Alouette Watershed Sockeye-Fish Passage Feasibility Project Year 2

COA-F19-F-2683

Prepared for:

Fish and Wildlife Compensation Program

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FINAL VERSION

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ACKNOWLEDGMENTS

This project thanks the commitment of the Alouette River Sockeye Reanadromization Project committee members and supporters of the committee including Cheryl Ashlie, Geoff Clayton, Ken Stewart, Sophie Sparrow (Alouette River Management Society), Ron MacLean, Mike Ilaender, Chris MacMillan, Lance Di Salvo (BC Corrections), Rick Bailey (Katzie First Nation), Bob Bocking, Megan Mathews, Elmar Plate (LGL Limited), Alexis Hall, Katy Jay, Alf Leake, Brent Wilson (BC Hydro), Michael Crowe, Scott Ducharme, Dave Nanson (Fisheries and Oceans Canada), Dr. Lyse Godbout (Pacific Biological Station, Fisheries and Oceans Canada), Shannon Harris, Dr. Brett Van Poorten (Ministry of Environment and Climate Change Strategy), Allison Hebert (Pacific Salmon Ecology and Conservation Laboratory, University of British Columbia), and Dr. Dan Selbie (Cultus Lake Salmon Research Laboratory Fisheries and Oceans Canada).

Special thanks to the Fish and Wildlife Compensation Program's- Coastal Program (FWCP) Manager Julie Fournier for her assistance and guidance throughout the 2018-2019 season and to FWCP Program Assistant, Lorraine Ens for assistance with navigating the new-ish FWCP Application and Reporting online portal.

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Task 1 – Alternative Independent Review of Sockeye Response Model and Alouette Program

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Task 2 – Reproductive Ecology and Habitat Assessment For Deep Spawning Sockeye Salmon and Kokanee (*Oncorhynchus nerka*) In Alouette Lake

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Task 4b – Kokanee Smolt Outmigration Enumeration

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Overview of the Alouette Watershed Sockeye – Fish Passage Feasibility Project

Sockeye restoration in the Alouette Watershed was identified as a key priority in FWCP's Alouette Watershed Action Plan (2017) and is of significant cultural importance to the Katzie First Nation. The Alouette River Sockeye Reanadromization Program (ARSRP) is a joint initiative among the Katzie First Nation, the Alouette River Management Society (ARMS), BC Hydro, Ministry of Environment and Climate Change Strategy (ENV), Fisheries and Oceans Canada (DFO), and local stakeholders that works to promote the re-establishment of anadromous Alouette Sockeye and investigate the feasibility of fish passage at the Alouette Dam. The ARSRP committee has been working to resolve uncertainties around feasibility of Sockeye restoration in the Alouette watershed for over 15 years and within the Fish Passage Decision Framework (FPDF) since 2008. The dam is owned and operated by BC Hydro, a crown corporation and is in Maple Ridge, British Columbia.

After the ARSRP group failed to receive funding in 2016 for an experimental Sockeye hatchery, a workshop was held with senior Katzie First Nation representatives, DFO, BC Hydro, ENV and political leads to reassess the Alouette fish passage plan. Attendees agreed that it was important to have the ENV's newly developed Kokanee/Sockeye Nerkid Model peer reviewed and to test the predictions from the Nerkid Model. Testing would involve: releasing Kokanee and Sockeye hatchery fry into the reservoir; smolt outmigration and adult returnee surveys would generate estimates of fry-to-smolt survival to inform density-dependence, and smolt-to-adult success to inform smolting heritability assumptions. As a commitment from the July 2016 workshop, BC Hydro would coordinate the development of a long-term plan and help develop a subsequent FWCP funding application for the Sockeye hatchery for that year. The DFO also requested that the Nerkid Model be provided to them for the basis of a review (Compass, 2016 unpublished). On that basis, the ARSRP committee developed an eleven-year plan which outlines the tasks to be implemented to address key knowledge gaps to Sockeye restoration and fish passage feasibility. The plan was originally presented to the Fish and Wildlife Compensation Program Board of Directors on September 19, 2016 by Debbie Miller representing Katzie First Nation, Greta Borick-Cunningham representing ARMS, and Dr. Brett Van Poorten representing then MOE.

The eleven-year plan included a formal scientific review of the Nerkid Model by DFO and the scientific community. To address any uncertainties identified in the eleven-year plan, the ARSRP will be reviewed by the Canadian Science Advisory Secretariat (CSAS). The review will investigate and report on our overall plan including 1) the structure and findings of the Nerkid Model; 2) limits to the Kokanee and Sockeye production as estimated from estimates of available habitat and the Nerkid Model; and 3) calculations of genetic consequences of continued release of smolts and the hatchery program. The review will focus on short-and long-term implications of Sockeye smolting for genetic and population integrity. However, the experimental Sockeye hatchery was not approved for funding by the FWCP for Year 1 so this work was not initiated, instead the CSAS review of both the Nerkid Model and the Alouette Sockeye fish passage feasibility program would need to provide the outstanding answers to the questions of minimum viable

populations for Sockeye in the Alouette Lake Reservoir and any potential "showstoppers" including genetic, biological or disease issues that would exclude the implementation of an experimental Sockeye hatchery for short-term enhancement and for data to feed into the Nerkid Model. The tasks and schedule of the eleven-year plan are summarized below.

Alouette Watershed Sockeye – Determination of Fish Passage Feasibility:
(2017 – 2027 Overall Plan - updated October 2018)

		Phase 1		Phase 2						Phase 3		
Tasks in the Feasibility Plan		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Task 1	Model Peer/CSAS Review	✓	✓	✓								
Task 2	Spawning habitat assessment and reproductive behaviour	✓	✓									
	Kokanee broodstock collection	×			✓	✓	✓	✓				
Task 3	Hatchery Raising Fry	×			✓	✓	✓	✓				
Task 4	Adult and Smolt Enumeration	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Task 5	Acoustic Assessment of Density Dependence	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Task 6	Heritability of smoltification				✓	✓	✓	✓	✓	✓	✓	✓

✓ Task implemented for the given year

✓ Task implemented subject to other study result

× Task not approved for funding and did not proceed

Note: Table updated 16 October 2018

This report presents the work implemented for Year 2 of this eleven-year plan. The goals for Year 2 were to:

1. Initiate a formal Canadian Scientfic Advisory Secretariat (CSAS) review of the ARSRP program and Nerkid Model (which projects impacts of stocking and fish passage on resident [kokanee] and anadromous [sockeye] salmon – collectively referred to here as *nerkids*) to determine the risks of re-establishment of Alouette sockeye and other salmon;
2. Monitor adult Sockeye returns and juvenile outmigration necessary for the evaluation of heritability, long-term sockeye projections and for eventual Fish and Wildlife Compensation Program (FWCP) endorsement;
3. Assess quality and quantity of potential nerkid spawning habitat in the Alouette Reservoir, as well as reproductive behavior as part of evaluating Biological Feasibility.

This report is presented as a compilation of 4 individual summaries/reports from the eleven-year plan. The first section is Task 1 – Independent Review of the Nerkid Model and Alouette Plan, the second section presents Task 2 – Spawning Habitat Assessment and Kokanee Spawner Behaviour ("Reproductive Ecology and Habitat Assessment for Deep Spawning Sockeye Salmon and Kokanee (*Oncorhynkus nerka*) In Alouette Lake"); the third section presents Task 4a – Alouette Adult Sockeye Enumeration; and the final section presents Task 4b –Kokanee Smolt Outmigration Enumeration.

Please note that Task 2 – Spawning Habitat Assessment and Kokanee Spawner Behaviour ("Reproductive ecology and habitat assessment for deep spawning Sockeye Salmon and kokanee (*Oncorhynchus nerka*) in Alouette Lake") was not funded by FWCP for Year 2 but has been included in this compilation report as the work is included in the eleven year plan. Other sources of funding were found to continue and finalizae the work in Year 2 of this project.

References:

Compass Resource Management, July 2016, unpublished minutes. Prepared for the Alouette River Sockeye Reanadromization Project committee.

Alouette Watershed Sockeye – Determination of Fish Passage Feasibility (2017 – 2027 Overall Plan) pg 10. Prepared for the Fish and Wildlife Compensation Program, September 2016

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Task 1 – Alternative Independent Review of Sockeye Response Model and Alouette Program

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The Ministry of Environment and Climate Change Strategy (ENV) developed a nerkid model to address questions related to the potential for kokanee and sockeye fisheries objectives being mutually feasible in the Alouette watershed. Results presented in a 2016 workshop with the Alouette River Sockeye Reanadromization Project (ARSRP) committee indicated that both populations could meet their goals in the watershed, but the sockeye run could only be sustainable under certain genetic and density dependent assumptions. The only way to meaningfully assess these assumptions is through direct observations on smolt outmigration success using hatchery augmentation. Fisheries and Oceans Canada (DFO) wanted to conduct a model review to confirm the initial findings before endorsing the hatchery augmentation phase and had recommended a review through the Canadian Science Advisory Secretariat (CSAS). Subsequent to this request, the province has published the model results in the Canadian Journal of Fisheries and Aquatic Sciences (CJFAS).

In 2018, due to unforeseen circumstances, DFO was not able to complete the CSAS review. To prevent further delay, an alternative Independent Scientific Review funded by BC Hydro has been proposed in place of the CSAS review. In late fall 2018, a terms of reference document was developed by a sub-committee of the ARSRP including representatives from BC Hydro, DFO, ARMS, and ENV defining the scope of the review as the following:

- Technical review of the nerkid model: a review to ensure the variables reflect appropriate levels of influence, from an Alouette Sockeye salmon reanadromization perspective. As the province has already completed the majority of this review as part of the model's publication peer review in CJFAS, this portion of the review is fairly routine.

- Hatchery augmentation assessment: a review of the biological, genetic, and disease risks, benefits and uncertainties of operating a hatchery required to inform and test the nerkid model, as proposed in the 11-Year Plan.

- DFO review and endorsement: if the above tasks indicate the model is technically appropriate and hatchery augmentation risks are manageable, DFO will endorse the continuation of the ARSRP 11-year plan to initiate hatchery augmentation to assess the influence of key model assumptions.

Proposals were requested from consultants pre-screened for expertise in fisheries and aquatics through BC Hydro's Request for Supplier Qualifications (RFSQ) process. Ecofish was selected by the ARSRP sub-committee to conduct the Independent Scientific Review with an anticipated completion date of June 2019.

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TASK 2 - Reproductive ecology and habitat assessment for deep spawning Sockeye Salmon and kokanee (*Oncorhynchus nerka*) in Alouette Lake

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Introduction

This document provides a brief update of preliminary results and progress of Task 2, Reproductive ecology and habitat assessment for deep spawning Sockeye salmon and kokanee (*Oncorhynchus nerka*) in Alouette Lake as of March 8, 2019. FWCP did not provide funding for Task 2 during the 2018-19 fiscal year. Funding was provided by BC Hydro ($13,000 plus $9,000 in-kind), the Ministry of Forests, Lands, Natural Resource Operations and Rural Development ($12,000), ENV ($14,000 in-kind), UBC ($9,000 in-kind), as well as Fisheries and Oceans Canada ($2,000 in-kind) for a total of $59,000 for this task.

The Alouette stock of Sockeye Salmon (*Oncorhynchus nerka*) and kokanee (i.e. the nonanadromous morph of Sockeye Salmon) are a unique reproductive ecotype that spawn in deep lake environments. There are only a handful of watersheds globally where Sockeye Salmon and kokanee exhibit this type of spawning behaviour[1] and little is known about spawning timing and habitat for this ecotype. Task 2 represents the initial study focused on the spawning life stage that will inform future experimental work and establish biological feasibility of fish passage within the Alouette watershed.

The objectives of Task 2 are to:

a) Establish the stock profiles of Alouette Sockeye Salmon and kokanee, which includes general spawning behaviour, timing and locations, including depths;

b) Define suitable spawning habitat for the deep spawning ecotype of Sockeye Salmon and kokanee; and

c) Assess spawning habitat capacity in Alouette Lake for Sockeye Salmon and kokanee; assess whether spawning habitat is a limiting factor; and assess potential interactions between resident and anadromous fish during spawning.

The results of Task 2 directly support:

- Task 1 (scientific review)
- Task 3 (efficient use of resources for egg collection if hatchery experiment proceeds)
- Establishing biological feasibility within the Fish Passage Decision Framework
- Priority actions 1, 2 and 18 of the Alouette River Watershed Action Plan.

Methods and Results Summary

To date, we have successfully established spawning timing, locations, depths and behaviours (objective a). Additional remote operated vehicle (ROV) surveys conducted in Year 2 were successful at observing kokanee spawners in the depths and habitat types identified in Year 1. ROV results provided a further line of evidence that spawning timing was generally consistent, and that the spawning locations described in Year 1 are likely used annually (Figure 1). As well, samples collected during Year 1 spawner surveys are being examined for

[1] Moreira, A. L., and E. B. Taylor. 2015. The origin and genetic divergence of "black" kokanee, a novel reproductive ecotype of *Oncorhynchus nerka*. Canadian Journal of Fisheries and Aquatic Sciences 72:1584–1595.

morphology (lengths, depth, mass etc.), age, egg size, fecundity, and gill raker counts. Results will characterize the Alouette spawning population and will be completed by summer 2019.

Habitat field work has been completed; this involved data collection on substrate and other physical habitat variables at approximately 1000 locations throughout Alouette Lake (Figure 2). Together with University of British Columbia's Master of Geomatics for Environmental Management program, habitat and fish occurrence data have been incorporated into preliminary habitat suitability models for Sockeye Salmon and kokanee (objectives b and c). These models suggest that areas of high suitability spawning habitat for the two morphs generally overlap within Alouette Lake.

Additionally, the installation of a data logger array in Year 2 allowed for examination of groundwater influences in spawning areas using sensitive temperature measurements (objective b). We hypothesized that surface water from high-gradient ephemeral streams was going subsurface and welling up in spawning areas, and that this process was an important component of suitable habitat for deep spawners. Initial results look promising at identifying potential upwelling sites and may explain observed spawning site selection.

Final habitat suitability modelling, assessment of spawning habitat capacity, and analysis of temperature measurements will be completed by summer 2019 and will include a more detailed examination of the implications to management (objectives b and c).

Figure 1. Still images captured from remote operated vehicle (ROV) video recordings taken at primary spawning areas within Alouette Lake, British Columbia, during the 2018-19 season.

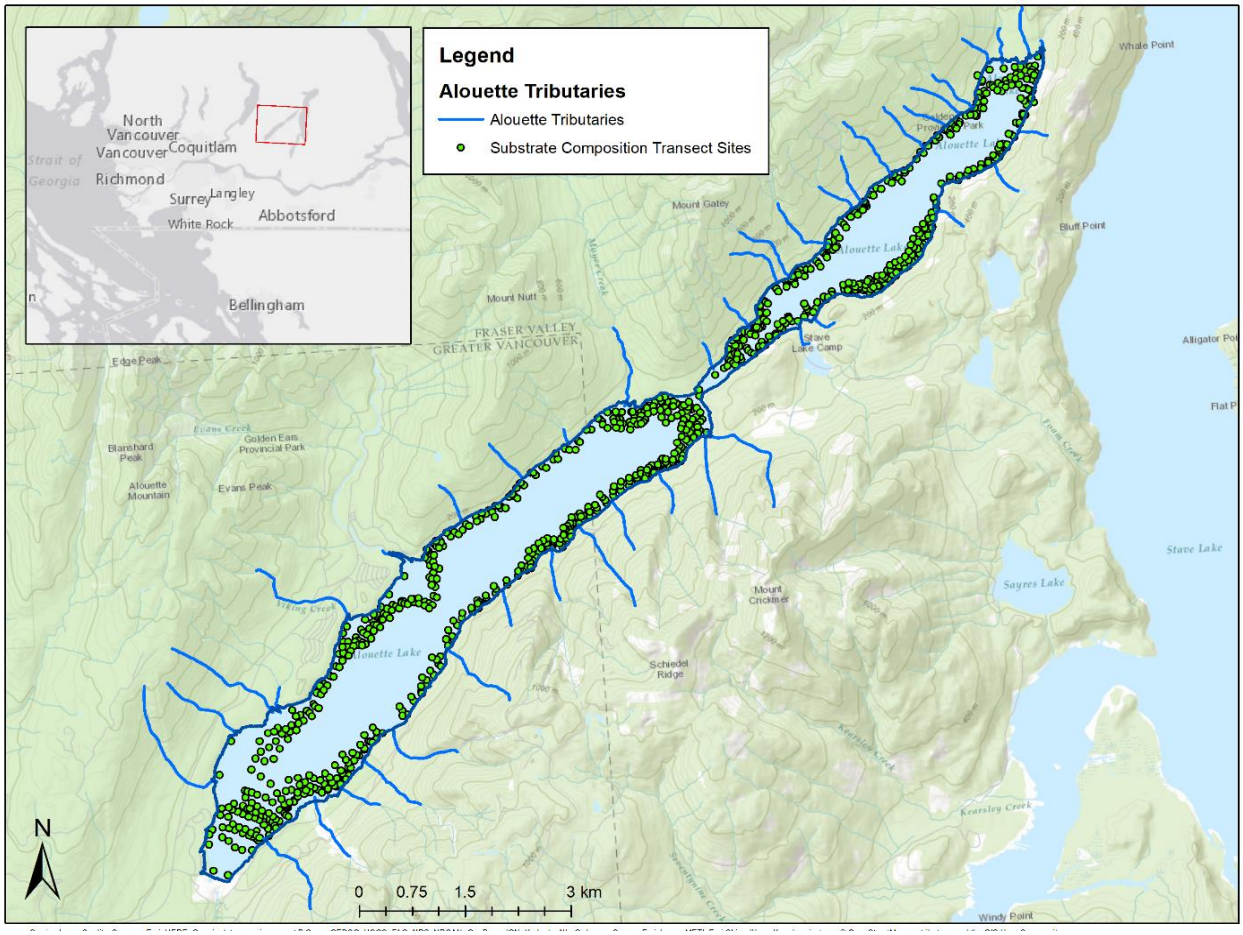

Figure 2. Map of Alouette Lake showing point locations where data on physical habitat variables were collected using underwater imagery methods during Year 1 (2017) and Year 2 (2018).

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Task 4a - Alouette Adult Sockeye Enumeration, 2018

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Reference: COA-F19-F-2683

15 February 2019

Acknowledgments

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This project was part of the Alouette River Sockeye Reanadromization Project committee's efforts to establish fish passage over the Alouette Dam. Committee members include: Alouette River Management Society (ARMS), BC Corrections Allco Fish Hatchery, BC Hydro, Department of Fisheries and Oceans (DFO), Katzie First Nation, LGL Limited and Ministry of the Environment and Climate Change Strategy (ENV). Our appreciation is extended to the following individuals for their continued commitment to the project and ARSRP committee: Cheryl Ashlie, Greta Borick-Cunningham, Geoff Clayton, Sophie Sparrow, and Ken Stewart (ARMS); Lyse Godbout (Pacific Biological Station-DFO); Bob Bocking, Megan Mathews, and Elmar Plate (LGL); Shannon Harris and Dr. Brett Van Poorten (ENV); Allison Hebert (Pacific Salmon Ecology and Conservation Laboratory UBC); Scott Ducharme, Michael Crowe, and Dave Nanson (DFO); Rick Bailey (Katzie First Nation); Dr. Dan Selbie (Cultus Lake Research Facility – DFO); Alexis Hall, Katy Jay, Alf Leake, and Brent Wilson (BC Hydro). For their long-standing efforts for trap and truck work to bring the returning adult Sockeye to the Alouette Reservoir: Ron MacLean and Mike Ilaender, Lance Di Salvo and Chris MacMillan (BC Corrections Allco Fish Hatchery).

Executive Summary

In order to assess the feasibility of anadromous Sockeye salmon *(Oncorhychus nerka)* re-introduction into the Alouette Reservoir, studies are being conducted to determine the return success of *O.nerka* adults to the Allco fish fence. 2018 was the twelfth year of studying Alouette adult sockeye salmon enumeration. In 2005, to address whether *O.nerka* smolts would exit over the Alouette Dam or through the north basin diversion tunnel into Stave Lake , a spring surface release from the Alouette Dam for kokanee/sockeye smolts to migrate to the ocean was funded by the Bridge Coastal Restoration Program (BCRP). In 2007 the first adult sockeye returned to the Alouette Watershed. The 2018 Alouette sockeye salmon run saw 15 adults returning between July 17 and October 25, 2018. All 15 sockeye were sampled at the Allco trap location, all of which were successfully transported to Alouette Reservoir. Fork length measurements were taken of all sockeye along with scale and tissue samples. The measurements indicated an average fork length of 55.6cm.

The genetic sampling identified all adults originated from Alouette stock. Between the return years of 2005-2015, the smolt to adult (return to the hatchery fish fence) survival of the Alouette sockeye has ranged from a low of 0.033% in the 2011 smolt year to a high of 1.408% in the 2008 smolt year. (Bocking and Mathews, 2019).

Since 2007, up to and including the 2018 season, 346 adult sockeye salmon have returned to the Allco fish fence, 284 of those have been successfully released into the reservoir.

This project aligns with Fish and Wildlife Compensation Program's Alouette River Watershed Action Plan. The priority which is addressed is:

- Sub-objective 1 - ALU.RLR.SB.18.01 - Conduct technical feasibility assessment, monitoring and/or species-based actions associated with Sockeye Salmon passage at Alouette Dam to support reintroduction to the Alouette system.

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Introduction

During the 2006 review of the Alouette Water Use Plan (A-WUP), the consultative Alouette Monitoring Committee identified the restoration of an anadromous sockeye salmon run as a key issue in the Alouette River system. Construction of the dam in the 1920's impounded the reservoir and extirpated the sockeye run soon after. As a means of re-establishing the stock, a spring surface release from the dam was integrated into the WUP. The testing of a specific surface release of $3m^3s^{-1}$ from April to June has indeed facilitated kokanee/sockeye out-migration from the reservoir. Since 2005, smolts have successfully outmigrated through the spillway gate during the spring release and to the ocean via the Alouette River.

Table 1 Estimated number of smolts leaving the Alouette Reservoir during the spring surface release, 2005-2018 (Mathews and Smith, 2019).

Year of Smolt Migration	Estimated Abundance of Smolts
2005	7,900
2006	5,064
2007	62,423
2008	7,957
2009	3,704
2010	12,363
2011	30,729
2012	648
2013	5,385
2014	11,523
2015	583*
2016	◊
2017	17,394
2018	**31,643**

**Note: 2015 season did not have the rotary screw trap in the collection site when BC Hydro had a controlled release of water due to storm events.*

◊Note: 2016 the FWCP funding application was denied to run the rotary screw trap and therefore no smolts were enumerated.

The viability and authenticity of kokanee smolt "re-anadromization" is dependent on the stocks ability to adapt to salt water conditions, to adopt behavioural strategies to compete and avoid predation in an ocean environment, and to recognize and return to their native lake/stream system to spawn (Gaboury & Bocking 2004). Through the original Alouette Adult Sockeye Enumeration monitoring program, sockeye returning to the Alouette River were collected, counted, aged, genetically tested and released into Alouette Lake. In 2007, it was found that returning sockeye salmon trapped at the Allco fish fence were genetically proven to be Alouette stock (Balcke, 2009).

The main purpose of the original seven-year Alouette Adult Sockeye Enumeration monitoring program as funded under BC Hydro's A-WUP was to establish whether out-migrating Alouette Lake Reservoir kokanee/sockeye smolts were capable of adapting to an anadromous existence. Adaptation is considered

successful when sockeye return from the ocean environment to spawn in Alouette Lake. Additionally, the original monitoring program sought to establish the timing and genetic structure of the returning sockeye run and to assess whether ocean survival rates of returning re-anadromized kokanee were comparable to that of sockeye stocks found elsewhere. During the first three years of the program (2008-2010), the Allco Hatchery fish fence was operated from April to December to determine the timing and volume of the run (Crowston & Borick-Cunningham, 2012). Based on the results of these efforts, the following eight years (2011-2018) had a shorter fence operation timeframe, which commenced mid-June through to early September. Tissue samples were also collected from all sockeye in order to ensure that returning adults were Alouette stock and not strays from other nearby coastal systems.

Objectives

The project objectives were to continue the enumeration program initially funded by BC Hydro under its Alouette Water Use Plan but now funded through annual applications to the Fish and Wildlife Compensation Program (FWCP). This year would allow continued data collection on the number of adult sockeye returning to the Alouette system and up to the Allco fish fence including completion of another year of genetic sampling. This continued sampling would reinforce the baseline data for sockeye as part of many years of ongoing efforts to re-introduce sockeye into the upper Alouette Watershed (Alouette Watershed Action Plan 2017). This year would include the continuation to trap, enumerate, sample, and with the assistance of BC Corrections supervisor and crew, transfer adult sockeye into the Alouette Reservoir.

As discussed in Plate et al (2014), there have been a variety of monitoring studies including the Alouette Sockeye Adult Enumeration Monitor (ALUMON#4) which have contributed to many years of research and data collection about the genetics, parentage and age of the Alouette adult sockeye (sockanee) returns. These studies were compiled in 2013-2014, along with the Kokanee Outmigration Monitor (ALUMON#2) and others, into a technical feasibility report which synthesized all the research done to date on Alouette sockeye and the process needed to be taken to re-establish sockeye in the Alouette Reservoir. This synthesis report outlines and recommends various ways in which sockeye can be brought back to the reservoir including hatchery intervention and speaks to the importance of the ongoing adult enumeration and sampling which will be a vital part of this future work.

Study Area

The South Alouette Watershed (144 km^2), comprised of the South Alouette River and Alouette Lake Reservoir, are located within the communities of Maple Ridge and Pitt Meadows (Figure 1). The site of the Alouette Adult Sockeye Enumeration program is approximately 8 km downstream from the Alouette Reservoir at the Allco Fish Hatchery operated by BC Corrections Fraser Regional Correctional Centre. The hatchery is well positioned to intercept all migrating adult sockeye on their way back to the reservoir.

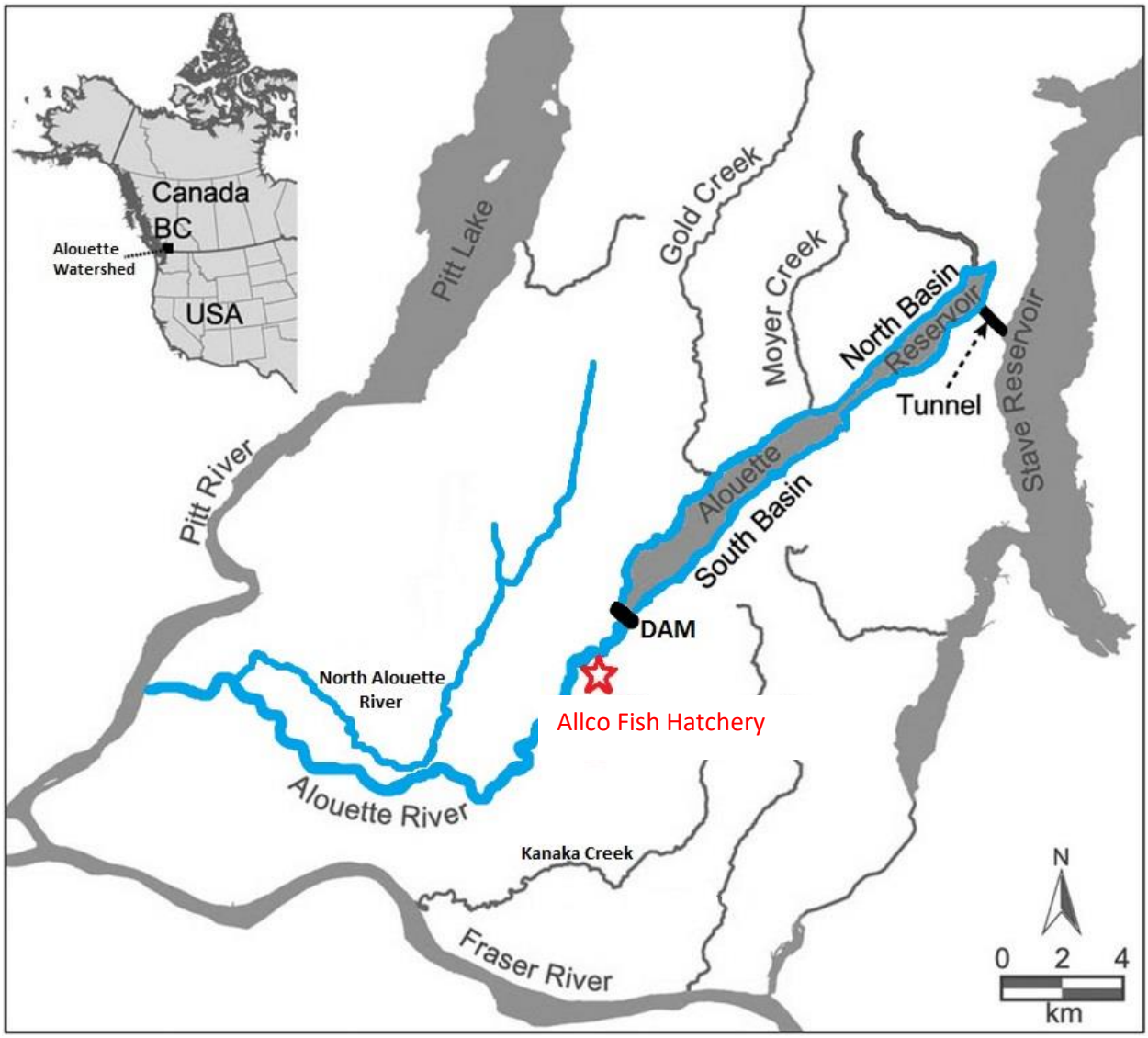

Figure 1 Map of Alouette Watershed

Methods

From the first year of monitoring in 2008, the adult sockeye run appeared to be a summer run, arriving in the Alouette Watershed in July and August (Balcke, 2009). Taking this into consideration, as well as the maintenance requirements, and downstream steelhead kelt passage, the Alouette Monitoring Committee (AMC) decided that in both 2009 and 2010 the fence would be in operation between April and December, rather than year-round (Cruickshank, 2010). In 2011, the fence operation was shortened and the monitor began on June 15, 2011. In 2018, although the Allco fish fence (Fig. 2) went up on June 15, returning sockeye sampling dates commenced on July 17th when the first adult arrived and completed on October 25th when the last adult arrived. The Allco fish fence remained in operation, following the Chum and Coho counts, into 2019 to enumerate the Alouette Steelhead run.

Figure 2 Allco Fish Hatchery Fence

The fish fence was designed to direct sockeye and other salmon into the trap, which was monitored daily in 2018 by BC Corrections staff and crew. In case of a failure at the Allco fish fence, BC Hydro operates a trap at the low-level outlet of the Alouette Dam to catch returning sockeye that are not captured at the Allco fence. There were no sockeye reported in the Hydro trap in 2018. For each returning sockeye in 2018, the date of capture was recorded. All 15 sockeye were successfully transported to Alouette Lake using a specialized tank and trailer system (Fig. 3). The first two fish returned to the fence, on July 17th, with a peak on July 23rd where 8 sockeye entered to the Allco trap.

Figure 3 Allco Hatchery sockeye transport tank and trailer

The last sockeye to enter the trap on October 25th, 2018 was unusually late, in full maturation colors. Unfortunately, no scale samples could be taken from this fish, however DNA samples were obtained along with fork length measurements. All returning sockeye were in great health and strong swimmers. Additionally, fork length measurements and pictures were taken of all 15 fish (Figure 4 - 18). The tissue and scale samples were sent to the Pacific Biological Station (Department of Fisheries and Oceans) laboratories in Nanaimo, B.C. for genetic analysis. All 15 sockeye were conclusively 100% Alouette origin.

Figure 4 Returning sockeye #1 dated – July 17, 2018

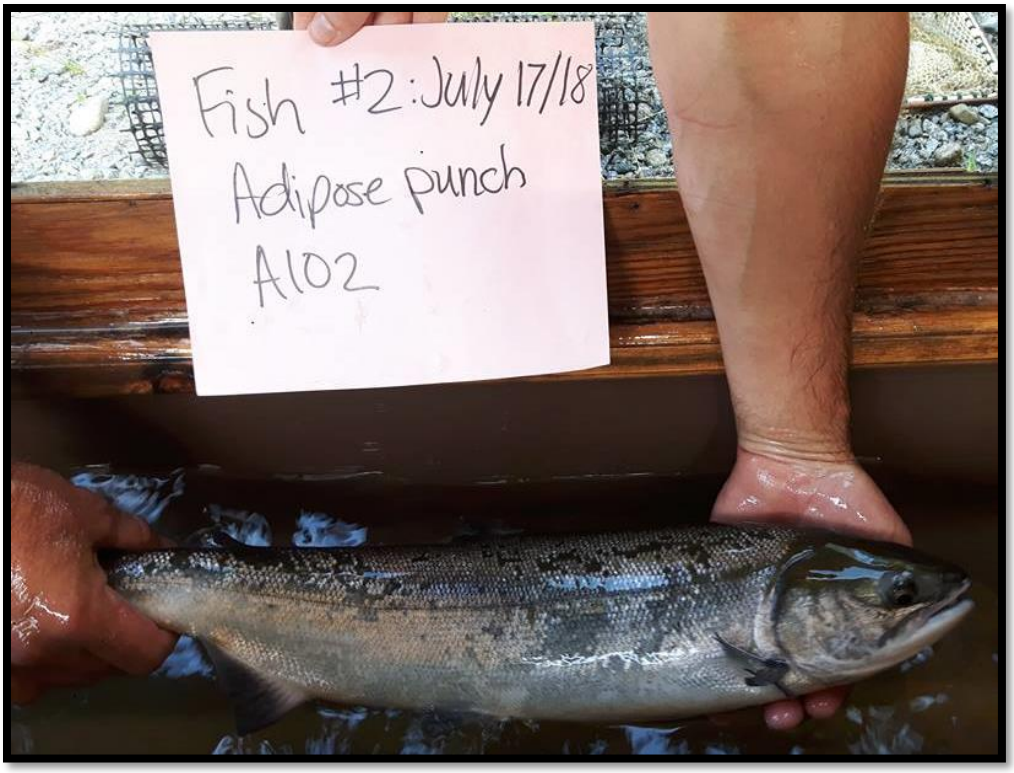

Figure 5 Returning sockeye #2 dated – July 17, 2018

Figure 6 Returning sockeye #3 dated – July 21, 2018

Figure 7 Returning sockeye #4 dated – July 21, 2018

Figure 8 Returning sockeye #5 dated – July 23, 2018

Figure 9 Returning sockeye #6 dated – July 23, 2018

Figure 10 Returning sockeye #7 dated – July 23, 2018

Figure 11 Returning sockeye #8 dated – July 23, 2018

Figure 12 Returning sockeye #9 dated – July 23, 2018

Figure 13 Returning sockeye #10 dated – July 23, 2018

Figure 14 Returning sockeye #11 dated – July 23, 2018

Figure 15 Returning sockeye #12 dated – July 23, 2018

Figure 16 Returning sockeye #13 dated – August 7, 2018

Figure 17 Returning sockeye #14 dated – September 4, 2018

Figure 18 Returning sockeye #15 dated – October 25, 2018

For each returning adult, scale samples and caudal fin hole punches were taken and sent to Pacific Biological Station (Fisheries and Oceans) in Nanaimo. Sampling followed protocols established in conjunction with DFO, ARMS and Corrections.

Figure 19 Sampling Sockeye (Left: DNA adipose punch, Right: Scale samples)

Figure 20 Sampling adult sockeye returnee

Results

Adult Sockeye Returns

A total of 15 sockeye returned to the Alouette Watershed during the 2018 run (Table 2). All fish were successfully released into the Alouette Reservoir.

Table 2 Number of returned adult sockeye to the Alouette Watershed, 2007-2018

Year of Adult Return	Number of Returned Adults	Number of Adults Released Alive into Alouette Reservoir
2007	38	5
2008	54	53
2009	45	43
2010	115	103
2011	11	8
2012	45	43
2013	10	7
2014	0	0
2015	4	0*
2016	6	6
2017	3	1
2018	15	15
Totals	**346**	**284**

*Transported to the Alouette Sockeye Research Facility for holding

Fork Length

Fork length measurements were collected from all returning sockeye. The fork length average for all returning fish was measured at 55.6cm.

Age Structure

Scale samples were analyzed from 13 of the 15 sockeye to determine the 2018 run age structure. Fish #10 scale samples could not be read and scale samples for fish #15 could not be obtained. See Godbout 2019 unpublished data. (Appendix A).

Table 3 Age class for Alouette Adult Sockeye 2018

(Godbout, L. et al 2019)

Sockeye ID	Origin	Age of Sockeye (Gilbert-Rich Age)
1	Alouette (100%)	5_3
2	Alouette (100%)	5_3
3	Alouette (100%)	4_2
4	Alouette (100%)	4_2
5	Alouette (100%)	6_4
6	Alouette (100%)	5_3
7	Alouette (100%)	4_2
8	Alouette (100%)	5_3
9	Alouette (100%)	4_2
10	Alouette (100%)	-
11	Alouette (100%)	4_2
12	Alouette (100%)	4_2
13	Alouette (100%)	5_3
14	Alouette (100%)	4_2
15	Alouette (100%)	-

Genetic Sampling

Results from this analysis indicate that all of the returning adults to the Allco fish fence in 2018 were from the Alouette Lake Reservoir. No parental analysis was performed on the 2018 samples.

Smolt to Spawner Survival

Smolt to spawner survival has ranged from a low of 0.033% to a high of 1.408% from 2005 to 2015 (Table 4). Smolt-to-spawner survival was calculated from age specific estimates of the number of smolts migrating out from the Alouette Lake Reservoir and the number of adults which returned to the reservoir (Bocking and Mathews, 2019).

Current marine survival rates (smolt – adult) being experienced by the Alouette River Sockeye (Table 4) are lower but in the same range as the Chilko Lake Sockeye which has seen marine survivals less than 3.5% since the 2007 return year and as low as 0.3% for the 2009 adult return year (2007 smolt year), respectively (Rensel et al. 2010). Survival rates for other Fraser River sockeye stocks, and in particular the Pitt River and early summer run stock grouping are not available from Fisheries and Oceans Canada. However, survival rates for Cultus Lake Sockeye which has undergone a re-building effort have also been poor in recent years (CSAS 2010).

Table 4 Alouette sockeye brood survivals, 2005-2015

(Bocking and Mathews, 2019)

Year of Smolt Migration	Survival (smolts:TRS)
2005	0.658%
2006	0.750%
2007	0.082%
2008	1.408%
2009	0.216%
2010	0.364%
2011	0.033%
2012	0.617%
2013	0.037%
2014	0.052%
2015	0.515%

Discussion

Adult Sockeye Returns

The 2018 Alouette Sockeye run continues to demonstrate timing comparable to a summer run, arriving at the Allco Fish Hatchery trapping location in July and August. However, 1 sockeye returned on October 25th which was proven to be 100% Alouette origin. The peak of the Alouette sockeye run for 2008-2018 is typically over the last week of July to the second week of August.

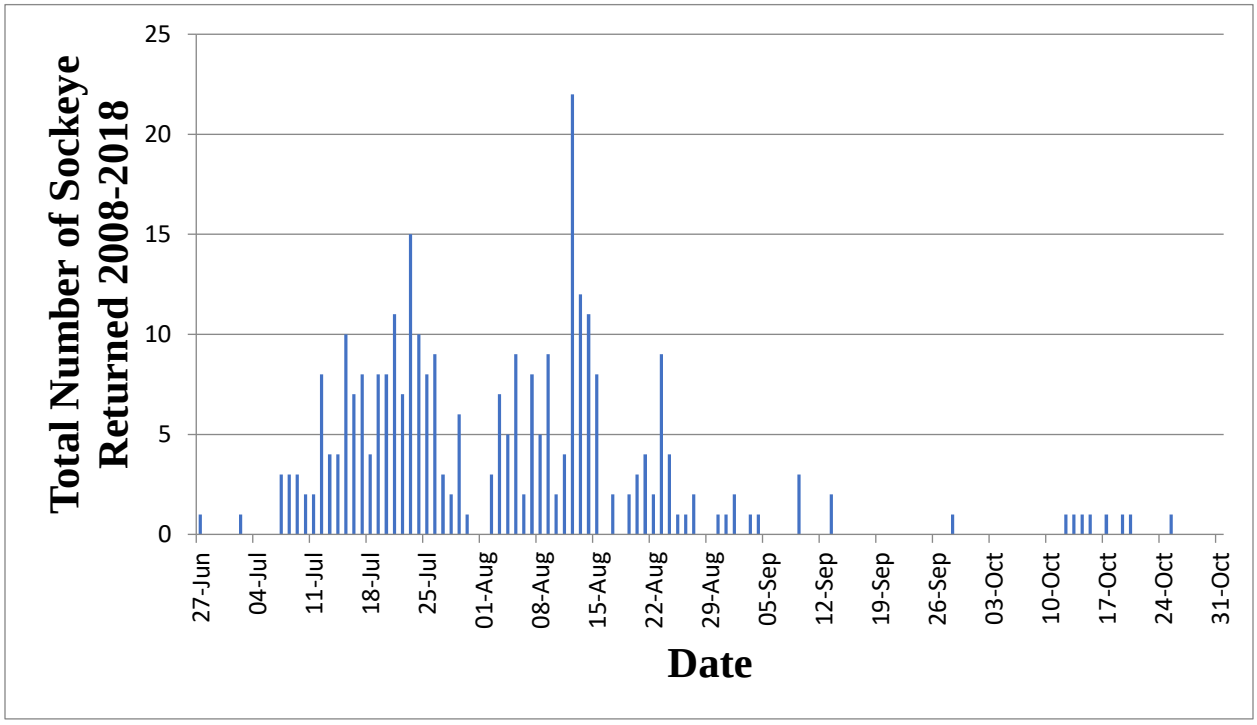

Figure 21 Total number of sockeye returned to Alouette watershed 2008-2018

A total of 346 adult sockeye returned to the Allco fish fence during the 2007–2018 runs, of which 284 have been successfully released back into the Alouette Reservoir since 2007. Although the number of total adult sockeye returns is low, the data shows that re-anadromization of kokanee/sockeye to the Alouette watershed is possible.

Fork Length

Measurements were collected for all 15 of the 2018 returning sockeye. This represented a sample size which showed an increase from the previous year in 2017 where three sockeye returned to the Allco fish fence. The average fork length measured in 2018 was 55.6 cm. (Table 5).

Table 5 Average sockeye fork length, 2008-2018

Year of Adult Return	Number of Adults Measured	Average Fork Length (cm)
2008	54	59.3
2009	15	59.1
2010	115	58.1
2011	10	60.4
2012	42	57.8
2013	8	46.6
2014[a]	0	0
2015	4	52.5
2016	6	60.1
2017	2	60.9
2018	15	55.6

a – No sockeye returned to the Allco fence in 2014.

Age Structure

The age class analysis completed by the Pacific Biological Station (Fisheries and Oceans Canada) for the 2018 season showed that the returning adult Alouette sockeye were represented by three age classes. (Appendix A Godbout, L. 2019 unpublished data).

The overall number of sampled sockeye from 2008 to 2018 was 197. The majority (50%) of these sampled returning spawners were age 4.2 years fish. Eight other age classes have been identified for the Alouette sockeye, representing the other 50% of the fish sampled (Table 6).

As background, up until and including 2014, the age class analyses were completed by the Pacific Salmon Commission (Sellars, J. 2014).

Table 6 Alouette adult sockeye age structure analysis, 2008-2018

Year (% of sampled)				Age Class (Gilbert Rich Scale)					
	2 years in ocean	3.2	4.2	4.3	5.2	5.3	5.4	6.3	6.4
2008 (53)			19 (36%)	1 (2%)	14 (26%)	19 (36%)			
2009 (11)			7 (63%)			4 (36%)			
2010 (68)			36 (53%)		3 (4%)	13 (19%)	1 (1%)		15 (22%)
2011 (6)			3 (50%)			1 (17%)		2 (33%)	
2012 (29)			20 (69%)			8 (28%)			1(3%)
2013[a] (4)			2 (50%)			2 (50%)			
2014[b] (0)									
2015 (4)		1 (25%)	1 (25%)		1 (25%)	1 (25%)			
2016[c] (6)	2 (33%)		4 (67%)						
2017 (3)						1(33%)			2 (66%)
2018 (13)			7 (54%)			5 (38%)			1 (7%)
Total sampled (197)	**2**	**1**	**99**	**1**	**18**	**54**	**1**	**2**	**19**
% of total adults sampled by age class	**1%**	**0.5%**	**50%**	**0.5%**	**9%**	**27%**	**0.5%**	**1%**	**10%**

[a] Of the four fish sampled in 2013 only two were successfully aged at 4.2, the other two samples were hypothesized to be age 5.3.
[b] No adult sockeye returned to the Allco fish fence in 2014.
[C] Due to sampling error, only partial reading could be taken in 2016

Recommendations

- To ensure the beginning of the sockeye run is captured, the Allco fish fence should continue to operate from the middle of June each year and again in 2019.
- Due to the late returning sockeye on October 25th the BC Hydro dam fish fence should remain in operation until Nov 1st each year.
- Sockeye should continue to be caught and sampled with oversight by appropriately trained staff from ARMS to ensure proper data collection procedures are followed and clear pictures are taken.
- Sockeye sampling will continue in 2019 as per 2018, with fork length, scale and tissue samples taken for all returning sockeye.
- All sockeye will then be transported to the Alouette Reservoir in 2019, unless are prespawn mortalities, which would then be sent ASAP to PBS for fresh sampling.
    - If this is not possible the fish will be frozen and shipped at the end of the sockeye run.

- Measurements will continue to be taken to ensure future scale samples are obtained from the correct location above the lateral line on the fish body, correctly placed in the sample booklets, and not taken near scars.

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Appendix A

Lyse Godbout – Age identification

Aloutte _Returning adults sockeye (1-14)

Specimen Label	Species	Reading Method	Gilbert-Rich Age
S0001	Sockeye	Scales	53
S0002	Sockeye	Scales	53
S0003	Sockeye	Scales	42
S0004	Sockeye	Scales	42
S0005	Sockeye	Scales	64
S0006	Sockeye	Scales	53
S0007	Sockeye	Scales	42
S0008	Sockeye	Scales	53
S0009	Sockeye	Scales	42
S0010	Sockeye	Scales	
S0011	Sockeye	Scales	42
S0012	Sockeye	Scales	42
S0013	Sockeye	Scales	53
S0014	Sockeye	Scales	42

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TASK 4B - EVALUATION OF THE MIGRATION SUCCESS OF *O. NERKA* (KOKANEE / SOCKEYE) FROM THE ALOUETTE RESERVOIR, 2018

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10 February 2019

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; 2018 was the thirteenth year of study of juvenile salmon migration from the Alouette Reservoir (no study occurred in 2016). Abundance estimates of *O. nerka* smolts migrating from the reservoir have ranged from 583 (95% CI: 300−865) in 2015 to 62,423 (95% CI: 47,936−76,910) in 2007.

The Mud Creek rotary screw trap (RST) was operated in 2018 during the typical timing of the *O. nerka* smolt migration from the Alouette Reservoir, from 13 April to 23 May. In total, 7,071 *O. nerka* smolts were captured, 3,324 of which were lower caudal clipped and released below the Alouette Dam, and 742 clipped fish were recaptured. Using an unbiased pooled Peterson equation for a single sampling site, an estimated 31,643 *O. nerka* smolts (95% CI: 29,537–33,750) migrated from the Alouette Reservoir between 13 April and 19 May. This was the second highest estimate in all thirteen years of studies.

In 2018, the mark-recapture equation was modified to ensure marked fish were not double counted; past annual *O. nerka* smolt estimates have also been re-calculated using this equation.

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 3.08−5.15 m^3/s; a seven-day pulse flow occurred from 30 April to 7 May, reaching a maximum flow of 5.15 m^3/s. The peak catch of *O. nerka* smolts (787 migrants) occurred on 25 April and a secondary peak catch occurred during the seven-day pulse flow (4 May; n = 689), indicating the higher pulse flows may have encouraged a secondary pulse of smolts to migrate.

A subsample of *O. nerka* smolts captured at the Mud Creek RST in 2018 were sampled for length, weight, age (scales), and genetics (fin tissue). Randomly chosen *O. nerka* smolts (<100 mm FL) averaged 71.4 mm FL (range: 47−98 mm FL; n = 1,031) and 3.2 g (range: 0.9−8.2 g; n = 1,030). Seventy-eight percent of all randomly sampled smolts analysed for age (all lengths) were Age 1 fish, 18% were Age 2, and 4% were Age 3. Other species captured were counted and released.

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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). 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). An estimated 62,423 (95% CI: 47,936−76,910) *O. nerka* emigrated from the Alouette Reservoir that year (Mathews and

Bocking 2007), the highest estimate to date[2]. Supported by the previous three years of results, and as part of the Alouette Project Water Use Plan (BC Hydro 2009), 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 7,957 fish; this included a mark-recapture estimate of 7,412 fish (95% CI: 6,381–8,442) 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 3,704 (95% CI: 3,250−4,157) for the period of 21 April to 28 May (Mathews and Bocking 2010).

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 11,130 fish (95% CI: 10,552–11,707) 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 12,363 *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 30,729 fish (95% CI: 29,221−32,238) 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 the second lowest mark-recapture estimate of 648 fish (95% CI: 268–1,028; Mathews et al. 2013). In 2013, an estimated 5,385 *O. nerka* (95% CI: 4,556−6,214) migrated from the Alouette Reservoir (Mathews et al. 2014) and in 2014 the migration was estimated at 11,523 smolts (95% CI: 10,531−12,514) (Mathews et al. 2015). The 2015 smolt migration was the lowest on record since the mark-recapture study began in 2005 as only 583 smolts (95% CI: 300−865) were estimated (Mathews et al. 2016). A total of 3,100 *O. nerka* were captured in 2017, yielding the second highest estimate of 31,643 (95% CI: 29,537−33,750) to date (Mathews and Smith 2018).

[2] Abundance estimates presented in this report for the 2007–2017 studies do not correspond to those found in earlier annual reports (see the METHODS section for more details).

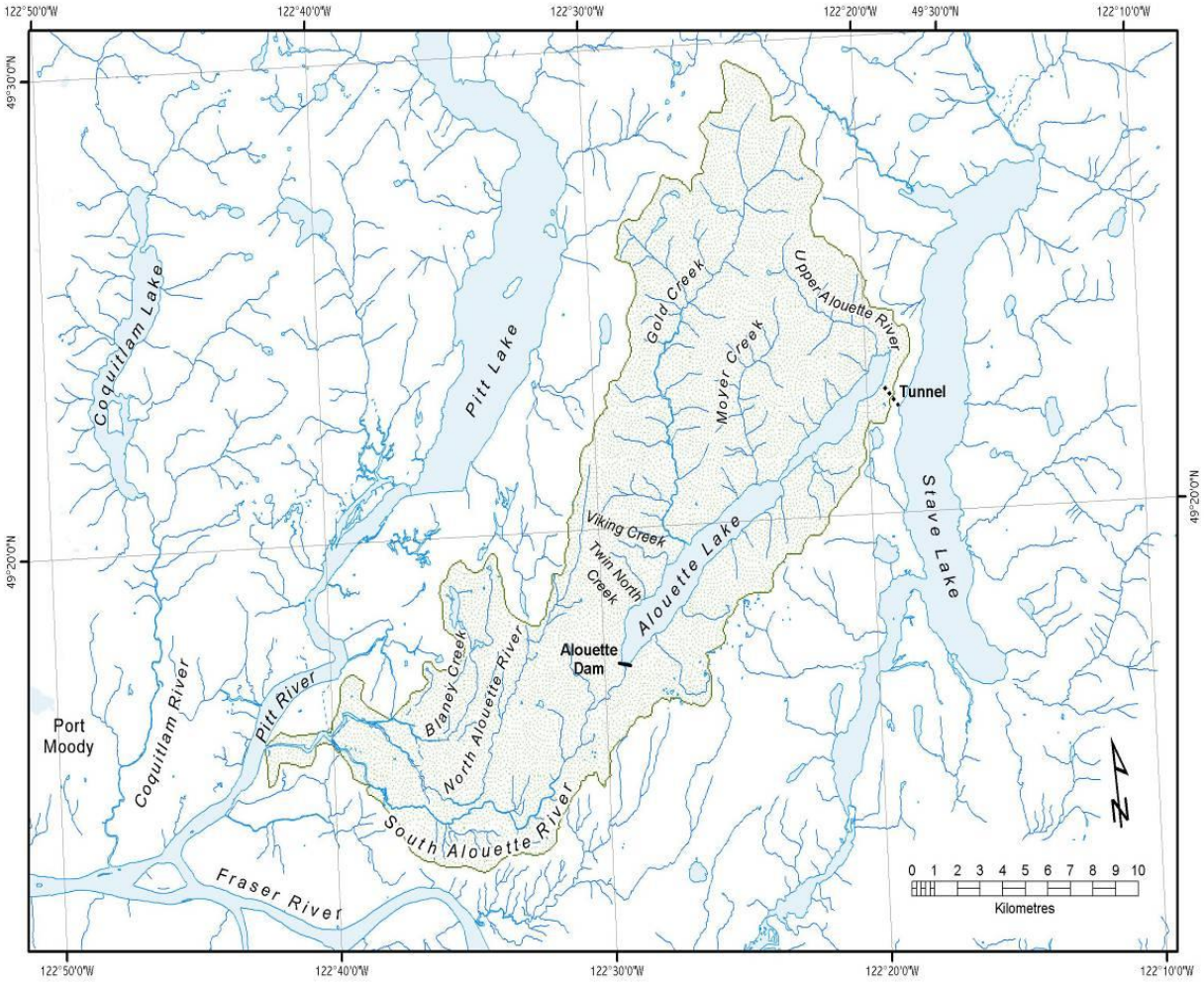

Figure 1. Map of the Alouette Watershed showing local communities and features.

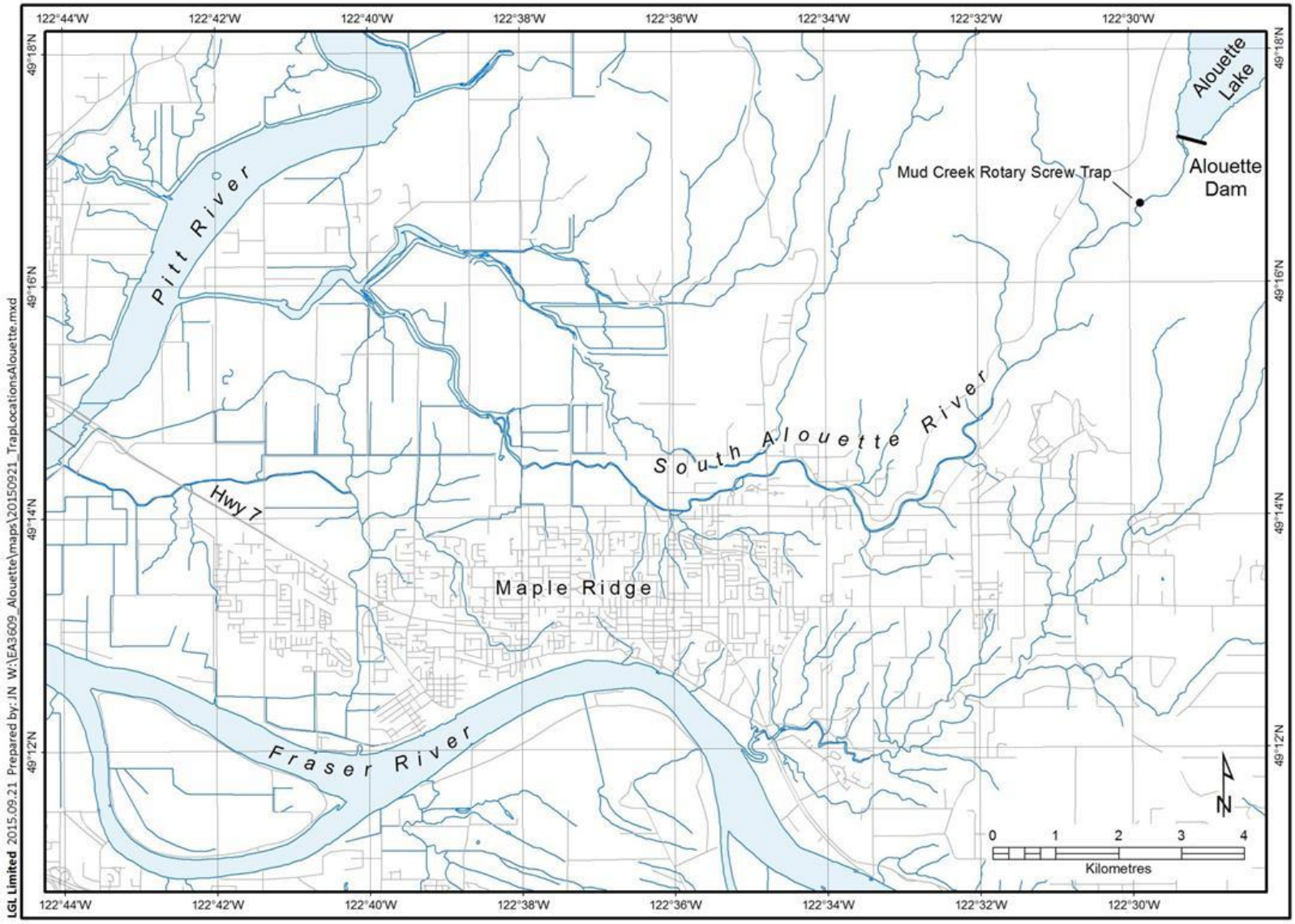

Figure 2. Map of the South Alouette River and location of the Mud Creek rotary screw trap in 2018.

In the summer and fall of 2018, 15 adult sockeye salmon returned to the Allco Hatchery fence (S. Sparrow, Alouette River Management Society, pers. comm.). Adult sockeye salmon have returned to the South Alouette River since 2007 and returns in previous years have ranged from zero (2014) to 115 migrants (2010) (Borick-Cunningham and Smith 2017).

Eleven 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 ten 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, 2009 and 2017 migrations, and two weeks later than in 2008, 2010, 2012, 2013, 2014, and 2015. The peak of the 2009 migration occurred in the latter half of May, while the peaks in 2007, 2008, 2010, 2013, and 2014 occurred in late April. The 2010 migration also began with high catches immediately once the spillway was opened in mid-April. Peak catches in 2015 occurred shortly after the opening of the spillway, peak catches in 2017 occurred one day following the peak spillway flow, and peak catches in 2012 occurred on the same date as 2011 (14 May); however, daily catches were extremely low in both 2012 and 2015 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. In 2014, four modified pulse flows (i.e., an increase to ~4.5 m^3/s for 24 hours) occurred in place of a post-surface release flush to see if there was a corresponding increase in the number of out-migrating juveniles in response to the pulses; no increase was observed.

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.

Although the WUP CC management questions were answered with the completion of the monitoring program (ALUMON#2), the Alouette River Sockeye Re-anadromization Project (ARSRP) Committee recommended continued annual monitoring of smolt outmigration at Mud Creek as this was deemed critical to the question of re-establishing a self-sustaining population of Alouette Reservoir sockeye salmon. Given this recommendation, a successful application for Fish and Wildlife Compensation Program (FWCP) funding was completed in 2015 and the annual monitoring continued. However, in 2016 FWCP funds were not awarded and hence no smolt migration monitoring occurred. The 2017 smolt monitoring proposal was then included as a component of the 'Alouette Watershed Sockeye Fish Passage Feasibility – Year 1' application, which included numerous projects recommended by the ARSRP Committee, and was successfully awarded funds by FWCP to continue the annual monitoring of the 2017 *O. nerka* smolt migration. Following this success, the 2018 smolt monitoring proposal was included as a task within the 'Alouette Watershed Sockeye Fish Passage Feasibility – Year 2' application and was successfully awarded FWCP funds to continue annual smolt migration monitoring.

Project Objectives

Specific objectives for the 2018 study year were to:

1) Operate a rotary screw trap (1.8 m diameter) continuously from 15 April to approximately early June (or when the migration ceases) at a site located 1.5 km downstream from the Alouette Dam;
2) Inspect all *O. nerka* captured for a mark, and apply marks to all unmarked *O. nerka* captured up to a specified daily target;
3) Transport all marked fish to the plunge pool located immediately downstream of the Alouette Dam and release (on a daily basis); and
4) Collect biosamples from a subset of individual *O. nerka* captured, including length, weight, scales (for ageing), and a tissue sample (fin clip for genetic analysis).

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 the 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 (*Mylocheilus caurinus*), bridgelip sucker (*Catostomus columbianus*), largescale sucker (*Catostomus macrocheilus*), and redside shiner (*Richardsonius balteatus*; Wilson et al. 2003).

BC Hydro Operations

As per the Water Act Order for the Alouette Reservoir, BC Hydro provided a spring surface release of a minimum 3 m^3/s for the period of 13 April to 14 June. Given the peak *O. nerka* catch occurred one day after the peak spillway flow of 4.76 m^3/s in 2017, indicating the higher spillway flows may have encouraged the main pulse of smolts to migrate, a pulse flow of approximately 5 m^3/s was conducted in 2018 for a seven-day period at the end of April (30 April to 7 May) once daily smolt catches were consistently high.

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 ; 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. 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 received 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 Fisheries and Oceans Canada (DFO) Pacific Biological Station (Nanaimo, B.C.) for ageing. Genetic samples (fin tissue) were collected from the first 40 randomly chosen *O. nerka* each day and from all target samples until 10 May (after which there was a shortage of sampling equipment). Genetic samples were sent to the Pacific Biological Station to process for stock identification at a later date.

Photo 1. Mud Creek rotary screw trap, 19 April 2018.

Statistical Analyses

Abundance Estimate

An unbiased pooled Peterson equation for a single sampling site (Volkhardt et al. 2007) was used to estimate the number of *O. nerka* migrating from the reservoir:

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

U = total number of unmarked fish caught in second sample,

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:

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

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

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

Note that prior to 2018, annual abundance estimates were incorrectly calculated using a pooled Petersen equation that is only appropriate when two sample sites are used (see Equation 3 in Volkhardt et al. 2007). In effect, marked fish captured at the RST were double-counted when generating the abundance estimates. Annual *O. nerka* smolt estimates for the 2007–2017 studies were re-calculated using Equation 1 and the revised values are presented in this report.

Fish Lengths, Weights, and Condition Factors

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.

RESULTS

BC Hydro Operations

The Alouette Dam spillway gate was opened on 13 April 2018 at 1222 hours and remained open until 14 June at 1452 hours. During the *O. nerka* smolt migration period from 15 April to 19 May, average daily releases from the spillway gate ranged from 3.08 m^3/s (minimum measured from the first full day of spilling from the crest gate) to 5.15 m^3/s (Figure 3; Appendix A). The low-level outlet gate was closed from 13 April (1218 hours) to 14 June (1424 hours). Spillway flows were similar to those maintained during the full monitoring years (2007 and later) and one pulse flow occurred from 30 April to 7 May, reaching a maximum flow of 5.15 m^3/s during the seven-day period. As was the case in most past years, the majority of Alouette flows were diverted to the Stave Reservoir via the adit gate during this spring period (ranging from 0 m^3/s–41.95 m^3/s).

Fishing Effort and Physical Conditions

The Mud Creek RST was installed and operational on 13 April (1200 hours), however heavy debris caused the RST to stop operating during the first two nights of the monitoring period (found blocked with debris the mornings of 14 and 15 April). Following these stoppages, the RST operated continuously until 23 May (1008 hours). Although spillway flows continued as planned until 14 June, monitoring ceased on 23 May when daily catches had ceased.

Water temperature, RST rotational speed, and general weather conditions were recorded daily each morning from 13 April to 22 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 3.37–9.89 m^3/s (mean = 4.89 m^3/s) between 13 April and 22 May (Figure 4). Alouette River discharge did vary throughout the smolt migration; the largest peak occurred on 17 April before dropping down to range from 2.46 m^3/s to 4.91 m^3/s for the remainder of the migration period; an increase in discharge was observed during the seven-day pulse flow from 30 April to 7 May. (Figure 4; Appendix A).

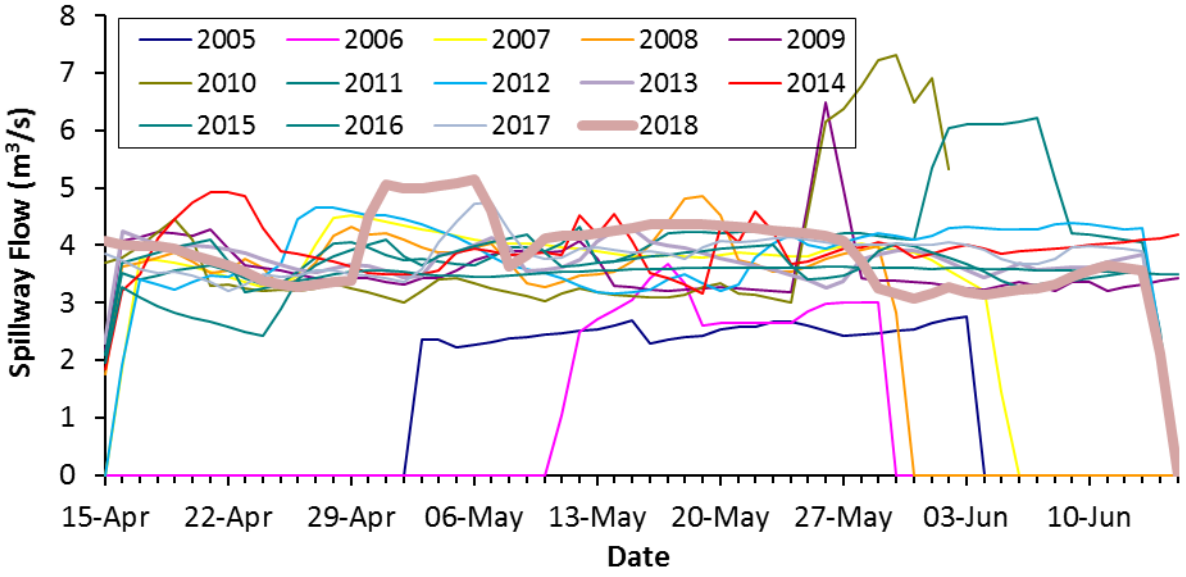

Figure 3. Comparison of flows at the Alouette Dam spillway gate during the *O. nerka* migration period, 2005–2018.

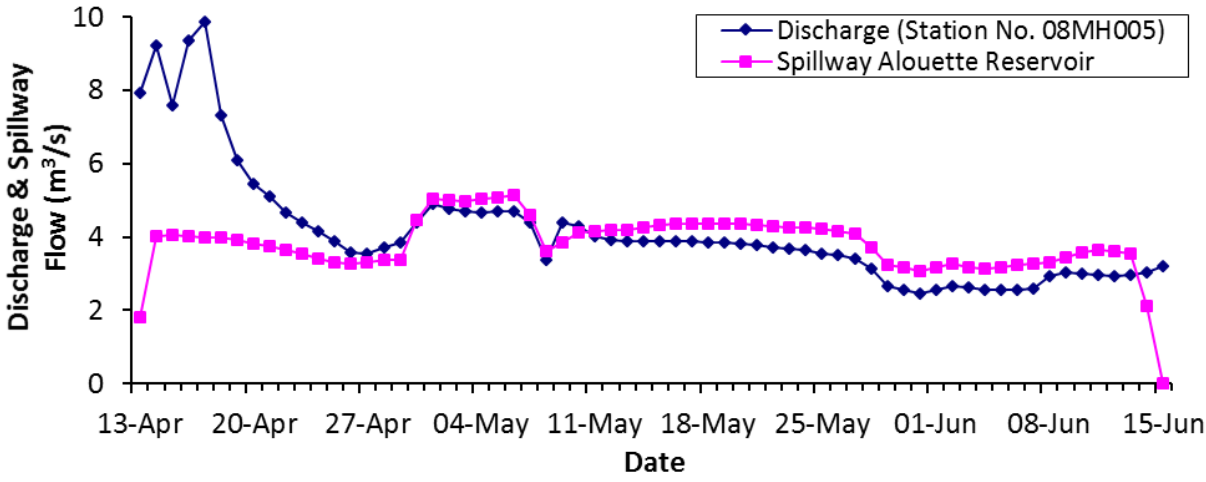

Figure 4. Daily discharge (m^3/s) at WSC Station No. 08MH005 and spillway flows from the Alouette Reservoir (13 April–15 June 2018). The WSC station is located on the mainstem South Alouette River at the 232nd Street bridge (discharge data from WSC website: https://wateroffice.ec.gc.ca/search/real_time_e.html).

Fish Capture and Sampling

O. nerka

In 2018, 7,071 unmarked *O. nerka* were captured in the Mud Creek RST from 13 April to 23 May (Table 1; Figure 5). The peak catch of 787 smolts occurred on 25 April. The first *O. nerka* was captured on 15 April, and the last *O. nerka* was captured on 19 May; a migration duration of 35 days.

A total of 3,324 *O. nerka* ('M') were marked (lower caudal clipped) and released below the dam from 13 April to 19 May 2018 (Table 2). A total of 7,071 unmarked ('U') *O. nerka* smolts captured at the Mud Creek RST were examined for marks and considered available for recapture, and 742 ('R') lower caudal clipped *O. nerka* smolts were recaptured. Capture efficiency at the Mud Creek RST was estimated to be 22.3% (742 recaptures out of 3,324 marked fish released). Using an unbiased pooled Peterson equation for a single sampling site, an estimated 31,643 ('N'; 95% CI: 29,537–33,750) smolts migrated from the Alouette Reservoir from 13 April to 19 May (Table 2).

A total of 1,197 unmarked *O. nerka* captured were measured for fork length, all but one of which were also weighed, 397 were scale sampled, and fin clip tissue was collected from 300 of those smolts for genetic stock identification.

The lengths of *O. nerka* sampled ranged from 47–241 mm FL (mean = 81 mm FL; n = 1,197; Figure 6). The largest number of *O. nerka* were in the 71–75 mm FL (n = 378) size class, the second largest size class was 66–70 mm FL (n = 360). The weights of *O. nerka* sampled ranged from 0.9–125.6 g and averaged 6.7 g (n = 1,196). Figure 7 displays a length−weight relationship established for the 2018 *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 ($F_{12, 6915} = 543.0$, $P < 0.0001$; Table 3). Post-hoc pairwise comparisons revealed a complex pattern of differences among years

Figure 8, where years that are not connected by the same letter are significantly different). Mean lengths in 2018 were significantly smaller than those in all other years except 2008.

The average weight of one-year-old *O. nerka* varied significantly among study years ($F_{10, 6203} = 659.0$, $P < 0.0001$; Table 4). Post-hoc pairwise comparisons revealed a complex pattern of differences among years (

Figure 8). Mean weights in 2018 were significantly lower than those in all other years except 2011 (weights in 2018 were significantly heavier than in 2011). Note that weights were not measured in 2008 and the weight data collected in 2005 was excluded due to sampling biases.

The average condition factor varied significantly among study years ($F_{10,6203} = 126.1$, $P < 0.0001$). 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. Mean condition factor in 2018 was significantly lower than in 2017, and significantly better than in 2010-2012 (2018 values did not differ significantly from those in 2006−2007, 2009, or 2013−2015). No condition factors were calculated from data collected in 2005 or 2008.

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.

Table 1. Daily catch of *O. nerka* in the Mud Creek rotary screw trap, 2018.

	Mud Creek	
Date	Unmarked	Clip Recaptures
13-Apr	0	0
14-Apr	0	0
15-Apr	1	0
16-Apr	64	0
17-Apr	89	10
18-Apr	152	10
19-Apr	256	23
20-Apr	333	34
21-Apr	249	47
22-Apr	252	32
23-Apr	215	31
24-Apr	478	36
25-Apr	787	44
26-Apr	380	27
27-Apr	235	40
28-Apr	533	47
29-Apr	127	44
30-Apr	27	51
01-May	121	22
02-May	452	21
03-May	566	32
04-May	689	25
05-May	357	26
06-May	223	24
07-May	115	36
08-May	87	16
09-May	65	11
10-May	67	17
11-May	19	11
12-May	42	4
13-May	21	3
14-May	7	3
15-May	35	1
16-May	8	1
17-May	12	6
18-May	4	5
19-May	3	0
20-May	0	2
Total	**7,071**	**742**

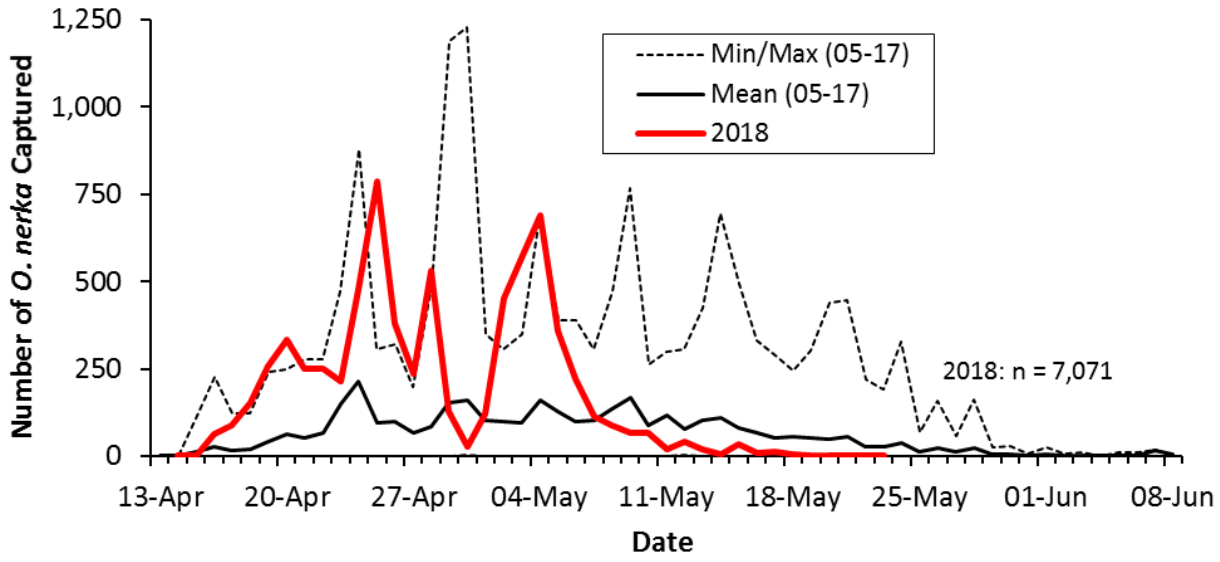

Figure 5. Daily catch of *O. nerka* at the Mud Creek rotary screw trap in 2018 in comparison to the maximum, mean, and minimum catches of the previous twelve years (spillway opened 3 May, 11 May, 16 April, 15 April, 15 April, 14 April, 15 April, 16 April, 15 April, 15 April, 15 April, 13 April, and 13 April for 2005–2018, respectively).

Table 2. Total estimated *O. nerka* migration from the Alouette Reservoir, 2018.

No. *O. nerka* Clipped and Released Below Dam ('M')	3,324
No. *O. nerka* Unmarked Fish ('U')	7,071
No. *O. nerka* Recaptures ('R')	742
Estimated *O. nerka* Passage (13 April–19 May 2018) ('N')	**31,643**
95% Confidence Interval	29,537–33,750
Trap Efficiency	22.3%

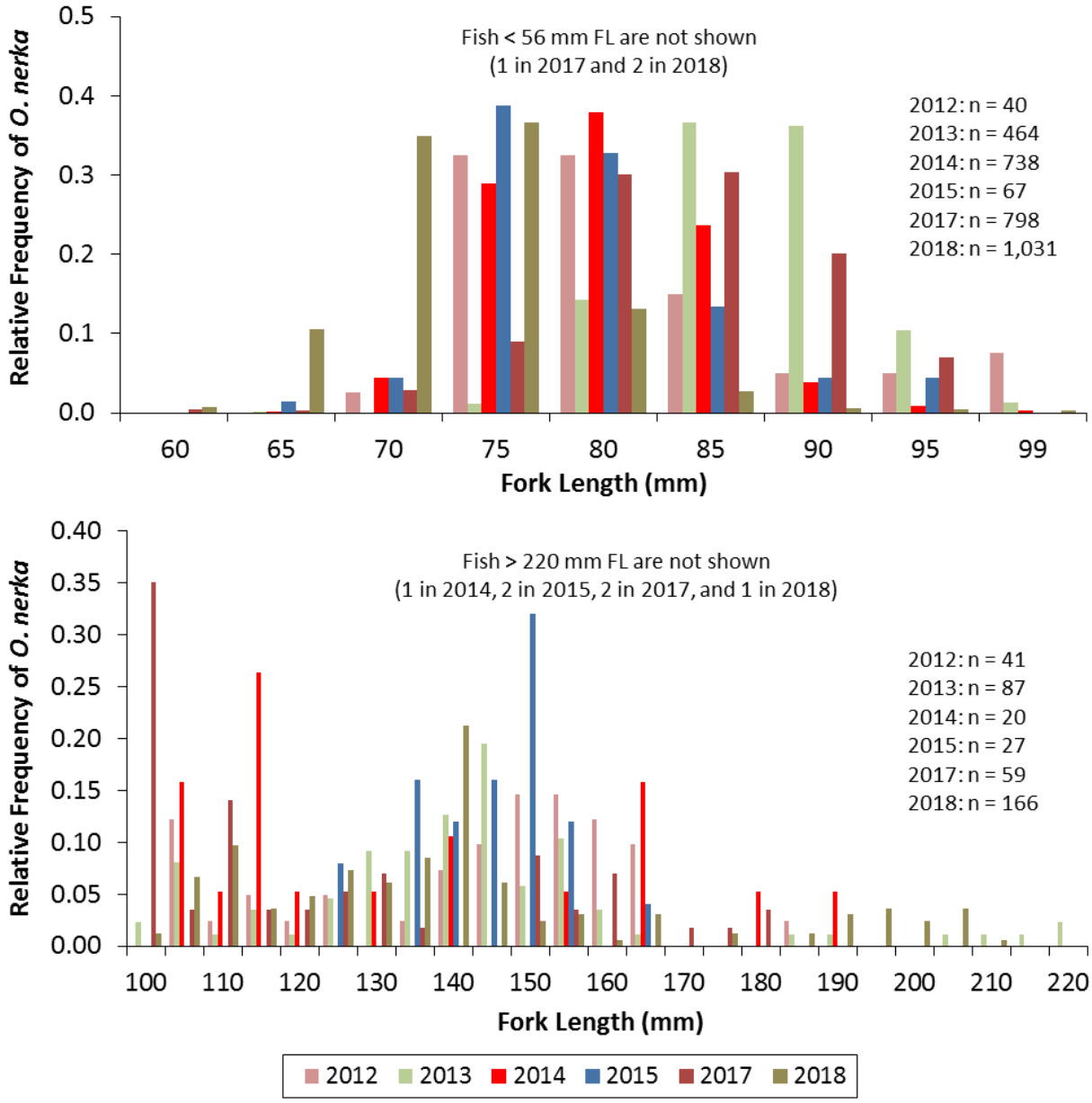

Figure 6. Length frequency distribution of *O. nerka* measuring less than 100 mm FL (top panel), and 100 mm FL or greater (bottom panel), captured in the Mud Creek rotary screw trap operated in the South Alouette River (random samples), 2012–2018.

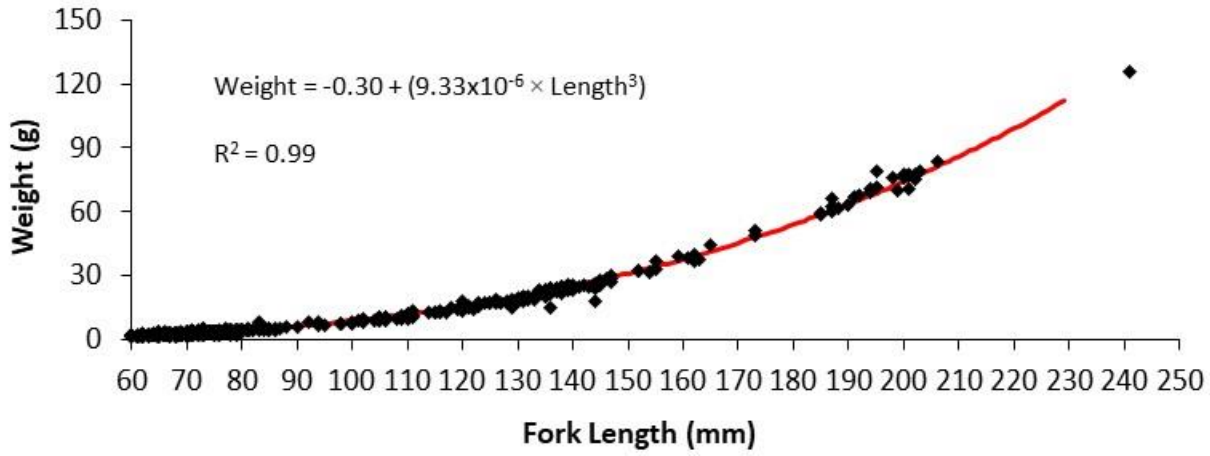

Figure 7. Length–weight relationship of *O. nerka* smolts migrating from the South Alouette Reservoir, 2018.

Table 3. Mean length of *O. nerka* less than 100 mm FL (random samples only), 2005−2018.

Year	Mean FL (mm)	SE	n
2005	78.6	0.35	233
2006	79.5	0.54	97
2007	80.8	0.38	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	0.84	40
2013	85.6	0.25	464
2014	78.1	0.20	738
2015	77.8	0.65	67
2017	83.7	0.19	798
2018	71.4	0.17	1,031

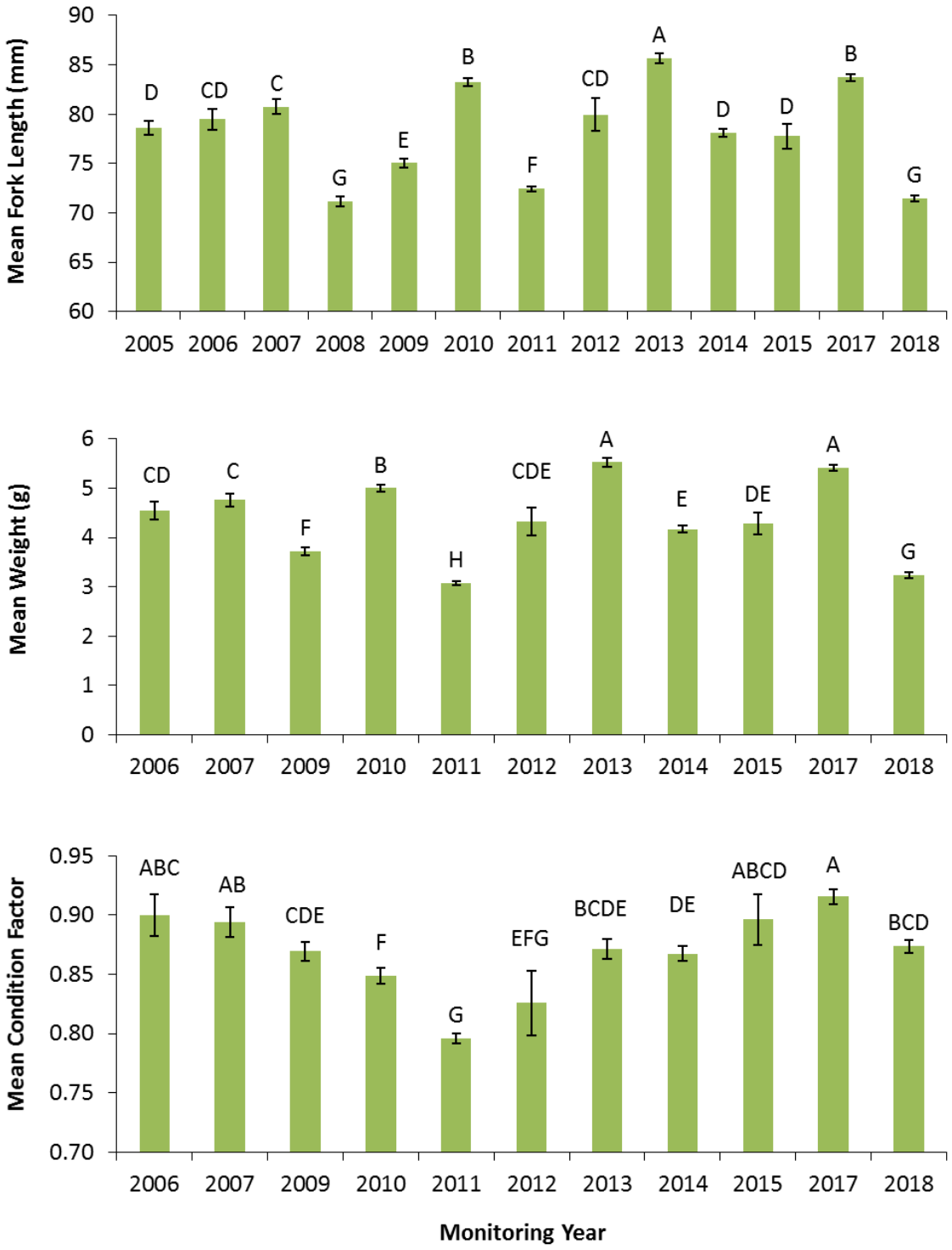

Figure 8. Comparison of mean fork length (top), weight (middle), and condition factors (bottom) across sampling years for *O. nerka* (<100 mm FL) captured at the Mud Creek RST, 2005–2018. Letters indicate results of the post-hoc pairwise comparisons between years, where years that are not connected by the same letter are significantly different.

Table 4. Mean weights of *O. nerka* less than 100 mm FL (random samples only), 2006−2007, 2009–2015, and 2017–2018.

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
2015	4.3	0.11	67
2017	5.4	0.03	789
2018	3.2	0.03	1,030

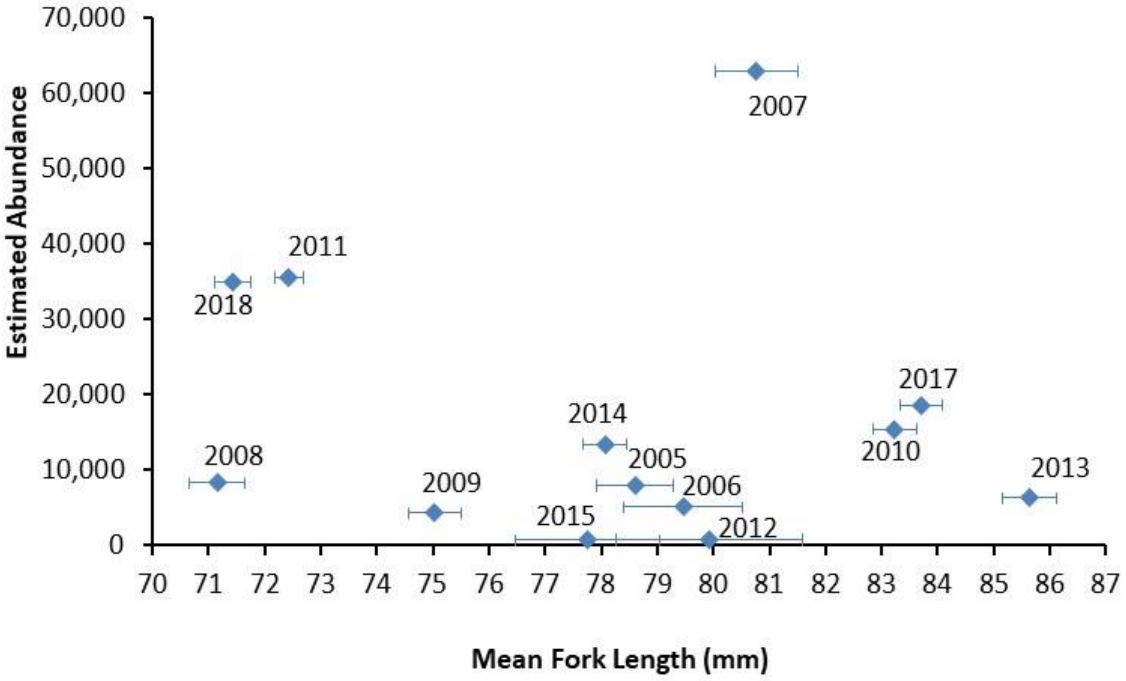

Figure 9. Comparison of the average length of *O. nerka* smolts measuring less than 100 mm FL and the estimated abundance of *O. nerka* (all sizes) that migrated from the South Alouette Reservoir, 2005–2018. Labels beside the data points indicate the study year.

Other Species

Appendix C for all non target species catch data

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); 2018 flows ranged from 3.08–5.15 m^3/s (Figure), and a pulse flow occurred from 30 April to 7 May, reaching a maximum flow of 5.15 m^3/s during the seven-day period. The opening of the spillway gate occurred on 13 April, slightly earlier than most past years. Flows to the Stave Reservoir via the adit gate were comparable to most past years, ranging from 0 m^3/s–41.95 m^3/s.

Trapping Effort

The Mud Creek RST was found jammed with debris during the morning checks on 14 & 15 April, likely due to debris flushing out of the reservoir upon the opening of the spillway. Following this the RST operated consistently throughout the *O. nerka* migration period. Crews were able to effectively and safely operate the RST over a range of water conditions, including the seven-day pulse flow, with no major down time.

Abundance Estimate

The South Alouette River *O. nerka* smolt migration at Mud Creek was estimated to be 31,643 (95% CI: 29,537–33,750) fish for the period of 13 April to 19 May 2018. This was the second highest estimate in all thirteen years of study, the highest migration estimated since 2007 and almost double the 2017 estimate (Table 5).

The total catch of *O. nerka* smolts (7,071 smolts) was the third highest catch of all years. The 2018 Mud Creek RST capture efficiency of 22.3% was slightly lower than the 2005–2017 median of 25.9%, 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 2018 to significantly influence the catch efficiency.

Table 5. Total catch at the Mud Creek rotary screw trap and the corresponding population estimate of *O. nerka* migrating from the Alouette Reservoir, 2005−2018.

Year	Total Catch	Abundance Estimate (N)	Lower 95% CL	Upper 95% CL	Trap Efficiency (%)
2005	3,310	7,900	-	-	42.0
2006	1,757	5,064	-	-	35.0
2007	7,787	62,423	47,936	76,910	12.2
2008	3,224	7,957	-	-	40.3
2009	1,247	3,704	3,250	4,157	33.4
2010	4,600	12,363	-	-	37.2
2011	8,525	30,729	29,221	32,238	27.7
2012	83	648	268	1,028	11.3
2013	1,032	5,385	4,556	6,214	18.8
2014	2,787	11,523	10,531	12,514	24.1
2015	94	583	300	865	14.9
2016					
2017	3,100	17,394	15,247	19,541	17.8
2018	7,071	31,643	29,537	33,750	22.3

*Note *O. nerka* enumeration did not occur in 2016.

Run Timing

The 35-day duration of the 2018 Alouette Reservoir *O. nerka* migration (15 April–19 May) was the shortest duration of all full seasons monitored (2007–2017, range: 37–51 days; Figure 5). The start and peak dates for the 2005 and 2006 migrations were not comparable to those from 2007 to 2018 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.

The first *O. nerka* captured in 2018 was on 15 April, two days after the opening of the spillway, indicating the spillway opening was timed well with the onset of the migration. However, the RST ceased operating sometime throughout the nights of both 13 and 14 of April due to debris; no *O. nerka* smolts were found in the live box the morning of 14 April and only a single smolt had been captured the morning of 15 April. Given catches then increased to 64 smolts on 16 April, it is likely smolts were migrating prior this date but were not captured as the RST had ceased operating.

The 2018 migration timing was similar to the start dates observed from 2007 to 2014 during full season monitoring (15–19 April). The peak catch of migrants occurred on 25 April (n = 787) and the second largest peak catch occurred on 4 May (n = 689), during the seven-day pulse flow that occurred from 30 April to 7 May, indicating the higher pulse flows may have encouraged a secondary pulse of smolts to migrate (Figure 10).

The 2018 peak catch occurred on 25 April when 787 smolts were captured. This timing was within the range of most full season monitoring years (2007–2017, range: 19 April–18 May). The 2018 midpoint in catches occurred on 28 April.

The end date of the 2018 migration, 19 May, was the earliest end date of all years sampled. Based on the thirteen years of monitoring, the target spill period from mid-April to mid-June (as effected from 2007 to 2018) appears to cover the bulk of the smolt migration window in most of the years monitored to-date.

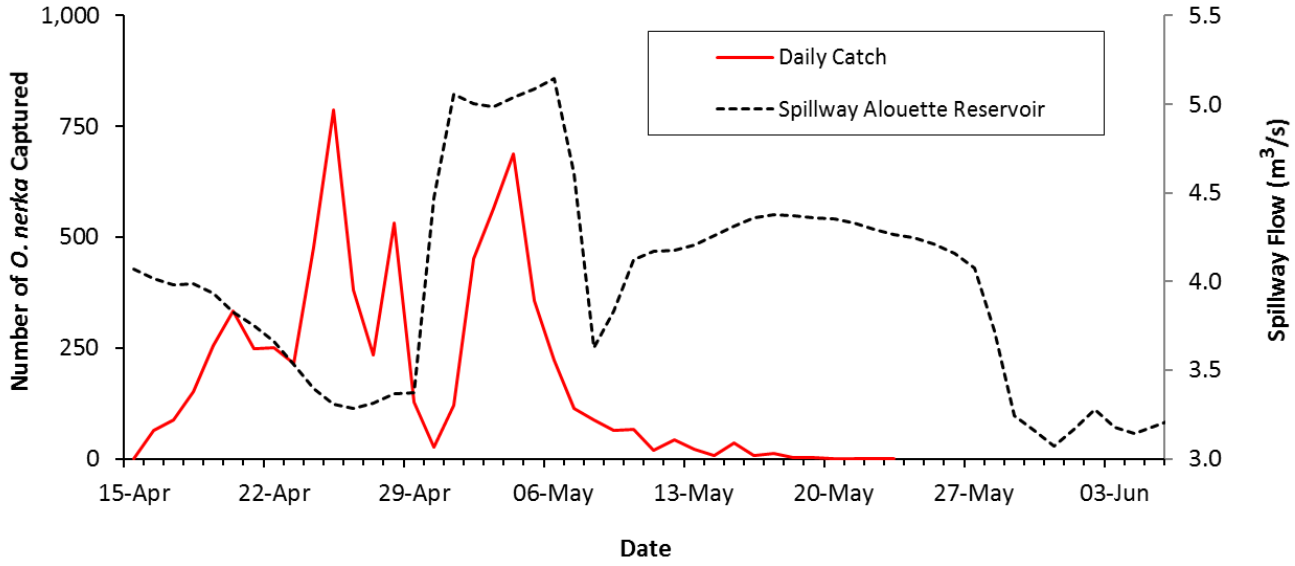

Figure 10. Comparison of daily catch of *O. nerka* captured at the Mud Creek rotary screw trap and spillway flows from the Alouette Reservoir, 2018.

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 2018 (71.4 mm FL; n = 1,031) was the second smallest observed in thirteen study years, only 0.2 mm greater than the lowest mean observed in all study years. In 2018, the greatest number of fish were in the 71–75 and 66–70 mm FL size classes, indicating smaller fish than those sampled in the last six years of sampling (Figure 6). Size classes comprising the largest number of *O. nerka* have varied over the years: 66–70 (2008), 71–75 (2009, 2011, 2012, 2015), 76−80 (2005, 2006, 2014, 2012; equal numbers of fish measured in 2012 were in both the latter two size classes), and 81−85 mm FL (2007, 2010, 2013, 2017). Figure 6 displays length data for the last six sampled years only (2012−2015, 2017−2018); length data for all previous years from 2005 to 2013 can be found in Mathews et al. (2014). The smallest *O. nerka* sampled in 2018 measured 47 mm FL, while the largest fish measured 241 mm FL.

Considerably more large fish (≥100 mm FL) were captured in 2018 compared with most previous years (Figure 6). In total, 14% of smolts measured in 2018 were ≥100 mm FL and almost half (47%) of these larger fish migrated from the reservoir during the pulse flow period. This raises the question of whether the increased pulse flow encouraged these larger fish to migrate, or if some were resident Kokanee which were flushed from the reservoir by the higher flows. In 2010, 17% of the smolts measured were ≥100 mm FL, this was a flush flow year however the increased flows did not occur until the tail end of the

migration, during which only a single smolt was captured. In 2015, 29% of the smolts measured were ≥100 mm FL however there were no flush or pulse flows and only 94 smolts were even captured (and measured) that year.

The mean weight of *O. nerka* (<100 mm FL) sampled in 2018 (3.2 g; n = 1,030) was the second smallest in all 11 years of weight data, only 0.1 g more than the mean weight determined in 2011, the smallest mean weight calculated (Table 4).

Condition factor was compared across all years with length and weight data (except for 2005 and 2008). The mean condition factor of the 2018 *O. nerka* smolts was 0.87 (n = 1,030), which was statistically similar to the condition factors in most years, only differing significantly from 2010, 2011, 2012, and 2017 (Figure 8).

In 2013, 2014, 2015, 2017 and 2018, the majority of *O. nerka* randomly sampled at the Mud Creek RST were one-year-old fish (70–99% of samples); of which the 2018 proportion was 78%. One-year-old fish measured less than 100 mm FL in 2013, 2014 and 2015 (range: 64−96 mm FL), however in 2017 and 2018, the maximum length exceeded 100 mm FL (115 and 106 mm, respectively). Two-year-old fish were captured in all years (1–27% of random samples) and ranged in length from 90−180 mm FL. Three-year-old fish were captured and randomly sampled in 2013 (9%), 2014 (<1%), 2015 (3%), and 2018 (4%), and ranged in length from 100−247 mm FL. Of the target fish sampled in 2018, 93% were two-year-old fish and the longest target fish sampled for age was 203 mm FL, one of three, three-year-old fish sampled for age in 2018.

No genetic analysis has been done thus far on the 2018 *O. nerka* samples. Results of past 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, 2013−2015, 2017−2018.

	Number of Fish (%)				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								
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
2015	62 (70)	24 (27)	3 (3)	88	64	94	78	95	162	141	225	231	228
2017	86 (99)	1 (1)	0 (0)	87	60	115	84	180	180	180	-	-	-
2018	271 (78)	64 (18)	13 (4)	348	60	106	72	90	173	131	185	241	197
					Target Samples								
2013	0 (0)	0 (0)	3 (100)	3	-	-	-	-	-	-	145	158	152
2017	3 (10)	25 (86)	1 (3)	29	110	135	123	100	175	131	230	230	230
2018	0 (0)	38 (93)	3 (7)	41	-	-	-	100	144	119	190	203	198

RECOMMENDATIONS

In October 2018, the Alouette River Management Society submitted the 'Alouette Watershed Sockeye Fish Passage Feasibility – Year 3' proposal to the Fish and Wildlife Compensation Program. As members of the ARSRP Committee, the Katzie First Nation and LGL Limited are proposing to continue monitoring the *O. nerka* smolt migration from the Alouette Reservoir in the spring of 2019 as a component of Task 4 of the Sockeye Fish Passage Feasibility proposal. The following recommendations are proposed for monitoring the *O. nerka* migration from the Alouette Reservoir in 2019:

1) Operate a rotary screw trap (1.8 m diameter) continuously from 15 April to approximately 31 May at a site located 1.5 km downstream from the Alouette Dam;
2) Maintain similar flows from the Alouette Dam spillway gate (3.0–4.5 m^3/s) throughout the out-migration period. If an early spill is required due to high reservoir levels (as was the case in

2015) it is requested that BC Hydro notify the ARSRP and all efforts should be made to operate the RST during and after the spill to enumerate any early migrants;

3) Inspect all *O. nerka* captured for a mark, and apply marks to all unmarked *O. nerka* captured up to a specified daily target;
4) Transport all marked fish to the plunge pool located immediately downstream of the Alouette Dam and release (on a daily basis);
5) Collect biosamples from a subset of individual *O. nerka* captured, including length, weight, scales (for ageing), and a tissue sample (fin clip for genetic analysis);
6) Use an unbiased pooled Peterson equation for a single sampling site to determine the population estimate of migrating *O. nerka* smolts; and
7) Record the number of all other fish captured.

ACKNOWLEDGMENTS

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APPENDICES

Appendix A. BC Hydro operations at the Alouette Reservoir, 12 April–15 June 2018.

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)
12-Apr	122.623	0	0.000	open	2.686	27.769
13-Apr	122.899	169.8 @ 12:22	1.802	open	1.365	35.066
14-Apr	122.930	169.8	4.028	closed	0.000	41.915
15-Apr	122.888	169.8	4.072	closed	0.000	41.951
16-Apr	122.860	169.8	4.019	closed	0.000	41.908
17-Apr	122.863	169.8	3.983	closed	0.000	35.745
18-Apr	122.822	169.8	3.986	closed	0.000	27.960
19-Apr	122.755	169.8	3.936	closed	0.000	27.934
20-Apr	122.707	169.8	3.831	closed	0.000	27.889
21-Apr	122.656	169.8	3.749	closed	0.000	27.857
22-Apr	122.579	169.8	3.664	closed	0.000	27.824
23-Apr	122.498	169.8	3.533	closed	0.000	27.773
24-Apr	122.447	169.8	3.395	closed	0.000	27.719
25-Apr	122.433	169.8	3.308	closed	0.000	27.685
26-Apr	122.452	169.8	3.282	closed	0.000	27.675
27-Apr	122.483	169.8	3.314	closed	0.000	27.688
28-Apr	122.487	169.8	3.366	closed	0.000	27.708
29-Apr	122.451	169.8	3.375	closed	0.000	27.711
30-Apr	122.391	280 @ 9:35	4.473	closed	0.000	27.688
01-May	122.375	280	5.054	closed	0.000	21.225
02-May	122.370	280	5.001	closed	0.000	15.123
03-May	122.388	280	4.986	closed	0.000	15.121
04-May	122.401	280	5.042	closed	0.000	15.128
05-May	122.423	280	5.084	closed	0.000	15.132
06-May	122.473	280	5.148	closed	0.000	15.140
07-May	122.517	180 @ 15:35	4.608	closed	0.000	15.158
08-May	122.636	180	3.630	closed	0.000	15.174

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)
09-May	122.792	180	3.837	closed	0.000	15.214
10-May	122.822	180	4.122	closed	0.000	15.271
11-May	122.827	180	4.170	closed	0.000	15.282
12-May	122.850	180	4.177	closed	0.000	15.284
13-May	122.888	180	4.207	closed	0.000	15.292
14-May	122.928	180	4.258	closed	0.000	15.305
15-May	122.963	180	4.312	closed	0.000	15.319
16-May	122.974	180	4.360	closed	0.000	15.332
17-May	122.971	180	4.375	closed	0.000	15.336
18-May	122.962	180	4.371	closed	0.000	15.335
19-May	122.958	180	4.360	closed	0.000	15.332
20-May	122.939	180	4.354	closed	0.000	15.330
21-May	122.912	180	4.329	closed	0.000	15.323
22-May	122.890	180	4.292	closed	0.000	15.314
23-May	122.877	180	4.263	closed	0.000	15.306
24-May	122.851	180	4.245	closed	0.000	15.302
25-May	122.812	180	4.210	closed	0.000	15.292
26-May	122.763	180	4.158	closed	0.000	15.279
27-May	122.712	180	4.075	closed	0.000	15.261
28-May	122.661	150 @ 14:45	3.721	closed	0.000	15.243
29-May	122.607	150	3.244	closed	0.000	14.983
30-May	122.548	150	3.163	closed	0.000	14.769
31-May	122.489	150	3.075	closed	0.000	14.749
01-Jun	122.427	170 @ 13:06	3.165	closed	0.000	14.729
02-Jun	122.370	170	3.278	closed	0.000	14.707
03-Jun	122.350	170	3.181	closed	0.000	14.687
04-Jun	122.375	170	3.145	closed	0.000	5.437

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)
05-Jun	122.397	170	3.187	closed	0.000	0.000
06-Jun	122.418	170	3.224	closed	0.000	0.000
07-Jun	122.452	170	3.261	closed	0.000	0.000
08-Jun	122.536	170	3.317	closed	0.000	0.000
09-Jun	122.603	170	3.459	closed	0.000	0.000
10-Jun	122.649	170	3.574	closed	0.000	0.000
11-Jun	122.625	170	3.654	closed	0.000	7.348
12-Jun	122.592	170	3.615	closed	0.000	12.466
13-Jun	122.568	170	3.558	closed	0.000	12.456
14-Jun	122.536	0 @ 14:52	2.113	open	1.044	12.449
15-Jun	122.811	0	0.000	open	2.682	12.440

Appendix B. Physical data collected at the Mud Creek rotary screw trap site, 2018.

Date	Water Temp (°C)	Weather Conditions	RST Speed (RPM)	Water Depth (cm)	Date	Water Temp (°C)	Weather Conditions	RST Speed (RPM)	Water Depth (cm)
13-Apr		Rain	6.0		15-May	15.0	Sunny	8.0	23.5
14-Apr		Cloudy	0.0	27.0	16-May	12.0	Cloudy	8.0	24.0
15-Apr	7.5	Cloudy	0.0	26.5	17-May	12.0	Cloudy	8.0	25.0
16-Apr	8.0	Rain	7.0	27.5	18-May	13.0	Cloudy	8.0	24.5
17-Apr	8.0	Rain	7.0	28.0	19-May	13.0	Cloudy	8.0	23.5
18-Apr	7.5	Sun / Cloud	7.0	26.5	20-May	12.0	Cloudy	8.0	24.0
19-Apr	8.0	Sunny	9.0	25.5	21-May	12.0	Cloudy	8.0	24.5
20-Apr	7.0	Sun / Cloud	9.0	25.0	22-May	12.0	Sunny	8.5	24.5
21-Apr	7.0	Sun / Cloud	9.0	24.0					
22-Apr	7.0	Sunny	10.0	23.5					
23-Apr	8.0	Sunny	9.0	23.0					
24-Apr	8.0	Sunny	9.0	23.0					
25-Apr	8.0	Sunny	8.0	23.5					
26-Apr	10.0	Sunny	8.0	23.5					
27-Apr	10.0	Sunny	7.0	23.5					
28-Apr	7.0	Rain	7.0	23.5					
29-Apr	9.0	Rain	8.0	23.0					
30-Apr	9.5	Rain	8.0	22.5					
01-May	9.0	Sun / Cloud	10.0	28.5					
02-May	8.5	Sunny	10.0	28.0					
03-May	10.0	Sunny	9.0	29.0					
04-May	10.0	Cloudy	10.0	28.0					
05-May	10.0	Sunny	10.0	28.5					
06-May	11.0	Sunny	9.0	28.5					
07-May	12.0	Cloudy	10.0	28.0					
08-May	10.0	Sunny	8.5	23.0					
09-May	9.0	Rain	9.0	25.0					
10-May	9.0	Cloudy	8.5	26.0					
11-May	9.0	Sunny	9.0	24.5					
12-May	12.0	Sunny	8.0	23.5					
13-May	13.0	Sunny	8.0	24.0					
14-May	17.0	Sunny	8.0	24.0					

Appendix C. Catch of non-target species at the Mud Creek rotary screw trap, 2018.

	Species Composition (%)		Total Catch (# fish)											
Date	Chum Fry	Chinook/ Coho Fry (<70 mm)	Salmon Fry (est.)	Chinook Parr/Smolt (>70 mm)	Coho Parr/Smolt (>70 mm)	Steelhead (<90 mm)	Steelhead (>90 mm)	Cutthroat	Dace Spp.	Sculpin Spp.	Stickle-back	Peamouth	Sucker Spp.	Lamprey
14-Apr	99.5	0.5	2,350		3		3		13	4	1			2
15-Apr	99.5	0.5	130							2	1			
16-Apr	99.5	0.5	1,680		3			2	17	8				1
17-Apr	99.5	0.5	3,635		5	4		1	9	11	2			6
18-Apr	99.5	0.5	940		3			1	7	2				
19-Apr	99.5	0.5	1,930		2			1	7	7	1		1	1
20-Apr	99.5	0.5	1,679	1	2				4	3	1			3
21-Apr	99.5	0.5	2,090		3	1	1	1	2	5	1			
22-Apr	99.5	0.5	1,050	1	2				1	4	1			2
23-Apr	99.5	0.5	900		8				3	2	3			2
24-Apr	99.5	0.5	3,060	2	5		2		4	1	3			1
25-Apr	99.5	0.5	2,250		2		1		8	4	3			1
26-Apr	99.5	0.5	4,180	1	2				53	8	4			
27-Apr	99.5	0.5	4,310	6					31	6	2			
28-Apr	99.5	0.5	2,470	1					6	3	1			
29-Apr	99.5	0.5	1,310	3					2		2			
30-Apr	99.5	0.5	1,170	2	1				10	2				
01-May	99.5	0.5	1,920	12	2				4					
02-May	99.5	0.5	1,900	5	3	1			3	4			2	
03-May	99.5	0.5	1,020	5	4				17	4	1			1
04-May	99.5	0.5	820	2	6		1		10	7	3			
05-May	99.5	0.5	1,060		10		1		5	3	4			1
06-May	99.5	0.5	600		5		1		3	4	2			2
07-May	98.0	2.0	550	6	16				5	5	4			

Appendix C. Continued.

	Species Composition (%)		Total Catch (# fish)												
Date	Chum Fry	Chinook/ Coho Fry (<70 mm)	Salmon Fry (est.)	Chinook Parr/Smolt (>70 mm)	Coho Parr/Smolt (>70 mm)	Steelhead (<90 mm)	Steelhead (>90 mm)	Cutthroat	Dace Spp.	Sculpin Spp.	Stickle-back	Peamouth	Sucker Spp.	Lamprey
08-May	99.0	1.0	520		23		3	3	1	4	1			
09-May	96.0	4.0	330		18		1		11	3	3			
10-May	96.0	4.0	200	3	49				3	5				
11-May	98.0	2.0	110		44		6		2	5	4			1
12-May	95.0	5.0	53	2	45				6	1	4			1
13-May	95.0	5.0	55	2	35		1		4		5	2		1
14-May	90.0	10.0	21	3	55		1		6	4		9		1
15-May	70.0	30.0	16		40		1		4	7	2	1		
16-May	50.0	50.0	18		24		1		2	5	5			
17-May	50.0	50.0	5		15		2		4	5	2			1
18-May					10				2	3				1
19-May				1	11				2	12	5			
20-May				1	9		1		4	7	3	2		1
21-May					9		2		9	4	17	1		
22-May					8				4	7	8			
Totals	--	--	44,332	59	482	6	29	9	288	171	99	15	3	30

Note: 1 Northern Pikeminnow was captured on 17 May, 2018.

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