Alouette Dam Water Use Plan

Alouette River Smolt Enumeration

Implementation Year 7

Reference: ALUMON-1

Alouette River Salmonid Smolt Migration Enumeration: 2014 Data Report

Study Period: March to June 2014

Westslope Fisheries Ltd.
800 Summit Drive
Cranbrook, B.C.
V1C 5J5

Project lead and report author:
Scott Cope, M.Sc., R.P.Bio.
Westslope Fisheries Ltd.

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Executive Summary

The South Alouette River salmonid smolt enumeration program was an outcome of both the 1996 and the subsequent 2006 BC Hydro Water Use Planning (WUP) process and was a water licence ordered monitoring program of the Alouette Dam WUP. This report presents the results of the seventeenth year of the salmonid smolt and fry out-migration enumeration program (1998-2014).

In total, 537,112 wild reared fish were captured during sampling in the mainstem South Alouette River from 3 March to 13 June 2014. The annual catch (1998 – 2014) has ranged from 253,761 (2007) to 2,702,981 (2003).

The 2014 chum fry out-migrant estimate was 5.46 million (95% C.I. 4.89 to 6.20 million). While there has been no significant increase in chum fry production over the duration of the study (regression; p=0.92, r=0.03, n=17), chum fry production has averaged 1,058,440 smolts/km (range 311,594 to 3,934,782 smolts/km) or 55.0 smolts/m^2 (range 16 to 205 smolts/m^2). These chum-fry yields are comparable to that expected from successful fish habitat restoration projects, and in some years, approaches the estimated production benefits expected from highly productive off-channel habitat.

Based on the increasing trend in chinook salmon out-migrants during the past five years, chinook salmon appear to be responding to stocking efforts (regression; p=0.07, r=0.46, n=17). The 2014 chinook fry out-migration was estimated to be 5,319 smolts (95% CI 4,343 – 6,672). Chinook fry out-migration has ranged between 5,000 and 30,000 smolts over the last three years. These estimates were likely biased low due to the end of trapping operations before the completion of chinook out-migration. Reliable population estimates would require continued trapping to at least the end of June.

The 2014 coho smolt out-migration estimate was 22,632 fish (95% C.I. 20,354 to 25,321). Since 2009, the annual coho smolt estimate has averaged 28,605 fish compared to 15,000 fish previously (1998 – 2008). Based on the last six years (2009-2014), the average coho smolt yield was 2,072 smolts/mainstem km (range 1,394 to 2,910) or 10.8 smolts/100m^2 (range 7.2 to 15.1); which was higher than the average yield predicted for Pacific Northwest streams of similar latitude (1,664 smolts/km).

The 2014 steelhead smolt out-migration estimate was 4,610 smolts (95% C.I. 3,422 to 6,204). Since 2008, the annual steelhead smolt estimate has averaged 5,630 fish (range 4,610 to 6,204; excluding 2010 anomaly) compared to 2,531 fish (range 784 to 3,768) previously (1999 – 2007).

Since 2008, the average steelhead smolt yield was 408 smolts/km (range 334 – 450) or 2.1 smolts/100m^2 (range 1.7 – 2.3). 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 2014 sockeye smolt out-migration estimate for the 224th St. Bridge site was 2,358 smolts (range 2,597 to 11,818). A 2014 sockeye smolt estimate of 13,413 out-migrants (95% C.I. 12,423 to 14,404) was provided for the Mud Creek site upstream. The mean annual estimated mortality for sockeye smolts migrating the approximately 14 km from the Mud Creek rotary screw trap to the 224th St. rotary screw trap (approximately from the dam to tidewater) has ranged from 24 to 88% (Mean = 53.8%, n=8); assuming the difference in estimates between traps was an accurate representation of enroute mortality. 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. Therefore, these estimates were consistent with expectations.

It was 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, annual flushing flow dam releases (2009-2011, 2014) of 5 or 6 m^3/s did not “flush out” reluctant sockeye migrants residing within the South Alouette River. Therefore, it appears typical mean daily flows of between 3.0 to 6.0 m^3/s were adequate to ensure movement of Alouette Lake sockeye smolts out of the system without delay.

Moving the rotary screw trapping location upstream to the 224th St. location (2008), incorporating flow deflection panels (2008), and extending trapping duration by 2 weeks to June 14 (2009) was 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. This was due to the increasing effect of tidal backwatering from the Pitt River at the 216th St. location.

Results to date are summarized below within the context of the three management questions identified by the Alouette Management Committee that were to be addressed through the smolt enumeration program:

1. Is the average base-flow release of 2.6 m^3/s from the Alouette Dam (obtained by fully opening the low level outlet) adequate to sustain or improve current levels of salmonid smolt production downstream of the dam? The species of interest include chum, pink, chinook, and coho salmon as well as steelhead and cutthroat trout.

The null hypothesis (Ho1) was accepted for chum, pink, coho and steelhead salmon as annual estimates of smolt abundance for these species has remained stable through time as indicated by a lack of a significant correlation between the two variables. In addition, bio-standards suggest that chum smolt (under-yearling fry) productivity in the South Alouette River was comparable to that expected from successful fish habitat restoration projects, and in some years, approaches the estimated production benefits expected from highly productive off-channel habitat. Coho smolt yields were within the range expected for Pacific Northwest streams of similar latitude to the South Alouette River and steelhead smolt yields meet or exceed the Provincial bio-standards. Chinook salmon and cutthroat trout were inconclusive given the low capture rates; however, increasing catch rates for wild-reared chinook salmon under-yearling smolts suggest this species is responding to stocking efforts.

Sub-hypotheses were examined for possible correlations with independent variables representing river discharge, water temperature, substrate quality and relative run strength. Relative run strength (density-dependent mortality) illustrated a strong effect on fry or under-yearling chum smolt production. This was expected and suggests that in some years the South Alouette River chum salmon spawning escapement meets or exceeds capacity. The remaining environmental variables examined illustrated little effect on chum fry production. This was due in large part to the high variability in smolt or under-yearling fry production and the low variability in the associated environmental data.

2. Following their migration out of Alouette Lake, do the kokanee smolts immediately continue their migration out of the Alouette River or do they delay their seaward migration for a period of time?

The null hypothesis (Ho3) was accepted based on the catch data for the Mud Creek and 224th St. traps that illustrate a delay of only a day or two (*i.e.,* Ho3; the time difference in peak out-migration between the Mud Creek trap and the 224th St Bridge is less than a few weeks).

3. Using chum salmon counts at the ALLCO Park Hatchery as an indicator of run strength and the results of the substrate quality monitor, is there evidence of a persistent, declining trend in egg to smolt (fry or under-yearling smolt) survival that would suggest a degrading condition in spawning substrate quality.

There has been no evidence of a persistent, declining trend in egg to smolt (fry or under-yearling smolt) survival that would suggest a degrading condition in spawning substrate quality. On the contrary, there is evidence that chum salmon escapements are at or exceed capacity in some years resulting in variable egg-to-fry survival year to year due to density-dependent mortality.

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 (ARMS), and one public representative.

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1. Introduction

The South Alouette River salmonid smolt enumeration program was an outcome of both the 1996 and the subsequent 2006 BC Hydro Water Use Planning (WUP) process and was 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 was 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. Since 1998, smolt out-migration from the South Alouette River has been monitored to track changes in the river's smolt carrying capacity following implementation of a new base flow regime from Alouette Dam in 1996. This report presents results from the 17th consecutive year (1998-2014) 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, and
- 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. Management Questions

The Fish Technical Committee (FTC) of the AMC identified three management questions that were to be addressed through the smolt enumeration program (BC Hydro 2010):

1. Is the average base-flow release of 2.6 m^3/s from the Alouette Dam (obtained by fully opening the low level outlet) adequate to sustain or improve current levels of salmonid

smolt production downstream of the dam? The species of interest include chum, pink, Chinook, and coho salmon as well as steelhead and cutthroat trout.

2. Following their migration out of Alouette Lake, do the kokanee (sockeye) smolts immediately continue their migration out of the Alouette River or do they delay their seaward migration for a period of time?
3. Using chum salmon counts at the ALLCO Park Hatchery as an indicator of run strength and the results of the substrate quality monitor, is there evidence of a persistent, declining trend in egg to smolt (fry or under-yearling smolt) survival that would suggest a degrading condition in spawning substrate quality.

The management questions above were to be addressed through tests of a series of hypotheses for each species (BC Hydro 2010). These hypotheses and summary of conclusions are presented in results (Section 3.11 Hypothesis Testing) and summary and Conclusions.

1.3. 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 (1998-2013). 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 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 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

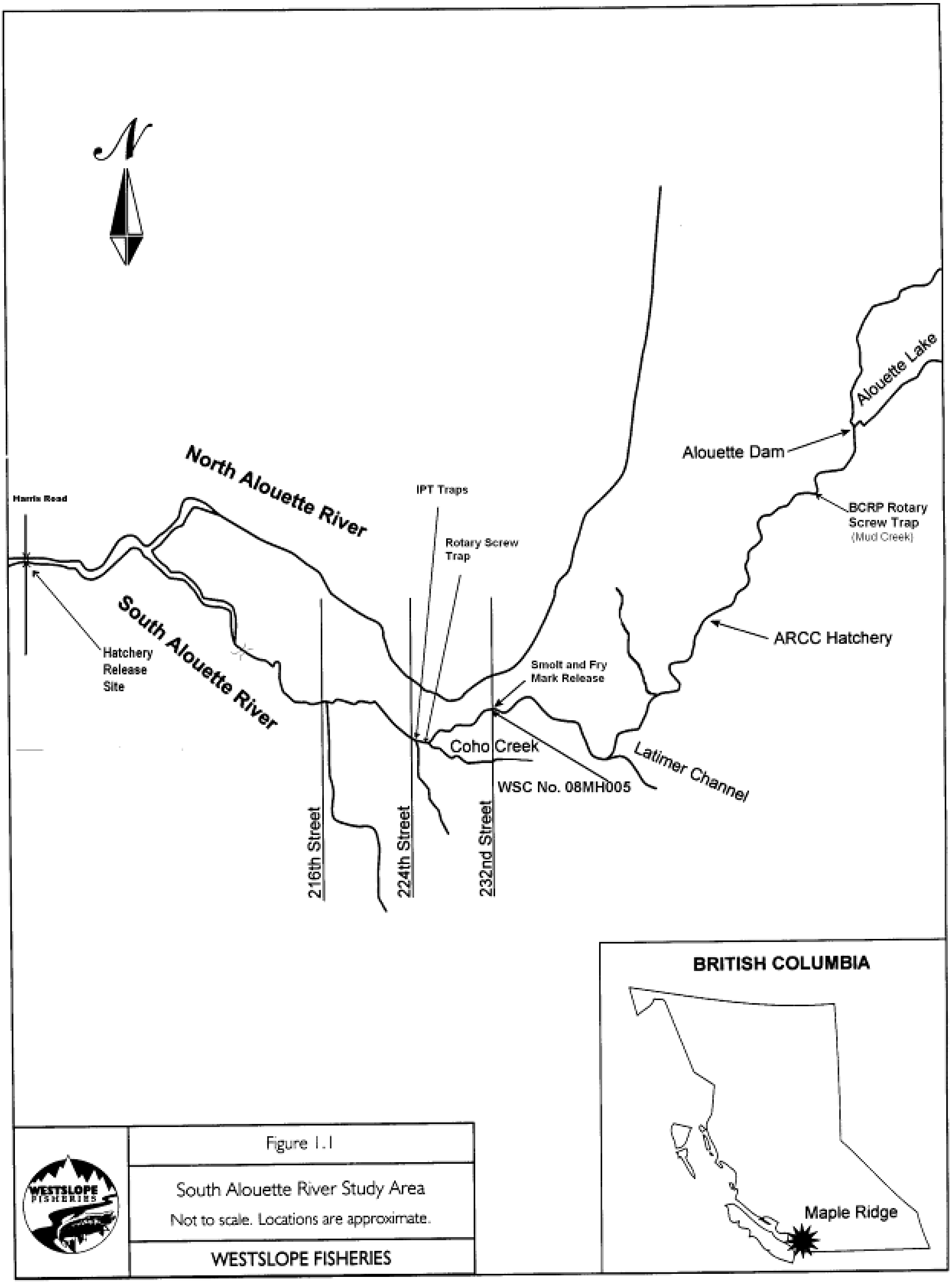

Figure 1.1. South Alouette River Study Area.

has also been very limited numbers of chum, chinook and coho fry released by school children as part of the ARMS-FRCC Hatchery Community Education and Stewardship Program.

1.4. Background

The South Alouette River historically supported all five species of salmon plus populations of sea-run cutthroat trout, steelhead, dolly varden (sea run bull trout) 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 1924-1926 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 Community Hatchery annually stocks chinook fry as well as coho fry and smolts and steelhead smolts and cutthroat trout (*see* Section 2.6 Hatchery Stocking Program).

The North Alouette, a tributary of the Alouette is also stocked with chum fry from the ALLCO ARMS Community Hatchery.

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 and smolts 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 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 were 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 13 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.

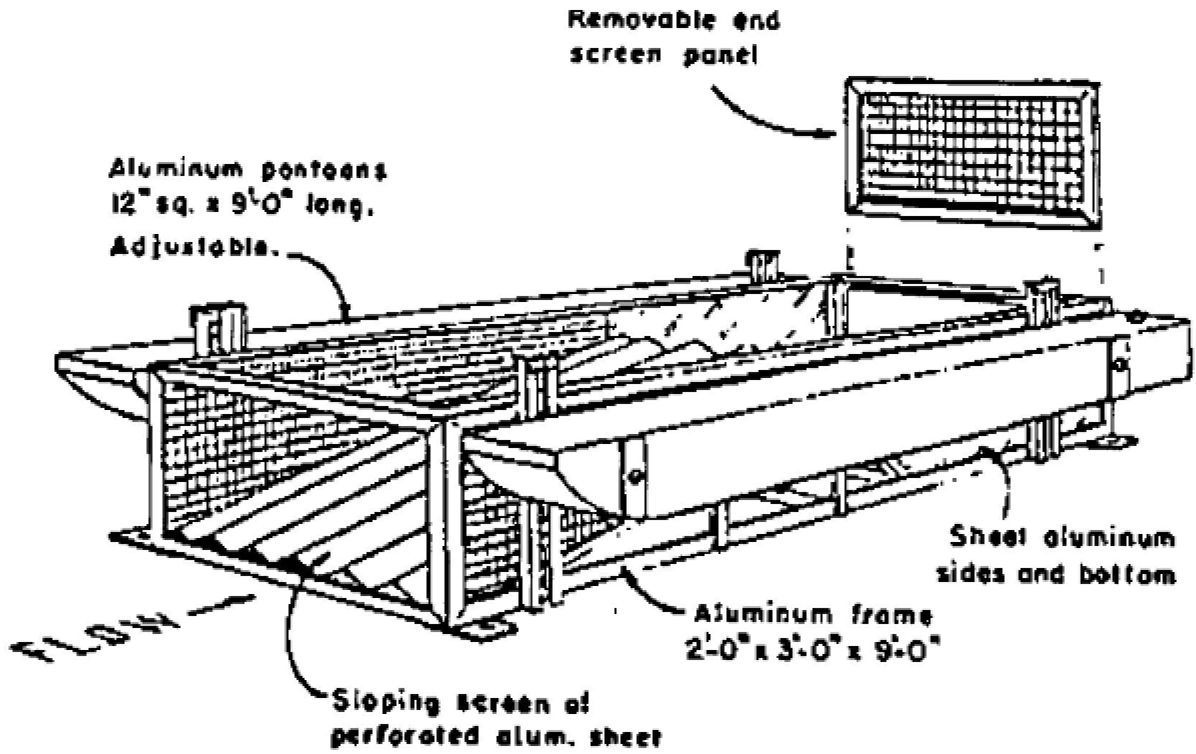

Figure 2.1. Diagram of floating incline-plane trap used to capture migrating fry (IPSFC drawing no. 53-55).

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.

Figure 2.4. Typical 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 were monitored, cleaned and/or adjusted. Frequency of trap maintenance was 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 was made to keep fishing conditions as consistent as possible. However, slight alterations to the traps on a daily basis were typical to adjust to the variable flow levels. The objective was 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 were made to the trap pontoons rather than the position of the trap.

If site conditions (*i.e.,* flow and/or debris conditions) were assessed as compromising worker safety or fish survival (*e.g.,* 224th St. staff gauge > 0.8 m and debris accumulating in traps, or jamming drum considered imminent) then the traps were disabled and trapping operations suspended until debris risk was reduced. Disabling traps and safely securing them to shore when debris risk was high was an effective strategy to prevent fish mortalities and protect worker safety. Non-fishing days were estimated as the average of the two adjacent days. In light of the detailed knowledge gained over the past 17 years in regard to the relationship between river discharge (*i.e.,* stage), debris load, trapping mortality and worker safety, trapping protocols were modified to include the suspension of trapping efforts at times when increases in river discharge and debris load approached known limits and logistical capabilities. Typically, suspension of operations need only occur for a matter of hours before the river stabilized and debris loads decreased to manageable levels. An RV trailer was 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 were 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 were exceeded a portion of the catch was 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^+ or under yearling fish recently emerged from the gravel (typically < 80 mm fork length). Smolts were defined as juveniles that had over-wintered for at least one season within their natal streams (typically >80 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 St. 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 St. 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 were 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 was 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 were recaptured over a period of approximately five 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 smolts were measured and the remainder were inspected for marks and released, 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 St. 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 St. 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 St. Bridge (WSC 08MH005).

2.6. Hatchery Stocking Program

The FRCC-ARMS Community 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 year 2000 out-migration.

After 2000, the FRCC-ARMS hatchery and MOE transports and releases all fish downstream of the traps within the vicinity of the Harris Road Bridge (Figure 1.1). The only exceptions were the very 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, hatchery reared chinook fry (50,000 – 349,800) were released upstream at ALLCO Park between April and June (G. Clayton, ARMS, Maple Ridge, B.C., *pers. comm*.). In 2012, 2013 and 2014 chinook fry were held until the completion of the downstream enumeration program (or nearly so), facilitating the estimation of wild chinook out-migrant smolt estimates for these years. 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, 1998-2014. 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
Chum Fry	1,200,00	1,676,075	661,126	884,593	134,979	-	-	-	-
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
Coho Fry	-	-	149,000	89,080	83,000	85,000	70,000	60,989	150,949
Coho Smolts	90,000	20,120	7,961	71,925	35,717	103,324	28,195	64,340	60,595
Steelhead Smolts	13,506	4,543	25,447	23,734	25,781	24,123	23,273	24,091	25,529
Cutthroat Trout	15,320	30,509	18,404	22,520	15,021	13,871	7,878	23,230	10,870

Species	2007	2008	2009	2010	2011	2012	2013	2014
Chum Fry	-	-	-	-	3,200	-	-	461,304*
Pink Fry	-	-	-	-	-	-	-	-
Chinook Fry	325,336	406,000	349,800	329,500	127,150	49,805	77,900	25,035
Coho Fry	-	115,159	108,491	-	76,400	81,500	33,598	36,412
Coho Smolts	73,201	17,238	79,412	35,148	25,111	24,007	22,998	22,275
Steelhead Smolts	17,780	26,390	21,004	24,652	31,141	25,354	19,203	28,967
Cutthroat Trout	344	6,788	1,800	4,856	8,761	8,520	-	1,370

*Chum fry are also released to the North Alouette

3. Results

In total, 203 trap days of effort were expended from 3 March to 13 June 2014. During the 103 consecutive days of trapping a total of 25 trap-days of effort were lost resulting in eight days (7.8%) 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 7 May 2014. The 1.8 m dia. rotary screw trap operated from 7 March to 13 June 2014.

Date Traps Not Operating	IPT #1	Trap IPT #2	1.8 m Rotary	Comment
7-March	X	X		Flood Flows and Debris[2]
9-March	X	X	X	Flood Flows and Debris[2]
10-March	X	X	X	Flood Flows and Debris[2]
16-March	X	X	X	Flood Flows and Debris[2]
17-March	X	X		Flood Flows and Debris[2]
17-Apr	X	X	X	Flood Flows and Debris[1]
18-Apr	X	X	X	Flood Flows and Debris[2]
19-Apr			X	Flood Flows and Debris[1]
30-Apr			X	Flood Flows and Debris[1]
5-May	X	X	X	Flood Flows and Debris[2]
29-May			X	Flood Flows and Debris[1]
Total Days Lost	8	8	9	
Total Effort (trap days)	57	57	89	Grand Total = 203 trap days

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

[2] – Rising river stage and debris load approaching limits of safe operating range and trap inundation considered imminent. Traps disabled to prevent fish mortalities and protect worker safety.

On those days where either the IPT's or RST's were not operating, the daily out-migration was estimated from the remaining traps. The catch for the eight days when no traps were operating was estimated as the average of the two adjacent days. During the late season period (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. Given the documented low proportion of the smolt catch during daylight (<1.0%) , the catch for these 24-hour periods was considered representative. Total trapping effort was consistent with the range of effort for previous years (Table 3.2). The 2007

Table 3.2. Time period (*i.e.,* consecutive days), lost trap-days, and total effort (trap-days) during the South Alouette Downstream Enumeration Program (1998-2014).

	1998	1999	2000	2001	2002	2003	2004	2005	2006
Start Date	5 Mar	27 Feb	25 Feb	27 Feb	26 Feb	27 Feb	25 Feb	2 Mar	27 Feb
Finish Date	8 Jun	28 May	2 Jun	2 Jun	27 May	2 Jun	2 Jun	25 May	25 May
No. Trap-Days lost	36	9	5	6	12	6	12	8	3
Total Effort (Trap-Days)	186	225	230	222	226	232	224	198	208
Consecutive Days Reported	89	91	97	96	89	96	96	72	87

	2007	2008	2009	2010	2011	2012	2013	2014
Start Date	27 Feb	27 Feb	27 Feb	1 Mar	3 Mar	1 Mar	28 Feb	3 Mar
Finish Date	24 May	5 Jun	14 Jun	14 Jun	14 Jun	14 Jun	14 Jun	13 Jun
No. Trap-Days lost	48	3	5	12	23	17	13	25
Total Effort (Trap-Days)	206	227	233	234	230	223	219	203
Consecutive Days Reported	26	99	107	106	104	105	106	103

year was the one exception where complete trapping was not possible due to the extreme flood event and flow releases from the dam.

3.1. Species Composition

Over the course of the salmonid smolt trapping program (1998-2014), 28 fish species have been confirmed; 19 species were captured in the 2014 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 extirpated in 1985. Since 1998, out-migrant fry or smolts of all three species have been captured and confirmed. Returning chinook, pink and sockeye salmon (*i.e.,* mature spawners) have been confirmed at the FRCC-ARMS hatchery broodstock fence (Table 3.4).

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. An increasing number of naturally spawned chinook fry are confirmed every year. Since 2005, 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 (ARMS 2007). Smolts are annually captured 1.5 kms below the dam in a rotary screw trap exiting the Alouette Reservoir as part of field trials to assess smolt migration success (Mathews *et al.* 2015).

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 (St. Amant and Hoover 1969). More recently, they have been reported as far north as Puget Sound and Snohomish County Washington (Tabor *et al.* 2001). In 2008 through 2014 a total of 99 oriental weatherfish have been captured. Annual captures have ranged from two to 24 oriental weatherfish. Captures have ranged between 101 mm to 205 mm and there were 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 2014, a total of 27 pumpkinseed sunfish were captured. Although this was 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.

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	2012	2013	2014
Chinook Salmon	*Oncorhynchus tshawytscha*	X*	X	X	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	X	X	X
Pink Salmon	*O. gorbuscha*	<u>X</u>	X		X		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	X	X	X
Sockeye Salmon	*O. nerka*	X*					X			X	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	X	X	X
Rainbow Trout	*O. mykiss*	X			X**					X+							X	X	
Cutthroat Trout	*O. clarki clarki*	X	X	X	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	X	X	X
Stickleback	*Gasterosteus sp.*	X	X	X	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	X	X	X
Lamprey	*Lampetra sp.*	X	X	X	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	X	X	X
Peamouth Chub	*Mylocheilus caurinus*	X		X	X	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						X	X
Longnose Sucker	*Catostomus catostomus*	X								X	X		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	X	X	X
Redside Shiner	*Richardsonius balteatus*	X	X	X	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	X	X	X
Oriental Weatherfish	*Misgunus anguillicaudata*												X	X	X	X	X	X	X
Brown Catfish	*Ameiurus nebulosus*	X		X			X											X	
Brassy Minnow	*Hybognathus hankinsoni*	X			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.

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	25,042	141	1,393	628	11
2012	129,554	350	n/a	52	42
2013	24,397	62	2,471	1,919	9[c]
2014	15,435	45	n/a	235	0

[a] Fence down 10 days.
[b] Fence down approximately 14 days.
[c] Some passed through fence and recovered at upstream dam trap.

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 was supported by anecdotal reports of local residents dip-netting for eulachon in the lower South Alouette River in the 1940's.

The 2014 catch and relative contribution of each fish species to the total catch are presented in Table 3.5. In total, 537,112 wild reared fish were captured. Previously (1998 – 2013), the total catch ranged from 253,761 (2007) to 2,702,981 (2003).

Moving the rotary screw trap upstream to the 224th St. site, combined with the use of flow deflection "panels" and extending the trapping period to mid-June has provided the desired increase in trap efficiency for smolts (Table 3.5). Longnose dace, lamprey *spp.* And sculpin *spp.,* dominate the non-sportfish catch.

Table 3.5. Catch composition (excluding recaptures and hatchery reared fry and smolts) of the 2014 South Alouette River downstream trapping program.

	Combined Totals	
Common Name	Catch	% Composition
Salmoniformes – Fry		
Chum	483,187	90.0
Pink	47,289	8.8
Coho	717	0.1
Chinook	1,639	0.3
Total	532,832	99.2
Salmoniformes – Smolts		
Coho	3,345	0.6
Sockeye[a]	181	<0.1
Steelhead	470	0.1
Cutthroat Trout	92	<0.1
Total	4,088	0.7
Incidental Catch		
Lamprey	41	<0.1
Longnose Sucker	4	<0.1
Longnose Dace	90	<0.1
Mountain Whitefish	2	<0.1
Northern Pikeminnow	2	<0.1
Oriental Weatherfish	15	<0.1
Peamouth Chub	1	<0.1
Pumpkinseed	5	<0.1
Redside Shiner	10	<0.1
Sculpin spp.	20	<0.1
Stickleback spp.	2	<0.1
Total	192	0.1
Grand Total	537,112	100

a – prior to 2007 referred to as kokanee. DNA testing confirmed as sockeye.

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 trap was more effective at capturing juveniles in excess of 60 mm and was 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.

3.1.1. Species at Risk

To date, capture of the SARA listed Salish sucker and Nooksack dace has not occurred. This assessment was based on visual examination only. Since 2009, 164 longnose suckers and 963 longnose dace were captured however; there has been some misidentification of longnose dace as longnose suckers. There was zero reported mortality for these species so any incidental misidentification of Salish sucker or Nooksack dace as longnose suckers or longnose dace 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 March, peak migration during April, and the end of migration in early May (Figure 3.1). In 2014, the dates of 10%, 50% and 90% migration were 31 March, 13 April, and 25 April, respectively. This represents typical chum fry out-migration timing; the median date of 90% out-migration for the period 1998 to 2014 was 23 April (range 17 Apr – 10 May, n=17).

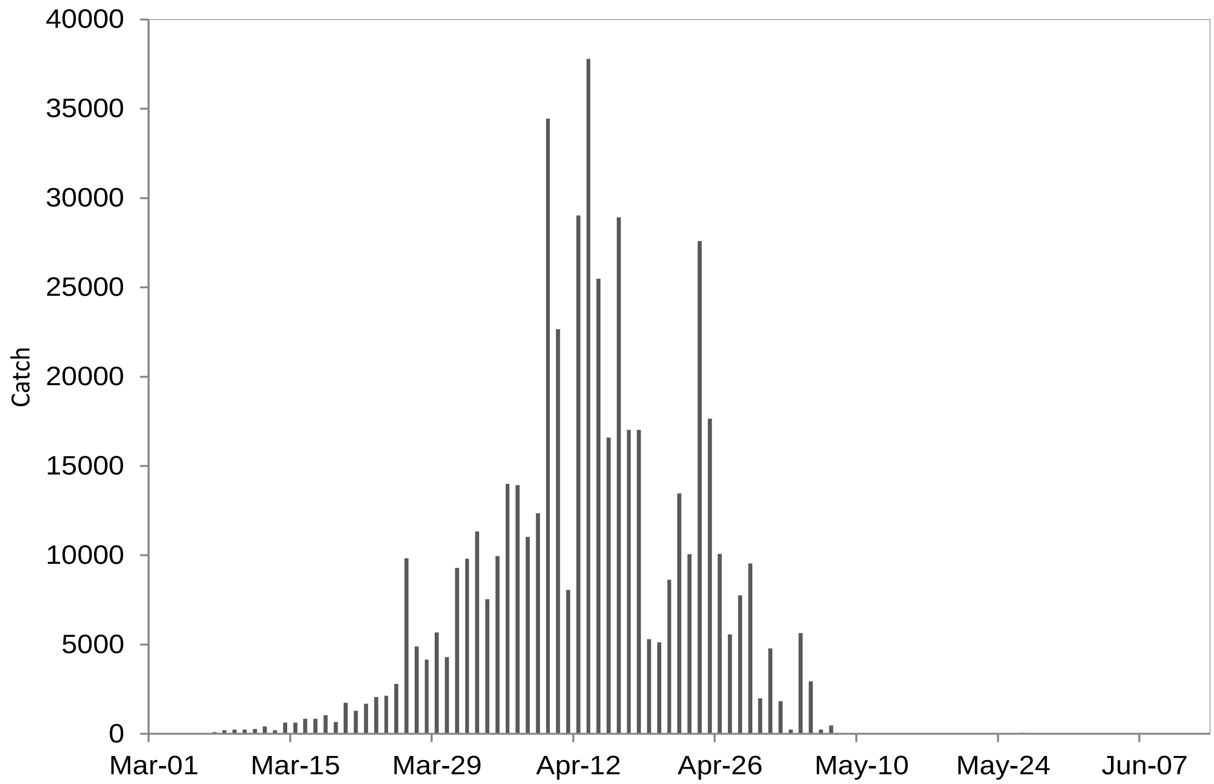

Figure 3.1. Daily chum salmon fry catch for the South Alouette River, 2014.

In total, 483,187 chum fry were captured. Including estimates for those days where catch was lost or traps were disabled (n=9), the total fry captures for the 2014 out-migration was 522,425 This represents 48% of the catch for the previous cycle-year in 2010 (Figure 3.2).

Nine marked fry releases were conducted and recovery data was generated from eight of the releases. The release of 5 May was interrupted by the disabling of traps during recapture due to storm and debris flows. The total marked fry released was 25,648 (4.9% total catch) and the number recaptured was 2,267 (8.8%). Releases ranged from 1,323 to 4,132 marked fry. Recovery (combined) rates ranged from 3.7% to 12.9% and the mean individual trap recovery rates were 2.83%, 2.18% and 3.10% for incline plane trap 1, incline plane trap 2, and the rotary

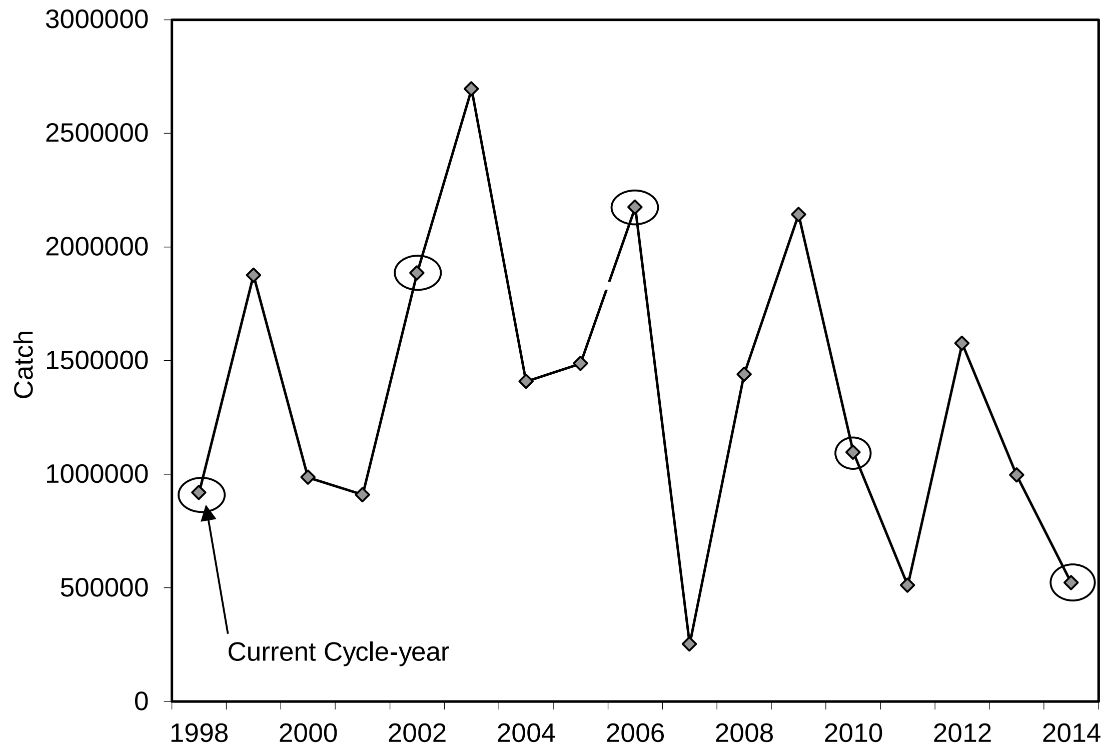

Figure 3.2. Summary of wild spawned chum fry captures within the South Alouette River, 1998 - 2014.

screw trap, respectively. Based on the pooled catch and recovery data (*i.e.,* pooled Peterson estimator) the 2014 chum fry out-migrant population was estimated to be 5.91 million fish (95% confidence interval: 5.67 to 6.16 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 2014 was 5.46 million fish (95% confidence interval: 4.89 to 6.20 million fish). Figure 3.3 illustrates the 2014 out-migration timing was typical in relation to the average for the years 1998 – 2013.

Figure 3.4 illustrates the annual chum fry out-migration estimates in time series. The 2014 estimate represents 54% of the fry production from the previous generation for this cycle year. Since 1998, chum fry out-migration estimates for this cycle-year (1998, 2002, 2006, 2010, 2014) have ranged between 5.46 (2014) to 30.28 (2006) million fry. The 2014 out-migration represents a low year for this cycle year (Table 3.4). However, the data has a lot of variation and there has been no significant change in chum fry production over the duration of the study (Figure 3.4; regression, p=0.92, r=0.03, n=17) or for this cycle-year (regression, p=0.79, r=0.17, n=5).

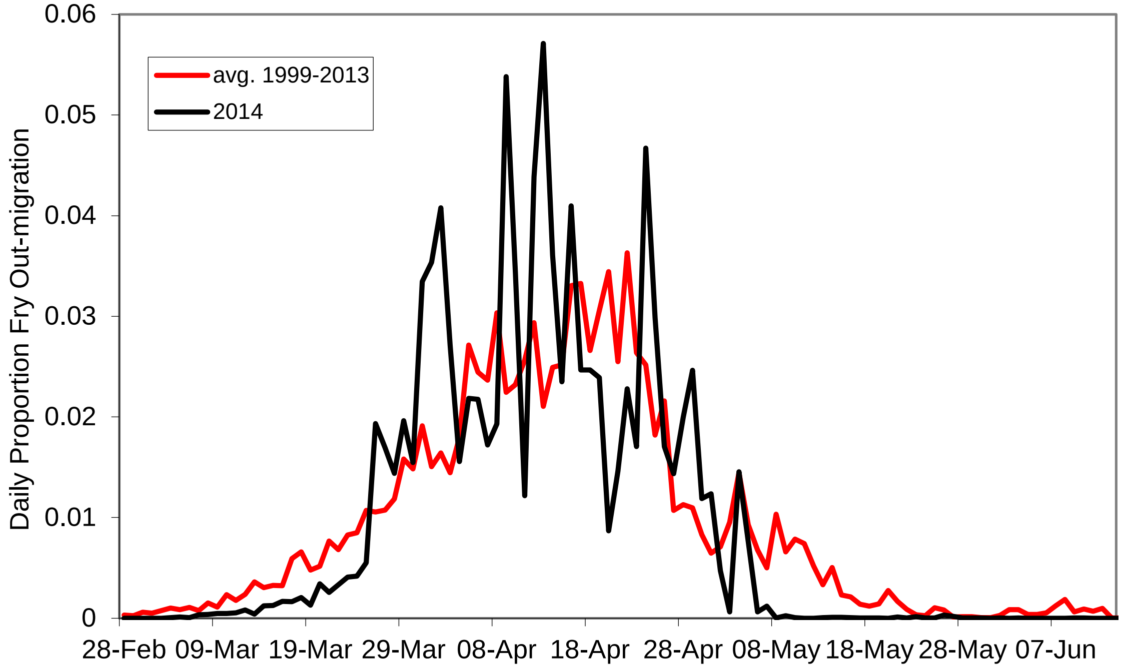

Figure 3.3. Daily chum fry out-migration estimates (2014) represented as a proportion of total annual out-migration illustrating the current year versus the 1999 to 2013 average.

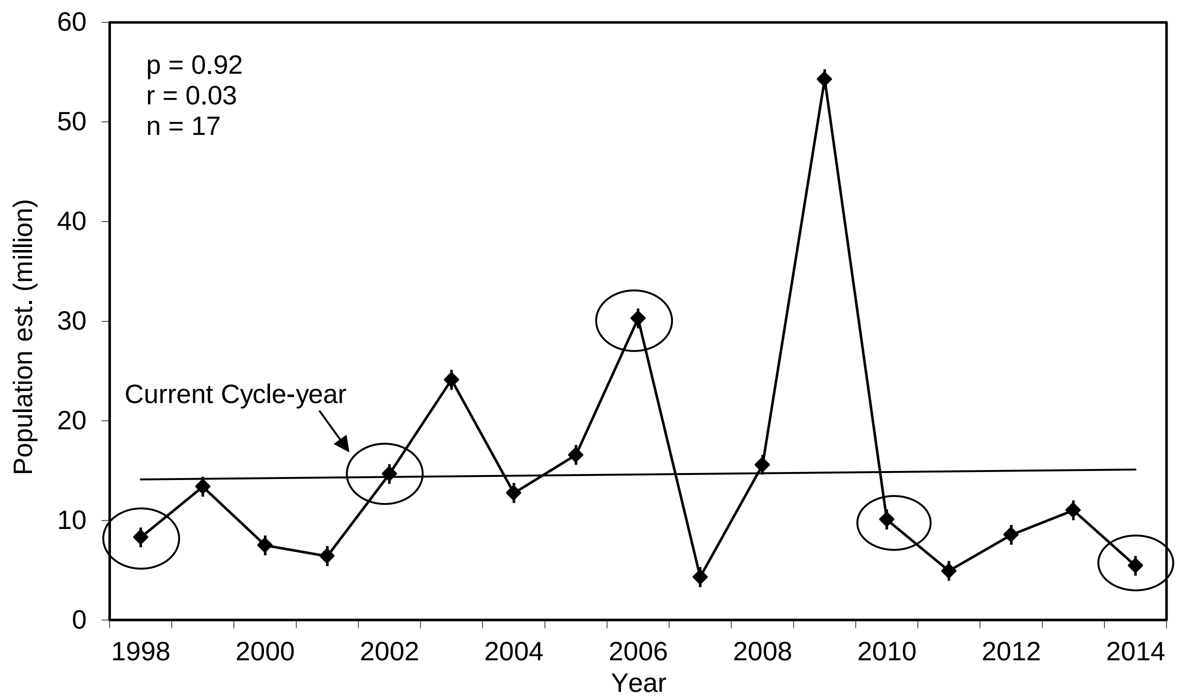

Figure 3.4. Summary of annual wild spawned chum fry out-migration estimates (+/- 95% confidence interval) for the South Alouette River, 1998 - 2014. A linear trendline has been superimposed for annual estimates.

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	4th generation Out-migration Estimate	Estimated Production Increase since start
1998/2002/2006/ 2010/2014	8.3	14.7	30.3	10.1	5.46	-1.5
1999/2003/2007/ 2011	13.4	24.1	4.3	4.9		-2.7
2000/2004/2008/ 2012	6.8	12.8	15.6	8.6		1.3
2001/2005/2009/ 2013	6.4	16.6	54.3	11.0		1.7

The low chum fry yields in 2007 and 2010 were preceded by very high spawner escapements (*i.e.,* ALLCO fence count >150,000, Table 3.4). The production estimates for these years of extremely high spawner escapement suggests the conclusion of previous years that egg-to-fry survival was relatively constant and the South Alouette River had not yet reached the point of density-dependent mortality was not accurate (*see* section 3.10 Hypothesis Testing).

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 8 March to 6 May illustrates the ongoing fry emergence and out-migration during this period. The mean fork length during this period averaged 38.5 mm (range 36.4 – 40.0). Mean chum fry lengths during the out-migration period have been consistent for the last six years (range 37.0 – 38.8). Previous years have demonstrated that after 6 May the mean fry length increases substantially illustrating the end of fry emergence and out-migration. The remaining small percentage of larger sized fry after 6 May represent fry that have not out-migrated immediately following emergence but rather have remained for a period of rearing within the Alouette River.

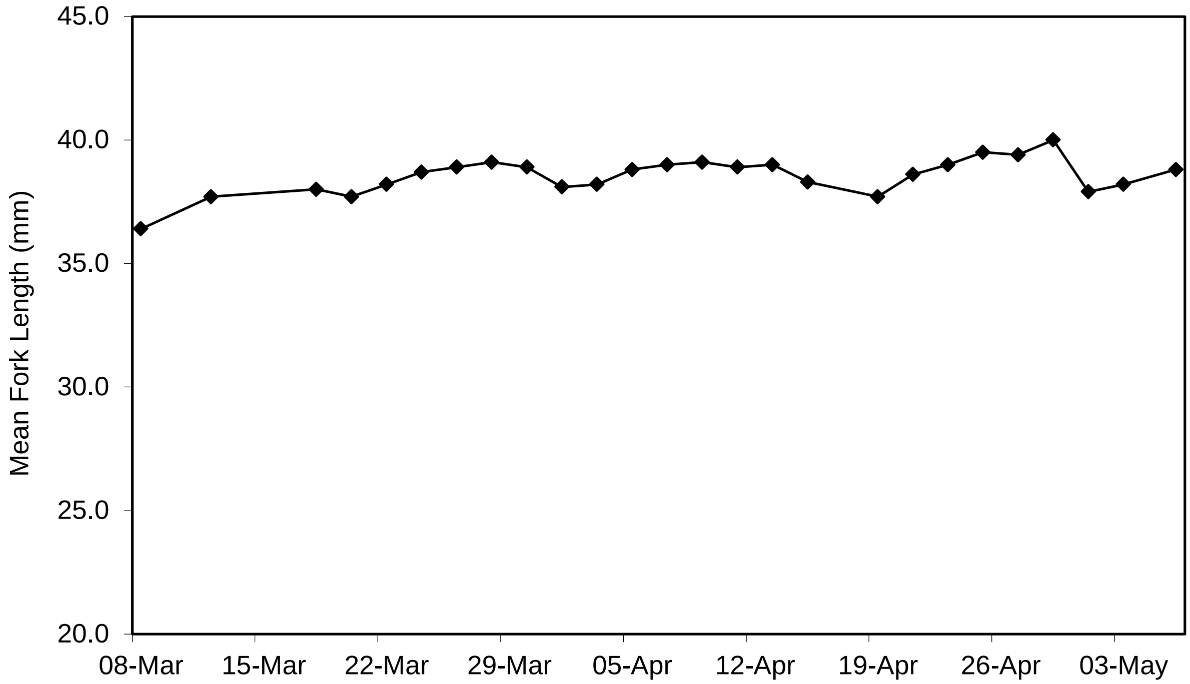

Figure 3.5. Mean fork length of out-migrant chum salmon fry, South Alouette River, 2014.

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3.3. Pink Fry

The seasonal pattern of pink fry out-migration in the South Alouette River was characterized by first emergence in early March, peak migration mid-April, and the end of migration in late April (Figure 3.6). In 2014, the dates of 10%, 50% and 90% migration were 31 March, 10 April, and 17 April, respectively. The timing of peak out-migration in 2014 was typical of the pattern demonstrated in previous study years (n=9).

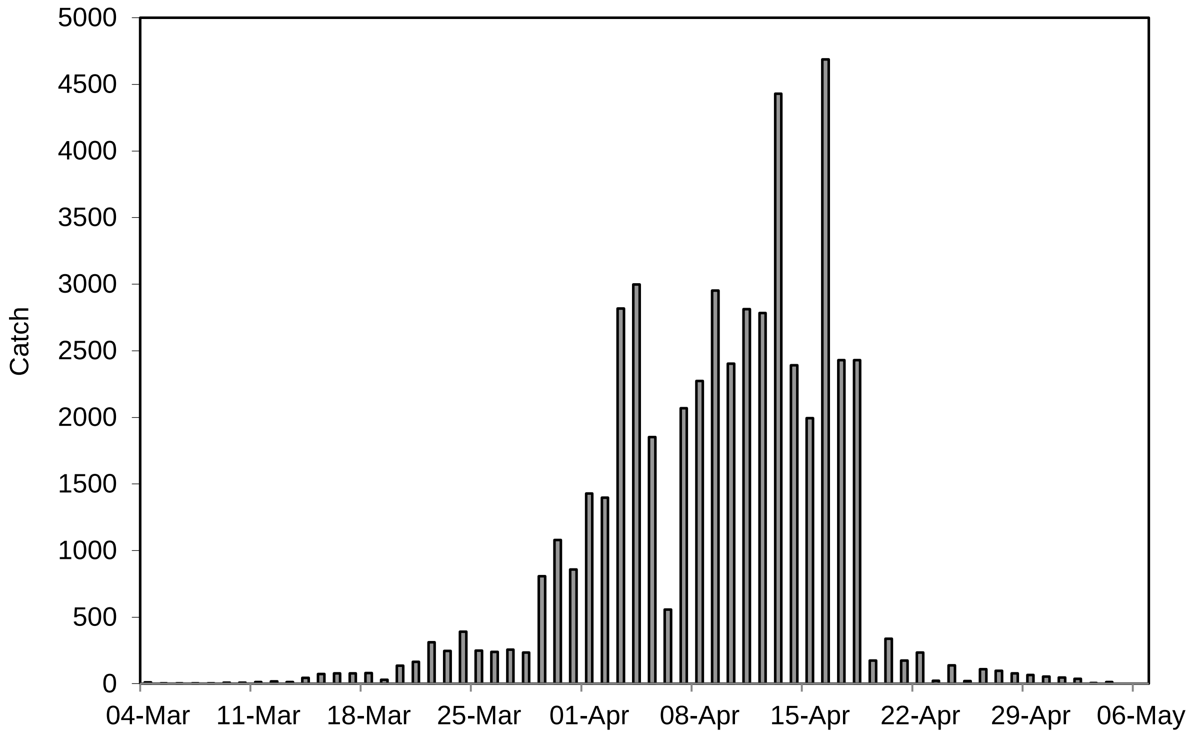

Figure 3.6. Daily pink salmon fry catch for the South Alouette River, 2014.

In total, 46,709 pink fry were captured. Including estimates for those days where catch was lost or traps were disabled (n=7), the total fry captures for the 2014 out-migration was 51,739. These totals represent the combined catch for the two Incline Plane traps. The rotary screw trap has extremely low catch efficiencies for pink fry and as such was not used for pink fry population estimation. The 2014 catch represents the second highest on record (n=9) and a 215% increase in catch over the previous year (Figure 3.7). The median annual capture was 22,617 (Figure 3.7).

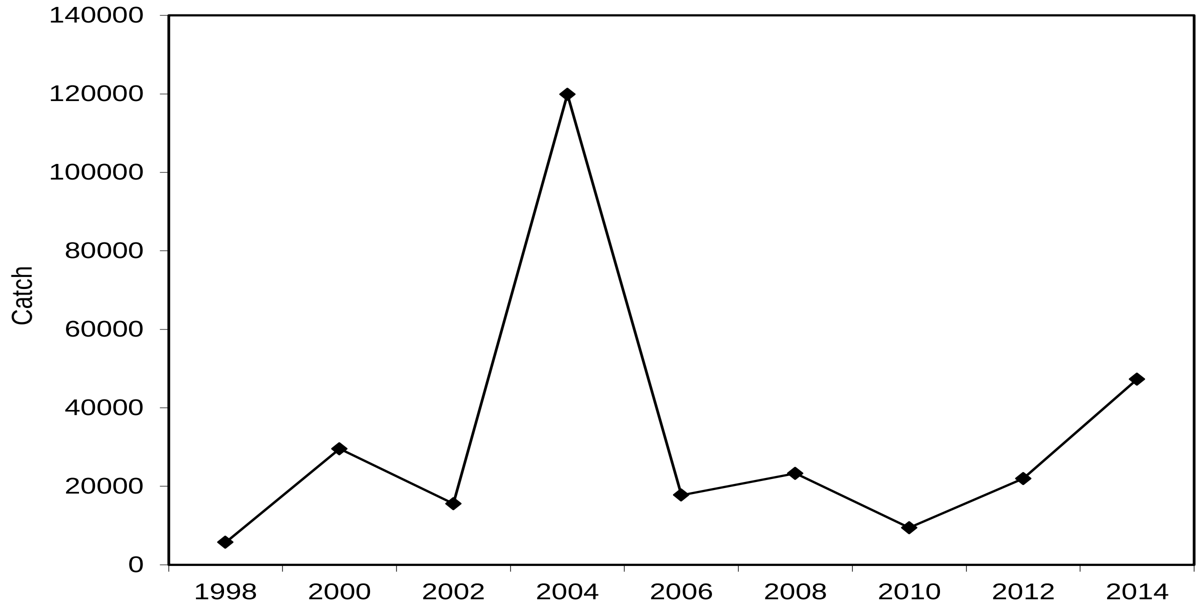

Figure 3.7. Summary of wild pink fry captures within the S. Alouette River, 1998 - 2014.

The total number of pink fry marked and released was 4,561 (9.6% of catch). There were 270 recaptures for all three traps combined resulting in a combined mean trap efficiency of 5.92%. The same as years previous, the rotary screw trap capture efficiency was extremely low and the population estimates for pink fry out-migrants were derived from the incline plane traps. The combined incline plane trap efficiency for pink fry was 5.7%, compared to 0.2% for the rotary screw trap. Based on the pooled catch and recovery data (*i.e.,* pooled Peterson estimator) the 2014 pink fry out-migrant population was estimated to be 900,000 fish (95% confidence interval: 801,000 to 1,021,000 fish).

Eight release events ranging from 23 to 1,658 marked pink fry were combined into 6 strata with a minimum of 20 recaptures. The stratified Peterson estimate for the 2014 pink fry out-migrant population was 950,000 fish (95% confidence interval 730,378 to 1,400,946 fish). Figure 3.8 illustrates the annual pink fry out-migration estimates for 1998 to 2014. Note that 2014 was the first time a stratified Peterson estimate was used as opposed to pooled Peterson estimate. While there has been no significant increase in pink fry production over the duration of the study (regression, p=0.35, r=0.36, n=9); the current emigrating pink fry estimate represents the second most productive year since 1998.

Figure 3.9 illustrates the 2014 out-migration timing in relation to the average for the previous study years (1998 – 2012).

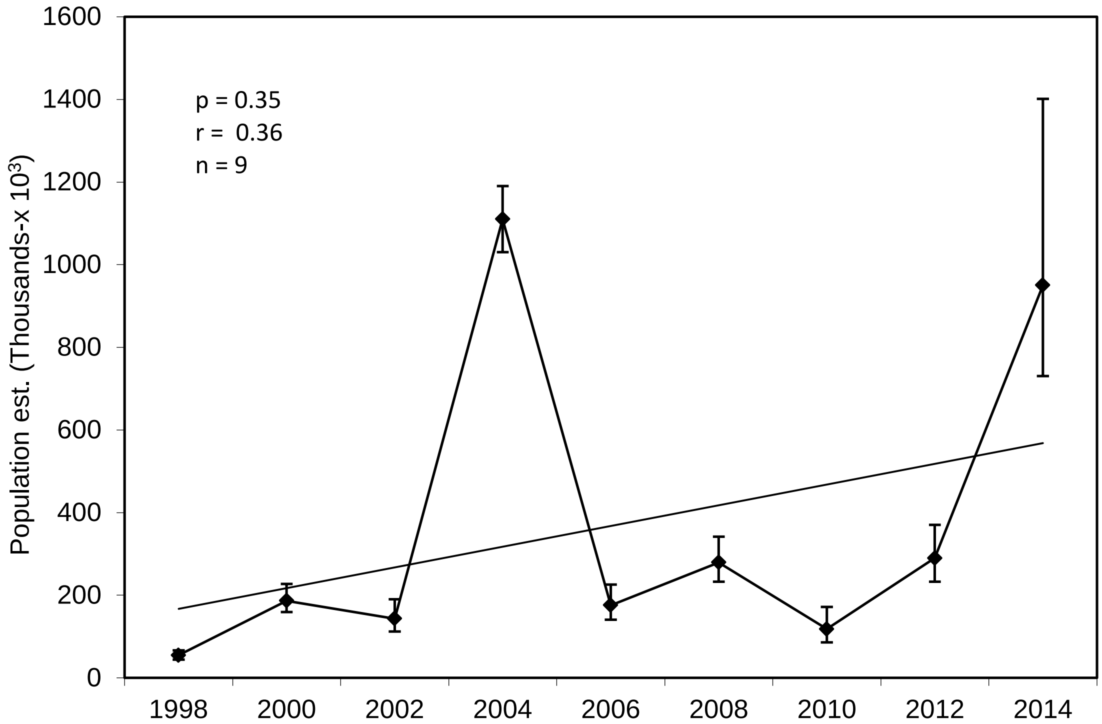

Figure 3.8. Summary of annual wild spawned pink fry out-migration estimates (+/- 95% confidence interval) for the South Alouette River, 1998 - 2014.

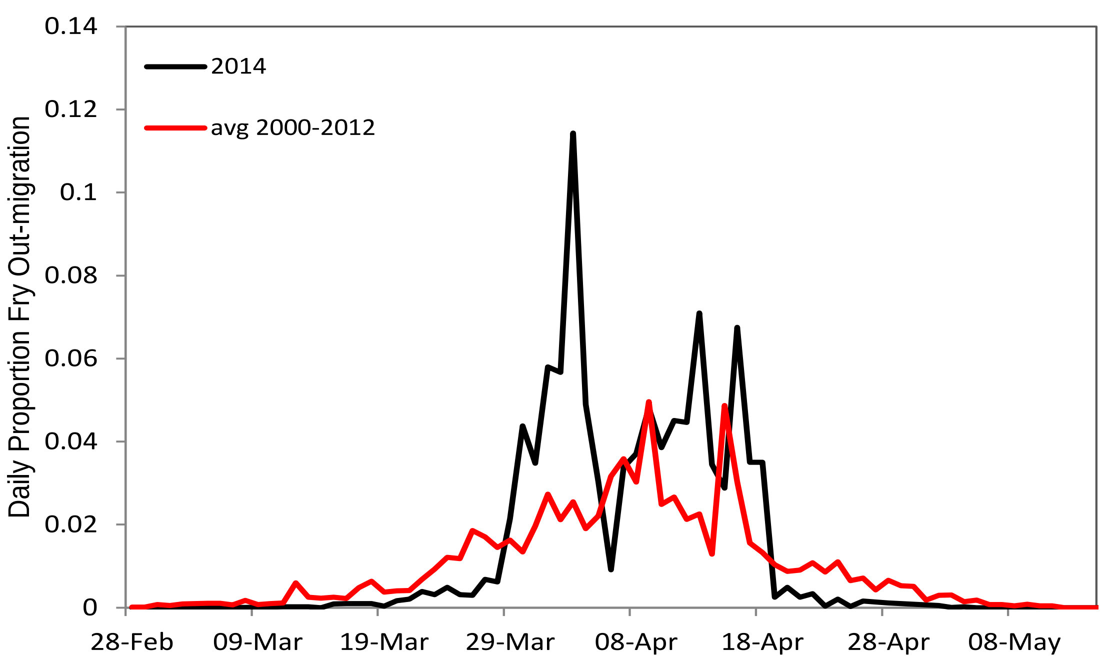

Figure 3.9. Daily pink fry out-migration catch represented as a proportion of total annual catch illustrating the timing observed in 2014.

Figure 3.10 illustrates the mean fork length of pink salmon fry out migrants through the enumeration period. The consistency of the mean fork length from 13 March to 1 May illustrates the ongoing fry emergence and out-migration during this period. The mean fork length during this period averaged 33.98 mm (range 32.5 – 35.1).

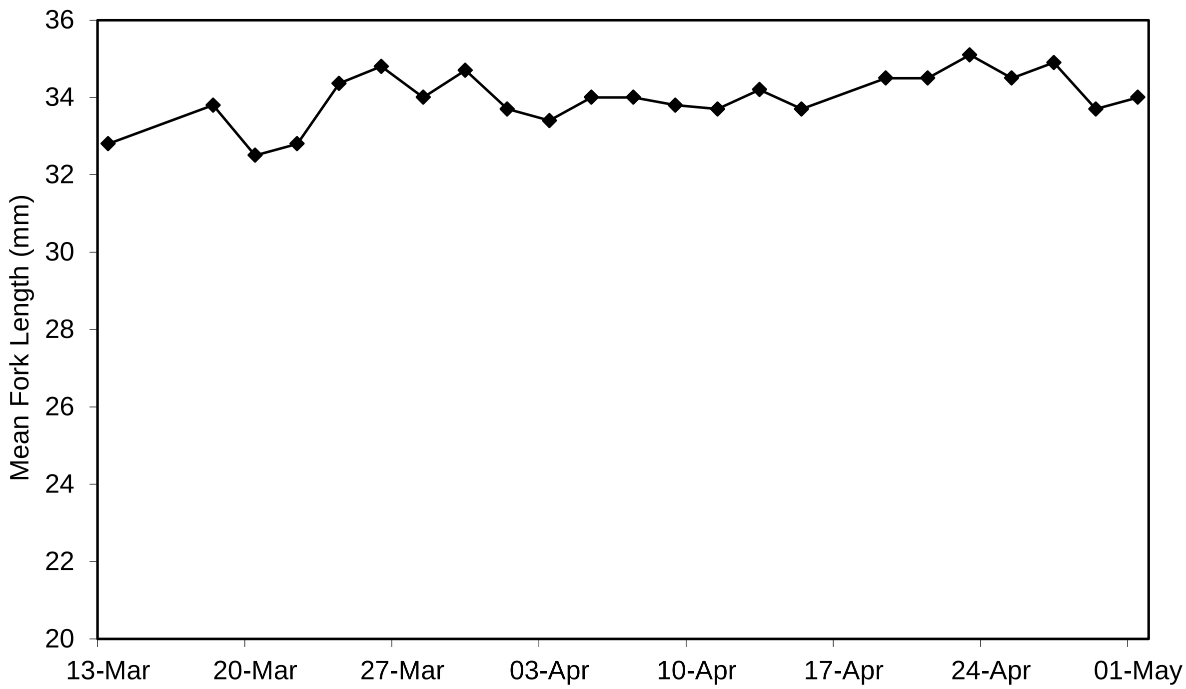

Figure 3.10. Mean fork length of out-migrant pink salmon fry, South Alouette River, 2014.

3.4. Coho Fry

A total of 717 wild coho fry were enumerated in 2014 (Table 3.7). This represents the fifth year in a row of above average coho fry catch (average = 287 coho fry, n=17). Higher fry catches of late coincide with improved average coho smolt production estimates (*see* Section 3.6 Coho Smolts) and generally, above average spawner escapements (Table 3.4); suggesting improved coho salmon production the last few years.

However, enumeration of coho fry was not considered reliable because coho stream rear for one year and fry captures do not represent a directed out-migration pattern, but rather incidental movements associated with storm events and increased flow (Figure 3.11).

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
2012	510
2013	323
2014	717

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

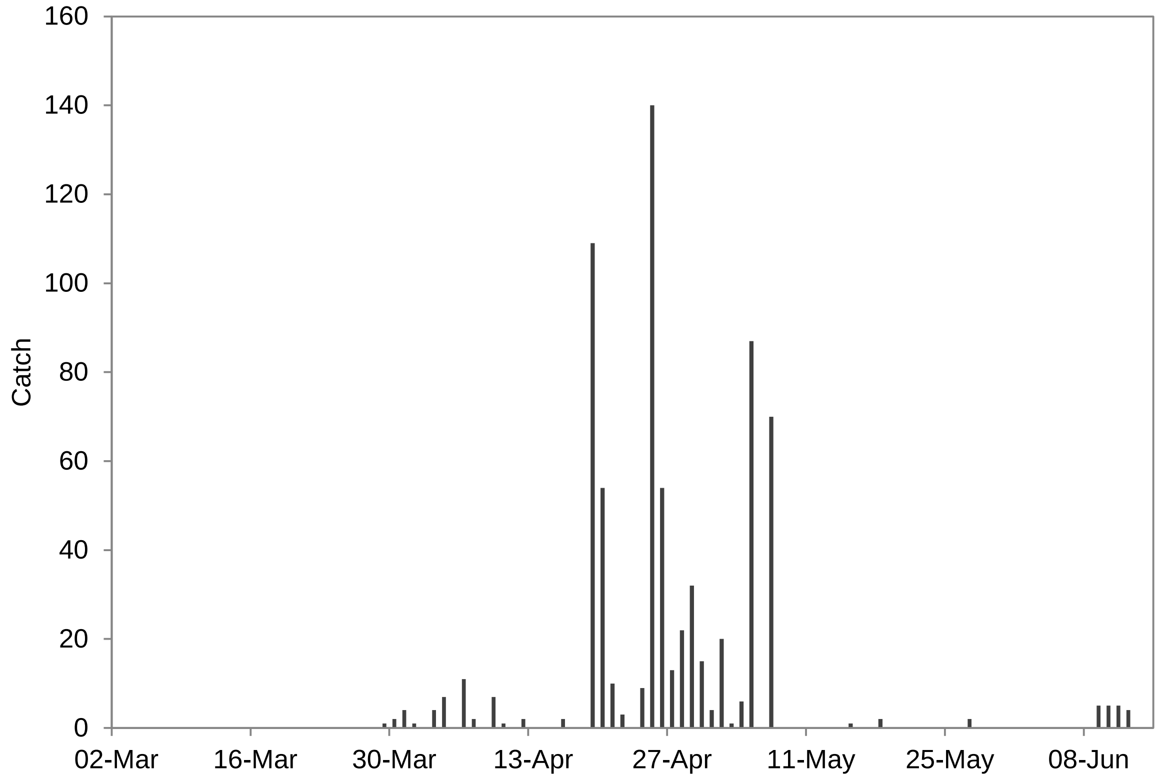

Figure 3.11. Daily coho salmon fry catch for the South Alouette River, 2014.

3.5. Chinook Fry

In total, 1,639 chinook fry (*i.e.,* Under-yearling smolts) were captured. This represents the third highest annual capture to date (Figure 3.12). Based on the increasing trend in chinook salmon out-migrants during the past five years, chinook salmon appear to be responding to stocking efforts (regression; p=0.07, r=0.46, n=17).

The seasonal pattern of chinook fry out-migration in the South Alouette River was characterized by first emergence in March, out-migration in May-June, and the end of migration at the end of June after enumeration operations have ended (Figure 3.13). In 2014, the dates of 10%, 50% and 90% migration were 15 May, 30 May, and 9 June, respectively. These dates and timing are biased early due to the end of enumeration operations 13 June when chinook out-migrants were still being captured in numbers. June is a well-documented month of active downstream movement of under-yearling chinook smolts and the timing in three Vancouver Island rivers suggest early to mid-June peak timing (Healey 1991).

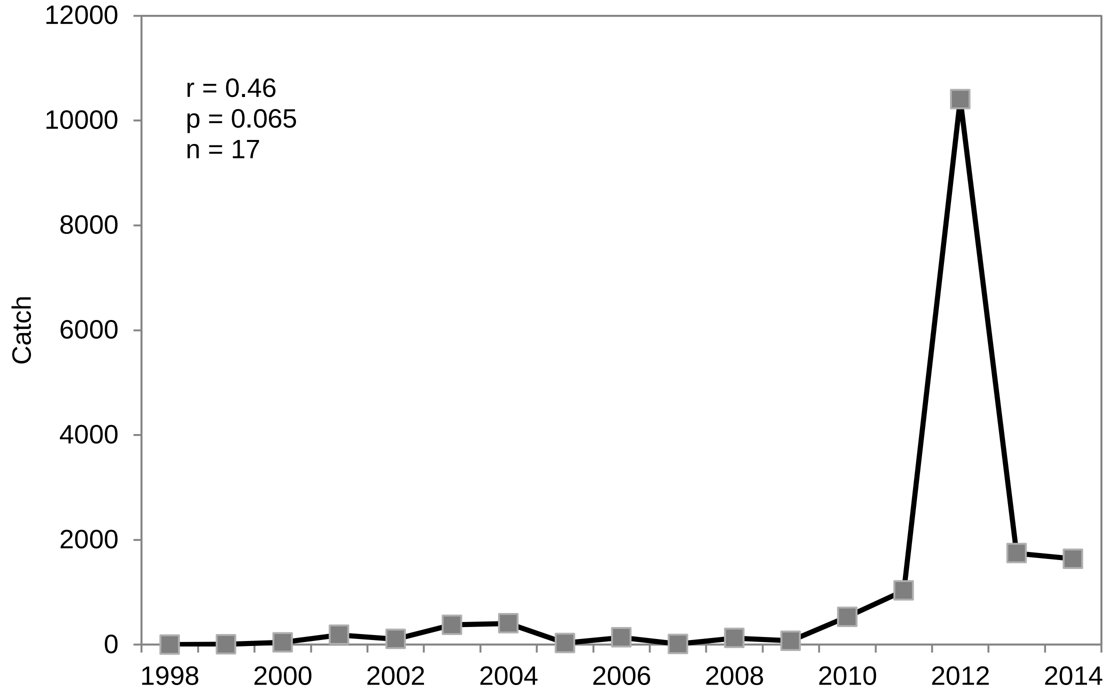

Figure 3.12. Summary of wild spawned chinook salmon fry captures within the South Alouette River, 1998 - 2014.

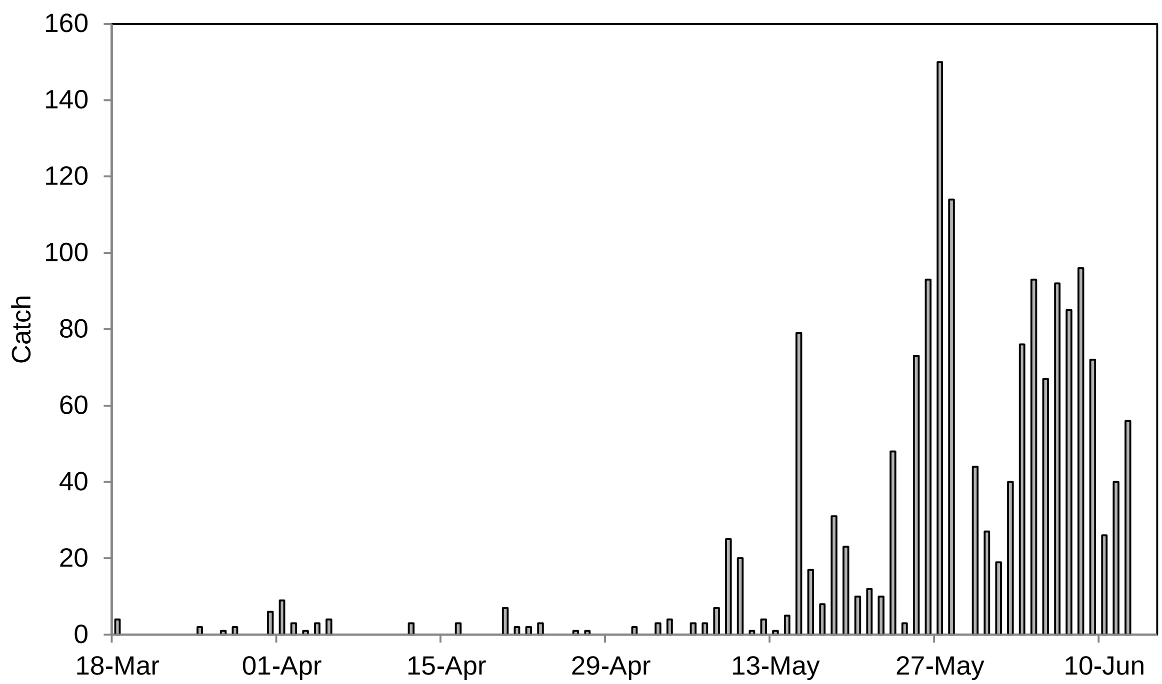

Figure 3.13. Daily chinook salmon fry catch for the South Alouette River, 2014.

Since 2012, hatchery reared chinook fry were not released until downstream trapping was completed and wild reared chinook fry out-migration has been enumerated. A mark recapture test confirmed a chinook fry recapture rate of 32.2% for the rotary screw trap. This was consistent with the 2012 trap efficiency of 35.0%. The 2014 chinook fry out-migration was estimated to be 5,319 smolts (95% Confidence Interval 4,343 to 6,672). Chinook fry out-migration has ranged between 5,000 and 30,000 smolts over the last three years.

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 (Figure 3.14). Timing has been consistent since the establishment of the current trapping location and duration in 2009 (Figure 3.14). Out-migration timing before 2009 was not summarized due to tidal backwatering, loss of trap efficiency and early cessation of trapping (see Section 3.11 Hypothesis testing).

In total, 3,345 wild coho smolts were captured. Including estimates for those days where catch was lost or traps were disabled (n=8), the total coho smolt captures for the 2014 out-migration was 3,600. Figure 3.15 clearly illustrates out-migration catch prior to 2009 was lower due to tidal backwatering and loss of trap efficiency resulting in early cessation of trapping (see Section 3.11 Hypothesis testing).

In total, 2,029 marks were applied to the catch and 322 of these were recaptured. This resulted in a mean trap efficiency of 15.9% compared to 17.3% the previous year. Prior to 2014, mean annual trap efficiency (n=14) has ranged between 4.1% and 28.6%. The pooled Peterson estimator results in a coho smolt out-migration estimate of 22,632 (95% confidence interval: 20,354 to 25,321; Figure 3.16).

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 3.16). 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 216th St. location. In 2008, it was also 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, annual coho smolt production estimates have exceeded 19,000 smolts (Figure 3.16).

The mean length and weight of emigrating, wild reared, coho smolts in 2014 was 100.2 mm (range 50 – 146 mm, n=2,105) and 11.8 g (range 1.8 – 207.0 g, n=2,079), respectively. Mean smolts size (fork length) has been trending downward since 2007 and the last three years have been the smallest (Figure 3.17). Smolt growth is often density-dependent and a relatively large out-migrant population would be expected to be relatively smaller.

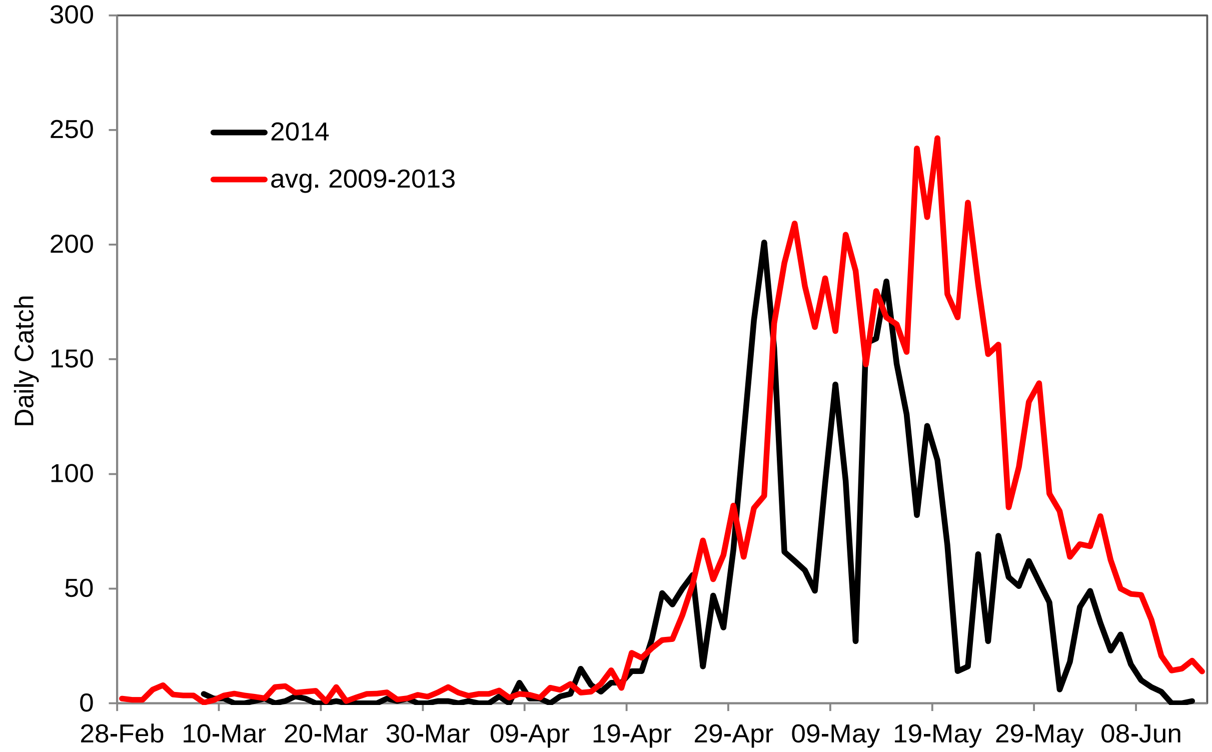

Figure 3.14. Daily coho smolt catch for the South Alouette River, 2014.

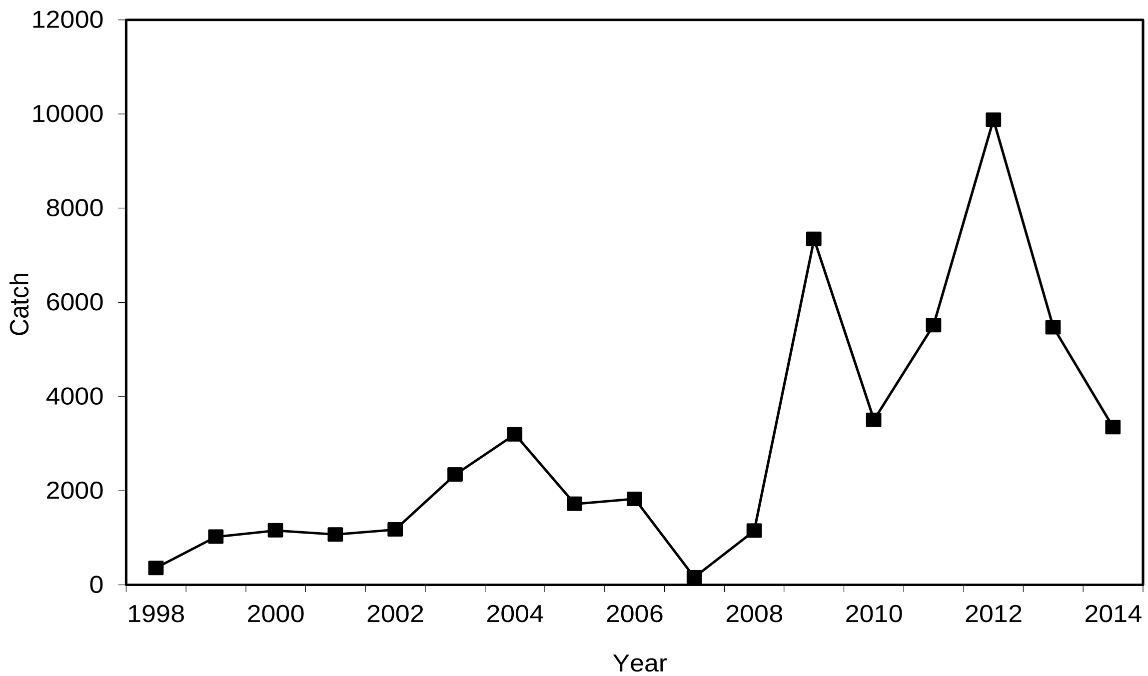

Figure 3.15. Summary of wild reared coho smolt captures within the South Alouette River, 1998 - 2014.

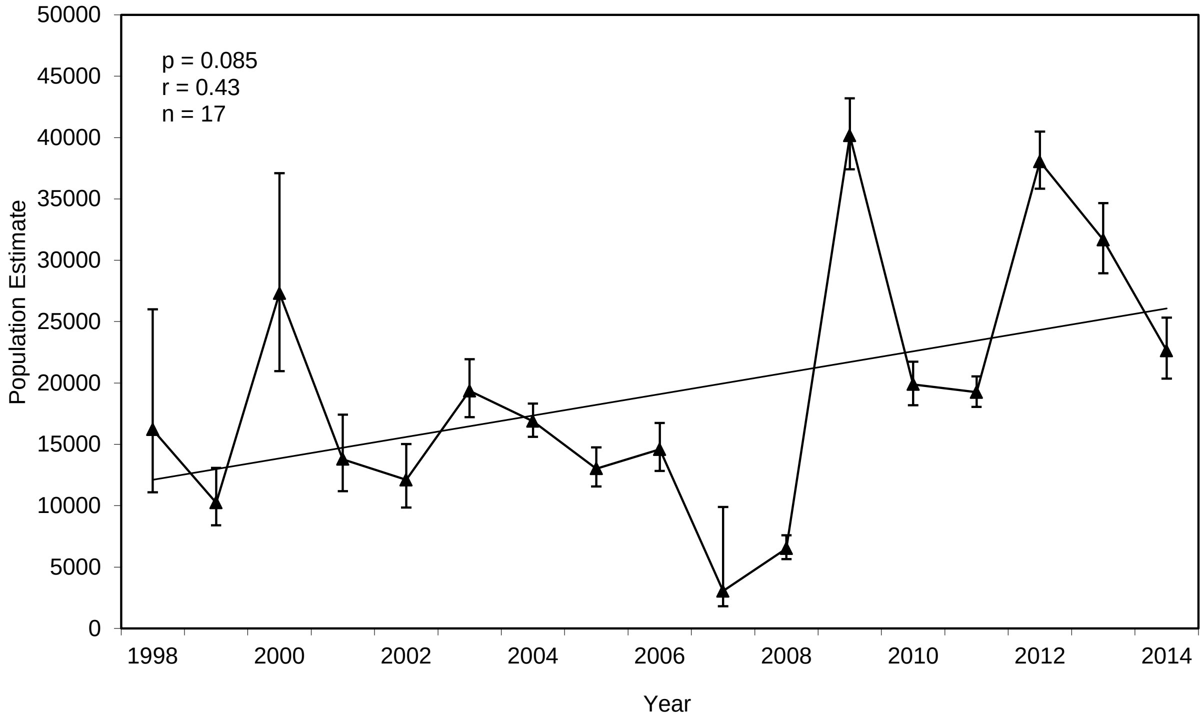

Figure 3.16. Summary of annual wild reared coho smolt out-migration estimates (+/- 95% confidence interval) for the South Alouette River, 1998 - 2014.

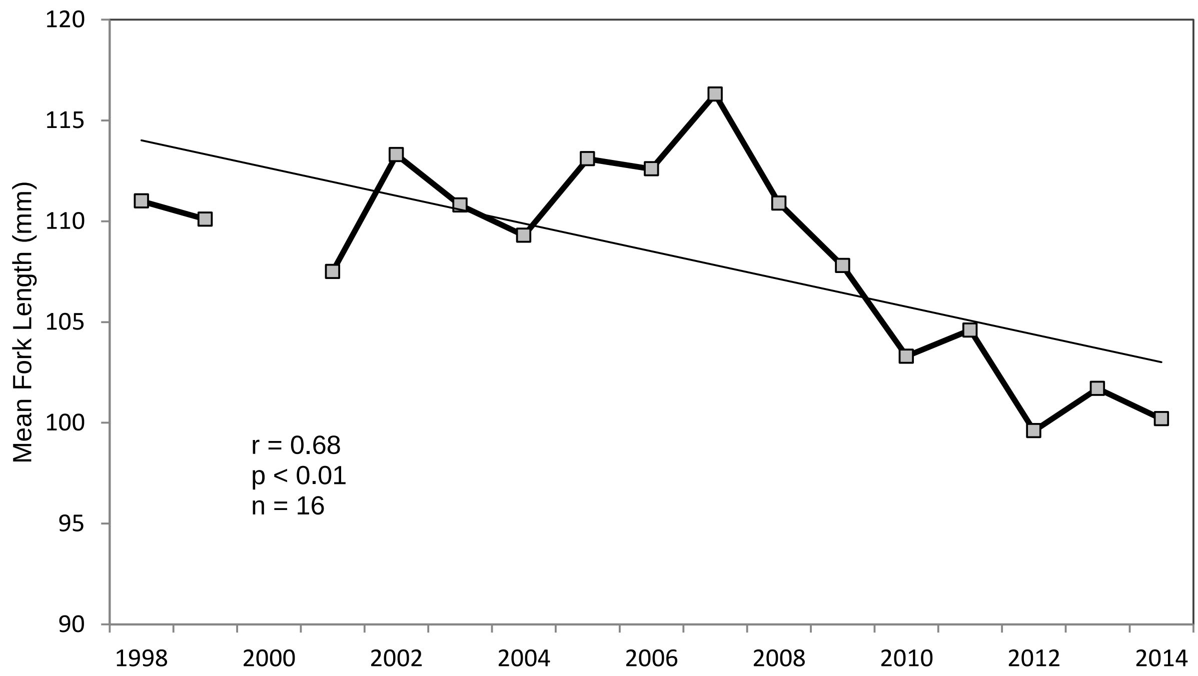

Figure 3.17. Summary of annual coho smolt size (fork length) for the South Alouette River Rotary Screw trap catch (1998 – 2014).

3.7. Steelhead Smolts

The seasonal pattern of smolt out-migration was characterized as starting in mid-April, peaking in May, and ending in June (Figure 3.18). Captures in March were associated with rainfall flow events and include rearing parr. Timing has been consistent since establishment of the current trapping location and duration in 2009. Out-migration timing before 2009 was not summarized due to tidal backwatering, loss of trap efficiency and early cessation of trapping (see Section 3.11 Hypothesis testing).

In total, 470 wild reared steelhead smolts were captured. Including estimates for those days where catch was lost or traps were disabled (n=8), the total steelhead smolt captures for the 2014 out-migration was 532. The 2014 out-migration catch was within the range expected since moving the trap upstream to the 224th St. location in 2008 (Figure 3.19). In total, 319 marks were applied to the catch and 36 of these were recaptured. This resulted in a mean trap efficiency of 11.3%. The mean annual trap efficiency from 2009 to 2014 has been 11.2%. The respective pooled Peterson estimator results in a steelhead smolt out-migration estimate of 4,610 (95% confidence interval: 3,422 to 6,560; Figure 3.20).

There has been a weak positive (*i.e.,* increasing) relationship for annual estimates of steelhead out-migrants (regression, p=0.08, r=0.45, n=16, Figure 3.20). 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. 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. In 2008, it was also 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. The current year represents the lowest annual steelhead smolt production estimate since 2009. Since 2009, the estimated annual steelhead smolt production has averaged 5,630 smolts (range 4,610 – 6,204, excluding 2010 anomaly; Figure 3.20).

The mean length and weight of emigrating, wild reared, steelhead smolts in 2014 was 144.2 mm (range 73 – 210 mm, n=332) and 32.3 g (range 5.0 – 90.5 g, n=323), respectively. Mean smolt size (fork length) has decreased significantly since monitoring began (regression, p<0.01, r=0.73, n=16, Figure 3.21). Smolt growth is often density-dependent and a relatively large out-migrant population would be expected to be relatively smaller.

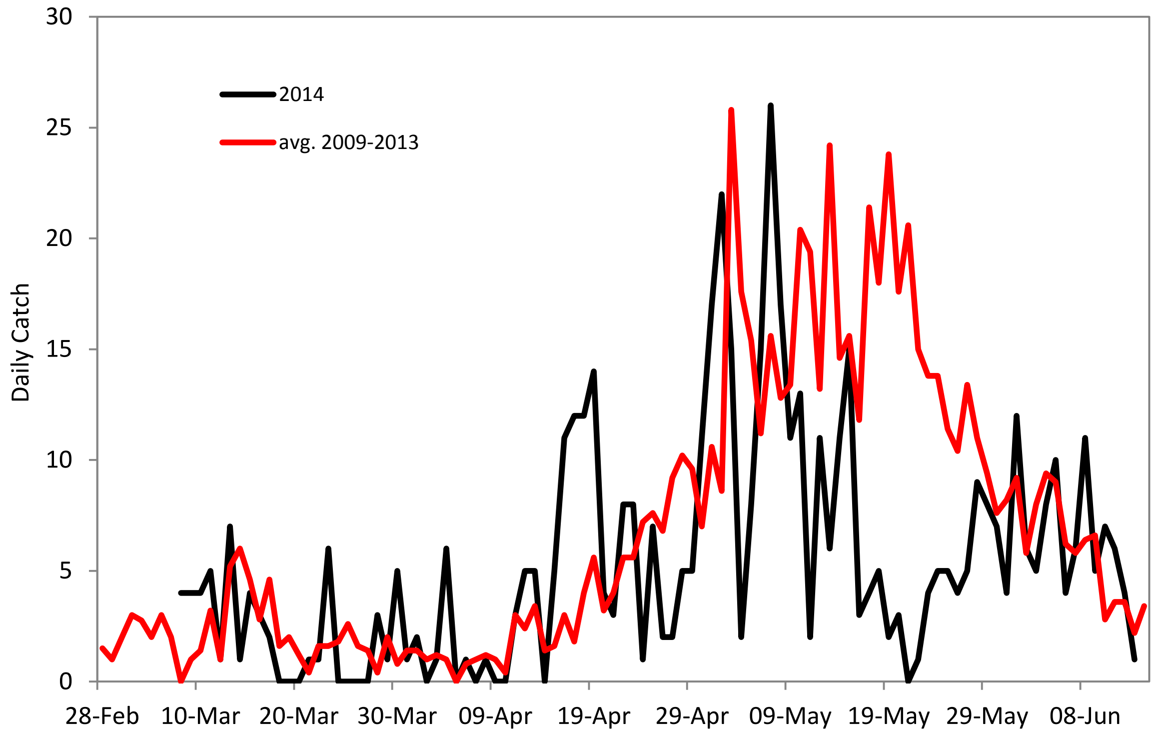

Figure 3.18. Daily steelhead smolt catch for the South Alouette River, 2009 - 2014.

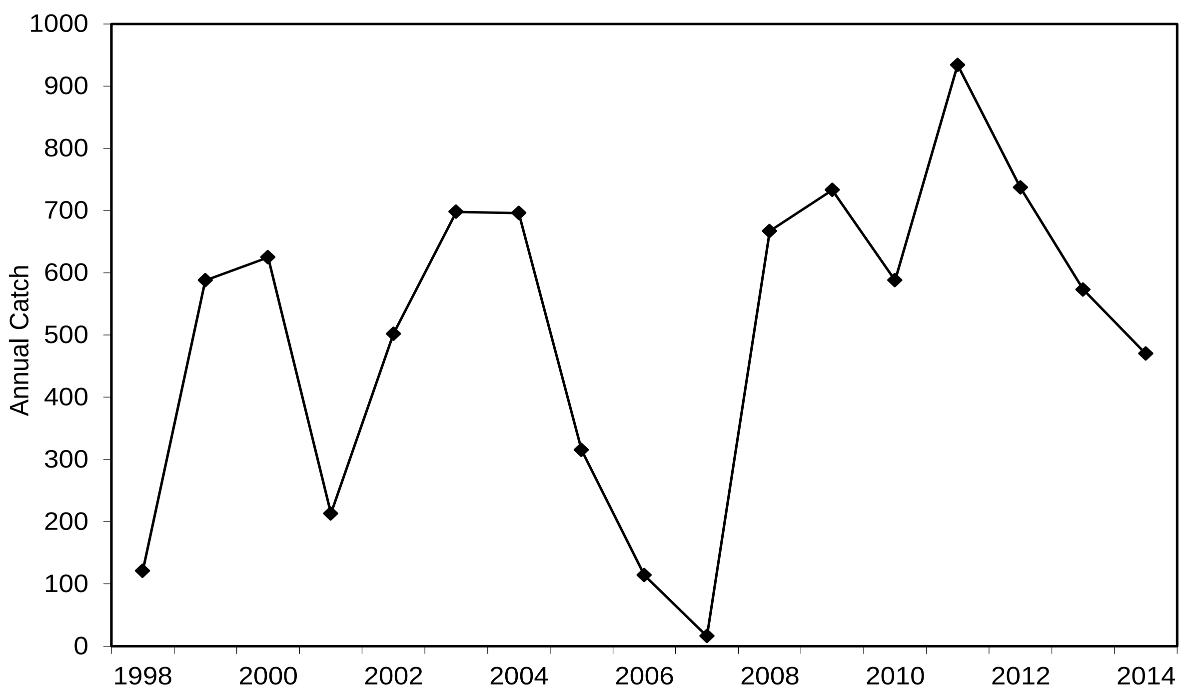

Figure 3.19. Summary of wild reared steelhead smolt captures within the South Alouette River, 1998 - 2014.

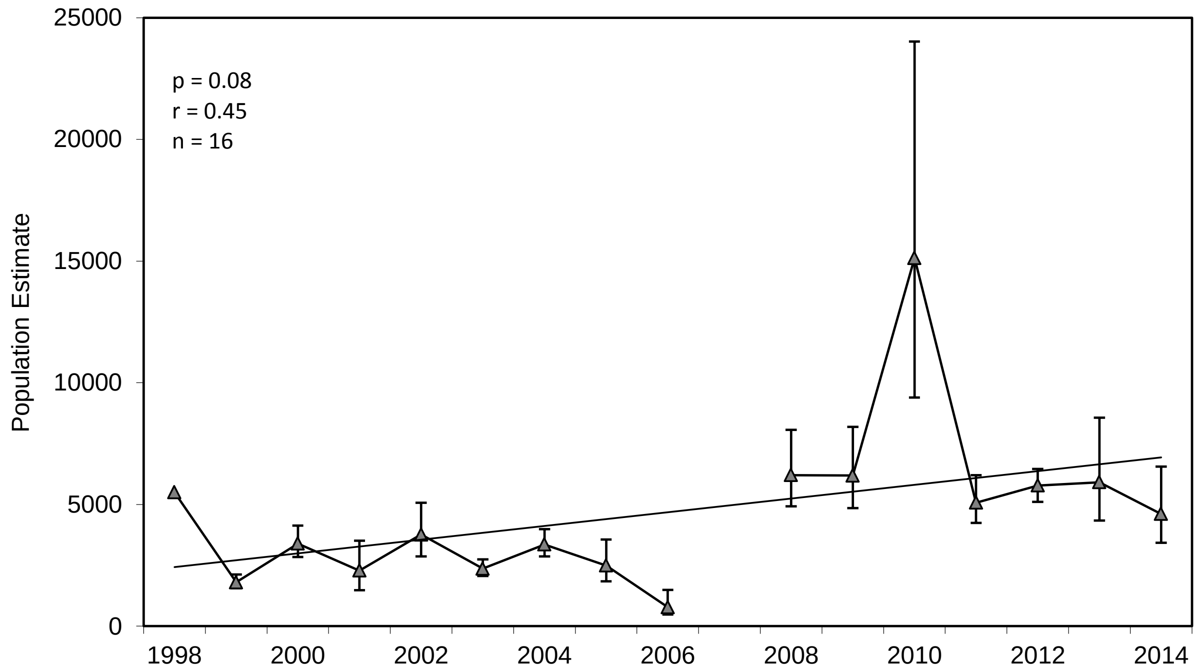

Figure 3.20. Summary of annual wild reared steelhead smolt out-migration estimates (+/- 95% confidence interval), South Alouette River, 1998 - 2014. The 2007 out-migration estimate could not be calculated due to low capture numbers for 2007 (n=16).

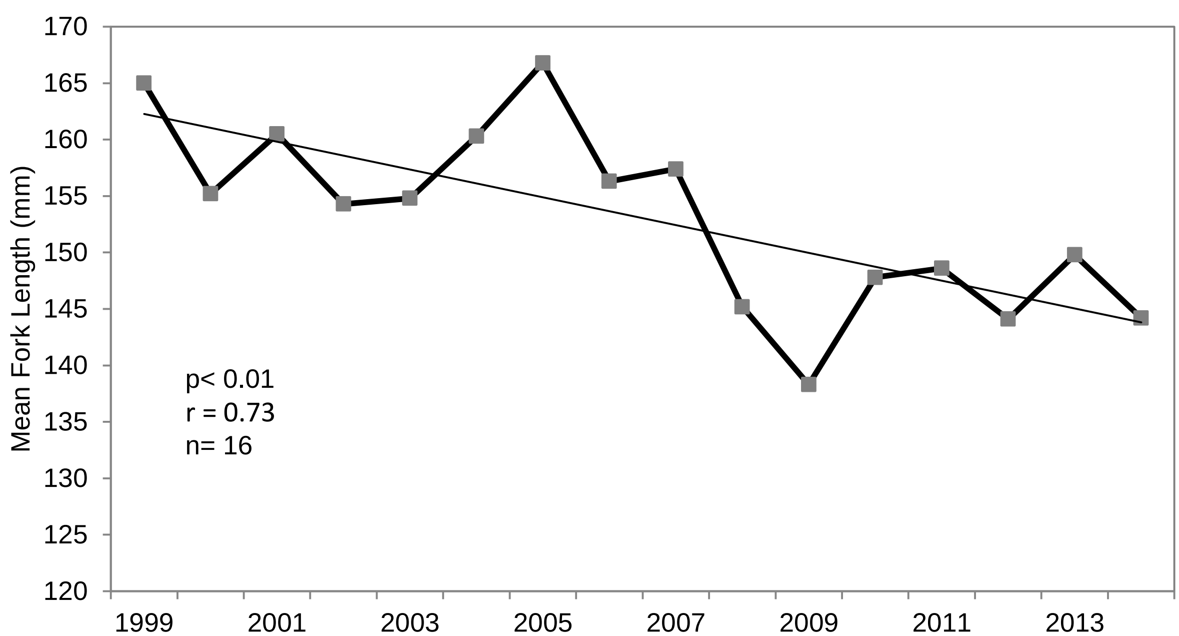

Figure 3.21. Summary of annual steelhead smolt size (fork length) for the South Alouette River Rotary Screw trap catch (1999 – 2014).

3.8. Cutthroat Trout

In total, 92 wild reared and 57 hatchery reared cutthroat trout were captured between 18 March and 13 June. Figure 3.22 illustrates the 2014 out-migration timing of wild reared cutthroat trout captures. The majority were captured in May and this has been consistent through the years.

In total, 75 cutthroat trout smolts were marked and there were 9 recaptures (12.0%). The 2014 trap efficiency met expectations based on previous years, however; annual captures were lower than recent years as the out-migrant catch had been rebuilding from the low in 2007 (Figure 3.23).

Although recaptures were below the statistically acceptable minimum number for avoiding small sample bias in population estimators (n=25; Ricker 1975), it was interesting to note the resulting population estimate of between 461 and 1,675 wild reared cutthroat trout (95% confidence interval). This was at the lower end of the range for similar recent estimates of 650 to 1,885 (2011), 706 to 1,592 (2012) and 1,121 to 2,963 (2013).

The mean length and weight of cutthroat trout out-migrants was 146.3 mm (range 87 - 192 mm) and 31.1 g (range 14.4 – 71.8 g).

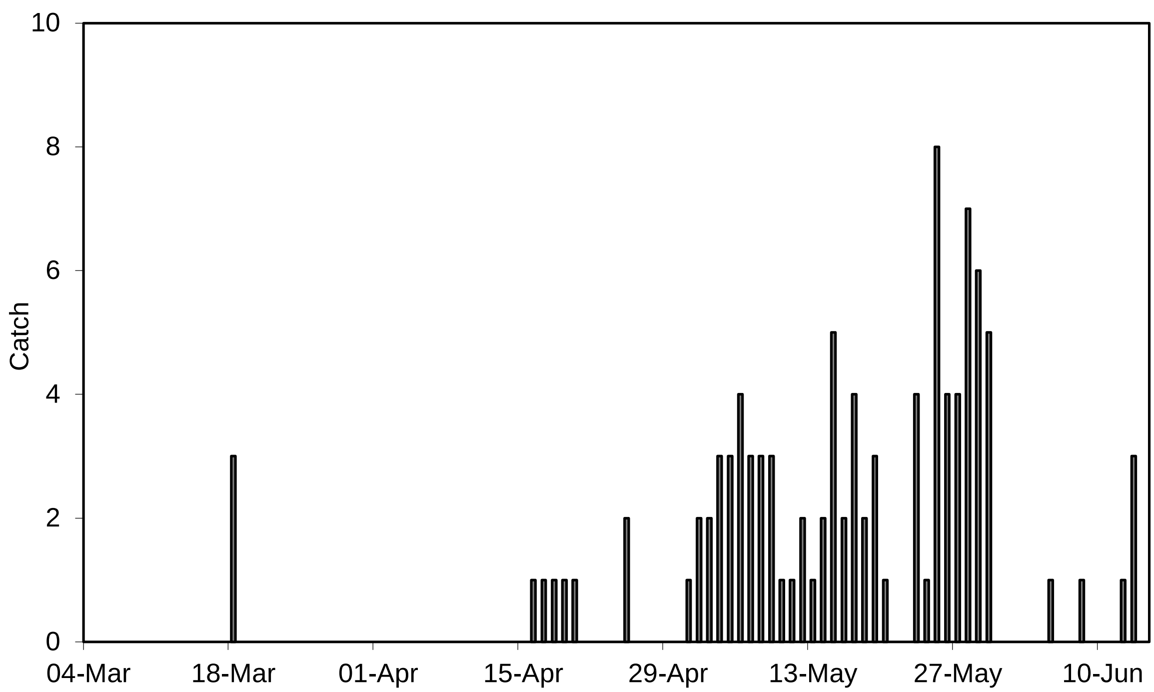

Figure 3.22. Daily catch for wild reared cutthroat trout smolts, South Alouette River, 2014.

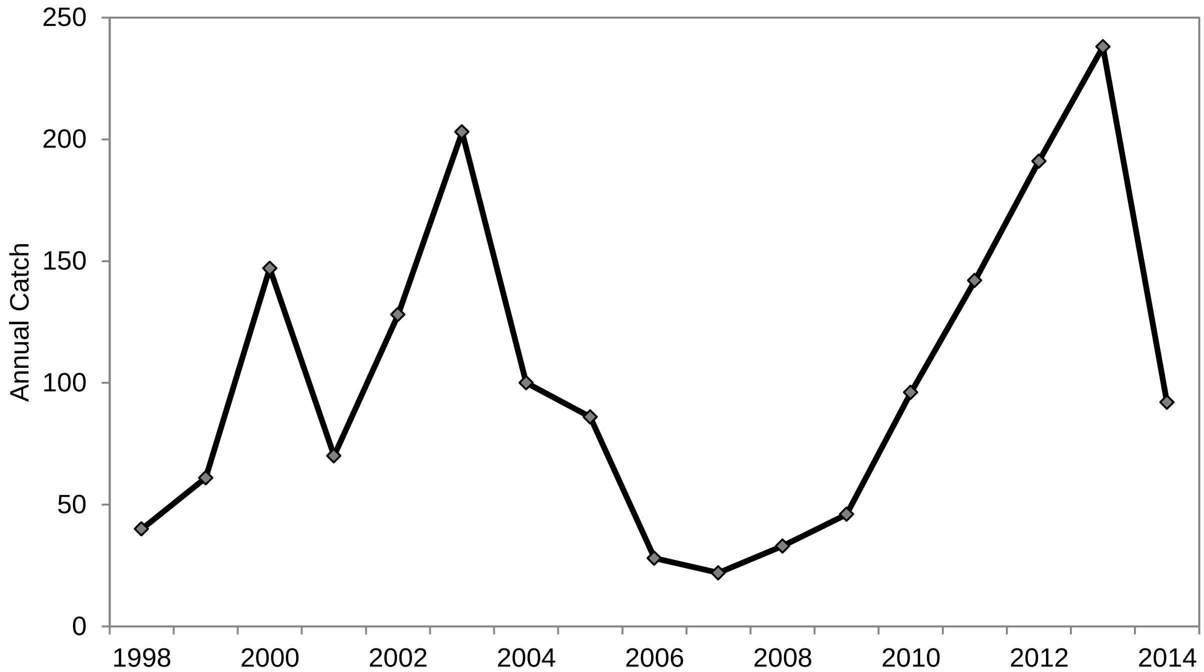

Figure 3.23. Summary of wild reared cutthroat trout smolt captures within the South Alouette River, 1998 - 2014.

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 – 2014) to assess smolt migration success through the Alouette Reservoir (Mathews *et al*. 2015). In 2014, the Alouette Dam crest gate was open from 15 April to 17 June to provide spring surface release for smolt out-migration using the spillway. A series of four modified pulse flows were provided between 12 May and 23 May. A modified pulse flow was an increase of 5 m^3/s for 24 hours. The mean daily flow for the South Alouette River at the Water Survey of Canada Station (232nd St. bridge) during this period averaged 7.64 m^3/s and ranged between 4.56 m^3/s and 13.70 m^3/s.

There were 181 sockeye smolts captured in the 224th St. rotary screw trap between 19 April and 19 May (Figure 3.24). These captures include 27 smolts that were mark recaptures from the Mud Creek trap upstream. In 2014, captures in the lower watershed at the 224th St. location closely tracked the captures immediately below the dam at the Mud Creek site (Figure 3.24). This pattern has been consistent for the last seven years (Figure 3.25). It was 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. It appears typical mean daily flows of between 3.0 m^3/s and 13.0 m^3/s were adequate to ensure movement of Alouette Lake sockeye smolts out of the system without delay.

In total, 150 sockeye smolts were marked and there were 12 recaptures for a mean trap efficiency of 8.0%. An accurate 2014 sockeye smolt out-migration population estimate could not be generated as the recaptures were not sufficient to avoid small sample bias (R>25, Ricker 1976). Nevertheless, for interests sake, the resulting 2014 out-migrant estimate was 2,358 (95% Confidence Interval 1,460 to 4,475). A 2014 sockeye smolt estimate of 13,413 out-migrants (95% Confidence Interval 12,423 to 14,404) was provided for the Mud Creek site (Figure 3.26; Mathews *et al*. 2015).

Assuming the difference in these estimates represent enroute mortality, the mean annual mortality for sockeye smolts migrating approximately 14 km from Mud Creek to 224th St. (approximately from the dam to tidewater) has ranged from 24.1 to 88.4% (Mean = 53.8%, n=8). A large portion of total smolt to adult natural mortality occurs during a short migration

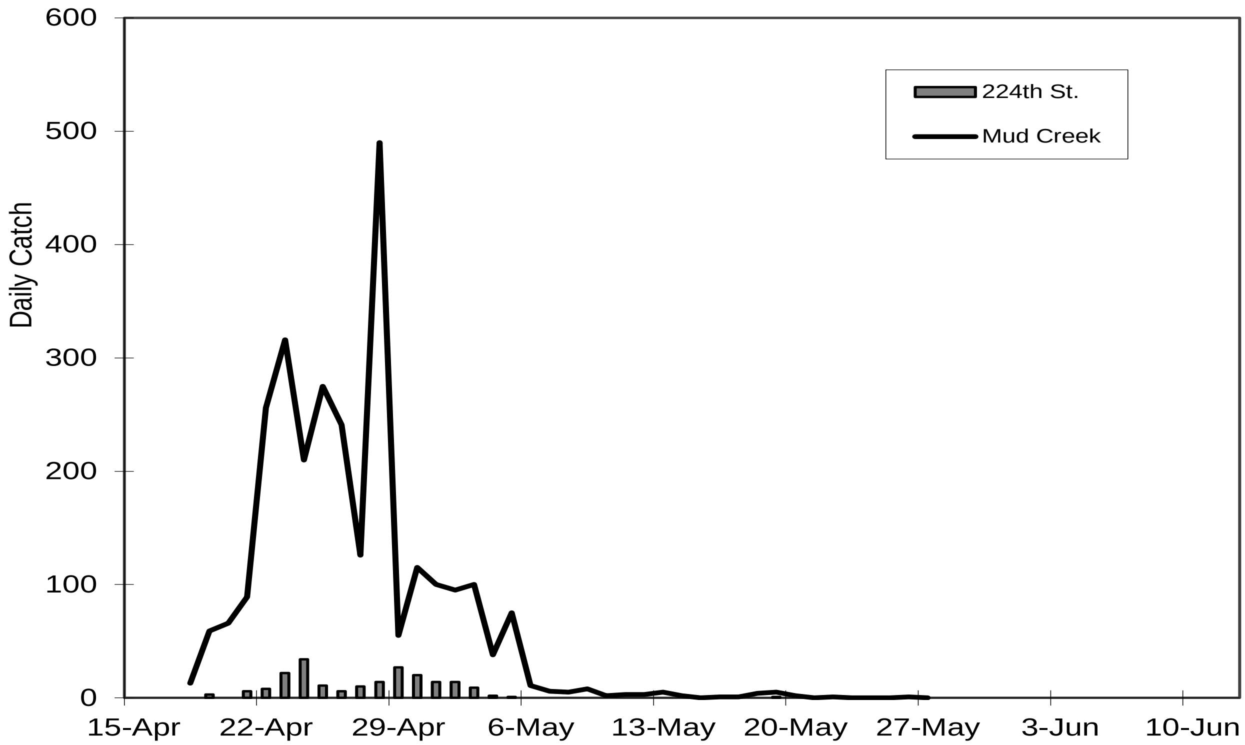

Figure 3.24. Daily sockeye smolt catch for the South Alouette River, 2014. Mud Creek data from LGL Limited (*see* Mathews *et al*. 2015).

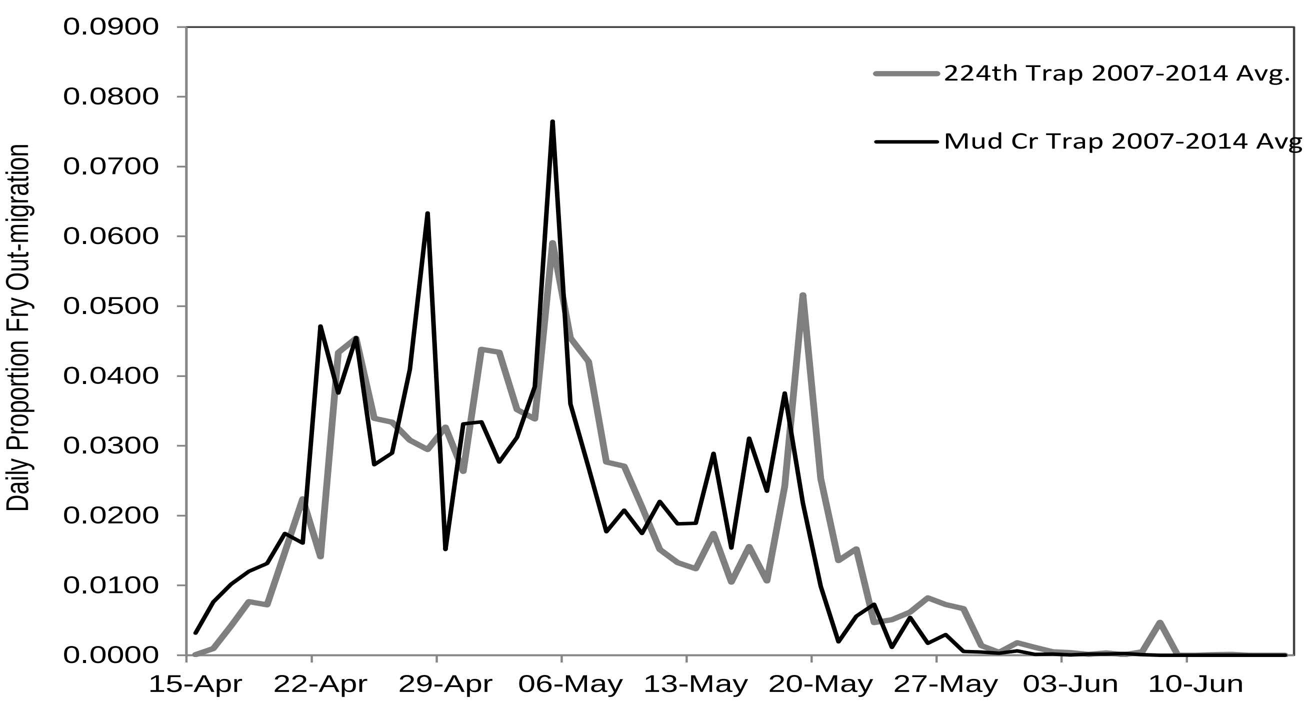

Figure 3.25. Daily sockeye smolt out-migration catch represented as a proportion of total annual catch illustrating the average out-migration timing (2007 – 2014).

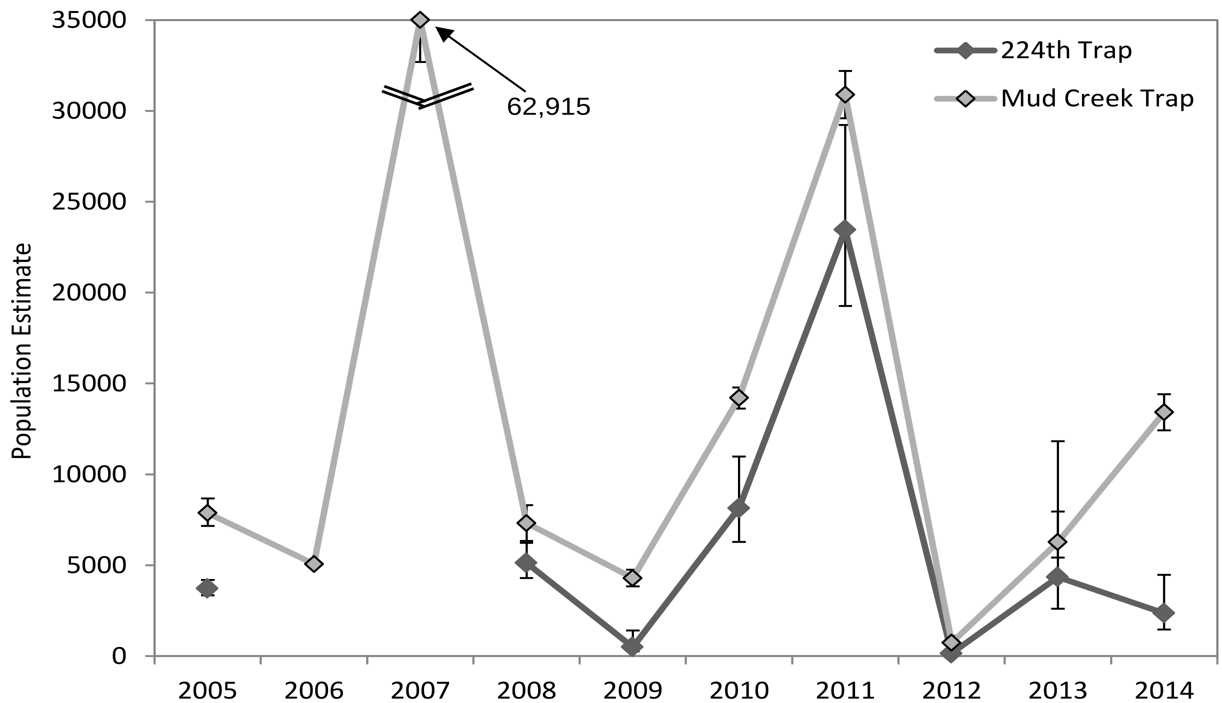

Figure 3.26. Summary of annual Alouette Lake sockeye smolt out-migration estimates (+/- 95% confidence interval) for the Mud Creek (upper watershed) and 224th Street (lower watershed) trapping locations. Mud Creek Data from LGL Limited (see Mathews *et al*. 2015). Note that Mud Creek confidence interval 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). Note that in some years minimum recapture targets necessary to avoid small sample bias (R>25) were not met.

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 80 mm (range 69 - 114 mm; n=150) and 4.5 g (range 2.7 – 12.1 g; n=148), respectively. Except for the first year of sockeye re-anadromization (2006), smolt size (mean annual fork length) has remained relatively constant the last 8 years (2007-2014, Figure 3.27).

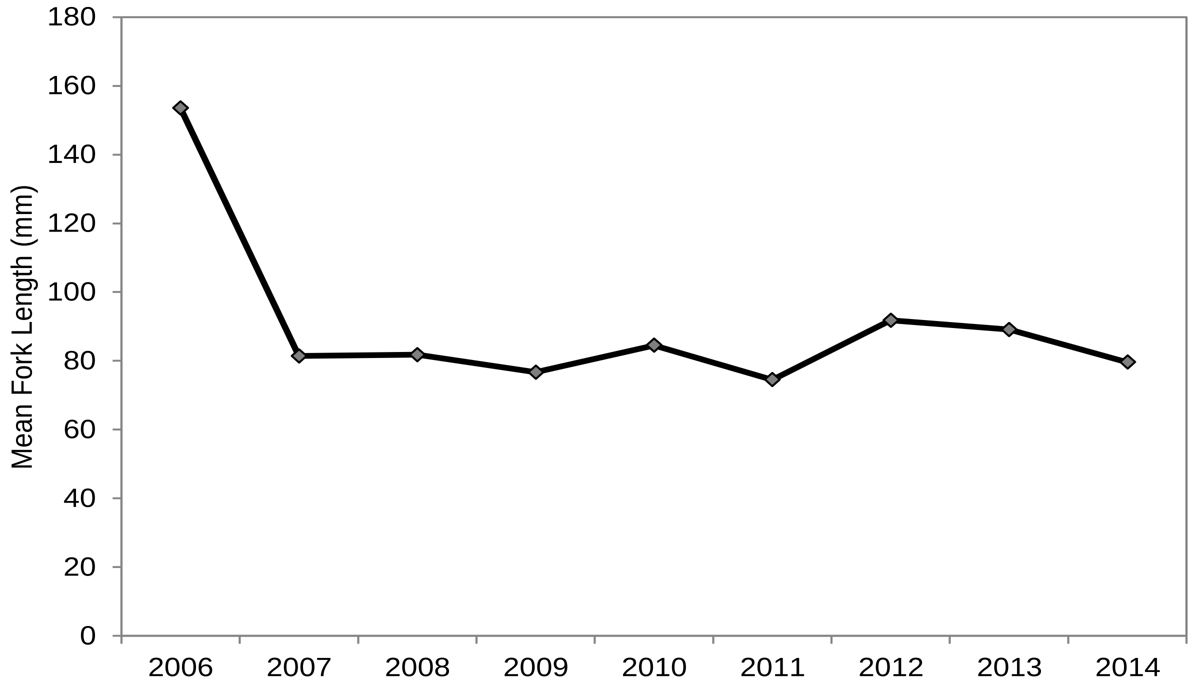

Figure 3.27. Summary of annual sockeye smolt size (fork length) for the South Alouette River, 224th Street Rotary Screw trap catch (2006 – 2014).

3.10. Physical Conditions

Mean daily water temperatures in the South Alouette River, during downstream trapping operations (3 March to 13 June 2014), ranged from 3.9 °C to 15.6 °C. The mean 2014 water temperature during the peak period of fry and smolt out-migration (18 March to 31 May) was 9.3 °C. This closely approximates the mean value observed over the last 17 years on record (Figure 3.28). The 17 year mean water temperature during the peak period of fry and smolt out-migration was 8.9 °C.

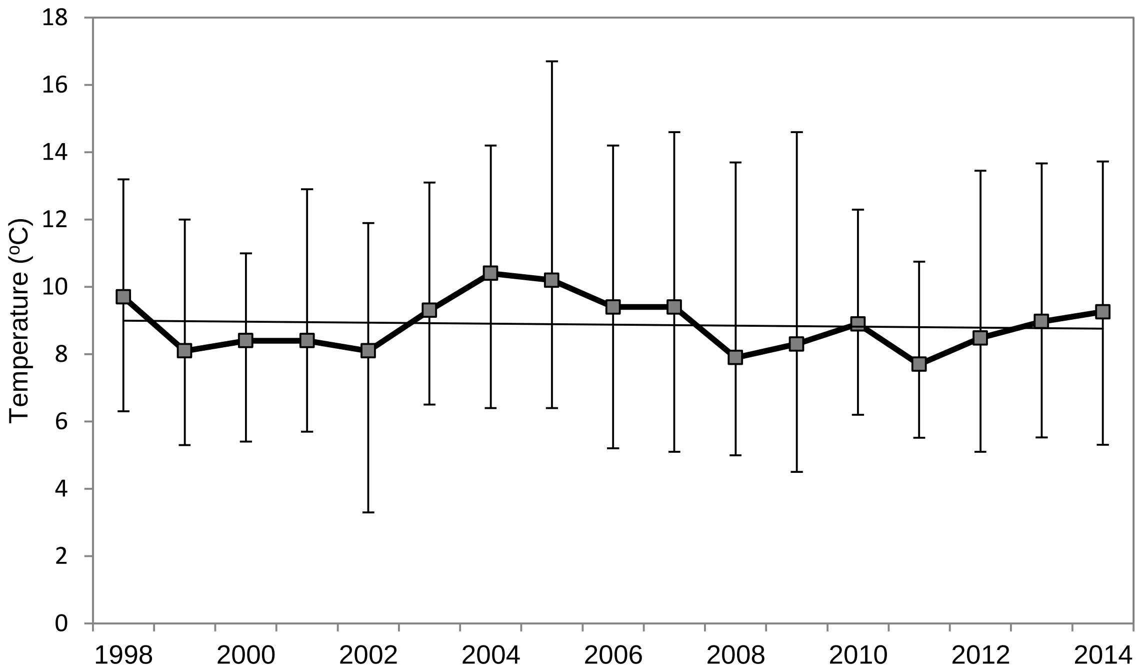

Figure 3.28. Mean, minimum and maximum mean daily water temperatures (°C) for the peak period of fry and smolt out-migration (18 March to 31 May) for the S. Alouette River downstream enumeration program (1998-2014).

Annual variation in mean daily water temperatures for the 1998 to 2013 period of record was illustrated in Figure 3.29 and the 2014 out-migration temperatures were overlain. In general, the 2014 fry out-migration water temperatures represented long-term averages and the smolt out-migration temperatures were higher than average (Figure 3.29).

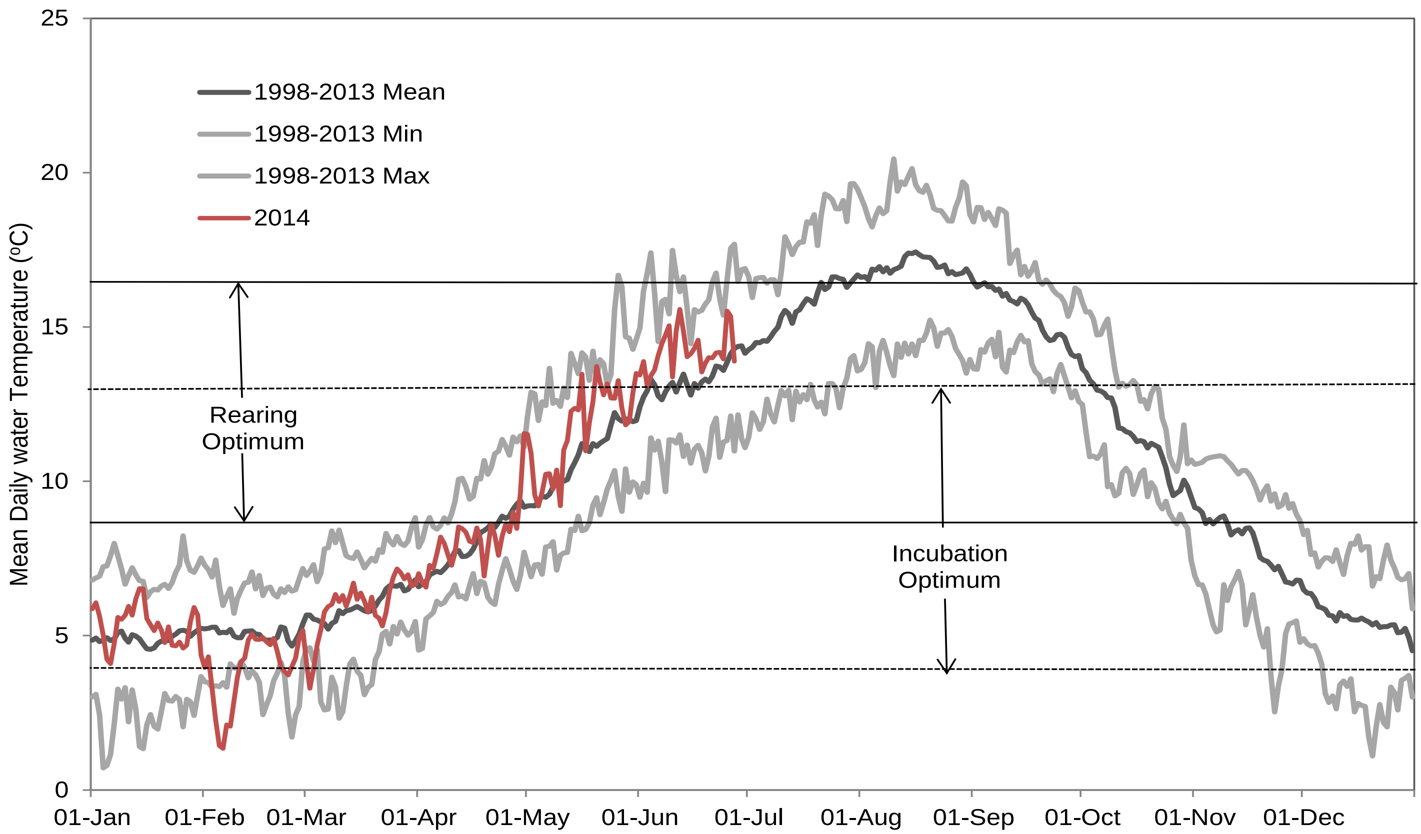

Figure 3.29. Mean daily water temperature for the mainstem South Alouette River at 224th St., 1998-2014.

Mean daily temperatures for the South Alouette River were generally within the provincial guidelines for optimum temperature ranges for incubation of salmon embryos (4.0 – 13.0 °C; Anon. 2001). Typically, there were 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 salmon. 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).

In general, water temperatures at the 224th St. location follow the typical pattern of generally remaining within the optimum temperature range for rearing coho salmon (9.0 – 16.0 °C; Anon. 2001) and juvenile rainbow trout/steelhead salmon growth (10.0 – 14.0 °C; Ford *et al.* 1995). The notable exception being that summer rearing temperatures approach or briefly exceed maximum optimum temperatures in August and September (Figure 3.29). Although this location was relatively low in the watershed, it was representative of the mainstem South Alouette River when compared to additional thermographs upstream (Cope 2006).

Mean daily discharge for the peak period of fry and smolt out-migration (25 February to 9 June) at the 232nd St. Water Survey of Canada Station (WSC No. 08MH005) was 7.2 m^3/s (range 3.5 – 14.8 m^3/s; Figure 3.30). This represents the second highest mean daily discharge on record. Only the flood year of 2007 which necessitated flood control releases from Alouette Dam was higher. Annual variation in mean daily discharge during the peak fry and smolt out-migration period for the 1998 to 2014 study years was illustrated in Figure 3.31. The extreme flows of 2007 were due to flood control releases and were not typical. The hydrometric station was not operating from 27 April, 2004 to 11 Apr, 2005 and data for the trapping period in these years was incomplete; therefore these years are excluded from the following discussion of average flows. The 14-year average mean daily discharge during the peak period of fry and smolt out-migration (excluding 2004, 2005, 2007, Figure 3.31) was 4.69 m^3/s. The difference of only 53% (2.52 m^3/s) between the 14 year mean daily flow and the highest mean annual flow illustrates the stable hydrograph resulting from upstream flow control.

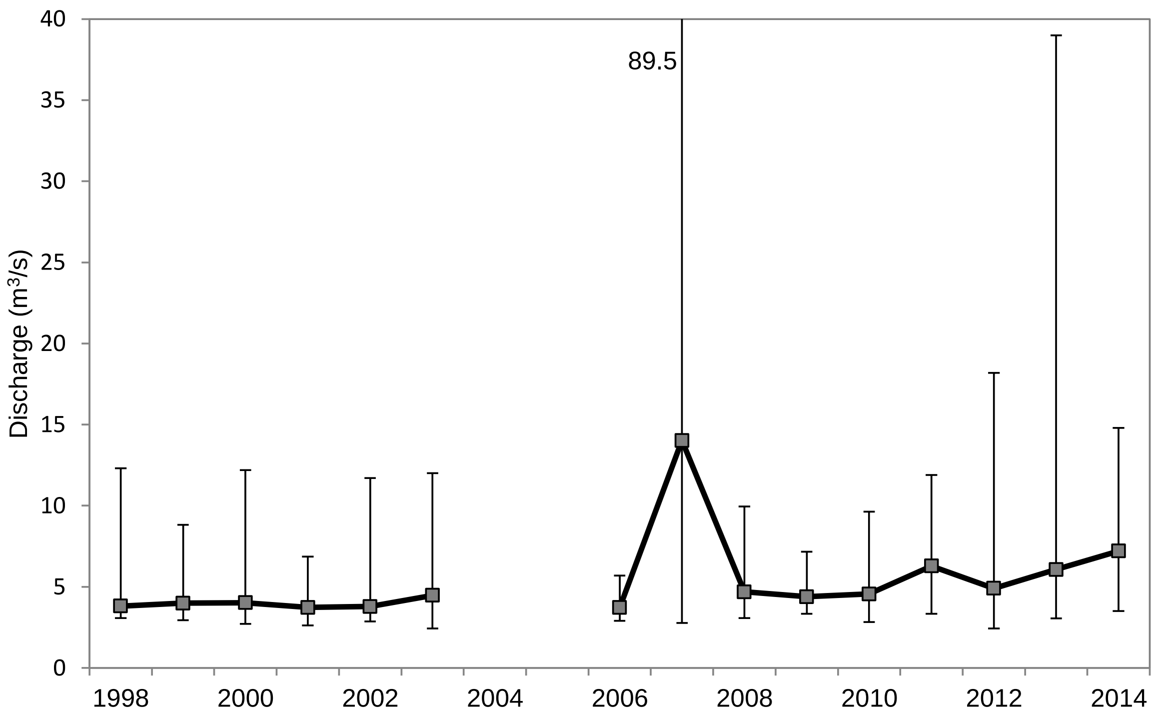

Figure 3.30. Mean, minimum and maximum daily discharge (m^3/s) for the peak period of fry and smolt out-migration (25 February to 9 June) for the S. Alouette River downstream enumeration program (1998-2014). Note that the hydrometric station was not operating from 27 April, 2004 to 11 Apr, 2005 and data for the trapping period in these years was incomplete.

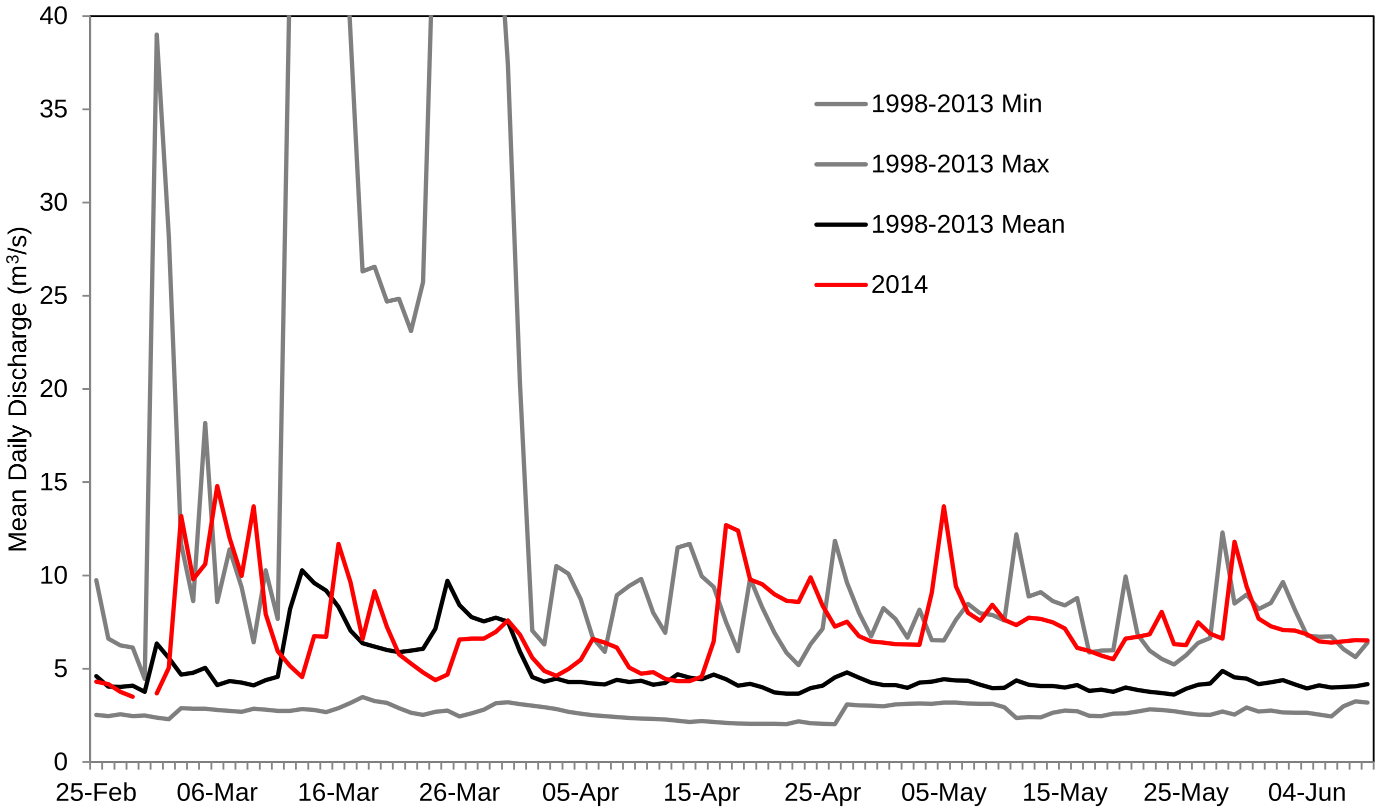

Figure 3.31. Mean daily discharge for the mainstem South Alouette River at Water Survey of Canada Station No. 08MH005 (232nd Street bridge), 1998-2014. Note that the 2014 data was preliminary and currently under review and revision.

The mainstem flows were controlled by the Alouette River Dam low-level outlet (outflow range 1.98 – 2.97) and typically, fluctuations in mainstem flows were due to tributary inflows resulting from precipitation events. Figure 3.31 illustrates there were six storm events that resulted in mean daily flows in excess of 8 m^3/s. In addition, a series of four modified pulse flows (*e.g.,* increase of 5 m^3/s for 24 hours) were provided between 12 May and 23 May. These effects resulted in flows that approached or exceeded daily maximums (n=17 years) in early March and mid-April through to cessation of trapping (13 June). This resulted in the second highest mean flows on record (during the smolt out-migration period).

3.11. Hypothesis Testing

The Fish Technical Committee (FTC) of the AMC identified three management questions that were to be addressed through the smolt enumeration program (BC Hydro 2010):

1. Is the average base-flow release of 2.6 m^3/s from the Alouette Dam (obtained by fully opening the low level outlet) adequate to sustain or improve current levels of salmonid smolt production downstream of the dam? The species of interest include chum, pink, Chinook, and coho salmon as well as steelhead and cutthroat trout.

Management Question 1 was to be tested individually for each species using the following hypothesis:

Ho1: Annual estimates of smolt abundance remain stable through time as indicated by a lack of a significant correlation between the two variables.

If Ho1 was rejected, the data was to be analysed for possible correlations with river discharge, water temperature, substrate quality and relative run strength using multiple regression techniques.

If Ho1 is not rejected, then the following null hypothesis was to be tested to determine whether there was sufficient between-year variance in annual smolt abundance to warrant further analysis:

Ho2: The between-year variance in annual estimates of smolt abundance is equal to or less than the average within year-variance of each annual smolt abundance estimate (or some other threshold level that may be indicative of an unstable rearing environment and or susceptibility to low seeding conditions).

If Ho2 was rejected, then tests of sub-hypotheses testing for possible correlations with river discharge, water temperature, substrate quality and relative run strength using multiple regression techniques was to be carried out.

Ho1 was not rejected as annual estimates of smolt abundance have remained stable through time as indicated by a lack of a significant correlation between the two variables for chum salmon (Figure 3.4, $p=0.92$, $r=0.03$, $n=17$) pink salmon (Figure 3.8, $p=0.35$, $r=0.36$, $n=9$), coho salmon (Figure 3.16, $p=0.085$, $r=0.43$, $n=17$) and Steelhead trout (Figure 3.20, $p=0.08$, $r=0.45$, $n=16$). Although there was a weak relationship for coho and steelhead this was due to the enumeration bias for the years 2003 to 2007. Enumeration bias was confirmed through field testing in 2007 (Cope 2007). Since 2009, when the trapping location was moved upstream and the trapping duration was extended by two weeks, smolt output has remained stable.

Ho2 was not tested. Instead the sub-hypotheses were examined for possible correlations with independent variables representing river discharge, water temperature, substrate quality and relative run strength (Appendix A, Table A1 and A2). Rather than multiple regression techniques these preliminary analyses consisted of separately plotting the independent variable as a function of smolt estimates. Chum salmon fry and coho salmon smolts were utilized for this preliminary analysis because these data were the most complete and have the greatest level of confidence in regards to their accuracy and precision.

Annual chum fry production was characterized by high variability and there was, as yet, no positive (*i.e.,* increasing) relationship for annual estimates of chum out-migrants (regression, p=0.92, r=0.03, n=17; *see* Figure 3.4). However, a non-linear relationship was 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 3.32 illustrates the emerging compensatory stock-recruitment relationship for South Alouette River chum salmon. The replication of low fry production results in 2007, 2010 and 2013 following similar high spawner escapements (*i.e.,* ALLCO fence count >125,000, 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 was not constant year to year but has hit the point of significant density-dependent mortality. This suggests that the 2006, 2009 and 2012 brood 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. Therefore, relative run strength appears to be influencing annual smolt output for chum salmon.

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 was due in large part to the high variability in smolt or under-yearling fry production and the low variability in the associated environmental data (Figure 3.33).

There was 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 3.34, regression, p=0.95, r=0.03, n=7). This suggests that fence counts were not a good indicator of coho run size in the river as a whole. This result was expected as coho are typically tributary spawners and the majority of tributary habitat was located downstream of the FRCC-ARMS hatchery fence.

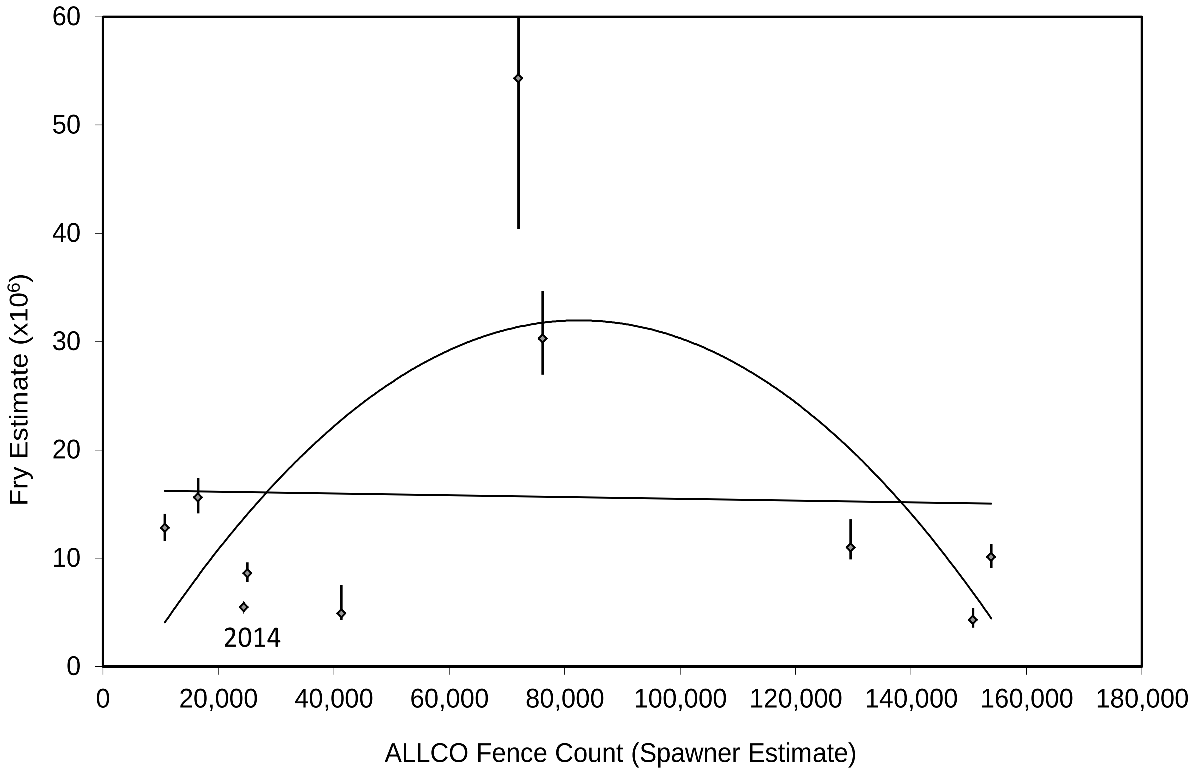

Figure 3.32. Relationship between chum salmon spawners enumerated at the FRCC-ARMS hatchery fence and the number of fry out-migrants the following spring.

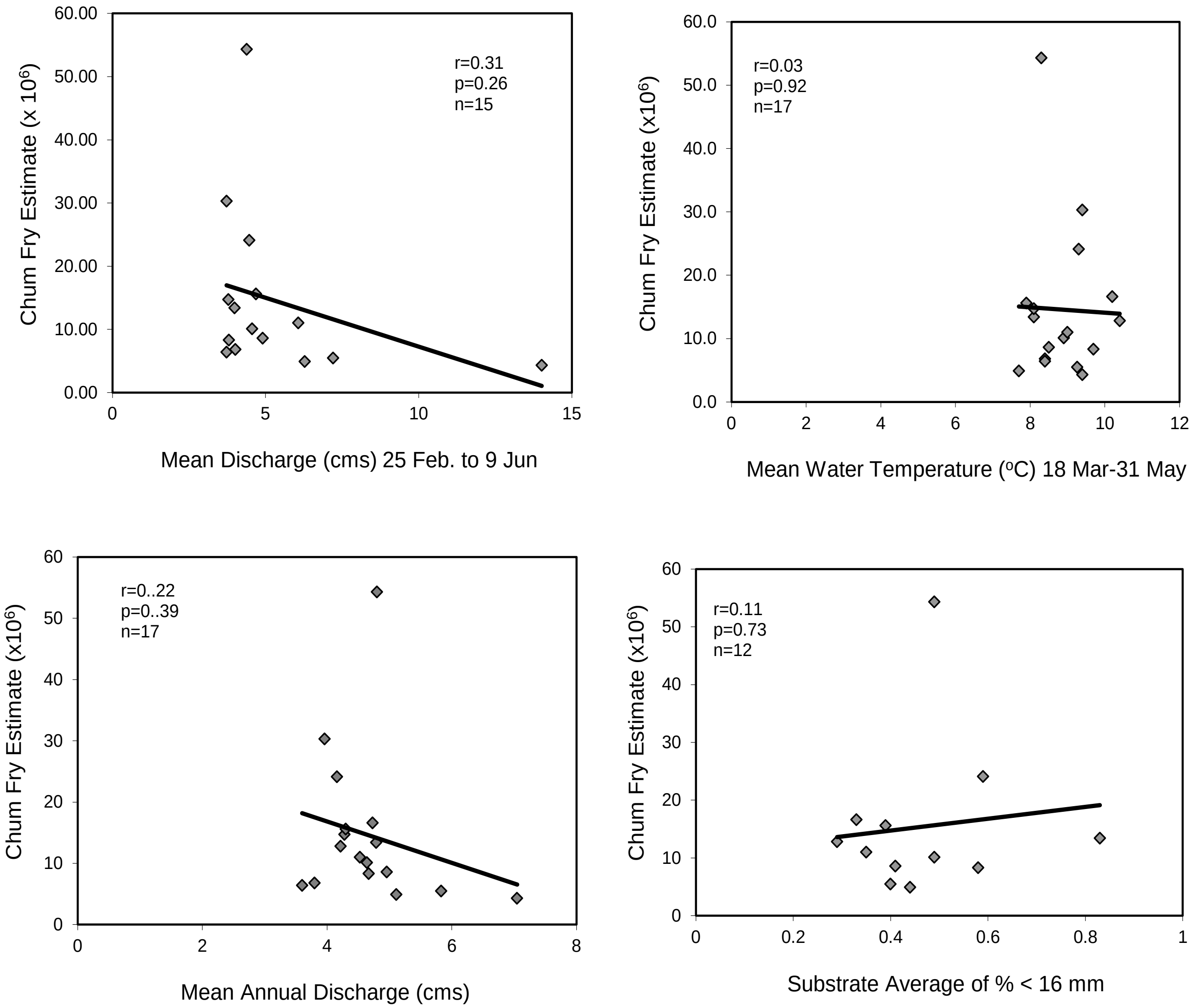

Figure 3.33. Relationship between chum fry production and environmental variables monitored within the South Alouette River.

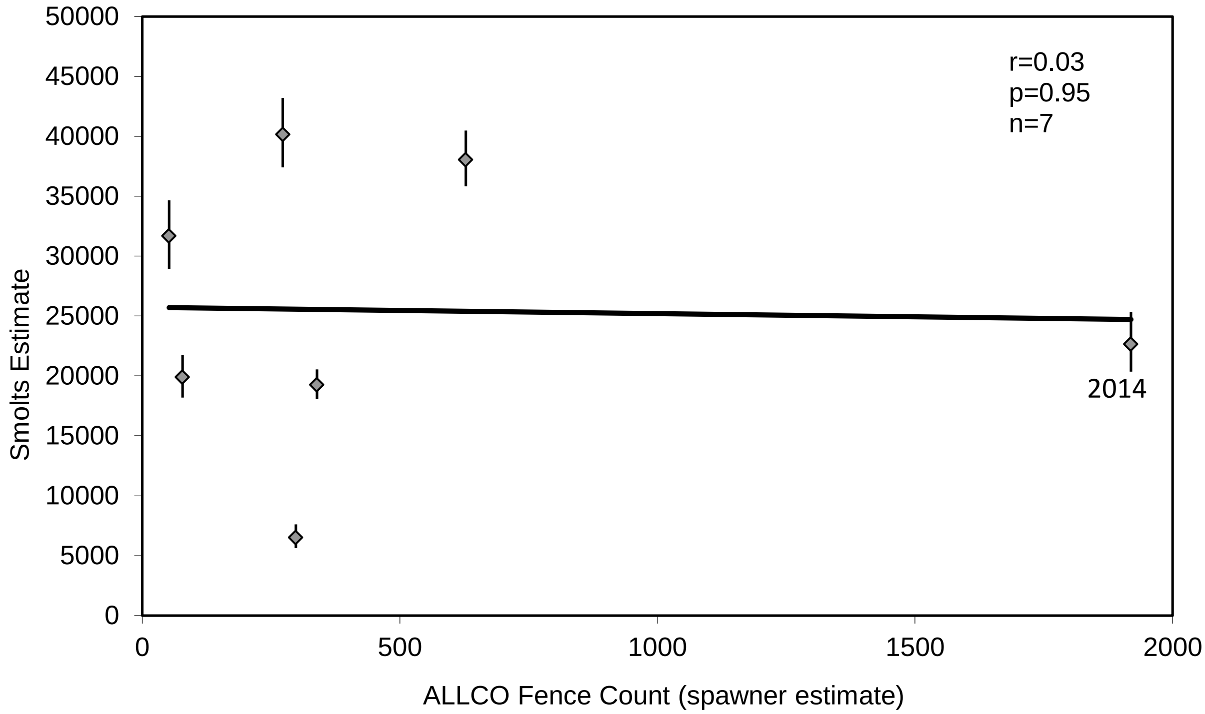

Figure 3.34. Relationship between coho salmon spawners enumerated at the FRCC-ARMS hatchery fence and the number of smolt out-migrants one year later.

There was a significant relationship between trapping duration and coho smolt out-migrant estimate (Figure 3.35; regression, $p<0.01$, $r=0.65$, $n=16$). This was due to the confounding effect of the increasing impact of tidal backwatering from the Pitt River on trapping efficiency at the previous (216th St.) trapping location (*i.e.,* 2003-2007). This effect was manifest as earlier end dates 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 was 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.

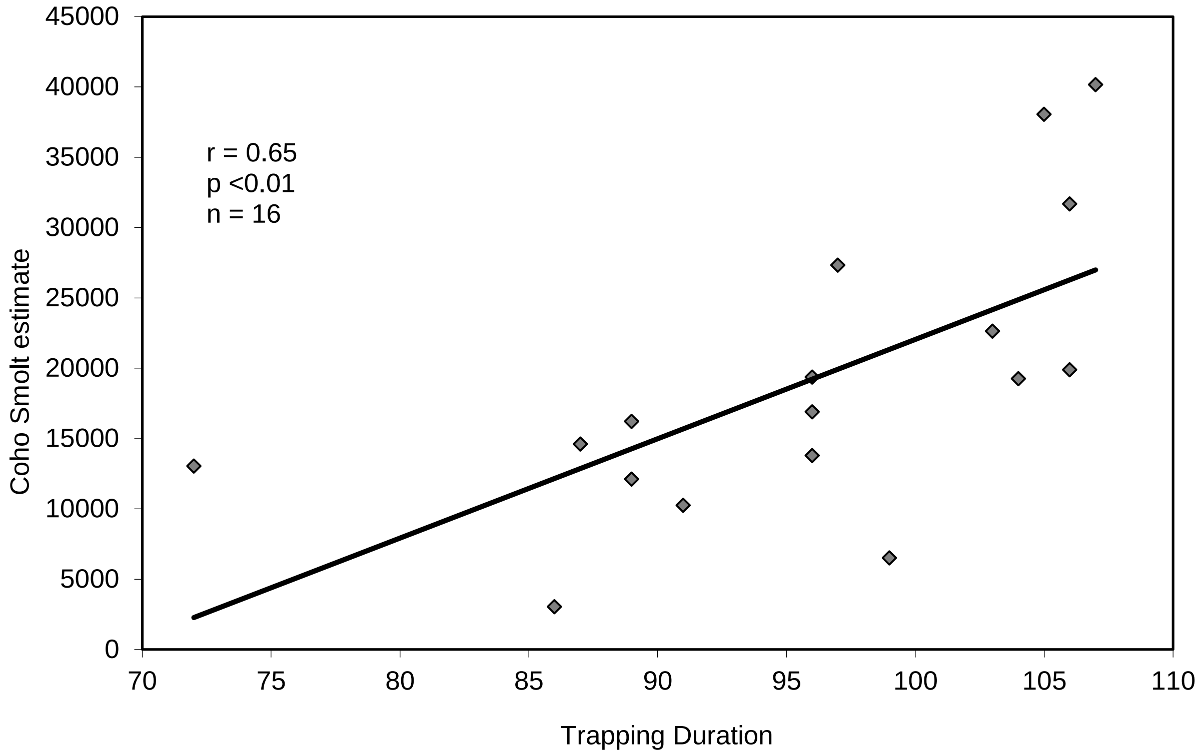

Figure 3.35. Relationship between trapping duration and coho smolt out-migrant estimate reflecting the effect of early trap backwatering in the years prior to 2008.

2. Following their migration out of Alouette Lake, do the kokanee (sockeye) smolts immediately continue their migration out of the Alouette River or do they delay their seaward migration for a period of time?

Sockeye (kokanee) smolts appear to continue their migration out of the Alouette River without delay (*i.e.,* the time difference in peak out-migration between the Mud Creek trap and the 224th St Bridge is less than a few weeks). Catch data for the Mud Creek and 224th St traps (Figures 3.24 and 3.25) illustrate a delay of only a day or two at most.

3. Using chum salmon counts at the ALLCO Park Hatchery as an indicator of run strength and the results of the substrate quality monitor, is there evidence of a persistent, declining trend in egg to smolt (fry or under-yearling smolt) survival that would suggest a degrading condition in spawning substrate quality.

There has been no evidence of a persistent, declining trend in egg to smolt (fry or under-yearling smolt) survival that would suggest a degrading condition in spawning substrate quality (Figure

3.33, p=0.73, r=0.11, n=12). On the contrary, there is evidence (Figure 3.32) that chum salmon escapements are at or exceed capacity in some years resulting in variable egg-to-fry survival year to year due to density-dependent mortality.

4. Discussion

4.1. Chum Fry

The 2014 chum salmon fry out-migrant estimate was 5.46 million smolts (95% confidence interval: 4.89 to 6.20 million; Table 4.1). There has been no significant increase in chum fry production over the duration of the study (regression, r=0.03, p=0.92, n=17). Population estimates suggest the South Alouette River egg-to-fry survival was not constant year to year and has experienced high density-dependent mortality in some years.

The rotary screw trap was 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, the annual estimate for South Alouette River chum fry (*e.g.,* under-yearling smolt) has averaged 14,606,470. This results in an estimated mean annual chum fry yield of 1,058,440 smolts/km (range 313,043 to 3,934,782 smolts/km) or 55.0 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 a similar 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 was 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 expected chum fry production benefits for off-channel fish habitat. 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 (55.0 smolts/m^2, range 16 – 205 smolts/m^2) was comparable to that expected from successful fish habitat restoration projects, and in some years, approaches the estimated production benefits expected from highly productive off-channel habitat.

Table 4.1. Cumulative catch (fry) and out-migration estimates for South Alouette River chum fry (1998 – 2014).

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	$4.3 – 6.9 \times 10^6$		
	2012	1,574,903	16.1	8.6×10^6	$7.7 – 9.6 \times 10^6$		
	2013	995,839	11.8	11.0×10^6	$9.9 – 12.5 \times 10^6$		
	2014	483,187	5.46	4.9×10^6	$6.2 – 12.5 \times 10^6$		

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

The replication of low fry production following high spawner escapements in 2006, 2009 and 2012 (*i.e.,* FRCC-ALLCO fence count >125,000) indicates that fence counts are a fair indicator of run size in the river as a whole and that egg-to-fry survival was not constant year to year. This was 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, 2009 and 2012 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 FRCC-ALLCO fence. The FRCC-ALLCO fence was 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 60,000 to 100,000 at the ALLCO fence would represent a total escapement of approximately 180,000 to 300,000.

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 was constant regardless of the number of spawners and that these survival estimates were still valid for the South Alouette River in subsequent years. It has been clearly demonstrated that these assumptions were not true given the compensatory stock-recruitment relationship emerging for South Alouette River chum salmon. For example, back-calculation of spawning escapement at very high escapements (*i.e.,* 2006, 2009 and 2012) were inaccurate. The maximum likelihood estimate back-calculated for the 2009 chum salmon spawning escapement was 77,973 fish. The ALLCO fence count was 153,882 and as previously pointed out this likely only represents about one third the escapement (461,646). The back-calculation estimator was inaccurate due to low egg-to-fry survival at high spawner escapements.

Prior to 1975, chum salmon spawner escapements were reduced to average run sizes of less than 3,000 spawners (Elson 1985).

4.2. Pink Fry

The 2014 pink fry out-migration estimate was 950,000 under-yearling smolts (95% confidence interval 730,378 to 1,400,946 fry). The 2014 pink fry estimate represents the second most productive year during the study period (1998-2014).

Just as with chum salmon, previous years have demonstrated that model assumptions of constant survival based on the lower chum salmon spawner escapement years of 1999 and 2000 were not valid. It was clear that pink salmon egg-to-fry survival also experiences density dependent mortality due to high chum spawner escapements in some years.

For example, in 2009 the FRCC-ALLCO fence count was the highest on record for pink salmon spawner escapement, yet the resulting fry out-migrant estimate in 2010 was the second lowest on record. Coincidentally, the chum salmon spawner escapement fence count was also the highest on record. In 2013, the pink salmon spawner escapement was average, the chum salmon spawner escapement was very low, and the resulting 2014 fry out-migration estimate was the second highest on record. The highest pink fry out-migration on record (2004) also followed the lowest recorded chum salmon escapement and average pink salmon escapement.

The FRCC-ALLCO fence was located approximately 7 km downstream of the Alouette Dam with approximately two thirds of the river length and the majority of the pink spawning habitat located downstream. This suggests average pink salmon escapements of 2,500 spawners (n=6) at the FRCC-ALLCO fence should represent at least 4,000 pink salmon.

In 1985, South Alouette River pink salmon were considered extirpated or locally extinct (Elson 1985).

Table 4.2. Cumulative catch (fry) and out-migration estimates for South Alouette River pink fry (1998 – 2014).

Species	Year	Catch	Mean Trap Efficiency (%)	Fry Estimate	95% C.I.	Egg-to-Fry (%)	95% C.I.
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		
	2012	21,944	7.5	289,844	233,040 – 370,736		
	2014	46,709	5.7	950,000	730,378-1,400,946		

* Includes hatchery captures

4.3. Chinook Fry

Based on the increasing trend in chinook salmon out-migrants during the past five years, chinook salmon appear to be responding to stocking efforts (regression; r=0.46, p=0.07, n=17). The pooled Peterson estimate for the 2014 chinook fry out-migrant population was 5,319 fish (95% confidence interval 4,343 to 6,672 fish). Chinook fry out-migration has ranged between 5,000 and 30,000 smolts over the last three years. Chinook out-migrant estimates were biased low due to the early end of trapping operations 14 June. Reliable population estimates would require continued trapping to at least the end of June to document the majority of the out-migration distribution. In 1985, South Alouette River chinook salmon were considered extirpated or locally extinct (Elson 1985).

4.4. Coho Smolts

In 2008, moving the rotary screw trapping location upstream to the 224th St. location upstream of the tidal backwatering influence and incorporating flow deflection panels was successful in restoring smolt catch. In 2009, extending the duration of trapping to 14 June enabled the more complete capture of the out-migration, resulting in much improved population estimates. The 2014 coho smolt out-migration estimate was 22,632 fish (95% Confidence Interval 20,354 to 25,321). This represents the second year in a row coho smolt production has declined, however; was still within the range of recent years. Since 2009, the annual coho smolt estimate has averaged 28,605 (range 19,240 to 40,156) compared to 15,000 smolts previously (1998 – 2008 excluding 2007 failure; Table 4.3).

Based on the last six years (2009-2014) results at the current location and duration, the mean coho smolt yield upstream of the RST has been 2,072 smolts/mainstem km (range 1,394 to 2,910) or 10.8 smolts/100m^2 (range 7.2 to 15.1; Table 4.4). 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. By comparison, the Coquitlam River produced an average of 1,893 smolts/km during a similar period (Table 4.4, 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

Table 4.3. Cumulative catch (smolt) and out-migration estimates for South Alouette River coho smolts (1998 – 2014).

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
	2012	9,878	25.9	38,046	35,824 – 40,484
	2013	5,452	17.3	31,673	28,941 – 34,662
	2014	3,345	15.9	22,632	20,354 - 25,321

* Includes Hatchery Captures.
+ Second Rotary Screw Trap (1.8 m dia.) added.
++Trapping ended approximately 1 week earlier than previous years.

Table 4.4. Summary of estimated coho smolt yields and densities for select watersheds within the southern coastal region of British Columbia.

River	Year	Km[1]	Smolt Yield Mean	Smolt Yield Range	Smolts/km Mean	Smolts/km Range	Smolts/100 m[2] Mean	Smolts/100 m[2] Range
S. Alouette	1998-2008[2]	14.8	15,000	6,508- 20,003	1,014	440- 1,352	5.3	2.3-7.0
	2009-2012	13.8	28,605	19,240- 40,156	2,072	1,394- 2,910	10.8	7.2-15.1
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.

(Cheakamus, Seymour) that are also currently being monitored using similar enumeration methodology (Table 4.4.).

The differences in coho smolt yield illustrated in Table 4.4 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 4.4, 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).

4.5. Steelhead Smolts

In 2008, moving the rotary screw trapping location upstream to the 224th St. location upstream of the tidal backwatering influence and incorporating flow deflection panels was successful in restoring smolt catch. In 2009, extending the duration of trapping to 14 June enabled the more complete capture of the out-migration, resulting in much improved population estimates (Table 4.5). The 2014 steelhead smolt out-migration estimate was 4,610 fish (95% Confidence Interval 3,422 to 6,560). Since 2008, the annual steelhead smolt estimate has averaged 5,630 fish (range 4,610 to 6,204; excluding 2010 anomaly) compared to 2,531 fish (range 784 to 3,768) previously (1999 – 2006; Table 4.5).

During 2008 to 2014 (excluding 2010 anomaly), steelhead smolt yield upstream of the RST averaged 408 smolts/km (range 334 – 450) or 2.1 smolts/100m^2 (range 1.7 – 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, tidal backwatering and early cessation of trapping (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 five years trap efficiency at this location. The low trap efficiency for steelhead smolts in 2010 remains unexplained (Table 4.5). The 2010 outlier will be re-examined if, in the future, estimates replicate this result.

Average South Alouette River steelhead smolt densities (2.1 smolts/100m^2, range 1.7 to 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 a similar 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 was 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 4.6).

Table 4.5. Cumulative catch (smolt) and out-migration estimates for South Alouette River steelhead smolts (1998 – 2014).

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
	2012	737	12.3	5,778	5,110 – 6,457
	2013	573	9.7	5,917	4,341 – 8,565
	2014	470	11.3	4,610	3,422 – 6,560

+ Second Rotary Screw Trap (1.8 m dia.) added.
++Trapping ended approximately 1 week earlier than previous years.

Table 4.6. Summary of estimated steelhead 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[5]	Mean	Range	Mean	Range	Mean	Range
S. Alouette	2008-2013	13.8	5,630	4,610-6,204	408	334-450	2.1	1.7-2.3
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.

4.6. Sockeye Salmon

Despite the low re-capture results (n=12) that were below target objectives to avoid small sample bias; the 2014 sockeye smolt out-migration estimate was 2,358 smolts (range 2,597 – 11,818; Table 4.7). A 2014 sockeye smolt estimate of 13,413 out-migrants (95% C.I. 12,423 – 14,404) was provided for the Mud Creek site (Figure 3.26; Mathews *et al*. 2015).

The mean annual estimated mortality for sockeye smolts migrating the approximately 14 km from the Mud Creek RST to the 224th Street RST (approximately from the dam to tidewater) has ranged from 24 to 88% (Mean 53.8%, n=8); assuming the difference in estimates between traps was an accurate representation of enroute mortality. 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 was 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, annual flushing flow dam releases (2009-2011, 2014) of 5 or 6 m^3/s did not “flush out” reluctant sockeye migrants residing within the South Alouette River. Therefore, it appears typical mean daily flows of between 3.0 to 6.0 m^3/s were adequate to ensure movement of Alouette Lake sockeye smolts out of the system without delay.

Table 4.7. Cumulative catch (smolt) and out-migration estimates for South Alouette River sockeye smolts (1998 – 2014).

Species	Year	Catch	Mean Trap Efficiency (%)	Population Estimate	95% Confidence Interval
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
	2012	28	N/a		
	2013	205	4.2	4,349*	2,597 – 11,818
	2014	181	8.0	2,358*	1,460 – 4,475

* Recaptures below target (R>25) required to avoid small sample bias.
\+ Second Rotary Screw Trap (1.8 m dia.) added.
++Trapping ended approximately 1 week earlier than previous years.

5. Summary and Conclusions

Results to date are summarized below within the context of the three management questions identified by the Alouette Management Committee that were to be addressed through the smolt enumeration program:

1. Is the average base-flow release of 2.6 m^3/s from the Alouette Dam (obtained by fully opening the low level outlet) adequate to sustain or improve current levels of salmonid smolt production downstream of the dam? The species of interest include chum, pink, chinook, and coho salmon as well as steelhead and cutthroat trout.

The null hypothesis (Ho1) was accepted for chum, pink, coho and steelhead salmon as annual estimates of smolt abundance for these species has remained stable through time as indicated by a lack of a significant correlation between the two variables. In addition, bio-standards suggest that chum smolt (under-yearling fry) productivity in the South Alouette River was comparable to that expected from successful fish habitat restoration projects, and in some years, approaches the estimated production benefits expected from highly productive off-channel habitat. Coho smolt yields were within the range expected for Pacific Northwest streams of similar latitude to the South Alouette River and steelhead smolt yields meet or exceed the Provincial bio-standards. Chinook salmon and cutthroat trout were inconclusive given the low capture rates; however, increasing catch rates for wild-reared chinook salmon under-yearling smolts suggest this species was responding to stocking efforts.

Sub-hypotheses were examined for possible correlations with independent variables representing river discharge, water temperature, substrate quality and relative run strength. Relative run strength (density-dependent mortality) illustrated a strong effect on fry or under-yearling chum fry production. This was expected and suggests that in some years the South Alouette River chum salmon spawning meets or exceeds capacity. The remaining environmental variables examined illustrated little effect on chum fry production. This was due in large part to the high variability in smolt or under-yearling fry production and the low variability in the associated environmental data.

2. Following their migration out of Alouette Lake, do the kokanee smolts immediately continue their migration out of the Alouette River or do they delay their seaward migration for a period of time?

The null hypothesis (Ho3) was accepted based on the catch data for the Mud Creek and 224th St. traps that illustrate a delay of only a day or two (*i.e.,* Ho3; the time difference in peak out-migration between the Mud Creek trap and the 224th St Bridge is less than a few weeks).

3. Using chum salmon counts at the ALLCO Park Hatchery as an indicator of run strength and the results of the substrate quality monitor, is there evidence of a persistent, declining trend in egg to smolt (fry or under-yearling smolt) survival that would suggest a degrading condition in spawning substrate quality.

There has been no evidence of a persistent, declining trend in egg to smolt (fry or under-yearling smolt) survival that would suggest a degrading condition in spawning substrate quality. On the contrary, there is evidence (Figure 3.32) that chum salmon escapements are at or exceed capacity in some years resulting in variable egg-to-fry survival year to year due to density-dependent mortality.

In 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 estimated to range between 4,000 to 20,000 spawners.
- Chinook salmon have re-colonized the South Alouette River and, based on the increasing trend in wild reared chinook salmon out-migrants during the past four years, chinook salmon appear to be responding to stocking efforts.
- Since 2009, the annual wild coho smolt production has averaged 28,605 smolts and the coho smolt yield averaged 2,072 smolts/km or 10.8 smolts/100m^2; which was comparable to both the Coquitlam River yield and the average yield predicted for streams of similar latitude (Bradford *et al.* 1997); but lower than other regional populations that are also currently being monitored using similar enumeration methodology.
- Since 2008, the annual wild steelhead smolt production has averaged 5,630 fish and the steelhead smolt yield was 408 smolts/km or 2.1 smolts/100m^2. Although steelhead smolt

yields meet or exceed the Provincial bio standards, they were lower than other regional steelhead populations that are also currently being monitored using similar enumeration methodology.

- Prior to 2007, the South Alouette River stock of sockeye salmon was considered extinct. 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.

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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

Year	Chum Fry Estimate	Low 95% C.I.	High 95% C.I.	Broodyear	ALLCO Fence Count	WSC 08MH005 Mean Discharge (CMS) (25 Feb - 9 June)	WSC 08MH005 Mean Annual Discharge (CMS)	224th ST. Mean Water Temp. (deg. C.) (18 Mar-31 May)	224th St. Mean Annual Water Temp. (deg. C.)	Surficial Substrate Particle Distribution Average of % < 2 mm	Average of % < 4 mm	Average of % < 8 mm	Average of % < 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	5.11	7.7	9.03	0.26	0.37	0.38	0.44
2012	8,600,000	7,800,000	9,600,000	2011	25,042	4.91	4.96	8.5	9.20	0.21	0.3	0.37	0.41
2013	11,000,000	9,900,000	12,500,000	2012	129,554	6.07	4.53	9.0	10.00	0.24	0.27	0.3	0.35
2014	5,460,000	4,890,000	6,200,000	2013	24,397	7.21	5.83	9.30	10.80	0.29	0.32	0.36	0.40

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
2012	38,046	2438	2222	2011	628	4.91	4.96	8.5	10.24	0.21	0.3	0.37	0.41
2013	31,673	2989	2732	2012	52	6.07	4.53	9.0	10.00	0.24	0.27	0.3	0.35
2014	22,632	2689	2278	2013	1,919	7.21	5.83	9.30	10.80	0.29	0.32	0.36	0.40