Alouette Project Water Use Plan

Alouette River Smolt Enumeration

Implementation Year 4

Reference: ALUMON-1

Alouette River Salmonid Smolt Migration Enumeration: 2011 Data Report.

Study Period: February 2011 to June 2011.

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February 2012

Executive Summary

The South Alouette River salmonid smolt enumeration program is an outcome of both the 1996 and the subsequent 2006 BC Hydro Water Use Planning (WUP) process and is a water licence ordered monitoring program of the Alouette Dam WUP. This report presents the results of the 14th year of the salmonid smolt and fry out-migration enumeration program (1998-2011).

In total, 509,139 wild reared fish were captured during sampling in the mainstem South Alouette River from 3 March to 14 June 2011. Previously (1998 – 2010), the annual catch ranged from 253,761 (2007) to 2,702,981 (2003).

The 2011 chum fry out-migrant estimate was 4.9 million smolts (95% C.I. 4.3 – 6.9 million). This represents a modest increase in smolt yield of 14.3% for this cycle-year. The current cycle-year is recovering from the lowest recorded smolt yield (2007) that occurred following extremely high spawner escapements the previous year (ALLCO fence count >150,000). Since 1998, chum smolt production has averaged 1,152,174 smolts/km (range 311,594 to 3,934,782 smolts/km) or 60 smolts/m^2 (range 16 – 205 smolts/m^2). These chum smolt yields are comparable to that expected from successful fish habitat restoration projects, and in some years, approaches the estimated production benefits expected from the creation of highly productive off-channel habitat.

The 2011 coho smolt out-migration estimate was 19,240 smolts (95% C.I. 18,062 to 20,540). The 14-year average coho smolt yield was 17,075 smolts or between 1,237 – 1,915 smolts/km (6.4 smolts/100m^2); which is comparable to the average yield predicted for Pacific Northwest streams of similar latitude.

The 2011 steelhead smolt out-migration estimate was 5,077 smolts (95% C.I. 4,238 to 6,198). Steelhead smolt yield upstream of the current RST location has averaged 5,824 smolts or alternatively, 422 smolts/km or 2.2 smolts/100m^2. Although steelhead smolt yields meet Provincial bio standards, they are lower than other regional steelhead populations that are also being monitored using similar enumeration methodology.

The 2011 sockeye smolt out-migration estimate was 23,465 smolts (95% C.I. 19,263 – 29,236). Since 2005, the average sockeye smolt enroute mortality has been 47.6% (range 24.1-88.4%) which is consistent with downstream (within river) smolt migration mortality documented for acoustic tagged pacific salmon smolts in Southern British Columbia. The primary cause of downstream mortality is predation (mergansers, ducks, herons, fish, and otters). It is clear from the time difference of only a day or two in out-migration peaks or pulses between the two

trapping locations that sockeye smolts, following their emigration from Alouette Lake, continue their migration out of the Alouette system without delay. Furthermore, the annual 6 m^3/s flushing flow dam releases (2009-2011) did not “flush out” reluctant sockeye migrants residing within the South Alouette River.

In total, 2,029 chinook salmon fry were captured representing the highest annual capture to date. Based on the significant increase in chinook salmon out-migrants during the past two years, chinook salmon appear to be responding to stocking efforts ($p=0.04$). An estimated 15,489 wild chinook smolts exited the South Alouette River during trapping operations however; accurate chinook estimates are not possible due to the early end of trapping operations. Reliable chinook smolt estimates would require continued trapping to at least the end of June to document the majority of the out-migration distribution.

Moving the rotary screw trapping location upstream to the 224th St. location and incorporating flow deflection panels has been successful in restoring smolt catch success. Results since 2008 clearly demonstrate the declines in coho and steelhead smolt out-migration in 2006 and 2007, and perhaps, the more subtle declines since 2003, were not accurate but an artifact of trapping bias due to the increasing effect of tidal backwatering from the Pitt River at the 216th St. location. Continued trapping at the current location is recommended to document inter-annual variability in smolt yields.

Acknowledgements

This study was part of a co-operative initiative funded by BC Hydro under the auspices of the Alouette Management Committee (AMC). Participants include; BC Hydro, B.C. Ministry of Environment, Department of Fisheries and Oceans, District of Maple Ridge, Katzie First Nation, Alouette River Management Society, and one public representative. The following people are gratefully acknowledged for contributions of information and assistance during this study:

BC Hydro

Ian Dodd
Dave Hunter
James Bruce

B.C. Ministry of Environment

Greg Wilson
Shannon Harris

Department of Fisheries and Oceans

Matt Foy
Maurice Coulter-Boisvert

Katzie First Nations

Harry Pierre
Crystal Pierre
Lawrence Orban
William Pierre
George Moody

Alouette River Management Society

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1. Introduction

The South Alouette River salmonid smolt enumeration program is an outcome of both the 1996 and the subsequent 2006 BC Hydro Water Use Planning (WUP) process and is a water licence ordered monitoring program of the Alouette Dam Water Use Plan. As part of the Alouette River Water Use Plan, the Alouette Management Committee (AMC) was established as an oversight body for all water licence related monitoring programs. The committee consists of representatives from BC Hydro, British Columbia Ministry of Environment (MOE), Department of Fisheries and Oceans (DFO), Katzie First Nation, the District of Maple Ridge, Alouette River Management Society (ARMS) and one public representative.

The smolt enumeration program is a component of a water licence requirement monitoring program to determine the effect of increased flow releases from the BC Hydro Alouette Dam into the South Alouette River on trout and salmon populations and habitat. This report presents results from the 14th consecutive year (1998-2011) of the salmonid smolt out-migration enumeration program on the South Alouette River.

1.1. Objectives

The goal of this project was to determine out-migration numbers of salmon and trout fry and smolts in the South Alouette River using downstream trapping methods and mark-recapture analysis.

Specific objectives include:

- Obtain abundance estimates of emigrant fry and smolts (by species).
- Determine the migration timing and biological characteristics of emigrant fry and smolts, and document general environmental conditions throughout the migration period.
- Examine assumptions inherent within the mark-recapture procedure to determine possible sampling bias of incline-plane traps, rotary screw traps, and marking methodology.

1.2. Study Area

The South Alouette River is located in the lower Fraser Valley 40 km east of Vancouver. The river extends approximately 24 km from the BC Hydro dam at Alouette Lake to its confluence with the Pitt River (Figure 1.1). Incline-plane trap placement was replicated from the previous years (1998-2010). Two incline-plane traps were installed directly upstream of the 224th St. bridge. In 2008, the rotary screw trap was moved to the current location, 100 m upstream of the incline-plane traps. In previous years (1999-2007), the rotary screw trap was located approximately 1.5 km downstream at the 216th St. Bridge. Relocation of the rotary screw trap

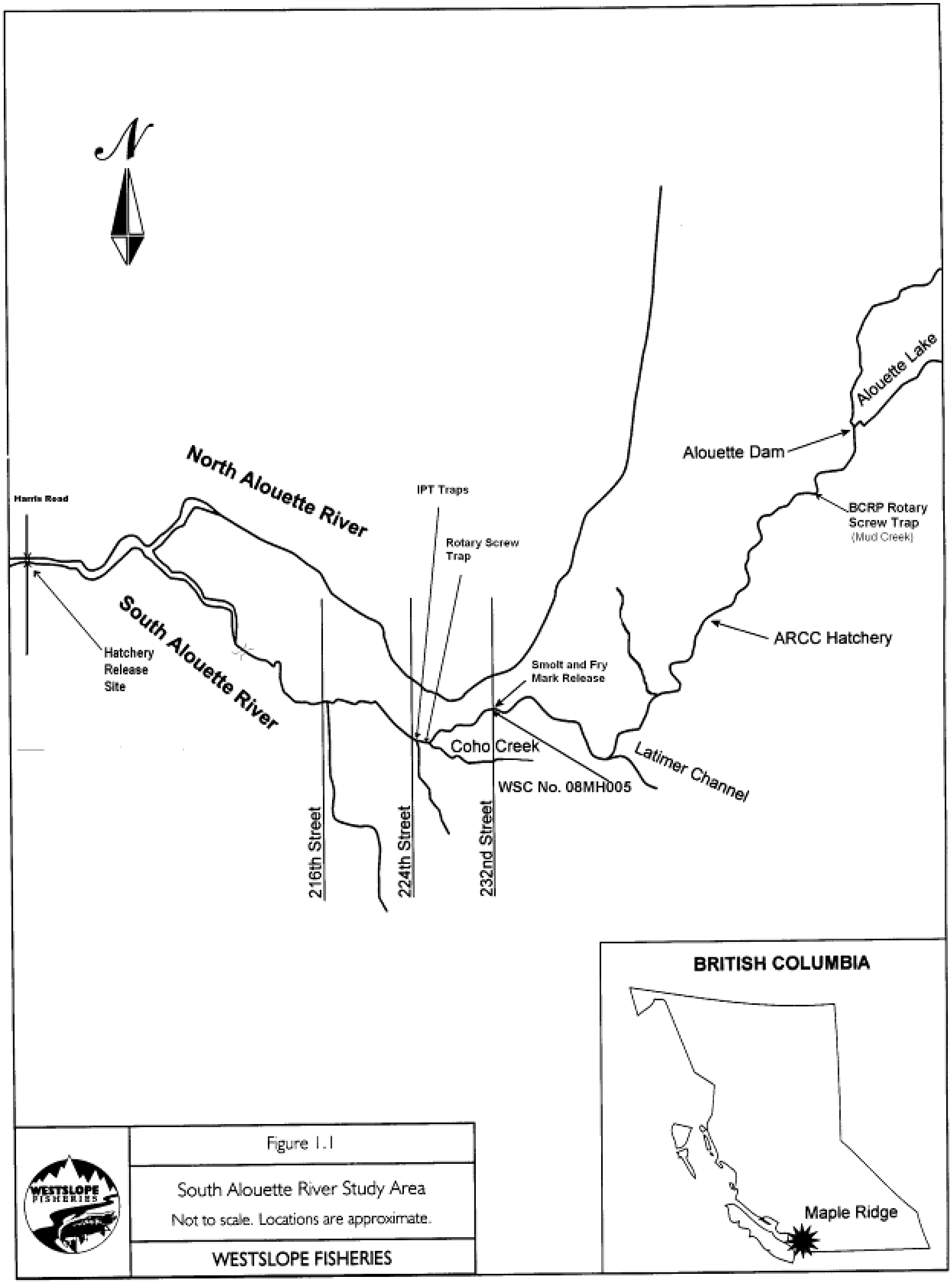

Figure 1.1. South Alouette River Study Area.

was necessary due to the effect of physical site changes and backwatering by the Pitt River. This problem had been getting progressively worse over the previous three years (2005-2007).

All marked fry and smolts were released at the 232nd St. Bridge. All Fraser Regional Corrections Centre-Alouette River Management Society (FRCC-ARMS) hatchery and MOE hatchery reared fry and smolts were released several kilometers downstream of the enumeration reach at the Harris Road Bridge (Figure 1.1).

Transport and release of hatchery reared fish downstream of trapping sites was implemented in 2001 to eliminate hatchery reared fry and smolts from the enumeration catch. Consequently, all production estimates are for wild reared salmon within the South Alouette River. The only exceptions are chum, chinook and coho fry. During the past three years (2009-2011), in an effort to improve chinook stocking results, hatchery reared chinook fry were released upstream at ALLCO Park (April–June) to facilitate imprinting (G. Clayton, ARMS, Maple Ridge, B.C., *pers. comm*.). There is also limited releases of chum, chinook and coho fry (April - June) by school children as part of the ARMS-FRCC Hatchery Community Education and Stewardship Program.

1.3. Background

The South Alouette River historically supported all five species of salmon plus populations of sea-run cutthroat trout, steelhead and resident rainbow trout. The decline of salmonids in the South Alouette River watershed was due, in part, to extensive development beginning in the late 1800s. The watershed was previously logged and land use has been dominated by agricultural development (including diking and draining of the tidal estuary), gravel mining, and currently, urban development. In 1925-1926 the Burrard Power and Light Co., a wholly owned subsidiary of the BC Electric Railway Co., built a low-head earth fill dam at the outlet of Alouette Lake. This dam has had two major persistent effects on salmon populations in the South Alouette River. Because no provision for fish passage was called for in construction of the dam, all fish species that historically ranged above the dam location were excluded from the upper South Alouette River, Alouette Lake and tributaries. In particular, documented spawning populations of sockeye, chinook, coho, and chum salmon, were prevented from entering historical spawning grounds in Alouette Lake and tributaries. The second lasting impact has been the severe reduction of flows in the South Alouette River resulting from construction of the dam at the outlet of Alouette Lake and diversion of water from Alouette Lake into the Stave River system (Griffith and Russell 1980). As a result of these impacts, Elson (1985) reported that Alouette River populations of chinook, sockeye, and pink salmon were extirpated.

While the original water license did not require releases through the dam to augment low flows (August to October), in 1971 BC Hydro implemented a minimum flow of 0.06 m^3/s at the low-level outlet. In 1983, summer mean average flows in the South Alouette River represented 11.5% of the pre-dam construction period (1916-1925). Minimum base flows were gradually increased by BC Hydro and, in 1993, minimum flows through the low-level outlet were set at 0.56 m^3/s. In September of 1995, minimum flows were increased to 2.0 m^3/s and subsequently, the Alouette River Water Use Plan (WUP) was implemented (BC Hydro 1996). The South Alouette River WUP required BC Hydro to release full pipe at the dam's low-level outlet. Full pipe release at the low-level outlet varies between 1.98 and 2.97 m^3/s depending on lake elevation (C. Lamont, BC Hydro, Power Facilities, Burnaby, B.C., *pers. comm*.).

Fisheries agencies have also implemented rehabilitation measures. In 1938, the British Columbia Fish & Wildlife Branch began to stock the Alouette River with eyed steelhead eggs. Since 1979, MOE has annually stocked the South Alouette River with steelhead smolts and anadromous cutthroat smolts (Hamilton 1993). The DFO Salmonid Enhancement Program (SEP) has funded the Alouette River Hatchery Project since 1979 and is operated by the staff of the FRCC and ARMS. Currently, the FRCC-ARMS hatchery annually stocks chinook fry as well as coho fry and smolts and steelhead smolts (*see* Section 2.6 Hatchery Stocking Program).

2. Methods

2.1. Trapping Methods

Trapping methods follow those outlined in Conlin and Tutty (1979), Hickey and Smith (1991) and Smith (1994). Emigrating fry were captured at the 224th St. Bridge location using two 0.6 m x 0.9 m x 2.75 m incline-plane traps (Figures 2.1 and 2.2). In addition, emigrating fry were also captured using a 1.8 m diameter rotary screw trap immediately upstream of the incline plane traps (Figure 2.3).

From 1998 to 2001, emigrating smolts were captured using a single 1.5 m dia. rotary screw trap located at the 216th St. bridge location. From 2002 to 2005, during the steelhead out-migration period (approximately 15 April to 1 June), a 1.8 m dia. rotary screw trap was added and both traps were operated simultaneously. In 2004 and 2005, these traps were operated in an adjacent alignment designed to maximize trapping efficiencies. Due to public safety concerns associated with entrapment risk, this practice was ended in 2006. In 2007, the protocol was to utilize the 1.5 m rotary screw trap from project start (27 February) to 14 April. After 14 April the 1.5 m rotary screw trap was replaced with the 1.8 m trap. This change in trapping operation was

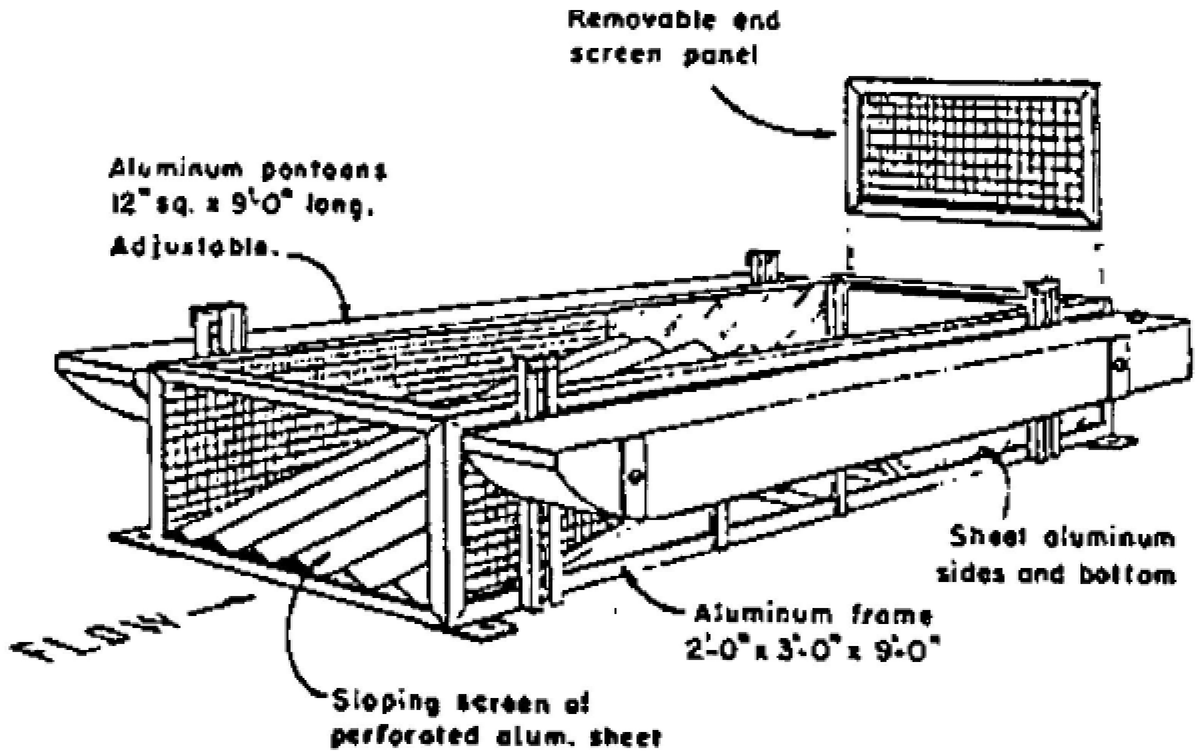

Figure 2.1. Diagram of floating incline-plane trap used to capture migrating fry (IPSFC drawing no. 53-55).

Figure 2.2. Photograph illustrating placement of the incline-plane traps. Note 1.8 m rotary screw trap in the background.

Figure 2.3. Typical rotary screw trap placement 27 February to 14 April at the 224th St. location.

implemented to maximize trapping efficiencies with a single trap, while minimizing the risk of entrapment to members of the public that may disregard the warning signage and attempt to navigate through the trapping site. Since 2008, the protocol has been to utilize the 1.8 m trap exclusively from 27 February to 15 June.

Since 2008, temporary flow deflection "panels" have been utilized in junction with the 1.8 m rotary screw trap. These temporary panels are used to enhance trap efficiencies during smolt out-migration, particularly steelhead and sockeye smolts (Figure 2.4). Fence panels were 1.2 m long and 0.9 m high wood frames with ¾" vexar plastic screen. Panel screens overlap with adjoining panels and the streambed to produce a tight seal. Eighty burlap sandbags and ½" rebar was used to support the panels and ensure a tight seal; thus directing increased volumes of water at the rotary screw trap. Between 32 to 40 linear feet of fence panel was maintained from 15 April to 14 June. During this time panels concentrate flows and direct these flows at the drum of the rotary screw trap. Higher drum velocities result and fence panels and trap position are manipulated daily to maintain a drum velocity of between 5 and 7 revolutions per minute (RPM). This range appears to provide the optimum trap efficiency while minimizing potential mortalities due to live box turbulence.

Figure 2.4. Typical 1.8 m rotary screw trap placement 14 April – 14 June. Note the use of screen panels and sandbags to concentrate flows and enhance trap efficiency.

Periodically throughout the 24-hour trapping period the traps are monitored, cleaned and/or adjusted. Frequency of trap maintenance is determined by flow and debris conditions to maintain trap efficiency and minimize live box turbulence and potential trap induced mortality. At all times, an effort is made to keep fishing conditions as consistent as possible. However, slight alterations to the traps on a daily basis are anticipated to adjust to the variable flow levels. The objective is to keep the trap fishing with strong enough flows to maintain trapping efficiency while limiting trap-induced mortality caused by live box turbulence. Whenever possible, adjustments are to be made to the trap pontoons rather than the position of the trap.

If site conditions (i.e. flow and/or debris conditions) are assessed as compromising worker safety or fish survival (e.g. 224th St. Staff gauge > 0.8 and debris accumulating in traps, or jamming drum considered imminent) then the traps are disabled and trapping operations suspended until debris risk is reduced. Disabling traps and safely securing them to shore when debris risk is high is more effective in protecting fish (and worker safety) and non-fishing days can be quantitatively estimated (Music *et al.* 2010). In light of our detailed knowledge gained over the past 14 years in regard to the relationship between river discharge (i.e. stage), debris load, trapping mortality and worker safety, we have modified our trapping protocols to include the suspension of trapping efforts at times when increases in river discharge and debris load approach known limits to worker safety and logistical capabilities. Typically, suspension of operations need only occur for a matter of hours before the river stabilizes and debris loads decrease to manageable levels. An RV trailer is maintained on-site to facilitate the safe monitoring of traps on a 24-hour, seven days a week schedule. Real-time awareness of conditions, increased trap maintenance and knowledge on when to cease trapping are the key to preventing fry and smolt mortalities and ensuring worker safety. These conclusions and protocols have been independently derived for similar long-term downstream trapping projects in other jurisdictions (Music *et al.* 2010).

Upon capture, fry and smolts were transferred to 20 liter plastic buckets for streamside processing. Catches were enumerated as expediently as possible to minimize stress. During enumeration, all marked fish were separated and subtracted from the total catch. The remaining fry and smolts were separated from any debris and counted individually.

On those occasions where trap catches exceeded the ability to count all individuals, a known sub-sample (minimum 10% of catch) was weighed using a digital analytic scale. The fry-per-gram calculation was used to determine the number of fry captured from the weight of the remaining catch. In extreme cases where the logistical capabilities of the crew and/or the live box capacity of the traps are exceeded a portion of the catch is released using a sieve calibrated to a known sample size (1,000 chum fry by weight).

2.2. Gear Efficiency

Gear-testing objectives were to release known numbers of marked fry at least weekly and smolts as captured, for recoveries of 1% or greater. For the purposes of this report, fry were defined as age group 0^+ fish recently emerged from the gravel (< 70 mm fork length). Smolts were defined as juveniles that had over-wintered for at least one season within their natal streams (>70 mm fork length). Fry were marked by immersion in Bismark Brown Y dye (concentration 1:100,000) for 1 hour (Figure 2.5).

After marking, fry were transported in 20 liter buckets to the 232nd Street release site. Marked fry were held for a minimum of 8 hours prior to release to acclimate to stream conditions. Fry were generally released between 20:00 to 23:00 hours, coinciding with maximum darkness. Smolts were caudal-fin clipped. After marking, smolts were transported and released at the 232nd Street release site (Figure 1.1).

Figure 2.5. Chum salmon fry (2,500 per 20 l bucket) immersed in Bismark Brown “Y” Dye at a concentration of 1:100,000. Note that this procedure requires the infusion of medical grade oxygen.

2.3. Population Estimates

Trap catches are used to estimate the number of fry and smolts emigrating on a nightly basis. The total nightly migration was estimated by applying the proportion of the marked fry recaptured to the nightly unmarked catch. Assuming random mixing of marked and unmarked fish and sufficient recoveries, the adjusted Peterson estimate gives an unbiased population estimate in most cases (Ricker 1975):

$$N = \frac{(M+1) \times (C+1)}{R+1} \qquad (1.1)$$

N = daily fry estimate
C = daily catch
R = number of marks recaptured
M = number of marks released

Ricker (1975) derives the large-sample sampling variance for N in (1.1) as approximately equal to:

$$V(N^*) = \frac{N^2 \times (C - R)}{(C + 1) \times (R + 2)} \qquad (1.2)$$

N* = estimated total out-migration

However, daily out-migrant estimates are independent populations and the total population estimate is the sum of these estimates. The perceived large-sample degrees of freedom over the period of out-migration (*i.e.,* pooled Peterson estimate) are a series of estimates of independent populations. Analyses of temporal and spatial bias have demonstrated that equal catchability and complete mixing assumptions are usually violated at some point (Decker 1998, Schubert *et al.* 1994). The stratified-Peterson approach has been proposed as a model to account for heterogeneity in catchability and/or mixing (Schwarz and Taylor 1998). In this study, where possible, both the pooled Peterson estimate and the stratified-Peterson approach were compared for out-migrating juvenile salmonid estimation.

If random mixing of marked with unmarked fry is assumed, then the variance of recovered marks is binomially distributed. Therefore, it is better to obtain approximate confidence intervals from tables or equations that approximate the binomial distribution using recovered marks as the key parameter. Secondly, since the true N is unknown, it is better to have a rule based on an observed statistic, the number of recaptures (R). For large values of R (>25), Pearson's formula is approximate in estimating the confidence limits for variables distributed in a Poisson frequency distribution for confidence coefficients of 0.95 (Ricker 1975):

$$R + 1.92 \pm 1.96 \sqrt{(R + 1.0)} \qquad (1.3)$$

By substituting the upper and lower limits of R calculated (1.3) into the adjusted Peterson estimate (1.1) the confidence limits for the daily population estimates can be calculated. The resulting confidence limits more accurately represent the daily uncertainty. A cumulative summation of the confidence intervals reflects the uncertainty contained within the total population estimate and stratification by release event (*i.e.,* stratified Peterson method) is the result. In theory, this methodology allows each release stratum to have its own distinct movement pattern and hence gear efficiency rating. On nights without releases, the percentage recovery from the previous release was applied. This was necessary due to the fact that marked fish from a given release event are recaptured over a period of approximately four days.

2.4. Biological Samples

All smolts were typically weighed and fork length recorded. The exceptions were; 1) during days when the coho catch exceeded 100 smolts, only the first 100 coho smolts were measured, and 2) due to the sensitivity of sockeye smolts to handling, sockeye smolts selected for mark – re-capture trials were not typically sampled for length or weight but rather sub-samples of sockeye smolts were selected for length and weight measurements on an opportunistic basis and these fish were not used for mark – re-capture trials.

Every second day, ten chum and ten pink salmon fry (when available) were randomly selected and measured for fork length and mean weight to track length and weight throughout the out-migration period. Chinook fry were sampled when available.

2.5. Physical Conditions

Water level (staff gauge) and water temperature (hand held thermometer) were recorded daily at the 224th Street location. Prior to 15 March 2001, water temperature was also monitored over the study period (*i.e*. trapping dates) using two Timbit™ thermographs. Since 15 March 2001, the 224th Street thermograph has been maintained by BC Hydro as part of an array for year-round water temperature monitoring in the South Alouette River. Mean daily discharge was obtained from the Water Survey of Canada Station at the 232nd Street Bridge (WSC 08MH005).

2.6. Hatchery Stocking Program

The FRCC-ARMS hatchery (a.k.a. ALLCO Hatchery) operates in the upper reach of the South Alouette River. In early study years (1998 – 2000), the majority of FRCC-ARMS reared fry and smolts were released from this location (Figure 1.1). During the years 1998-2000, hatchery reared chum fry were held until late April when approximately 90% of the wild reared fry had emigrated. By this time, hatchery reared fry were easily differentiated by size. In 1998, hatchery reared coho smolts were differentiated by size and in 1999 were identified by a clipped adipose fin. In 2000, chum salmon fry were released five weeks earlier than usual. As a result, hatchery and wild reared fry were similar in size and the size-based separation of hatchery and wild reared chum fry was not possible (Cope 2002). Similarly, hatchery reared coho smolts were not adipose fin clipped nor was there a significant size difference between hatchery and wild reared smolts (Cope 2002). This resulted in uncertainty in the chum fry and coho smolt estimates for the 2000 out-migration.

Since 2000, the FRCC-ARMS hatchery transports and releases all fish downstream of the traps within the vicinity of the Harris Road Bridge (Figure 1.1). Since 1998, MOE has released steelhead smolts and anadromous cutthroat trout below the South Alouette trapping locations within the vicinity of Harris Road.

The only exceptions in recent years are the limited releases of chum, chinook and coho fry by school children as part of the FRCC-ARMS Hatchery Community Education and Stewardship Program. Also, in an effort to facilitate imprinting and improve chinook-stocking results, 50,000 hatchery reared chinook fry were released upstream at ALLCO Park on 27 April 2011 (G. Clayton, ARMS, Maple Ridge, B.C., *pers. comm*.). Annual hatchery releases within the South Alouette River are summarized in Table 2.1.

Table 2.1. Hatchery reared salmonids released into the South Alouette River, 1998-2011. Note that due to the success of restoration efforts chum and pink salmon are no longer a target species for hatchery enhancement (data courtesy FRCC-ARMS and BC Ministry of Environment).

Species	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Chum Fry	1,200,00	1,676,075	661,126	884,593	134,979	-	-	-	-	-	-	-	-	3,200
Pink Fry	8,000	-	197,487	-	126,176	-	-	-	-	-	-	-	-	-
Chinook Fry	182,760	213,168	149,807	84,842	138,487	148,789	98,972	350,000	259,000	325,336	406,000	349,800	329,500	127,150
Coho Fry	-	-	149,000	89,080	83,000	85,000	70,000	60,989	150,949	-	115,159	108,491	-	76,400
Coho Smolts	90,000	20,120	7,961	71,925	35,717	103,324	28,195	64,340	60,595	73,201	17,238	79,412	35,148	25,111
Steelhead Smolts	13,506	4,543	25,447	23,734	25,781	24,123	23,273	24,091	25,529	17,780	26,390	21,004	24,652	31,141
Cutthroat Trout	15,320	30,509	18,404	22,520	15,021	13,871	7,878	23,230	10,870	344	6,788	1,800	4,856	8,761

3. Results

In total, 230 trap days of effort were expended from 3 March to 14 June 2011. During the 104 consecutive days of trapping a total of 23 trap-days of effort were lost resulting in four days (3.8%) when there was no catch enumerated and the daily catch was estimated. Table 3.1 summarizes the dates traps were inundated and catch was lost or traps were not operating and the reason why catch was lost or not enumerated (i.e. safety hazard, rising river stage and debris load etc.).

Table 3.1. Dates traps were not operating are identified in the following table. Incline-plane traps operated from 3 March to 4 May 2011. The 1.8 m dia. rotary screw trap operated from 3 March to 14 June 2011. Note that night-time catch was enumerated for shaded days when traps not operating.

Date/Time Traps Not Operating	IPT #1	Trap IPT #2	1.8 m Rotary	Comment
15 Mar 18:00 16 Mar 19:00	X			Flood Flows and Debris[1]
16 Mar 12:00–19:00	X	X		Flood Flows and Debris[3]
29 Mar 23:00 30 Mar 08:00	X	X		Flood Flows and Debris[1]
30 Mar 09:00 31 Mar 19:00	X	X	X	Flood Flows and Debris[3]
04 Apr 06:00-19:00	X	X		Flood Flows and Debris[1]
04 Apr 19:00 5 Apr 09:00	X	X	X	Flood Flows and Debris[3]
05 Apr 09:00 6 Apr 19:00	X	X		Flood Flows and Debris[3]
10 Apr 10:00-19:00	X	X		Flood Flows and Debris[3]
25 Apr 07:00-20:00	X	X		Flood Flows and Debris[1]
25 Apr 20:00 26 Apr 20:00	X	X		Flood Flows and Debris[3]
27 Apr 05:00-20:00	X	X		Flood Flows and Debris[1]
27 Apr 20:00 28 Apr 17:00	X	X	X	Disable Trap for Hatchery CH[4]
26 May 08:00			X	Debris Jammed Drum
Total Days Lost	10	9	4	
Total Effort (trap days)	63	63	104	Grand Total = 230 trap days

[1] – Rising river stage and increased debris load resulting in inundated trap and lost catch.

[2] – High winds create overhead safety hazard (i.e. falling branches). Cannot safely access traps. Storm event and debris concerns. Traps disabled to prevent potential trap inundation and fish mortalities.

[3] – Rising river stage and debris load. River stage exceeding safe operating range and trap inundation considered imminent. Traps disabled to prevent potential trap inundation and fish mortalities.

[4] – Hatchery Chinook release upstream. Catch exceeding logistic capabilities. Stressing fish so disable trap until pulse moves through.

On those days where IPT's were not operating but the RST was operating, the daily catch was estimated from the RST catch. The catch for the 4 days when no traps were operating was estimated as the average of the two adjacent days. The remaining time periods noted in Table 3.1 for which the traps were not operating were during daylight periods. Given the documented low proportion of the catch during daylight, the catch for these 24-hour periods was considered representative. Similarly, during the late season period from 29 May to 14 June, the rotary screw trap was disabled and pulled to shore during daylight when staff was not on-site (generally 13:00 – 19:30). This change in trap operation was implemented with the on-set of warm summer weather to minimize the risk of entrapment to members of the recreating public (i.e. "tubers") that may disregard the warning signage and attempt to navigate through the trapping site.

With the exception of the 4 days when all three traps were not operating or catch was lost in Table 3.1, daily salmonid out-migration estimates were generated for the 100 remaining days from 3 March to 14 June. Total trapping effort was consistent with the range of effort for previous years (Table 3.2).

Table 3.2. Time period (*i.e.* consecutive days), lost trap-days, and total effort (trap-days) during the South Alouette Downstream Enumeration Program (1998-2011).

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Start Date	5 Mar	27 Feb	25 Feb	27 Feb	26 Feb	27 Feb	25 Feb	2 Mar	27 Feb	27 Feb	27 Feb	27 Feb	1 Mar	3 Mar
Finish Date	8 Jun	28 May	2 Jun	2 Jun	27 May	2 Jun	2 Jun	25 May	25 May	24 May	5 Jun	14 Jun	14 Jun	14 Jun
No. Trap-Days lost	36	9	5	6	12	6	12	8	3	48	3	5	12	23
Total Effort (Trap-Days)	186	225	230	222	226	232	224	198	208	206	227	233	234	230
Consecutive Days Reported	89	91	97	96	89	96	96	72	87	n/a	99	107	106	104

3.1. Species Composition

Over the course of the salmonid smolt trapping program (1998-2011), 28 fish species have been confirmed; 17 species were captured in the 2011 enumeration program (Table 3.3). While this species assemblage was similar to that previously reported from the study area (Elson 1985), there were several notable exceptions.

Chinook, pink and sockeye salmon were considered extinct in 1985. Since 1998, all three species have been captured and confirmed. Returning chinook, pink and sockeye salmon (e.g. mature pre-spawners) have been confirmed at the FRCC-ARMS hatchery broodstock fence (Table 3.4).

Table 3.4. Annual FRCC-ARMS Hatchery fish fence counts, S. Alouette River (data courtesy of FRCC-ARMS).

Year	Chum	Chinook	Pink	Coho	Sockeye
2003[a]	10,727	0	2,275	51	
2005	76,191	296	2,043	451	
2006	150,734	39	N/a	146	
2007	16,502	369	103	298	28
2008	71,980	78	N/a	273	54
2009[b]	153,882	24	6,766	78	45
2010	41,312	325	n/a	339	115
2011[c]	25,042	141	1,393	628	11

[a] Fence down 10 days.
[b] Fence down approximately 14 days.
[c] preliminary data as of Dec 7, 2011.

Fry and smolt enumeration has documented naturally spawned chinook and pink fry out-migrants. These results have documented the successful re-establishment of pink salmon with an estimated escapement of between 4,500 to 20,000 spawners. A small but consistent number of naturally spawned chinook fry are confirmed every year. Since 2005, what were assumed to be kokanee smolts from Alouette Reservoir have been genetically confirmed to represent descendants of sockeye salmon trapped within Alouette Lake at the time of dam construction in the 1920's, over 80 years ago (ARMS 2007). These smolts are annually captured exiting the Alouette Reservoir as part of field trials to assess smolt migration success (Mathews and Bocking 2012).

Table 3.3. Species of fish present or recorded from the Alouette River system (Elson 1985) and those encountered in the present study.

Common Name	Scientific Name	Elson 1985	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Chinook Salmon	*Oncorhynchus tshawytscha*	X*	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Coho Salmon	*O. kisutch*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Pink Salmon	*O. gorbuscha*	<u>X</u>	X		X		X		X		X		X		X	
Chum Salmon	*O. keta*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sockeye Salmon	*O. nerka*	X*					X			X	X	X	X	X	X	X
Kokanee	*O. nerka*	X														
Steelhead	*O. mykiss*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Rainbow Trout	*O. mykiss*	X			X**					X^{+}						
Cutthroat Trout	*O. clarki clarki*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Dolly Varden Char	*Salvelinus malma*	X		X**												
Lake Trout	*S. namaycush*	X														
Mountain Whitefish	*Prosopium williamsoni*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Stickleback	*Gasterosteus sp.*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Sculpin	*Cottus sp.*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Lamprey	*Lampetra sp.*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Northern Pikeminnow	*Ptycheilus oregonensis*	X						X		X		X	X	X	X	X
Peamouth Chub	*Mylocheilus caurinus*	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Largescale Sucker	*Catostomus macrocheilus*	X	X	X**	X			X	X	X		X				
Longnose Sucker	*Catostomus catostomus*	X								X	X		X	X	X	X
Longnose Dace	*Rhinichthys cataractae*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Redside Shiner	*Richardsonius balteatus*	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Black Crappie	*Pomoxis nigromaculatus*	X									X					
Pumpkinseed Sunfish	*Lepomis gibbosus*												X		X	X
Oriental Weatherfish	*Misgunus anguillicaudata*												X	X	X	X
Brown Catfish	*Ameiurus nebulosus*	X		X			X									
Brassy Minnow	*Hybognathus hankinsoni*	X			X	X	X	X	X	X		X				
Eulachon	*Thaleichthys pacificus*			X			X									
Common Carp	*Cyprinus carpio*		X**	X		X								X^{++}		

<u>X</u> – Extinct. X* - Isolated after dam construction (1925), extinct. X** - Observed. X^{+}- Identified as hatchery stock released into Alouette Lake. ++ ornamental aquarium goldfish.

In 2008, two non-indigenous “exotics” were captured in the S. Alouette River for the first time. Oriental weatherfish (*Misgurnus anguillicaudata*) were captured in the S. Alouette River. These captures represent the first reported occurrence for this alien species in British Columbia waters. The aquarium trade imports this species and feral populations were first reported in California in 1968. More recently, they have been reported as far north as Puget Sound and Snohomish County Washington. In 2008 through 2011 there were five, two, 22 and 17 oriental weatherfish captured, respectively. Captures have ranged between 101 mm to 205 mm and there is likely more than one-year class present in the S. Alouette River. This raises the possibility that they have established a self- sustaining population (J.D. McPhail, U.B.C., Vancouver, B.C., *pers. comm.*).

In 2008 through 2011, a total of 14 pumpkinseed sunfish were captured. Although this is a new species report for the S. Alouette River, McPhail (2007) reports they occur in the lower Fraser Valley. This non-native species has been widely introduced into Western North America.

Both eulachon and carp were not previously recorded within the Alouette River. Elson (1985) records common carp within the Pitt River watershed, but not the Alouette River watershed. Eulachon are a culturally significant species and local first nation reports suggest they may have utilized the Alouette River for spawning in the past. This is supported by anecdotal reports of local residents dip-netting for eulachon in the lower South Alouette River in the 1940’s.

The 2011 catch and relative contribution of each fish species to the total catch are presented in Table 3.5. In total, 509,139 wild reared fish were captured. Previously (1998 – 2010), the total catch ranged from 253,761 (2007) to 2,702,981 (2003).

Moving the rotary screw trap site upstream to the 224th St. location, combined with the use of the temporary “efficiency panels” has provided the desired increase in trap efficiency for smolts (Table 3.5). Lamprey *spp.,* longnose dace and sculpin *spp.* dominate the non-sportfish catch.

Catch results between the incline plane traps and rotary screw traps reflect program objectives for each gear type. Incline plane traps were utilized primarily to capture fry and rotary screw traps for smolts. This was due to the size selectivity of the trapping methods. For incline plane traps, the larger the juvenile fish, the lower the efficiency rating (Cope 1998). The fork-length cut-off, while dependent on the water velocities of the incline-plane, would appear to be in the order of 50 - 70 mm. The larger rotary screw traps were more effective at capturing juveniles in excess of 60 mm and were necessary to achieve smolt capture objectives. The incline plane traps have a higher efficiency rating for fry at lower fork lengths and this effect becomes particularly evident for pink salmon fry, the smallest of the emigrating target species.

Table 3.5. Catch composition (excluding recaptures and hatchery reared fry and smolts) of the 2011 South Alouette River downstream trapping program.

	Combined Totals	
Common Name	Catch	% Composition
Salmoniformes – Fry		
Chum	496,852	97.6
Pink	n/a	-
Coho	913	<0.2
Chinook	2,029	<0.4
Mountain Whitefish [a]	n/a	-
Total	499,794	98.2
Salmoniformes – Smolts		
Coho	5,344	1.0
Sockeye[b]	1,971	<0.4
Steelhead	898	<0.2
Cutthroat Trout	142	<0.1
Total	8,355	1.6
Non-Sportfish		
Lamprey	333	<0.1
Longnose Sucker	41	<0.1
Longnose Dace	308	<0.1
Northern Pikeminnow	57	<0.1
Oriental Weatherfish	17	<0.1
Peamouth Chub	12	<0.1
Pumpkinseed	2	<0.1
Redside Shiner	8	<0.1
Sculpin spp.	169	<0.1
Stickleback spp.	43	<0.1
Total	990	0.2
Grand Total	509,139	100

[a] – alevins smaller than mesh size, present but not enumerated.
[b] – previously referred to as kokanee. DNA testing confirmed as sockeye.

3.1.1. Species at Risk

To date, capture of the SARA listed Salish sucker and Nooksack dace has not occurred. This assessment is based on visual examination only. Since 2009, 138 longnose suckers and 478 longnose dace were captured. There were zero reported mortalities for these species so any incidental misidentification would not have resulted in any impact to these species.

3.2. Chum Salmon Fry

The seasonal pattern of chum fry out-migration in the South Alouette River was characterized by first emergence in late February, peak migration mid-April, and the end of migration in early May (Figure 3.1). In 2011, the dates of 10%, 50% and 90% migration were 26 March, 15 April, and 23 April, respectively. This represents typical chum fry out-migration timing; the median date of 90% out-migration for the period 1998 to 2010 was 22 April (range 17 Apr – 10 May, n=13).

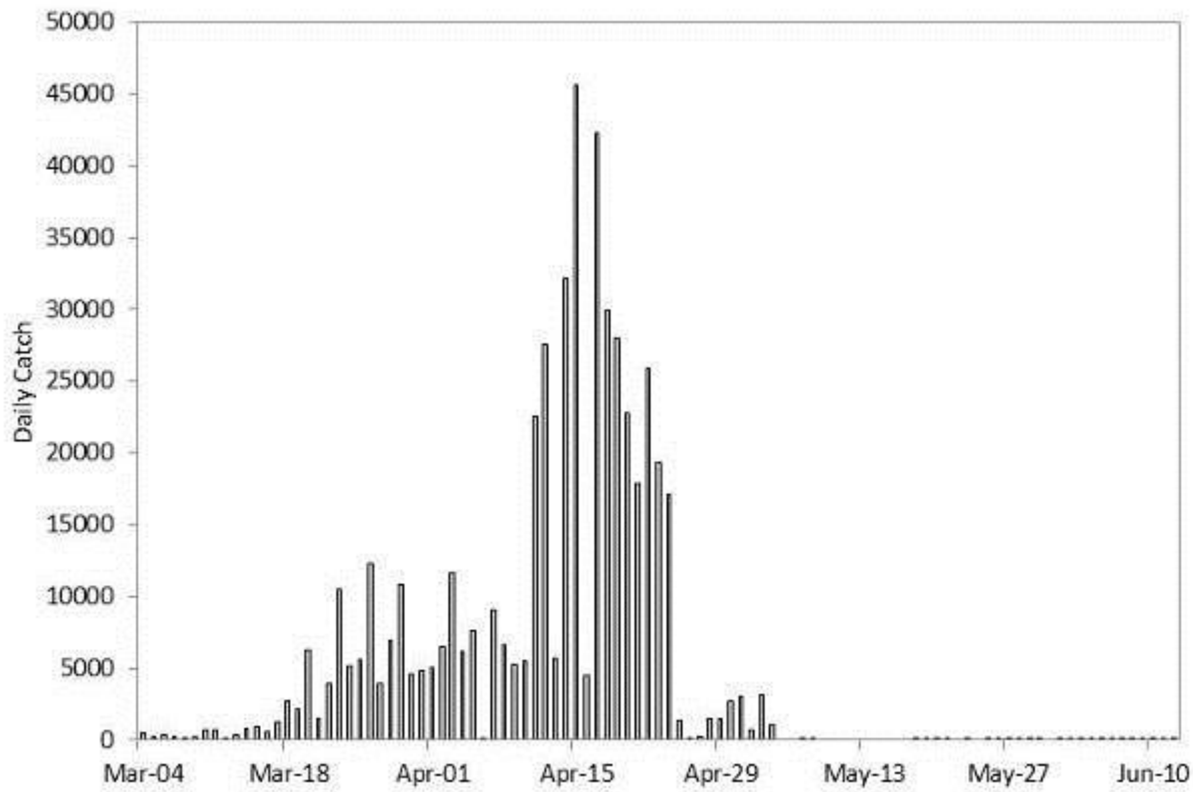

Figure 3.1. Daily chum salmon fry catch for the South Alouette River, 2011.

The total number of chum fry captured in 2011 was 496,852. Including estimates for those days where catch was lost or traps were disabled, the total fry captures for the 2011 out-migration was 557,602. This represents double (202%) the catch from the previous cycle for this broodyear (2007; Figure 3.2). This cycle is rebuilding after the collapse of chum fry production in 2007 that was preceded by very high spawner escapements (i.e. ALLCO fence count >150,000).

Nine marked fry releases were conducted and recovery data was generated from seven of the releases. The release of 16 March could not be completed due to flood flows and debris conditions. Marked chum on 23 April were noted as having poor vigor and high mortalities and recoveries would not have been representative so this release was abandoned.

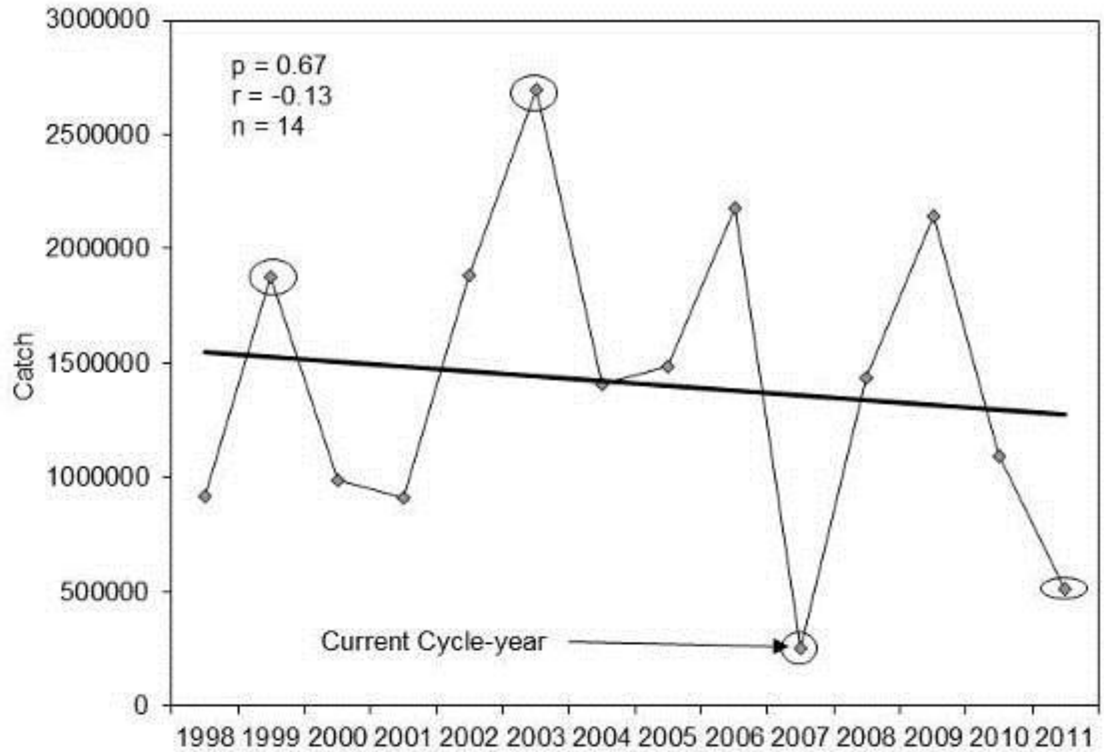

Figure 3.2. Summary of wild spawned chum fry captures within the South Alouette River, 1998 - 2011.

The total remaining marked fry released was 19,687 (4.0% total catch) and the number recaptured was 2,574 (13.1%). Releases ranged from 665 to 4,400 marked fry. Recovery (combined) rates ranged from 7.5% to 15.4% and the mean individual trap recovery rates were 3.3%, 3.9% and 5.9% for incline plane trap 1, incline plane trap 2, and the rotary screw trap, respectively. Based on the pooled catch and recovery data (*i.e.,* pooled Peterson estimator), the chum fry out-migrant population was estimated to be 3.9 million fish (95% confidence interval: 3.7 to 4.1 million fish).

Based on the pooled daily trap catches stratified by release and recapture period (*i.e.* stratified Peterson estimator), the out-migrant estimate of chum salmon fry in 2011 was 4.9 million fish (95% confidence interval: 4.3 to 6.9 million fish). Figure 3.3 illustrates the 2011 out-migration timing in relation to the average for the years 1998 – 2010).

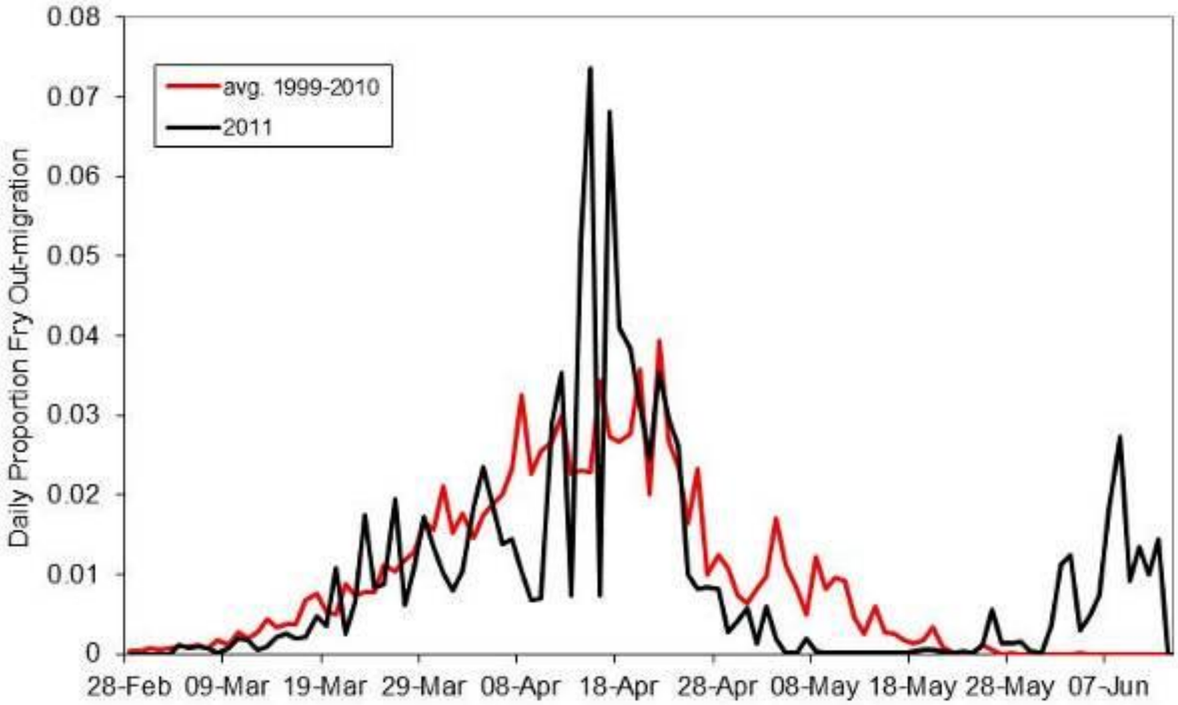

Figure 3.3. Daily chum fry out-migration estimates represented as a proportion of total annual out-migration illustrating the current year versus the 1998 to 2010 average.

Figure 3.4 illustrates the annual chum fry out-migration estimates in time series. The 2011 estimate represents a modest increase in fry production of 14.3% over the previous generation for this cycle year. The low production estimate and the modest increase for the current cycle year are due to the 2007 fry production collapse. The low chum fry yield in both 2007 and 2010 were preceded by very high spawner escapements (i.e. ALLCO fence count >150,000, Table 3.4). In 2007, low fry production coincided with an extreme storm event in March that resulted in flushing flows and streambed scour. As a result, the low 2007 chum fry production estimate was considered an outlier and was not included in further analyses under the assumption that the atypical flood conditions and lack of confidence in the 2007 estimates was the most likely cause for the low out-migrant estimate. Given that the low 2010 chum fry estimate replicates the 2007 results following a remarkably similar, and extremely high spawner escapement year, without the atypical flood conditions. This suggests that the conclusion of previous years where egg-to-fry survival is relatively constant and the South Alouette River has not yet reached the point of density-dependent mortality, may not be accurate (*see* section 3.10 Hypothesis Testing).

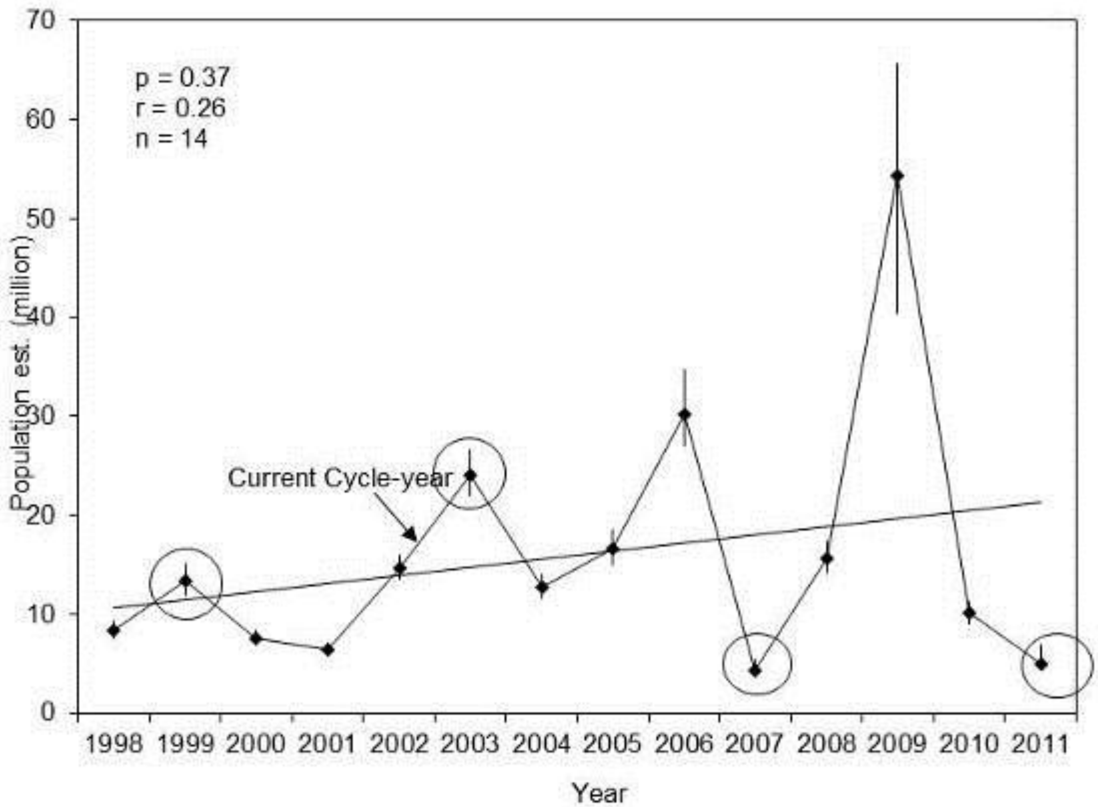

Figure 3.4. Summary of annual wild spawned chum fry out-migration estimates (+/- 95% confidence interval) for the South Alouette River, 1998 - 2011. A linear trendline has been superimposed for annual estimates.

Table 3.6. Summary of estimated chum fry production (x 10^6) between cycle-years (*i.e.* based on a dominant 4 year (0.3) cycle), South Alouette River.

Cycle-Year	1st generation Out-migration Estimate	2nd generation Out-migration Estimate	3rd generation Out-migration Estimate	4th generation Out-migration Estimate	Estimated Production Increase
1998/2002/2006/2010	8.3	14.7	30.3	10.1	1.2
1999/2003/2007/2011	13.4	24.1	4.3	4.9	-2.7
2000/2004/2008	6.8	12.8	15.6		2.3
2001/2005/2009	6.4	16.6	54.3		8.5

Figure 3.5 illustrates the mean fork length of chum salmon fry out migrants through the chum salmon capture period. The consistency of the mean fork length from 4 March to 4 May illustrates the ongoing fry emergence and out-migration during this period. The mean fork length during this period averaged 38.4 mm (range 35.9 – 40.9). Mean chum fry lengths during the out-migration period have been consistent for the last three years (range 37.0 – 38.4). After 1 May the daily catch of chum fry was typically less than 1,500 while the daily catch of smolts was increasing to as much as 400 smolts. This resulted in almost 100% predation of fry within the live box after 4 May. This was confirmed by mark – recapture. The RST trap efficiency dropped from 9.34% 18 April to 0.07% 1 May. There were no fry for length measurements after 4 May however, the mean fry length typically increases substantially after 4 May illustrating the end of fry emergence and the out-migration of the remaining rearing fry (Cope 2011).

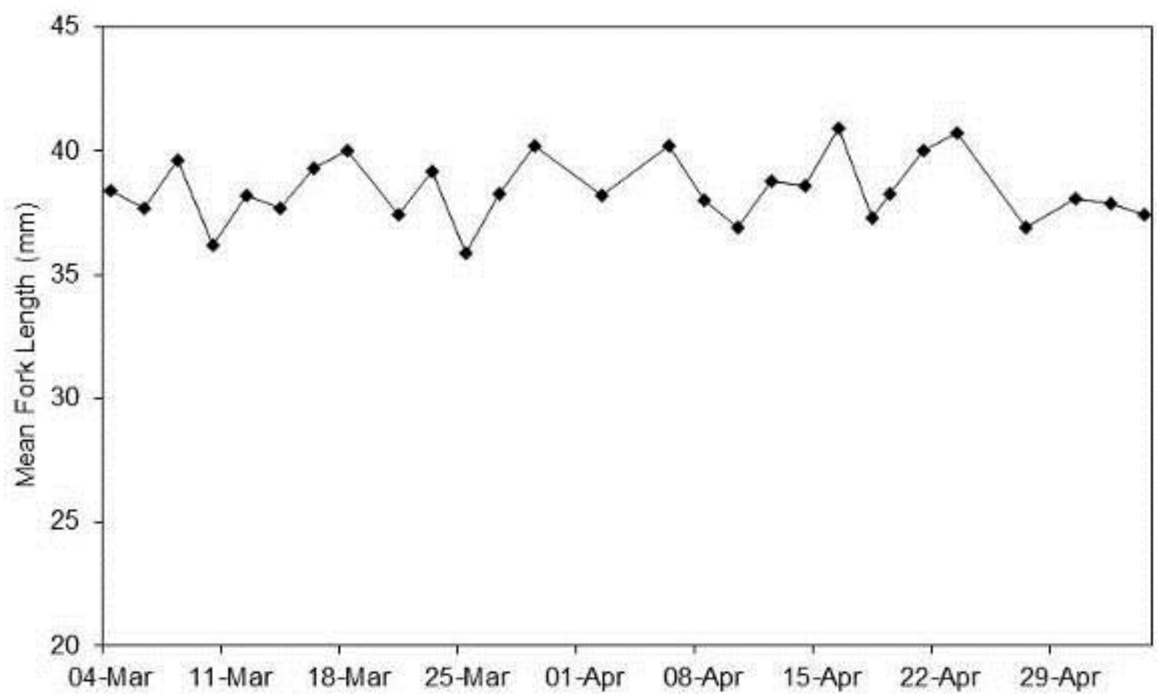

Figure 3.5. Mean fork length of out-migrant chum salmon fry, South Alouette River 4 March to 4 May, 2011.

3.3. Pink Fry

Pink salmon spawn in odd years and fry out-migration follows in the following spring; therefore, there was no out-migration to enumerate in the current year.

3.4. Coho Fry

A total of 913 wild coho fry were enumerated in 2011 (Table 3.7). This represents the second highest coho fry catch to date and was most likely a result of a strong spawning escapement (second highest since 2003, Table 3.4). Coho fry captures are confirmed wild spawned as all coho fry releases by the FRCC-ARMS Hatchery Community Education and Stewardship Program (n=400) occurred after 9 May and 910 or 99.7% of all coho fry captures occurred before 9 May (Figure 3.6). Enumeration of coho fry is not considered reliable because coho fry captures do not represent a directed out-migration pattern, but rather incidental movements associated with storm events and increased flow. The peak catches between 29 April to 3 May were associated with a large storm event and flushing flows, particularly within South Alouette River coho rearing tributaries (*see* 3.10 Physical Conditions).

Table 3.7. Summary of coho fry captures within the South Alouette River.

Year	Catch
1998	116
1999	86
2000	582
2001	87
2002	313
2003	3,902*
2004	135
2005	390
2006	15
2007	52
2008	29
2009	22
2010	309
2011	913

*Note: Incidental coho fry captures may include hatchery-raised individuals. Hatchery coho fry were released unmarked.

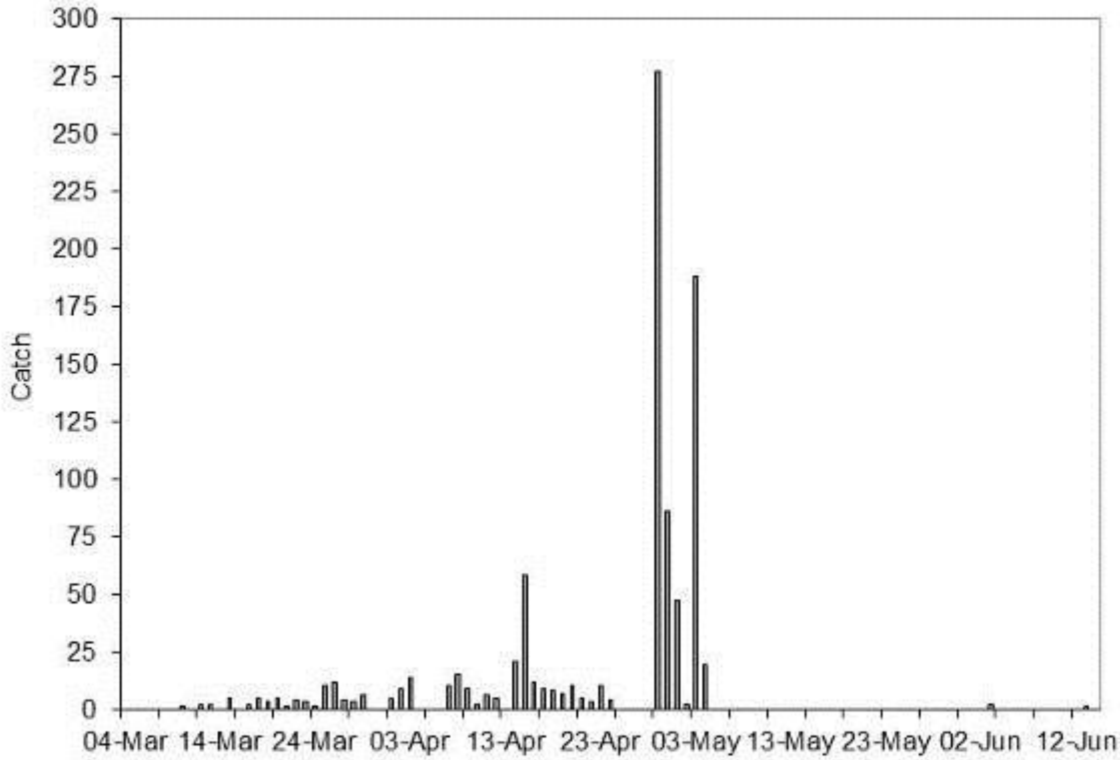

Figure 3.6. Daily coho salmon fry catch for the South Alouette River, 2011.

3.5. Chinook Fry

In total, 2,029 chinook fry were captured and assessed as being wild reared. This represents the highest annual capture to date (Figure 3.7). Based on the significant increase in chinook salmon out-migrants during the past two years, chinook salmon appear to be responding to stocking efforts ($p=0.04$; regression, $n=14$).

Recently emerged chinook fry were first identified in the catch on 21 March. Very few hatchery reared chinook were captured following the 28 April release of 50,000 hatchery reared chinook fry upstream at ALLCO Park. This was due to the release timing that coincided with a large storm event and flushing flows (*see* 3.10 Physical Conditions). For example, the hatchery chinook recapture rate was 17.6% (n=35,110) in 2010 and the corresponding recapture rate was 2.1% (n=1,031) in 2011. As a result, separation and enumeration of wild-reared chinook fry out-migrants by size after 28 April was possible with some level of confidence due to the small numbers of hatchery reared chinook fry at large (Figure 3.8).

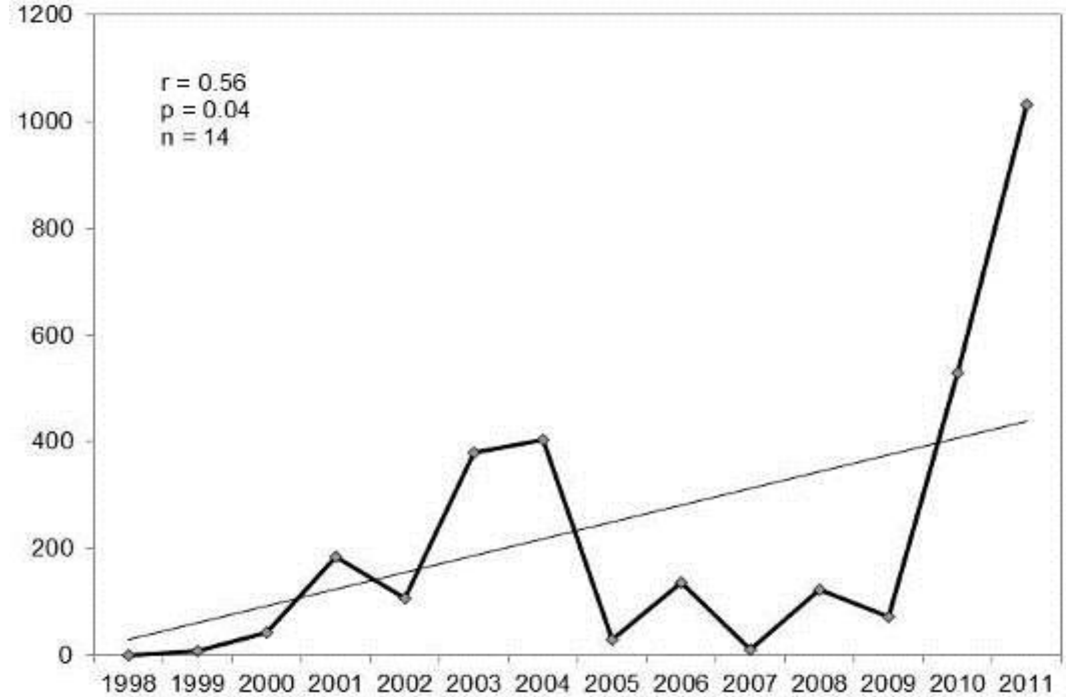

Figure 3.7. Summary of wild spawned chinook salmon fry captures within the South Alouette River, 1998 - 2011.

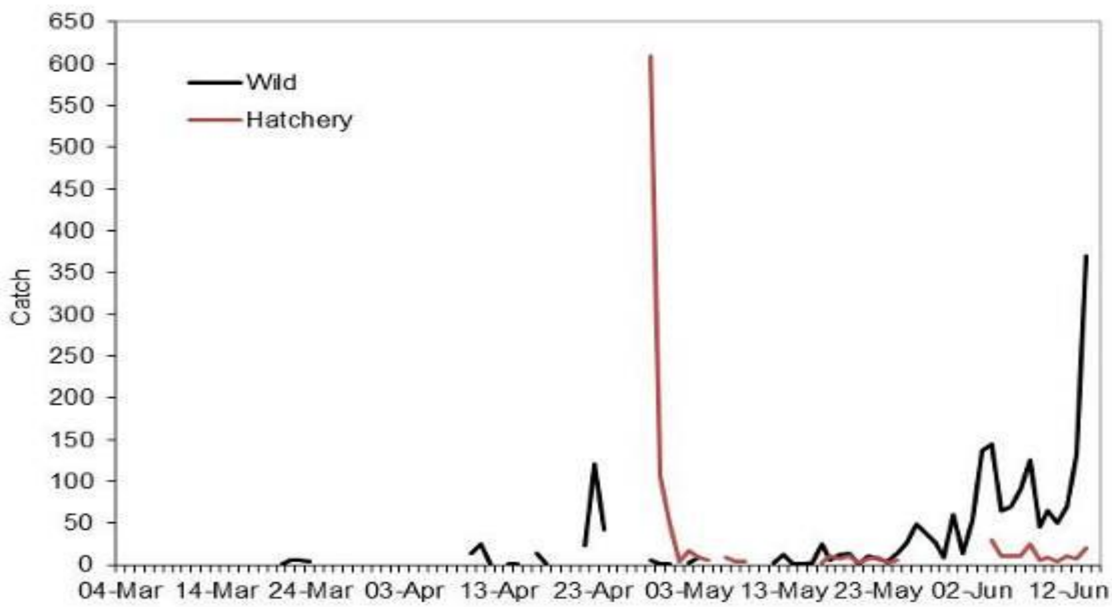

Figure 3.8. Daily chinook salmon fry catch for the South Alouette River, 2011.

Mark – recapture methods were not applied to chinook fry due to the low daily catch numbers of wild reared Chinook fry however, assuming a trap efficiency of 13.1% (derived from the average trap efficiency for chum fry, sockeye and coho smolts) an estimated 15,489 wild chinook out-migrants exited the South Alouette River during trapping operations. Figure 3.8 clearly illustrates accurate out-migration estimates are not possible due to the early end of trapping operations 14 June. This date coincided with the ascending limb of the out-migration distribution. Reliable population estimates would require continued trapping to at least the end of June to document the majority of the out-migration distribution.

June is a well-documented month of active downstream movement of under-yearling chinook smolts and the temporal pattern in three Vancouver Island rivers suggest early to mid-June peak timing (Healey 1991). For discussions sake, if it is assumed the 14 June peak represents the peak out-migration, and that the distribution is symmetrical, then an estimated 30,978 wild spawned chinook smolts were produced. Assuming a mean fecundity of 4,800 eggs (Hart 1973) and an egg to out-migrant survival of 3 – 34% (Healey 1991) and a 1:1 sex ratio, then a spawner escapement between 40 and 430 would be expected. Since the FRCC-ARMS fence enumerated 325 returning chinook (Table 3.4), and at least two thirds of the spawning habitat lies downstream of the fence, these estimates are too low, suggesting more than the estimated 50% out-migration occurred after 14 June and the chinook spawning escapement likely exceeded 1,000 fish. Elson (1985) reported chinook as extirpated in 1985 and the increasing trend in chinook spawning within the South Alouette River is a direct result of water releases from Alouette Dam and restoration stocking efforts from FRCC-ARMS and Chilliwack hatcheries.

3.6. Coho Smolts

The seasonal pattern of smolt out-migration was characterized as starting in Mid-April, peaking in May, and ending in mid-June and this was consistent with timing in 2009 and 2010 (Figure 3.9). Out-migration timing before 2009 is not summarized due to incomplete enumeration resulting from tidal backwatering and loss of trap efficiency and early cessation of trapping (see Section 3.11 Hypothesis testing).

In total, 5,344 wild coho smolts were captured. In addition, a further 170 (3.2%) coho smolt captures were estimated for the 4 days of lost catch (Table 3.1). This results in a total estimated out-migrant catch of 5,514 coho smolts (Figure 3.10). In total, 3,247 marks were applied to the catch and 930 of these were recaptured. This resulted in a mean trap efficiency of 28.6%, which was the highest to date. The mean annual trap efficiency (n=12) from 1999 to 2010 has been 12.4% (range 4.1 – 18.9%). Two mark - recapture periods (4 March – 24 May and 25 May – 14 June) were completed and recapture rates were consistent for the early (29.5%) and late (25.0%) trapping periods. The respective pooled Peterson estimator results in a coho smolt out-migration estimate of 19,240 (95% confidence interval: 18,062 to 20,540; Figure 3.11)

Prior to 2008, before the smolt trapping location was moved upstream to the current location, the linear trend line for the previous five years (2003-2007) suggested a significant decline in coho smolt production for the South Alouette River was occurring (Figure 3.11). However, it was suspected that much of the decline was due to early tidal backwatering effects on trap efficiency. In 2008, the trap was moved upstream, out of the tidal influence and this resulted in the expected improvements to trap efficiency thus confirming the loss of trap efficiency and resulting enumeration bias at the 216^{th} St location. However, it was discovered that smolt out-migration was longer in duration than previously thought. In 2009 the trapping duration was extended almost two weeks to June 14. Since 2009, estimated coho smolt production has met or exceeded the 15,000 to 20,000 smolt range (Figure 3.11). Hatchery reared coho fry releases do not account for the differences in annual coho smolt production between the years 2008 and 2010 (Table 2.1).

The mean length and weight of emigrating, wild reared, coho smolts in 2011 was 104.6 mm (range 65 – 195 mm, n=2,642) and 12.5 g (range 4.1 – 108.0 g, n=2,601), respectively. Mean smolts size (fork length) has been trending downward since 2007 and the 2011 mean fork length represents the second smallest mean size on record (Figure 3.12). Smolt growth is often density-dependent and a relatively large out-migrant population would be expected to be relatively smaller.

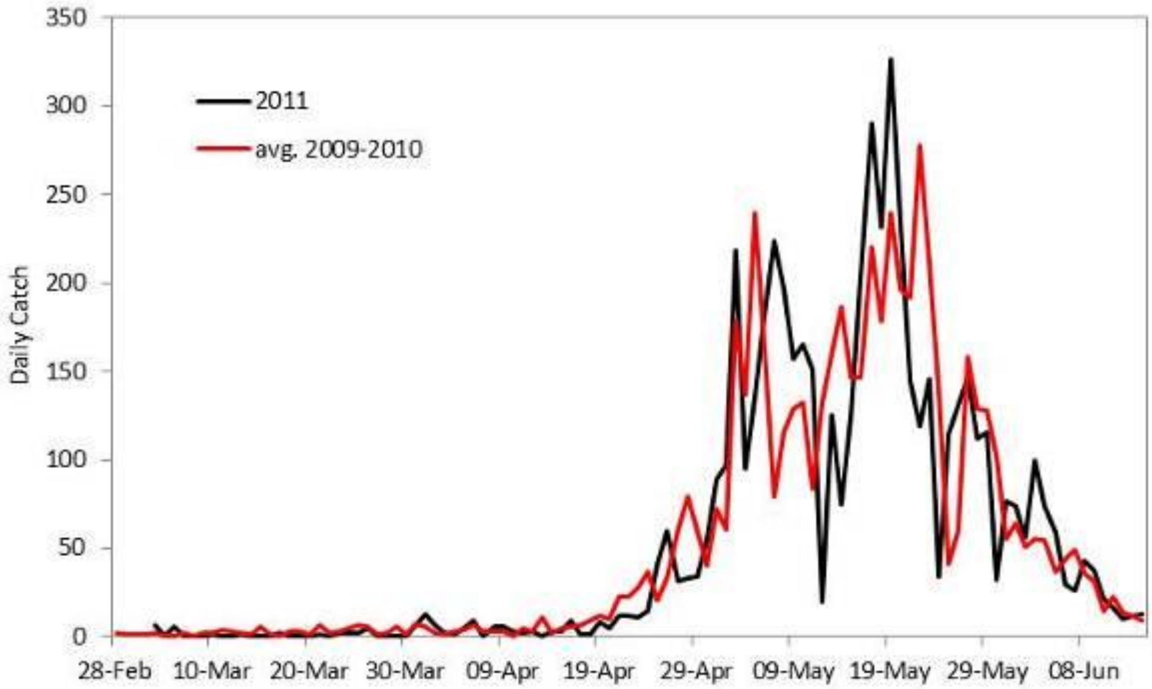

Figure 3.9. Daily coho smolt catch for the South Alouette River, 2011.

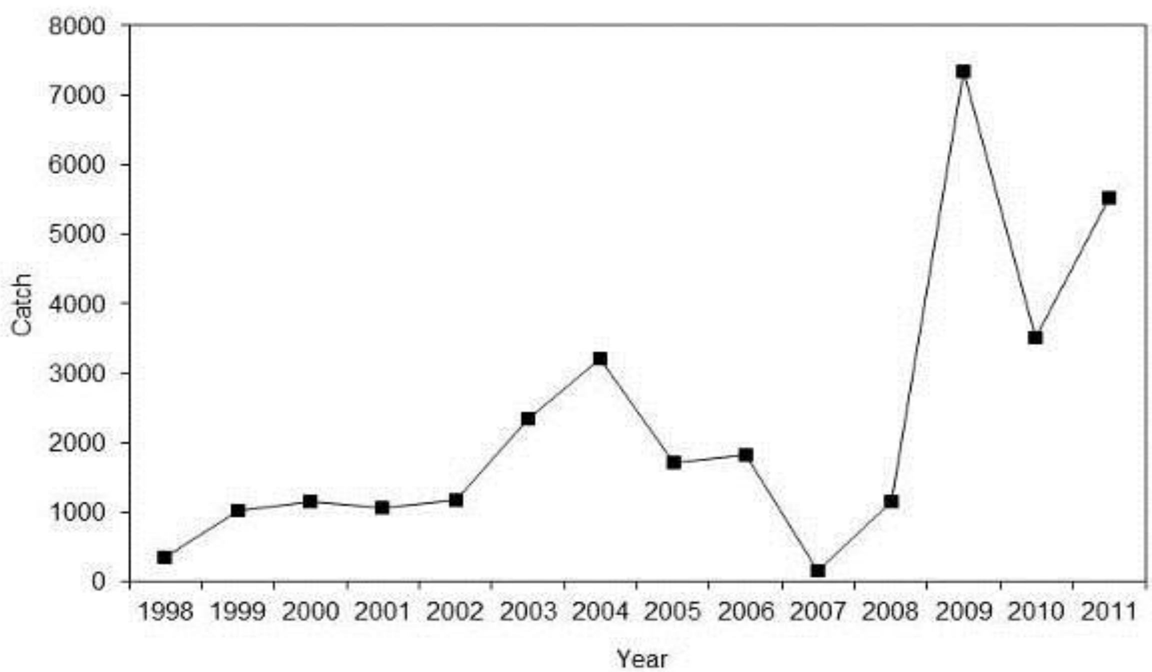

Figure 3.10. Summary of wild reared coho smolt captures within the South Alouette River, 1998 - 2011.

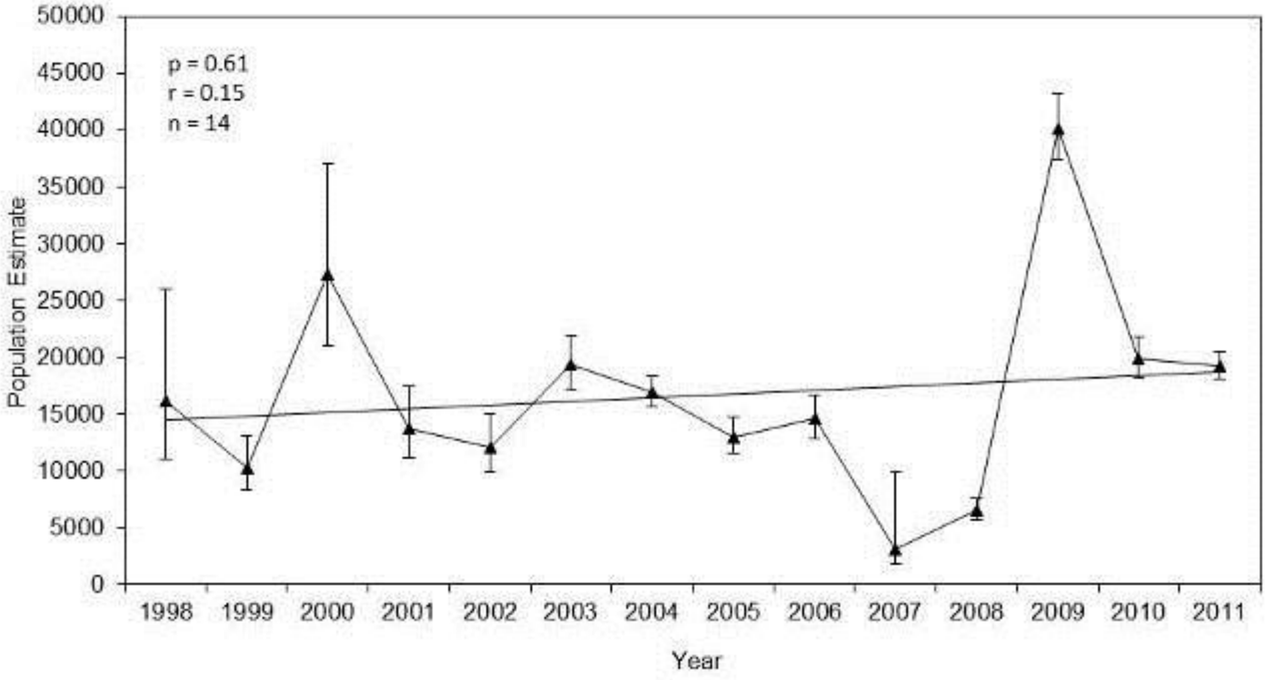

Figure 3.11. Summary of annual wild reared coho smolt out-migration estimates (+/- 95% confidence interval) for the South Alouette River, 1998 - 2011.

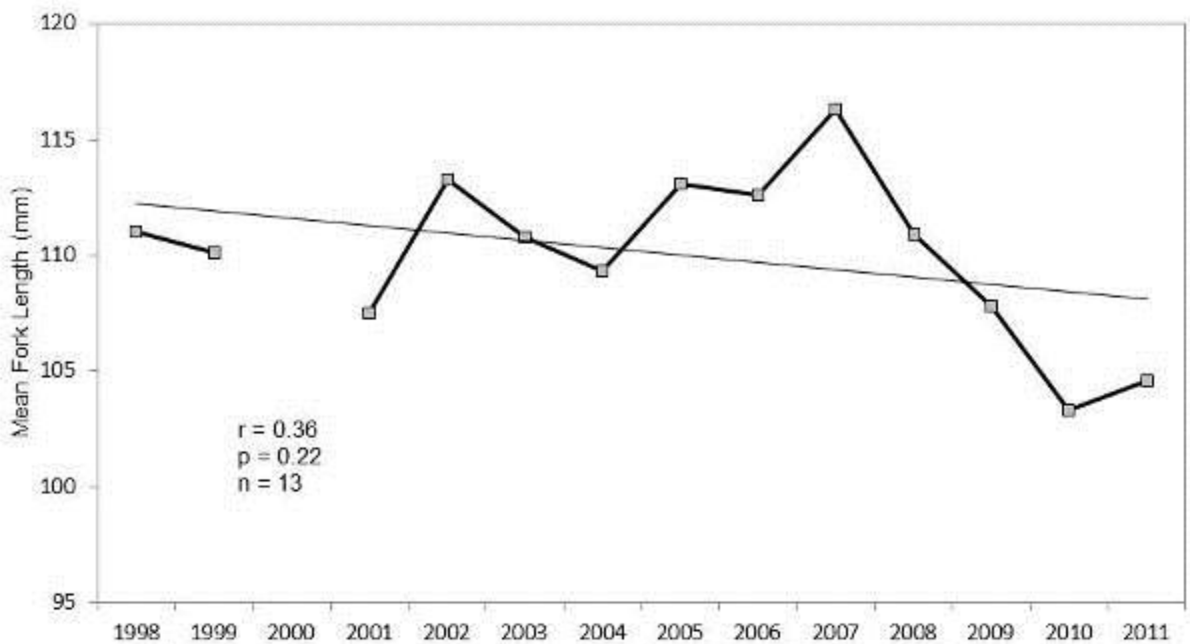

Figure 3.12. Summary of annual coho smolt size (fork length) for the South Alouette River Rotary Screw trap catch (1998 – 2011).

3.7. Steelhead Smolts

In total, 898 wild reared steelhead smolts were captured and a further 36 (4%) smolts were estimated for the 4 days of lost catch. This results in a total estimated out-migrant catch of 934 steelhead smolts. The seasonal pattern of smolt out-migration was characterized as starting in late-April, peaking in May, and ending in mid-June and this was consistent with timing in 2009 and 2010 (Figure 3.13). Out-migration timing before 2009 is not summarized due to tidal backwatering, loss of trap efficiency and early cessation of trapping (see Section 3.11 Hypothesis testing).

The 2011 out-migration catch of 934 steelhead smolts represents the highest annual catch since monitoring began and was within the range expected since moving the trap upstream to the 224th St. location in 2008 (Figure 3.14). In total, 580 marks were applied to the catch and 106 of these were recaptured. This resulted in a mean trap efficiency of 18.3%, which was above average. The mean annual trap efficiency from 1998 to 2011 has been 14.4% (range 0.0 – 32.6%). Two mark - recapture periods (4 March – 24 May and 25 May – 14 June) were completed and recapture rates were similar for the early (16.9%) and late (22.3%) trapping periods. The respective pooled Peterson estimator results in a steelhead smolt out-migration estimate of 5,077 (95% confidence interval: 4,238 to 6,198; Figure 3.15)

There has been a weak positive (i.e. increasing) relationship for annual estimates of steelhead out-migrants (regression, p=0.07, n=13, Figure 3.15). Prior to 2008, the linear trend line for the previous five years (2003-2007) suggested a decline in steelhead smolt production for the South Alouette River was occurring (Figure 3.15). However, it was suspected the decline was due to tidal backwatering effects on trap efficiency. In 2008, the trap was moved upstream, out of the tidal influence and this resulted in the expected improvements to trap efficiency thus confirming the loss of trap efficiency and resulting enumeration bias at the 216th St location. However, it was discovered that smolt out-migration was longer in duration than previously thought. In 2009 the trapping duration was extended almost two weeks to June 14. Since 2009, estimated steelhead smolt production has met or exceeded the 5,000 to 6,000 smolt range (Figure 3.15).

The mean length and weight of emigrating, wild reared, steelhead smolts in 2011 was 148.6 mm (range 77 – 240 mm, n=706) and 33.6 g (range 6.9 – 119.6 g, n=696), respectively. Mean smolts size (fork length) has been trending downward since 2005 (regression, p=0.01, n=14, Figure 3.16). Smolt growth is often density-dependent and a relatively large out-migrant population would be expected to be relatively smaller.

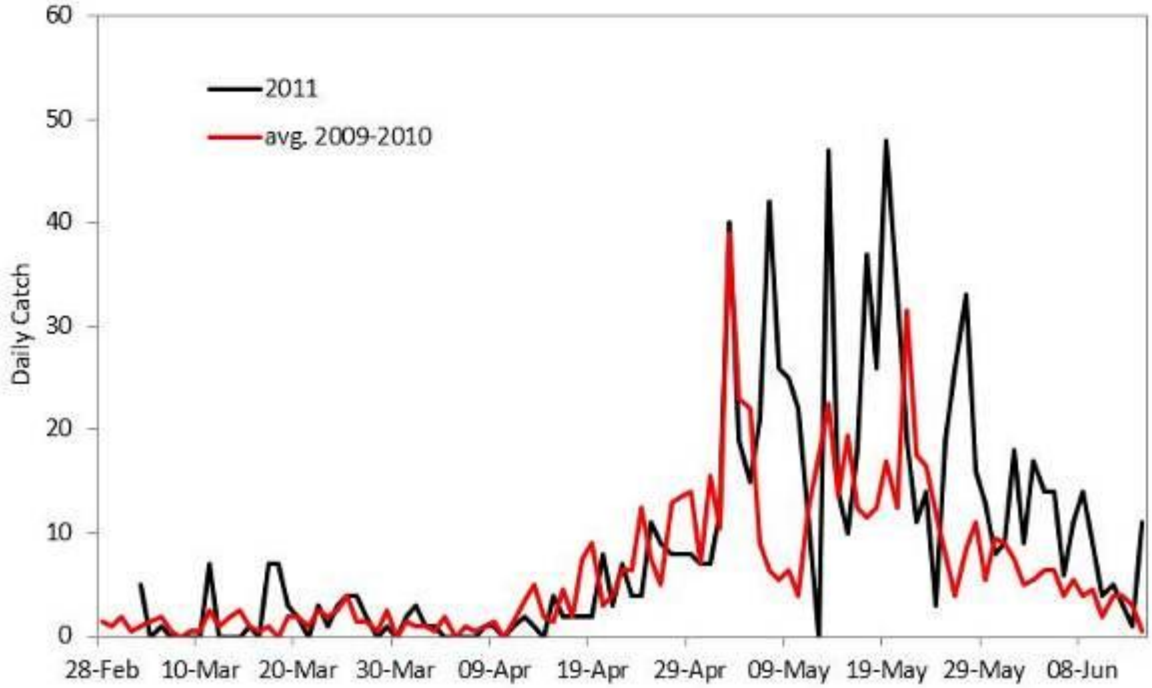

Figure 3.13. Daily steelhead smolt catch for the South Alouette River, 2011.

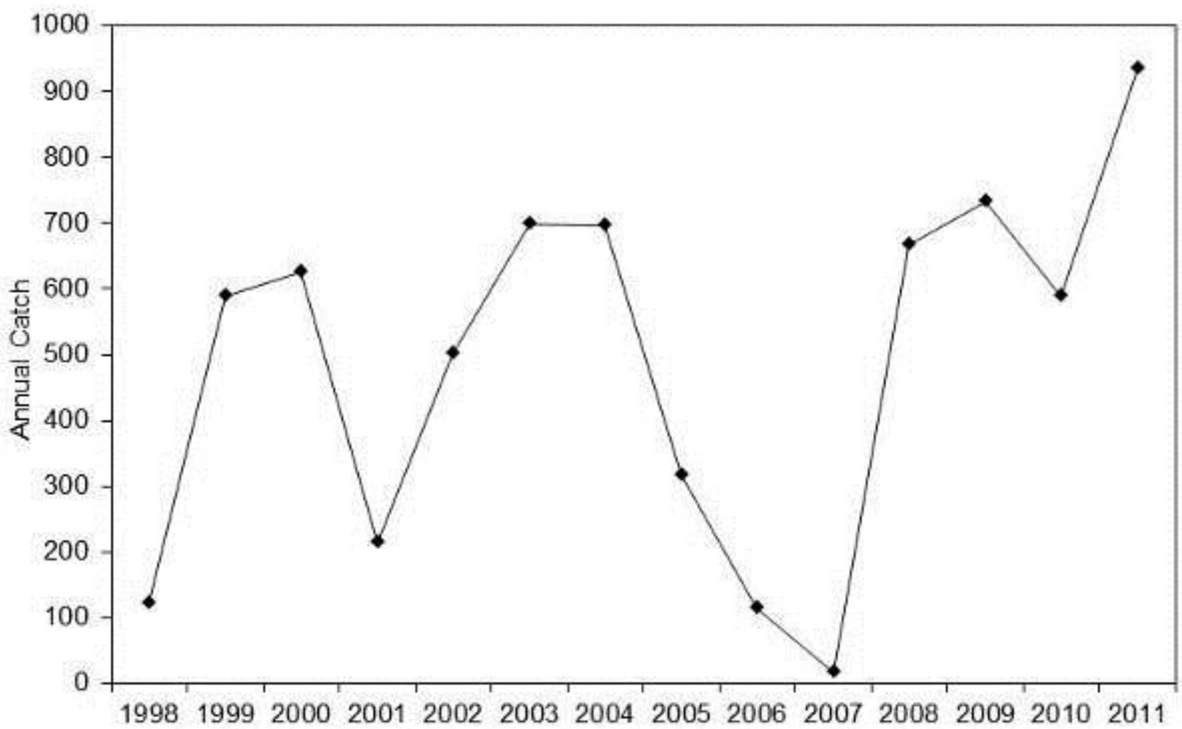

Figure 3.14. Summary of wild reared steelhead smolt captures within the South Alouette River, 1998 - 2011.

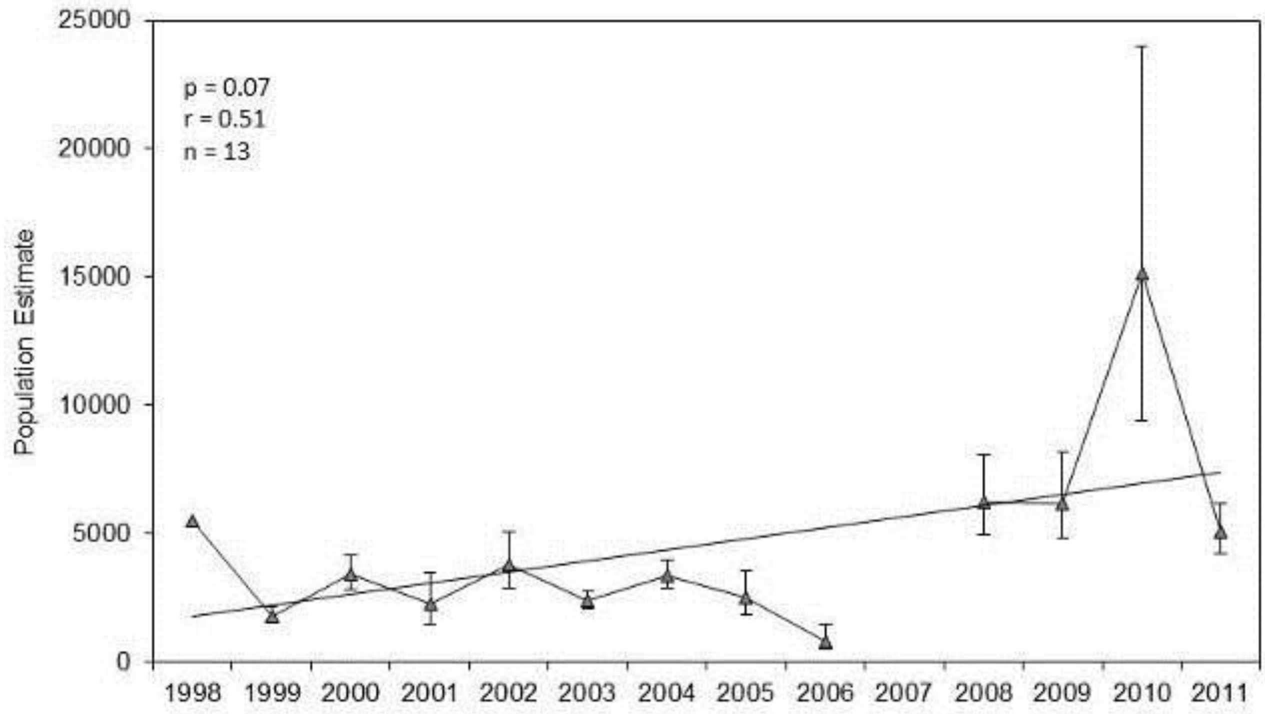

Figure 3.15. Summary of annual wild reared steelhead smolt out-migration estimates (+/- 95% confidence interval), South Alouette River, 1998 - 2011. The 2007 out-migration estimate could not be calculated due to low capture number for 2007 (n=16).

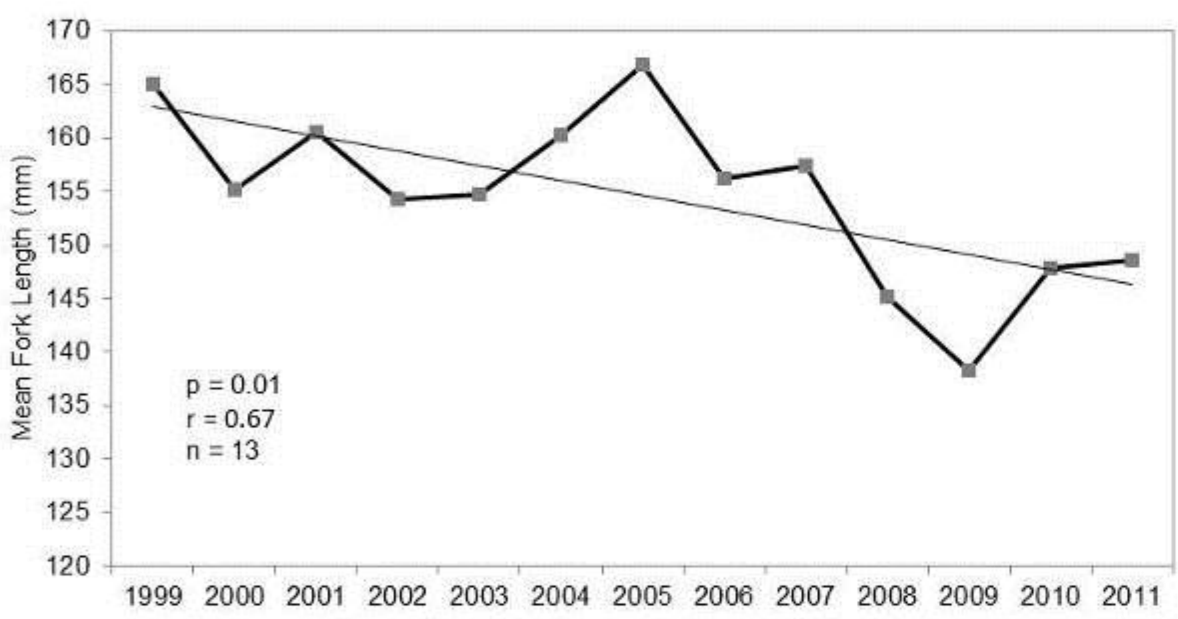

Figure 3.16. Summary of annual steelhead smolt size (fork length) for the South Alouette River Rotary Screw trap catch (1998 – 2011).

3.8. Cutthroat Trout

In total, 142 wild reared and 132 hatchery reared cutthroat trout smolts were captured between 10 March and 14 June (Figure 3.17). Ninety-three cutthroat trout smolts were marked and there were 11 recaptures (11.8%). Although captures were insufficient to determine out-migration timing as opposed to incidental captures of rearing juveniles, and the recaptures were below the statistically acceptable minimum number for avoiding small sample biases in population estimators (Ricker 1975), it is interesting to note the resulting population estimate of between 650 and 1,885 wild reared cutthroat trout out-migrant smolts.

Annual captures have been rebuilding the last four years from the low in 2007 (Figure 3.18). From 2003 to 2007 annual cutthroat catch results were in decline.

The mean length and weight of cutthroat trout out-migrants was 146.6 mm (range 82 - 207 mm) and 32.4 g (range 6.1 - 87.1 g).

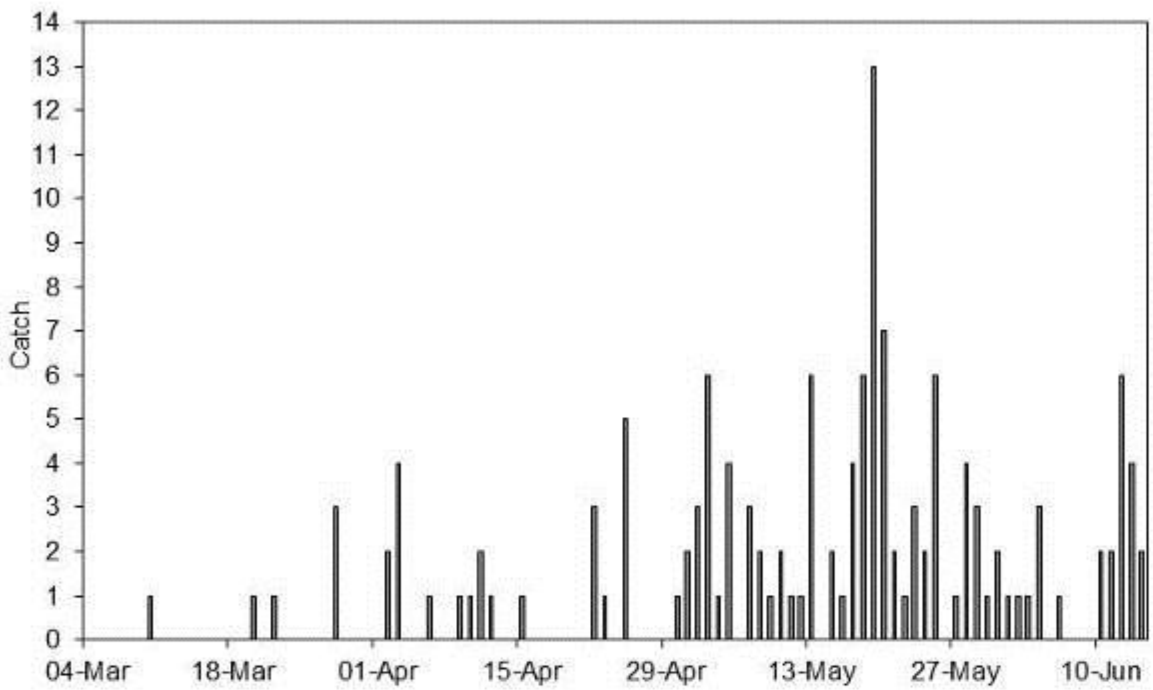

Figure 3.17. Daily wild reared cutthroat trout smolt catch for the South Alouette River, 2011.

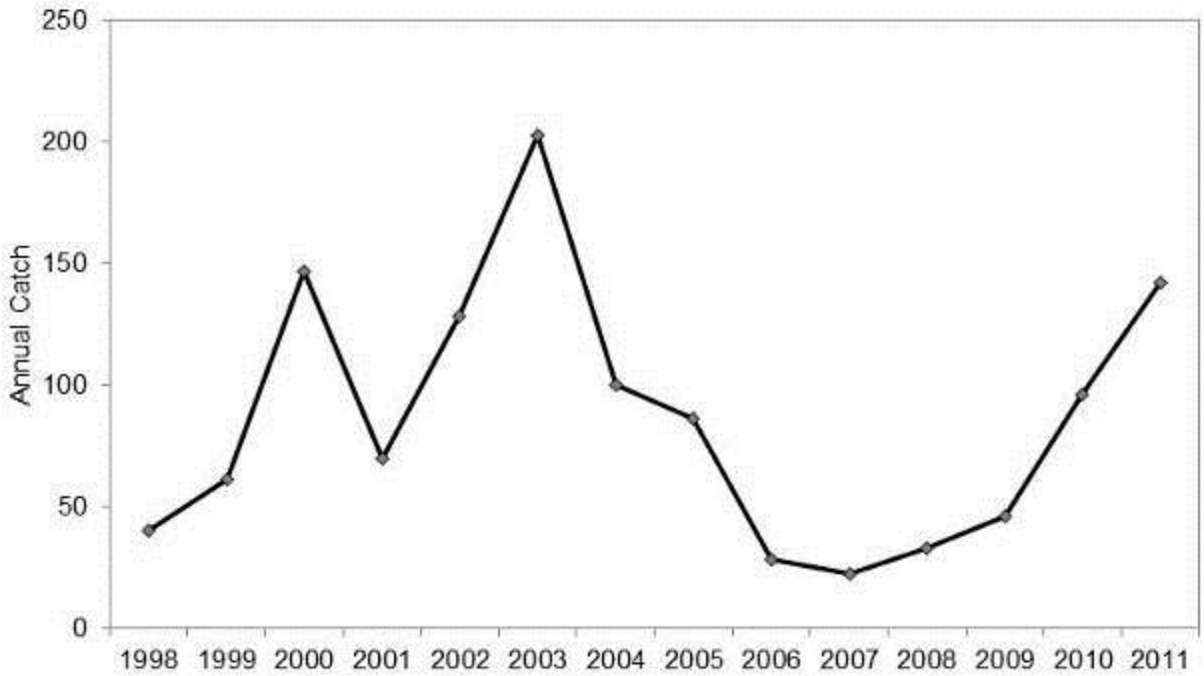

Figure 3.18. Summary of wild reared cutthroat trout smolt captures within the South Alouette River, 1998 - 2011.

3.9. Sockeye

Previously, the 2005 and 2006 data reports referred to sockeye salmon smolts captured exiting the Alouette Reservoir as kokanee. In 2007, what were assumed to be kokanee smolts from Alouette Lake were genetically confirmed to represent descendants of sockeye salmon trapped within Alouette Lake at the time of Dam construction (ARMS 2007). These smolts are captured exiting the Alouette Reservoir as part of the on-going field trials (2005 – 2011) to assess smolt migration success out of the Alouette Reservoir (Mathews and Bocking. 2011). In 2011, the spillway gate on Alouette Dam was opened for smolt migration trials 15 April to 14 June. A 6 m^3/s flushing flow was implemented 1 to 9 June.

There were 1,971 sockeye smolts captured in the 224th St. rotary screw trap between 15 April and 12 June. These captures include 162 smolts that were mark recaptures from the Mud Creek trap upstream. In addition, a further 69 sockeye smolt captures were estimated for the two days of lost catch. This results in a total estimated out-migrant catch of 2,040 sockeye smolts (Figure 3.19).

In 2011, captures in the lower watershed at the 224th Street location closely tracked the captures immediately below the dam at the Mud Creek site (Figure 3.19). This pattern has been consistent for the last five years (Figure 3.20). It is clear from the time difference of only a day or two in out-migration peaks or pulses between the two trapping locations that sockeye smolts, following their emigration from Alouette Lake, continue their migration out of the Alouette system without delay. There is no evidence to-date of an effect of the late season surface release flush on sockeye smolt migration timing or movement out of the South Alouette River. Therefore, it appears typical mean daily flows of between 3.0 to 6.0 m^3/s is adequate to ensure movement of Alouette Lake sockeye smolts out of the system without delay.

In total, 1,058 sockeye smolts were marked and released at the 232nd St. Bridge. There were 88 recaptures for a mean trap efficiency of 8.3%. This compares with 9.4% in 2010. The resulting pooled Peterson population estimate was 23,465 (95% C.I. 19,263 – 29,236; Figure 3.21). This represents 75.9% of the Mud Creek estimate of 30,899 (95% C.I. 29,603 – 32,195) sockeye smolts exiting the Alouette Reservoir 13.8 km upstream (Mathews and Bocking 2012).

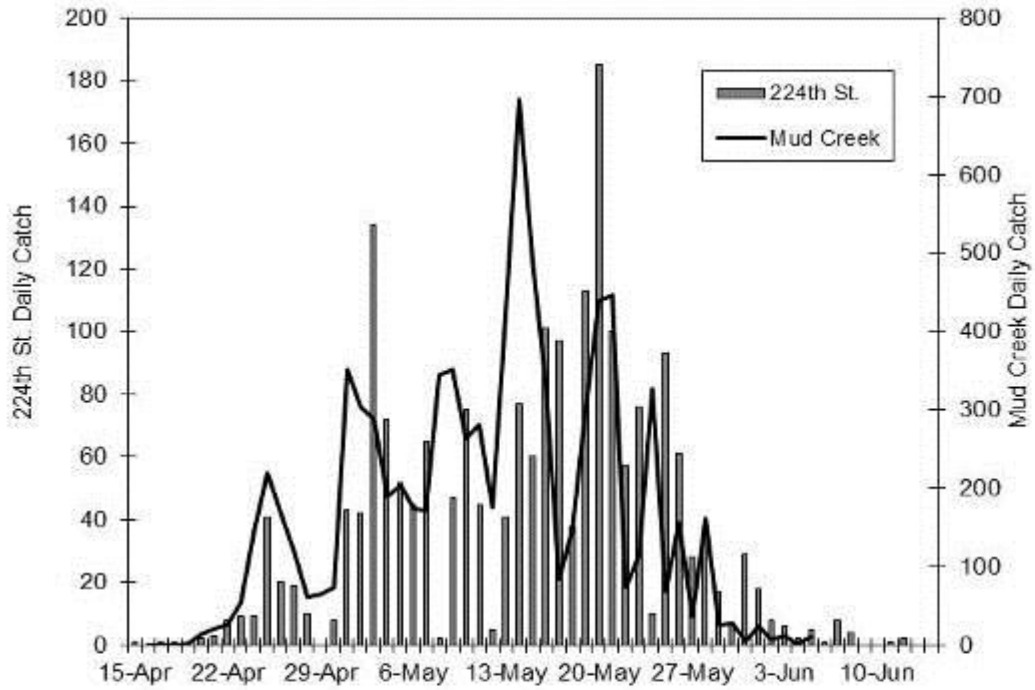

Figure 3.19. Daily sockeye smolt catch for the South Alouette River, 2011. Mud Creek data from LGL Limited (*see* Mathews and Bocking 2012).

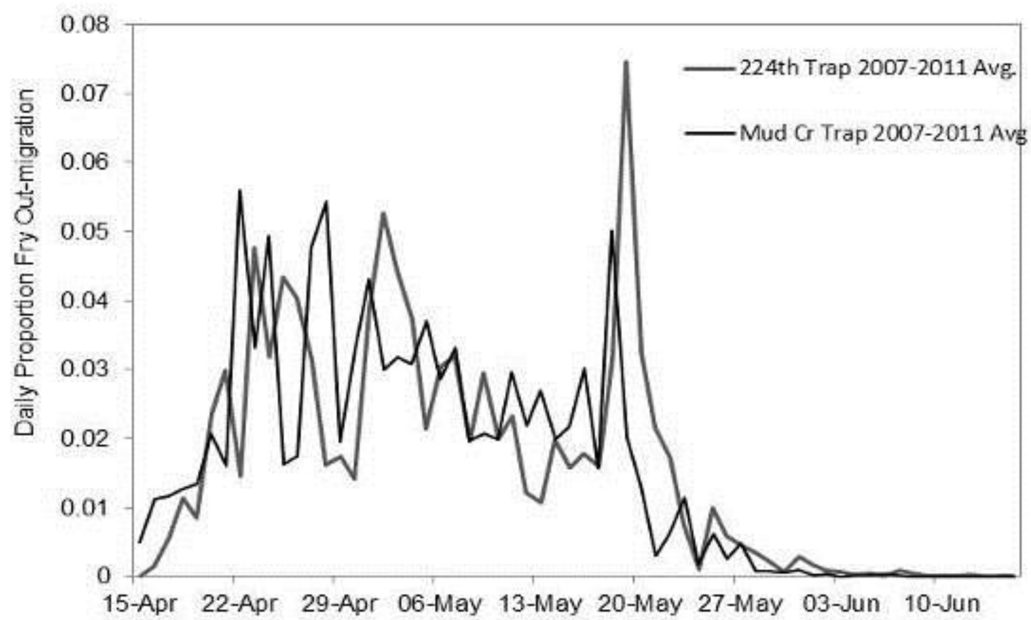

Figure 3.20. Daily sockeye smolt out-migration catch represented as a proportion of total annual catch illustrating the average out-migration timing (2007 – 2011).

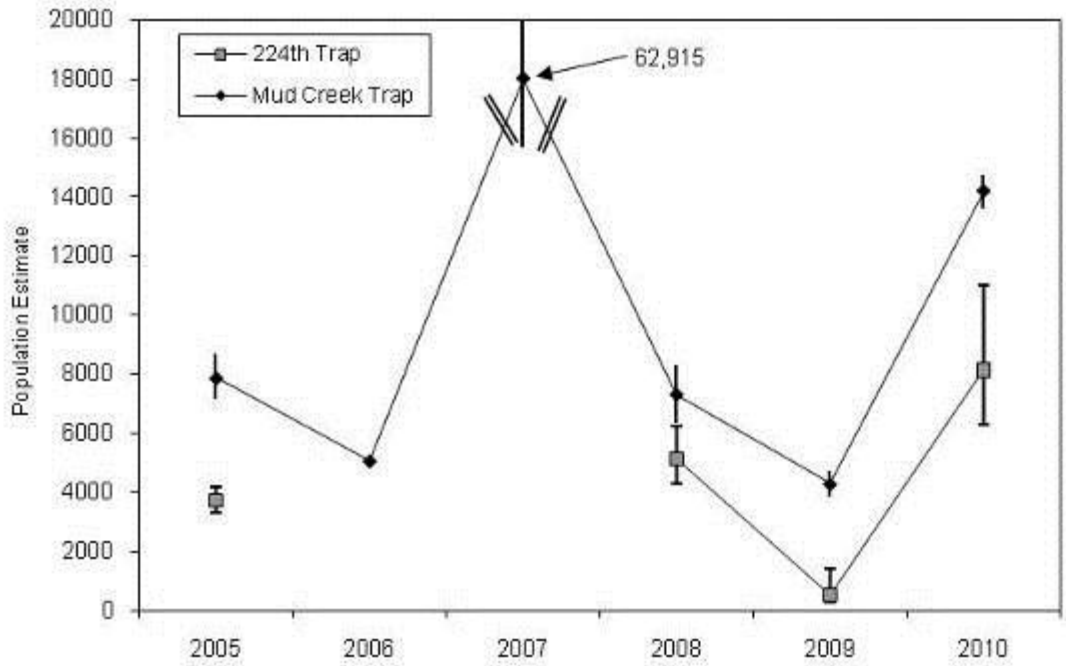

Figure 3.21. Summary of annual Alouette Lake sockeye smolt out-migration estimates (+/- 95% confidence interval) for the Mud Creek (upper watershed) and 224th Street (lower watershed) trapping locations. Mud Creek Data from LGL Limited (see Mathews and Bocking 2012). Note that Mud Creek confidence interval for 2005 was derived from hatchery coho trap efficiency ratings (Baxter and Bocking 2006) and 2006 was derived from steelhead smolt trap efficiency ratings (Humble *et al*. 2006).

Assuming differences in population estimates are primarily due to downstream migration mortality (predation), the mean annual estimated mortality for sockeye smolts migrating the 13.8 km from the Alouette Reservoir (Mud Creek RST) to tidewater (224th Street RST) has ranged from 24 – 70% (Mean = 47.5%, n=5). A large portion of total smolt to adult natural mortality occurs during a short migration window of a few weeks during within river downstream migration (Melnychuk 2009). Melnychuk (2009) reported within river mortality for acoustic tagged migrating pacific salmon smolts in Southern B.C. was 42%; and this was likely low due to bias associated with tagging the upper size distribution to meet minimum body size guidelines.

The mean length and weight of sockeye smolts captured in the 224th St. rotary screw trap was 74.5 mm (range 58 - 173 mm; n=747) and 6.7 g (range 2.1 - 49.6 g; n=58), respectively. Except for the first year of sockeye re-anadromization (2006), smolt size (mean annual fork length) has remained relatively constant the last 5 years (2007-2011, Figure 3.22).

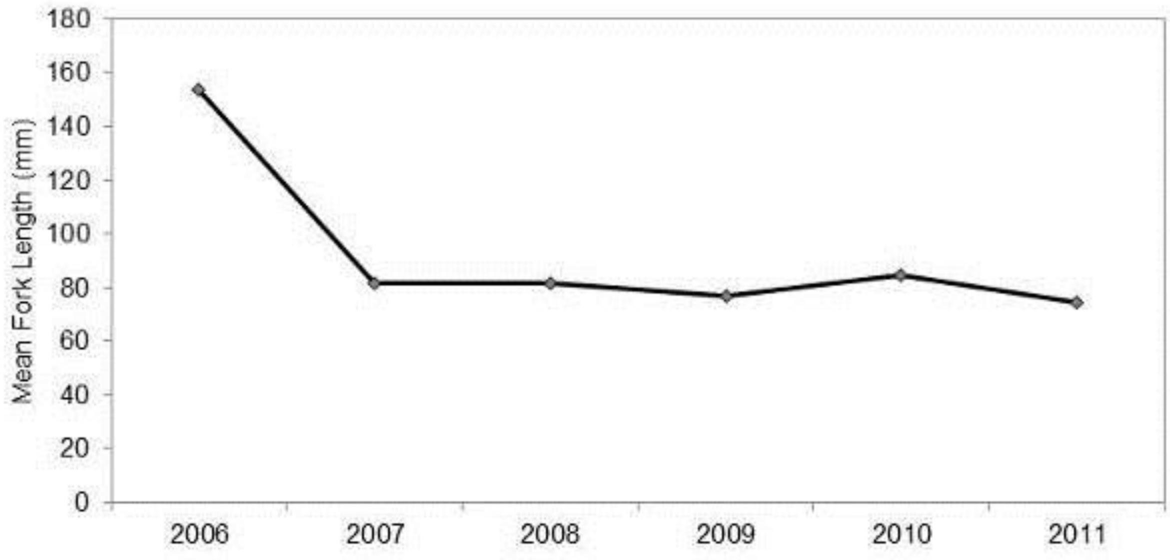

Figure 3.22. Summary of annual sockeye smolt size (fork length) for the South Alouette River, 224th Street Rotary Screw trap catch (2006 – 2011).

3.10. Physical Conditions

Mean daily water temperatures in the South Alouette River, during downstream trapping operations (3 March to 14 June 2011) ranged from 4.2 °C to 13.4 °C. The mean 2011 water temperature during the peak period of fry and smolt out-migration (18 March to 31 May) was 7.70 °C. This represents the lowest out-migration temperature observed over the last 14 years on record (Figure 3.23).

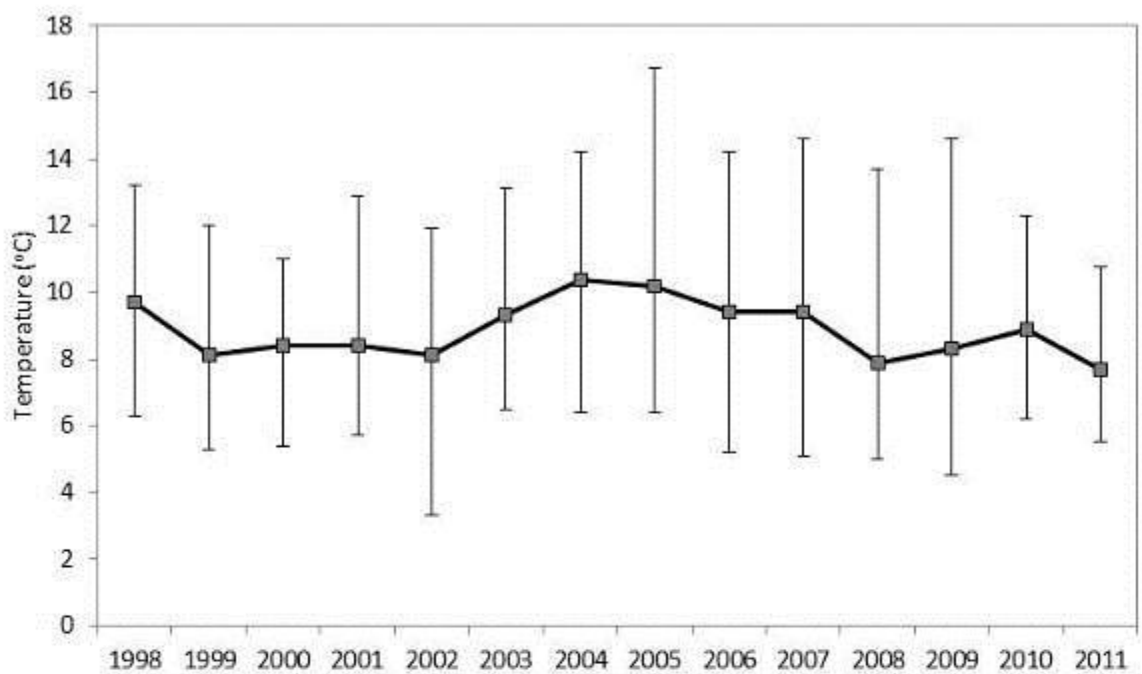

Figure 3.23. Mean, minimum and maximum daily water temperatures (°C) for the peak period of fry and smolt out-migration (18 March to 31 May) for the S. Alouette River downstream enumeration program (1998-2011).

Annual variation in mean daily water temperatures for the 1998 to 2011 period of record is illustrated in Figure 3.24 and the 2011 out-migration temperatures are highlighted. In general, the 2011 water temperatures were low, and in the case of the spring smolt out-migration season and summer rearing temperatures were the lowest on record (Figure 3.24). Lower incubation temperatures prolong incubation time of eggs and the time of hatching and emergence varies among stocks because of differences in the number of temperature units required for hatching and development (Salo 1991).

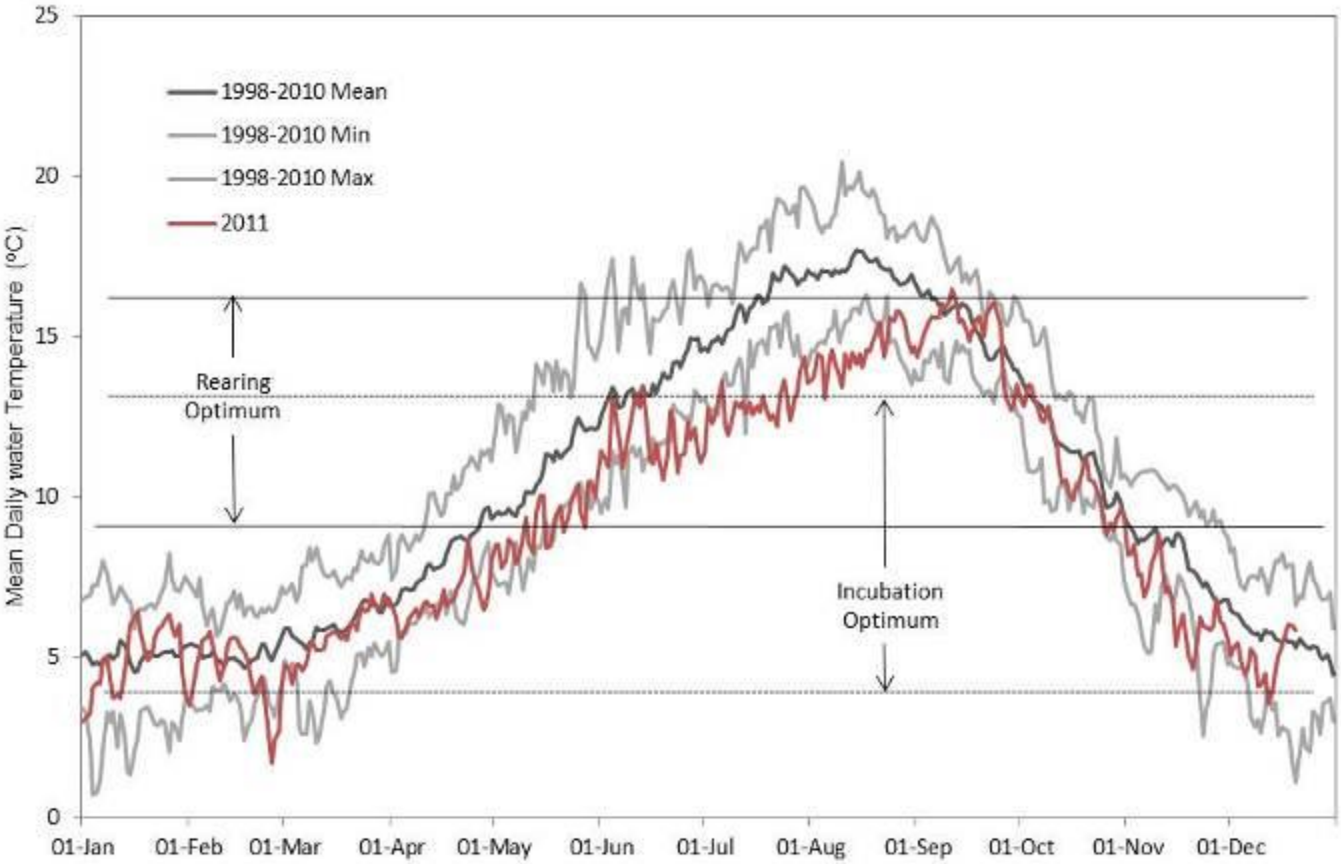

Figure 3.24. Mean daily water temperature for the mainstem South Alouette River at 224th Street, 1998-2011.

Mean daily temperatures of the South Alouette River are generally within the provincial guidelines for optimum temperature ranges for incubation of salmon embryos (4.0 – 13.0 ^{o}C; Anon. 2001). Typically, there are short periods of lower than optimal incubation temperatures in December through March however; they do not appear to adversely affect incubation survival of South Alouette River chum salmon.

In 2011, water temperatures at the 224th location remained within the optimum temperature range for rearing coho salmon (9.0 – 16.0 ^{o}C; Anon. 2001). Ford *et al.* (1995) reports a similar optimum temperature range (10.0 – 14.0 ^{o}C) for juvenile rainbow trout/steelhead growth. Typically, the South Alouette River exceeds optimum summer rearing temperatures in July through September (Figure 3.24). Although this location is relatively low in the watershed, it is generally representative of the mainstem South Alouette River when compared to additional thermographs upstream at the FRCC-ARMS hatchery and the Alouette dam outlet (Cope 2006).

Mean daily discharge for the peak period of fry and smolt out-migration (25 February to 9 June) at the 232nd Street Water Survey of Canada Station (WSC No. 08MH005) was 6.28 m^3/s. Excluding the 2007 anomaly due to flood control releases, this was the highest mean discharge for the period of record (Figure 3.25).

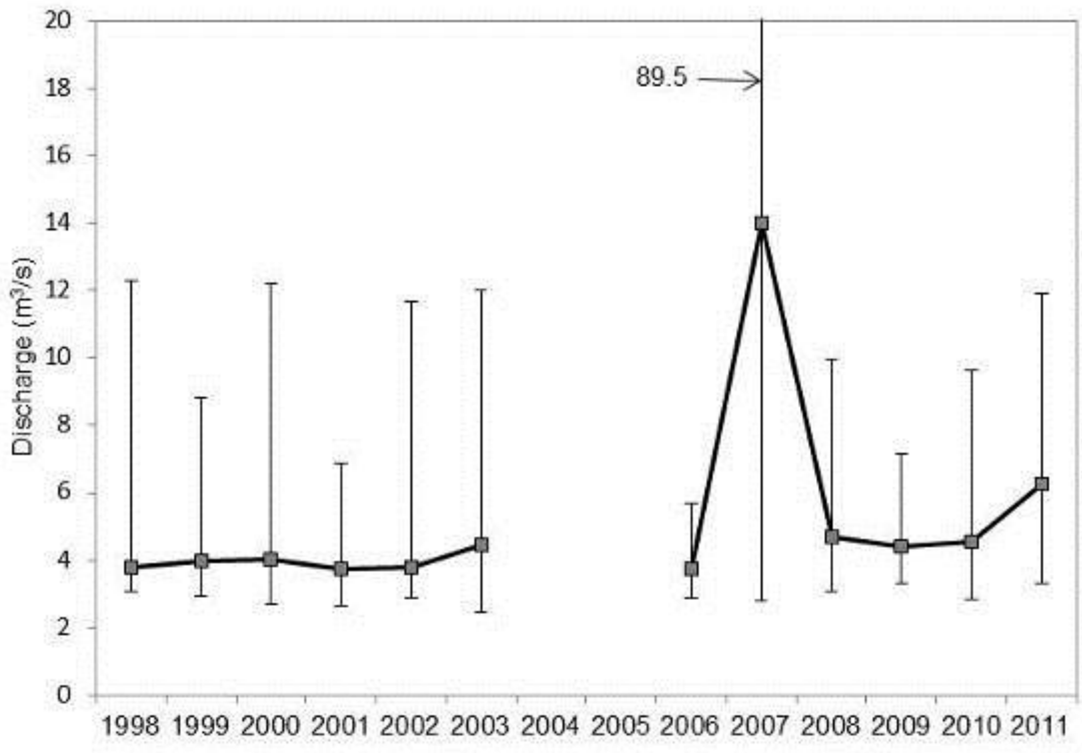

Figure 3.25. Mean, minimum and maximum daily discharge (m^3/s) for the peak period of fry and smolt out-migration (25 February to 9 June) for the S. Alouette River downstream enumeration program (1998-2011). Note that the hydrometric station was not operating from 27 April, 2004 to 11 Apr, 2005 and data for the trapping period in these years is incomplete.

Annual variation in mean daily discharge for the 1998 to 2011 period of record is illustrated in Figure 3.26. The extreme flows of 2007 were due to flood control releases and are not typical, therefore they are excluded from the following discussion of average flows. The 11-year average mean daily discharge during the peak period of fry and smolt out-migration (excluding 2004, 2005, 2007, Figure 3.25) was 4.3 m^3/s. The difference of only 46% (2.0 m^3/s) between the 11 year mean daily flow and the highest annual flow illustrates the stable hydrograph resulting from upstream flow control.

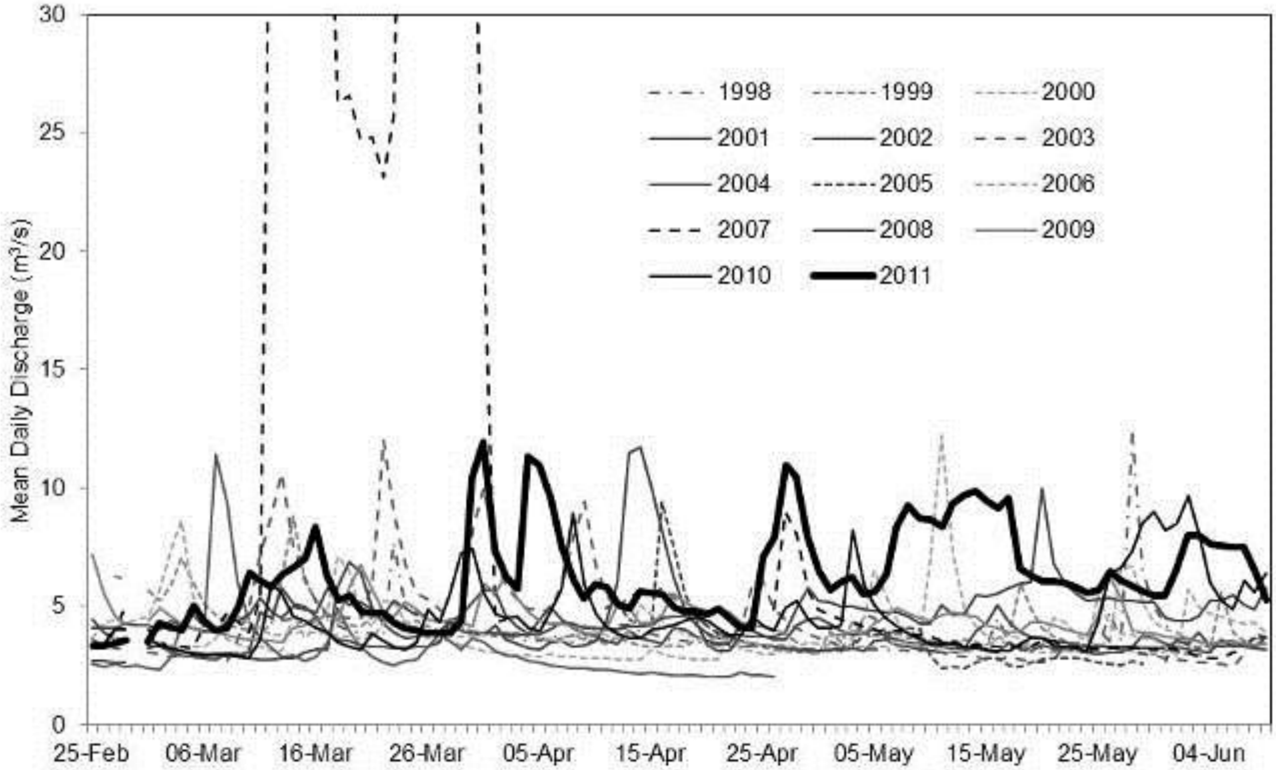

Figure 3.26. Mean daily discharge for the mainstem South Alouette River at Water Survey of Canada Station No. 08MH005 (232nd Street bridge), 1998-2011. Note that the 2011 data is preliminary and currently under review and revision.

The mainstem flows are controlled by the Alouette River Dam low-level outlet (outflow range 1.98 – 2.97) and typically, fluctuations in mainstem flows are due to tributary inflows resulting from precipitation events. Figure 3.26 illustrates the higher than average sustained flows for 2011. There were six storm events that resulted in mean daily flows in excess of 8 m^3/s.

3.11. Hypothesis Testing

Preliminary analysis for possible correlations with independent variables available (Appendix A, Table A1) consisted of separately plotting the independent variable as a function of smolt estimates. Chum salmon was utilized for this preliminary analysis because these data are the most complete and have the greatest level of confidence in regards to their accuracy and precision. Similar analyses will be conducted for additional species as the data becomes available in future years.

There has been a weak positive (i.e. increasing) relationship for annual estimates of chum out-migrants (regression, p=0.37, n=14; *see* Figure 3.4). However, a non-linear relationship is expected for pacific salmon species that typically have variable egg-to-fry survival year to year due to density-dependent mortality (i.e. a plateau or decline in recruitment in a compensatory relationship like a Beverton-Holt or Ricker relationship). Figure 3.27 illustrates the emerging compensatory stock-recruitment relationship for South Alouette River chum salmon. The assumption that the low 2007 fry production was due to the atypical flood conditions was inaccurate. The replication of the low fry production results in 2010 following similar high spawner escapements (i.e. ALLCO fence count >150,000, Table 3.4) indicates that fence counts are a fair indicator of run size in the river as a whole and that egg-to-fry survival is not constant year to year but has hit the point of significant density-dependent mortality. This suggests that the 2007 and 2010 years represent over-escapement and maximum chum fry production would be achieved in the range of 60,000 to 100,000 chum spawners at the ALLCO fence. Unfortunately, the 2011 chum fry production was much lower than the approximately 25 million fry the stock-recruitment curve predicts (Figure 3.27). Due to the low sample size and large amount of variation, caution should be exercised in interpreting results and further data is required to comment with any confidence.

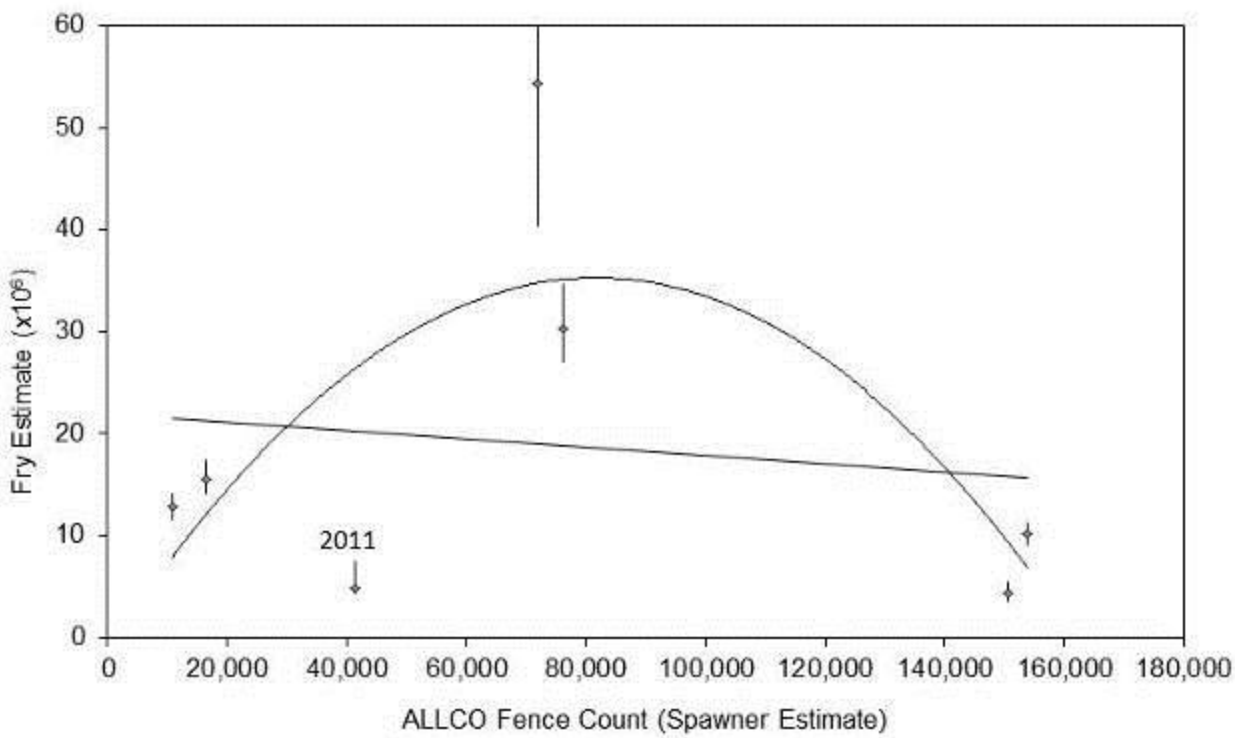

Figure 3.27. Relationship between chum salmon spawners enumerated at the FRCC-ARMS hatchery fence and the number of fry out-migrants the following spring.

The remaining independent variables of water discharge (during out-migration period and mean annual), water temperature (during out-migration period) and substrate quality illustrated little effect on chum fry production. This is due in large part to the high variability in fry production and the low variability in the associated environmental data (Figure 3.28).

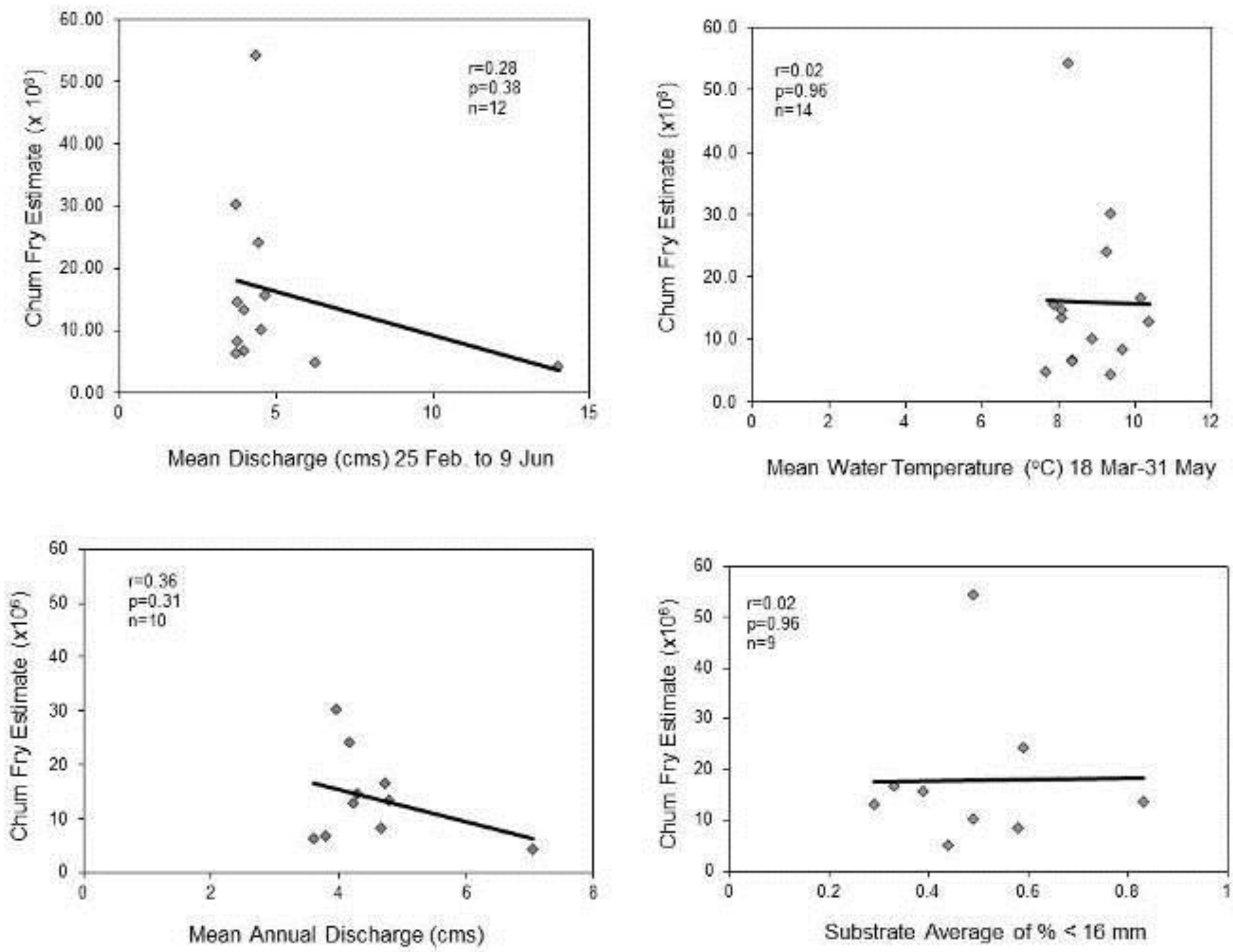

Figure 3.28. Relationship between chum fry production and environmental variables monitored within the South Alouette River.

There is no relationship between fence counts of coho salmon spawners at the FRCC-ARMS hatchery fence and the number of smolt out-migrants one year later in the spring (Figure 3.29). As more data points are acquired the relationship is becoming weaker (see Cope 2009). This suggests that fence counts are not a good indicator of coho run size in the river as a whole. This result was expected as coho are typically tributary spawners.

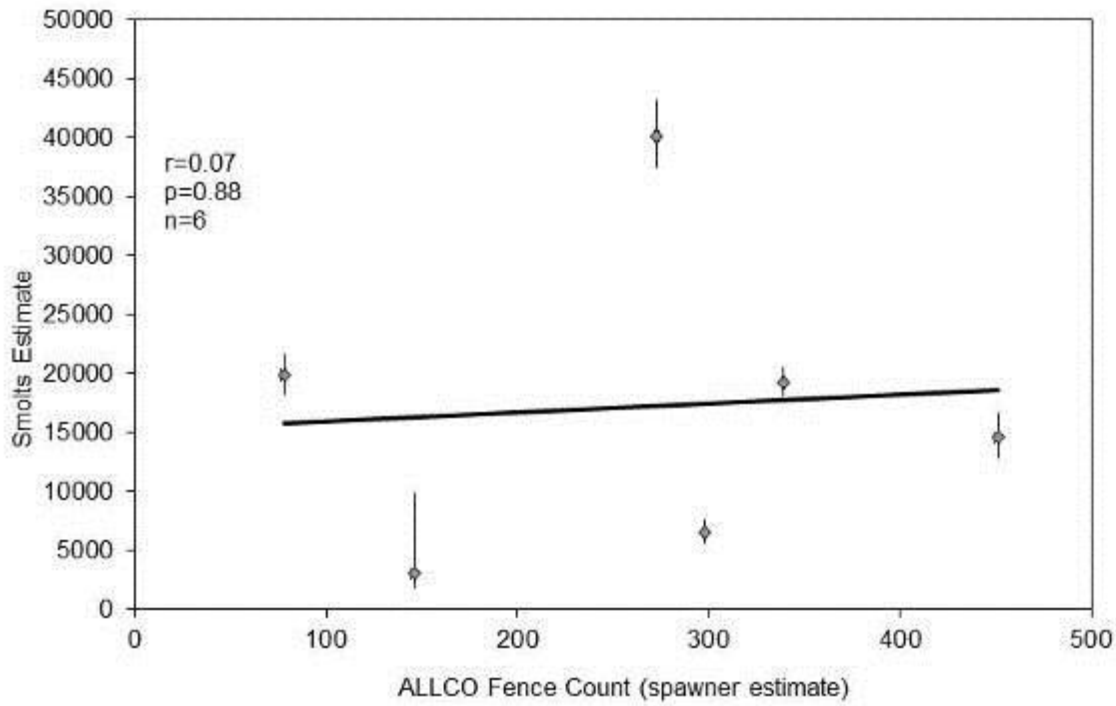

Figure 3.29. Relationship between coho salmon spawners enumerated at the FRCC-ARMS hatchery fence and the number of smolt out-migrants one year later.

There is a significant relationship between trapping duration and coho smolt out-migrant estimate (Figure 3.30; regression, p=0.04). This was due to the confounding effect in recent years (i.e. 2003-2007) of the increasing impact of tidal backwatering from the Pitt River on trapping efficiency at the previous (216th St.) trapping location. This effect was manifest as earlier end dates (i.e. trap duration) resulting from declining and/or inefficient trapping. The strong positive relationship between trap duration and coho smolt out-migrants confirms incomplete enumeration during these years.

The independent variables of water discharge (during out-migration period and mean annual), water temperature (during out-migration period) and substrate quality illustrated little effect on coho smolt production. This is not surprising as alternative environmental variables that more accurately reflect rearing conditions during the year of tributary residence (coho freshwater rearing occurs primarily in tributary and off-channel habitat not mainstem habitat) would be more appropriate variables for further analysis.

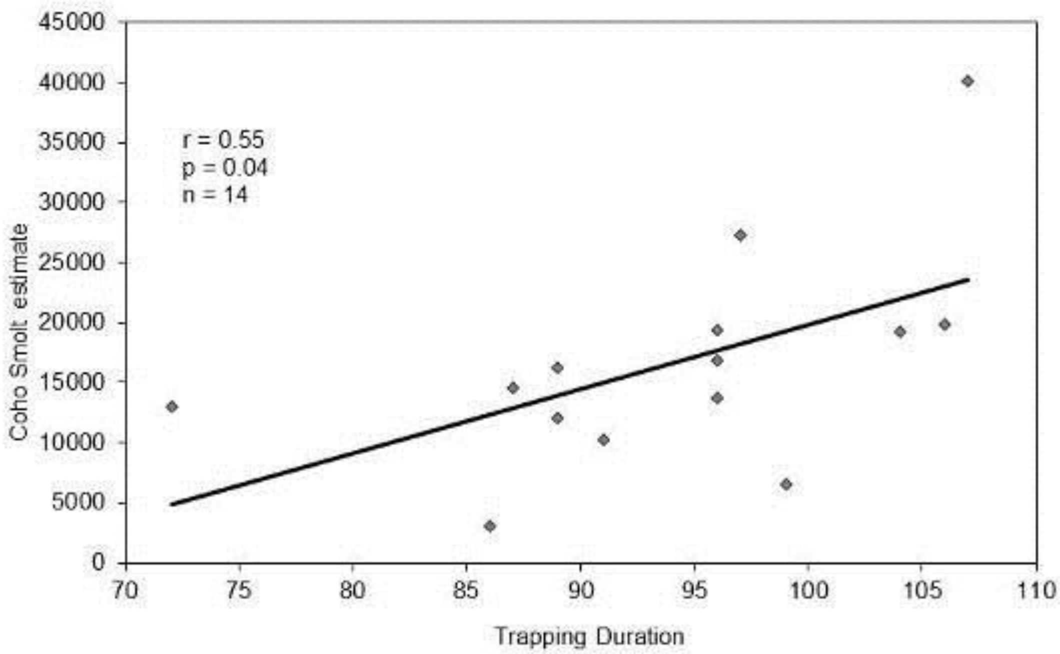

Figure 3.30. Relationship between trapping duration and coho smolt out-migrant estimate reflecting the effect of early trap backwatering in the years 2003 – 2007.

4. Discussion

4.1. Chum Fry

The 2011 chum salmon fry out-migrant estimate was 4.9 million smolts (95% confidence interval: 4.3 to 6.9 million). This represents the second lowest annual smolt yield during the period of study, but also represents a small increase (14%) in production for this cycle-year (Table 4.1). The current cycle-year is recovering from the lowest recorded smolt yield (2007) that occurred following extremely high spawner escapements the previous year (ALLCO fence count >150,000).

The RST trap is located 13.8 km downstream from the Alouette Dam and the mean wetted width was estimated to be 19.24 m (BC Hydro 1998). Since 1998, South Alouette River chum smolt yield has averaged 1,152,174 smolts/km (range 311,594 to 3,934,782 smolts/km) or 60 smolts/m^2 (range 16 – 205 smolts/m^2). This compares with 106,667 to 560,000 smolts/km or between 4.5 and 24 smolts/m^2 produced in the Coquitlam River during the same time period (2000 – 2010, Decker *et al.* 2011). The Alouette and Coquitlam Rivers are nearby rivers within the same regional area that share many similarities (regulated by dams with flow diversions, headed by large reservoirs, comparable in size, gradient, morphology and support similar fish communities) and chum smolt abundance are correlated (r=0.63, Decker *et al.* 2011). Annual chum fry enumeration has also been monitored for the Cheakamus River using similar methodology over the same time period (2000-2010) and chum out-migrant yield has ranged between 130,435 to 426,087 smolts/km (Melville and McCubbing 2011). The Cheakamus River is also regulated by a dam with flow diversion.

By comparison, Koning and Keeley (1997) suggest a bio standard of 76 migrating fry or smolts/m^2 based on post restoration values for spawning gravel enhancement projects. Keeley *et al.* (1996) recommend a bio standard of 225 chum fry/m^2 (range 4 – 552 fry/m^2) for estimation of expected chum fry production benefits for off-channel fish habitat rehabilitation. Off-channel habitats can provide highly productive fish habitat, especially for chum and coho salmon, and fry yields would be expected to be higher within these habitats. These bio standards suggest that chum smolt productivity in the South Alouette River (60 smolts/m^2, range 16 – 205 smolts/m^2) is comparable to that expected from successful fish habitat restoration projects, and in some years, approaches the estimated production benefits expected from the creation of highly productive off-channel habitat.

Table 4.1. Cumulative catch (fry) and out-migration estimates for South Alouette River chum and pink fry (1998 – 2011).

Species	Year	Catch	Mean Trap Efficiency(%)	Fry Estimate	95% C.I.	Egg-to-Fry(%)	95% C.I.
Chum Fry	1998	918,376	13.5	8.3×10^6	$7.5 – 9.3 \times 10^6$		8.2 – 17.9**
	1999	1,875,131	16.7	13.4×10^6	$12.0 – 15.2 \times 10^6$	8.7	7.2 – 10.8
	2000	985,672*	16.8	6.8×10^6	$6.2 – 7.6 \times 10^6$	12.1	10.3 – 14.6
	2001	909,102	14.4	6.4×10^6	$5.9 – 7.0 \times 10^6$		
	2002	1,885,532	12.0	14.7×10^6	$13.5 – 16.0 \times 10^6$		
	2003	2,694,767	14.3	24.1×10^6	$22.0 – 26.6 \times 10^6$		
	2004	1,408,019	13.4	12.8×10^6	$11.6 – 14.1 \times 10^6$		
	2005	1,486,963	10.9	16.6×10^6	$15.0 – 18.5 \times 10^6$		
	2006	2,174,360	7.6	30.3×10^6	$26.9 – 34.6 \times 10^6$		
	2007	251,976	10.3	4.3×10^6	$3.6 – 5.4 \times 10^6$		
	2008	1,439,429	10.0	15.6×10^6	$14.1 – 17.4 \times 10^6$		
	2009	2,142,604	8.0	54.3×10^6	$40.4 – 65.6 \times 10^6$		
	2010	1,122,960	12.3	10.1×10^6	$9.1 – 11.3 \times 10^6$		
	2011	557,602	13.0	4.9×10^6	$4.3 – 6.9 \times 10^6$		
Pink Fry	1998	5,716*	11.0	55,000	44,000 – 67,000		
	2000	29,558*	16.5	190,000	160,000 – 230,000		
	2002	15,550	10.7	143,291	112,087 – 189,925		
	2004	119,904	10.8	1.25×10^6	$1.16 – 1.35 \times 10^6$		
	2006	17,742	10.0	175,630	140,585 – 225,922		
	2008	23,290	8.3	279,167	232,435 – 341,800		
	2010	9,433	7.8	118,068	86,238 – 171,944		

Note: * Includes hatchery captures
** Estimate (re-capture objectives not met).

The replication of low fry production following high spawner escapements in 2006 and 2009 (i.e. ALLCO fence count >150,000) indicates that fence counts are a fair indicator of run size in the river as a whole and that egg-to-fry survival is not constant year to year but has hit the point of significant density-dependent mortality. This is expected for pacific salmon species that typically have variable egg-to-fry survival year to year due to density-dependent mortality (i.e. a plateau or decline in recruitment in a compensatory relationship like a Beverton-Holt or Ricker relationship). In this model, the 2006 and 2009 years represent over-escapement and maximum chum fry production would be achieved in the range of 60,000 to 100,000 chum spawners at the ALLCO fence. The ALLCO fence is located approximately 7 km downstream of the Alouette Dam with approximately two thirds the available chum spawning habitat located downstream. This suggests that spawning escapements of 150,000 fish at the ALLCO fence would represent a total escapement of approximately 450,000 fish. Therefore, maximum chum fry production would be achieved in the range of 180,000 to 300,000 spawners.

Koning and Keeley (1997) report density of migrating fry reaches a maximum 500 smolts/m^2 when female spawner densities approach 1 female per m^2. Based on an assumed 1:1 sex ratio and the estimated 265,512 m^2 mainstem river habitat available (BC Hydro 1998), this would suggest South Alouette River spawner escapements beyond approximately 500,000 would not result in any further chum fry or smolt production. Estimated maximum fry production would result from chum salmon spawner densities of between 0.67 spawners/m^2 to 1.13 spawners/m^2.

In previous years, chum salmon spawning escapement for the South Alouette River was not estimated but was back calculated using the mean egg-to-fry survival estimates for the 1999 and 2000 out-migration years, when escapements were estimated. This assumes egg-to-fry survival is constant regardless of the number of spawners and that these survival estimates are still valid for the South Alouette River in 2011. It is unlikely these assumptions are true given the compensatory stock-recruitment relationship emerging for South Alouette River chum salmon. Back-calculation of spawning escapement at very high escapements such as 2006 and 2009 are inaccurate. For example, the maximum likelihood estimate for the 2009 chum salmon spawning escapement was 77,973 fish. The ALLCO fence count was 153,882. While it is unknown what percentage of the total run the ALLCO fence count represents, it is clear the back-calculation estimator is low and inaccurate due to low egg-to-fry survival at high spawner escapements. These results are replicated in the 2006 broodyear data.

4.2. Coho Smolts

In 2008, moving the rotary screw trapping location upstream to the 224th St. location and incorporating flow deflection panels was successful in restoring smolt catch. The 2011 coho smolt catch represented the second highest annual catch to date (1998-2011, Table 4.2). The high 2011 catch was a result of higher trapping efficiency (28.6%) in 2011 (Table 4.2). The higher trap efficiency results were consistent for steelhead, coho and chum out-migrants. The resulting 2011 coho smolt estimate was 19,240 (95% C.I. 18,062 – 20,540).

The mean coho smolt yield (1998-2011) upstream of the RST was 17,075 smolts (range 6,508 – 40,156 smolts) or alternatively, 1,237 smolts/km (range 472 – 2,910) or 6.4 smolts/100m^2 (range 2.4 – 15.1). These estimates are likely conservative as data prior to 2009 are included and the smolt catch at the 216th St. location was confirmed to be biased low due to physical site changes and tidal backwatering (Cope 2007). The 2007 smolt outlier was less than 20% that expected and likely biased due to low recaptures (Table 4.2). Therefore, this estimate was excluded. The 2007 outlier will be re-examined if, in the future, estimates replicate this result.

Bradford *et al.* (1997) predict an average coho smolt yield of 1,664 smolts/km for Pacific Northwest streams of similar latitude to the South Alouette River. The overall mean coho smolt yield of 1,237 smolts/km for the South Alouette River represents 75% of the predicted coho smolts. However, coho smolt productivity in the South Alouette River is likely comparable to the average for streams of this latitude due to the bias noted above within the overall mean productivity estimate. The average smolt yield for the years at the current trapping location (2009-2011), where the effects of tidal backwatering and earlier trapping end date are eliminated, was 1,915 smolts/km.

By comparison, the Coquitlam River produced an average of 1,893 smolts/km during the same time period (Table 4.3, Decker *et al.* 2011). The Alouette and Coquitlam Rivers are nearby rivers within the same regional area that share many similarities (regulated by dams with flow diversions, headed by large reservoirs, comparable in size, gradient, morphology and support similar fish communities). Coho smolt yield between these two watersheds has been strongly correlated (r=0.89, Decker *et al.* 2011). Although coho smolt yields within the South Alouette and Coquitlam Rivers are most likely within the range predicted by the empirical model developed by Bradford *et al.* (1997) they are lower than other regional coho populations (Cheakamus, Seymour) that are also currently being monitored using similar enumeration methodology (Table 4.3.).

Table 4.2. Cumulative catch (smolt) and out-migration estimates for South Alouette River coho smolts (1998 – 2011).

Species	Year	Catch	Mean Trap Efficiency (%)	Population Estimate	95% Confidence Interval
Coho Smolt	1998	358	2.2	16,200	11,100 – 26,000
	1999	1,020	9.2	10,238	8,407 – 13,089
	2000	888*	4.1	20,003	16,125 – 28,543
	2001	1,068	7.7	13,789	11,191 – 17,429
	2002+	1,173	9.6	12,102	9,846 – 15,017
	2003+	2,340	12.1	19,358	17,220 - 21,926
	2004+	3,197	18.9	16,880	15,600 – 18,326
	2005+	1,717++	15.7	13,020	11,575 – 14,758
	2006	1,825++	12.5	14,591	12,837 – 16,737
	2007	159	4.6	3,040	1,796 – 9,901
	2008	1,117	17.6	6,508	5,638 – 7,600
	2009	7,346	19.0	40,156	37,422 – 43,205
	2010	3,503	17.6	19,885	18,186 – 21,743
	2011	5,514	28.6	19,240	18,062 – 20,540

* Includes Hatchery Captures.
** Estimate (re-capture objectives not met).
+ Second Rotary Screw Trap (1.8 m dia.) added.
++Trapping ended approximately 1 week earlier than previous years.

Table 4.3. Summary of estimated coho smolt yields and densities for select watersheds within the southern coastal region of British Columbia.

			Smolt Yield		Smolts/km		Smolts/100 m^2	
River	Year	Km[1]	Mean	Range	Mean	Range	Mean	Range
S. Alouette	1998-2011[2]	13.8	17,075	6,508- 40,156	1,237	472- 2,910	6.4	2.4-15.1
Coquitlam[4]	2000-2010	7.5[3]	14,200	8,400- 24,500	1,893	1,120- 3,267	Main	1.9-9.2
							Off-ch	19.9-44.9
Cheakamus[5]	2001-2010	11.5[6]	73,184	36,209-127,974	6,364	3,149-11,128	n/a	n/a
Seymour[7]	2010	19.3[6]	53,422	40,791- 66,054	2,768	2,114- 3,422	11.9	9.0-14.7

[1] refers to mainstem river km above the enumeration trapping site.
[2] excluding 2007.
[3] includes constructed off-channel habitat representing 10% available habitat producing 33-77% annual smolt yield.
[4] Decker *et al.* 2011.
[5] Melville and McCubbing 2011.
[6] includes extensive rehabilitated and constructed off-channel habitat.
[7] Enumeration data - McCubbing 2010 (*preliminary file data*) and habitat estimates -Jarvis and Gidora 1987.

The differences in coho smolt yield illustrated in Table 4.3 are due to the availability and quality of highly productive off-channel habitat within the respective watersheds. Off-channel habitats can provide highly productive fish habitat for some species of rearing juvenile salmonids, especially for coho and chum salmon (Koning and Keeley 1997). Koning and Keeley (1997) report average coho smolt densities of 67 – 69 smolts/100m^2 for constructed side-channels and ponds in other Pacific Northwest streams. Both the Seymour and Cheakamus Rivers contain extensive constructed and rehabilitated off-channel habitat. Within the Coquitlam River, off-channel coho smolt densities were several times higher than the mainstem portion of the study area, with approximately 10% of the available habitat supporting 33% to 77% of the overwintering coho smolt population (Table 4.3, Decker *et al.* 2011). Minnow trapping catch-per-unit-effort data within the South Alouette River clearly demonstrate the highest densities of over-wintering coho smolts were located in small, low gradient tributaries and rehabilitated off-channel habitat (Cope 2001).

4.3. Steelhead Smolts

In 2008, moving the rotary screw trapping location upstream to the 224th St. location and incorporating flow deflection panels was successful in restoring smolt catch. The 2011 steelhead smolt catch represented the highest annual catch to date (1998-2011, Table 4.4). The 2011 trap efficiency of 18.3% was the highest to date at the new trapping location (2008-2011) but was within the range expected (Table 4.4). The higher trap efficiency results in 2011 were consistent for steelhead, coho and chum out-migrants. The resulting 2011 steelhead smolt estimate was 5,077 (95% C.I. 4,238 – 6,198).

During 2008, 2009 and 2011, steelhead smolt yield upstream of the RST averaged 5,824 smolts (range 5,077 – 6,204 smolts) or alternatively, 422 smolts/km (range 367 – 449) or 2.2 smolts/100m^2 (range 1.9 – 2.3). Data prior to 2008 were not included as the smolt catch at the 216th St trapping location was confirmed to be biased low due to physical site changes and tidal backwatering (Cope 2007). The 2010 steelhead smolt outlier was over double that expected and was most likely biased as a result of the low recaptures in 2010 (Cope 2011). Therefore, this estimate was also excluded as these results were inconsistent with the additional three years trap efficiency at this location and the low trap efficiency for steelhead smolts remains unexplained (Table 4.4). The 2010 outlier will be re-examined if, in the future, estimates replicate this result.

Average South Alouette River steelhead smolt densities (2.2 smolts/100m^2, range 1.9 – 2.3) exceed the provincial steelhead bio standard of 2.0 smolts/100m^2 (Tautz *et al.* 1992). This compares with 2.7 smolts/m^2 produced in the Coquitlam River during the same time period (2000 – 2010, Decker *et al.* 2011). The Alouette and Coquitlam Rivers are nearby rivers within the same regional area that share many similarities (regulated by dams with flow diversions, headed by large reservoirs, comparable in size, gradient, morphology and support similar fish communities). Unlike chum and coho, steelhead smolt abundance was not correlated (r=0.44, Decker *et al.* 2011), however, this is most likely due to the bias identified in the Alouette data prior to 2008. Although steelhead smolt yields meet or exceed the Provincial bio standards, they are lower than other regional steelhead populations that are also currently being monitored using similar enumeration methodology (Table 4.5).

Table 4.4. Cumulative catch (smolt) and out-migration estimates for South Alouette River steelhead and sockeye smolts (1998 – 2011).

Species	Year	Catch	Mean Trap Efficiency(%)	Population Estimate	95% Confidence Interval
Steelhead Smolt	1998	121	0.0		
	1999	585	32.6	1,803	1,565 – 2,125
	2000	625	18.3	3,392	2,837 – 4,131
	2001	231	9.0	2,286**	1,474 – 3,508
	2002+	502	13.1	3,768	2,871 – 5,067
	2003+	698	29.5	2,364	2,058 – 2,745
	2004+	696	20.7	3,355	2,861 – 3,992
	2005+	315++	12.4	2,493	1,844 – 3,567
	2006	114++	12.2	784**	485 – 1,495
	2007	16++	9.0	N/a	
	2008	667	11.1	6,204	4,926 – 8,063
	2009	733	12.0	6,191	4,852 – 8,183
	2010	588	3.7	15,130	9,397 – 24,016
	2011	934	18.3	5,077	4,238 – 6,198
Sockeye Smolts	2005+	1,115	29.9	3,720	3,333 – 4,180
	2006	34	N/a		
	2007	231	N/a		
	2008	999	19.8	5,123	4,290 – 6,231
	2009	114	20.0	498	255 – 1410
	2010	779	9.4	8,143	6,285 – 10,987
	2011	2,040	8.3	23,465	19,263 – 29,236

* Includes Hatchery Captures.
** Estimate (re-capture objectives not met).
+ Second Rotary Screw Trap (1.8 m dia.) added.
++Trapping ended approximately 1 week earlier than previous years.

Table 4.5. Summary of estimated steelhead smolt yields and densities for select watersheds within the southern coastal region of British Columbia.

River	Year	Km[5]	Smolt Yield Mean	Smolt Yield Range	Smolts/km Mean	Smolts/km Range	Smolts/100 m^2 Mean	Smolts/100 m^2 Range
S. Alouette	2008-2011	13.8	5,824	5,077-6,204	422	367-449	2.2	1.9-2.3
Coquitlam[1]	2000-2010	7.5	4,100	2,300-5,600	547	307-747	2.7	1.7-3.7
Keogh[2]	1976-1982	25.0	7,500	5,725-10,750	300	229-430	2.7	2.1-3.9
Cheakamus[3]	2010	11.5	6,959	2,837-10,657	605	247-927	n/a	n/a
Seymour[4]	2010	19.3	17,314	10,000-30,000	897	518-1,554	3.8	2.2-6.7

1 Decker *et al.* 2011
2 Ward and Slaney 1993
3 Melville and McCubbing 2011
4 Enumeration data - McCubbing 2010 (*preliminary file data*) and habitat estimates -Jarvis and Gidora 1987.
5 refers to mainstem river km above the enumeration trapping site.

4.4. Sockeye Salmon

The 2011 sockeye smolt out-migration estimate was 23,465 (95% C.I. 19,263 – 29,236). This represents 75.9% of the upstream estimate at Mud Creek (30,899 smolts). The distance between traps is approximately 13.0 km and some enroute mortality would be expected between exiting the reservoir and reaching tidewater. The primary cause of downstream mortality is predation (mergansers, ducks, herons, osprey, fish, mink and otters).

Assuming the difference in estimates between traps is an accurate representation of enroute mortality, the average sockeye smolt enroute mortality has been 47.6% (range 24.1 - 88.4%). Downstream (within river) smolt migration mortality for acoustic tagged pacific salmon smolts in Southern British Columbia was reported to be 42% and likely biased low due to tagging the upper size distribution to meet minimum body size guidelines (Melnychuk 2009). Therefore, these estimates are consistent with expectations.

It is clear from the time difference of only a day or two in out-migration peaks or pulses between the two trapping locations that sockeye smolts, following their emigration from Alouette Lake, continue their migration out of the Alouette system without delay. Furthermore, the annual 6 m^3/s flushing flow dam releases (2009-2011) did not “flush out” reluctant sockeye migrants residing within the South Alouette River.

4.5. Physical Conditions

The mean 2011 water temperature during the peak period of fry and smolt out-migration (7.70 ^{o}C) represents the lowest out-migration temperature observed over the last 14 years on record. However, this was only 1.1 ^{o}C lower than the overall mean out-migration temperature for the period of study and out-migration timing was within the range observed during previous years.

Mean daily discharge for the peak period of fry and smolt out-migration (25 February to 9 June) at the 232nd Street Water Survey of Canada Station (WSC No. 08MH005) was 6.28 m^3/s. Excluding the 2007 anomaly due to flood control releases, this was the highest mean discharge for the period of record. The 11-year average mean daily discharge during the peak period of fry and smolt out-migration was 4.3 m^3/s (excluding 2004, 2005, 2007). The difference of only 46% (2.0 m^3/s) between the 11 year mean daily flow and the highest annual flow illustrates the stable hydrograph resulting from upstream flow control.

The moderately higher flows in 2011 were the most likely mechanism for the higher trap efficiencies in 2011. The slight increase (2.0 m^3/s) resulted in improved trap RPM's and catch. Although the higher flows result in a trade-off between higher trap efficiency and more lost days trapping (Table 3.2), flows were generally manageable and the total days with no trapping data (n=4) were well within the range considered acceptable.

Preliminary examination of independent environmental variables of water temperature, water discharge and substrate quality illustrate little evidence of effects on chum fry or coho smolt production among years for which data is available. This is in part due to the low variability in these data, the high variability in out-migrant estimates, and the small sample size (see Appendix A).

4.6. Summary

Increased flow releases, stocking, and rehabilitation efforts within the South Alouette River have resulted in the following salmon restoration milestones:

- Prior to 1975, the South Alouette River stock of chum salmon was reduced to average run sizes less than 3,000 spawners (Range 200 to 7,500; Elson 1985). Substantial increases were first noted in the early 1980's, partly due to the returns from the FRCC-ARMS Hatchery. This stock has continued rebuilding to spawning escapements well in excess of 200,000 fish. Egg-to-fry survival now appears to be variable indicating the S. Alouette River has hit the point of significant density-dependent mortality during high escapement years.
- Prior to 1985, the South Alouette River stock of pink salmon was considered extinct. This stock had been re-building to run sizes that range between 4,500 to 20,000 spawners.
- Chinook salmon have re-colonized the South Alouette River and a small but stable trend of successful spawning, incubation and out-migration of smolts has been documented. Chinook spawning escapement likely exceeded 1,000 fish in 2010.
- Annual coho smolt production estimates are in the 19,000 smolt range. The 2011 coho smolt estimate of 19,240 met expectations. The 14-year average coho smolt yield was 17,075 smolts or between 1,237 – 1,915 smolts/km or 6.4 smolts/100m^2, which is comparable to the average yield predicted for streams of similar latitude.
- Annual steelhead smolt production estimates are in the 5,500 smolt range. The 2011 steelhead smolt estimate of 5,077 met expectations. The current average steelhead smolt yield was 5,824 smolts or alternatively, 422 smolts/km or 2.2 smolts/100m^2. Although steelhead smolt yields meet or exceed the Provincial bio standards, they are lower than other regional steelhead populations that are also currently being monitored using similar enumeration methodology.
- The 2011 sockeye smolt out-migration estimate was 23,465 and the average within river enroute mortality was estimated to be 47.6%. Since 2007 returning sockeye salmon (e.g. mature pre-spawners) have been documented at the base of the Alouette Dam and at the FRCC-ARMS Hatchery fence. DNA testing has confirmed these sockeye are from Alouette Lake smolt out-migrants.

5. Recommendations

- Moving the rotary screw trapping location upstream to the 224th St. location and incorporating flow deflection panels has been successful in restoring smolt catch success. Results since 2008 clearly demonstrate the declines in coho and steelhead smolt out-migration in 2006 and 2007, and perhaps, the more subtle apparent declines since 2003, were not accurate but an artifact of trapping bias due to the increasing effect of tidal backwatering from the Pitt River at the 216th St. location. Continued trapping at the current location is recommended to document inter-annual variability in smolt yields. Vandalism at the 224th St. location is a concern but is mitigated by frequent daily site visits to maintain a presence, particularly in the evenings.
- Incorporation of flow deflection panels in trapping methods should be continued in future years. Fence panels should be maintained from 15 April to 15 June. Fence panels and trap position should be managed to maintain a drum velocity of between 5 and 7 RPM. This range provides the optimum trap efficiency while minimizing potential mortalities due to live box turbulence. In addition these RPM help ensure worker safety (i.e. potential pinch points and minimizing excessive force) while also minimizing potential entrapment risk to the recreating public. Vandalism at the 224th St. location is a concern but is mitigated by frequent daily site visits to maintain a presence, particularly in the evenings.
- Extension of the trapping operations to June 15 should be continued to ensure capture of the declining limb of the out-migration curve for coho and steelhead smolts. During the June dates, or sooner if weather warrants, the trap should be disabled during daylight hours to ensure public safety. Daylight captures of steelhead and/or coho smolts during hot, sunny weather (i.e. low turbidity) when the public is using the river in large numbers has been a rare occurrence.
- Annual spawner enumeration at the FRCC-ARMS fish fence should be continued as a relative indicator of spawner escapement, particularly for chum salmon.

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Appendix A - Smolt Abundance and Potential Physical Correlates Database

Table A1. Chum fry annual abundance estimates and possible physical correlates (data sources: ALLCO fence count from FRCC-ARMS hatchery, Discharge from Water Survey Canada, water temperature from BC Hydro and substrate from Ross Davies).

CHUM SALMON S. ALOUETTE RIVER													
						WSC 08MH005	WSC 08MH005	224th ST.	224th St.				
						Mean	Mean	Mean	Mean	Surficial Substrate Particle Distribution			
	Chum				ALLCO	Discharge	Annual	Water Temp.	Annual	Average	Average	Average	Average
	Fry	Low	High		Fence	(CMS)	Discharge	(deg. C.)	Water Temp.	of %	of %	of %	of %
Year	Estimate	95% C.I.	95% C.I.	Broodyear	Count	(25 Feb - 9 June)	(CMS)	(18 Mar-31 May)	(deg. C.)	< 2 mm	< 4 mm	< 8 mm	< 16 mm
1998	8,300,000	7,500,000	9,300,000	1997		3.81	4.67	9.7	++	0.36	0.42	0.48	0.58
1999	13,400,000	12,000,000	15,200,000	1998		3.99	4.79	8.1	++	0.7	0.76	0.81	0.83
2000	6,800,000	6,200,000	7,600,000	1999		4.02	3.8	8.4	++				
2001	6,400,000	5,900,000	7,000,000	2000		3.73	3.6	8.4	++				
2002	14,700,000	13,500,000	16,000,000	2001	*	3.79	4.28	8.1	9.82				
2003	24,100,000	22,000,000	26,600,000	2002	*	4.47	4.16	9.3	10.82	0.46	0.5	0.55	0.59
2004	12,800,000	11,600,000	14,100,000	2003**	10,727	+	4.22	10.4	11.07	0.13	0.19	0.21	0.29
2005	16,600,000	15,000,000	18,500,000	2004	*	+	4.73	10.2	10.54	0.22	0.3	0.32	0.33
2006	30,300,000	26,900,000	34,600,000	2005	76,191	3.73	3.96	9.4	++				
2007	4,300,000	3,600,000	5,400,000	2006	150,734	14.02	7.05	9.4	++				
2008	15,600,000	14,100,000	17,400,000	2007	16,502	4.69	4.3	7.9	++	0.27	0.28	0.33	0.39
2009	54,300,000	40,400,000	65,600,000	2008	71,980	4.39	4.8	8.3	9.99	0.23	0.29	0.38	0.49
2010	10,100,000	9,100,000	11,300,000	2009	153,882	4.56	4.64	8.9	10.34	0.22	0.3	0.44	0.49
2011	4,900,000	4,300,000	6,900,000	2010	41,312	6.28	n/a	7.7	9.15	0.26	0.37	0.38	0.44

n/a data not available at time of reporting
* data lost on computer due to virus
** fence down 10 days in 2003
+ Hydrometric station not operating
++ Missing data

Table A2. Coho smolt annual abundance estimates and possible physical correlates (data sources: ALLCO fence count from FRCC-ARMS hatchery, Discharge from Water Survey Canada, water temperature from BC Hydro and substrate from Ross Davies).

Alouette River Coho Smolts													
						WSC 08MH0	SC 08MH0	224th ST.	224th St.				
						Mean	Mean	Mean	Mean	Surficial Substrate Particle Distribution			
					ALLCO	Discharge	Annual	Water Temp.	Annual	Average	Average	Average	Average
					Fence	(CMS)	Discharge	(deg. C.)	Vater Temp	of %	of %	of %	of %
Year	pooled POP est	"+"	"-"	Broodyear	Count	Feb - 9 Ju	(CMS)	8 Mar-31 Ma	(deg. C.)	< 2 mm	< 4 mm	< 8 mm	< 16 mm
1998	16200	9800	5100			3.81	4.67	9.7	++	0.36	0.42	0.48	0.58
1999	10238	2851	1831			3.99	4.79	8.1	++	0.7	0.76	0.81	0.83
2000	27311	9783	6337			4.02	3.8	8.4	++				
2001	13789	3640	2598			3.73	3.6	8.4	++				
2002	12102	2915	2256			3.79	4.28	8.1	9.82				
2003	19358	2568	2138			4.47	4.16	9.3	10.82	0.46	0.5	0.55	0.59
2004	16880	1446	1280			+	4.22	10.4	11.07	0.13	0.19	0.21	0.29
2005	13020	1738	1445			+	4.73	10.2	10.54	0.22	0.3	0.32	0.33
2006	14591	2146	1754	2005	451	3.73	3.96	9.4	++				
2007	3040	6861	1244	2006	146	14.02	7.05	9.4	++				
2008	6508	1092	870	2007	298	4.69	4.3	7.9	++	0.27	0.28	0.33	0.39
2009	40156	2734	3049	2008	273	4.39	4.8	8.3	9.99	0.23	0.29	0.38	0.49
2010	19,885	1858	1699	2009	79	4.56	4.64	8.9	10.34	0.22	0.3	0.44	0.49
2011	19,240	1300	1178	2010	339	6.28	n/a	7.7	9.15	0.26	0.37	0.38	0.44