Alouette Project Water Use Plan

Kokanee Out-Migration

Implementation Year 4

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Study Period: 2011

LGL Limited

February 2012

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Evaluation of the Migration Success of *O. nerka* (Kokanee / Sockeye) from the Alouette Reservoir, 2011

Prepared for:

BC Hydro
Water License Requirements
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EXECUTIVE SUMMARY

In order to assess the feasibility of Sockeye re-introduction into the Alouette Reservoir, studies are being conducted to determine the migration success of *O. nerka* (*Oncorhynchus nerka*) from the reservoir. This was the seventh year of study of juvenile salmon migration from the Alouette Reservoir. In 2005, spillway releases at the Alouette Dam occurred from 3 May to 3 June to evaluate the migration success of marked Coho smolts as they were captured in the Mud Creek rotary screw trap (RST). In 2006, spillway releases at the Alouette Dam again occurred from 11-31 May to evaluate the migration success of marked Steelhead from the reservoir. In both years coincidental *O. nerka* emigrations were also monitored and an estimated 7,900 and 5,064 *O. nerka* smolts migrated from the reservoir respectively. From 2007 – 2010, *O. nerka* smolts again migrated from the reservoir during spillway releases and total estimates of out-migrants ranged from 4,287 (3,833 – 4,741; 95% CL) in 2009 to 62,923 (48,436 – 77,410; 95% CL) in 2007.

The Mud Creek RST was again operated in 2011 for the duration of the *O. nerka* migration from the Alouette Reservoir. A total of 8,525 migrants were captured and a pooled Peterson yielded a total estimate of 35,542 smolts (34,034 – 37,051; 95% CL) for the duration of the migration period, 15 April to 8 June. Spillway gate flows were maintained at similar levels as past years, ranging from 3.31-4.32 m^3/s until 1 June, after which a seven day post-surface release flush reached maximum flows of 6.21 m^3/s.

Biosampling conducted on the migrating *O. nerka* smolts included length, weight, age and genetic sampling. The 2011 migrants were most abundant in the 71-75 mm length class and the average weight of all *O. nerka* sampled was 4.5 grams.

For the third year in a row a post-surface release flush occurred at the end of the typical migration timing. During the 2009 flush the RST was unable to be monitored safely and consistently hence no conclusions were drawn regarding the impact of the flush. The 2010 flush monitoring proved successful and no increases in *O. nerka* catch were observed during the flushing flows (only one unmarked *O. nerka* was captured). The 2011 flush monitoring again proved to be feasible and although a total of 86 unmarked migrants were captured, catches were consistent for the tail end of the migration, hence no increases in *O. nerka* catches were observed due to the flushing flows.

In addition to monitoring *O. nerka* migrations, all other species captured were enumerated. This included monitoring Steelhead smolt captures of which there were a total of 350 at the Mud Creek RST in 2011.

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INTRODUCTION

Numerous interested parties in the Alouette Watershed, including government agencies, the Katzie First Nation, stewardship groups, environmental Non-Government Organizations (NGOs), and concerned citizens have a vision of restoring historic salmon runs above the Alouette Dam at the outlet of the Alouette Reservoir. Among other things, salmon re-introduction to the Alouette Reservoir hinges on determining whether or not sufficient numbers of juvenile salmonids (smolts) will exit over the dam at the south end of Alouette Reservoir or through the diversion to Stave Lake at the north end of Alouette Reservoir. A previous feasibility assessment on fish passage by Bengeyfield et al. (2001) suggested that the majority of out-migrating smolts would orient to the much higher diversion flows in watersheds with inter-basin water transfers (Alouette, Coquitlam and Carpenter). As a consequence, Bengeyfield et al. (2001) believed there was a reduced likelihood of successful re-introduction of anadromous salmonids above dams in these watersheds.

In 2002, LGL Limited developed a framework for evaluating fish passage issues in the Bridge-Coastal hydro operating area (Bocking and Gaboury 2002). Following this, the Bridge Coastal Restoration Program (BCRP) sponsored an evaluation of the feasibility of restoring anadromous fish passage into the Alouette Reservoir (Gaboury and Bocking 2004). Numerous recommendations were made for future studies to address the fish passage question at Alouette Reservoir. To address the issue of whether smolts would exit over the dam or the diversion to Stave Lake, the BCRP sponsored a study in 2005 that monitored the migration of Coho smolts out of the Alouette Reservoir and down the South Alouette River using unique colours of visible implant elastomer tags during a test surface release of ~ 3 m^3/s from the Alouette Dam (Baxter and Bocking 2006). Estimated migration success rates of Coho smolt to the Lower Alouette River ranged from 79% for smolts released at the spillway to 31% – 38% for smolts released in the reservoir. The 2005 study also monitored the migration of acoustic transmitter-tagged Kokanee / Sockeye or *O. nerka* (raised to a suitable size) for subsequent detection in listening arrays in the lower Fraser, Juan de Fuca Strait, and Strait of Georgia. Estimated migration success from the release location was 26% to the lower Fraser detection array and 5.3% to the Juan de Fuca detection array. In 2005, an estimated 7,900 *O. nerka* also emigrated from the reservoir. This unexpected result prompted the Water Use Plan Consultative Committee (WUP CC) to recommend the surface release be done annually.

In 2006, a study was conducted to monitor Steelhead smolt migration success out of the Alouette Reservoir and down the South Alouette River using both visible implant elastomer tags and adipose fin clips (Humble et al. 2006). The estimated migration success rate to the Lower Alouette River was only 5.8% for Steelhead smolts released in the reservoir. This low rate was believed to be, at least in part, related to the delayed opening of the spillway gate due to low water levels in the reservoir. The 2006 project also provided a second year of *O. nerka* passage with an estimated 5,064 *O. nerka* migrating from the reservoir during the surface release flow of ~ 3 m^3/s.

The 2005 and 2006 study results indicated that *O. nerka* were successfully migrating from the Alouette Reservoir and suggested the potential for adult Sockeye returns as early as 2007. In

order to begin assessing the feasibility of Sockeye re-introduction into the Alouette Reservoir, the 2007 smolt study was conducted to determine the volitional migration success of *O. nerka* from the reservoir during the surface release flow of ~ 3 m^3/s. In 2007, a total of 7,787 *O. nerka* were captured in the Mud Creek RST located 1.5 km downstream of the dam, as they migrated, yielding a total estimate of 62,923 (48,436 – 77,410; 95% CL) *O. nerka* that emigrated from the Alouette Reservoir (Mathews and Bocking 2007). Supported by the previous three years of results and as part of the Water Use Plan, the surface release flow was planned to continue annually with the expectation of re-establishing a Sockeye run. As monitoring continued in 2008, a total of 3,224 *O. nerka* were captured at Mud Creek from 15 April to 26 May. The total 2008 migration was estimated to be 8,257 fish and included a mark-recapture estimate of 7,712 (6,682 – 8,742; 95% CL) from 21 April to 8 May and an additional 545 migrants based on trap efficiency outside of the marking period (Mathews and Bocking 2009). Monitoring continued at Mud Creek throughout the 2009 migration; in total 1,247 *O. nerka* were captured in the RST, yielding a total estimate of 4,287 (3,833 – 4,741; 95% CL) for the period of 21 April to 28 May 2009 (Mathews and Bocking 2010). Monitoring again occurred during the 2010 migration however two study sites were planned to be used. The Mud Creek RST was initially intended to operate as a recapture site only as two inclined plane traps (IPTs) were operated side by side approximately 500 m upstream and were intended to operate as the marking site. The IPTs were also intended to be used as a safe and effective trapping method during the flush. However, after numerous modifications to the IPTs and the trapping site they proved to be unsuccessful at catching *O. nerka* smolts and were removed in early May. Fortunately the RST was able to be operated as both the mark and recapture site (as has been the case in previous years) and was also used safely and effectively during the 2010 flush period. In total 4,600 *O. nerka* were captured at the RST, yielding a total estimate of 14,201 (13,624 – 14,778; 95% CL) from 18 April to 24 May. An additional 1,233 migrants were estimated based on trap efficiency (37.2%) outside of the marking period, resulting in a total estimate of 15,434 *O. nerka* (Mathews and Bocking 2011).

In the summer of 2007, 28 adult Sockeye returned to the Alouette River; DNA and scale sample analysis indicated these fish were from the 2005 *O. nerka* smolt emigration from the reservoir. During the summer of 2008, 54 adult Sockeye returned to the Alouette River and genetic analysis indicated no discernible difference between these returning adults and the *O. nerka* smolt migrants (Mathews and Bocking 2009). Adult returns continued in 2009 as 45 Sockeye returned to the outlet of the Alouette Reservoir; 15 of these fish were tagged and tracked with radio telemetry to help determine the spawning location and timing of returns (Plate and Bocking 2010). The 2010 Alouette adult Sockeye returns proved to be the largest run thus far as 113 migrants returned to the outlet of the reservoir. Radio telemetry was again used to help determine spawning locations and timing; 20 Sockeye were tagged and tracked (Plate and Bocking 2011). These four years of returns, along with the continued smolt migration, lend support to the expectation that an Alouette River Sockeye run, extirpated since the mid 1920s following the impoundment of the reservoir, could be re-established.

The revised Alouette Water License issued in April 2009 confirmed the surface release and associated *O. nerka* out-migration enumeration through 2014. Due to run timing uncertainty, it has been proposed that the surface release be done for a period of 8 weeks and annual monitoring

of the migration should continue to identify the typical start, duration and peak in hopes of shortening the duration of the release and reducing the corresponding flood risks. Although the migration timing has remained relatively consistent during the three years of full season monitoring there have been differences in peak timing and duration. Both the 2009 and 2007 migrations continued approximately an additional week after the 2010 and 2008 migrations tapered off, and the 2009 peak occurred in the latter half of May while the peaks of 2010, 2008 and 2007 occurred late April. The 2010 migration also began with high catches immediately once the spillway was opened. Subsequent years of monitoring are, therefore, beneficial to help to improve the understanding of the timing of the run.

To address the uncertainty of whether the current magnitude of release is sufficient to promote migration among all seaward smolts, an experimental post-surface release flush was proposed for every second year of monitoring to determine if a doubling of flows for seven days could induce additional migrants to move out of the reservoir. The first year of flush was attempted in 2009 and was scheduled for seven days at the tail end of the migration. However once flows reached a maximum of 6.5 m^3/s the integrity of the RST and safety of the crew and fish captured became a concern so the flush was terminated after three days. Given the unsuccessful attempt of the first year of the post surface release flush it was proposed the flush occur again in 2010 with an alternative gear type, inclined plane traps, which could be operated safely during high flows. Due to the lack of success with the IPTs *O. nerka* capture rate modifications to the operational and safety plans were made and allowed the RST to be operated safely and effectively during the seven day flush period.

Management Questions

Three management questions are to be addressed throughout the subsequent years of monitoring:

1. Is the surface release of at least 3 m^3/s from the Alouette Dam (obtained through the spillway gate) adequate to promote the downstream migration of *O. nerka* smolts out of the Alouette Reservoir?

To address Question 1, the following hypothesis will be tested:

H_O1: The seaward movement of Kokanee smolts, as identified from RST data collected at the confluence of Mud Creek, has a start, peak and end that is characteristic of Kokanee / Sockeye smolts found in other systems (e.g., Cultus Lake Sockeye).

2. Does a post-surface release flush of 6-9 m3/s, lasting 7 days following the tail end of the out-migration period, encourage more smolts to leave the system?

To address Question 2, the following hypothesis will be tested:

H_O2: The seaward movement of Kokanee smolts, as identified from RST data collected at the confluence of Mud Creek, has a start, peak and end (i.e., a bimodal out-migration pattern) during those years when a post-surface release flush of 6-9 m^3/s

is implemented (the post surface release flush will be implemented on average every two years).

3. How long should the surface release last to ensure out-migration of all smolts prepared to leave the system?

Question 3 will be addressed through consideration of the results of the two hypotheses identified above, the start, peak and end dates of the migration period, the duration of the surface release, the results of the downstream movement pattern assessment and the smolt out-migration data of other coastal systems. This result will then form the basis for an alternative surface release regime to be considered at the next WUP review in 2014.

Specific Objectives for 2011

The specific objectives for the 2011 study year were:

1. BC Hydro to operate the Alouette Dam spillway to allow ~ 3.0-4.5 m^3/s of flow from 15 April to 14 June 2011, including a post-surface release flush of 6.0-9.0 m^3/s, lasting seven days following the tail end of the out-migration period. Flows through the low level outlet will be held near 0.0 m^3/s for the study period;
2. Install and operate a RST at the Mud Creek site, located 1.5 km downstream of the Alouette Dam, from 15 April to 14 June 2011 (or earlier if the migration ceases) to monitor the migration of *O. nerka* from the reservoir;
3. Capture *O. nerka* from the Alouette Reservoir in the Mud Creek RST;
4. Mark all *O. nerka* captured (up to a maximum of 150 fish + 10 target samples / day) throughout the entire migration (differing fin clips to distinguish pre-flush and flush migrants) and re-capture these same marked *O. nerka* in the Mud Creek RST to estimate total emigration;
5. Determine the abundance, timing and biological characteristics of *O. nerka* migrating from the Alouette Reservoir;
6. Collect genetic tissue from 100 individuals of *O. nerka* to determine stock identification; and
7. Record incidental catches of all other species.

METHODS

Alouette Reservoir Study Area

The Alouette Reservoir is located in east Maple Ridge in southwest British Columbia (Figure 1). The South Alouette River watershed is a relatively small system (144 km^2) that arises in the Coastal Mountains of Golden Ears Provincial Park, approximately 50 km northeast of Vancouver, B.C. The upper watershed flows into an impounded reservoir known as Alouette Lake. At the reservoir's river outlet, the South Alouette River flows for 21 km before entering Pitt River near Pitt Meadows and the Pitt River, in turn, flows south into the Fraser River at Douglas Island.

Present fish resources within the Alouette Reservoir include Kokanee (*O. nerka*), Rainbow Trout (*O. mykiss*), Bridge-lip Sucker (*Catostomus columbianus*), Bull Trout (*Salvelinus confluentus*), Cutthroat Trout (*O. clarki clarki*), Lake Trout (*Salvelinus namaycush*), Stickleback (*Gasterosteus sp.*), Sculpin (*Cottus sp.*), Northern Pike Minnow (*Ptycheilus oregonensis*), Peamouth Chub (*Mylocheilus caurinus*), Large Scale Sucker (*Catostomus macrocheilus*), and Red Side Shiner (*Richardsonius balteatus)*; (Wilson et al. 2003).

BC Hydro Operations

To facilitate the 2011 study, BC Hydro agreed to release water from the Alouette Dam, over the spillway while closing the low level outlet for the period of 15 April to 14 June. This was the second year of full implementation of the post-surface release flush which occurred from 1 June to 8 June. The post-surface release flush was originally intended to occur every two years, however due to potential logistical and Hydro operational issues in 2012 (the next scheduled year of a flush) it was decided to go ahead with the flush year in 2011. With the exception of increased flows during the flush period the spillway release and low level closure were consistent throughout the duration of the trapping operations.

Fish Captures

RSTs located approximately 1.5 and 16 km downstream of the Alouette Dam were used to capture all migrating salmonids with the primary focus of this study being the trap at Mud Creek (Photo 1), 1.5 km below the dam (Figure 2). The RST at the 216th Street location, 16 km downstream, was operated by Westslope Fisheries Ltd. (Cope, in draft).

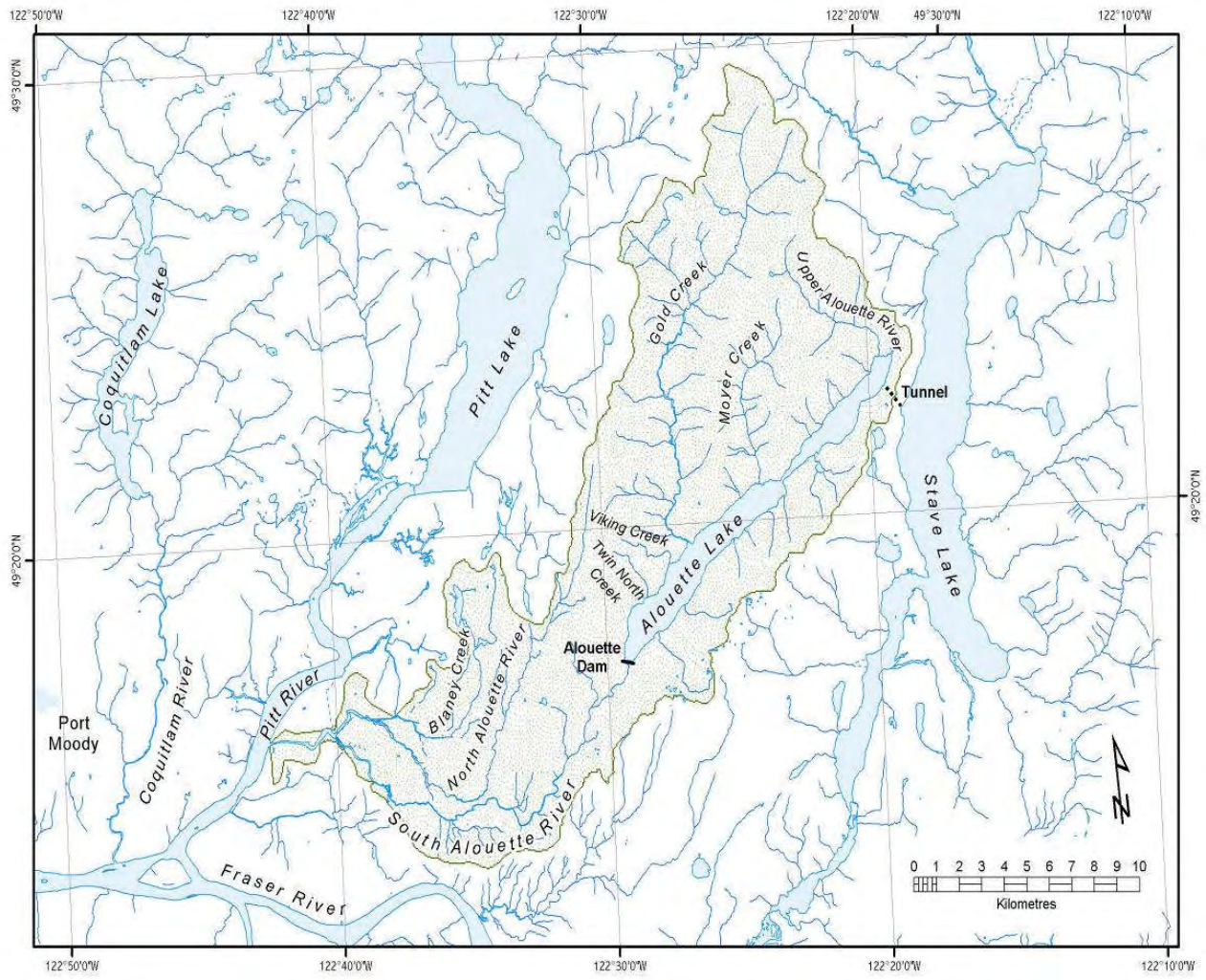

Figure 1. Map of Alouette Watershed showing local communities and features.

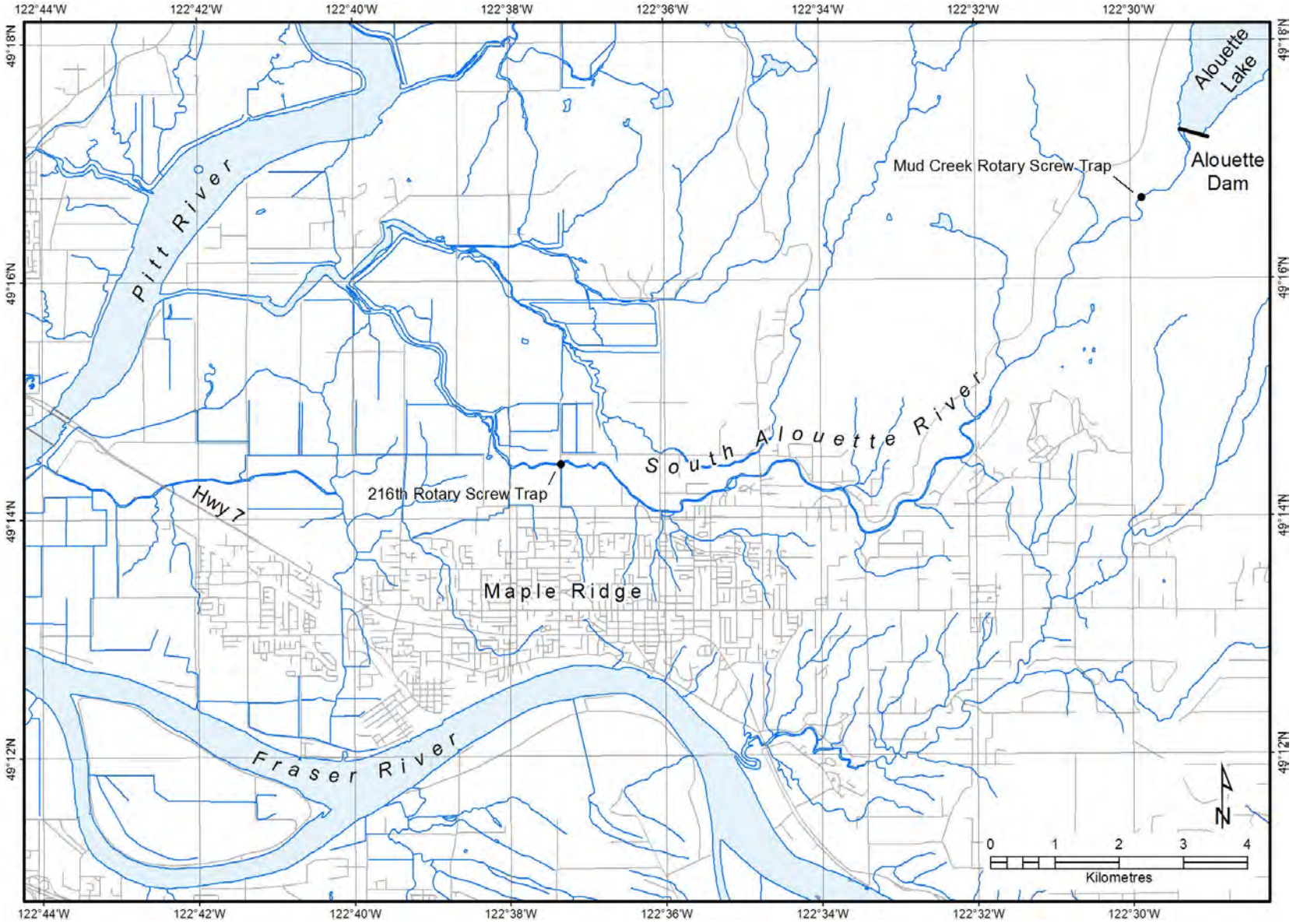

Figure 2. Map of the South Alouette River and locations of the RSTs operational in 2011.

Prior to the post-surface release flush period, the Mud Creek RST was checked twice daily. The morning trap checks consisted of enumerating all species of fish within the holding box. Unmarked fish were enumerated to species and released downstream of the trap. All Steelhead were examined for adipose fin clips (clipped in 2006) and if clipped were also examined for the presence of a fluorescent VIE tag prior to their release downstream. Evening trap checks were conducted to ensure no debris issues and that the captured fish were healthy in the live well; all fish captured during the day and inspected in the evening check were left to be processed the following morning. Once the seven day flush period began, the RST was checked several times during the daylight hours and debris was removed immediately. Catches were typically only processed during the morning sampling checks but this was dependent on the health and safety of the fish (i.e., no problems from debris or overcrowding).

A pooled (unstratified) Peterson estimate was used to estimate the number of emigrating *O. nerka* from the reservoir from 15 April to 8 June. This estimated period included the full 2011 *O. nerka* migration; hence the seven day flush period was included.

The approximately unbiased estimate of the population size using a pooled Peterson estimator with a Chapman modification includes the following statistics:

$$N = \frac{(M+1)(C+1)}{R+1} - 1 \quad (1)$$

where,

C= total number of fish caught in second sample (including recaptures),
M= number of fish caught, marked and released in first sample,
N= population estimate,
R= number of recaptures in the second sample (fish marked and released in the first sample).

An approximately unbiased estimate of the variance of the stratum population is:

$$\text{Variance of } N = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)^2(R+2)} \quad (2)$$

Standard error is calculated as:

$$\text{Standard error} = \sqrt{Variance of N} \quad (3)$$

An approximate 95% confidence interval for N is:

$$N \pm 1.96 * \text{Standard error} \quad (4)$$

Marking was conducted by fin clipping all fish captured in the RST up to a daily maximum of 150 (randomly chosen) and including ten large fish greater than 100 mm. If the random sample did not produce ten large fish then target samples were collected from additional catches if possible. This was done throughout the entire operating period and a total of 4,813 *O. nerka* from the Mud Creek RST catch were marked and included in the 2011 population estimate. Four days prior to the flush period (pre-flush) the mark applied was changed from a lower caudal clip to a combination lower caudal / adipose clip to allow distinct mark groups and a comparison of the catches 'pre-flush' and during the flush. The intention was to have seven day estimates of both the pre-flush and flush period, the first five days include marking and the last two days allowing for travel time. However during the pre-flush period daily catches began decreasing quickly so the flush period began after only four days of pre-flush to ensure the *O. nerka* migration did not cease prior to the flush period. All marked fish were released into the plunge pool below the dam in the evening of the marking day to allow adequate time for recovery.

A total of 1,667 *O. nerka* captured at the Mud Creek RST were sampled for size (both fork length and weight). The first 40 fish per day were sampled randomly and measured for size (n=1,628), after which any fish greater than 100 mm were target samples (maximum of 10 fish greater than 100 mm per day, including any large (>100 mm) random samples, n=49). Additional samples of large fish were targeted (not randomly selected) for sampling to achieve a full spectrum of age classes. Of the 1,667 fish sampled for size, scale samples were collected from 521 smolts over the course of the project (from the first 10 fish per day randomly chosen plus a maximum of 10 fish greater than 100 mm per day).

In total, 1,678 individual genetic samples were collected from the migrating smolts (fin tissue clips from both live fish and morts) to be processed for stock identification at the Pacific Biological Station. These samples were from the first 40 fish randomly chosen per day plus a maximum of 10 fish greater than 100 mm per day. All mortalities were also sampled for genetics. Of these samples 100 were randomly chosen throughout the duration of the migration to confirm or clearly define the Alouette stock membership and the remaining samples were collected for a stock identification research project being conducted by the Department of Fisheries and Oceans (Godbout et al., in draft).

Statistical Analysis

An ANOVA comparison of fork length of all randomly sampled smolts less than 100 mm from all age classes and from all seven years of monitoring was conducted. Tukey's HSD post-hoc multiple comparison was used to indicate any significant differences among years. A non-parametric Wilcoxon/Kruskal-Wallis test on rank sums was also used to confirm the results of the ANOVA. Also, a two-sample t test assuming unequal variances was conducted to compare weights of all 2010 and 2011 *O. nerka* sampled.

RESULTS

BC Hydro Operations

The Alouette Dam spillway gate was opened on 15 April and remained open until 14 June. During the *O. nerka* migration period, which ended 8 June, and with the exception of the post-surface release flush period, flows were maintained between 3.31 and 4.32 m^3/s. The flush period occurred from 1 June to 8 June and maximum flows reached 6.21 m^3/s. Gate openings ranged from 0.15-0.22 m until closed 14 June (Table 1).

Spillway flows in 2011 were very similar to those maintained in 2007 and 2008 (~ 4.0 m^3/s), on average slightly greater than the 2009 and 2010 flows (2.98-4.45 m^3/s) and consistently greater than the 2005 and 2006 flows (2.5-3.0 m^3/s with the exception of a spike in mid May of 2006) (Figure 3). This was the third year of the post-surface release flush during the migration period. The 2011 flush flows had the lowest peak of all three years. The 2011 flush flows were similar in duration to the 2010 flush, but considerably longer than the 2009 flush which ended early due to difficulties monitoring the Sockeye smolt migration. Flows did not occur through the low level outlet at Alouette Dam from 15 April to 14 June. During the migration period, the majority of flow continued to be diverted to the Stave Reservoir through the adit gate (Table 1).

Photo 1. Daily sampling at the Mud Creek RST on the Alouette River, 2011.

Table 1. Hydro operations at the Alouette Reservoir during the 2011 study period.

Date	Daily Average Alouette Reservoir Elevation (m)	Alouette Spillway Gate Position (m)	Daily Average Alouette Reservoir Spill to Alouette River (cms)	Alouette Low Level Outlet Gate Position (m)	Daily Average Alouette Reservoir spill to Alouette River via low level outlet (cms)	Daily Average Alouette Reservoir spill to Stave Reservoir via Adit Gate (cms)
14-Apr	122.486	0.00	0.000	open	2.677	25.517
15-Apr	122.426	0.05 at 9:55 to settle at 0.19 at 10:18	2.104	closed mid morning	1.140	25.481
16-Apr	122.351	0.19	3.521	closed	0.000	25.435
17-Apr	122.296	0.19	3.414	closed	0.000	8.661
18-Apr	122.334	0.19	3.483	closed	0.000	0.000
19-Apr	122.372	0.19	3.556	closed	0.000	0.000
20-Apr	122.404	0.19	3.617	closed	0.000	0.000
21-Apr	122.423	0.19	3.654	closed	0.000	6.518
22-Apr	122.371	0.19	3.558	closed	0.000	15.122
23-Apr	122.304	0.19	3.431	closed	0.000	15.099
24-Apr	122.243	0.19	3.314	closed	0.000	15.077
25-Apr	122.263	0.19	3.347	closed	0.000	15.083
26-Apr	122.362	0.19	3.535	closed	0.000	15.118
27-Apr	122.493	0.19	3.780	closed	0.000	19.249
28-Apr	122.621	0.19	4.029	closed	0.000	24.951
29-Apr	122.632	0.19	4.052	closed	0.000	24.958
30-Apr	122.586	0.19	3.966	closed	0.000	24.931
1-May	122.520	0.19	3.841	closed	0.000	24.893
2-May	122.467	0.19	3.738	closed	0.000	24.860
3-May	122.479	0.19	3.760	closed	0.000	24.867
4-May	122.463	0.19	3.730	closed	0.000	24.858
5-May	122.431	0.19	3.671	closed	0.000	24.839
6-May	122.428	0.19	3.663	closed	0.000	24.837
7-May	122.497	0.19	3.790	closed	0.000	24.877
8-May	122.588	0.19	3.966	closed	0.000	24.932
9-May	122.587	0.19	3.967	closed	0.000	24.932
10-May	122.556	0.19	3.908	closed	0.000	24.913
11-May	122.624	0.19	4.026	closed	0.000	24.950
12-May	122.951	closed to 0.18 at 17:10 to settle at 0.15 at 17:55	4.316	closed	0.000	25.145
13-May	123.023	0.15	3.700	closed	0.000	25.190
14-May	123.039	0.15	3.718	closed	0.000	25.200
15-May	123.150	0.15	3.841	closed	0.000	25.265

Table 1. continued.

Date	Daily Average Alouette Reservoir Elevation (m)	Alouette Spillway Gate Position (m)	Daily Average Alouette Reservoir Spill to Alouette River (cms)	Alouette Low Level Outlet Gate Position (m)	Daily Average Alouette Reservoir spill to Alouette River via low level outlet (cms)	Daily Average Alouette Reservoir spill to Stave Reservoir via Adit Gate (cms)
16-May	123.315	0.15	4.004	closed	0.000	25.362
17-May	123.530	0.15	4.208	closed	0.000	25.491
18-May	123.564	0.15	4.241	closed	0.000	25.513
19-May	123.549	0.15	4.228	closed	0.000	25.504
20-May	123.540	0.15	4.219	closed	0.000	25.499
21-May	123.568	0.15	4.245	closed	0.000	25.515
22-May	123.576	0.15	4.253	closed	0.000	25.520
23-May	123.554	0.15	4.232	closed	0.000	25.507
24-May	123.511	0.15	4.193	closed	0.000	25.482
25-May	123.464	0.15	4.148	closed	0.000	25.454
26-May	123.497	0.15	4.177	closed	0.000	25.472
27-May	123.542	0.15	4.221	closed	0.000	25.500
28-May	123.523	0.15	4.204	closed	0.000	25.489
29-May	123.472	0.15	4.156	closed	0.000	25.459
30-May	123.438	0.15	4.124	closed	0.000	25.438
31-May	123.417	0.15	4.104	closed	0.000	25.425
1-Jun	123.440	opened to 0.17 at 8:15 to	5.361	closed	0.000	25.439
2-Jun	123.458	0.22	6.044	closed	0.000	25.449
3-Jun	123.500	0.22	6.102	closed	0.000	25.474
4-Jun	123.500	0.22	6.104	closed	0.000	25.475
5-Jun	123.511	0.22	6.117	closed	0.000	25.481
6-Jun	123.540	0.22	6.157	closed	0.000	25.498
7-Jun	123.580	0.22	6.212	closed	0.000	25.522
8-Jun	123.569	closed to 0.21 at 9:30 to settle at 0.15 at 12:30	5.144	closed	0.000	25.516
9-Jun	123.543	0.15	4.222	closed	0.000	25.500
10-Jun	123.510	0.15	4.192	closed	0.000	25.481
11-Jun	123.467	0.15	4.152	closed	0.000	25.456
12-Jun	123.414	0.15	4.102	closed	0.000	25.424
13-Jun	123.372	0.15	4.062	closed	0.000	25.399
14-Jun	123.372	closed to 0.14 at 12:35 to settle at 0.00 at 15:30	2.491	opened mid afternoon	1.012	25.399
15-Jun	123.333	0.00	0.000	open	2.762	25.376

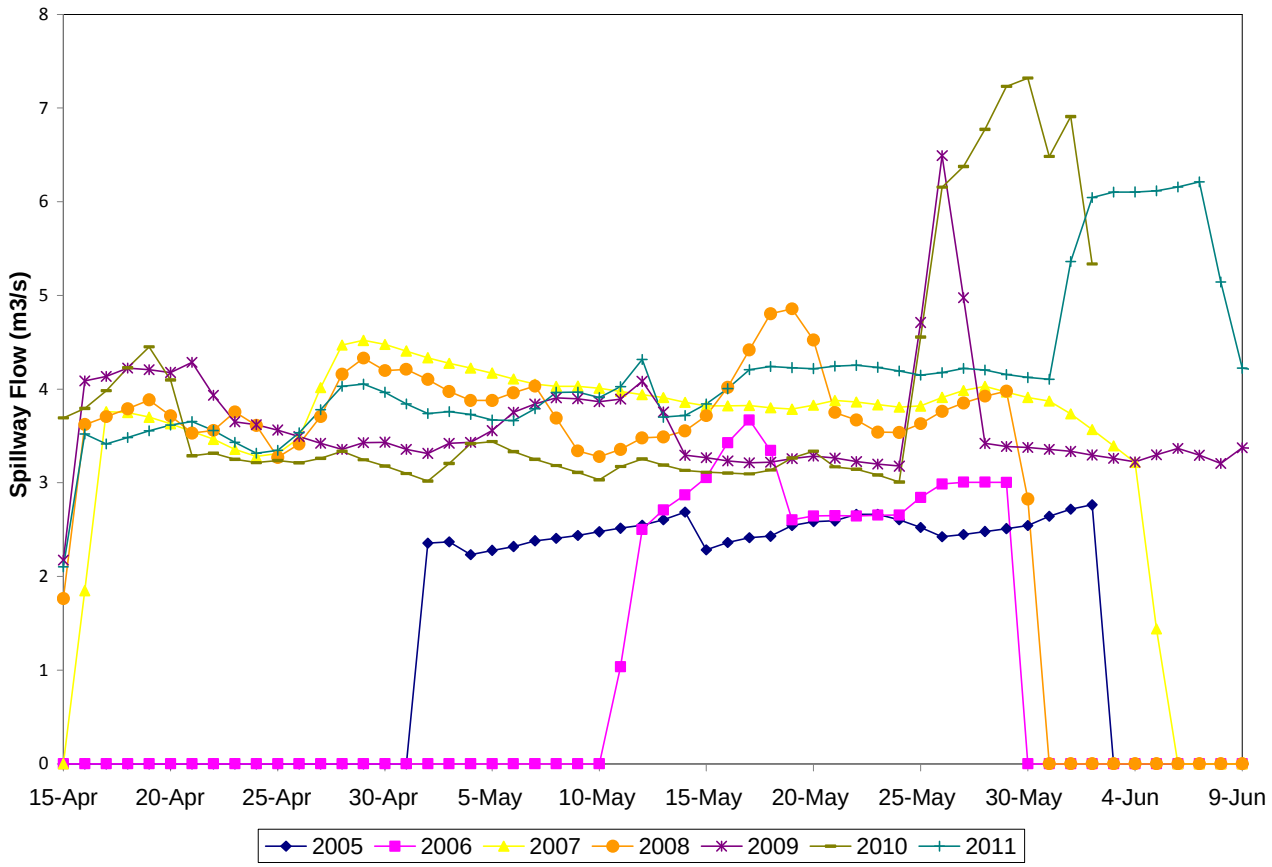

Figure 3. Comparison of spillway gate flows during the *O. nerka* migration period, 2005 – 2011.

RST Operations and Physical Conditions

The Mud Creek RST was operated consistently from 13 April to 8 June. Although spillway flows continued as planned until 14 June, monitoring ceased on 8 June once daily catches diminished and it was believed the migration had finished. The 216th Street RST was operated by Westslope Fisheries Ltd. from 15 April to 14 June and it operated consistently with the exception of two days. On 28 April the 216th Street RST was disabled to allow hatchery Chinook releases to flush through; and on 26 May debris jammed in the RST causing the catch to be lost. The catch for those dates was estimated as the average catch of the adjacent days (R.S. Cope, Senior Fisheries Biologist, Westslope Fisheries Ltd., 2012, pers. comm.).

Water temperature, RST revolutions per minute (RPM), water levels and general weather conditions were recorded daily during the study from 13 April to 8 June at the Mud Creek site (Appendix A). Daily discharge for Water Survey of Canada Station No. 08MH005, located on the mainstem South Alouette River, is presented in Figure 4. The spillway flushing flows in early June corresponded to an increase in discharge; however, there was no increase in spillway flow corresponding to earlier spikes in discharge that occurred in May (Table 1, Figure 4).

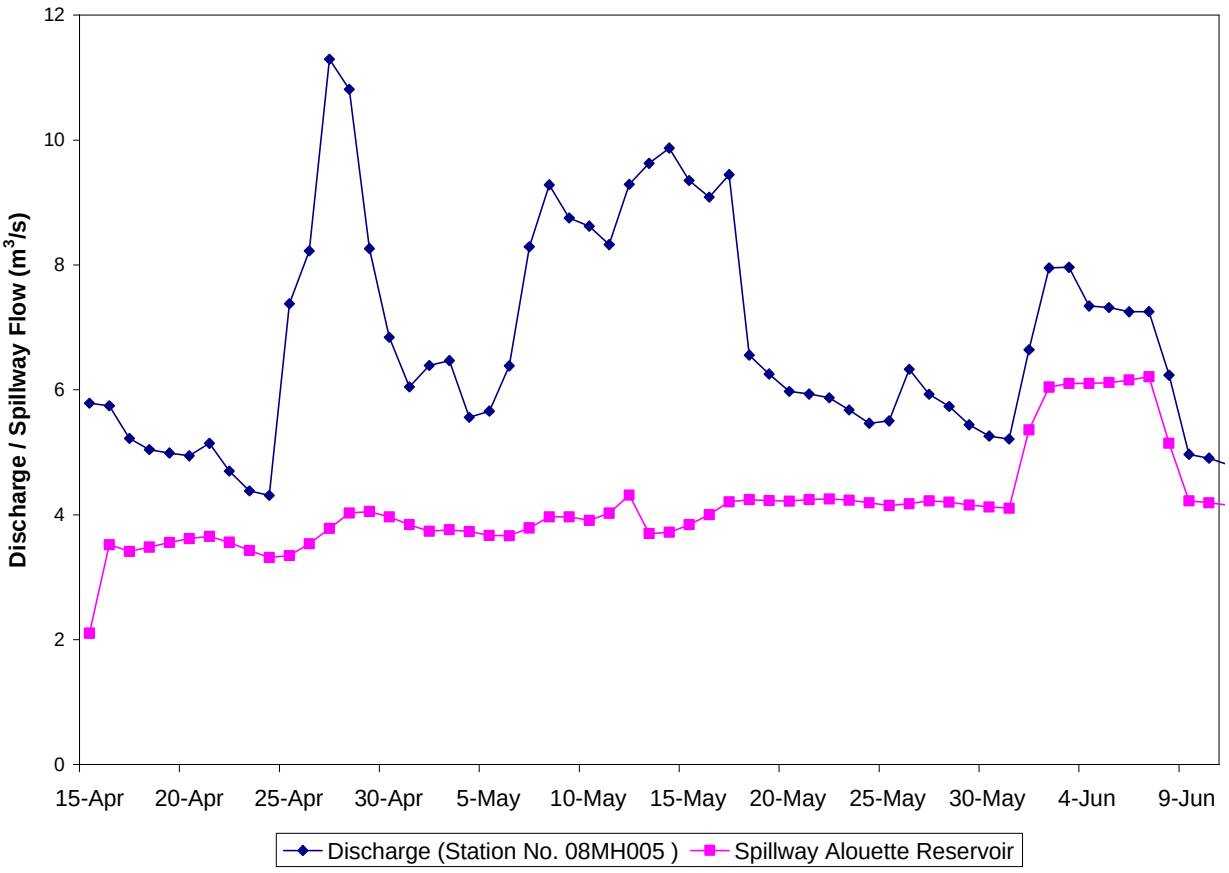

Figure 4. Daily discharge (m^3/sec) for Water Survey of Canada Station No. 08MH005 and spillway flow data from the Alouette Reservoir. Station is located on the mainstem South Alouette River at the 232nd Street bridge (discharge data from Water Survey of Canada website: http://www.ec.gc.ca/rhc-wsc/).

Fish Captures

O. nerka

During the 2011 migration, 8,525 *O. nerka* were captured in the Mud Creek RST and the peak catch occurred on 14 May (n=696; Table 2). Recaptures of 1,332 of 4,813 marked *O. nerka* released below the dam resulted in a pooled Peterson estimate of 35,542 (34,034 – 37,051; 95% CL) smolts migrating from the Alouette Reservoir from 15 April to 8 June in 2011 (Table 3). During the flushing flow period from 1 June to 8 June a total of 86 unmarked *O. nerka* were captured.

The 2011 migration of 35,542 *O. nerka* smolts from the Alouette Reservoir is the second largest estimate since monitoring began in 2005 (Table 4). With the exception of the higher 2007 estimate of 62,923 (48,436 – 77,410; 95% CL) the 2011 total migration estimate is approximately double or greater than the total estimates of the previous years monitored (2010: 15,434, 2009: 4,287 (3,833 – 4,741; 95% CL) and 2008: 8,257), although the 2006 and 2005 estimates (5,064 and 7,900 respectively) were incomplete as the spillway opening was delayed until after the migrations had started. The 2011 trap efficiency of 28% is lower than the previous

years which ranged from 34% – 42%, other than the low efficiency of 12% in 2007. The daily catches of *O. nerka* at the Mud Creek RST in 2011 as compared to the previous six years are shown in Figure 5; the 2011 absolute catch is the highest recorded since monitoring began in 2005.

The 2011 run timing was also the longest migration of all seven years monitored (Figure 5). As has been the case in previous years, the migration began in mid April shortly after the spillway opened, but continued for the longest duration thus far, finishing in early to mid June, considerably later than the previous latest finish of 1 June in 2007. Previous migrations have had similar timing among the years; however the 2009, 2007 and 2006 migrations continued approximately an additional week after the 2010, 2008 and 2005 migrations tapered off. The peak in 2011 occurred in mid May, later than most years which occurred in late April (2010: 24 April, 2008: 23 April and 2007: 30 April) but comparable to the 2009 peak on 18 May. The 2005 and 2006 migrations are not comparable as the spillway was opened late (3 May and 11 May respectively) in those years.

A total of 1,806 unmarked *O. nerka* and 162 lower caudal clipped recaptures marked at the Mud Creek trap were captured in the trap at the 216th Street location 16 km below the dam (Table 2). Unlike the 2009 and 2010 migrations, the peak catch did not occur one day following the Mud Creek peak catch but rather six days later on 20 May (n=171). No increases in catch occurred during the flush period when a total of 19 unmarked migrants were captured following a total capture of 179 *O. nerka* the seven days previous to the flush. A complete summary of RST operations and fish captures at the trap at the 216th Street location can be found in Cope (2012).

Table 2. Daily catch of *O. nerka* in the Mud Creek and 216th Street RSTs, 2011.

Date	2011 Daily Total			
	Mud Creek		216th St	
	unmarked	clip recaptures	unmarked	clip recaptures
15-Apr	0	0	1	0
16-Apr	0	0	0	0
17-Apr	0	0	1	0
18-Apr	0	0	1	0
19-Apr	2	0	0	0
20-Apr	14	0	2	0
21-Apr	21	0	3	0
22-Apr	26	2	8	0
23-Apr	55	4	9	0
24-Apr	145	12	9	0
25-Apr	220	48	41	0
26-Apr	168	53	20	0
27-Apr	120	52	19	0
28-Apr[a]	61	46	0	0
29-Apr	65	17	0	0
30-Apr	74	22	8	0
1-May	351	23	43	0
2-May	305	18	42	0
3-May	289	54	134	0
4-May	189	24	72	0
5-May	204	36	52	0
6-May	174	62	44	1
7-May	173	63	65	0
8-May	344	51	2	0
9-May	352	33	47	0
10-May	263	22	75	0
11-May	282	37	43	2
12-May	176	77	5	0
13-May	425	19	40	1
14-May	696	38	77	0
15-May	493	34	59	1

Table 2. continued.

Date	2011 Daily Total			
	Mud Creek		216th St	
	unmarked	clip recaptures	unmarked	clip recaptures
16-May	332	55	93	8
17-May	84	26	77	20
18-May	148	22	18	20
19-May	303	18	106	7
20-May	440	31	171	14
21-May	447	31	85	15
22-May	73	40	57	0
23-May	115	19	69	7
24-May	327	53	10	0
25-May	68	21	80	13
26-May[a]	157	32	0	2
27-May	37	29	26	2
28-May	161	26	34	2
29-May	26	28	3	14
30-May	28	20	7	0
31-May	6	9	29	0
1-Jun	24	5	15	3
2-Jun	7	9	0	8
3-Jun	12	2	0	6
4-Jun	1	4	1	1
5-Jun	11	1	0	5
6-Jun	10	0	0	1
7-Jun	17	1	1	7
8-Jun	4	3	2	2
9-Jun			0	0
10-Jun			0	0
11-Jun			1	0
12-Jun			2	0
Totals	**8,525**	**1,332**	**1,806**	**162**

[a] 216th St unmarked daily total is estimate for lost catch (based on average of adjacent days).

Table 3. Total estimated 2011 *O. nerka* migration from the Alouette Reservoir.

No. *O.nerka* clipped and released below dam ('M')	4,813
No. *O.nerka* examined ('C')	9,841
No. *O. nerka* recaps ('R')	1,332
Estimated *O. nerka* passage (15 April - 8 June 2012)	**35,542**
95% Confidence Limits	(34,034 - 37,051)
Trap efficiency	27.68%

Table 4. Total catch at the Mud Creek RST and corresponding population estimate of *O. nerka* migrating from the Alouette Reservoir, 2005 – 2011.

Year	Total Catch	Estimate	95% Confidence Limits	Trap Efficiency
2005[a]	3,310	7,900	--	42%
2006[b]	1,757	5,064	--	35%
2007[c]	7,787	62,923	48,436 - 77,410	12%
2008[d]	3,224	8,257	--	40%
2009[e]	1,247	4,287	3,833 - 4,741	34%
2010[f]	4,600	15,434	--	37%
2011[g]	8,525	35,542	34,034 - 37051	28%

[a]Based on coho trap efficiency *(Baxter and Bocking 2006)*

[b]Based on *O. nerka* trap efficiency *(Humble et al. 2006)*

[c]Pooled Peterson estimate: 19 April to 1 June *(Mathews and Bocking 2007)*

[d]Trap efficiency estimate of 545 (15 April to 20 April & 9 May to 26 May) +

Pooled Peterson estimate of 7,712 (95% C.L. 6,682 to 8,742; 21 April to 8 May) *(Mathews and Bocking 2009)*

[e]Pooled Peterson estimate (21 April to 1 June) *(Mathews and Bocking 2010)*

[f]Trap efficiency estimate of 1,232 (15 to 17 April) +

Pooled Peterson estimate of 14,201 (95% C.L. 13,624 to 14,778; 18 April to 24 May) +

Total catch of 1 (25 May to 1 June) *(Mathews and Bocking 2011)*

[g]Pooled Peterson estimate (15 April to 8 June) *(Mathews et al. 2012)*

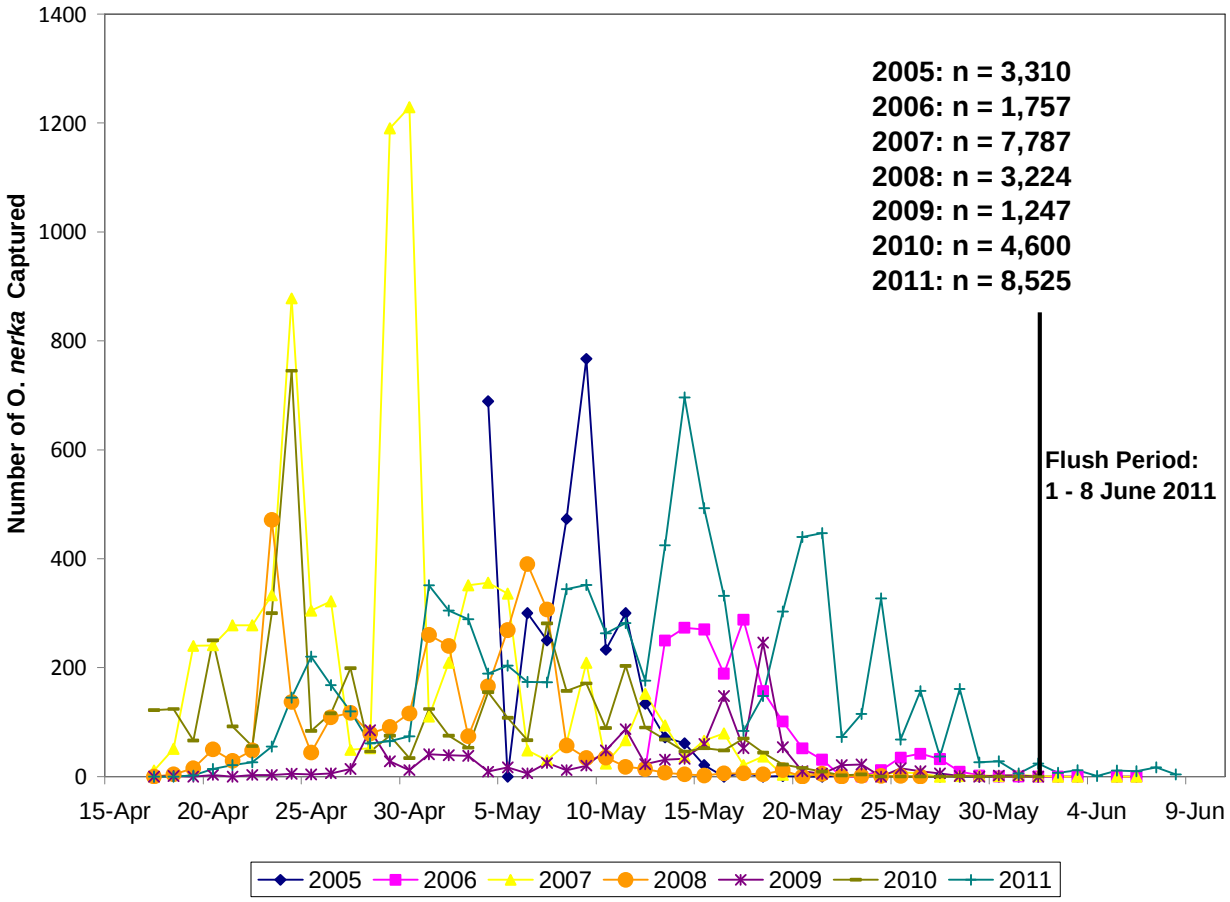

Figure 5. Daily catch of *O. nerka* at the Mud Creek RST in 2011 in comparison to the previous five years (spillway opened 3 May, 11 May, 16 April, 15 April, 15 April, 14 April and 15 April for 2005 – 2011, respectively).

<u>*O. nerka* Bio Sampling</u>

Of the 1,667 *O. nerka* sampled for length (random and target samples) at the Mud Creek RST, in 2011, the largest number were the 71-75 mm length class (n=600; Figure 6). In 2009 this same length class comprised the largest number of migrants however in both 2010 and 2007 the 81-85 mm length class had the greatest abundance. In 2008, 2005 and 2006 the largest number of migrants comprised the 66-70 mm, 76-80 mm and 76-80 mm length classes respectively. Also in 2011 the largest smolt ever sampled at the Mud Creek RST was captured on 5 June, this migrant had a fork length of 284 mm and weighed 179.3 g (Figure 7). Previous to this capture the largest migrant ever sampled occurred in 2010 (266 mm and 175.0 g). The weights of the 1,667 migrants sampled ranged from 1.5-179.2 g, with a mean of 4.5 g. This was significantly different than the 2010 mean of 9.5 g (t=8.04, df=1,184, P<0.0001). A length-weight relationship with a fitted regression line (r^2=0.99) is displayed in Figure 8.

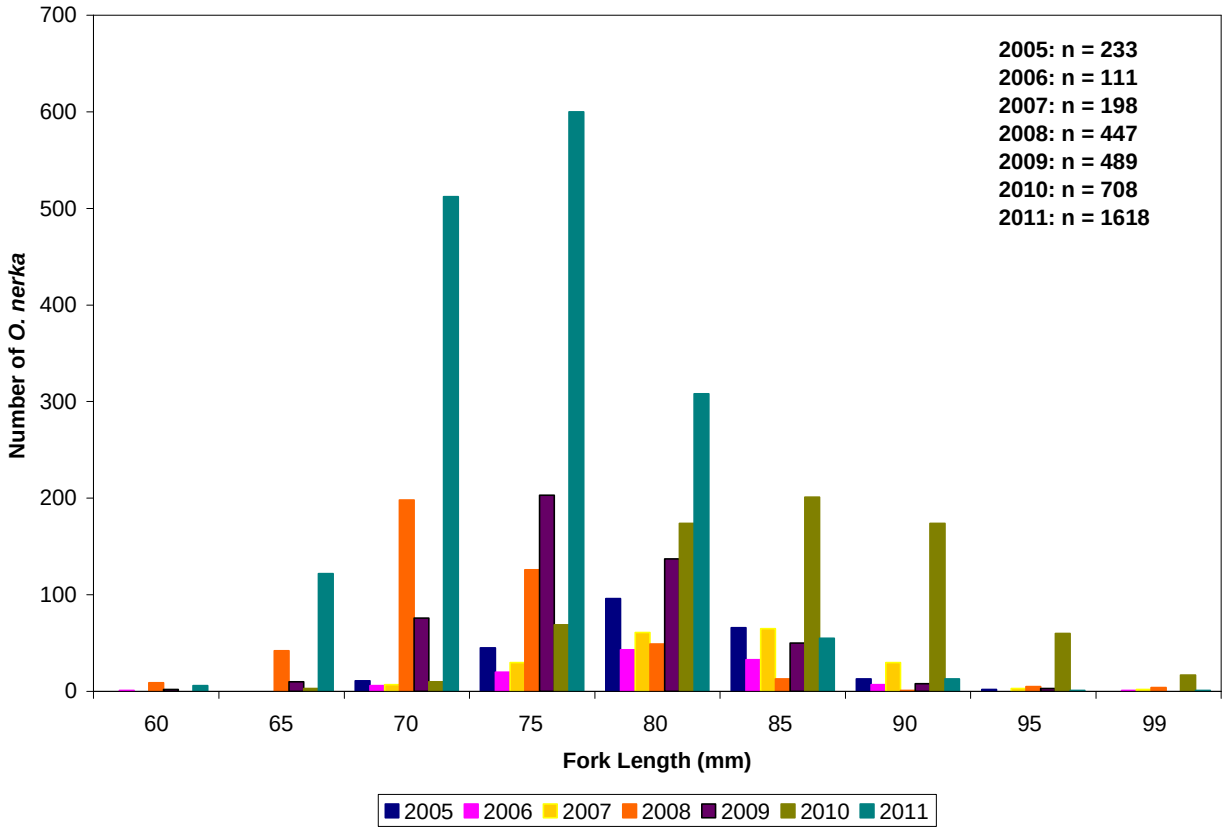

Figure 6. Length frequency of all *O. nerka* <100 mm captured in the Mud Creek RST operated in the South Alouette River (random and target samples), 2005 – 2011.

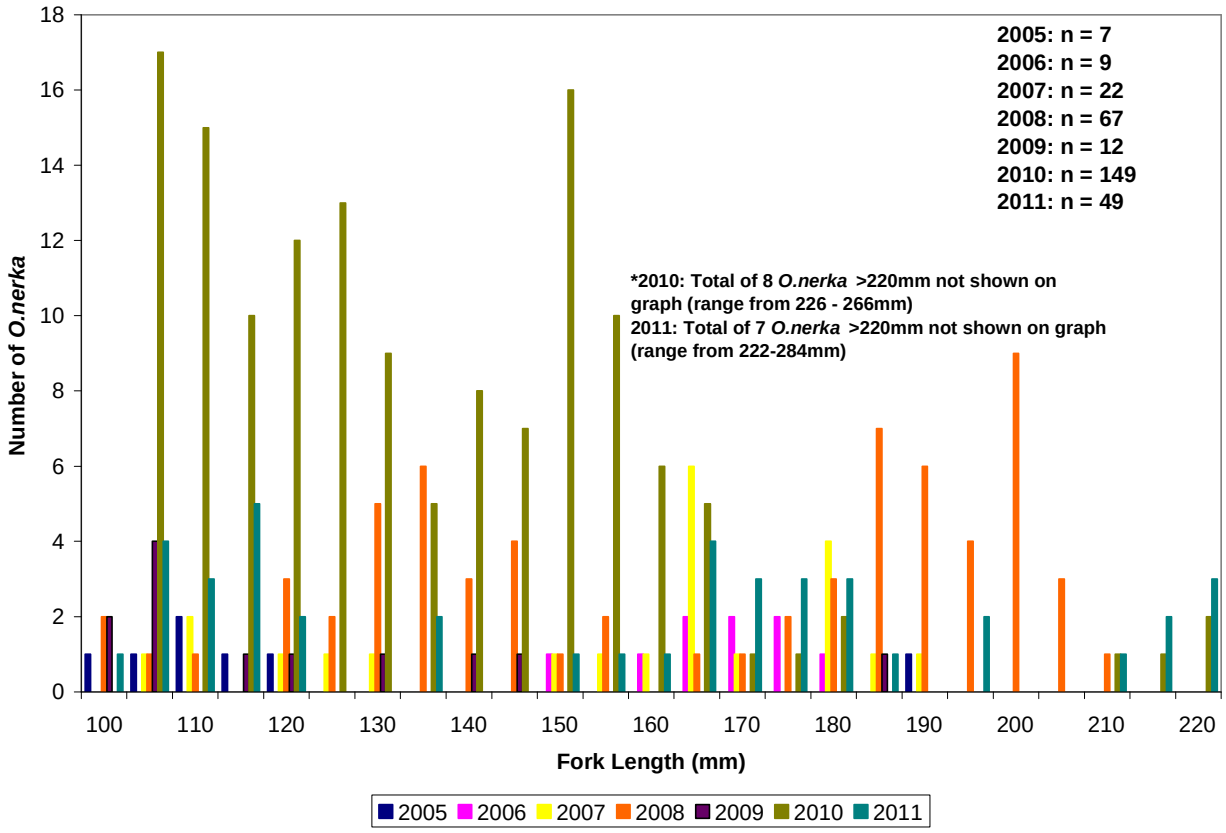

Figure 7. Length frequency of all *O. nerka* ≥100 mm captured in the Mud Creek RST operated in the South Alouette River (random and target samples), 2005 – 2011.

Photo 2. Genetic tissue sampling at the Mud Creek RST on the Alouette River, 2011.

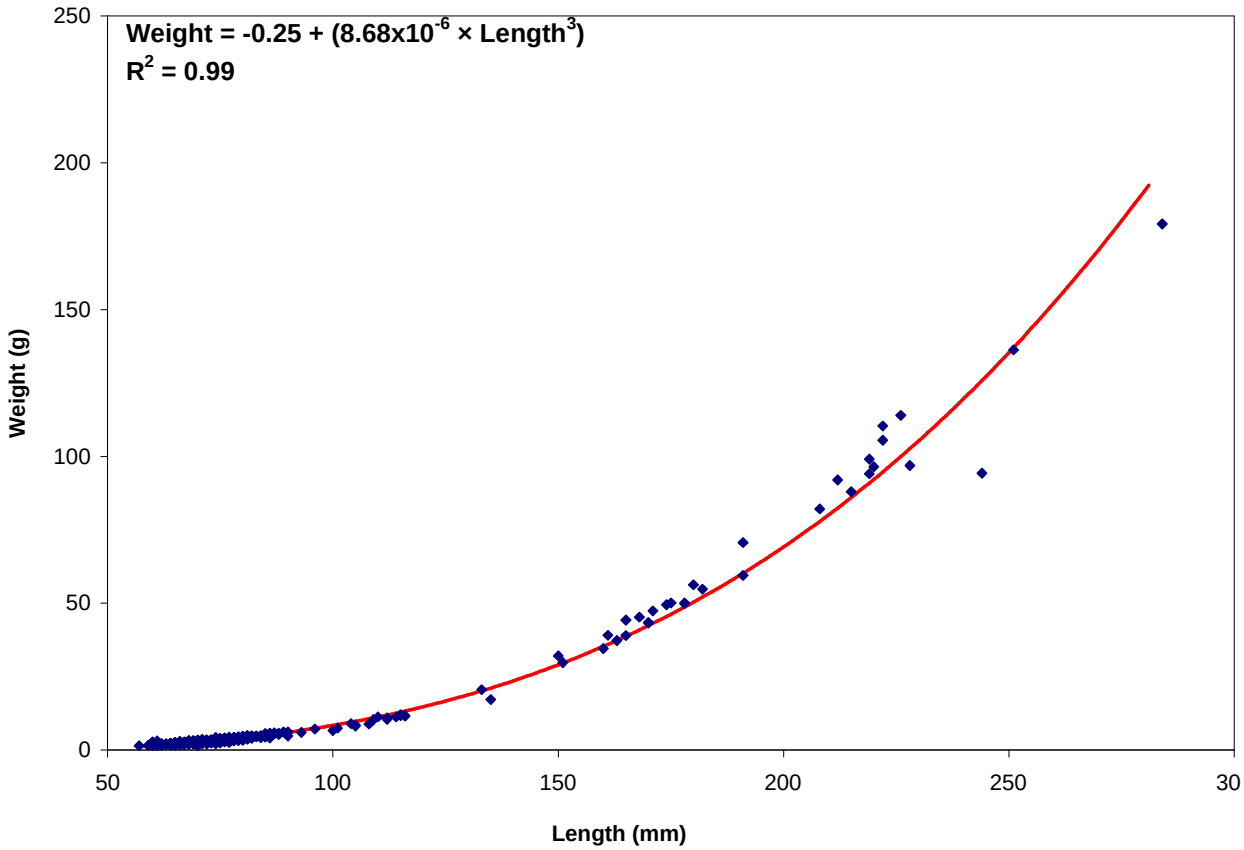

Figure 8. Length-weight relationship of the *O. nerka* smolts migrating from the Alouette Reservoir, 2011.

Of those *O. nerka* less than 100 mm in length (random samples only), mean fork length varied significantly among years (F=440.5, df=6,3783, *P*<0.0001; Table 5). Post-hoc pairwise comparisons between years indicated the 2005 and 2006 mean fork lengths (78.6 and 79.5 mm respectively) were not significantly different, and neither were the 2006 and 2007 mean fork lengths (79.5 and 80.8 mm respectively). However the mean fork length from all other year combinations differed from one another. Although model residuals were non-normal (*P*=0.01) and had unequal variance across groups (*P*<0.0001), a common problem in large datasets, visual inspection of the data showed an approximately normal distribution and reasonably similar variances. Nevertheless, we conducted a non-parametric Wilcoxon/Kruskal-Wallis test on rank sums to confirm results of our parametric ANOVA, and indeed there was a significant year effect on fork lengths (Chi^2=1549.8, df=6, *P*<0.0001). We are therefore confident in our ANOVA results because of agreement with the non-parametric test result, and because ANOVAs are robust to such mild departures from normality and equal variance (Glass et al. 1972).

Table 5. Mean fork length of *O. nerka* less than 100 mm (random samples only), 2005 – 2011.

Year	Mean fork length (mm)	SE	n
2005	78.6	0.31	233
2006	79.5	0.54	97
2007	80.8	0.38	198
2008	71.2	0.28	447
2009	75.0	0.23	489
2010	83.2	0.23	708
2011	72.4	0.12	1618

The 521 scale samples collected for age analysis in 2011 were sent to the Pacific Salmon Commission to be processed; however, these results were not ready at the time this report was prepared. The 100 fin-tissue clips collected for genetic analysis, as well as all individual tissue samples collected for the Department of Fisheries and Oceans (total of 1,678 samples collected), will be processed for stock identification at the Pacific Biological Station.

Steelhead Smolts

A total of 350 wild Steelhead smolts were captured in the Mud Creek RST once the spillway was opened; peak catch occurred on 28 April 2011 (n=25; Figure 9). The 2011 timing of Steelhead peak catch was very similar to 2008 (29 April) and close to 2010 (3 May) but was considerably earlier than 2009 (14 May), 2007 (9 May) and 2006 (12 May). Since enumeration of Steelhead began in 2006, the total catch of wild smolts had been increasing significantly until 2010. However, the 2011 catch was approximately half that of the 2010 total (n=602) and considerably less than both 2009 and 2008 (n=467 and 476 respectively) totals. As was the case in 2010, no adipose clipped Steelhead were captured in 2011.

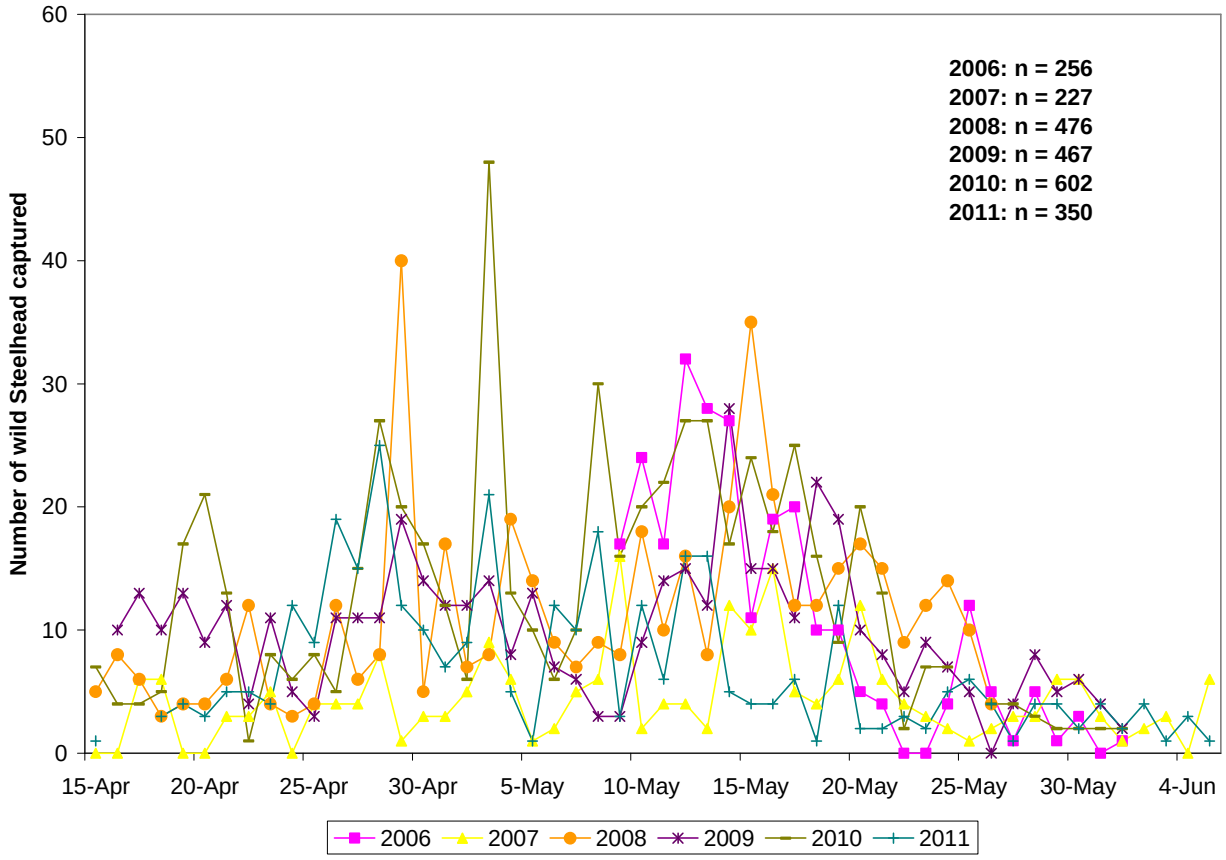

Figure 9. Daily catch of wild Steelhead smolts at the Mud Creek RST, 2005 – 2011.

Other Species

Many other non-target species were captured in the Mud Creek RST in 2011 including large numbers of salmonid fry. The majority of fry were Chum, as well as Coho and Chinook fry. Chinook parr and smolts and Steelhead (<90 mm) were captured in small numbers while greater totals of Coho parr and smolts were also enumerated. In addition to salmonids, Dace species, Sculpin species, Stickleback species, Lamprey, Northern Pike Minnow, Red Side Shiners and crayfish were also captured (Appendix B).

Fish Captures during the Flush Period

A total of 86 unmarked and 25 marked *O. nerka* smolts were captured in the RST during the post-surface release flush (Table 2). In addition, Steelhead, salmonid fry and several of the other non salmonid species captured throughout the season continued to be captured during the flush week, indicating the RST was operating effectively (Figure 9, Appendix B). A comparison of *O. nerka* catches during the flush week and the six and half weeks prior during the monitored period does not indicate a peak in catch totals due to the flush.

DISCUSSION

BC Hydro Operations – Flush

The post-surface release flush occurred for the third consecutive year in 2011. To address the management question of whether a flush encourages more smolts to leave the system the post-surface release flush was originally scheduled to occur every second year. Given the initial flush monitoring attempted in 2009 ceased early due to safety issues the flush was attempted again in 2010, and with operational and safety modifications, full monitoring was completed. Due to potential BC Hydro operational changes in 2012 the decision was made to complete a second full year of the post-surface release flush in 2011. Now that two successful years of monitoring have occurred the next post-surface release flush is tentatively scheduled for 2013.

Trap Operations

For the second consecutive year, the Mud Creek RST was operated consistently throughout the entire migration period, including the post-surface release flush. Operations in 2010 proved that with increased monitoring and safety checks the RST could be used successfully for enumerating the *O. nerka* migration throughout the increased flush flows. Continuous catches during the flush of all the typical species captured throughout the monitoring period indicated the RST was still operating effectively under the higher flows.

***O. nerka* Migration**

The full 2011 *O. nerka* migration, from 15 April to 8 June, was estimated with the pooled Peterson method and yielded a total estimate of 35,542 (34,034 – 37,051), the second largest estimate since monitoring began in 2005. The 2011 total abundance was more than double all previous annual estimates with the exception of the large 2007 estimate with very broad confidence intervals (62,923: 48,436 – 77,410; 95% CL). The capture efficiency of 28% in 2011 was less than in previous years which ranged from 34 – 42%, with the exception of the low 2007 efficiency of 12% due to natural alterations of the RST site from a rockslide. The mark-recapture study continued throughout the flush period; however a stratified estimate of pre-flush and flush periods was not considered valid as the pre-flush period was truncated due to decreased catches and the unmarked *O. nerka* capture in the second event could not be separated. Given that daily catch decreased during the flush, as would be expected at the tail end of a migration, and that the RST proved to be effectively capturing salmonids, the post-surface release flush did not appear to encourage an increased pulse of migrants to leave the reservoir. Two years of post-surface release flush data have shown no evidence of a surge in migrants. An additional year of flush results, tentatively scheduled for 2013, will further clarify this question.

During the last five years of full season monitoring the *O. nerka* migration has begun in mid April and continued until late May or early to mid June. The 2011 migration was the longest monitored thus far, lasting a total of 51 days, and ending later in June than has been typical. The 2010 and 2008 migrations both tapered off approximately two weeks earlier, and the 2009 and 2007 migrations ended approximately one week earlier. The 2011 peak catch also occurred mid May, considerably later than the 2010, 2008 and 2007 peak counts, but similar to 2009. Unlike 2010 the 2011 catches did not begin with high numbers when the spillway was first opened but began to increase gradually, indicating the 2011 spillway opening was timed well with the

migration. Given the initial high catches enumerated upon immediately opening the spillway in 2010, and to a lesser extent in 2007, it is possible that the migration could have begun earlier if the spillway was open. Variation in start dates, peak timing, and end dates indicate that continued monitoring will improve our understanding of typical run timing. As has been the case in the last 3 years (but contrary to the 2007 results) the 2011 peak catch did not correspond to peaks in spillway flow.

Fork lengths of migrants sampled in 2011 were in range with previous years. On average, fish sampled in 2011 were smaller than fish sampled in 2010 and 2007, similar to fish sampled in 2009, and larger than fish sampled in 2008, 2006 and 2005. As was the case in 2010, several migrants were also very large in size; the largest ever sampled from the Alouette Reservoir was captured in 2011.

Steelhead Smolts

The number of wild Steelhead smolts captured in 2011 was less than half the 2010 catch, and the lowest number caught since 2007. Given the apparent decrease in abundance, it will remain important to monitor the number of Steelhead captured during the *O. nerka* migration.

RECOMMENDATIONS

The following recommendations are proposed for the monitoring of juvenile migration at Alouette Reservoir in 2012:

- Maintain a similar spill volume (3.0-4.5 m^3/s) of flow releases in 2012 and if possible open the spillway earlier in April to determine if the migration would commence earlier given the opportunity;
- Conduct daily marking at the RST throughout the duration of the run to be used for calculating a population estimate;
- Collect genetic tissue from approximately 100 individuals of *O. nerka* for stock identification; and
- Continue to monitor Steelhead migration and total catches of other species.

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REFERENCES

Baxter, B.E. and R.C. Bocking. 2006. Field trials to assess Coho smolt migration success through the Alouette Reservoir, 2005. Report prepared by LGL Limited for BC Hydro Bridge Coastal Fish and Wildlife Restoration Program. BCRP Report No. 05.Al.02.

Bengeyfield, W., D. Hay, S. Joyce, and J. Greenbank. 2001. Evaluation of restoring historic fish passage for anadromous fish at BC Hydro facilities. Report prepared for Power Supply Environment, BC Hydro, Burnaby, B.C.

Bocking, R.C. and M.N. Gaboury. 2002. Framework for the evaluation of restoring historic passage for anadromous fish at BC Hydro Bridge-Coastal Generation Area dams. Prepared for Bridge-Coastal Fish and Wildlife Restoration Program.

Cope, R.S. (*In draft*). Alouette River salmonid smolt migration enumeration: 2011 data report. Report prepared by Westslope Fisheries Ltd. for Alouette River Management Committee and BC Hydro Generation, Burnaby, B.C.

Gaboury, M.N. and R.C. Bocking. 2004. Feasibility of reintroducing Sockeye and other species of pacific salmon in the Alouette Reservoir, B.C. Report prepared for Alouette River Management Society, Maple Ridge, B.C.

Glass, G.V., P.D. Peckham and J.R. Sanders. 1972. Consequences of failure to meet assumptions underlying the fixed effects analyses of variance and covariance. Review of Educational Research 42:237.

Godbout, L., C. Wood, R. Withler and D. Menard. (*In draft*). Parentage assessment of 2011 Alouette juvenile downstream migrants against returning Sockeye Salmon to evaluate spawning success.

Humble, S.R., A.C. Blakley, and R.C. Bocking. 2006. Field trials to assess Steelhead smolt migration success through the Alouette Reservoir, 2006. Report prepared by LGL Limited, Sidney, B.C., for BC Hydro Bridge Coastal Restoration Program.

Mathews, M.A. and R.C. Bocking. 2007. Evaluation of the migration success of *O. nerka* (Kokanee / Sockeye) from the Alouette Reservoir, 2007. Report prepared by LGL Limited, Sidney, B.C., for BC Hydro Bridge Coastal Restoration Program.

Mathews, M.A. and R.C. Bocking. 2009. Evaluation of the migration success of *O. nerka* (Kokanee / Sockeye) from the Alouette Reservoir, 2008. Report prepared by LGL Limited, Sidney, B.C., for BC Hydro Water License Requirements.

Mathews, M.A. and R.C. Bocking. 2010. Evaluation of the migration success of *O. nerka* (Kokanee / Sockeye) from the Alouette Reservoir, 2009. Report prepared by LGL Limited, Sidney, B.C., for BC Hydro Water License Requirements.

Mathews, M.A. and R.C. Bocking. 2011. Evaluation of the migration success of *O. nerka* (Kokanee / Sockeye) from the Alouette Reservoir, 2010. Report prepared by LGL Limited, Sidney, B.C., for BC Hydro Water License Requirements.

Plate, E.M. and R.C. Bocking. 2010. Alouette Lake Sockeye tracking study 2009. Report prepared by LGL Limited, Sidney, B.C., for BC Hydro Bridge Coastal Restoration Program, Burnaby, B.C.

Plate, E.M. and R.C. Bocking. 2011. Alouette Lake Sockeye tracking study 2010. Report prepared by LGL Limited, Sidney, B.C., for BC Hydro Bridge Coastal Restoration Program, Burnaby, B.C.

Water Survey of Canada [Internet]. 2011. Gatineau, Q.C.: Government of Canada, Environment Canada; [modified 8 July 2011; accessed February 2012]. Available from: http://www.ec.gc.ca/rhc-wsc/

Wilson, G., K. Ashley, M. McCusker, R. Land, J. Stockner, G. Scholten, D. Dolecki, and D. Sebastian. 2003. The Alouette Reservoir Fertilization Project: Years 2000 and 2001 experiment, whole reservoir fertilization. Fisheries Project Report No. RD 99 2003. Ministry of Water, Land & Air Protection, Aquatic Ecosystem Section, Province of B.C.

APPENDICES

Appendix A. Physical data at the Mud Creek RST site, 2011.

Date	Water Temp (ºC)	Precipitation Activity (y/n)	RST RPM	Water Depth (cm)
13-Apr	--	y	8	--
14-Apr	6	y	8	32
15-Apr	5	y	9	32
16-Apr	6	n	8	35
17-Apr	5	n	8	34
18-Apr	5	n	8	34
19-Apr	6	n	8	35
20-Apr	6	n	8	34
21-Apr	6	n	8	35
22-Apr	6	n	8	34
23-Apr	8	n	8	33
24-Apr	6	n	8	34
25-Apr	6	y	9	33
26-Apr	6	y	8	36
27-Apr	6	y	9	38
28-Apr	6	y	8	38
29-Apr	6	n	8	36
30-Apr	7	n	8	35
1-May	7	n	8	34
2-May	8	y	8	34
3-May	6	n	8	34
4-May	6	n	8	33
5-May	9	y	8	33
6-May	8	y	8	33
7-May	7	y	8	35
8-May	8	n	9	37
9-May	8	n	8	35
10-May	8	n	8	34
11-May	7	y	8	35
12-May	7	n	9	39
13-May	8	n	8	34
14-May	10	y	8	33
15-May	10	y	8	33
16-May	8	y	8	34
17-May	7	n	8	36
18-May	8	n	8	35
19-May	8	n	8	36
20-May	8	n	8	36
21-May	8	y	8	36
22-May	9	y	8	36
23-May	8	n	8	36
24-May	9	y	8	36
25-May	10	n	8	35
26-May	7	n	8	35
27-May	9	n	8	36
28-May	10	n	8	35
29-May	9	n	8	35
30-May	9	n	8	35
31-May	10	n	8	35
1-Jun	11	n	8	35
2-Jun	10	y	12	42
3-Jun	10	n	12	43
4-Jun	11	n	11	42
5-Jun	10	n	11	42
6-Jun	10	n	11	42
7-Jun	8	n	11	42
8-Jun	10	n	11	42

Appendix B. Catch of non-target species at Mud Creek RST, Alouette River, 2011.

Date	Count & Release																
	Salmonid Fry	Chum Fry[a]	Coho / Chinook Fry (<70 mm)[a]	Chinook Parr /Smolt (>70 mm)	Coho Parr /Smolt (>70 mm)	Steelhead <90 mm	Dace Spp.	Sculpin Spp.	Northern Pike Minnow	Red Side Shiner	Peamouth Chub	Stickleback	Cutthroat	Lamprey	Rainbow no Clip	Crayfish	Other
14-Apr	4,000	100					4	5						2			
15-Apr	2,000	100				2	8	1						1			
16-Apr	8,000	100				1	39	3						4			
17-Apr	2,000	100				1	19	1									
18-Apr	2,000	100					12							1			
19-Apr	6,500	100					28	1						2			
20-Apr	6,500	99	1				53	3									
21-Apr	7,500	95	5	1	1		49	4						4			
22-Apr	4,100	98	2		2		12	8						2			
23-Apr	6,000	97	3	1	2	2	91	5								2	
24-Apr	6,500	96	4		3		40	4				1		1		2	
25-Apr	8,000	80	20		3		10	2									
26-Apr	4,000	90	10	6	8		13	5						2			
27-Apr	2,000	97	3	2	7		15	6						3			
28-Apr	500	90	10	4	3		6	16						5			
29-Apr	200	90	10	5	4		8			1				3		1	
30-Apr	100	97	3	3	10		23	1						3			
1-May	100	96	4		8		30	5						1			
2-May	100	97	3		2		36	1	1								
3-May	<100	98	2	1	3	1	7	4									
4-May	<100	60	40	1	8							1		2			
5-May	250	50	50	1	10		5										
6-May	200	50	50		6		1	1				1		1			
7-May	600	40	60	1	15	1		1		1							
8-May	600	10	90	8	45		3	2				2		1			
9-May	400	70	30	3	25		4	4									
10-May	150	90	10	1	12		9	1									
11-May	<100	97	3	2	6		2	2	1								
12-May	3,000	60	40	6	54	2	7	3									

Appendix B. continued.

Date	Count & Release																
	Salmonid Fry	Chum Fry[a]	Coho / Chinook Fry (<70 mm)[a]	Chinook Parr /Smolt (>70 mm)	Coho Parr /Smolt (>70 mm)	Steelhead <90 mm	Dace Spp.	Sculpin Spp.	Northern Pike Minnow	Red Side Shiner	Peamouth Chub	Stickleback	Cutthroat	Lamprey	Rainbow no Clip	Crayfish	Other
13-May	<200	40	60		17	1	22	2				4					
14-May	200	50	50	1	11		18	1				2				2	
15-May	2,000	70	30	2	4		4	3				1					
16-May	120	60	40	1	14												
17-May	<50	60	40		17	2	1					1					
18-May	<20	50	50		22		2	1						1			
19-May	500	50	50		32		5	5									
20-May	100	50	50		12	2		1				3					
21-May	<20	40	60		12	1											
22-May	1,000	30	70		16		2					1					
23-May	200	20	80		21			1	1							1	
24-May	200	25	75		8		3	3				8					
25-May	20	10	90	1	10	1		4	5			2		1			
26-May	1,000	10	90		21							4				1	
27-May	20	10	90		10				2			2					
28-May	<100	30	70		9				1			3					
29-May	<50	40	60		4			1				3					
30-May	<50	60	40		6			2				2					
31-May	<20	60	40		2	1	2	2	2								
1-Jun	<20	60	40		2		6	4	7			6		2		1	
2-Jun	<20	60	40		14		19	2	6			6					
3-Jun	<50	60	40		9			2	2	1				1		1	
4-Jun	50	60	40		3		16	1	4			8		1			
5-Jun	<50	10	90		4		15	2	3	1		9					
6-Jun	20	10	90	1	2		5	3	5			10					
7-Jun	20	10	90	1	2		1	3				6		1			
8-Jun	<20	-	-	1			2	1	2			3				1	
Totals	**<81,720**	**--**	**--**	**54**	**521**	**18**	**657**	**133**	**42**	**4**	**0**	**89**	**0**	**45**	**0**	**12**	**0**

[a] Species estimate of salmonid fry