

Alouette Watershed Sockeye-Fish Passage Feasibility Project Year 3

COA-F20-F-3072

Prepared for:

Fish and Wildlife Compensation Program

Coastal Region

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FINAL VERSION

April 27, 2020

This Project was funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is a partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations, and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.

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 (BC Corrections), Rick Bailey (Katzie First Nation), Bob Bocking, Megan Mathews, Elmar Plate (LGL Limited), Katy Jay, Alf Leake, Brent Wilson (BC Hydro), Scott Ducharme, Dave Nanson (Fisheries and Oceans Canada), Dr. Lyse Godbout (Pacific Biological Station, Fisheries and Oceans Canada), Shannon Harris, Dr. Brett Van Poorten and Allison Hebert (Ministry of Environment and Climate Change Strategy).

Special thanks to the Fish and Wildlife Compensation Program's - Coastal Program (FWCP) Manager Julie Fournier for her guidance and support during the 2019-2020 season and to FWCP Program Assistant, Lorraine Ens for assistance with navigating the FWCP Application and Reporting online portal.

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Individual task reports prepared and reviewed by:**Task 1 – Independent review of Nerkid Model and Alouette 11-year Plan**

Short summary of Executive Summary of Ecofish Research Ltd (July 2019)

“Alouette River Sockeye Reanadromization Project (ARSRP) – Independent Review of the Nerkid Model and Risk Assessment”

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Task 4a – Adult Sockeye Enumeration

“Alouette Sockeye Adult Enumeration Monitor Final Report 2019”

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Task 4b – Kokanee Smolt Outmigration Enumeration

“Evaluation of the Migration Success of O.Nerka (Kokanee/Sockeye) From the Alouette Reservoir, 2019”

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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 River 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 Corrections, BC Hydro, Ministry of Environment and Climate Change Strategy (ENV), Fisheries and Oceans Canada (DFO), and local stakeholders that works to promote the restoration 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 located in Maple Ridge, British Columbia.

In 2016, after the ARSRP committee did not receive funding to run 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: 1) releasing Kokanee and Sockeye hatchery fry into the reservoir; 2) smolt outmigration and adult returnee surveys would generate estimates of fry-to-smolt survival to inform density-dependence, and 3) 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 Borrick-Cunningham representing ARMS, and Dr. Brett Van Poorten representing the Ministry of Environment (MoE).

The eleven-year plan included a formal scientific review of the Nerkid Model by DFO and the scientific community. Originally the Canadian Science Advisory Secretariat was to review it however, in 2019 due to capacity issues to review the Nerkid Model and Alouette plan, the committee had to reconsider who would be able to do so. After discussion with ARSRP members, it was decided that BC Hydro would seek out an independent environmental research group to review the Model and Plan. With instruction by the ARSRP committee, this independent consulting group, Ecofish Research Ltd, was engaged and funded by BC Hydro, to review the Model and the Plan as to how and to what extent both documents address any uncertainties identified in the eleven-year plan. The review investigated and reported 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 focused on short-and long-term implications of Sockeye smolting for genetic and population integrity. This review of both the Nerkid Model and the Alouette Sockeye fish passage feasibility program should 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)**

Tasks in the Feasibility Plan		Phase 1		Phase 2						Phase 3		
		2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027
Task 1	Model & Plan Independent 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 3 of this eleven-year plan. The goals for Year 3 were to:

1. Initiate a formal independent 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; and
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.

This report is presented as a compilation of 3 individual summaries or reports from the eleven-year plan. The first section is a summary of Task 1 – Independent Review of the Nerkid Model and Alouette Plan; the second section presents the report for Task 4a – Alouette Adult Sockeye Enumeration; and the final section presents the report for Task 4b – Kokanee Smolt Outmigration Enumeration.

Please note that the consultant engaged to complete the Independent Review of the Nerkid Model and Alouette Plan was not funded by FWCP, but BC Hydro. A short summary of this report by Ecofish Research Ltd 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 finalize the work in Year 3 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 – Independent Review of Nerkid Model and Alouette Program

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*“Alouette River Sockeye Reanadromization Project (ARSRP)-
Independent Review of the Nerkid Model and Risk Assessment” (July 2019)*

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In early 2019, BC Hydro engaged Ecofish Research Ltd. to complete an independent review of the Nerkid Model (van Poorten *et al.* 2018a) and the ARSRP committee’s 11-year fish passage feasibility plan (ARSRP Plan; ARSRP 2008). Ecofish Research completed a draft report which was reviewed and discussed with the ARSRP committee on May 30, 2019 at BC Hydro’s Edmonds office. This section is a summary of the findings in the final report as published in July 2019, “*Alouette River – Review of the Nerkid Model and Risk Assessment*” to be referred to as the “report”. The report from Ecofish Research determined that there were “no significant risks or ‘show-stoppers’” for the ability to reconnect the lower and upper Alouette watershed through a permanent fish passage into the Alouette Reservoir. This conclusion was drawn from the Ecofish Research report (July 2019) which set out to review the management questions as follows:

“This report addresses three management questions:

1. *Does the Nerkid Model adequately consider the factors driving Sockeye production in the Alouette Watershed and are the model variables represented at an appropriate level? If not, what are the potential uncertainties or additional factors that should be considered?*
3. *Is the absence of fish passage potentially limiting the Sockeye productivity and behavior under current conditions?*
4. *What are the ecological, genetic disease, and habitat capacity and displacement risks, benefits and uncertainties associated with providing permanent fish passage and/or operating a hatchery to restore an anadromous Sockeye Salmon run to the Alouette Reservoir? What are the mitigation options?”*

Overall, the following observations were drawn from the review’s executive summary:

1. Model results are highly sensitive to stock recruitment function and low marine survival rates. More empirical information is needed to support the model assumptions.
2. Spawning habitat was determined not to be a limiting factor for Sockeye salmon production.
3. Rearing habitat was determined to be a limiting factor for nerkids but this seems to be somewhat difficult to confirm as there are different studies that have provided different lake rearing capacities.
4. Marine survival is exceedingly low for Alouette sockeye salmon and if we had both parents being sockeye the marine survival rates could potentially increase.
5. The various risks including ecological and disease, in most cases, could be mitigated through ongoing monitoring, design and fishway management, targeted fishway practices and hatchery enhancement best practices.
6. The various risks associated with genetics were determined to be minimal as the resident nerkids and returning adults have been found to be genetically the same.

7. The risk associated with “staying the course” or doing nothing to allow for permanent fish passage would be the potential for the resident nerkid population in the Alouette to select against anadromy and thus eventually, with an ever-dwindling timeframe, lose the ability to outmigrate, thus losing the potential to restore an unimpeded historical Alouette sockeye salmon run.

References

- Buchanan, S., A. Buren, S. Johnson, D. Barker, M. Sheng and M. Hocking. 2019. Alouette River Sockeye Re-anadromization Project (ARSRP) – Independent Review of the Nerkid Model and Risk Assessment. Consultant’s report prepared for BC Hydro by Ecofish Research Ltd, July 31, 2019.
- Van Poorten, B.T., S. Harris and A. Hebert. 2018a Evaluating benefits of stocking on sockeye recovery projections in a nutrient-enhanced mixed life history population. *Can. J. fish. Aquat. Sci.* 75 (12): 2280-2290

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TASK 4A – ALOUETTE ADULT SOCKEYE ENUMERATION

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9 March 2020

Acknowledgments

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, 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 and Ken Stewart (ARMS); Lyse Godbout (Pacific Biological Station-DFO); Bob Bocking and Megan Mathews (LGL); Shannon Harris and Dr. Brett Van Poorten and Allison Hebert (ENV); Scott Ducharme and Dave Nanson (DFO); Rick Bailey (Katzie First Nation); Katy Jay, Alf Leake, and Brent Wilson (BC Hydro). For their many years of dedication to the ALLCO trap and truck program to bring the returning adult Sockeye back to the Alouette Reservoir: Ron MacLean and Mike Ilaender, Lance Di Salvo and Chris MacMillan (BC Corrections ALLCO Fish Hatchery).

The Alouette Watershed Sockeye-Fish Passage Feasibility Year 3 project was managed and delivered with the financial support from the Fish and Wildlife Compensation Program. www.fwcp.ca

Special thanks goes to FWCP for funding this project and for its continued support of sockeye restoration in the Alouette Watershed.



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 return success of *O.nerka* adults to the ALLCO fish fence. 2019 was the thirteenth year of studying Alouette adult sockeye salmon enumeration. Originally, through BC Hydro's Water Use Plan for the Alouette Watershed, a spring surface release from the Alouette Dam has allowed for kokanee/sockeye smolts to migrate to the ocean from the years 2007 to 2019. The first surface releases occurred in 2005 and in 2007 the first adult sockeye returned to the Alouette Watershed. The 2019 Alouette adult sockeye salmon run saw fifteen adults return between July 22 and October 16, 2019. Ten out of the fifteen sockeye were sampled at the ALLCO trap location, five were caught and sampled at the BC Hydro trap just below the Alouette Dam. Fourteen of which were successfully transported to Alouette Lake, one fish died in the trap. Fork length measurements were taken of all sockeye along with scale and tissue samples. The measurements indicated an average fork length of 60.3 centimetres.

The genetic sampling identified all adults originated from Alouette stock. Between the return years of 2005-2016, the smolt to adult (return to the hatchery fish fence) survival of the Alouette sockeye has ranged from a low of 0.06% in the 2014 smolt year to a high of 1.43% in the 2008 smolt year. (Mathews, 2020 unpublished data).

Since 2007, up to and including the 2019 season, 361 adult sockeye salmon have returned to the ALLCO fish fence, 298 of those have been successfully released into the reservoir.

This project aligns with Fish and Wildlife Compensation Program's Alouette River Watershed Action Plan (2017). The priority which is addressed are:

- Action #18, Priority Action 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 - P1
- Priority Action Description: Work must build upon the Alouette River Sockeye Re-Introduction Synthesis (13.ALU.02) and the Alouette Watershed Sockeye -Fish passage feasibility (COA-F18-F-2385). Proponents looking for an FWCP grant to evaluate opportunities to restore fish production above BC Hydro facilities that previously blocked fish passage are required to work through the Fish Passage Decision Framework

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Introduction

During the 2006 review of the Alouette Water Use Plan (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 $3\text{m}^3\text{s}^{-1}$ from April to June has indeed facilitated kokanee/sockeye out-migration from the reservoir. Since 2005, smolts have successfully out-migrated through the spillway gate during the spring release and to the ocean via the Alouette River (Table 1, Mathews et al. 2020).

Table 1 Estimated number of smolts leaving the Alouette Reservoir during the spring surface release, 2005-2019. (Mathews and Smith 2020)

Year of Smolt Migration	Estimated Abundance of Smolts
2005	7,900
2006	5,064
2007	62,915
2008	7,957
2009	3,704
2010	12,363
2011	30,729
2012	648
2013	5,385
2014	11,523
2015 ^A	583
2016	◇
2017	17,394
2018	31,643
2019 ^B	1

^ANote: 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 denied the rotary screw trap application and therefore no smolts were enumerated.

^B Note: 2019-The opening of the Alouette Reservoir spillway gate was delayed due to low water levels within the reservoir; spillway flows began May 22, 38 days later than the typical start date of April 15.

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 adult 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 Alouette Water Use Plan was to establish whether out-migrating Alouette Lake Reservoir kokanee/sockeye smolts could adapt 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. In the last two years of 2018 and 2019, the ALLCO fish fence has stayed in operation until October 31 to facilitate late return catches of returning sockeye salmon. 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 objective of this task was 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. This project year, 2019, would allow continued data collection on the number of adult sockeye salmon 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 restore sockeye to the upper Alouette Watershed (Alouette River Watershed – Action Plan 2017). This year would include the continuation to trap, enumerate, sample, and with the assistance of the BC Corrections supervisor and crew, transfer adult sockeye into the Alouette Reservoir.

As discussed in Plate *et. al.* technical feasibility report (Oct 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 that 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 km²), 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.

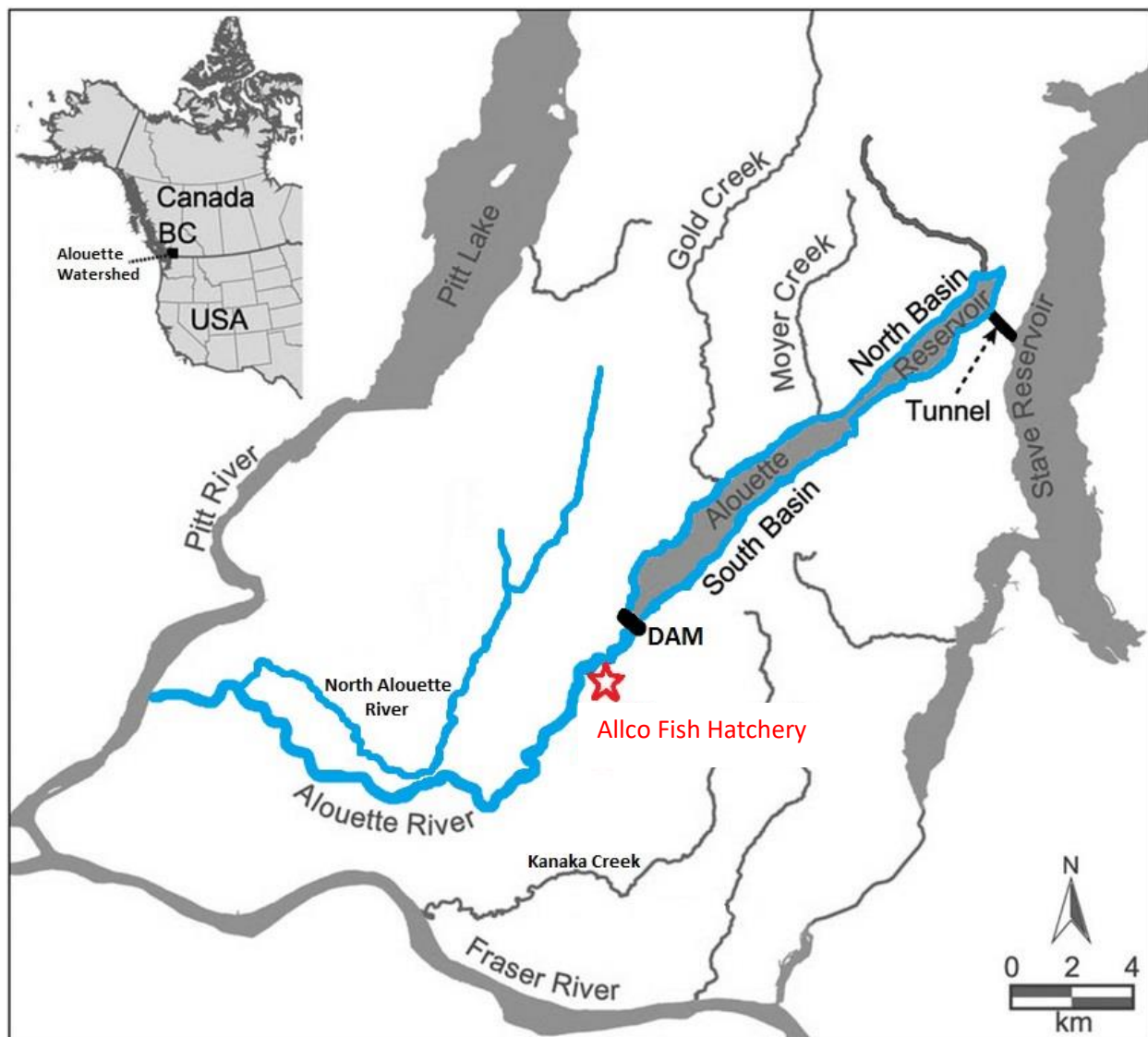


Figure 1 Map of Alouette Watershed

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 decided that in both the 2009 and 2010 the fence would be in operation between April and December, rather than year-round (Cruickshank, 2010). In 2019, although the ALLCO fish fence (Figure 2) went up on June 15, returning sockeye sampling dates commenced on July 22nd when the first adult arrived and completed on October 16th when the last adult arrived.



Figure 2 ALLCO Fish Fence

The fish fence was designed to direct sockeye and other salmon into the trap, which was monitored daily in 2019 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 five sockeye reported in the Hydro trap in 2019.

The BC Hydro fence and trap (Figure 3) operations went in at the base of the Alouette Dam on June 17th and closed on November 1st, 2019. The ALLCO fish fence was pulled out in late December for repair and maintenance. This trap was monitored by a BC Hydro contractor three times per week.



Figure 3 BC Hydro Fish Fence & Trap

For each returning sockeye in 2019, the date of capture was recorded. Fourteen out of fifteen sockeye were successfully transported to Alouette Lake with a dedicated fish transport unit (Figure 4).



Figure 4 ALLCO Hatchery Sockeye transport trailer

The first adult sockeye salmon returned to the fence on July 22, with a peak on August 15, 2019 when two sockeye adults entered the ALLCO trap. The last sockeye trapped on October 16, 2019 arrived unusually late, in full maturation colors (Figure 5).



Figure 5 Returning sockeye #15 dated – October 16, 2019

This late return in October 2019 was the second adult sockeye salmon recorded to return in full maturation colors. Unfortunately, no scale samples could be taken from this fish, however DNA samples were obtained along with fork length measurements. For all other sockeye salmon trapped in this season, sampling protocol followed Department of Fisheries and Oceans guidelines as set out at the beginning of 2019 and reviewed by project technicians before implementing on site at the ALLCO fish fence.



Figure 6-Sampling sockeye salmon; DNA adipose punch (left) and scale sample (right)

All returning sockeye were observed to be in great health and strong swimmers. Additionally, fork length measurements and pictures were taken of all fifteen fish. 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 fifteen sockeye (Figures 5 and 7-19) were conclusively 100% Alouette origin.



Figure 7 Returning sockeye #1 dated – July 22, 2019



Figure 8 Returning sockeye #2 dated – July 26, 2019



Figure 9 Returning sockeye #3 dated – August 2, 2019



Figure 10 Returning sockeye #4 dated – August 9, 2019



Figure 11 Returning sockeye #5 dated – August 11, 2019



Figure 12 Returning sockeye #6 dated – August 15, 2019



Figure 13 Returning sockeye #7 dated – August 15, 2019



Figure 14 Returning sockeye #8 dated – August 19, 2019



Figure 15 Returning sockeye #9 dated – August 21, 2019



Figure 16 Returning sockeye #10 dated – August 23, 2019



Figure 17 Returning sockeye #11 dated – August 27, 2019



Figure 18 Returning sockeye #12 dated – August 27, 2019



Figure 19 Returning sockeye #13 dated – September 16, 2019



Figure 20 Returning sockeye #14 dated – September 18 2019

Five sockeye salmon were trapped at the BC Hydro fish fence, held and measured using the ALLCO sampling box. Project technicians and hatchery staff conducted the sampling on site at the base of the Alouette Dam where the BC Hydro trap is located (Figure 21 and 22)



Figure 21 Sockeye sampling box



Figure 22 Alouette sockeye sampling team, Alouette Reservoir, August 2019

Sockeye salmon that were trapped at either the ALLCO fish fence or the BC Hydro back-up trap were released into the Alouette Reservoir from a beach access point on the east side of the Alouette Reservoir approximately nine kilometres from the ALLCO fish hatchery site using the dedicated fish transport trailer and BC Corrections hatchery staff and inmate crew (Figure 23).



Figure 23 Releasing sockeye into Alouette Reservoir, August 2019

Results

Adult Sockeye Returns

A total of fifteen sockeye returned to the Alouette Watershed during the 2019 run (Table 2). Fourteen fish were successfully released into the Alouette Reservoir, one died in the trap.

Table 2 Number of returned adult sockeye to the Alouette Watershed, 2007-2019

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
2019	15	14
Totals	361	298

*Transported to the Alouette Sockeye Research Facility for holding

Fork Length

Fork length measurements were collected for all returning sockeye. The fork length average for all returning fish was measured at 60.3 centimetres.

Age Structure

Scale samples were analyzed from thirteen of the fifteen sockeye to determine the 2019 run age structure. See Godbout. 2019 unpublished data. (Appendix A). Seven of the adults were from the brood year 2014, five from the brood year 2015 and one from the brood year 2013.

Table 3 Age class for Alouette Adult Sockeye 2019 (Godbout, L. et al 2019)

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

NA indicated the sample was not available.

Genetic Sampling

Results from this analysis indicate that all returning adults to the ALLCO fish fence in 2019 were from the Alouette Lake Reservoir. Tissue samples were analyzed for DNA based on procedures described by Beacham et al. (2005) and used to determine the population of origin stock ID using 90 coast wide populations of sockeye and kokanee. The probability of an individual's belonging to a given population was calculated, and each individual was assigned to the population for which it had the highest marginal probability (Godbout. 2019 unpublished data).

Smolt to Spawner Survival

Smolt to spawner survival has ranged from a low of 0.062% to a high of 1.428% since 2005 to 2016 (see 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 returned to the reservoir (Mathews et al., 2020).

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, 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, 2005-2016, Mathews *et al.* 2020

Year of Smolt Migration	Survival (smolts:TRS)
2005	0.662%
2006	0.765%
2007	0.082%
2008	1.428%
2009	0.198%
2010	0.364%
2011	0.033%
2012	0.463%
2013	0.037%
2014	0.061%
2015	0.712%
2016	n/a

Discussion

Adult Sockeye Returns

The 2019 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, having another adult sockeye return in October, which was proven to be of Alouette origin, could depict a longer run or two separate runs, a summer and late fall run. The peak of the Alouette sockeye run for 2008-2019 is typically over the last week of July to the second week of August (Figure 24).

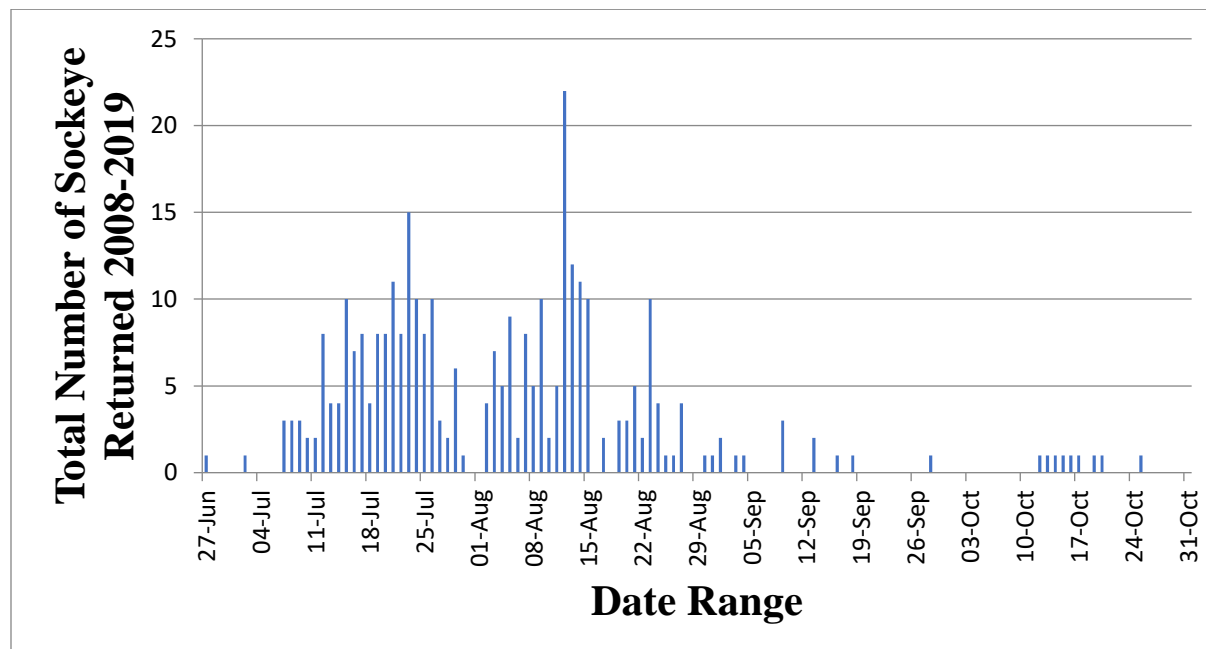


Figure 24 Total number of sockeye adults returned to Alouette watershed 2008-2019 over the season

A total of 361 adult sockeye returned to the ALLCO fish fence during the 2007–2019 runs, of which 298 have been successfully released back into the Alouette Lake 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 continues to occur annually.

Fork Length

Measurements were collected for all fifteen 2019 returning sockeye. This represented a sample size which was the same from the previous year in 2018 where fifteen sockeye returned to the ALLCO fish fence. The average fork length measured in 2019 was 60.3 centimetres. (Table 5).

Table 5 Average sockeye fork length, 2008-2019

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
2019	15	60.3

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 2019 season showed that the returning adult Alouette sockeye were represented by three age classes. (Godbout 2019, unpublished data.)

The overall number of sampled sockeye count for 2008 to 2019 was 210. The majority (50%) of these sampled returning spawners were age 4.2 years fish. Seven 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 2014).

Table 6 Alouette adult sockeye age structure analysis, 2008-2019

Year (# of sampled)	Age Class (Gilbert Rich Scale)									
	2 years in ocean	3.2	4.2	4.3	5.2	5.3	5.4	6.2	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%)
2019 (13)			5 (38%)		7 (54%)			1 (8%)		
Total (210)	2 (1%)	1 (0.5%)	104 (50%)	1 (0.5%)	25 (12%)	54 (25%)	1 (0.5%)	1 (0.5%)	2 (1%)	19 (9%)

^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 15 June each year until 1 November.
- Due to the number of adult sockeye salmon captured below the dam, the BC Hydro trap should operate from 15 June to 1 November.
- Sockeye should continue to be trapped and sampled by trained ARMS staff, and supervising BC Corrections crew.
- Sockeye sampling will continue for the 2020 season as per 2019, with fork length, scale and tissue samples taken for all returning sockeye.
- All adult sockeye will then be transported to the Alouette Reservoir in 2020, unless they are pre-spawn mortalities, which would then be sent as soon as possible to PBS for fresh sampling.
- If this is not possible each 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 –

Alouette Project, Lyse Godbout – Pacific Biological Station

Fish No.	DNA Whatcom	Date Caught	Fork Length (inches)	Scale book No	Scale cell No.	Age Gilbert-Rich	Prob. Alouette
1	221	22-Jul-19	27	75307	1,1,2,2	52	100.0%
2	222	26-Jul-19	25	75307	3,3,4,4	52	100.0%
3	223	2-Aug-19	23	-	No Scales	NA	100.0%
4	224	9-Aug-19	21	75307	7,7,8,8	42	100.0%
5	225	11-Aug-19	22.5	75307	9,9,10,10	42	100.0%
6	226	15-Aug-19	24	75306	1,1,2,2	42	100.0%
7	227	15-Aug-19	27	75306	3,3,4,4	52	100.0%
8	228	19-Aug-19	25	75306	5,5,6,6	52	100.0%
9	229	21-Aug-19	22.5	75306	7,7,8,8	52	100.0%
10	230	23-Aug-19	21.5	75306	9,9,10,10	52	100.0%
11	231	27-Aug-19	20	75306	11,11,12,12	42	100.0%
12	232	27-Aug-19	22.5	75306	13,13,14,14	62	100.0%
13	233	16-Sep-19	25.5	75306	15,15,16,16	52	100.0%
14	234	18-Sep-19	23	75305	1,1,2,2	42	100.0%
15	241	19-Oct-19	27	NA	NA	NA	100.0%

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TASK 4B - EVALUATION OF THE MIGRATION SUCCESS OF O. NERKA (KOKANEE / SOCKEYE) FROM THE ALOUETTE RESERVOIR, 2019

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6 March 2020

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; 2019 was the fourteenth 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 2019 during the typical timing of the *O. nerka* smolt migration from the Alouette Reservoir, from 11 April to 15 June. However, due to unseasonably low water levels of the Alouette Reservoir, BC Hydro was unable to provide the spring surface release minimum of 3 m³/s until 22 May, a 37-day delay from preferred timing. Given no *O. nerka* smolts were captured upon the spillway opening, a seven-day pulse flow was initiated on 30 May to encourage migration, after which flows were dropped back down to the 3 m³/s range until 14 June. Unfortunately, only a single degraded *O. nerka* mortality was captured on 13 April; this fish was assumed to have washed down the low-level outlet. No live *O. nerka* smolts were captured migrating from the Alouette Reservoir in 2019 (hence no abundance estimate). All other species captured were counted and released.

Due to the physical blockage, it is assumed those *O. nerka* smolts wishing to migrate in the spring of 2019 remained in the reservoir. Determining age at migration of the 2020 migrants will be crucial to understanding whether fish blocked in 2019 will migrate after an additional year in freshwater or remain in the reservoir as kokanee.

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LIST OF ABBREVIATIONS

ARMS	Alouette River Management Society
ARSRP	Alouette River Sockeye Re-anadromization Project
BC / B.C.	British Columbia
BCRP	Bridge Coastal Restoration Program
CI	confidence interval
FWCP	Fish and Wildlife Compensation Program
IPT	inclined plane trap
KDLP	Katzie Development Limited Partnership
NGO	non-governmental organization
RST	rotary screw trap
sp.	species (singular)
spp.	species (plural)
VIE	visible implant elastomer
WSC	Water Survey of Canada
WUP CC	Water Use Plan Consultative Committee
WUP	Water Use Plan

INTRODUCTION

Numerous interested parties in the Alouette Watershed, including government agencies, the Katzie First Nation, stewardship groups, environmental non-governmental 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 through 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 $\sim 3 \text{ m}^3/\text{s}$ 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 $\sim 3 \text{ m}^3/\text{s}$.

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 $\sim 3 \text{ m}^3/\text{s}$. 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 62,423 (95% CI: 47,936–76,910) *O. nerka* emigrated from the Alouette Reservoir that year (Mathews and Bocking 2007), the highest estimate to date¹. 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, 8,525 *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 an estimate of 17,394 (95% CI: 15,247–19,541; Mathews and Smith 2018) and 7,071 smolts were captured in 2018, resulting in an estimated 31,643 *O. nerka* (95% CI: 29,537–33,750), the second highest estimate in all thirteen years of studies (Mathews and Smith 2019).

¹ Abundance estimates presented in this report for the 2007–2017 studies do not correspond to those found in earlier annual reports (see Mathews and Smith [2019] for more details).

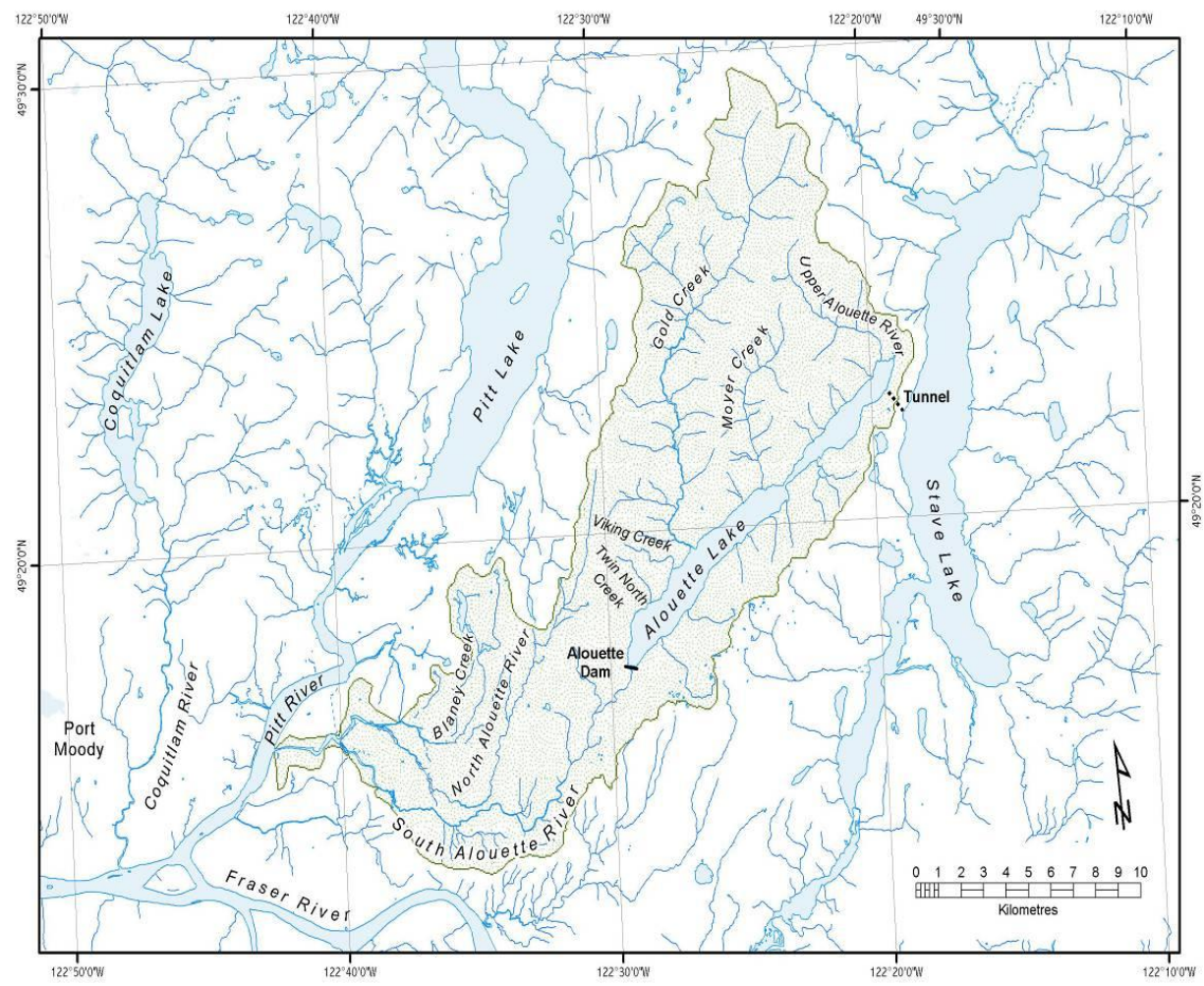


Figure 1 Map of the Alouette Watershed showing local communities and features

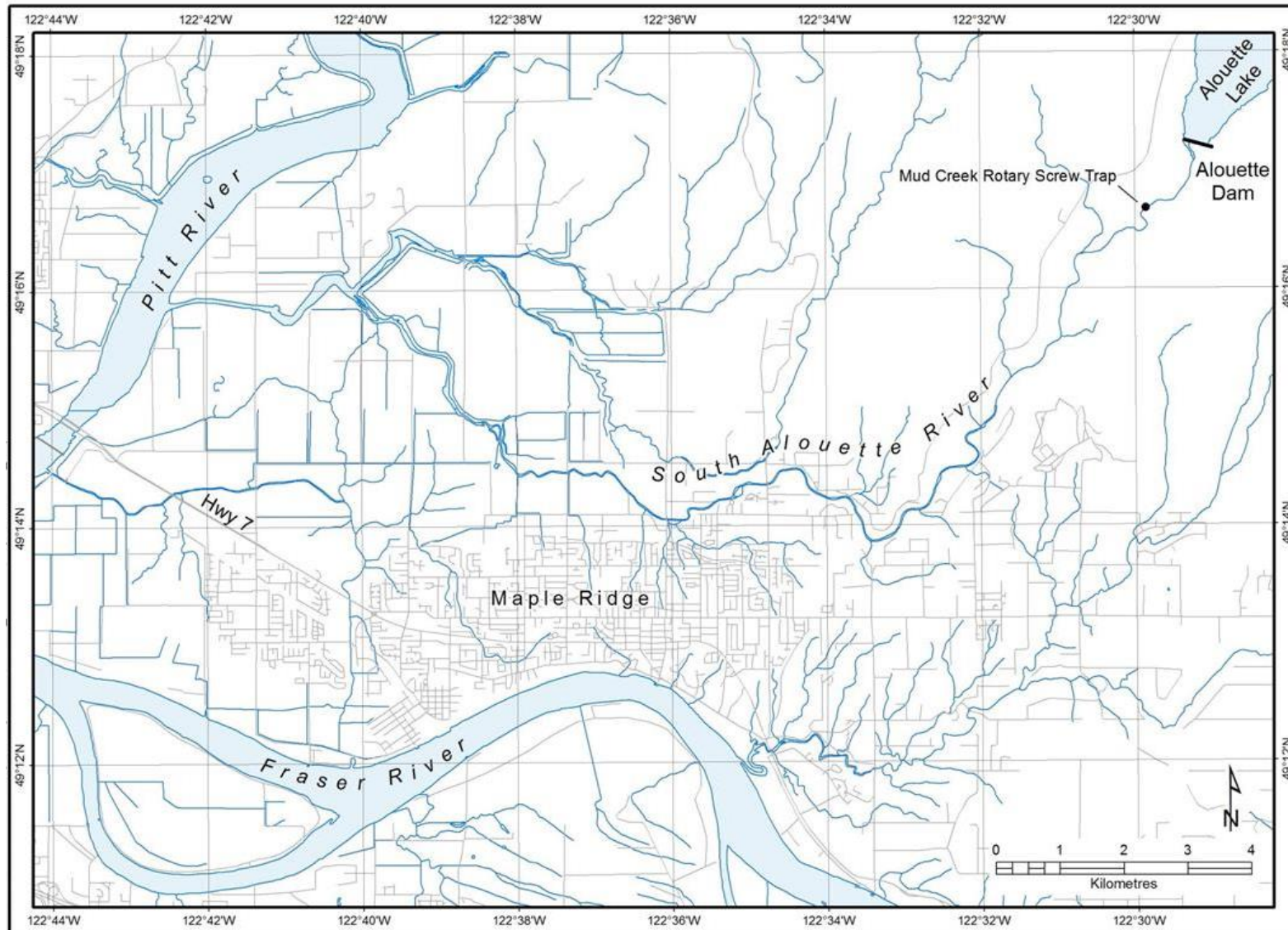


Figure 2 Map of the South Alouette River and location of the Mud Creek rotary screw trap in 2019

In the summer and fall of 2019, 15 adult Sockeye Salmon returned to the Allico Hatchery fence (S. Smith, 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).

Twelve 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 11 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, while the 2018 migration was the shortest duration of all full seasons monitored (35 days). The peak of the 2009 migration occurred in the latter half of May, while the peaks in 2007, 2008, 2010, 2013, 2014, and 2018 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 m³/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 (e.g., 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 m³/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 m³/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 Salmon smolts. Second, this monitoring program revealed that a post-surface release flush of 6–9 m³/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 RST². 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 and 2018 smolt monitoring proposals were then included as components of the Alouette Watershed Sockeye Fish Passage Feasibility – Year 1 and 2 applications, respectively, and were successfully awarded funds by FWCP to continue annual monitoring. Following this success, the 2019 smolt monitoring proposal was included as a task within the Alouette Watershed Sockeye Fish Passage Feasibility – Year 3 application and was successfully awarded FWCP funds to continue monitoring.

Project Objectives

Specific objectives for the 2019 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 (for² ageing), and a tissue sample (fin clip for genetic analysis).

² Unlike previous years, higher pulse flows from 30 April to 7 May 2018 appear to have encouraged a second peak in smolt migration from the reservoir (Mathews and Smith 2019).

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 km²) 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. clarkii clarkii*), Lake Trout (*Salvelinus namaycush*), Three-spined Stickleback (*Gasterosteus aculeatus*), sculpin (*Cottus* sp.), Northern Pikeminnow (*Ptycheilus oregonensis*), Peamouth (*Mylocheilus caurinus*), Bridgelip Sucker (*Catostomus columbianus*), Largescale Sucker (*C. macrocheilus*), and Redside Shiner (*Richardsonius balteatus*; Wilson et al. 2003).

BC Hydro Operations

Due to unseasonably low water levels of the Alouette Reservoir, BC Hydro was unable to provide the spring surface release minimum of 3 m³/s until 22 May in 2019. A seven-day pulse flow was initiated on 30 May to encourage *O. nerka* migration from the reservoir, after which flows were reduced to the 3 m³/s range until 14 June.

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. 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. Given only a single *O. nerka* smolt was captured in 2019, a very degraded mortality, no sampling occurred.



Photo 1 Mud Creek rotary screw trap, 2 May 2019

RESULTS

BC Hydro Operations

The Alouette Dam spillway gate was opened on 22 May 2019 at 1221 hours and remained open until 14 June at 1317 hours. During this period the average daily releases from the spillway gate ranged from 1.59 m³/s (minimum measured from the first full day of spilling from the crest gate) to 6.44 m³/s (Figure 3; Appendix A). In all 15 years of Alouette Reservoir spring surface releases, 2019 experienced the most delayed opening due to unseasonably low water levels (Figure 3). The low-level outlet gate was closed from 22 May to 14 June. Spillway flows were similar to those maintained during the full monitoring years (2007 and later) and one pulse flow occurred from 30 May to 6 June, reaching a maximum flow of 6.44 m³/s during the seven-day period. No Alouette flows were diverted to the Stave Reservoir via the adit gate during the 15 April to 15 June period in an effort to raise Alouette Reservoir levels for the spring surface release.

Fishing Effort and Physical Conditions

The Mud Creek RST was installed and operational on 11 April (1350 hours) and operated continuously until 15 June (1203 hours). Water temperature, water depth, RST rotational speed, and general weather conditions were recorded daily each morning from 12 April to 15 June (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 3.32–12.02 m³/s (mean = 4.43 m³/s) between 13 April and 15 June (Figure 4). Alouette River discharge varied throughout the smolt migration. Peak discharge occurred on 19 April (12.02 m³/s), and an increase in discharge was also observed during the seven-day pulse flow from 30 May to 6 June (Figure 4; Appendix A).

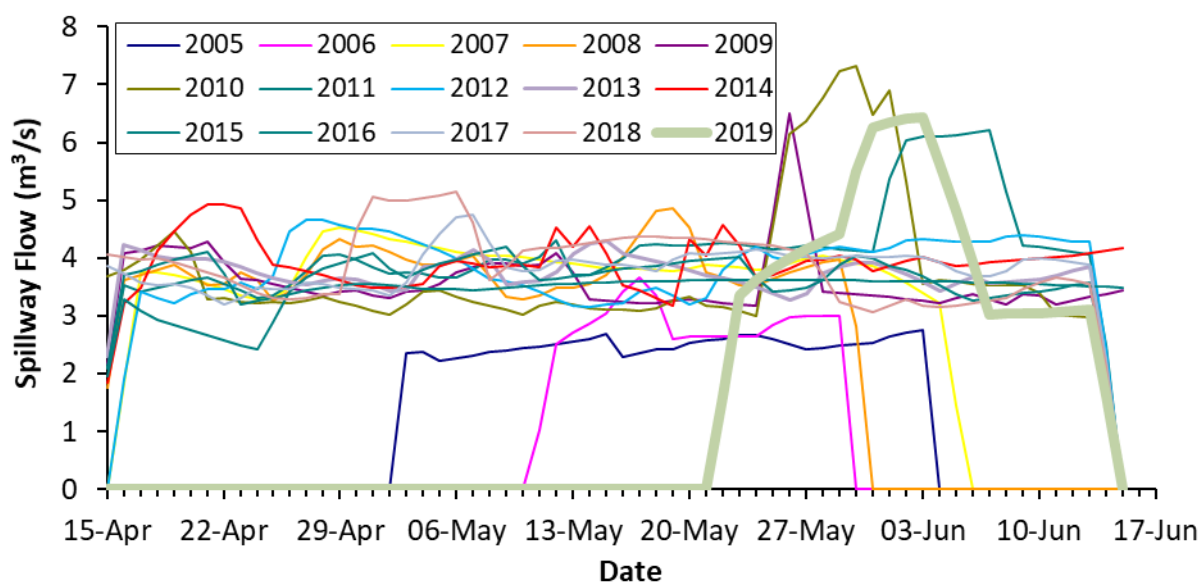


Figure 3 Comparison of flows at the Alouette Dam spillway gate during the *O. nerka* migration period, 2005-2019

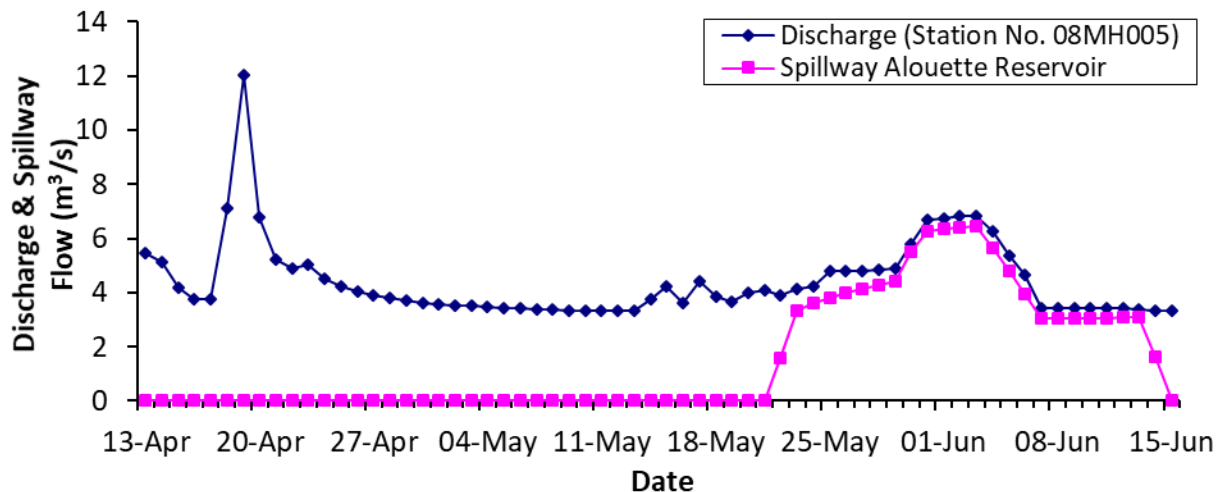


Figure 4 Daily discharge (m³/s) at WSC Station No. 08MH005 and spillway flows from the Alouette River, 13 April – 15 June 2019. The WSC station is located on the mainstem South Alouette River at the 232nd Street bridge (discharge data from WSC website: https://wateroffice.ec.gc.ca/search/real_time_e.html)

Fish Capture and Sampling

O. nerka

Only one *O. nerka* smolt was captured in 2019 (13 April), a single degraded mortality assumed to have washed through the low-level outlet.

Other Species

Although *O. nerka* smolt catches were essentially non-existent, many other species of both salmonids and non-salmonids were captured in 2019, including Chum Salmon (*O. keta*) fry, Chinook (*O. tshawytscha*) and Coho salmon (*O. kisutch*) fry and parr/smolts, steelhead, Cutthroat Trout, dace (*Rhinichthys* sp.), sculpin species, Three-spined Stickleback, Peamouth, and lamprey (Order: Petromyzontiformes) (Appendix C).

DISCUSSION

BC Hydro Operations

Due to unseasonably low water levels of the Alouette Reservoir, BC Hydro was unable to provide the spring surface release minimum of 3 m³/s until 22 May. This release date was 37 days later than the planned annual release date of 15 April, the date dictated in the *Water Act* Order for the Alouette Reservoir. Given no *O. nerka* smolts were captured once the surface releases began, a pulse flow was initiated on 30 May in hopes of encouraging *O. nerka* smolts to migrate from the reservoir. The flow reached a maximum of 6.44 m³/s, but after a seven-day pulse during which no migrants were captured, flows were reduced to the 3 m³/s range until 14 June.

Trapping Effort

The Mud Creek RST operated consistently from 11 April until 15 June. 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. Although no live *O. nerka* were captured in 2019, it does not appear that operational issues were a factor since several thousand other fish, including salmonid species, were captured consistently throughout the entire season.

Abundance Estimate

No live *O. nerka* smolts were captured in 2019, hence an abundance estimate could not be calculated. Total catch and abundance estimates from the last thirteen years monitored can be found in Table 1 and have ranged from a high of 62,423 (95% CI: 47,936–76,910) smolts in 2007 to a low of 583 smolts (95% CI: 300–865) in 2015.

Table 1 Total catch at the Mud Creek rotary screw trap and the corresponding population estimate of *O. nerka* migrating from the Alouette Reservoir, 2005-2019.

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 ^a					
2017	3,100	17,394	15,247	19,541	17.8
2018	7,071	31,643	29,537	33,750	22.3
2019 ^b	1				

^a *O. nerka* enumeration did not occur in 2016.

^b A single *O. nerka* (degraded mort) was captured on 13 April 2019.

Run Timing

The delayed spring surface release from the Alouette Reservoir was an unfortunate occurrence due to unseasonably low winter water levels in the Alouette and Stave systems. In 2005 and 2006, the spillway did not open in mid-April, but rather early May (3 May 2005 and 11 May 2006). Smolts were observed migrating following those late openings, however those delays were

considerably shorter than the 37-day delay experienced in 2019. Any *O. nerka* smolts planning to begin their migration in 2019 at the preferred timing of mid to late April, the timing consistently observed for the past 11 smolt migrations when the spillway was opened on schedule on 15 April, would not have been able to migrate. One can assume that prior to the spillway opening this year, those *O. nerka* wishing to migrate but physically blocked from doing so, simply remained in the reservoir. Determining age at migration of the 2020 migrants will be crucial to understanding whether fish blocked in 2019 will migrate after an additional year in freshwater or remain in the reservoir as kokanee.

Given no live captures occurred, including during the seven-day high flows flushing period, it is believed no smolts migrated, indicating the decision to migrate is indeed a volitional one being made by the Alouette *O. nerka* smolts, as opposed to the fish being forcibly flushed from the reservoir.

RECOMMENDATIONS

In October 2019, the Alouette River Management Society was informed of the decision by the Fish and Wildlife Compensation Program to direct reward funding for the 'Alouette Watershed Sockeye Fish Passage Feasibility – Year 4' project which includes the smolt monitoring program as a component. As members of the ARSRP Committee, the Katzie First Nation, and LGL Limited will continue monitoring the *O. nerka* smolt migration from the Alouette Reservoir in the spring of 2020 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 2020:

- 1) Operate a rotary screw trap (1.8 m diameter) continuously from 15 April to approximately early June 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 m³/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.

ACKNOWLEDGEMENTS

The cooperation of many people was essential in meeting the objectives of this study. Special thanks to Curtis Chapman and Laurie Sylvester from the Katzie Development Limited Partnership (KDLP) for their assistance with daily operations and data collection. Thanks also to Denise Horvath and Mike Leon from KDLP for their assistance in planning and project coordination. We are grateful to Greta Borick–Cunningham of the Alouette River Management Society (ARMS) for her assistance throughout the smolt monitoring program, as well as her overall project management and leadership of the greater ‘Alouette Watershed Sockeye Fish Passage Feasibility – Year 3’ project. From FWCP we thank Julie Fournier and Lorraine Ens for project coordination. From BC Hydro we thank Brent Wilson for project coordination and logistics management, and Katy Jay for project assistance as well as technical review. From LGL Limited, Bob Bocking assisted as a technical advisor, Shane Johnson assisted with data collection and field operations, and Dawn Keller formatted and edited the final report. We appreciate BC Hydro altering their operational procedures at the Alouette Dam to accommodate the needs of this study. Funding for this project was provided by the Fish and Wildlife Compensation Program – Coastal; special thanks to FWCP.



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APPENDICES

Appendix A. BC Hydro operations at the Alouette Reservoir, 12 April–15 June 2019.

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	117.964	0	0	open	2.138	0
13-Apr	118.086	0	0	open	2.153	0
14-Apr	118.282	0	0	open	2.180	0
15-Apr	118.436	0	0	open	2.201	0
16-Apr	118.549	0	0	open	2.216	0
17-Apr	118.651	0	0	open	2.229	0
18-Apr	118.849	0	0	open	2.253	0
19-Apr	119.471	0	0	open	2.327	0
20-Apr	119.826	0	0	open	2.371	0
21-Apr	119.984	0	0	open	2.390	0
22-Apr	120.091	0	0	open	2.403	0
23-Apr	120.217	0	0	open	2.417	0
24-Apr	120.339	0	0	open	2.431	0
25-Apr	120.421	0	0	open	2.441	0
26-Apr	120.484	0	0	open	2.448	0
27-Apr	120.535	0	0	open	2.454	0
28-Apr	120.579	0	0	open	2.460	0
29-Apr	120.613	0	0	open	2.464	0
30-Apr	120.641	0	0	open	2.467	0
01-May	120.666	0	0	open	2.470	0
02-May	120.692	0	0	open	2.473	0
03-May	120.721	0	0	open	2.477	0
04-May	120.746	0	0	open	2.480	0
05-May	120.772	0	0	open	2.483	0
06-May	120.811	0	0	open	2.488	0
07-May	120.864	0	0	open	2.494	0
08-May	120.926	0	0	open	2.501	0

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 Aduit Gate (cms)
09-May	120.993	0	0	open	2.509	0
10-May	121.059	0	0	open	2.517	0
11-May	121.128	0	0	open	2.525	0
12-May	121.196	0	0	open	2.533	0
13-May	121.249	0	0	open	2.539	0
14-May	121.309	0	0	open	2.546	0
15-May	121.452	0	0	open	2.563	0
16-May	121.538	0	0	open	2.572	0
17-May	121.625	0	0	open	2.581	0
18-May	121.714	0	0	open	2.591	0
19-May	121.768	0	0	open	2.596	0
20-May	121.816	0	0	open	2.601	0
21-May	121.869	0	0	open	2.607	0
22-May	121.912	280 @ 12:21	1.592	closed	1.291	0
23-May	121.952	280	3.344	closed	0	0
24-May	121.995	280	3.617	closed	0	0
25-May	122.039	280	3.810	closed	0	0
26-May	122.087	280	3.998	closed	0	0
27-May	122.126	280	4.150	closed	0	0
28-May	122.161	280	4.287	closed	0	0
29-May	122.192	280	4.408	closed	0	0
30-May	122.218	410 @ 9:50	5.499	closed	0	0
31-May	122.236	410	6.259	closed	0	0
01-Jun	122.253	410	6.348	closed	0	0
02-Jun	122.264	410	6.410	closed	0	0
03-Jun	122.270	410	6.440	closed	0	0
04-Jun	122.269	290 @ 14:50	5.645	closed	0	0

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	122.272	290	4.813	closed	0	0
06-Jun	122.274	170 @ 14:25	3.921	closed	0	0
07-Jun	122.281	170	3.028	closed	0	0
08-Jun	122.289	170	3.041	closed	0	0
09-Jun	122.292	170	3.047	closed	0	0
10-Jun	122.296	170	3.054	closed	0	0
11-Jun	122.302	170	3.064	closed	0	0
12-Jun	122.312	170	3.080	closed	0	0
13-Jun	122.325	170	3.102	closed	0	0
14-Jun	122.336	0 @ 13:17	1.626	open	1.225	0
15-Jun	122.340	0	0	open	2.660	0

Appendix B. Physical data collected at the Mud Creek rotary screw trap site, 2019.

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	9	rain	5.5	11.5	15-May	9	sun/cloud	6.5	15.5
14-Apr	7	sun/cloud	5.0	12.0	16-May	10	sun/cloud	6.5	15.5
15-Apr	7	sun/cloud	6.0	12.5	17-May	9	cloud	6.0	16.0
16-Apr	8	cloud	4.5	12.5	18-May	12	cloud	6.5	16.0
17-Apr	8	rain	4.5	12.5	19-May	12	sun/cloud	7.0	15.5
18-Apr	7	rain	4.0	13.5	20-May	--	--	--	--
19-Apr	9	cloud	5.0	20.5	21-May	12	cloud	7.0	15.5
20-Apr	8	sunny	4.5	15.5	22-May	13	sun/cloud	6.5	16.0
21-Apr	8	sun/cloud	4.5	13.5	23-May	14	sun	6.0	19.0
22-Apr	9	rain	4.5	13.5	24-May	14	rain/cloud	5.5	18.5
23-Apr	9	cloud	5.0	14.0	25-May	13	rain	6.0	20.5
24-Apr	8	sun	5.5	14.5	26-May	13	sun	5.5	20.5
25-Apr	10	sun	5.0	13.5	27-May	15	sun	5.5	21.5
26-Apr	9	sun/cloud	5.5	14.0	28-May	15	cloud	5.5	22.0
27-Apr	8	sun	5.0	14.5	29-May	14	cloud	5.5	22.5
28-Apr	9	sun	6.0	14.5	30-May	15	cloud	6.0	23.0
29-Apr	10	sun	5.5	14.0	31-May	16	sun	6.0	31.0
30-Apr	9	sun	5.0	14.0	01-Jun	16	sun	7.0	31.5
01-May	9	cloud	5.0	13.5	02-Jun	16	sun/cloud	8.0	32.0
02-May	8	cloud	6.0	14.0	03-Jun	17	cloud	7.5	31.5
03-May	10	cloud	5.0	14.0	04-Jun	17	sun/cloud	7.5	32.0
04-May	9	sun	5.0	14.0	05-Jun	16	cloud	6.0	24.0
05-May	10	sun	5.5	14.0	06-Jun	16	sun/cloud	5.5	24.0
06-May	9	sun	6.0	14.0	07-Jun	16	cloud	4.0	15.5
07-May	9	sun	6.0	14.5	08-Jun	15	cloud	4.0	15.5
08-May	9	sun	6.0	14.5	09-Jun	15	sun	4.0	15.5
09-May	9	sun	6.0	15.0	10-Jun	14	cloud	4.5	15.5
10-May	10	sun	6.0	15.0	11-Jun	17	sun	4.5	15.5
11-May	9	sun	6.0	14.5	12-Jun	17	sun	4.5	16.0
12-May	9	sun/cloud	6.5	15.0	13-Jun	17	sun	4.5	16.0
13-May	9	sun	6.5	15.0	14-Jun	16	cloud	4.5	16.0
14-May	10	rain	6.0	15.5	15-Jun	17	cloud	4.5	15.5

* Note no physical data was collected on 20 May 2019 due to staffing shortage.

Appendix C. Catch of non-target species at the Mud Creek rotary screw trap, 2019.

Date	Species Composition		Total Catch (# fish)										
	Chum Fry	Chinook/ Coho Fry (<70 mm)	Salmon Fry (est.)	Chinook Parr/Smolt (>70 mm)	Coho Parr/Smolt (>70 mm)	Steelhead (>90 mm)	Cutthroat	Dace Spp.	Sculpin Spp.	Stickle-back	Peamouth	Lamprey	Other
	12-Apr	97%	3%	630					7	3			
13-Apr	93%	7%	750		1			7	5				1
14-Apr	95%	5%	420						1				
15-Apr	95%	5%	450		1			1	1				1
16-Apr	96%	4%	460					6	2				
17-Apr	96%	4%	460			1		3	1	1			
18-Apr	95%	5%	510					1	1				
19-Apr	80%	20%	2,510		7			16	9	3			14
20-Apr	97%	3%	620		4	1		9	2	1			3
21-Apr	91%	9%	610		1			3	3				1
22-Apr	96%	4%	280		2			5	4	2			
23-Apr	93%	7%	730					4	7	1			1
24-Apr	94%	6%	370		3			6	8	2			
25-Apr	93%	7%	230			1			6	1			1
26-Apr	96%	4%	270		5			3	3	1			
27-Apr	97%	3%	520		2			3	3				2
28-Apr	95%	5%	260		2	1		3	11	1			2
29-Apr	97%	3%	290		4	3		1	4	2			2
30-Apr	98%	2%	220		8	1		5	5	3			2
01-May	98%	2%	150		3	1		3	3	2			2
02-May	96%	4%	100		7	3		4	2	1			
03-May	98%	2%	100		5	2			3	1			1
04-May	97%	3%	80	2	10	4		12	5	1			1
05-May	96%	4%	80		9	5		5	5	2			1

Appendix C. Continued.

Date	Species Composition		Total Catch (# fish)										
	Chum Fry	Chinook/ Coho Fry (<70 mm)	Salmon Fry (est.)	Chinook Parr/Smolt (>70 mm)	Coho Parr/Smolt (>70 mm)	Steelhead (>90 mm)	Cutthroat	Dace Spp.	Sculpin Spp.	Stickle-back	Peamouth	Lamprey	Other
	06-May	96%	4%	90		26	5		2	6	2		
07-May	98%	2%	60		14	6	1	3	7	2			
08-May	95%	5%	30		28	9		1	3			2	
09-May	92%	8%	120		18	5		2	2	2		1	
10-May	94%	6%	60		27	4		6	1	2			
11-May	80%	20%	40		30	7		8	3	5			
12-May	80%	20%	30		18	5		4	2	1		1	
13-May	10%	90%	10		18	6		2	3	3			
14-May	0%	100%	3		17	2		1	1			1	
15-May	40%	60%	70		59	8		5	5			1	
16-May					12	3		3	1	7		1	1 carp?
17-May					1	3		1	1				
18-May	0%	100%	3		9	3		1	4	1		2	
19-May	0%	100%	2		11	2		3	2	12		1	
20-May													
21-May	0%	100%	5		6	2		5	6	11		1	
22-May	0%	100%	13		4	2		4	2	8			
23-May	0%	100%	7		5	2		5	1	13			
24-May	10%	90%	20		1	2		4	2	26		3	
25-May	20%	80%	30		3	2		6	3	16		2	
26-May	0%	100%	10		1			2	3	12		2	
27-May	0%	100%	5		1	1		5	3	41		3	
28-May	0%	100%	3		2	1		8	4	43		1	
29-May	0%	100%	6		1			1	4	5	1		

Appendix C. Continued.

Date	Species Composition		Total Catch (# fish)										
	Chum Fry	Chinook/ Coho Fry (<70 mm)	Salmon	Chinook	Coho	Steelhead	Cutthroat	Dace Spp.	Sculpin Spp.	Stickle- back	Peamouth	Lamprey	Other
			Fry (est.)	Parr/Smolt (>70 mm)	Parr/Smolt (>70 mm)	(>90 mm)							
30-May	0%	100%	2		7			1	2	28	3		
31-May					3		2	4	5	118	8	3	
01-Jun					39			1	2	38	14	2	1 carp?
02-Jun	0%	100%	20		53			4	2	35	23	1	
03-Jun	0%	100%	6		45			4	4	19	28	1	
04-Jun	0%	100%	6		35			3	2	20	19	1	
05-Jun	0%	100%	4		5			5	3	5	23		
06-Jun					14		1	2	4	2	25	1	
07-Jun	0%	100%	2		2		1	5	4	5	8	2	
08-Jun					1			3	4	3	6	4	
09-Jun					4		1	3	2		8		
10-Jun								4	1	6	8		
11-Jun					1			4	3	4	7		
12-Jun					3			3	5	3	5		1 carp?
13-Jun					2			3	3		4		
14-Jun				1	3			8	4	5	15	1	
15-Jun								11	6	1	7		1 carp?
Totals	--	--	11,757	3	603	108	1	257	222	529	212	74	4

* Note no catch data was collected on 20 May 2019 due to staffing shortage; 21 May 2019 catches include all fish captured in RST after the 19 May 2019 sampling session.

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