach levels considered optimal for management purposes (i.e. less than 25%). If there is a desire to start incorporating some of these indices promptly, managers will have to accept the fact that escapement estimates for individual streams in individual years derived from these mean expansion factor values will be of relatively low precision for many populations.

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APPENDICES

Appendix 1. Stream morphology and characteristics definitions for Sockeye salmon spawning stream-types in the Fraser River watershed.

Stream Size

Very Small:	Typically on average <5 m wetted width. Wadable in all locations (e.g. Forfar Creek).
Small:	Typically on average 5-10 m wetted width. Wadable at most locations (e.g. Penfold Creek).
Medium:	Typically on average 10m-30m wetted width. Wadable in some locations. Possible use of a jet boat and Raftable (e.g. Mitchell River).
Large:	Typically on average >30m wetted width, depth less than 4 m. Not Wadable. Boat or Raft only. Survey requires 2 or more observers, scanning bank to bank from a vessel (e.g. Adams River).
X-Large:	Typically on average >30 m wetted width, depth greater than 4 m. Not Wadable. Counting from a boat is ineffective. Survey requires scanning bank to bank from a helicopter (e.g. Harrison River).

Water Clarity

Clear:	Visibility usually >3m; can see bottom of deep pools and shallow areas to count spawners and holders (e.g. Horsefly River).
Tannic:	The leaching of highly water soluble tannins from decaying vegetation and leaves along a stream that produces a tea-colour apperance that can sometimes create difficult counting conditions (e.g. Nadina River).
Partially Turbid:	Visibility 1-3m depending on weather; can only observe fish in shallow areas (likely spawners) with fish holding or spawning in deeper pools being difficult or impossible to observe (e.g. Harrison River).
Turbid:	Visibility usually <1m; Fish are very difficult, if not impossible to observe (e.g. Taseko River).

Substrate Colour

Light:	White, light blue, light green substrates that provide good contrast with redds and fish are clearly visible (e.g. Adams River).
Medium:	Yellow, orange and light brown substrate that can reduce counting efficiency in deeper pools and riffles (e.g. Horsefly River).
Dark:	Substrate includes tannic systems; difficult to distinguish fish from dark bottom substrate, unless fish are directly on or over a redd (e.g. Tachie River).

Canopy Cover

Low:	Small amount of overhead vegetation. Little to no influence on counting efficiency (accuracy). Canopy Cover <25%. Aerial surveys typically used. (e.g. Tachie River).
Medium:	Moderate amount of overhead vegetation. Some influence on counting efficiency (accuracy). Canopy Cover 25-75%. Ground surveys typically used (e.g. Ankwill Creek).
High:	Large amount of overhead vegetation. Significant influence on counting efficiency (accuracy). Canopy Cover >75%. Ground surveys always used (e.g. Narrows Creek).

Appendix 2. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2018.

Year	Stream	Size	Water Clarity	Low Precision Visual Method	Low Precision Visual Count	High Precision Estimate Method	High [a] 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
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	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-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	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 2. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2018 (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-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
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-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	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 2. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2018 (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-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
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-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
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-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	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-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

Continued

Appendix 2. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2018 (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 2. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2018 (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 2. Comprehensive summary of calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2018 (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
2018	Adams River, lower*	Large	Clear	Ground	181,880	MR	535,564	2.94
2018	Birkenhead River *	Medium	Pt. Turbid	Ground	4,727	Sonar	15,066	3.19
2018	Eagle River (late)*	Medium	Clear	Aerial	78,495	Sonar	179,736	2.29
2018	Harrison River *	X-Large	Clear	Aerial	4,520	MR	15,177	3.36
2018	Harrison River *	X-Large	Clear	Ground	1,655	MR	15,177	9.17
2018	Little River*	X-Large	Clear	Aerial	51,480	MR	127,386	2.47
2018	Little River*	X-Large	Clear	Ground	53,100	MR	127,386	2.40
2018	Nadina River *	Medium	Tannic	Aerial	123,964	Sonar	177,194	1.43
2018	Scotch Creek *	Small	Clear	Aerial	22,777	Fence	81,169	3.56
2018	Seymour River *	Medium	Clear	Aerial	37,730	MR	119,462	3.17
2018	Seymour River *	Medium	Clear	Ground	75,846	MR	119,462	1.58
2018	Stellako River *	Medium	Clear	Aerial	91,008	Sonar	176,904	1.94
2018	Stellako River *	Medium	Clear	Ground	79,640	Sonar	176,904	2.22

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

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

Appendix 3. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (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.)	Medium	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 3. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (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 3. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (water clarity and method may vary annually) (cont'd).

Population Group	Population	Size	Water Clarity	Visual Method
South Thompson (cont'd)	**Shuswap River**			
	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
	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 Thompson	Barriere River	Medium	Clear	Aerial
	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 3. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (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 3. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (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 3. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (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	Clear / 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 3. Comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed by stream size, water clarity, and visual method under typical conditions (water clarity and method may vary annually) (cont'd).

Group	Population	Size	Water Clarity	Visual Method
Nechako (cont'd)	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	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 4. Summary of aerial to ground comparison surveys by specific streams for Fraser Sockeye salmon spawning populations, 2002-2018.

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 Perr	2002	Medium	Part. Turbid	17,538	31,470	0.56
Eagle River - Upper (above Perr	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

Continued

Appendix 4. Summary of aerial to ground comparison surveys by specific streams for Fraser Sockeye salmon spawning populations, 2002-2018 (cont'd).

Stream	Year	Stream Size	Water Clarity	Aerial Count	Ground Count	Aerial / Ground Ratio
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
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

Continued

Appendix 4. Summary of aerial to ground comparison surveys by specific streams for Fraser Sockeye salmon spawning populations, 2002-2018 (cont'd).

Stream	Year	Stream Size	Water Clarity	Aerial Count	Ground Count	Aerial / Ground Ratio
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
Chilliwack (Upper)	2018	Medium	Clear	610	1,200	0.51
Corbold	2018	Small	Part. Turbid	1,101	1,551	0.71
Corbold	2018	Small	Part. Turbid	1,579	1,904	0.83
Dust	2018	Small	Tannic	399	489	0.82
Harrison	2018	X-Large	Clear	4,520	1,655	2.73
Kuzkwa	2018	Medium	Tannic	1,220	2,719	0.45
Little	2018	X-Large	Clear	51,480	53,100	0.97
North Thompson	2018	X-Large	Part. Turbid	1,759	1,346	1.31
Stellako	2018	Medium	Clear	91,008	79,640	1.14
Seymour	2018	Medium	Clear	37,730	75,846	0.50
South Thompson	2018	X-Large	Clear	242	247	0.98