Calibration of Assessment Methods for Fraser River Sockeye Salmon *(Oncorhynchus nerka)* Spawning Populations between 25,000 and 75,000.

2011

Paul Welch[1], Keri Benner[1] and Brian Leaf[1]

Fisheries and Oceans Canada[1]
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

CONTENTS

Page

LIST OF FIGURES

Page

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 <25,000, and high precision techniques (fences or mark-recaptures) for escapements >25,000. However, pressures on financial resources coupled with an increasing number of larger populations on the spawning grounds have strained capacity to meet these standards. This resulted in an increase of the threshold level to 75,000 spawners in 2004, with the objective of maintaining coverage on as many populations as possible while realizing minimal negative precision related impacts to the enumeration program overall. As a result of the threshold change, visual methods are now being used to enumerate much larger populations than they were ever intended to estimate. The standard expansion factor currently applied to visual counts (to account for the consistent underestimation of live counts) was developed for very small, clear stream populations in the Fraser system. Its application to larger populations (>25,000) will lead to substantial negative bias in spawning estimates.

Large populations (>25,000) tend to spawn in larger streams where the relative proportion of the Sockeye population vulnerable to survey crews is much different than in smaller systems. Simultaneous comparisons of high and low precision methods have occurred since 1998 for large Fraser River Sockeye salmon escapements with resulting indices reaching as high as 7.44. This is much higher than the current standard index of 1.8 and its improper application could lead to estimates that are only a fraction of a high precision estimate. As the proportion of the total Fraser Sockeye salmon escapement that is enumerated using visual techniques increases as a result of the change in enumeration threshold, it is crucial that structured calibration studies are undertaken to produce stream-type and method specific expansion factors for Sockeye spawning populations between 25,000 and 75,000 to avoid serious negative bias in future escapement estimates.

In 2010, the Southern Boundary Restoration and Enhancement Fund (SEF) funded a study to build on techniques developed in the 2007 SEF Fraser Sockeye Calibration of Assessment Methods study to minimize bias in visually enumerated Sockeye salmon escapements with populations ranging between 25,000 and 75,000 through the continued development of stream-type and method specific indices. Originally the study was to focus on numerous populations throughout the Fraser Watershed based on expected returns relative to brood year escapements. However, due to a much higher than expected Sockeye return to the Fraser River in 2010, escapements to most areas substantially exceeded the 75,000 threshold which limited calibration opportunities to the Quesnel System, specifically the Mitchell and Horsefly rivers. This study had the following objectives:

1. Develop stream specific visual expansion factors by calibrating low precision visual counts to high precision escapement estimates on the Mitchell and Horsefly rivers.
2. Compare and calibrate simultaneous aerial based live counts to ground based live counts where feasible throughout the Fraser watershed.
3. Summarize all Fraser Sockeye calibration efforts to date.

STUDY AREA

FRASER RIVER WATERSHED

Efforts to calibrate visual estimates of Sockeye spawning escapement have been conducted opportunistically throughout the Fraser Watershed since 1988. Historically, these efforts have focused on the small clear streams, such as those in the Early Stuart aggregate. Since the increase in the high precision threshold in 2004, calibration efforts have expanded to include larger streams with typically larger populations in several areas throughout the watershed. The 2010 study focuses on the Mitchell and Horsefly Rivers in the Quesnel Lake drainage (Fig. 1).

Mitchell River

The Mitchell River originates in the Cariboo Mountains of east-central British Columbia. The river flows southwest for 50 km, entering Quesnel Lake at the upper end of the North Arm. The river and two main tributaries, Cameron and Penfold creeks, drain a relatively small watershed (574 km^2) which is glaciated in the extreme upper reaches (Fig. 2). Mean monthly discharge of the Mitchell River at the Mitchell Lake outlet averages 12 m^3s^{-1} (1961-1982), with mean monthly maxima (33 m^3s^{-1}) and mean monthly minima (2 m^3s^{-1}) occurring in June and March, respectively (Environment Canada 2011a). A flow control structure, installed at the outlet of Mitchell Lake in 1989, augments winter flows to improve egg incubation conditions.

The 2010 calibration study on the Mitchell River included the entire accessible spawning area of the river from the mouth at Quesnel Lake upstream 16 km to a set of falls impassable to Sockeye (Fig. 2). The mid and lower sections of the study area are accessible by jet-boat or aircraft while the upper section (beginning at the Cameron Creek confluence) is accessible by foot and aircraft only. The upper section of the river is mostly confined to a single channel flowing through a deep valley, with the exception of a few side channels. At the Cameron Creek confluence (extent of boat traffic due to a large log jam) the river flows out of the mountains onto a 1.5 km wide, flat, marshy low-land area. The gradient declines and the substrate changes from small boulders and cobble to a cobble, gravel and sand complex. The river braids occasionally, but remains mostly confined to a single channel as it meanders towards the mouth at Quesnel Lake. The lower section of the river consists of slow moving water and very limited spawning habitat. Spawning primarily occurs in the middle sections of the river where substrate and gradient are ideal for spawning Sockeye salmon.

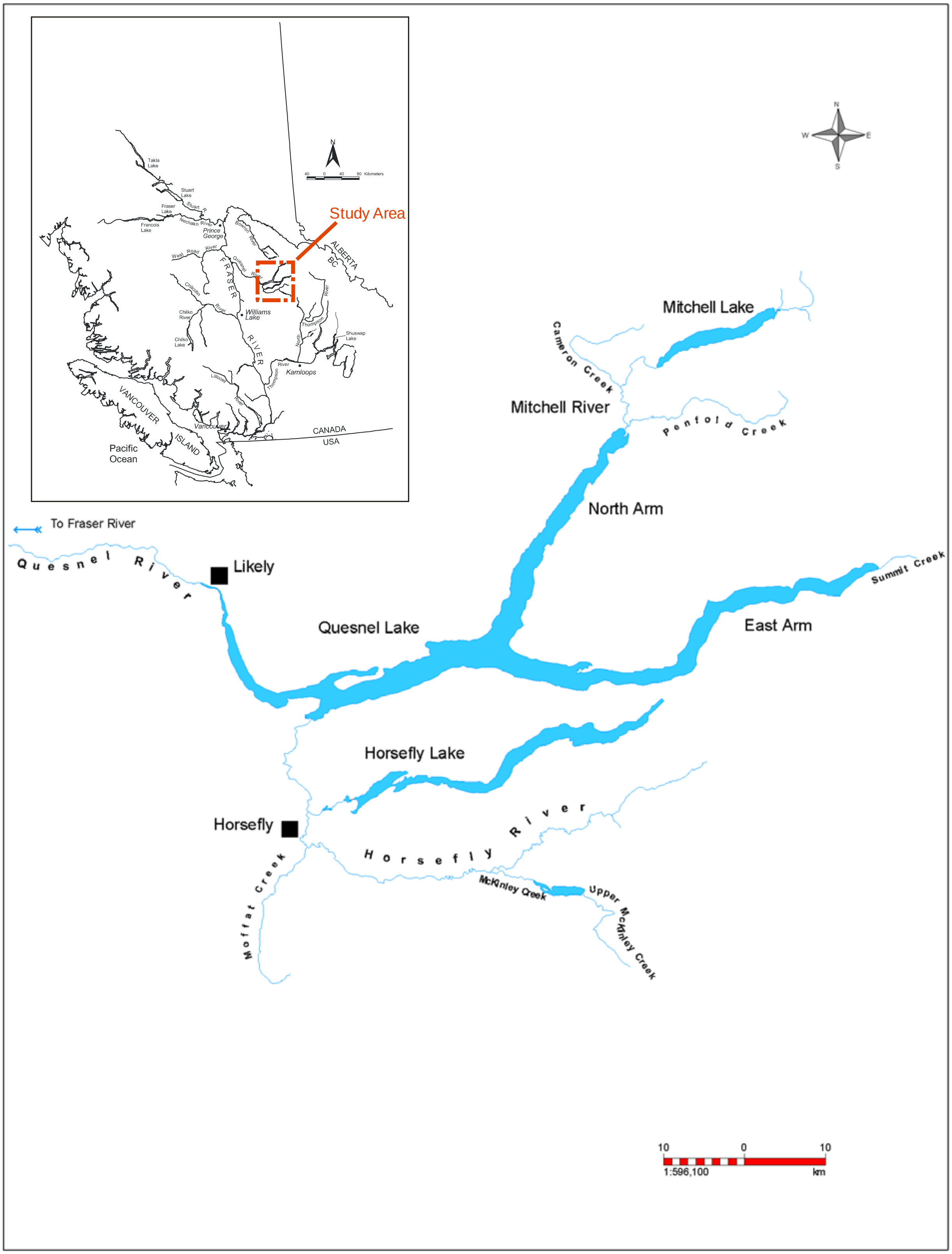

Figure 1. Overview map of the Quesnel and Fraser River watersheds.

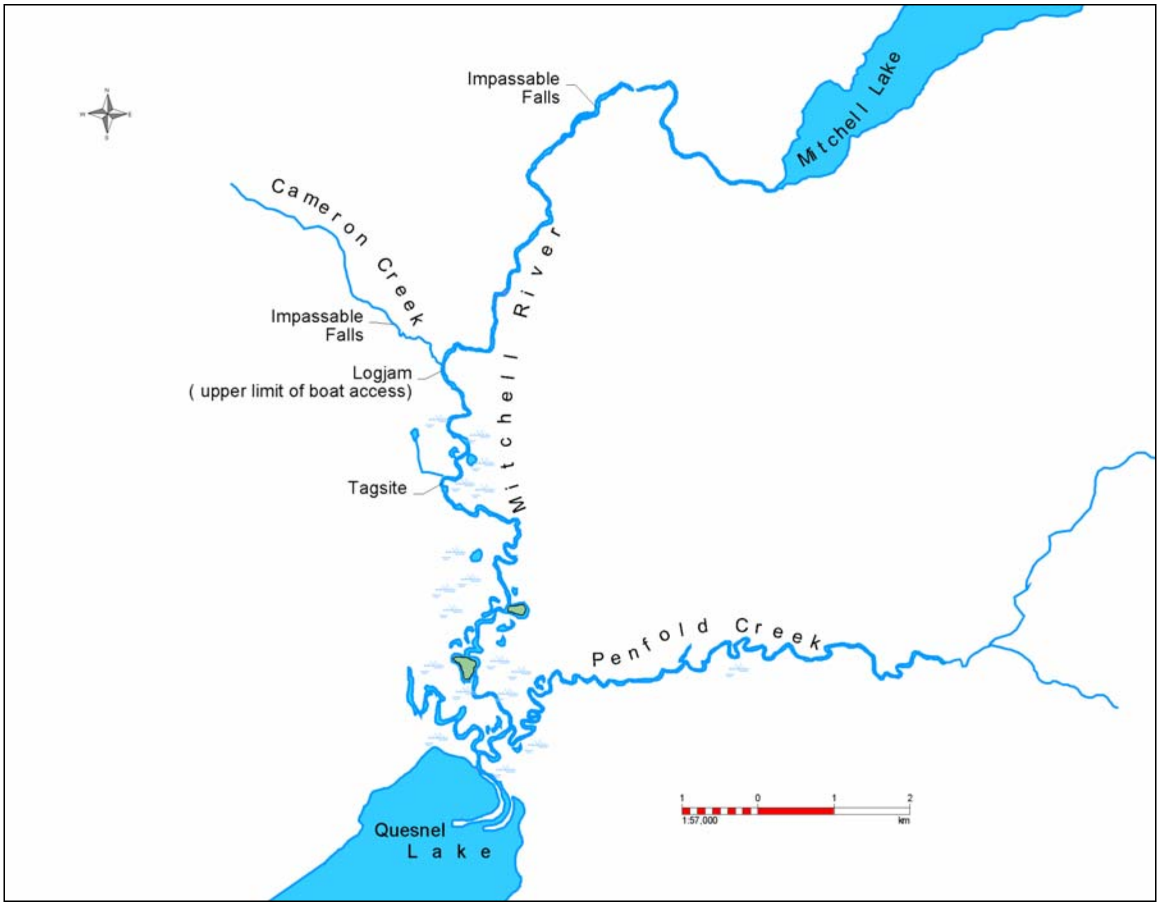

Figure 2. Overview map of the Mitchell River system.

Horsefly River

The Horsefly River originates in Wells Grey Provincial Park within the Cariboo Mountains. It is a relatively large tributary (~110 km in length) entering the southwest corner of the main arm of Quesnel Lake draining a watershed of 2,756 km^2. The Horsefly River system consists of three main tributaries: Little Horsefly River, McKinley Creek and Moffat Creek (Fig. 3). Mean monthly discharge of the Horsefly River above Quesnel Lake averages 33.9 m^3s^{-1} with a mean monthly maxima of 105 m^3s^{-1} and mean monthly minima of 10 m^3s^{-1} occurring in July and March, respectively (Environment Canada 2011b).

The 2010 calibration study on the Horsefly River included the entire accessible spawning area of the river from the mouth at Quesnel Lake upstream 62.6 km to a set of falls impassable to Sockeye (Fig. 3). The upper most areas of the Horsefly River near the McKinley Creek confluence are characterized by riffles, pools and cobble and gravel substrate within a well defined, low to moderate gradient channel. Further downstream the river meanders through a broad flood plain and has a substrate primarily consisting of mud, silt and sand before transitioning back to larger substrates and moderate gradients. The flow regime of the lower river differs from the upper river due to the increased discharge from Little Horsefly River. The gradient is low to moderate below the townsite then increases as it flows though a series of small steps in exposed bedrock. Further downstream the river decreases in gradient and substrate size and braids frequently as it extends to Quesnel Lake. Spawning occurs throughout the entire river with the prime habitat occurring in the upper portions near McKinley Creek confluence followed by areas between the Horsefly townsite and Little Horsefly River, as well as large sections between Rat Creek and the mouth.

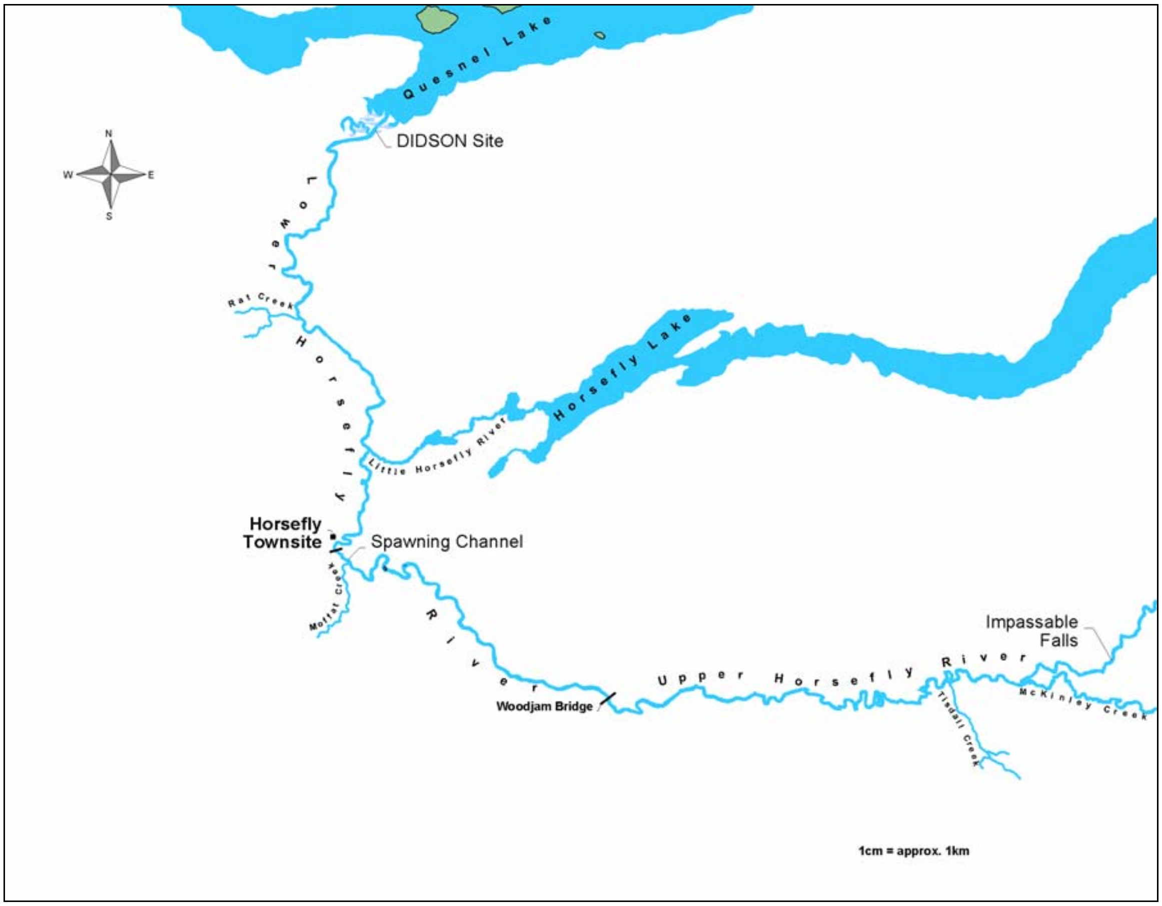

Figure 3. Overview map of the Horsefly River system.

METHODS

This section describes the field methods and analytical procedures used for the enumeration (high and low precision) and calibration techniques employed in this study. It focuses on the 2010 work conducted in the Mitchell and Horsefly rivers, but incorporates data collected from all calibration efforts since 1988.

HIGH PRECISION METHODS

Three high precision techniques are typically employed to estimate Sockeye spawning escapements in the Fraser River watershed including mark-recapture, Dual Frequency Identification Sonar (DIDSON) and fish weirs (fences). Method choice depends on a number of factors including river size and morphology, fish behaviour, budget and logistical issues, such as river access and equipment availability. In 2010, mark-recapture and DIDSON were employed on the Mitchell and Horsefly rivers, respectively.

Mark-Recapture

In 2010, a mark-recapture study was conducted to generate a high precision Sockeye salmon escapement estimate to the Mitchell River. The precision objective of a mark-recapture study for management purposes is to estimate the sex specific escapement with 95% confidence limits of ± 25%. The accuracy of a mark-recapture escapement estimate depends on how well the study satisfies the mark-recapture assumptions as outlined in Seber 1982. The field methods and analytical procedures employed in the 2010 mark-recapture study at the Mitchell River are described in detail in Benner and Leaf (*In prep.*).

DIDSON

In 2010, DIDSON was used to generate a high precision Sockeye salmon escapement estimate to the Horsefly River system, including all of its major tributaries and the Horsefly River Spawning Channel (ASG). DIDSON is an underwater acoustic camera that produces near video quality images utilizing multiple sound beams focused through a movable lens. Objects within the field (also known as the ensonified area) reflect sound back to the sonar where the echoes are used to develop an image. It has the ability to provide images in turbid or dark water. When proper protocols and procedures are followed, DIDSON estimates of fish passage can be as accurate as enumeration fence counts (Holmes et al. 2006). DIDSON was previously used on the Horsefly River in conjunction with a broader feasibility study in 2004 identifying potential DIDSON sites for adult Sockeye salmon enumeration in the Fraser River watershed (Holmes et al. 2005) and finally utilized for salmon escapement estimation on the Horsefly River in 2005 (Cronkite et al. 2006), 2006 (DFO, unpublished data), and 2007 (Welch et al. 2007).

The site chosen for DIDSON on the Horsefly River in 2010 was identical to that in 2007, which was approximately 400 m upstream from the river mouth (Fig. 4). Approximately 55 m of fish deflection weir was used to direct migrating adult Sockeye through a 10 m opening in the weir. DIDSON set-up (including weir construction) and operation follows procedures outlined in Cronkite et al. 2006; Enzenhofer and Cronkite 2005; and Enzenhofer et al. 2005. The DIDSON data collection and analysis protocols followed in 2010 are identical to 2007 and are described in detail in Welch et al. 2007 and Cronkite et al. 2006.

In conjunction with DIDSON, visual surveys were conducted on all Sockeye salmon spawning tributaries of the Horsefly River (Little Horsefly River, McKinley Creek and Moffat Creek) to generate independent population estimates, which along with the Horsefly Spawning Channel absolute count were removed from the total system DIDSON count to produce a Horsefly River mainstem estimate.

Figure 4. Downstream view of the 2010 Horsefly River DIDSON site.

LOW PRECISION METHODS

Visual surveys are typically employed to produce low precision Sockeye spawning escapement estimates in the Fraser River watershed. Visual surveys are conducted aerially (helicopter) or by ground (foot surveys or raft/boat drift surveys). The criteria determining what type of visual survey is employed depends on the river size and morphology, fish behaviour, budget and logistical issues such as river access, remoteness and equipment availability.

Aerial Surveys

In 2010, three aerial surveys of the Mitchell River and two aerial surveys of the Horsefly River were conducted. All flights were scheduled to capture the peak of spawn at both locations and were conducted during the best possible lighting and weather conditions of the day to minimize surface glare. All aerial surveys were conducted by two experienced (greater than three years) observers with the same observers being present for all surveys when possible. All surveys covered the entire length of spawning with each observer recording individual counts of live and dead Sockeye salmon by reach. All observers wore polarized sunglasses and used mechanical counters to keep track of their individual counts of Sockeye salmon. Counts between individual observers were averaged to produce mean aerial counts by reach.

Ground Surveys

In 2010, ground surveys were paired with aerial surveys (conducted within 24 hours of the aerial survey) at the Mitchell, Horsefly and Little Horsefly rivers to permit direct comparisons of the ground and aerial counts. Ground surveys, which were performed by jet boat at the Mitchell River, inflatable raft at the Horsefly River and by foot at the Little Horsefly River, were conducted in designated sections or “calibration reaches” due to river length and program logistics. All ground surveys were conducted by two observers with each observer recording individual counts of live Sockeye salmon. In contrast to the aerial surveys, most ground surveys were performed by relatively inexperienced observers in 2010, primarily due to lack of resources. All observers wore polarized sunglasses and used mechanical counters to keep track of their individual counts of Sockeye salmon. Individual counts were averaged to produce mean ground live counts by calibration reach.

CALCULATION OF INDICES

In 2010, aerial counts were compared directly to mark-recapture and DIDSON estimates at Horsefly River and Mitchell Rivers, respectively. System-specific indices were produced by dividing the high precision estimate by the peak aerial count (live plus dead). Additionally, ground to aerial live count comparisons occurred in both systems to determine the relative difference between the two visual counting techniques.

RESULTS

HIGH PRECISION METHODS

Mitchell Mark-Recapture

The 2010 Mitchell River Sockeye spawning escapement, based on the Pooled Petersen Estimator (PPE) and adjusted data, is 31,879 adult males and 42,443 adult females with 95% confidence limits of ± 5,368 (16.8%) and 5,951 (14.0%), respectively. The total river escapement, produced by summing the sex specific estimates, is 74,322 ± 8,014 (10.8%) adult Sockeye (Table 1). The results and analysis of the 2010 Mitchell River mark-recapture are described in detail in Benner and Leaf (*In prep.*). In summary, all indications were that the tagging process was relatively stress-free (i.e. no indication of differences in recovery probabilities between tagged and untagged Sockeye salmon) and that application and/or recovery was proportional with respect to sex, size, time and space in both sexes. Therefore, there is no indication that the male or female PPE estimates are biased.

Table 1. High precision estimates for the Mitchell and Horsefly rivers by sex with 95% confidence limits and percent of the population estimate (N), 2010.

Stream	Sex	Population Estimate (N)	95% c.l.	Percent of N
Mitchell	Male	31,879	5,368	16.8%
	Female	42,443	5,951	14.0%
	Jack	0	-	-
	Total	74,322	8,014	10.8%
Horsefly Sytem	Total	152,167	22,911	15.0%
Horsefly Mainstem	Male	53,992	-	-
	Female	70,061	-	-
	Jack	21	-	-
	Total	124,074	-	-

Horsefly DIDSON

The 2010 Sockeye salmon migration into the Horsefly River began mid-August and finished in late September (DIDSON operated from August 14 to September 30, 2010). Daily expanded and cumulative DIDSON counts are presented in Appendix 1. Sockeye migration past the DIDSON site was multi-modal with a maximum daily net upstream escapement estimate of 12,333 Sockeye salmon on September 7, 2010 (Figure 5). Total Sockeye salmon escapement to the Horsefly system (including all tributaries) estimated using DIDSON was 152,167 with 95% confidence limits of ± 22,911 (± 15%) (Table 1). The width of this interval reflects errors associated with 1) counting the DIDSON data sets (accuracy), 2) the repeatability of counts between different individuals for the same data sets (precision), and 3) temporal sub-sampling (representativeness of the sampling). The error in counting the DIDSON data sets can be considered overall to be zero for this population estimate as the DIDSON data are not biased by fish moving past the site undetected (Holmes et al. 2006). The repeatability of counts, expressed using average percent error (APE), contributed an overall error of ±5% and the temporal sub-sampling of 20 minutes out of every hour contributed an overall error of ±5%. After removal of independent estimates of Sockeye spawners in Little Horsefly River (4,068), McKinley Creek (1,534), Moffat Creek (0) and the Horsefly Spawning Channel (22,493) (DFO, unpublished data), a total of 124,074 Sockeye salmon were estimated to be utilizing the Horsefly River mainstem (Table 1). Estimates generated from lower precision visual surveys are inherently uncertain; thus, the precision of the mainstem estimate will be unavoidably impacted by removing the Horsefly River tributaries from the DIDSON count. However given the relatively small number of spawners estimated in the tributaries (total of 5,602), the overall impact on the precision of the Horsefly mainstem estimate is likely very small.

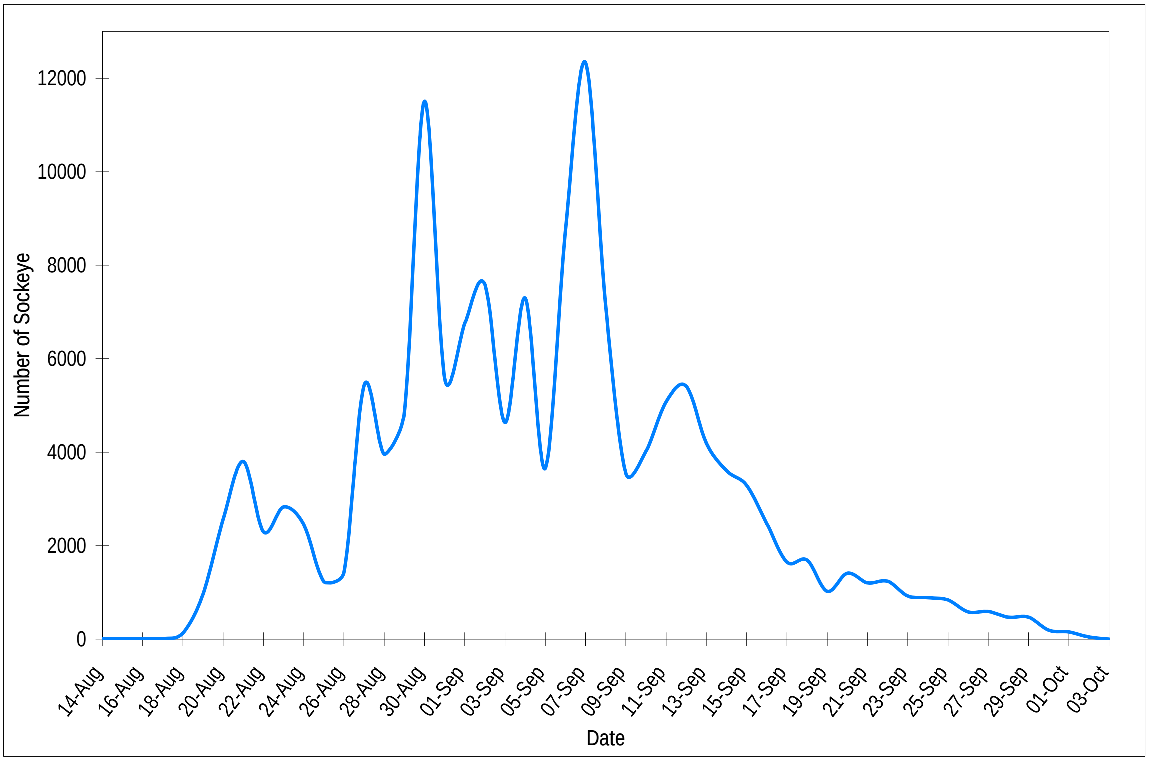

Figure 5. Daily net upstream Sockeye counts past the Horsefly River DIDSON site, 2010.

LOW PRECISION METHODS AND INDICES

Mitchell River

Three aerial surveys of the Mitchell River were conducted on September 20th, 24th and the 28th with a total of 36,346, 38,415 and 26,032 Sockeye salmon (live + dead) enumerated on the mainstem, respectively (Appendix 2). The index generated from comparing the peak aerial count (September 24th flight of 38,415 Sockeye) to the mark-recapture estimate of 74,322 Sockeye salmon for the Mitchell River is 1.93 (Table 2). Aerial live counts represented 134%, 153% and 167% of the corresponding simultaneous ground counts of the calibration reach on the three consecutive surveys, respectively (Table 3).

Horsefly River

Two aerial surveys of the Horsefly River were conducted on September 9th and 13th with a total of 43,249 and 63,186 Sockeye salmon (live + dead) enumerated on the mainstem, respectively (Appendix 3). The index generated from comparing the peak aerial count (September 13th flight of 63,186 Sockeye) to the DIDSON estimate of 124,074 Sockeye salmon for the Horsefly River is 1.96 (Table 2). Aerial live counts represented 59% and 95% of the corresponding simultaneous ground counts of the calibration reaches in the Horsefly and Little Horsefly rivers, respectively (Table 3).

Table 2. Summary of low precision (aerial) and high precision (DIDSON and Mark/Recapture) estimates and the resulting indices at Mitchell and Horsefly rivers, 2010.

		Low Precision		High Precision		
Stream	Date	Method	Count [a.]	Method	Estimate	Index
Mitchell	24-Sep	Aerial	38,415	M/R	74,322	1.93
Horsefly	13-Sep	Aerial	63,186	DIDSON	124,074	1.96

[a.] Peak live count plus dead carcasses observed.

Table 3. Summary of aerial and ground counts by date of calibration reaches at Mitchell, Horsefly and Little Horsefly, rivers, 2010.

Stream	Date	Aerial Count	Ground Count	Aerial : Ground (%)
Mitchell	20-Sep	19,010	14,163	134%
Mitchell	24-Sep	21,765	14,213	153%
Mitchell	28-Sep	13,235	7,935	167%
Horsefly	09-Sep	511	861	59%
Little Horsefly	12-Sep	1,757	1,843	95%

DISCUSSION

Fraser River Sockeye salmon spawning escapement data has been collected and recorded annually since 1939. Gradual improvements in data collection standards, enumeration techniques, access, equipment, knowledge and crew skill level over the years have resulted in a steady increase in the quality of the escapement estimates through the time series. These changes over time must be considered when comparing past data to the present. In most cases, it is only appropriate to utilize data subsequent to 1988 for comparison or calibration purposes. Furthermore, since 2007 rigorous standards have been developed and implemented regarding calibration protocols and procedures. As a result, thorough comparisons and trend analysis have occurred primarily on data subsequent to 2007.

ACCURACY OF HIGH PRECISION ESTIMATES

The mark-recapture and DIDSON studies conducted at the Mitchell and Horsefly rivers respectively in 2010 provided escapement estimates with precision within 95% confidence limits of ± 25%. All assumptions of the Petersen mark-recapture method were addressed and satisfied at the Mitchell River indicating that the sex-specific PPE estimates for this system are unbiased. Additionally, the Horsefly DIDSON operated efficiently and without any issues identified that would potentially affect the precision and accuracy of this estimate.

Additional studies have been conducted, specifically at Horsefly and Chilko, to corroborate the accuracy of different high precision techniques. In 2007, three independent high precision techniques (fence, DIDSON and mark-recapture) implemented on the Horsefly River produced nearly identical estimates (Welch et al. 2007). Similar comparisons were made at Chilko River in 2006 when mark-recapture and DIDSON studies were conducted simultaneously also producing nearly identical estimates (DFO, unpublished data). The close agreement between these high precision estimates lends additional credibility and reliability to mark-recapture and DIDSON estimates as suitable standards for comparison and calibration with visual methods.

LOW PRECISON (VISUAL) METHODS

The accuracy and variance of visual estimates can vary greatly and can be influenced by multiple factors including those related to stream morphology such as stream size, water clarity, substrate colour, canopy cover and in-stream large woody debris (Appendix 4). A comprehensive list of all Sockeye salmon spawning streams within the Fraser watershed has been developed with streams being categorized by these criteria (Appendix 5). Indices developed at one location may be used for streams at other locations that share similar stream type criteria.

Additional factors influencing the accuracy and variance of visual estimates include fish density issues related to both intra- and interspecific abundance, although, on most systems, it is typically Sockeye salmon abundance that leads to decreased counting efficiency (Trouton 2004). Results from Shardlow et al. 1987 showed that that the accuracy of observer counts might be inversely proportional to the density of salmon, especially when fish are observed in pre-spawn or schooling behaviour. As a result, peak counts are always scheduled to capture the peak of spawn, when the majority of fish are in the river and dispersed on redds. Related to density is the total length of river containing suitable spawning habitat. Peak live counts from the 2010 studies on the Horsefly and Mitchell Rivers differed considerably with the Horsefly counts more than doubling the Mitchell counts; however, densities on the spawning grounds were much greater on the Mitchell River since spawners are limited to approximately 6 km of usable spawning habitat in the Mitchell River compared to over 40 km of prime spawning habitat for Sockeye salmon to utilize on the Horsefly River. Given the similarities in river size, morphology and spawner behaviour at the Horsefly and Mitchell river systems, it is likely the influence of spawner density that largely contributed to the similar indices generated for two systems in 2010 (1.96 and 1.93, respectively) despite the larger Sockeye escapement to the Horsefly River.

These factors combined with highly dynamic weather conditions can result in survey inconsistencies further contributing to variance in the estimates. Therefore, it is important to obtain as many calibration data points as possible that would provide greater insight on how and to what degree these criteria influence observer efficiency (the proportion of fish counted relative to the actual fish present) and the development of indices. General trends in the data suggest that observer efficiency is typically greater on the following: smaller streams compared larger; clear water compared to tannic or turbid; light substrate compared to darker; minimal canopy cover or riparian vegetation compared to more; lower amounts of large woody debris (LWD) compared to higher amounts, and streams with lower fish densities (typically smaller populations) compared to higher densities (typically larger populations). This is consistent with other studies which found that fish are more visible in certain habitats and types of river morphology (Shardlow et al. 1987).

Overall, it is believed that the main criteria affecting observer efficiency and the development of indices are stream size and water clarity. Appendix 6 displays the eighteen stream-types found within the Fraser Watershed based on these two main criteria, of which eleven have been calibrated since 1988. As expected, these data generally reveal that indices are higher in larger streams (typically larger populations) and streams with reduced water clarity as compared to smaller streams (typically smaller populations) and streams with increased water clarity. Historically, only very small streams with relatively small populations were assessed using visual surveys, hence most calibration efforts since 1988 have focused on these stream-types (53 calibration surveys). Moderate calibration effort has also occurred on medium sized streams (24); and only three calibration surveys have occurred on both small and large streams. As it is typically the small, medium and larger size streams that support populations within the 25,000 to 75,000 range (Appendix 6), future calibration efforts should focus on these eleven stream-types.

EFFECTS OF MIGRATION DURATION AND SURVEY FREQUENCY

The variation associated with visual estimates described above is compounded by the issue of spawner replenishment (migration duration) and survey frequency. Understanding the degree of spawner replenishment and how survey frequency affects the ability to capture an accurate peak live count is extremely important as they both directly contribute to the development of an index.

Most Fraser River Sockeye populations exhibit a relatively normal migration distribution and spawning timing pattern where a distinct peak in abundance is observed. However, some populations exhibit a multi-modal or protracted migration and spawning period, where Sockeye arrival, spawning and death occur at a relatively constant rate for an extended period of time. Indices in these systems will invariably be higher than those with a normally distributed migration pattern to account for spawner replenishment. This was observed at the Horsefly River in 2007, where the independent calibration of the upper and lower river produced notably different indices (1.75 and 3.63, respectively; Appendix 10) in part due to a much more protracted migration in the lower river (Welch et. al., 2007)

Survey frequency and timing also represent important aspects that influence the development of indices. Surveys that begin too late or are not conducted frequently enough will most likely underestimate the population because the early carcasses will not be available for counting and the true peak of spawn may occur before or in between surveys. While the carcass count does influence the estimate, typically only a small percent (~5%) die before the peak, and therefore has a minimal effect. However, the possibility of missing the peak of spawn can potentially introduce a substantial negative bias (Schubert, 2007). This bias is typically minimized by using historical run timing data in combination with in-season observations to schedule to most adequate visual survey dates.

AERIAL VS. GROUND COUNTS

When comparing aerial to ground based surveys it is assumed that the ground based counts are more accurate in most cases since observers are able to move at a slower and constant rate when counting and viewing the stream from a closer and constant distance. Generally, conditions encountered during ground surveys when compared to aerial surveys are considerably less varied (Crawford et al. 2007; Edgar et al. 2007), which should provide greater standardization and precision in ground survey methodology. Exceptions remain in extremely wide systems, such as the South Thompson or Harrison Rivers, where the ability to view the entire channel from a ground survey is virtually impossible. Excluding the Mitchell River in 2010, the comparison of simultaneous aerial to ground counts on all streams calibrated since 2007 reveals that on average aerial counts are approximately 80% of ground based counts (77% and 81% for foot and raft surveys, respectively) (Appendix 7). In addition, the average aerial index of 2.66 generated from this time period is considerably higher than the average ground index of 1.91 from the same period (Appendix 8). These data confirm that there is a considerable difference between aerial and ground based counts which must be considered when applying expansion factors. For example, the average index of 2.18 for the Horsefly River since 2007 (2.40 and 1.96 in 2007 and 2010, respectively; Appendix 8) has been developed using aerial methods; therefore future visual surveys of the Horsefly River should be conducted aerially. If logistics or finances determine that a ground survey must be used, the expansion factor applied should be adjusted accordingly.

Comparisons of the aerial to ground based visuals at the Mitchell River in 2010 revealed results that are contrary to most observations since 2007. In three consecutive surveys, the aerial counts within a calibration reach were considerably higher than the corresponding ground based counts (Appendix 7). There are likely two main factors that contributed to these results. First, since much of the reach consisted of shallow riffles and runs, crews were forced to conduct ground surveys by jet boat at relatively high speed. This is inconsistent with ground survey methods since 2007 which have been conducted by foot or raft (drifting), to allow observers to move at a slow and relatively constant rate of speed, thereby minimizing the likelihood for observers to miss fish. Second, ground surveys at the Mitchell were performed by relatively inexperienced observers in 2010 primarily due to lack of available experienced staff. Since 2007, all visual surveys (aerial and ground) conducted for the purpose of calibration have been conducted by experienced observers (greater than three years experience) as it is believed that inexperienced counters tend to underestimate the number of fish and show greater inconsistency in counts (Cousens et al. 1982;

Edgar et al. 2007). These factors combined with the relatively high spawner density in the area likely resulted fewer Sockeye counted than expected in the ground counts at the Mitchell in 2010.

APPLICATION OF INDICES

Since 1988, indices have been generated by comparing visual estimates (i.e. both aerial and ground surveys) to high precision estimates throughout the watershed and range between 1.07 at Gluske Creek in 1999 to 7.44 at Eagle River (early component) in 1998 (Appendix 9). This range is likely a result of the various compounding factors mentioned above; however, certain trends do exist in the data that can be used as an appropriate guideline for index development. For example, since 2007, indices developed for populations under 25,000 using ground based visual methods average 1.76, while indices developed for populations in the 25,000 – 75,000 range using aerial visual methods average 2.41 (Appendix 10). Although it is understood that the enumeration of large populations (> 75,000) using visual surveys is inappropriate (Schubert 2007), opportunistic calibration of three large populations since 2008 have generated an average index of 3.40. In addition, the high variability associated with indices generated from larger populations further validates the inadequacy of using visual surveys to enumerate larger populations (Appendix 10).

In some cases, it may be difficult to assess the relative influence that one criterion may have on the development of an index. For example, larger rivers typically exhibit larger populations that are most commonly assessed using aerial surveys. Rarely does a small, clear stream have large abundances (greater than 25,000) that are enumerated by an aerial survey. Therefore, it is difficult to determine whether an index is a function of stream size, abundance or survey type (i.e. ground vs. aerial). As a result, it is necessary to establish stream type, method and abundance specific (between 25,000 - 75,000) indices where most index influencing criteria would remain relatively constant with the exception of annual variations in environmental and weather conditions.

SUMMARY

Historically, there has been little effort to improve visual methodology since only a small proportion of the total Fraser River escapement was assessed by visual surveys (Schubert 2007). However, since the precision threshold has increased from 25,000 to 75,000 spawners, a shift towards developing more accurate system specific indices is imperative. The application of the standard 1.8 index to all visually assessed populations can be highly subjective, and in some cases can generate estimates that may be less accurate than an educated guess. This method does not account for the influence of stream morphology and Sockeye abundance on observer efficiency and likely underestimates the true population size, especially among turbid or large systems and larger populations (Schubert 2007). Therefore, it is recommended that calibration studies be continued over multiple years at many locations to address variation in indices that would invariably occur due to changes in Sockeye salmon densities and annual environmental conditions (water levels, light conditions, water clarity, etc). Adopting an analytical procedure that is sufficiently sophisticated to incorporate all necessary criteria to generate relatively accurate visual estimates is essential in providing fishery managers with the most accurate information possible for sound decision making.

ACKNOWLEDGEMENTS

We thank the mark-recapture and DIDSON crews from the Mitchell and Horsefly rivers for their diligent and hard work in helping obtain the data necessary for this study as well as Ken Knight of Pacific Western Helicopters Ltd. for piloting the aerial surveys in this study. This project was funded through the Pacific Salmon Commission's Southern Boundary Restoration and Enhancement Fund.

REFERENCES

Benner, K. and Leaf, B. Estimation of the 2010 Mitchell River Sockeye salmon (*Oncorhynchus nerka*) Escapement. *In preparation.*

Cousens, N.B.F., Thomas, G.A., Swann, C.G., and Healey, M.C. 1982. A review of salmon escapement estimation techniques. Can. Tech. Rep. Fish. Aquat. Sci. 1108: 122p.

Crawford, B., Mosey, T.R., and Johnson, D.H. 2007. Foot Based Visual Surveys for Spawning Salmon. *In* Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout population. American Fisheries Society, Bethesda, Maryland. pp. 435-442.

Cronkite, G.M.W., Enzenhofer, H.J., Ridley, T., Holmes, J., Lilja, J., and Benner, K. 2006. Use of high-frequency imaging sonar to estimate adult Sockeye salmon escapement in the Horsefly River, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2647: vi +47p.

Edgar, L.J. III, Heinl, S., Pahlke, K. 2007. Aerial Counts. *In* Salmonid field protocols handbook: techniques for assessing status and trends in salmon and trout population. American Fisheries Society, Bethesda, Maryland. pp. 399-409.

Environment Canada 2011a. Water Level and Streamflow Statistics for the Mitchell River at the outlet of Mitchell Lake (Station No. 08KH014). http://www.wsc.ec.gc.ca/staflo/index_e.cfm (accessed on website April 21, 2011).

Environment Canada 2011b. Water Level and Streamflow Statistics for the Horsefly River above McKinley Creek (Station ID 08KH010). http://www.wsc.ec.gc.ca/staflo/index_e.cfm (accessed on website April 21, 2011).

Enzenhofer, H.J., Cronkite, G.M.W., and Holmes, J.A. 2005. A sectional fish deflection weir and installation boom riverine applications. Can. Tech. Rep. Fish. Aquat. Sci. 2605: iv + 14p.

Enzenhofer, H.J. and Cronkite, G. 2005. A simple adjustable pole mount for deploying DIDSON and split-beam transducers. Can. Tech. Rep. Fish. Aquat. Sci. 2570: iv + 14p.

Holmes, J.A.. Cronkite, G.M.W., Enzenhofer, H.J., and Mulligan, T.J. 2006. Accuracy and precision of fish-count data from a dual-frequency identification sonar (DIDSON) imaging system. ICES J. Mar. Sci. 63 (543-555).

Holmes, J.A., Cronkite, G.M.W., and Enzenhofer, H.J. 2005. Feasibility of implementing a dual-frequency identification sonar (DIDSON) imaging system to estimate Sockeye salmon escapement in major tributary systems of the Fraser River, British Columbia. Can. Tech. Rep. Fish. Aquat. Sci. 2592: xii + 51p.

Schubert, N.D. 2007. Estimating the 1995 Fraser River Sockeye salmon *(Oncorhynchus nerka)* escapement. Can. Tech. Rep. Fish. Aquat. Sci. 2737: ix + 71p.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters, second edition. Griffin, London.

Shardlow, T., Hilborn, R. and Lightly, D. 1987. Component analysis of instream escapement methods for Pacific salmon (Oncorhynchus spp.). Can. J. Fish. Aquat. Sci. 44: 1031-1037.

Trouton, N.D. 2004. An investigation into the factors influencing escapement estimation for chinook salmon *(Oncorhynchus tshawytscha)* on the Lower Shuswap River, British Columbia. Thesis submitted (M.Sc.)

Welch, P., Benner, K. and Leaf, B. 2007. Calibration of Assessment Methods for Fraser River Sockeye Salmon (*Oncorhynchus nerka*) Spawning Populations (25,000 to 75,000) in the Horsefly, Stellako and Adams River Systems. Report prepared by Fisheries and Oceans Canada for the Pacific Salmon Commission, Southern Boundary Restoration and Enhancement Fund.

APPENDICES

Appendix 1. Horsefly DIDSON Daily Expanded and Cumulative Counts of Sockeye salmon, 2010.

Date	Daily Expanded Count	Cumulative Count
14-Aug	14	14
15-Aug	12	26
16-Aug	12	38
17-Aug	11	49
18-Aug	134	183
19-Aug	966	1,149
20-Aug	2,561	3,710
21-Aug	3,801	7,511
22-Aug	2,297	9,808
23-Aug	2,828	12,636
24-Aug	2,456	15,092
25-Aug	1,229	16,321
26-Aug	1,427	17,748
27-Aug	5,435	23,183
28-Aug	3,957	27,140
29-Aug	4,854	31,994
30-Aug	11,507	43,501
31-Aug	5,576	49,077
01-Sep	6,755	55,832
02-Sep	7,581	63,413
03-Sep	4,635	68,048
04-Sep	7,291	75,339
05-Sep	3,658	78,997
06-Sep	8,753	87,750
07-Sep	12,333	100,083
08-Sep	7,106	107,189
09-Sep	3,546	110,735
10-Sep	4,022	114,757
11-Sep	5,076	119,833
12-Sep	5,409	125,242
13-Sep	4,194	129,436
14-Sep	3,603	133,039

Continued

Appendix 1. Horsefly DIDSON Daily Expanded and Cumulative Counts of Sockeye salmon, 2010 (cont'd).

Date	Daily Expanded Count	Cumulative Count
15-Sep	3,291	136,330
16-Sep	2,472	138,802
17-Sep	1,647	140,449
18-Sep	1,691	142,140
19-Sep	1,023	143,163
20-Sep	1,410	144,573
21-Sep	1,206	145,779
22-Sep	1,238	147,017
23-Sep	924	147,941
24-Sep	886	148,827
25-Sep	837	149,664
26-Sep	581	150,245
27-Sep	591	150,836
28-Sep	468	151,304
29-Sep	471	151,775
30-Sep	191	151,966
01-Oct	155 [a.]	152,121
02-Oct	46 [a.]	152,167

[a.] Daily expanded count extrapolated.

Appendix 2. Mitchell River Sockeye salmon aerial counts (live and dead) by date, reach and observer, 2010.

Date	Reach	Obs #1 Live+Dead	Obs #2 Live+Dead	Average
20-Sep	1 to 4	17,560	16,660	17,110
	4 to 6	20,570	17,450	19,010
	6 to 9	248	190	219
	9 to Mouth	7	7	7
	Total	38,385	34,307	36,346
24-Sep	1 to 4	14,600	17,650	16,125
	4 to 6	20,200	23,330	21,765
	6 to 9	455	390	423
	9 to Mouth	104	100	102
	Total	35,359	41,470	38,415
28-Sep	1 to 4	14,400	11,010	12,705
	4 to 6	14,160	12,310	13,235
	6 to 9	123	58	91
	9 to Mouth	1	1	1
	Total	28,684	23,379	26,032

Appendix 3. Horsefly River Sockeye salmon aerial counts (live and dead) by date, reach and observer, 2010.

Date	Reach	Obs #1 Live+Dead	Obs #2 Live+Dead	Average
09-Sep	1	24	20	22
	2-6	11,742	9,600	10,671
	7	442	411	427
	8-10	2,696	2,475	2,586
	11	9,124	7,778	8,451
	12-13	3,772	3,844	3,808
	14	3,230	3,321	3,276
	15	9,242	11,860	10,551
	16	3,362	3,555	3,459
	Total	43,634	42,864	43,249
13-Sep	1	215	234	225
	2-6	15,782	19,190	17,486
	7	130	124	127
	8-10	6,917	7,700	7,309
	11	11,798	14,160	12,979
	12-13	3,390	4,440	3,915
	14	5,383	4,900	5,142
	15	14,241	14,270	14,256
	16	1,898	1,600	1,749
	Total	59,754	66,618	63,186

Appendix 4. Stream morphology and characteristics definitions for Sockeye salmon spawning stream-types in the Fraser River watershed, 2010.

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 the use of a jet boat and Raftable. Cannot wade in all places (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).

Large Woody Debris

Low:	Low densities of log jams, sweepers and root wads within the stream that have little impact on counting. Large Woody Debris (LWD) <25% of channel structure (e.g. Tachie River).
Medium:	Medium densities of log jams, sweepers and root wads within the stream that have some impact on counting that may reduce counting efficeincy (accuracy). LWD 25-50% of channel structure (e.g. Mitchell River).
High:	High densities of log jams, sweepers and root wads within the stream that have a high impact on counting that definately reduces counting efficeincy (accuracy). LWD >50% of channel structure (e.g. Gluske Creek).

Appendix 5. Comprehensive list of all Sockeye salmon spawning streams within the Fraser River watershed by stream size, water clarity, substrate colour, canopy cover, in-stream large woody debris and visual method.

Group	Stream	Size	Water Clarity	Substrate Colour	Canopy Covery	Large Woody Debris	Visual Method
Lower Fraser	Blue Creek	Very Small	Clear	Light	High	Medium	Foot
	Corbold Creek	Small	Clear	Light	Medium	Medium	Foot
	Depot Creek	Very Small	Clear	Medium	Low	Low	Foot
	Dolly Varden Creek	Small	Clear	Medium	Medium	Low	Foot
	Johnson Slough	Small	Turbid	Light	Medium	High	Foot
	Kawkawa Creek	Very Small	Clear	Medium	Medium	Low	Foot
	Nahatlatch River	Medium	Turbid	Light	Medium	Medium	Foot
	North Boise Creek	Very Small	Part. Turbid	Light	Medium	High	Foot
	Pitt River, upper	Large	Turbid	Light	High	Low	Foot
	Ruby Creek	Very Small	Clear	Light	Medium	Low	Foot
	Silver Hope Creek	Small	Clear	Light	Medium	Medium	Foot
	South Boise Creek	Very Small	Clear	Light	Medium	Medium	Foot
	Upper Pitt Channel	Very Small	Clear	Medium	High	Low	Foot
	Waleach Creek	Very Small	Clear	Light	Medium	Medium	Foot
	Widgeon Slough	Very Small	Clear	Medium	Medium	Low	Foot
Harrison-Lillooet	Big Silver Creek	Small	Clear	Light	Medium	Low	Foot
	Birkenhead River	Medium	Part. Turbid	Light	Medium	Medium	Raft
	Cogburn Creek	Small	Clear	Medium	High	Low	Foot
	Douglas Creek	Small	Clear	Medium	Medium	Medium	Aerial
	Green River	Medium	Turbid	Light	Medium	Medium	Aerial
	Harrison River	X-Large	Part. Turbid	Light	Low	Low	Aerial
	Hatchery Creek	Very Small	Clear	Light	High	High	Foot
	Miller Creek	Small	Clear	Medium	Low	Low	Foot
	Poole Creek	Small	Clear	Medium	High	High	Foot
	Railroad Creek	Very Small	Clear	Light	High	Low	Foot
	Sampson Creek	Very Small	Clear	Medium	High	Medium	Foot
	Ryan River	Medium	Clear	Medium	Low	Low	Foot
	Sloquet Creek	Very Small	Clear	Medium	Medium	Medium	Foot
	Tipella Creek	Small	Part. Turbid	Light	High	High	Foot
	Weaver Channel	Very Small	Clear	Medium	Medium	Low	Census
	Weaver Creek	Very Small	Clear	Medium	Medium	Low	Foot
Seton-Anderson	Bridge River	Medium	Turbid	Light	Medium	Low	Aerial
	Cayoosh Creek	Small	Clear	Medium	Medium	Low	Foot
	Churn Creek	Very Small	Clear	Medium	Medium	Low	Foot
	Gates Channel	Very Small	Clear	Medium	Medium	Low	Census
	Gates Creek	Very Small	Clear	Medium	High	Low	Foot
	Portage Creek	Small	Clear	Medium	Medium	Medium	Foot
	Seton River	Medium	Part. Turbid	Medium	Medium	Low	Aerial
	Yalakom River	Small	Clear	Medium	Medium	Low	Aerial
South Thompson	Adams Lake						
	Bush Creek	Very Small	Clear	Medium	High	Medium	Foot
	Cayenne Creek	Very Small	Tannic	Medium	Medium	High	Foot
	Momich Creek	Small	Clear	Medium	Medium	Low	Foot
	Pass Creek	Very Small	Clear	Light	Medium	Low	Foot
	Upper Adams River	Medium	Turbid	Light	Low	Medium	Boat
	Upper Momich Creek	Very Small	Clear	Medium	High	Medium	Foot

Continued

Appendix 5. Comprehensive list of all Sockeye salmon spawning streams within the Fraser River watershed by stream size, water clarity, substrate colour, canopy cover, in-stream large woody debris and visual method (cont'd).

Population Group	Population	Size	Water Clarity	Substrate Colour	Canopy Covery	Large Woody Debris	Visual Method
South Thompson (cont'd)	Shuswap Lake - Main Arm						
	Adams River	Large	Clear	Medium	Medium	Medium	Raft
	Adams Channel	Very Small	Clear	Medium	High	High	Foot
	Bear (Huihill) Creek	Very Small	Clear	Light	High	Medium	Foot
	Gold (Nikwikwaia) Creek	Very Small	Clear	Light	High	Medium	Foot
	Hlina Creek	Very Small	Clear	Medium	High	Low	Foot
	Onyx Creek	Very Small	Clear	Light	High	High	Foot
	Ross Creek	Very Small	Clear	Light	Low	Low	Foot
	Scotch Creek	Small	Clear	Light	Medium	High	Raft
	Shuswap Lake - Salmon Arm						
	Canoe Creek	Very Small	Clear	Medium	High	High	Foot
	Crazy Creek	Very Small	Clear	Medium	Medium	Low	Foot
	Eagle River	Medium	Turbid	Light	Medium	Medium	Boat
	Gorge Creek	Very Small	Clear	Medium	High	Low	Foot
	Loftus Creek	Very Small	Clear	Medium	High	Medium	Foot
	Perry River	Small	Turbid	Light	Medium	Low	Foot
	Owlhead Creek	Very Small	Clear	Medium	High	High	Foot
	Reinecker Creek	Very Small	Clear	Medium	High	Medium	Foot
	Sicamous Creek	Very Small	Clear	Medium	High	Medium	Foot
	Tappen Creek	Very Small	Clear	Medium	High	Medium	Foot
	Yard Creek	Very Small	Clear	Light	High	Low	Foot
	Shuswap Lake - Seymour Arm						
	Blueberry Creek	Very Small	Clear	Light	High	Medium	Foot
	Celista Creek	Small	Clear	Medium	Medium	Low	Foot
	McNomee Creek	Very Small	Tannic	Medium	High	High	Foot
	Seymour River	Medium	Part. Turbid	Medium	Low	Medium	Raft
	Shuswap Lake - Anstey Arm						
	Anstey River	Small	Part. Turbid	Light	High	High	Foot
	Hunakwa Creek	Very Small	Tannic	Medium	High	Low	Foot
	Four Mile Creek	Very Small	Clear	Medium	High	Medium	Foot
	Shuswap River						
	Bessette Creek	Very Small	Clear	Medium	Medium	Low	Foot
	Blurton Creek	Very Small	Clear	Medium	High	Medium	Foot
	Cooke Creek	Very Small	Clear	Medium	Medium	Medium	Foot
	Fortune Creek	Very Small	Clear	Medium	High	Medium	Foot
	Johnson Creek	Very Small	Clear	Medium	High	Medium	Foot
	Kingfisher Creek	Very Small	Clear	Medium	Medium	Low	Foot
	Noisy Creek	Very Small	Clear	Light	High	Medium	Foot
	Shuswap R., lower	Large	Clear	Medium	Medium	Medium	Boat
	Shuswap R., middle	Medium	Clear	Medium	Medium	Medium	Boat
	Trinity Creek	Very Small	Clear	Light	Medium	Medium	Foot
	Tsuius Creek	Small	Clear	Light	Medium	Low	Foot
	Wap Creek	Small	Clear	Medium	High	High	Foot
	South Thompson River						
	Little River	X-Large	Clear	Medium	Low	Low	Aerial
	South Thompson River	X-Large	Clear	Medium	Low	Low	Aerial

Continued

Appendix 5. Comprehensive list of all Sockeye salmon spawning streams within the Fraser River watershed by stream size, water clarity, substrate colour, canopy cover, in-stream large woody debris and visual method (cont'd).

Population Group	Population	Size	Water Clarity	Substrate Colour	Canopy Covery	Large Woody Debris	Visual Method
North Thompson	Barriere River	Medium	Clear	Light	Medium	Low	Aerial
	Clearwater River	Large	Clear	Medium	Medium	Low	Aerial
	Dunn Creek	Very Small	Clear	Light	Medium	Medium	Foot
	Fennell Creek	Very Small	Clear	Medium	High	Medium	Foot
	Finn Creek	Very Small	Tannic	Dark	Medium	High	Foot
	Grouse Creek	Very Small	Clear	Medium	High	Medium	Foot
	Harper Creek	Very Small	Clear	Medium	Medium	Medium	Foot
	Hemp Creek	Very Small	Clear	Medium	Medium	Medium	Foot
	Lemieux Creek	Very Small	Clear	Medium	Medium	Medium	Foot
	Lion Creek	Very Small	Clear	Medium	Medium	High	Foot
	Mann Creek	Very Small	Tannic	Medium	Medium	Medium	Foot
	North Thompson River	X-Large	Turbid	Light	Medium	Medium	Aerial
	Raft River	Medium	Clear	Medium	Medium	Low	Raft
Chilcotin	Chilko River	Large	Part. Turbid	Medium	Medium	Low	Aerial
	Elkin Creek	Very Small	Clear	Medium	High	Medium	Foot
	Yohetta Creek, upper	Very Small	Clear	Light	Medium	Medium	Foot
	Yohetta Creek, lower	Small	Part. Turbid	Light	Medium	Medium	Foot
Mid-Fraser	Baezaeko River	Medium	Tannic	Dark	Medium	Medium	Aerial
	Hawks Creek	Very Small	Clear	Medium	Medium	Low	Foot
	Williams Lake River	Small	Tannic	Medium	Medium	Low	Foot
Quesnel	<u>Quesnel River</u>						
	Cariboo River, lower	Large	Part. Turbid	Medium	Medium	Low	Aerial
	Cariboo River, upper	Large	Turbid	Light	Medium	Low	Aerial
	Quesnel River	Large	Clear	Medium	Medium	Low	Aerial
	<u>Horsefly River</u>						
	Archie Creek	Very Small	Tannic	Medium	High	High	Foot
	Horsefly Channel	Very Small	Clear	Medium	Medium	Low	Census
	Horsefly River	Medium	Clear	Medium	Medium	Medium	Aerial
	Little Horsefly River	Small	Clear	Medium	Medium	Medium	Aerial
	Lower McKinley Creek	Small	Clear	Medium	Medium	Medium	Foot
	Moffat Creek	Very Small	Clear	Medium	Medium	Medium	Aerial
	Upper McKinley Creek	Very Small	Clear	Medium	Medium	Low	Foot
	Tisdall Creek	Very Small	Tannic	Medium	High	Low	Foot
	<u>Mitchell River</u>						
	Cameron Creek	Very Small	Clear	Medium	Medium	Medium	Foot
	Mitchell River	Medium	Part. Turbid	Light	Medium	Medium	Aerial
	Penfold Creek	Small	Part. Turbid	Light	Medium	Low	Aerial
	<u>Quesnel Lake - East Arm</u>						
	Bill Miner Creek	Very Small	Clear	Medium	High	High	Foot
	Blue Lead Creek	Small	Turbid	Light	Medium	High	Foot
	Bouldery Creek	Very Small	Clear	Medium	High	High	Foot
	Buckingham Creek	Very Small	Clear	Medium	High	High	Foot
	Franks Creek	Very Small	Clear	Medium	High	Medium	Foot
	Killdog Creek	Very Small	Clear	Medium	High	Low	Foot
	Lynx Creek	Very Small	Clear	Medium	High	Low	Foot

Continued

Appendix 5. Comprehensive list of all Sockeye salmon spawning streams within the Fraser River watershed by stream size, water clarity, substrate colour, canopy cover, in-stream large woody debris and visual method (cont'd).

Population Group	Population	Size	Water Clarity	Substrate Colour	Canopy Covery	Large Woody Debris	Visual Method
Quesnel (cont'd)	Quesnel Lake - East Arm						
	Niagara Creek	Medium	Turbid	Light	Medium	Low	Boat
	Stranger Creek	Very Small	Clear	Medium	High	High	Foot
	Summit Creek	Very Small	Tannic	Dark	High	Medium	Foot
	Taku Creek	Very Small	Clear	Medium	High	Medium	Foot
	Quesnel Lake - North Arm						
	Adams Creek	Very Small	Clear	Medium	High	High	Foot
	Bowling Creek	Very Small	Clear	Medium	High	High	Foot
	Devoe Creek	Very Small	Clear	Medium	High	High	Foot
	Grain Creek	Very Small	Clear	Medium	High	High	Foot
	Isaiah Creek	Very Small	Clear	Light	High	High	Foot
	Junction Creek	Very Small	Clear	Medium	High	High	Foot
	Limestone Creek	Very Small	Clear	Medium	High	Medium	Foot
	Quesnel Lake - North Arm						
	Long Creek	Very Small	Clear	Medium	High	High	Foot
	Marten Creek	Very Small	Clear	Medium	High	High	Foot
	Roaring River	Small	Part. Turbid	Light	High	Low	Foot
	Service Creek	Very Small	Clear	Medium	High	High	Foot
	Sue Creek	Very Small	Clear	Medium	High	High	Foot
	Trickle Creek	Very Small	Clear	Medium	High	High	Foot
	Wasko Creek, lower	Very Small	Clear	Medium	Medium	Medium	Foot
	Wasko Creek, upper	Very Small	Clear	Medium	Medium	Medium	Foot
	Watt Creek	Very Small	Clear	Light	High	High	Foot
	Quesnel Lake - West Arm						
	Abbott Creek	Very Small	Tannic	Medium	Medium	Medium	Foot
	Clearbrook Creek	Very Small	Clear	Medium	High	Medium	Foot
	Hazeltine Creek	Very Small	Tannic	Medium	High	Low	Foot
	Spusks Creek	Very Small	Clear	Medium	High	Medium	Foot
	Quesnel Lake - West Arm						
	Tasse Creek	Very Small	Clear	Medium	High	Medium	Foot
	Whiffle Creek	Very Small	Clear	Medium	High	High	Foot
Early Stuart	Driftwood River						
	Blackwater Creek	Very Small	Clear	Medium	High	High	Foot
	Driftwood River	Medium	Part. Turbid	Medium	Medium	Medium	Aerial
	Kastberg Creek	Very Small	Tannic	Medium	Low	Low	Aerial
	Kotsine Creek	Small	Turbid	Light	Medium	Medium	Aerial
	Lion Creek	Very Small	Clear	Medium	Medium	Medium	Aerial
	Porter Creek	Very Small	Clear	Medium	High	High	Foot
	Takla Lake, N.E. Arm						
	Ankwill Creek	Small	Clear	Light	Medium	Medium	Foot
	Bates Creek	Very Small	Tannic	Medium	High	High	Foot
	Blanchette Creek	Very Small	Clear	Light	Medium	Low	Foot
	Forsythe Creek	Very Small	Clear	Medium	High	High	Foot
	French Creek	Very Small	Tannic	Medium	High	High	Foot
	Frypan Creek	Very Small	Clear	Medium	Medium	Medium	Foot

Continued

Appendix 5. Comprehensive list of all Sockeye salmon spawning streams within the Fraser River watershed by stream size, water clarity, substrate colour, canopy cover, in-stream large woody debris and visual method (cont'd).

Population Group	Population	Size	Water Clarity	Substrate Colour	Canopy Covery	Large Woody Debris	Visual Method
Early	Takla Lake, N.E. Arm						
Stuart	Hudson's Bay Cr.	Very Small	Clear	Dark	High	Medium	Foot
(cont'd)	Shale Creek	Very Small	Clear	Medium	High	Medium	Foot
	Unnamed Creek (North of Blanchette)	Very Small	Clear	Light	High	Medium	Foot
	Five Mile Creek	Very Small	Clear	Medium	High	Medium	Foot
	Ten Mile Creek	Very Small	Clear	Light	High	Low	Foot
	Fifteen Mile Creek	Very Small	Clear	Light	High	Low	Foot
	Twenty-Five Mile Cr.	Very Small	Clear	Dark	High	Medium	Foot
	Takla Lake, N.W. Arm						
	Crow Creek	Very Small	Clear	Medium	High	High	Foot
	Dust Creek	Small	Tannic	Medium	Medium	Medium	Aerial
	Hooker Creek	Very Small	Clear	Light	High	High	Foot
	McDougall Creek	Very Small	Tannic	Medium	High	High	Foot
	Point Creek	Very Small	Clear	Light	High	High	Foot
	Sinta Creek	Very Small	Clear	Light	High	Medium	Foot
	Takla Lake, S. Arm						
	Bivouac Creek	Very Small	Clear	Medium	High	High	Foot
	Gluske Creek	Very Small	Clear	Light	High	High	Foot
	Leo Creek	Very Small	Clear	Dark	High	High	Foot
	Narrows Creek	Very Small	Clear	Medium	High	High	Foot
	Sakeniche River	Medium	Tannic	Dark	Medium	Medium	Aerial
	Sandpoint Creek	Very Small	Clear	Medium	High	High	Foot
	Middle River						
	Baptiste Creek	Very Small	Tannic	Medium	High	Medium	Foot
	Forfar Creek	Very Small	Clear	Medium	High	High	Foot
	Kazchek Creek	Small	Clear	Medium	High	Medium	Foot
	Kynock Creek	Very Small	Clear	Medium	High	Medium	Foot
	Rossette Creek	Very Small	Clear	Medium	High	High	Foot
	Trembleur Lake						
	Butterfield Creek	Very Small	Tannic	Medium	Medium	Medium	Aerial
	Felix Creek	Very Small	Clear	Medium	High	High	Foot
	Fleming Creek	Very Small	Clear	Medium	Medium	High	Aerial
	Paula Creek	Very Small	Clear	Light	High	Medium	Foot
	Tarnazell Creek	Very Small	Tannic	Medium	High	High	Foot
	Tildesley Creek	Very Small	Tannic	Medium	Medium	High	Aerial
	Stuart Lake						
	Nancut Creek	Very Small	Tannic	Dark	Low	Low	Aerial
Late	Kuzkwa River	Medium	Tannic	Medium	Medium	Medium	Aerial
Stuart	Middle River	X-Large	Tannic	Medium	Low	Low	Aerial
	Pinchi Creek	Very Small	Clear	Medium	High	Medium	Foot
	Sowchea Creek	Very Small	Tannic	Dark	High	Medium	Foot
	Tachie River	X-Large	Tannic	Dark	Low	Low	Aerial
Nechako	Endako River	Medium	Tannic	Dark	Low	Low	Aerial
	Glacier Creek	Very Small	Clear	Medium	Medium	Low	Aerial

Continued

Appendix 5. Comprehensive list of all Sockeye salmon spawning streams within the Fraser River watershed by stream size, water clarity, substrate colour, canopy cover, in-stream large woody debris and visual method (cont'd).

Population Group	Population	Size	Water Clarity	Substrate Colour	Canopy Covery	Large Woody Debris	Visual Method
Nechako	Nadina Channel	Very Small	Clear	Medium	Low	Low	Census
	Nadina River	Medium	Tannic	Dark	Medium	High	Aerial
	Nechako River	Large	Clear	Medium	Medium	Low	Aerial
	Nithi River	Small	Tannic	Medium	Medium	Low	Foot
	Ormonde Creek	Very Small	Tannic	Medium	High	Medium	Foot
	Stellako River	Medium	Clear	Medium	Medium	Low	Boat
	Sweetnum Creek	Very Small	Clear	Medium	High	High	Foot
	Uncha Creek	Very Small	Clear	Medium	High	High	Foot
Upper Fraser	Bowron River, lower	Medium	Clear	Medium	Medium	Low	Aerial
	Bowron River, upper	Medium	Tannic	Medium	Medium	Medium	Aerial
	Huckey Creek	Very Small	Tannic	Medium	High	Medium	Aerial
	Indianpoint Creek	Small	Clear	Medium	Medium	Medium	Aerial
	Pomeroy Creek	Very Small	Tannic	Medium	High	Medium	Aerial
	Sus Creek	Very Small	Tannic	Medium	High	Medium	Aerial

Appendix 6. Summary of Sockeye salmon spawning stream-types within the Fraser River watershed, the percent calibrated, number of calibration surveys, average population and average index stratified by stream size and water clarity, 1988-2010.

Size	Water Clarity	Number of streams	% of streams calibrated	Number of calibration surveys	Average Population Estimate	Average Index	Standard Deviation	Coefficient of Variation
Very Small	Clear	119	7%	53	9,005	1.70	0.28	0.15
	Tannic	24	0%	0	-	-	-	-
	Part. Turbid	1	0%	0	-	-	-	-
Small	Clear	21	5%	1	83,406	1.26	-	-
	Tannic	3	33%	2	12,710	2.54	0.72	0.28
	Part. Turbid	5	0%	0	-	-	-	-
	Turbid	4	0%	0	-	-	-	-
Medium	Clear	7	43%	14	77,138	2.23	0.66	0.29
	Tannic	6	33%	2	24,057	2.49	0.50	0.20
	Part. Turbid	5	40%	6	66,713	2.37	0.62	0.26
	Turbid	6	33%	2	49,900	5.80	2.32	0.40
Large	Clear	5	20%	3	139,947	2.99	0.18	0.06
	Part. Turbid	2	0%	0	-	-	-	-
	Turbid	2	0%	0	-	-	-	-
X-Large	Clear	2	50%	2	218,068	2.45	0.21	0.09
	Tannic	2	100%	10	190,328	2.83	1.63	0.58
	Part. Turbid	1	100%	1	307,373	2.63	-	-
	Turbid	1	0%	0	-	-	-	-

Appendix 7. Summary of Sockeye salmon aerial to ground live count comparisons by stream and year stratified by ground survey method in the Fraser River watershed, 2007-2010.

Stream	Year	Ground Method	Aerial Count	Ground Count	Aerial : Ground
Forfar	2008	Foot	767	1,956	39.2%
Kynock	2008	Foot	2,109	4,303	49.0%
Big Silver	2009	Foot	2,659	3,255	81.7%
Cameron	2009	Foot	88	130	67.7%
Dolly Varden	2009	Foot	772	919	84.0%
Little Horsefly	2009	Foot	2,840	3,376	84.1%
Ankwill (1-Aug)	2010	Foot	1,215	1,115	109.0%
Ankwill (7-Aug)	2010	Foot	1,369	1,469	93.2%
Dolly Varden (13-Aug)	2010	Foot	74	133	55.3%
Dolly Varden (20-Aug)	2010	Foot	111	157	70.4%
Little Horsefly	2010	Foot	1,757	1,843	95.3%
Paula	2010	Foot	348	384	90.6%
				Average	76.6%
Adams	2007	Raft	15,450	18,788	82.2%
Horsefly	2007	Raft	6,464	7,964	81.2%
Upper Horsefly	2007	Raft	4,270	5,613	76.1%
Lower Horsefly	2007	Raft	2,194	2,351	93.3%
Stellako	2007	Raft	10,110	12,489	81.0%
Kuzkwa	2008	Raft	1,856	2,624	70.7%
Kuzkwa	2008	Raft	827	942	87.8%
Stellako	2009	Raft	17,520	21,274	82.4%
Horsefly	2010	Raft	511	861	59.3%
Kuzkwa	2010	Raft	824	827	99.6%
				Average	81.4%
Mitchell (20-Sep)	2010	Jet Boat	19,010	14,163	134.2%
Mitchell (24-Sep)	2010	Jet Boat	21,765	14,213	153.1%
Mitchell (28-Sep)	2010	Jet Boat	13,235	7,935	166.8%
				Average	151.4%

Appendix 8. Summary of indices for all calibrated Sockeye salmon populations in the Fraser River watershed stratified by visual survey method (aerial or ground), 2007-2010.

		High Precision			Low Precision		
Stream [a.]	Year	Mark/ Recapture estimate	DIDSON estimate	Fence estimate	Aerial or Ground	Visual estimate	Index
Adams	2007	52,713	-	-	Aerial	16,050	3.28
Horsefly	2007	55,181	-	-	Aerial	22,972	2.40
Upper Horsefly	2007	-	-	24,461	Aerial	13,943	1.75
Lower Horsefly	2007	30,720	-	-	Aerial	8,463	3.63
Stellako	2007	41,481	-	-	Aerial	14,242	2.91
Tachie	2008	123,014	-	-	Aerial	21,940	5.61
Mitchell	2009	-	45,741	-	Aerial	18,950	2.41
Stellako	2009	-	-	26,608	Aerial	17,566	1.51
Tachie	2009	47,452	-	-	Aerial	26,275	1.81
Horsefly	2010	-	124,074	-	Aerial	63,187	1.96
Mitchell	2010	74,322	-	-	Aerial	38,415	1.93
						Average	2.66
Adams	2007	52,713	-	-	Ground	19,405	2.72
Gluske	2007	-	-	167	Ground	79	2.11
Stellako	2007	41,481	-	-	Ground	22,435	1.85
Forfar	2008	-	-	2,608	Ground	1,667	1.56
Gluske	2008	-	-	1,515	Ground	778	1.95
Forfar	2009	-	-	3,244	Ground	1,862	1.74
Gluske	2009	-	-	1,494	Ground	1,042	1.43
						Average	1.91

[a.] Stellako River (2008) and Harrison River (2009) were omitted as the high precision estimates greatly exceeded the 75,000 threshold.

Appendix 9. Comprehensive summary of all calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2010.

Year	Location	Size	Water Clarity	Substrate Colour	Canopy Covery	Large Woody Debris	Low Precision Estimate Method	Low Precision Estimate	High Precision Estimate Method	High Precision Estimate	Index
1988	Fennell	V. Small	Clear	Medium	High	Medium	Foot	15,284	Fence	26,932	1.76
1989	Stellako	Medium	Clear	Medium	Medium	Low	Raft	21,142	MR	43,189	2.04
1990	Forfar	V. Small	Clear	Medium	High	High	Foot	7,329	Fence	13,770	1.88
1990	Gluske	V. Small	Clear	Light	High	High	Foot	7,578	Fence	11,058	1.46
1990	Scotch	Small	Clear	Light	Medium	High	Foot	66,274	MR	83,406	1.26
1991	Forfar	V. Small	Clear	Medium	High	High	Foot	11,083	Fence	18,522	1.67
1991	Gluske	V. Small	Clear	Light	High	High	Foot	8,321	Fence	15,294	1.84
1991	Kynock	V. Small	Clear	Medium	High	Medium	Foot	11,413	Fence	25,352	2.22
1991	Stellako	Medium	Clear	Medium	Medium	Low	Raft	42,300	MR	94,931	2.24
1992	Forfar	V. Small	Clear	Medium	High	High	Foot	3,674	Fence	7,940	2.16
1992	Kynock	V. Small	Clear	Medium	High	Medium	Foot	3,430	Fence	8,585	2.50
1992	Stellako	Medium	Clear	Medium	Medium	Low	Raft	89,103	MR	97,985	1.10
1993	Stellako	Medium	Clear	Medium	Medium	Low	Raft	46,658	MR	91,443	1.96
1994	Bowron	Medium	Tannic	Medium	Medium	Medium	Aerial	12,110	Fence	34,431	2.84
1994	Fennell	V. Small	Clear	Medium	High	Medium	Foot	3,879	Fence	5,919	1.53
1994	Forfar	V. Small	Clear	Medium	High	High	Foot	3,692	Fence	4,377	1.19
1994	Gluske	V. Small	Clear	Light	High	High	Foot	1,825	Fence	3,372	1.85
1994	Kynock	V. Small	Clear	Medium	High	Medium	Foot	2,904	Fence	3,860	1.33
1994	Mitchell	Medium	Pt. Turbid	Light	Medium	Medium	Aerial	36,500	MR	124,148	3.40
1994	Seymour	Medium	Pt. Turbid	Light	Medium	Medium	Raft	25,866	MR	56,192	2.17
1994	Tachie	X-Large	Tannic	Dark	Low	Low	Aerial	7,216	MR	42,688	5.92
1995	Fennell	V. Small	Clear	Medium	High	Medium	Foot	4,343	Fence	11,251	2.59
1995	Forfar	V. Small	Clear	Medium	High	High	Foot	12,343	Fence	16,478	1.34
1995	Gluske	V. Small	Clear	Light	High	High	Foot	8,972	Fence	15,044	1.68
1995	Kynock	V. Small	Clear	Medium	High	Medium	Foot	16,784	Fence	26,985	1.61
1995	Seymour	Medium	Pt. Turbid	Light	Medium	Medium	Raft	28,509	MR	40,687	1.43

Continued

Appendix 9. Comprehensive summary of all calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2010 (cont'd).

Year	Location	Size	Water Clarity	Substrate Colour	Canopy Covery	Large Woody Debris	Low Precision Estimate Method	Low Precision Estimate	High Precision Estimate Method	High Precision Estimate	Index
1995	Stellako	Medium	Clear	Medium	Medium	Low	Raft	75,611	Fence	126,743	1.68
1996	Crow	V. Small	Clear	Medium	High	High	Foot	433	Fence	845	1.95
1996	Fennell	V. Small	Clear	Medium	High	Medium	Foot	16,994	Fence	32,278	1.90
1996	Forfar	V. Small	Clear	Medium	High	High	Foot	6,055	Fence	8,381	1.38
1996	Gluske	V. Small	Clear	Light	High	High	Foot	7,179	Fence	8,582	1.20
1996	Kynock	V. Small	Clear	Medium	High	Medium	Foot	9,527	Fence	10,772	1.13
1996	Narrows	V. Small	Clear	Medium	High	High	Foot	2409	Fence	2846	1.18
1996	Paula	V. Small	Clear	Light	High	Medium	Foot	2866	Fence	4702	1.64
1996	Weaver	V. Small	Clear	Medium	Medium	Low	Foot	23,681	MR	38,248	1.62
1997	Forfar	V. Small	Clear	Medium	High	High	Foot	5,329	Fence	10,070	1.89
1997	Gluske	V. Small	Clear	Light	High	High	Foot	7,098	Fence	11,557	1.63
1997	Middle	X-Large	Tannic	Medium	Low	Low	Aerial	90,598	MR	281,472	3.11
1997	Stellako	Medium	Clear	Medium	Medium	Low	Raft	22,853	Fence	55,385	2.42
1997	Tachie	X-Large	Tannic	Dark	Low	Low	Aerial	251,926	MR	491,098	1.95
1998	Eagle (early)	Medium	Turbid	Light	Medium	Medium	Aerial	3,827	MR	28,478	7.44
1998	Forfar	V. Small	Clear	Medium	High	High	Foot	420	Fence	956	2.28
1998	Gluske	V. Small	Clear	Light	High	High	Foot	459	Fence	812	1.77
1998	Weaver	V. Small	Clear	Medium	Medium	Low	Foot	9,828	MR	28,042	2.85
1999	Adams	Large	Clear	Medium	Medium	Medium	Raft	105,654	MR	314,416	2.98
1999	Forfar	V. Small	Clear	Medium	High	High	Foot	1,488	Fence	1,797	1.21
1999	Gluske	V. Small	Clear	Light	High	High	Foot	1,183	Fence	1,264	1.07
1999	Kynock	V. Small	Clear	Medium	High	Medium	Foot	4,585	Fence	6,630	1.45
1999	Little	X-Large	Clear	Medium	Low	Low	Aerial	7,432	MR	19,345	2.60
1999	Seymour	Medium	Pt. Turbid	Light	Medium	Medium	Raft	5,399	MR	14,420	2.67
1999	Stellako	Medium	Clear	Medium	Medium	Low	Raft	38,867	Fence	136,105	3.50
2000	Forfar	V. Small	Clear	Medium	High	High	Foot	4,144	Fence	7,315	1.77

Continued

Appendix 9. Comprehensive summary of all calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2010 (cont'd).

Year	Location	Size	Water Clarity	Substrate Colour	Canopy Covery	Large Woody Debris	Low Precision Estimate Method	Low Precision Estimate	High Precision Estimate Method	High Precision Estimate	Index
2000	Gluske	V. Small	Clear	Light	High	High	Foot	2,877	Fence	3,936	1.37
2000	Kynock	V. Small	Clear	Medium	High	Medium	Foot	7,325	Fence	10,890	1.49
2000	Raft	Medium	Clear	Medium	Medium	Low	Foot	25,305	MR	66,292	2.62
2000	Tachie	X-Large	Tannic	Dark	Low	Low	Aerial	229,427	MR	368,966	1.61
2000	Upper Adams	Medium	Turbid	Light	Low	Medium	Aerial	17,116	MR	71,322	4.17
2001	Dust	Small	Tannic	Medium	Medium	Medium	Aerial	11,309	Fence	23,032	2.04
2001	Forfar	V. Small	Clear	Medium	High	High	Foot	7,704	Fence	12,868	1.67
2001	Gluske	V. Small	Clear	Light	High	High	Foot	6,142	Fence	10,990	1.79
2001	Kynock	V. Small	Clear	Medium	High	Medium	Foot	5,881	Fence	14,010	2.38
2002	Dust	Small	Tannic	Medium	Medium	Medium	Aerial	783	Fence	2,387	3.05
2002	Forfar	V. Small	Clear	Medium	High	High	Foot	1,088	Fence	1,912	1.76
2002	Gluske	V. Small	Clear	Light	High	High	Foot	1,173	Fence	1,866	1.59
2002	Kynock	V. Small	Clear	Medium	High	Medium	Foot	1,432	Fence	2,201	1.54
2002	Seymour	Medium	Pt. Turbid	Light	Medium	Medium	Raft	43,099	MR	111,501	2.59
2003	Gluske	V. Small	Clear	Light	High	High	Foot	611	Fence	872	1.43
2003	Kynock	V. Small	Clear	Medium	High	Medium	Foot	1,949	Fence	3,295	1.69
2003	Tachie	X-Large	Tannic	Dark	Low	Low	Aerial	9,994	MR	28,309	2.83
2004	Forfar	V. Small	Clear	Medium	High	High	Foot	706	Fence	1,003	1.42
2004	Tachie	X-Large	Tannic	Dark	Low	Low	Aerial	27,706	MR	60,862	2.20
2005	Forfar	V. Small	Clear	Medium	High	High	Foot	3,225	Fence	5,274	1.64
2005	Gluske	V. Small	Clear	Light	High	High	Foot	1,822	Fence	3,342	1.83
2005	Kuzkwa	Medium	Tannic	Medium	Medium	Medium	Aerial	6,415	Fence	13,682	2.13
2005	Middle	X-Large	Tannic	Medium	Low	Low	Aerial	49,636	MR	73,270	1.48
2005	Tachie	X-Large	Tannic	Dark	Low	Low	Aerial	104,532	MR	185,889	1.78
2006	Forfar	V. Small	Clear	Medium	High	High	Foot	2,071	Fence	3,850	1.86
2006	Gluske	V. Small	Clear	Light	High	High	Foot	1,429	Fence	2,075	1.45

Continued

Appendix 9. Comprehensive summary of all calibrated Sockeye salmon populations in the Fraser River watershed by year and stream type characteristics, 1988-2010.

Year	Location	Size	Water Clarity	Substrate Colour	Canopy Covery	Large Woody Debris	Low Precision Estimate Method	Low Precision Estimate	High Precision Estimate Method	High Precision Estimate	Index
2006	Little	X-Large	Clear	Medium	Low	Low	Aerial	180,953	MR	416,790	2.30
2006	Stellako	Medium	Clear	Medium	Medium	Low	Raft	44,997	Fence	146,051	3.25
2007	Adams	Large	Clear	Medium	Medium	Medium	Aerial	16,050	MR	52,713	3.28
2007	Adams	Large	Clear	Medium	Medium	Medium	Raft	19,405	MR	52,713	2.72
2007	Gluske	V. Small	Clear	Light	High	High	Foot	79	Fence	167	2.11
2007	Horsefly	Medium	Clear	Medium	Medium	Medium	Aerial	22,405	MR	55,181	2.46
2007	Horsefly (Lower)	Medium	Clear	Medium	Medium	Medium	Aerial	8,463	MR	30,720	3.63
2007	Horsefly (Upper)	Medium	Clear	Medium	Medium	Medium	Aerial	13,943	Fence	24,461	1.75
2007	Stellako	Medium	Clear	Medium	Medium	Low	Aerial	14,242	MR	41,481	2.91
2007	Stellako	Medium	Clear	Medium	Medium	Low	Raft	22,435	MR	41,481	1.85
2008	Forfar	V. Small	Clear	Medium	High	High	Foot	1,667	Fence	2,608	1.56
2008	Gluske	V. Small	Clear	Light	High	High	Foot	778	Fence	1,515	1.95
2008	Stellako	Medium	Clear	Medium	Medium	Low	Raft	75,026	MR	159,749	2.13
2008	Tachie	X-Large	Tannic	Dark	Low	Low	Aerial	21,940	MR	123,014	5.61
2009	Forfar	V. Small	Clear	Medium	High	High	Foot	1,862	Fence	3,244	1.74
2009	Gluske	V. Small	Clear	Light	High	High	Foot	1,042	Fence	1,494	1.43
2009	Harrison	X-Large	Pt. Turbid	Light	Low	Low	Aerial	116,891	MR	307,373	2.63
2009	Mitchell	Medium	Pt. Turbid	Light	Medium	Medium	Aerial	18,950	DIDSON	45,741	2.41
2009	Stellako	Medium	Clear	Medium	Medium	Low	Aerial	17,566	Fence	26,608	1.51
2009	Stellako	Medium	Clear	Medium	Medium	Low	Raft	20,874	Fence	26,608	1.27
2009	Tachie	X-Large	Tannic	Dark	Low	Low	Aerial	26,275	MR	47,452	1.81
2010	Horsefly	Medium	Clear	Medium	Medium	Medium	Aerial	63,187	MR	124,074	1.96
2010	Mitchell	Medium	Pt. Turbid	Light	Medium	Medium	Aerial	38,415	DIDSON	74,322	1.93

Appendix 10. Summary of indices for all calibrated Sockeye salmon populations in the Fraser River watershed stratified by population size, 2007-2010.

			High Precision Estimate			Low Precision Estimate		
Population Size	Stream [a.]	Year	Mark/ Recapture estimate	DIDSON estimate	Fence estimate	Aerial or Ground	Visual estimate	Index
Populations below 25,000	Gluske	2007	-	-	167	Ground	79	2.11
	Forfar	2008	-	-	2,608	Ground	1,667	1.56
	Gluske	2008	-	-	1,515	Ground	778	1.95
	Forfar	2009	-	-	3,244	Ground	1,862	1.74
	Gluske	2009	-	-	1,494	Ground	1,042	1.43
							Average	1.76
							SD	0.28
							CV	0.16
Populations between 25,000 - 75,000	Adams	2007	52,713	-	-	Aerial	16,050	3.28
	Horsefly	2007	55,181	-	-	Aerial	22,972	2.40
	Upper Horsefly	2007	-	-	24,461	Aerial	13,943	1.75
	Lower Horsefly	2007	30,720	-	-	Aerial	8,463	3.63
	Stellako	2007	41,481	-	-	Aerial	14,242	2.91
	Mitchell	2009	-	45,741	-	Aerial	18,950	2.41
	Stellako	2009	-	-	26,608	Aerial	17,566	1.51
	Tachie	2009	47,452	-	-	Aerial	26,275	1.81
	Mitchell	2010	74,322	-	-	Aerial	38,415	1.93
							Average	2.41
							SD	0.74
							CV	0.31
Populations above 75,000	Harrison	2009	307,373	-	-	Aerial	116,891	2.63
	Tachie	2008	123,014	-	-	Aerial	21,940	5.61
	Horsefly	2010	-	124,074	-	Aerial	63,187	1.96
							Average	3.40
							SD	1.94
							CV	0.57

[a.] Stellako River (2007, 2008) and Adams River (2007) were omitted for consistency in the low precison methods (aerial and ground) by population size.