Alouette Project Water Use Plan

Kokanee Out-Migration

Implementation Year 7

Reference: ALUMON-2

Evaluation of the Migration Success of O. nerka (Kokanee/Sockeye) from the Alouette Reservoir, - 2014

Study Period: 2014

LGL Limited

May 26, 2015

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Evaluation of the Migration Success of *O. nerka* (Kokanee / Sockeye) from the Alouette Reservoir, 2014

Prepared for:

BC Hydro
Water License Requirements
6911 Southpoint Drive, E16
Burnaby, BC V3N 4X8

Prepared by:

M. A. Mathews, J. J. Smith, and R. C. Bocking

LGL Limited
environmental research associates
9768 Second Street
Sidney, BC V8L 3Y8

May 2015

LGL LIMITED
environmental research associates

EVALUATION OF THE MIGRATION SUCCESS OF *O. NERKA* (KOKANEE / SOCKEYE) FROM THE ALOUETTE RESERVOIR, 2014

Prepared by:

M. A. Mathews, J. J. Smith, and R. C. Bocking

LGL Limited
environmental research associates
9768 Second Street
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EXECUTIVE SUMMARY

In order to assess the feasibility of anadromous sockeye salmon (*Oncorhynchus nerka*) re-introduction into the Alouette Reservoir, studies are being conducted to determine the migration success of *O. nerka* smolts from the reservoir; 2014 was the tenth 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 salmon (*O. kisutch*) smolts as they were captured in the Mud Creek rotary screw trap (RST), located 1.5 km downstream of the Alouette Dam. In 2006, spillway releases at the Alouette Dam again occurred from 11–31 May to evaluate the migration success of marked steelhead trout (*O. mykiss*) from the Alouette Reservoir. In both years, coincidental *O. nerka* migrations were monitored and an estimated 7,900 and 5,064 smolts migrated from the reservoir, respectively. From 2007 to 2013, the spillway was opened from mid-April until mid-June (but closed approximately two weeks earlier in 2007, 2008, and 2010, once the migration had ceased) and estimates of *O. nerka* smolt migrations from the reservoir ranged from 728 (95% CI: 348–1,108) in 2012 to 62,923 (95% CI: 48,436–77,410) in 2007.

The Mud Creek RST was operated during the complete duration of the *O. nerka* smolt migration from the Alouette Reservoir in 2014, from 15 April to 27 May. In total 2,878 *O. nerka* smolts were captured, 1,897 of which were lower caudal clipped and released below the Alouette Dam, 3,236 fish were inspected for clips, and 457 clipped fish were recaptured. Using a pooled Petersen estimator, an estimated 13,413 *O. nerka* smolts (95% CI: 12,423–14,404) migrated from the Alouette Reservoir between 16 April and 26 May. This was the fourth highest estimate in ten years of studies. Average daily spillway flows to the South Alouette River during the *O. nerka* migration were maintained at similar levels to past years and ranged from 3.17−4.93 m^3/s. No post-surface release flush occurred in 2014; however, four modified pulse flows (i.e., an increase to ~4.5 m^3/s for 24 hours) occurred between 12 May and 23 May. These pulses were performed to see if there was a corresponding increase in the number of out-migrating juveniles in response to the flush.

A subsample of *O. nerka* smolts captured at the Mud Creek RST in 2014 were sampled for length, weight, age (scales), and genetics (fin tissue). Randomly chosen *O. nerka* smolts (<100 mm FL) averaged 78 mm FL (range: 64–99 mm FL; n = 738) and 4.2 g (range: 2.1–8.3 g; n = 738); 94% of all randomly sampled smolts (all lengths) were Age 1 fish. All other species captured were counted and released, including 70 steelhead smolts (>90 mm FL), 203 coho parr/smolts (>70 mm FL) and more than 100,000 salmonid fry, most of which were chum salmon (*O. keta*).

The 2014 study was the final year of the Kokanee Out-Migration (ALUMON#2) project funded through the Alouette Water Use Plan (WUP) Monitoring Program. This monitoring program successfully addressed the three management questions originally proposed in the WUP terms of reference. First, this monitoring program showed that a surface release of at least 3 m^3/s from the Alouette Dam (obtained through the spillway gate) was adequate to promote the downstream migration of *O. nerka* smolts out of the Alouette Reservoir. In each year of study, *O. nerka* catches at the Mud Creek RST showed a distinct start, peak, and end, which is a characteristic pattern for out-migrating kokanee/sockeye smolts. Second, this monitoring program revealed that a post-surface release flush of 6–9 m^3/s, lasting seven days following the tail end of the

out-migration period, did not encourage more smolts to leave the system. Flush events (2009, 2010, and 2011) and pulse flows (2014) did not yield an increase in *O. nerka* catches at the Mud Creek RST. And third, this monitoring program showed that a surface-release period from mid-April to early June will ensure the out-migration of all *O. nerka* smolts that are prepared to leave the system. It is anticipated that the monitoring program at Mud Creek will continue through other funding avenues.

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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 (*Oncorhynchus* spp.) runs above the Alouette Dam at the outlet of the Alouette Reservoir (Figure 1). 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 the Alouette Reservoir or through the diversion to Stave Lake at the north end of the Alouette Reservoir.

In 2002, LGL Limited (Sidney, B.C.) 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 the Alouette Reservoir.

To address the issue of whether smolts would exit over the Alouette dam or the diversion to Stave Lake, the BCRP sponsored a study in 2005 that monitored the migration of coho salmon (*O. kisutch*) smolts out of the Alouette Reservoir and down the South Alouette River using unique colours of visible implant elastomer (VIE) 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 salmon smolts to the lower Alouette River ranged from 79% for fish released at the spillway to 31–38% for fish released in the reservoir. The 2005 study also monitored the migration of sockeye salmon (*O. nerka*; raised to a suitable size) that were tagged with acoustic transmitters for subsequent detection in listening arrays in the lower Fraser River, Juan de Fuca Strait, and Strait of Georgia. From the release location, the estimated migration success was 26% to the lower Fraser River 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 that the surface release occur annually.

In 2006, a study was conducted to monitor steelhead (*O. mykiss*) smolt migration success out of the Alouette Reservoir and down the South Alouette River using both VIE 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 success 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 fish migrating from the reservoir during the surface release flow of ~3 m^3/s.

The 2005 and 2006 study results indicated that *O. nerka* smolts were successfully migrating from the Alouette Reservoir and there was the potential for adult sockeye salmon to return as early as 2007.

In order to assess the feasibility of sockeye salmon 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 rotary screw trap (RST), located 1.5 km downstream of the Alouette Dam (Figure 2). An estimated 62,923 (95% confidence interval [CI]: 48,436−77,410) *O. nerka* emigrated from the Alouette Reservoir that year (Mathews and Bocking 2007). Supported by the previous three years of results, and as part of the Alouette Project Water Use Plan (BC Hydro 2009a), surface release flows were scheduled to continue annually with the expectation of re-establishing a sockeye salmon run. In 2008, 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; this included a mark-recapture estimate of 7,712 fish (95% CI: 6,682–8,742) passing Mud Creek from 21 April to 8 May, plus an additional 545 fish (estimate based on trap efficiency) that passed outside of the marking period (Mathews and Bocking 2009). In 2009, 1,247 *O. nerka* were captured in the RST, yielding a total estimate of 4,287 (95% CI: 3,833–4,741) for the period of 21 April to 28 May (Mathews and Bocking 2010).

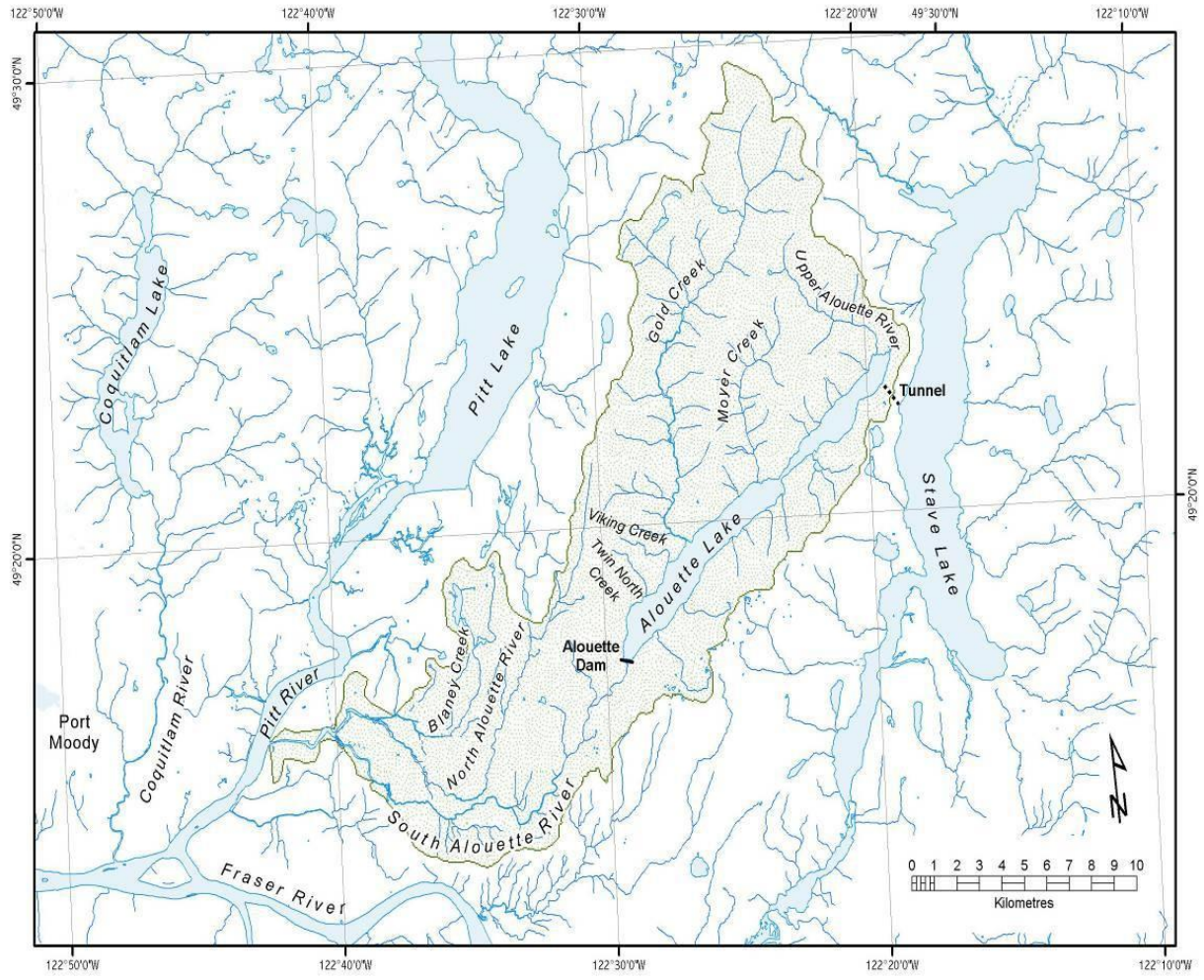

Figure 1. Map of the Alouette Watershed showing local communities and features.

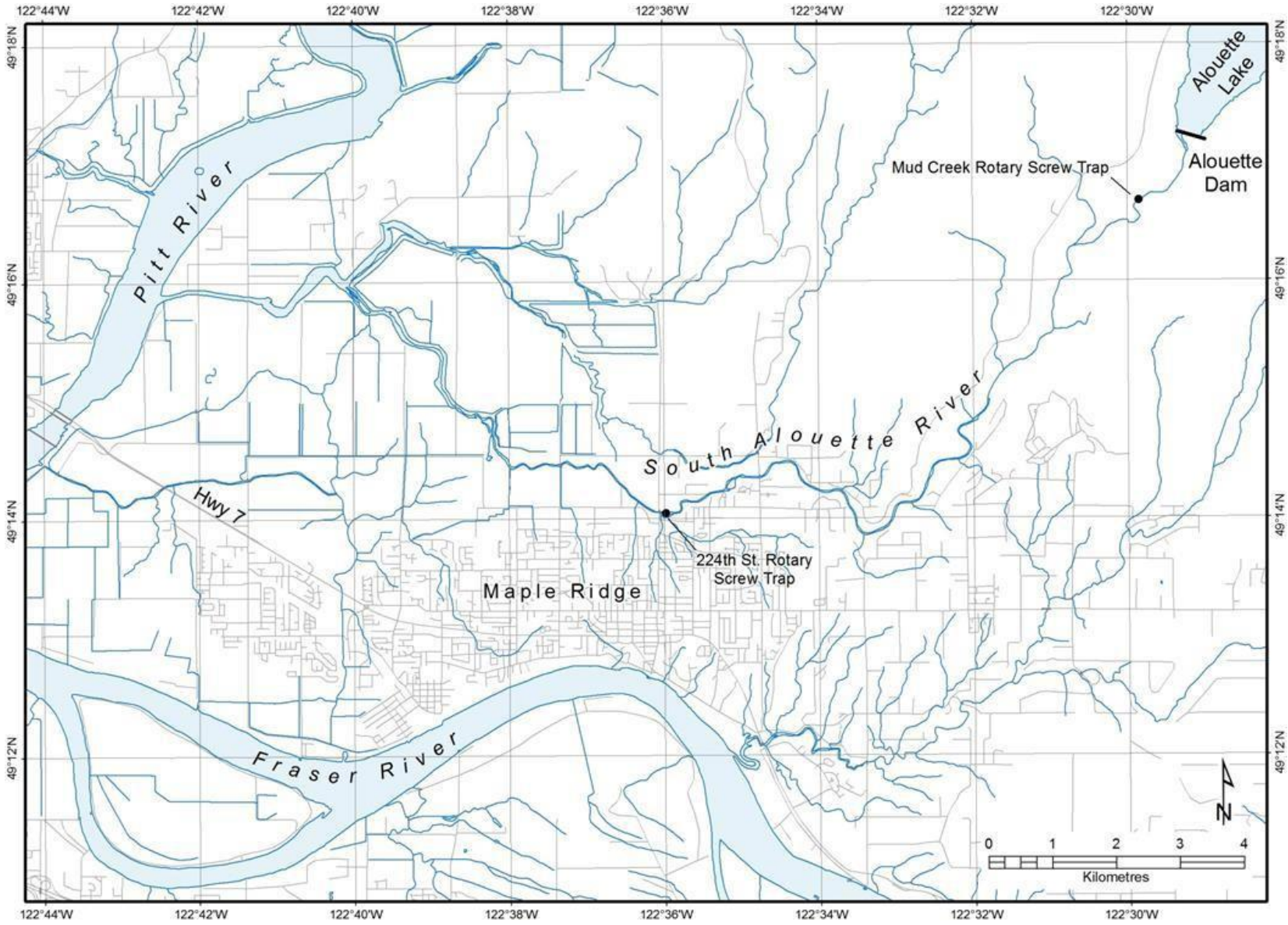

Figure 2. Map of the South Alouette River and locations of the rotary screw traps operational in 2014.

In 2010, two sites were to be used for the mark-recapture study. The Mud Creek RST was initially intended to operate as the recapture site. Two inclined plane traps (IPTs) located approximately 500 m upstream from the RST were intended to operate as the marking site. The IPTs were also to be used as a safe and effective trapping method during the flush. However, despite numerous modifications to the IPTs and the trapping site, they were not successful at capturing *O. nerka* smolts and were removed in early May. Fortunately, the RST operated as both the mark and recapture sites (as in previous years), and was used effectively during the 2010 flush period. In total, 4,600 *O. nerka* were captured at the RST, yielding a total estimate of 14,201 fish (95% CI: 13,624–14,778) 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 2011, 9,841 *O. nerka* were captured at the Mud Creek RST and a mark-recapture estimate of 35,542 fish (95% CI: 34,034−37,051) was generated (Mathews et al. 2012). The 2012 study recorded the lowest catches (83 *O. nerka*) since trapping began at the Mud Creek site; resulting in a mark-recapture estimate of 728 fish (95% CI: 348–1,108; Mathews et al. 2013). In 2013, an estimated 6,179 *O. nerka* (95% CI: 5,350−7,008) migrated from the Alouette Reservoir (Mathews et al. 2014).

In the summer of 2007, 28 adult sockeye salmon returned to the South Alouette River (Balcke 2009). Genetic and scale-sample analyses indicated that these fish were from the 2005 *O. nerka* smolt migration from the reservoir (Godbout et al. 2011). During the summer of 2008, 54 adult sockeye salmon returned to the South 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 salmon 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). Returns of adult sockeye salmon to the Alouette River in 2010 were the largest thus far as 115 migrants returned to the outlet of the reservoir (Cruikshank and Crowston 2011). Radio telemetry was again used to help determine spawning locations and timing; 20 sockeye salmon were tagged and tracked (Plate and Bocking 2011). In 2011, 11 adult sockeye salmon returned (Crowston and Borick-Cunningham 2012), of which four were tagged (E. Plate, LGL Limited, pers. comm.). Adult returns then increased again in 2012 as 45 sockeye salmon returned to the South Alouette River (Borick-Cunningham 2013). Of these fish, 21 were tagged and tracked which improved our understanding of spawning timing and locations within the reservoir (Plate and Bocking 2013). Nine adult sockeye salmon were counted at the Allco Hatchery fence in 2013, but none returned in 2014 (N. Driedger, Alouette River Management Society, pers. comm.).

Seven years of adult returns, along with the continued smolt migration, lend support to the feasibility that a South Alouette River sockeye salmon 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 that the surface release and associated *O. nerka* out-migration enumeration would be conducted through 2014. Due to run-timing uncertainty, it was proposed that the surface release be done for a period of eight weeks each year. Annual monitoring would continue in order to identify the typical start, duration, and peak of the outmigration in hopes of shortening the duration of the surface release and reducing the corresponding flood risks. Although the migration timing has remained

relatively consistent during the seven years of full-season monitoring, there have been differences in peak timing and duration. The 2011 migration continued through the first week of June, which was approximately a week later than the 2007 and 2009 migrations, and two weeks later than in 2008 and 2010. The peak of the 2009 migration occurred in the latter half of May, while the peaks in 2007, 2008, 2010, and 2013 occurred in late April. The 2010 migration also began with high catches immediately once the spillway was opened in mid-April. Peak catches in 2012 occurred on the same date as 2011 (14 May); however, daily catches were extremely low and hence not readily comparable to previous years. Subsequent years of monitoring are, therefore, beneficial to help to improve our 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 only three days. As a result, it was proposed that a flush occur again in 2010 with an alternative gear type (IPTs) that could be operated safely during high flows. However, as discussed earlier, the IPTs were not effective at capturing *O. nerka* smolts, so operational modifications were made to the RST so that it could operate safely and effectively during the seven day flush period. No increases in *O. nerka* catches were observed at the Mud Creek RST during the 2010 and 2011 post-surface release flush periods.

Management Questions

Three management questions related to the out-migration of salmonids were formulated by the WUP CC (BC Hydro 2009b):

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/sockeye smolts, as identified from RST data collected at the confluence of Mud Creek, has a start, peak, and end that are characteristic of kokanee/sockeye smolts found in other systems (e.g., Cultus Lake sockeye salmon).

2) Does a post-surface release flush of 6–9 m^3/s, lasting seven 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/sockeye 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 was to 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, an assessment of downstream movement patterns, and smolt out-migration data from other coastal systems. These findings were to form the basis for an alternative surface release regime to be considered at the next WUP review in 2014/2015.

Project Objectives

Specific objectives for the 2014 study year were to:

1) Operate the Alouette Dam spillway to allow ~3.0–4.5 m^3/s of flow from 15 April to 14 June; flows through the low level outlet will be held near 0.0 m^3/s for the study period;
2) Provide pulse flows of ~4.5 m^3/s on 4 separate occasions throughout the outmigration period;
3) 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 (or earlier if the migration ceases) to monitor the migration of *O. nerka* from the reservoir;
4) Capture *O. nerka* from the Alouette Reservoir in the Mud Creek RST;
5) Mark all *O. nerka* captured (up to a maximum of 150 fish + 10 target samples / day) throughout the entire migration and re-capture these same marked *O. nerka* in the Mud Creek RST to estimate total migration;
6) Determine the abundance, timing and biological characteristics of *O. nerka* migrating from the Alouette Reservoir;
7) Collect genetic tissue from 100 individuals of *O. nerka* to determine stock identification; and
8) Record incidental catches of all other species.

METHODS

Study Area

The Alouette Reservoir is located in east Maple Ridge in southwest British Columbia (Figure 1). The 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*), bull trout (*Salvelinus confluentus*), cutthroat trout (*O. clarki clarki*), lake trout (*Salvelinus namaycush*), stickleback (*Gasterosteus* sp.), sculpin (*Cottus* sp.), northern pikeminnow (*Ptycheilus oregonensis*), peamouth chub (*Mylocheilus caurinus*), bridgelip sucker (*Catostomus columbianus*), largescale sucker (*Catostomus macrocheilus*), and redside shiner (*Richardsonius balteatus*; Wilson et al. 2003).

BC Hydro Operations

To facilitate the 2014 study, BC Hydro agreed to release water over the spillway at the Alouette Dam, while closing the low level outlet, for the period of 15 April to 14 June. The spillway release and low level outlet closure were consistent throughout the duration of the RST operation. Four modified pulse flows, where flows were increased to ~4.5 m^3/s for 24 hours, occurred between 12 May and 23 May.

Fish Capture and Sampling

All fish for this study were captured at the Mud Creek RST, located on the South Alouette River approximately 1.5 km downstream of the Alouette Dam (Figure 2; Photo 1). The Mud Creek RST was checked twice daily. Each morning, crews enumerated all species of fish in the holding box. Unmarked non-target fish were enumerated to species and released downstream of the trap. All steelhead were examined for adipose fin clips (applied in 2006); and if clipped, were also examined for the presence of a fluorescent VIE tag prior to release. Each evening, crews checked the RST for debris and ensured that all fish in the holding box were healthy. All fish captured after the morning check were processed the following morning.

Up to a daily maximum of 150 randomly chosen *O. nerka* were marked with a lower caudal fin clip. If the random sample did not produce ten large fish (≥100 mm FL), then additional target samples were to be collected until this goal was reached (up to a maximum of 10 fish per day). All target fish were to receive an adipose fin clip instead of a lower caudal fin clip. All marked fish were released into the plunge pool below the dam during the evening on the day they were marked which allowed adequate time for recovery.

The first 40 randomly chosen *O. nerka* each day, as well as any target samples of large fish, were measured for fork length (to the nearest millimetre) and weighed (to the nearest tenth of a gram). Fish scales were collected from the first 10 randomly chosen *O. nerka* each day, and from all target samples. Scales were sent to the Pacific Salmon Commission (Vancouver, B.C.) for ageing (age results from 2010–2014 can be found in the Discussion section). Genetic samples (fin tissue) were collected from the first 40 randomly chosen *O. nerka* each day, from all target samples, and from any mortalities. Genetic samples were sent to the Pacific Biological Station (Nanaimo, B.C.) to process for stock identification (2014 results can be found in Godbout et al. 2014).

Photo 1. Mud Creek rotary screw trap, 14 April 2014.

Statistical Analyses

Abundance Estimate

A pooled Petersen estimator with Chapman modification was used to estimate the number of *O. nerka* migrating from the reservoir:

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

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, and
R = number of recaptures in the second sample (i.e., fish that were marked and released in the first sample).

The variance, standard error, and approximate 95% confidence interval for the abundance estimate (*N*) were calculated as follows:

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

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

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

Fish Lengths, Weights, and Condition Factor

The lengths, weights, and condition factors of randomly chosen one-year-old *O. nerka* smolts (i.e., fish considered to have over-wintered for one year in the Alouette Reservoir) were compared by year of monitoring using ANOVA. Length-at-age data from 2005 to 2010 (Mathews and Bocking 2011) indicated that one-year-old fish were 100 mm FL or less, thus bigger fish were excluded from the length and weight analyses. When ANOVA results were statistically significant, Tukey's HSD post-hoc multiple comparison was used to assess pairwise differences.

224th Street Rotary Screw Trap

Westslope Fisheries Ltd. has been conducting a separate smolt migration enumeration study on the South Alouette River since 1998. This monitoring project has been a requirement of the Alouette WUP (ALUMON-1) since 2008. The current trapping site is located approximately 14 km downstream of the Alouette Reservoir near 224th Street (Figure 2; Cope 2015). The main objective of this annual study was to obtain abundance estimates of emigrant fry and smolts (by species) using mark-recapture techniques. Crews at the 224th Street RST inspected all *O. nerka* for fin clips that were applied at the Mud Creek RST.

RESULTS

BC Hydro Operations

The Alouette Dam spillway gate was opened on 15 April 2014 at 0948 hours and remained open until 17 June at 1136 hours. During the *O. nerka* smolt migration period from 15 April to 25 May, average daily releases from the spillway gate ranged from 3.17 m^3/s (as measured on 16 April, the first full day of spilling from the crest gate) to 4.93 m^3/s (Figure 3; Appendix A). The low level outlet gate was closed from 15 April (1004 hours) to 17 June (1110 hours). Spillway flows were similar to those maintained during the full monitoring years (2007 and later); however, no flushing flows occurred at the tail end of the 2014 migration. Four pulse

flows occurred during the latter half of the migration; average daily releases from the spillway gate during the pulses were 4.52 m^3/s, 4.54 m^3/s, 4.32 m^3/s, and 4.58 m^3/s (occurred on 12 May, 14 May, 20 May, and 22 May, respectively). Also, as has been the case in past years, the majority of Alouette flows in 2014 were diverted to the Stave Reservoir via the adit gate (ranged from 0.00 to 28.74 m^3/s during the migration).

Fishing Effort and Physical Conditions

The Mud Creek RST was operated almost continuously from 15 April (0930 hours) to 27 May (1030 hours). The RST was stopped for 3.3 hours (0930–1245 hours) on 16 April to adjust a collar on the drum. Although spillway flows continued as planned until 17 June, monitoring ceased on 27 May because only one *O. nerka* had been captured since 22 May, and the migration was presumed to have ended.

Water temperature, water depth, RST rotational speed, and general weather conditions were recorded daily each morning from 15 April to 27 May at the Mud Creek site (Appendix B). Water temperature was measured using a hand-held thermometer. Daily discharge of the South Alouette River was recorded at the Water Survey of Canada (WSC) Station No. 08MH005 (~10 km downstream of the Mud Creek RST site), and ranged from 4.56–14.03 m^3/s (mean = 7.75 m^3/s) between 15 April and 27 May (Figure 4). Two spikes (17–18 April, 5 May) in Alouette River discharge occurred during the smolt migration; however, only the first spike was associated with a large increase in spillway flows at the Alouette Dam (the latter spike in discharge was likely due to an increase in tributary input; Figure 4; Appendix A).

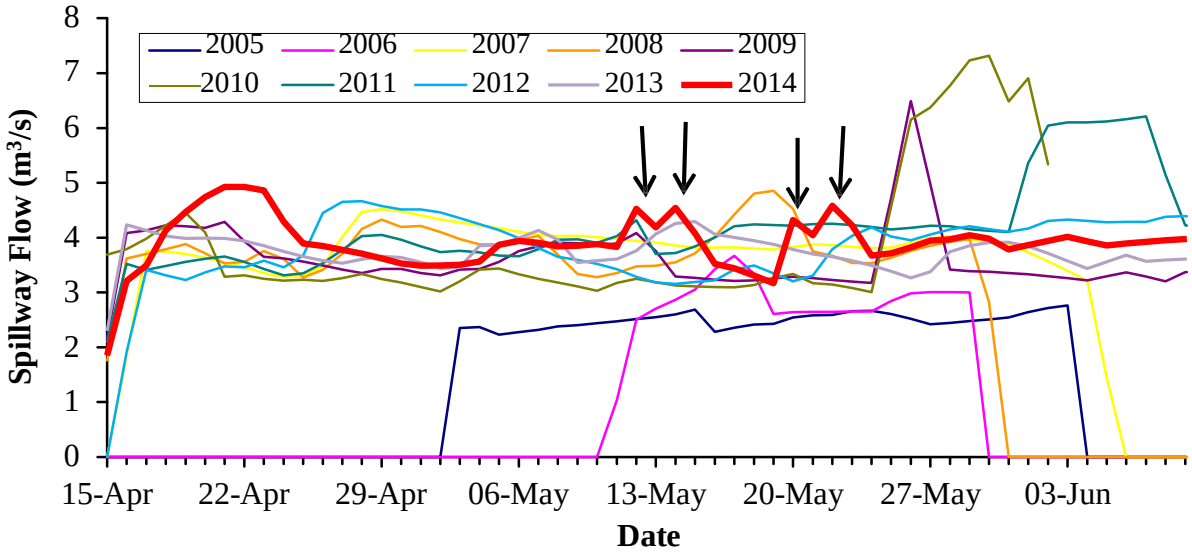

Figure 3. Comparison of flows at the Alouette Dam spillway gate during the *O. nerka* migration period, 2005–2014. Black arrows indicate four pulse flows.

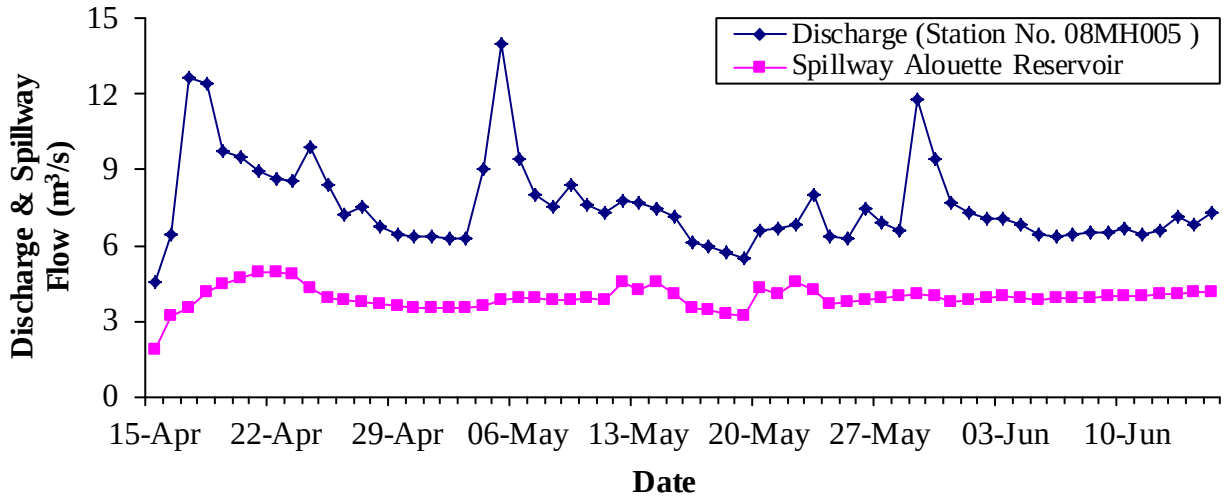

Figure 4. Daily discharge (m^3/s) at WSC Station No. 08MH005 and spillway flows from the Alouette Reservoir (15 April–15 June 2014). The WSC station is located on the mainstem South Alouette River at the 232nd Street bridge (discharge data from WSC website: http://www.ec.gc.ca/rhc-wsc/).

Fish Capture and Sampling

O. nerka

In 2014, 2,787 unmarked *O. nerka* were captured in the Mud Creek RST from 15 April to 27 May (Table 1; Figure 5). The peak catch of 490 smolts occurred on 28 April. The first *O. nerka* was captured on 16 April, and the last *O. nerka* was captured on 26 May; a migration duration of 41 days.

A total of 1,897 *O. nerka* ('M') were marked (lower caudal clipped) and released below the dam from 15 April to 25 May 2014 (Table 2). In total, 3,236 smolts ('C') captured at the Mud Creek RST were examined for marks and considered available for recapture, 457 ('R'; 14.1%) of those examined were lower caudal clipped recaptures. One *O. nerka* marked and released on 26 May was censored from the first-event sample since the RST was shut down for the season the following day (27 May). Eight *O. nerka* captured from 16–17 April were censored from the second-event sample due to the assumption of a two day travel time from the plunge pool release site to the RST capture site (i.e., it was highly unlikely that these 8 fish were already marked and hence had the potential of being recaptures). Capture efficiency at the Mud Creek RST was estimated to be 24.1% (457 recaptures out of 1,897 marked fish released). Using a pooled Petersen estimator, an estimated 13,413 ('N'; 95% CI: 12,423–14,404) smolts migrated from the Alouette Reservoir from 16 April to 27 May (Table 2). No target fish were sampled in 2014, hence, no *O. nerka* were adipose clipped.

Of the 2,787 unmarked *O. nerka* captured at Mud Creek in 2014, 758 were biosampled for fork length and weight, and their corresponding fin clips were collected for genetic stock identification. Of those biosampled, 256 smolts were also scale-sampled for age analysis.

The lengths of *O. nerka* sampled ranged from 64–247 mm FL (mean = 80 mm FL; n = 758; Figure 6). The largest number of *O. nerka* were in the 76–80 mm (n = 280) size class, followed closely by the 71–75 mm (n = 213) size class. The weights of *O. nerka* sampled ranged from 2.1–146.9 g and averaged 4.8 g (n = 758). Figure 7 displays a length-weight relationship established for the 2014 *O. nerka* smolts migrating from the Alouette Reservoir.

Of those *O. nerka* measuring less than 100 mm FL (i.e., fish considered to have over-wintered for one year in the Alouette Reservoir), mean lengths varied significantly among years ($F_{9,5022} = 481.7$, $P < 0.01$; Table 3; Figure 8). Post-hoc pairwise comparisons between years indicated the 2005, 2006, 2012, and 2014 mean fork lengths (78.6, 79.5, 79.9, and 78.1 mm, respectively) were not significantly different, and neither were the 2006, 2007, and 2012 mean fork lengths (79.5, 80.8, and 79.9 mm FL, respectively). However, the mean fork lengths from all other year combinations differed significantly from one another. The mean fork length of fish (<100 mm) measured in 2014 (78.1 mm) was the fourth lowest observed in the ten years of study.

No weight data was collected in 2008, and the weight data collected in 2005 was excluded due to sampling biases. The average weight of one-year-old *O. nerka* varied significantly among the remaining study years ($F_{7,4320} = 608.7$, $P < 0.0001$; Table 4). Post-hoc pairwise comparisons between years indicated that the mean weights in 2006, 2007, and 2012 (4.6, 4.8, and 4.3 g, respectively) were not significantly different, and neither were the 2012 and 2014 mean weights (4.3 and 4.2 g, respectively; Figure 8). However, the mean weights from all other year combinations differed significantly. The mean weight of fish (<100 mm) measured in 2014 (4.2 g) was the sixth highest observed in eight years of study.

No condition factors were calculated from data collected in 2005 or 2008. The average condition factor varied significantly among the remaining study years ($F_{7,4320} = 156.7$, $P < 0.0001$). Results of the post-hoc pairwise comparisons between years are shown in Figure 8, where years that are not connected by the same letter are significantly different (2013 was not different from 2009 or 2014; 2012 was not different from 2010 or 2011, etc.). The mean condition factor of fish (<100 mm) in 2014 (0.87) was the fifth highest in eight years of study.

The average length of *O. nerka* smolts measuring less than 100 mm FL and the estimated abundance of *O. nerka* (all sizes) that migrated from the South Alouette Reservoir were also compared (Figure 9). There was no apparent relationship between smolt size and abundance.

Steelhead Smolts

In 2014, a total of 69 wild steelhead smolts (>90 mm FL) were captured in the Mud Creek RST. Wild steelhead smolts were caught fairly consistently from 16 April to 27 May, and the peak catch occurred on 5 May (n = 8; Figure 10). In addition, one adipose-clipped steelhead smolt (>90 mm FL) was captured on 27 May.

Table 1. Daily catch of *O. nerka* in the Mud Creek and 224th Street rotary screw traps, 2014.

	Mud Creek		224th Street	
Date	Unmarked	Clip Recaptures	Unmarked	Clip Recaptures[a]
13-Apr				
14-Apr				
15-Apr	0	0		
16-Apr	4	0		
17-Apr	4	0		
18-Apr	13	0		
19-Apr	59	1	3	0
20-Apr	66	10	0	0
21-Apr	89	13	6	3
22-Apr	256	12	8	0
23-Apr	316	25	22	1
24-Apr	210	24	34	0
25-Apr	275	37	11	0
26-Apr	241	29	6	0
27-Apr	126	20	10	3
28-Apr	490	33	14	3
29-Apr	55	21	27	3
30-Apr	115	27	20	0
01-May	100	38	14	5
02-May	95	36	14	5
03-May	100	30	9	3
04-May	38	43	2	1
05-May	75	13	1	0
06-May	11	21	0	0
07-May	6	2	0	0
08-May	5	4	0	0
09-May	8	5	0	0
10-May	2	1	0	0
11-May	3	1	0	0
12-May	3	0	0	0
13-May	5	0	0	0
14-May	2	1	0	0
15-May	0	1	0	0
16-May	1	0	0	0
17-May	1	0	0	0
18-May	4	0	0	0

Table 1. Continued.

	Mud Creek		224th Street	
Date	Unmarked	Clip Recaptures	Unmarked	Clip Recaptures[a]
19-May	5	4	1	0
20-May	2	2	0	0
21-May	0	1	0	0
22-May	1	1	0	0
23-May	0	1	0	0
24-May	0	0	0	0
25-May	0	0	0	0
26-May	1	0	0	0
27-May	0	0	0	0
28-May			0	0
29-May			0	0
30-May			0	0
31-May			0	0
01-Jun			0	0
02-Jun			0	0
03-Jun			0	0
04-Jun			0	0
05-Jun			0	0
06-Jun			0	0
07-Jun			0	0
08-Jun			0	0
09-Jun			0	0
10-Jun			0	0
11-Jun			0	0
12-Jun			0	0
Total	**2,787**	**457**	**202**	**27**

[a] Clip recaptures from the Mud Creek RST; an additional 12 fish (not displayed) were recaptures from the 224th Street location.

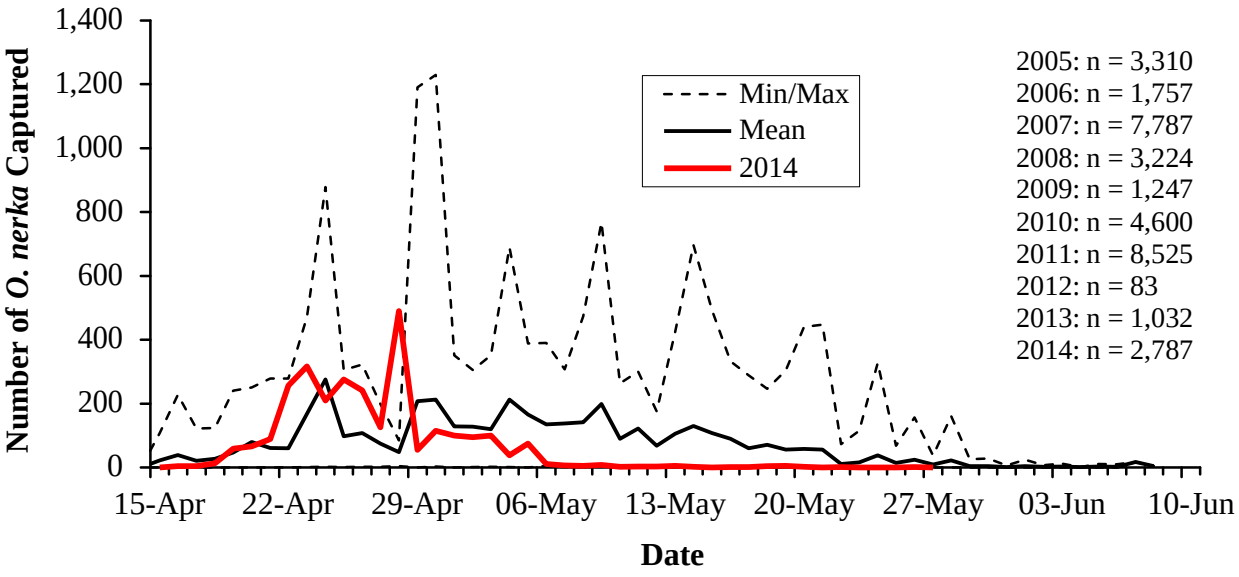

Figure 5. Daily catch of *O. nerka* at the Mud Creek rotary screw trap in 2014 in comparison to the maximum, mean and minimum catches of the previous nine years (spillway opened 3 May, 11 May, 16 April, 15 April, 15 April, 14 April, 15 April, 16 April, 15 April, and 15 April for 2005–2014, respectively).

Table 2. Total estimated *O. nerka* migration from the Alouette Reservoir, 2014.

No. *O. nerka* Clipped and Released Below Dam ('M')	1,897
No. *O. nerka* Examined for Clips ('C')	3,236
No. *O. nerka* Recaptures ('R')	457
Estimated *O. nerka* Passage (15 April–25 May 2014) ('N')	**13,413**
95% Confidence Intervals	(12,423–14,403)
Trap Efficiency	24.1%

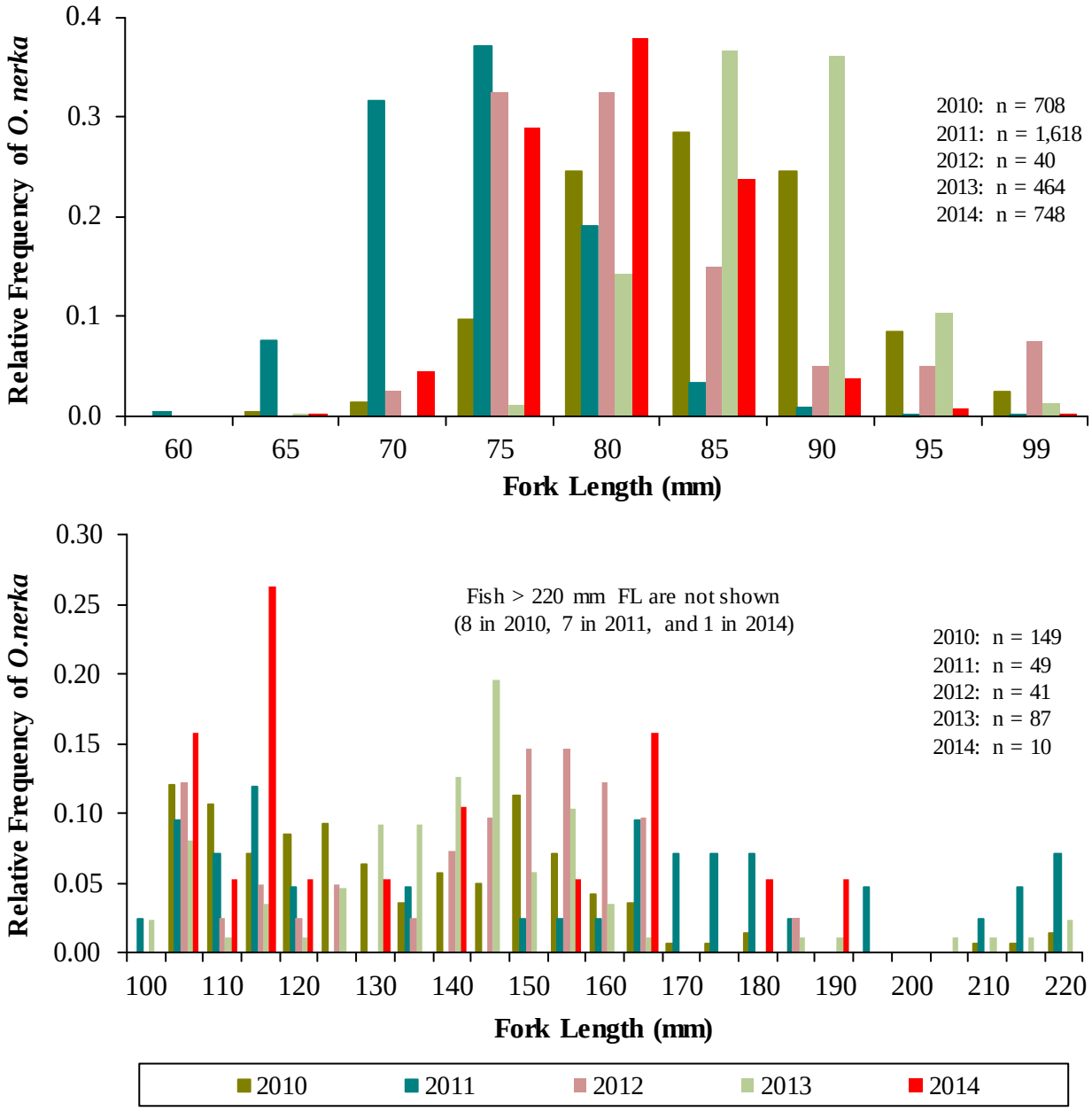

Figure 6. Length frequency distribution of *O. nerka* measuring less than 100 mm FL (top panel), and 100 mm FL or greater (bottom panel), captured in the Mud Creek rotary screw trap operated in the South Alouette River (random samples), 2010–2014.

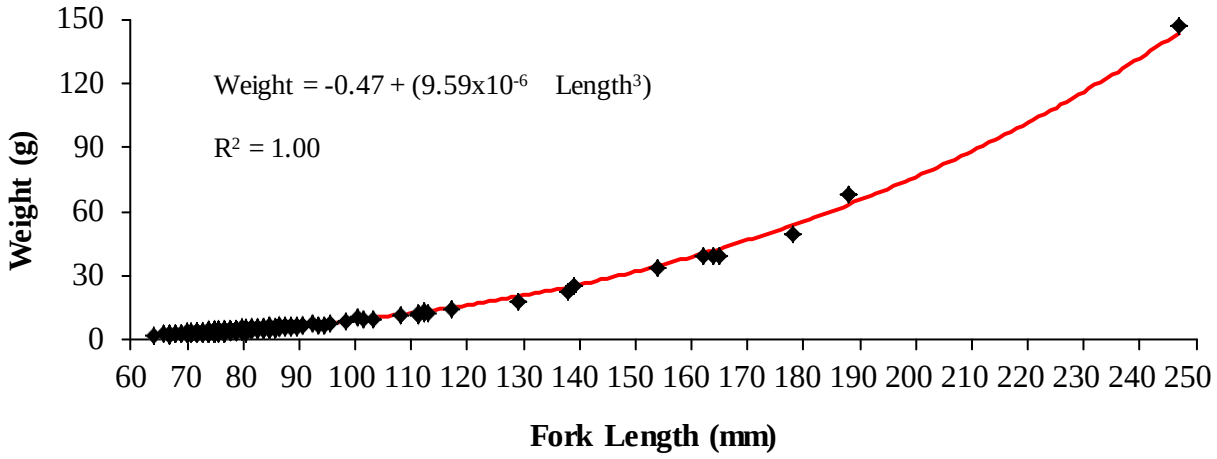

Figure 7. Length-weight relationship of *O. nerka* smolts migrating from the South Alouette Reservoir, 2014.

Table 3. Mean length of *O. nerka* less than 100 mm FL (random samples only), 2005−2014.

Year	Mean FL (mm)	SE	n
2005	78.6	0.34	233
2006	79.5	0.53	97
2007	80.8	0.37	198
2008	71.2	0.25	447
2009	75.0	0.24	489
2010	83.2	0.20	708
2011	72.4	0.13	1,618
2012	79.9	0.83	40
2013	85.6	0.24	464
2014	78.1	0.19	738

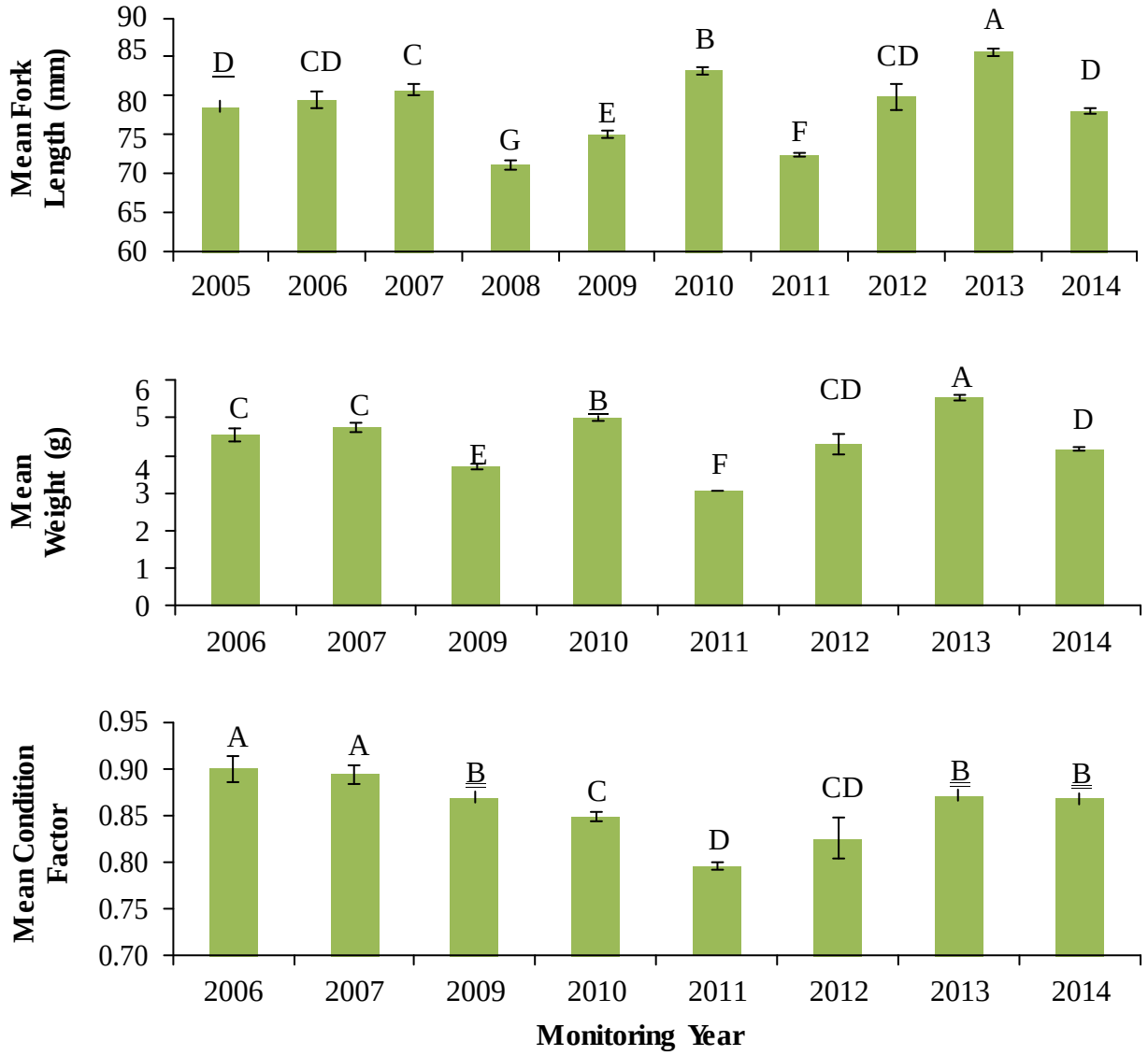

Figure 8. Comparison of mean fork length (top), weight (middle), and condition factors (bottom) across sampling years for *O. nerka* (<100 mm FL) captured at the Mud Creek RST, 2005–2014. Letters indicate results of the post-hoc pairwise comparisons between years, where years that are not connected by the same letter are significantly different.

Table 4. Mean weights of *O. nerka* less than 100 mm FL (random samples only), 2006−2007 and 2009–2014.

Year	Mean Wt (g)	SE	n
2006	4.6	0.09	97
2007	4.8	0.06	198
2009	3.7	0.04	489
2010	5.0	0.03	684
2011	3.1	0.02	1,618
2012	4.3	0.14	40
2013	5.5	0.04	464
2014	4.2	0.03	738

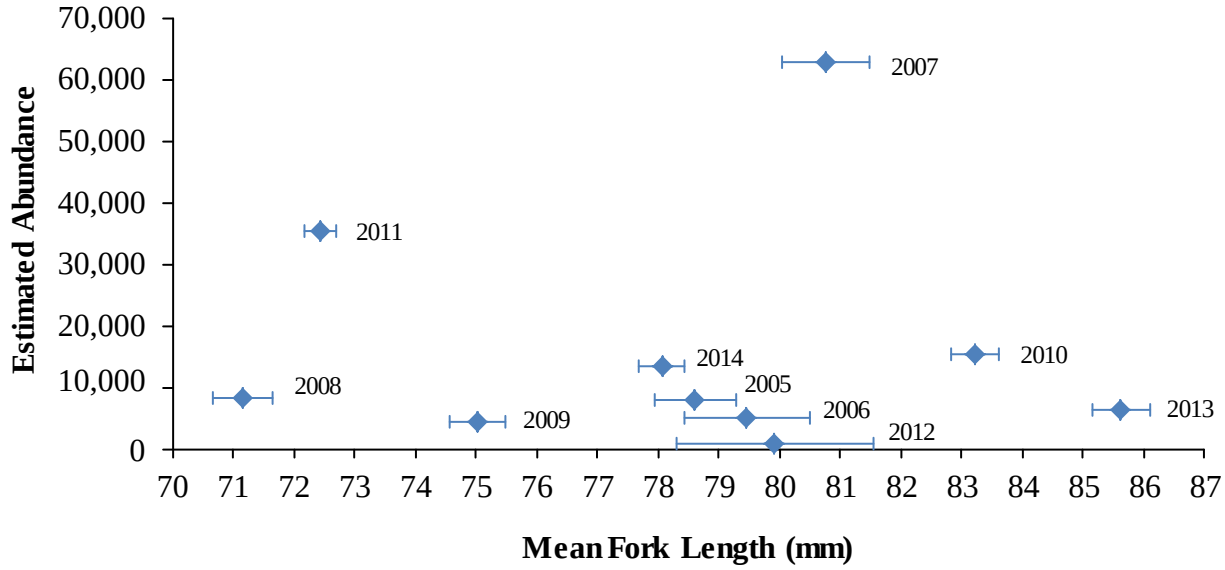

Figure 9. Comparison of the average length of *O. nerka* smolts measuring less than 100 mm FL and the estimated abundance of *O. nerka* (all sizes) that migrated from the South Alouette Reservoir, 2005–2014. Labels beside the data points indicate the study year.

Other Species

Consistent with past sampling years, many other non-target species were captured in the Mud Creek RST in 2014. Greater than 100,000 salmonid fry were estimated from daily catches. The vast majority of fry were chum salmon (*O. keta*) and the remainder were Chinook (*O. tshawytscha)* and coho salmon (Appendix C). Other salmonid catches included a total of 213 coho salmon parr/smolts (>70 mm FL), 25 Chinook salmon parr/smolts (>70 mm FL), 11 steelhead (<90 mm FL), and 1 adult steelhead (~2.7 kg). In addition to these salmonids, dace (*Rhinichthys* spp.), sculpin spp., northern pikeminnow, stickleback, sucker spp., and lamprey (*Lampetra* sp.) were also counted and released.

224th Street Rotary Screw Trap

The 224th Street RST operated from 7 March to 13 June 2014 (Cope 2015). In total, 202 *O. nerka* were captured from 19 April to 19 May, of which 27 were lower caudal clipped fish (i.e., marked at the Mud Creek RST; Table 1). An additional 12 upper caudal clipped fish were recaptured after having been previously caught and marked at the 224th Street site. The estimated *O. nerka* catch efficiency of the 224th Street RST was 8.0% (12 recaptures out of 150 marked fish released). Due to small sample sizes an accurate population estimate could not be generated for *O. nerka* at the 224th Street site in 2014.

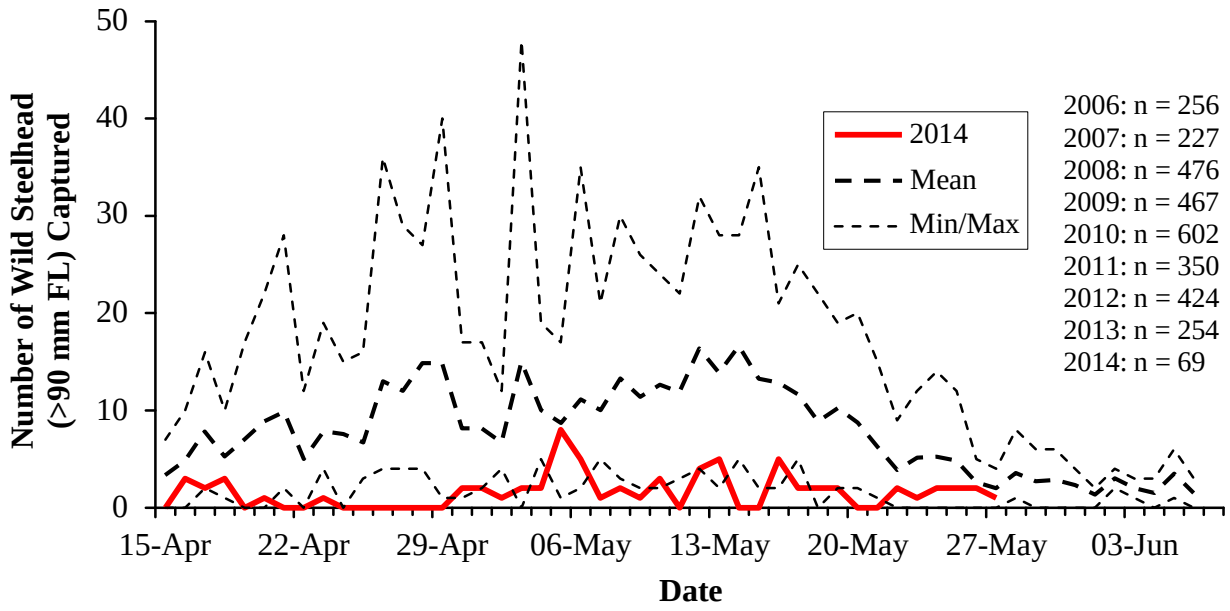

Figure 10. Daily catch of wild steelhead smolts (>90 mm FL) at the Mud Creek rotary screw trap, 2014. Minimum, maximum, and mean daily catches from 2006−2013 were plotted for reference.

DISCUSSION

BC Hydro Operations

Average daily spillway gate flows to the South Alouette River during the smolt migration were maintained at a similar range as past full monitoring years (2007 onward); 2014 flows ranged from 3.17–4.93 m^3/s (Figure 3). As was the case in 2013, no post-surface release flush occurred in 2014 as catches ceased by 27 May. Four modified pulse flows occurred between 12 May and 23 May 2014. Flows to the Stave Reservoir via the adit gate in 2014 (0.00 to 28.74 m^3/s) were similar to previous years with the exception of 2012 (2012 adit gate flows were approximately double those of other years).

Trapping Effort

For the fifth consecutive year, the Mud Creek RST was operated consistently throughout the *O. nerka* migration period. Crews were able to effectively and safely operate the RST over a range of water conditions with very minimal down time.

Abundance Estimate

At Mud Creek, the South Alouette River *O. nerka* smolt migration was estimated to be 13,413 (95% CI: 12,423–14,403) fish for the period of 15 April to 27 May 2014. This was the fourth highest estimate in ten years of study. The 2014 estimate was 1.7 times greater than the 2005−2013 median (7,900 fish) and 18.4 times greater than the lowest historical estimate (N = 728 in 2012; Table 5).

Although the 2014 abundance estimate ranked fourth highest (or sixth lowest) of the ten years of study, the total catch of 2,787 *O. nerka* ranked fourth lowest, following the extreme low in 2012 of only 83 smolts caught. The Mud Creek RST capture efficiency in 2014 of 24.1% was lower than the 2005–2013 median of 33.5%, but within the range of observed catch efficiencies since 2005 (11.3–42.0%; Table 5; Figure 5). There were no operational issues at the Mud Creek RST in 2014 to significantly influence the catch efficiency, and this was again supported by the fact that a large number of non-target species were captured. Again, relative to previous years, there was no significant variation in the location or cross-sectional position of the RST in the channel (i.e., relative to the thalweg).

Run Timing

The 41-day duration of the 2014 Alouette Reservoir *O. nerka* migration (16 April–26 May) was the fifth longest of all full seasons monitored (2007–2014, range: 39–51 days; Figure 5). The start and peak dates for the 2005 and 2006 migrations were not comparable to those from 2007 to 2014 because the spillway was opened much later in those years (3 May 2005 and 11 May 2006), and presumably after the onset of the *O. nerka* migrations.

Table 5. Total catch at the Mud Creek rotary screw trap and the corresponding population estimate of *O. nerka* migrating from the Alouette Reservoir, 2005−2014.

Year	Total Catch	Abundance Estimate (N)	Lower 95% CL	Upper 95% CL	Trap Efficiency (%)
2005[a]	3,310	7,900	-	-	42.0
2006[b]	1,757	5,064	-	-	35.0
2007[c]	7,787	62,923	48,436	77,410	12.0
2008[d]	3,224	8,257	-	-	40.0
2009[e]	1,247	4,287	3,833	4,741	33.5
2010[f]	4,600	15,434	-	-	37.0
2011[g]	8,525	35,542	34,034	37,051	28.0
2012[h]	83	728	348	1,108	11.3
2013[i]	1,032	6,179	5,350	7,008	19.0
2014[j]	2,787	13,413	12,423	14,403	24.1

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

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

[c] Pooled Petersen 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 Petersen estimate of 7,712 (95% CI 6,682 to 8,742; 21 April to 8 May) (*Mathews and Bocking 2009)*.

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

[f] Trap efficiency estimate of 1,232 (15 to 17 April) + Pooled Petersen estimate of 14,201 (95% CI 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 Petersen estimate (15 April to 8 June) *(Mathews et al. 2012)*.

[h] Pooled Petersen estimate (17 April to 1 June) *(Mathews et al. 2013)*.

[i] Pooled Petersen estimate (16 April to 31 May) *(Mathews et al. 2014)*.

[j] Pooled Petersen estimate (15 April to 25 May) *(Mathews et al. 2015 In Press)*.

In 2014, the first *O. nerka* were captured on 16 April, which was two days after the spillway was opened. This timing was similar to the start dates observed from 2007 to 2012 during full season monitoring (15–19 April). No *O. nerka* were captured on 15 April in 2014, and only four fish were caught on each of the next two days, indicating the spillway opening was timed well with the onset of the migration. This was not always the case in past years. High catches of *O. nerka* upon immediate opening of the spillway in 2010, and to a lesser extent in 2007 indicated it was possible that the migrations in these years may have begun sooner if the spillway had been opened earlier.

Unlike the previous three years (2011–2013), catches during the first week of the 2014 migration increased quite substantially. The midpoint in catches in 2014 occurred on 26 April, which was similar to 2010, but 9–17 days earlier than the midpoint in catches observed from 2011–2013 (5−13 May). Two large pulses of *O. nerka* were observed at Mud Creek, one on 23 April (316 fish) and another on 28 April (490 fish). Corresponding pulses in catch were observed at the 224th Street RST on 24 April (34 fish) and 29 April (27 fish), indicating about a one day travel time between the capture sites which are located approximately 12.5 km apart. The timing of peak catch at Mud Creek in 2014 (28 April) was in the range of past study years; it was 4−5 days later than 2008 and 2010 (23−24 April), and 2–20 days earlier than 2007, 2009, 2011, 2012, and 2013 (30 April–18 May). Similar to 2008 to 2013, the date of peak catch in 2014 did not correspond to the date of peak spillway flows. In contrast, peak catches in 2007 did occur during the period of highest spillway flows.

The end date of the 2014 migration (26 May) was within the range observed in previous years (23 May–8 June). The 2014 end date was 1–3 days later than in 2005, 2008, 2012, and 2013 (23−25 May); less than a week earlier than in 2006, 2007, 2009, and 2010 (28 May–1 June); and almost two weeks earlier than the end date in 2011 (8 June). Based on the ten years of monitoring, the target spill period from mid-April to mid-June (as effected from 2007 to 2014) appears to cover the bulk of the smolt migration window in most years monitored to-date.

Biosamples

Mean fork length of *O. nerka* (<100 mm FL) captured at the Mud Creek RST has varied from a low of 71.2 mm FL in 2008 to a high of 85.6 mm FL in 2013 (Table 3). The mean fork length observed in 2014 (78.1 mm FL; n = 738) was the fourth lowest observed in ten study years. In 2014, the largest number of fish were in the 76–80 mm FL size class, followed by the 71−75 mm FL size class (Figure 6). Size classes comprising the largest number of *O. nerka* have varied over the years: 66–70 (2008), 71–75 (2009, 2011, 2012), 76–80 (2005, 2006, 2012; equal numbers of fish measured in 2012 were in both the latter two size classes), and 81–85 mm FL (2007, 2010, 2013). Figure 6 displays length data for the last five years only (2010 to 2014); length data for all previous years (2005 to 2013) can be found in Mathews et al. (2014). The smallest *O. nerka* sampled in 2014 measured 64 mm FL, while the largest fish measured 247 mm FL. The mean weight of *O. nerka* (<100 mm FL) sampled in 2014 (4.2 g; n = 738) was the third lowest in eight study years – only mean weights in 2009 and 2011 were lower (Table 4).

Condition factor was compared across all years with length and weight data (with the exception of 2005 and 2008). The mean condition factor of the 2014 *O. nerka* smolts was 0.87 (n = 738), which was within the range of previous years (0.80–0.90), and statistically similar to the condition factors in 2009 and 2013 (Figure 8).

In 2010, 2011, 2013, and 2014, the majority of *O. nerka* randomly sampled at the Mud Creek RST were one-year-old fish (88–99% of samples); whereas two-year-old fish were the predominant age class in 2012 (71% of samples; Table 6). Across all years, every one-year-old fish measured less than 100 mm FL (range: 57–96 mm FL). Two-year-old fish were present annually from 2010 to 2014 (0.3–70.6% of random samples) and ranged in length from

80−191 mm FL. Three-year-old fish were sampled in 2010, 2011, 2013, and 2014 (0.0–9.5% of random samples), but not in 2012; and ranged in length from 100–251 mm FL.

Results of genetic analysis of the Alouette Reservoir sockeye salmon population, including *O. nerka* smolt samples collected at Mud Creek during past study years, can be found in Godbout et al. (2011, 2013, 2014).

Table 6. Age composition and length-at-age results for *O. nerka* sampled at the Mud Creek rotary screw trap, 2010–2014.

	Number of Fish (Percent)				Length at Age (mm FL)								
					Age 1			Age 2			Age 3		
Year	Age 1	Age 2	Age 3	n	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
					Random Samples								
2010	191 (99)	2 (1)	0 (0)	193	64	95	81	91	95	93	-	-	-
2011	286 (99)	1 (0)	1 (0)	288	57	93	73	105	105	105	228	228	228
2012	20 (29)	48 (71)	0 (0)	68	70	82	76	80	184	127	-	-	-
2013	139 (88)	4 (3)	15 (9)	158	73	96	85	95	103	98	100	146	133
2014	210 (94)	12 (5)	1 (0)	223	67	95	78	96	165	118	247	247	247
					Target Samples								
2010	0 (0)	57 (98)	1 (2)	58	-	-	-	101	180	121	156	156	156
2011	0 (0)	5 (50)	5 (50)	10	-	-	-	112	191	152	180	251	217
2013	0 (0)	0 (0)	3 (100)	3	-	-	-	-	-	-	145	158	152

Steelhead Smolts (>90 mm FL)

The total catch of wild steelhead smolts (>90 mm FL) at the Mud Creek RST in 2014 (69 fish) was the lowest of the past nine years of monitoring (Figure 10), and over three times less than the next lowest catch year (227 fish in 2007). The date of peak catch in 2014 (5 May) was 6−9 days later than 2008, 2011, and 2012; similar to 2010 and 2013 (3–6 May); and 4–9 days earlier than in 2006, 2007, and 2009 (9–14 May).

Management Questions

The 2014 study was the final year of the Kokanee Out-Migration (ALUMON#2) project funded through the Alouette WUP Monitoring Program. The monitoring program successfully addressed the three management questions originally proposed in the terms of reference (see the Methods section; BC Hydro 2009b). First, this monitoring program showed that a surface release of at least 3 m^3/s from the Alouette Dam (obtained through the spillway gate) was adequate to promote the downstream migration of *O. nerka* smolts out of the Alouette Reservoir. In each year of study, *O. nerka* catches at the Mud Creek RST showed a distinct start, peak, and end (see Figure 5), which is a characteristic pattern for out-migrating kokanee/sockeye smolts.

Second, this monitoring program also revealed that a post-surface release flush of 6–9 m^3/s, lasting seven days following the tail end of the out-migration period, did not encourage more smolts to leave the system. Flush events occurred in 2009 (albeit truncated to just 3 days), 2010, and 2011, but not in 2012, 2013, or 2014. In each of the three years when flush events occurred, no increase in *O. nerka* catches were observed at the Mud Creek RST. Catches during each flush event were consistent with those expected at the tail end of the migrations. Four pulse flow events occurred during the latter half of the migration in 2014 but did not yield an increase in *O. nerka* catches either.

And lastly, this monitoring program showed that a surface-release period from mid-April to early June will ensure the out-migration of all *O. nerka* smolts that are prepared to leave the system. From 2007 to 2014, no *O. nerka* were captured prior to 14 April (spillway has never opened prior to 14 April), and none were captured after 8 June (see Figure 5). In some years, however, the *O. nerka* migration ended as early as 23 May (e.g., 2013).

Sockeye smolts generally begin their migration within days of ice break-up and the slight warming of the lake outlet. Consequently there is a gradual change in timing of smolt migrations to lake outlets from south to north, also influenced by the lake altitude and multi-basin characteristics of the lakes involved. Smolt migration has been found to be earliest for the lakes which seldom freeze, such as nearby Cultus Lake B.C., usually occurring in April, and latest for northern lakes, such as Tazlina Lake of the interior Copper River system in Alaska, often occurring late June and early July. Also, the smolt exodus occurs over a shorter duration for single lake basins versus outlet lakes of multi-lake basins (Groot and Margolis 1991).

The Cultus Lake sockeye population, currently listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (DFO 2003), is one of the most intensively studied salmon stocks in British Columbia. Cultus Lake and its outlet stream, Sweltzer Creek, flow into the Vedder-Chilliwack system and are located approximately 112 km

upstream from the Strait of Georgia (SAFMWG 2002). This is the only Lower Fraser system in which extensive sockeye smolt timing data has been collected (Tracy Cone, DFO, pers. comm.), as intermittent assessments have been done since 1926. The Cultus sockeye smolt migration typically begins in March (or sometimes early April in recent years) and is complete by June, peaking in late April (SAFMWG 2002). From 2009 to 2014, Cultus Lake *O. nerka* were observed out-migrating from 13 March to 26 May (Figure 11; T. Cone, DFO, pers. comm.).

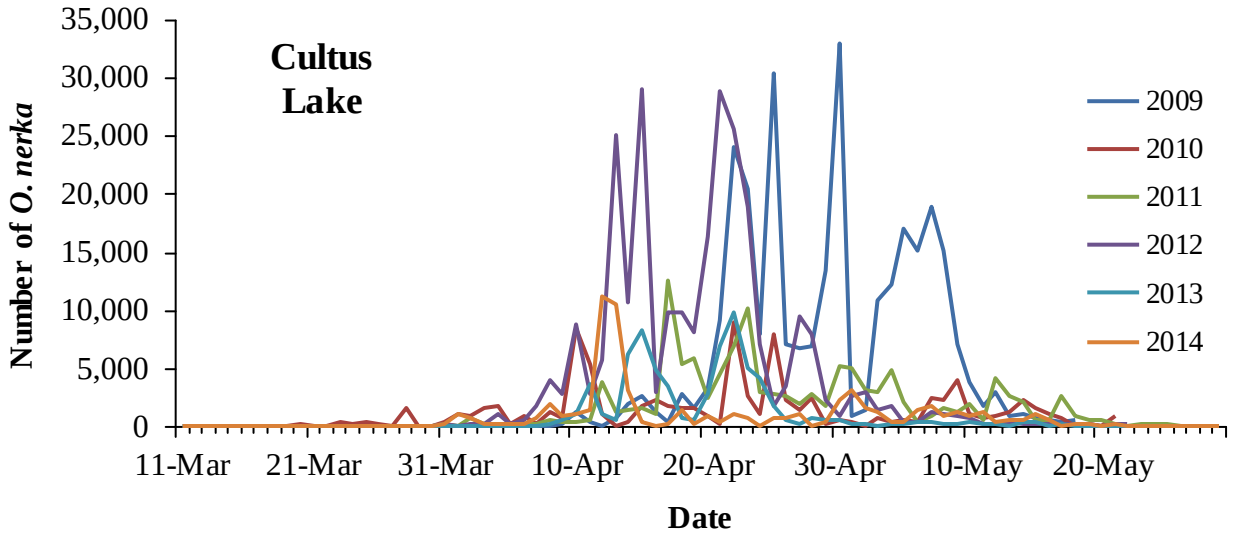

Figure 11. Number of *O. nerka* counted at the Sweltzer Creek enumeration fence located near the outlet of Cultus Lake, 2009–2014.

Within the Lower Fraser system, incidental daily catches of sockeye smolts in the Chilliwack River were recorded in 2002 during a Coho study. The migration began in mid-April and continued until early June, peaking in the middle of May (DFO unpublished data). Sockeye smolt migration timing in the Pitt River was also discussed in Elson (1985), indicating probable dates of migration from 15 April to 15 May from Pitt Lake.

Wood et al. (1993) studied the migration timing and behaviour of sockeye smolts emigrating from Great Central Lake via the Stamp and Somass rivers to Barkley Sound, Vancouver Island, in 1989. The migration began in mid-April, peaked at the beginning of May and declined gradually throughout May and June. This timing was expected based on previous relationships of migration timing and latitude.

The Sakinaw Lake sockeye population, also currently listed as endangered by COSEWIC, is located on the Sechelt Peninsula in south western British Columbia (DFO 2002). Murray and Wood (2002) discuss the extensive data set collected on this system, including the smolt assessments conducted from 1994 to 1997. Smolt migrations began during the first week of April, peaked on average in the first week of May, and extended until the middle of June.

RECOMMENDATIONS

In November 2014, the Katzie First Nation submitted a proposal to BC Hydro's Fish and Wildlife Compensation Program (FWCP) requesting funds to continue monitoring efforts in 2015, 2016, and 2017. At the time this report was prepared, BC Hydro had just issued a notification indicating the proposal was awarded for 2015. The following recommendations are proposed for monitoring the *O. nerka* migration from the Alouette Reservoir in 2015:

1) Maintain similar flows from the Alouette Dam spillway gate (3.0–4.5 m^3/s) throughout the out-migration period; and discontinue the post-surface release flush (6.0–9.0 m^3/s);
2) Conduct daily marking of *O. nerka* at the RST across the entire migration period to ensure an accurate abundance estimate can be generated;
3) Collect genetic tissue from at least 100 *O. nerka* for stock identification;
4) Collect scale samples from *O. nerka* for ageing; and
5) Continue to enumerate all non-target fish species, including steelhead.

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APPENDICES

Appendix A. BC Hydro operations at the Alouette Reservoir during the 2014 study period.

Date	Daily Average Alouette Reservoir Elevation (m)	Alouette Spillway Gate Position (mm)	Daily Average Alouette Reservoir Spill to Alouette River (cms)	Alouette Low Level Outlet Gate Position (open/closed)	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	122.177	0	0.000	open	2.641	9.926
15-Apr	122.176	190 @ 10:05	1.856	closed (10:04)	1.103	9.925
16-Apr	122.193	190	3.213	closed	0.000	20.051
17-Apr	122.344	190	3.493	closed	0.000	28.642
18-Apr	122.679	190	4.129	closed	0.000	6.991
19-Apr	122.872	190	4.468	closed	0.000	0.000
20-Apr	123.062	190	4.738	closed	0.000	0.000
21-Apr	123.191	190	4.923	closed	0.000	3.596
22-Apr	123.190	190	4.927	closed	0.000	27.967
23-Apr	123.144	190	4.862	closed	0.000	27.937
24-Apr	123.149	150 @ 11:27	4.295	closed	0.000	26.583
25-Apr	123.196	150	3.896	closed	0.000	28.705
26-Apr	123.152	150	3.848	closed	0.000	28.676
27-Apr	123.092	150	3.780	closed	0.000	28.635
28-Apr	123.029	150	3.710	closed	0.000	28.593
29-Apr	122.952	150	3.624	closed	0.000	28.542
30-Apr	122.869	150	3.529	closed	0.000	28.485
01-May	122.836	150	3.491	closed	0.000	28.462
02-May	122.839	150	3.494	closed	0.000	28.464
03-May	122.851	150	3.507	closed	0.000	28.472
04-May	122.901	150	3.561	closed	0.000	28.504
05-May	123.177	150	3.868	closed	0.000	28.689

Appendix A. Continued.

Date	Daily Average Alouette Reservoir Elevation (m)	Alouette Spillway Gate Position (mm)	Daily Average Alouette Reservoir Spill to Alouette River (cms)	Alouette Low Level Outlet Gate Position (open/closed)	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)
06-May	123.243	150	3.941	closed	0.000	28.736
07-May	123.207	150	3.907	closed	0.000	28.713
08-May	123.147	150	3.842	closed	0.000	28.673
09-May	123.159	150	3.853	closed	0.000	28.679
10-May	123.185	150	3.884	closed	0.000	28.698
11-May	123.136	150	3.830	closed	0.000	28.665
12-May	123.069	200 @ 09:18	4.524	closed	0.000	28.620
13-May	123.000	150 @ 11:10	4.189	closed	0.000	28.574
14-May	122.948	210 @ 08:30	4.541	closed	0.000	28.538
15-May	122.909	210	4.080	closed	0.000	28.512
16-May	122.861	210	3.521	closed	0.000	28.480
17-May	122.793	210	3.440	closed	0.000	28.435
18-May	122.705	210	3.310	closed	0.000	28.375
19-May	122.610	210	3.169	closed	0.000	28.312
20-May	122.511	260 @ 08:50	4.323	closed	0.000	28.245
21-May	122.418	180 @ 11:45	4.045	closed	0.000	18.570
22-May	122.400	290 @ 08:55	4.581	closed	0.000	10.165
23-May	122.443	180 @ 11:15	4.226	closed	0.000	10.174
24-May	122.542	180	3.674	closed	0.000	10.198
25-May	122.565	180	3.717	closed	0.000	10.204
26-May	122.627	180	3.826	closed	0.000	10.218
27-May	122.692	180	3.945	closed	0.000	10.234

Appendix A. Continued.

Date	Daily Average Alouette Reservoir Elevation (m)	Alouette Spillway Gate Position (mm)	Daily Average Alouette Reservoir Spill to Alouette River (cms)	Alouette Low Level Outlet Gate Position (open/closed)	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)
28-May	122.706	180	3.972	closed	0.000	10.238
29-May	122.749	180	4.046	closed	0.000	10.248
30-May	122.817	160 @ 14:42	3.981	closed	0.000	5.466
31-May	122.889	160	3.785	closed	0.000	0.000
01-Jun	122.956	160	3.865	closed	0.000	0.000
02-Jun	123.018	160	3.941	closed	0.000	0.000
03-Jun	123.079	160	4.013	closed	0.000	0.000
04-Jun	123.127	150 @ 11:12	3.936	closed	0.000	0.000
05-Jun	123.167	150	3.862	closed	0.000	0.000
06-Jun	123.197	150	3.896	closed	0.000	0.000
07-Jun	123.226	150	3.924	closed	0.000	0.000
08-Jun	123.254	150	3.950	closed	0.000	0.000
09-Jun	123.278	150	3.973	closed	0.000	0.000
10-Jun	123.311	150	4.004	closed	0.000	0.000
11-Jun	123.336	150	4.028	closed	0.000	0.000
12-Jun	123.359	150	4.049	closed	0.000	0.000
13-Jun	123.402	150	4.089	closed	0.000	0.000
14-Jun	123.444	150	4.129	closed	0.000	0.000
15-Jun	123.499	150	4.179	closed	0.000	0.000

Appendix B. Physical data collected at the Mud Creek rotary screw trap site, 2014.

Date	Water Temp (ºC)	Weather Conditions	RST Speed (RPM)	Water Depth (cm)
15-Apr	6	Overcast	8	15
16-Apr	7	Rainy	8	15
17-Apr	7	Rainy	8	15
18-Apr	6	Sunny	8	24
19-Apr	5	Overcast	8	25
20-Apr	6	Overcast	8	25
21-Apr	7	Sunny	8	25
22-Apr	6	Overcast	8	27
23-Apr	6	Rainy	8	25
24-Apr	7	Overcast	8	25
25-Apr	7	Sunny	8	23
26-Apr	7	Overcast	8	23
27-Apr	8	Rainy	8	22
28-Apr	7	Sunny	8	22
29-Apr	7	Sunny	8	22
30-Apr	10	Sunny	8	20
01-May	10	Sunny	8	20
02-May	9	Sunny	8	20
03-May	7	Rainy	8	20
04-May	9	Rainy	8	20
05-May	9	Overcast	8	23
06-May	10	Sunny	8	23
07-May	8	Sunny	8	22
08-May	9	Sunny	8	22
09-May	9	Overcast	8	22
10-May	8	Rainy	8	23
11-May	10	Sunny	8	23
12-May	10	Sunny	8	23
13-May	11	Sunny	8	25
14-May	11	Sunny	8	25
15-May	11	Sunny	8	23
16-May	13	Sunny	8	20
17-May	9	Overcast	8	20
18-May	10	Sunny	8	20
19-May	12	Rainy	8	19
20-May	10	Sunny	8	23
21-May	13	Sunny	8	24
22-May	10	Sunny	8	20
23-May	13	Rainy	8	25
24-May	12	Overcast	8	20
25-May	13	Rainy	8	20
26-May	13	Overcast	8	22
27-May	12	Sunny	8	20

Appendix C. Catch of non-target species at the Mud Creek rotary screw trap, 2014.

	Species Composition (%)		Total Catch (# fish)											
Date	Chum Fry	Chinook/ Coho Fry	Salmon Fry (est.)	Chinook Parr/Smolt (>70 mm)	Coho Parr/Smolt (>70 mm)	Steelhead (<90 mm)	Steelhead (>90 mm)[a]	Dace Spp.	Sculpin Spp.	Northern Pike-minnow	Stickle-back	Sucker Spp.	Lamprey
15-Apr	98	2	60										
16-Apr	98	2	9,500				3	1					
17-Apr	98	2	12,000				2	1					
18-Apr	100	0	1,000	6			3			1			3
19-Apr	100	0	4,000			1							
20-Apr	100	0	5,000	1		1	1		2				
21-Apr	100	0	7,000	2				1		1			
22-Apr	98	2	5,000	2	1	1			1				
23-Apr	99	1	1,000	1	3	1	1		1				1
24-Apr	99	1	7,000		1								
25-Apr	100	0	14,000	1	3	1				1			
26-Apr	100	0	7,000		3	1			3				
27-Apr	100	0	5,000	1	2			1	2				1
28-Apr	99	1	5,000	1	1				2				1
29-Apr	99	1	1,000	1	1			1					
30-Apr	100	0	7,000		1	1	2	5					
01-May	100	0	1,000	1	5	1	2		1				
02-May	100	0	1,000	1	5		1						1
03-May	99	1	1,000		5		2						
04-May	99	1	1,000		9		2						1
05-May	75	25	1,000	1	24	1	8		1				1
06-May	90	10	1,000		11	1	5		1				
07-May	90	10	1,000		14		1			1	1		
08-May	98	2	200		7		2						1

Appendix C. Continued.

	Species Composition (%)		Total Catch (# fish)											
Date	Chum Fry	Chinook/ Coho Fry	Salmon Fry (est.)	Chinook Parr/Smolt (>70 mm)	Coho Parr/Smolt (>70 mm)	Steelhead (<90 mm)	Steelhead (>90 mm)[a]	Dace Spp.	Sculpin Spp.	Northern Pike-minnow	Stickle-back	Sucker Spp.	Lamprey
09-May	80	20	1,000		3		1						
10-May	100	0	<100		8		3			1			
11-May	75	25	<100		6								
12-May	99	1	<100		9		4				1		
13-May	60	40	<100		7		5						
14-May	50	50	<20		7					1			
15-May	50	50	<20	1	6								
16-May	50	50	<200		5		5						
17-May	50	50	<100		5	1	2						
18-May	50	50	400	1	12		2						
19-May	50	50	200		5		2			1			1
20-May	60	40	500	1	6								
21-May	50	50	<100		5				2				
22-May	50	50	400				2						
23-May	50	50	100	1	1		1						
24-May	50	50	1,000		6		2		1				1
25-May	50	50	500	2	2		2		1				
26-May	70	30	1,000		9		2						2
27-May	70	30	200		5		2			1		1	
Totals	--	--	>103,060	25	203	11	70	10	18	8	2	1	14

[a] Includes 1 steelhead with an adipose clip captured on 27 May.