Coquitlam-Buntzen Project Water Use Plan

Coquitlam River Rampdown Fish Stranding Monitoring

Implementation Year 15

Reference: COQMON-2

Study Period: May 1, 2019 – April 30, 2020

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Executive Summary

This report summarizes rampdown events occurring on the Lower Coquitlam River for the water year May 1, 2019 to April 30, 2020. A total of 4 rampdown events were monitored during the annual survey period: three scheduled rampdowns; May 1, 2019, June 1 2019, and September 1, 2019, and one unscheduled rampdown: February 5-6, 2020. In addition to the 2019-2020 water year, rampdown events from June 2020 are also included in this document.

The 2019-2020 water year was the twelfth complete year under the Treatment 2 flow regime. Under Treatment 2, rampdowns are more frequent, but of a much smaller scale in terms of total reduction in flow volume. Additionally, they are predictable due to their scheduled operational dates. The removal of the temporary dam safety 149m maximum allowable reservoir operating level in 2008, following commissioning of the new dam, increased reservoir storage but has not lead to a reduction in the frequency of large scale flow releases and subsequent full river rampdown fisheries impact surveys. Under Treatment 2, the total number of rampdowns per year has increased to an average of 7.4 up from 2.7 per year prior to 2009.

Areas previously identified as susceptible to de-watering and fish stranding were visually inspected by survey crews during each rampdown event. Stranded fish are captured and relocated to the river mainstem by dip netting, seine netting or gee-type minnow traps. The three scheduled rampdowns stranded a total of 4704 fish, 3994 of which were salvaged alive. The one unscheduled rampdown event produced a total of 105 stranded fish observed. The total number of fish stranded for all rampdowns, was 4809 with a mortality rate of 15.5%. The majority of stranded fish observed during fish salvage operations were juvenile Coho Salmon (96.3% of the total).

Acknowledgements

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BC Hydro operations staff for access to the gate house and updates.

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1.0 Introduction and Site Description

The Coquitlam River watershed, located in the Greater Vancouver area in southwestern British Columbia, is a typical southwest Pacific coastal watershed. Natural river flows are dominated by snowmelt during the spring months, with lower flows through dry summer months prior to elevated precipitation driven flows October through March. The Coquitlam Lake Reservoir portion of the watershed is utilized by two facilities. Coquitlam Dam, with origins dating back to 1892, also provides an intake for domestic water supply by Metro Vancouver for the Greater Vancouver area. The other facility, BC Hydro's Lake Buntzen generation project dates to 1903 and uses water diverted from Coquitlam Lake Reservoir via a 3.9 km tunnel to Buntzen Lake Reservoir for electricity generation, located on Indian Arm, Burrard Inlet (Figure 1) (BC Hydro 2005).

The Lower Coquitlam River watershed covers an area of approximately 80 km^2 and has its source at the Coquitlam Dam located within the Metro Vancouver watershed boundary. The Lower Coquitlam River flows though the municipality of Port Coquitlam before its' confluence with the Fraser River. At present the lower watershed is impacted by gravel extraction, the many impacts of urban and industrial development and the variable controlled discharges from the dam.

Controlled flow releases from the Coquiltam Dam have potential impacts on downstream aquatic communities. Fish can be affected by ramping rates (rate at which flow is released or decreased from the dam outlets) at all life-history stages. Impacts can include stranding of redds, fry, juveniles or adults depending on time of year. Rampdown monitoring serves to minimize the potential impacts by identifying areas known to be susceptible to stranding during rampdown events.

Investigations into the impact of rampdowns on fish in the Lower Coquitlam River have been ongoing since 2001. Rampdown assessments undertaken since 2001 have focused on developing survey methods that will enable BC Hydro to evaluate the performance of the interim ramping rate (Table 2), and its influence on mitigating fish stranding on the Coquitlam River. With respect to this, the management questions outlined by the WUP Consultative Committee (CC) and addressed during monitoring in 2003-2020 (BC Hydro CQD WUP TOR 2006) are:

> *a) What is the most appropriate ramping rate protocol that should be developed for the Coquitlam Dam that best reduces fish stranding risk while being operationally feasible?*
>
> *b) What are the ongoing fish stranding risks and/or impacts of the revised ramping rate protocol?*

The result of management question (a) being addressed, was the implementation of the interim ramping rate protocol in 2005. The following hypothesis will be tested over the remainder of the review period to continue to evaluate the performance of the interim ramp rate protocol:

H1: *The LB1 WUP interim ramping rate protocol does not strand fish at index sites in the lower Coquitlam River.*

The ramping rate established under Treatments 1 and 2 has the goal of minimizing the impact of stranding during rampdowns, while maintaining operational feasibility (BC Hydro 2005) (See Table 2). Following completion of the seismic upgrade on the Coquitlam Dam in October 2008, a new flow release schedule (Treatment 2) was initiated. Under this new flow regime a series of scheduled rampdowns occur at pre-determined times throughout the year. These rampdowns amount to small scale reductions (between 3.00 m^3/s and 0.60 m^3/s) in the total volume of water released from the Coquitlam Dam (Table 1), but can represent a sizeable decrease in the total volume of water entering the Lower Coquitlam River. For example, rampdowns scheduled for the dates January 15 and June 1 constitute a drop in the total flow release into the Lower Coquitlam River of 51% and 62% respectively (Table 1).

The introduction of the new flow regime is tied to the Lower Coquitlam Fish Productivity Index study (COQMON-7) as part of the Coquitlam River Water Use Plan (LB1 WUP). It is central to a long-term adaptive management study being conducted in the Lower Coquitlam River to compare anadromous fish production under two experimental flow regimes. Fish population monitoring under the first flow regime (Treatment 1) occurred from 2000 until the completion of the Coquitlam Dam seismic upgrade in October 2008. Fish productivity under Treatment 2 is continuing to be monitored; 2009 was the first complete year of monitoring under Treatment 2.

The low level outlet (LLO) knife-gates installed at the Coquitlam Dam in 2008 will maintain the flow reduction at the same rate as the Treatment 1 rampdown schedule (Table 2 for revised gate adjustment schedule). With the seismic upgrade to the Coquitlam Dam complete, BC Hydro dam safety constraints no longer stipulate a maximum reservoir elevation of 149 metres, to ensure dam integrity. The Normal Maximum Reservoir Operating Level (MROL) depends on the time of year. It was anticipated that the increased reservoir capacity would reduce the frequency of unscheduled spills from the Coquitlam Dam but this has not been the case to date.

Since 2001, downstream stranding risk has been assessed on the lower Coquitlam River at several locations from the dam to the confluence with Maple Creek (Macnair et.al 2004-2019). The total survey area incorporates approximately 14 river kilometers. Maps of the area in Appendix 3 identify all stranding index sites and discrete stranding locations.

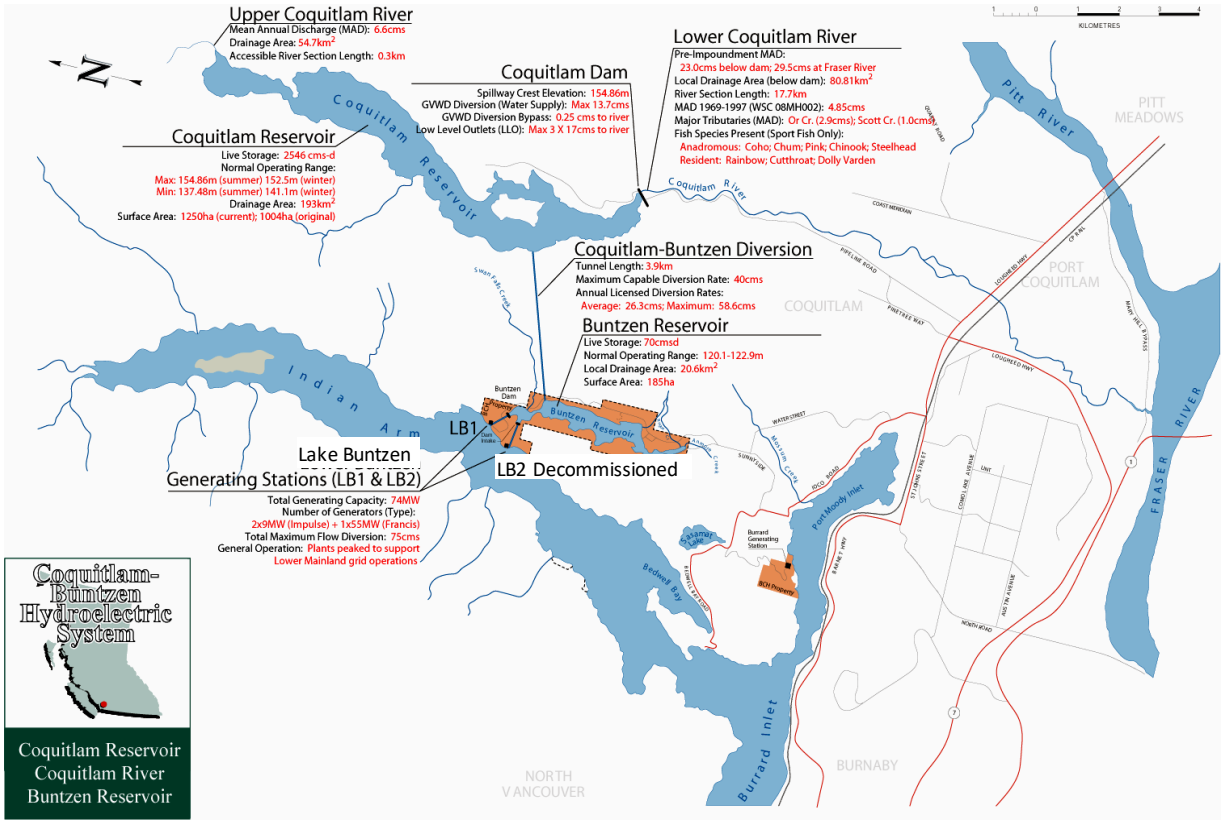

Figure 1 Coquitlam-Buntzen Reservoir, Diversion and Generating System. Map adapted from BC Hydro. Coquitlam-Buntzen Water Use Plan Monitoring Program Terms of Reference Revision 1: December 14, 2006

Due to the size of the study area, some sections of the river have received little investigation. Areas that are not highlighted on the maps in Appendix 3 are generally free of any characteristics that would indicate susceptibility to stranding. All areas not highlighted have been surveyed at least once over the past several years and have been determined by survey crews to have minimal or no stranding risk due to the complete absence of any observed stranding and the stream morphology of the area, therefore, they are not regularly included in any rampdown assessments.

Stranding is identified by three categories:

1. Adult stranding of spawning salmon, which is confined to the active spawning period (Oct.- Jan. depending on species), or other resident adult species.
2. Redd stranding during active spawning and incubation period for Pacific salmon, autumn and winter and steelhead (*Oncorhynchus mykiss*) in the spring (March-June).
3. Juvenile stranding (fry, parr and smolt), potential risk exists year round.

These categories are used to distinguish stranding by the life stage of salmonids using the Coquitlam River. A single adult female stranded or redd stranded may represent the

possible loss of thousands of eggs and the resulting loss of fry, whereas the loss of one fry among potential millions (e.g. Chum (*Oncorhynchus keta*) and Pink Salmon (*Oncorhynchus gorbuscha*) fry) would not have the same impact on fish productivity. Redd and adult stranding, however, is much less frequent than juvenile fish stranding.

Mortalities of adults and juveniles during rampdown events can result from fish being caught in pools or ephemeral channels which dewater during flow reductions. This leaves fish isolated in areas that eventually dewater. In addition, fry are vulnerable to increased predation risk and oxygen depletion when trapped in highly visible, shallow pools (Bradford, 1997). Elevated dam releases during the fall or spring may temporarily give access to spawning areas which dewater during subsequent flow reduction. This can strand redds, and render incubated eggs or alevin unviable.

Table 1 Coquitlam River flow release schedule 2019-2020. *Estimated flow is based on monthly flow transects performed to confirm flow target compliance. Table adapted from BC Hydro. Coquitlam-Buntzen Water Use Plan Monitoring Program Terms of Reference

Reservoir Diversion Schedule (m^3/sec)						
		Domestic Water		Coquitlam Dam Releases		
				Treatment 1	Treatment 2	
Month	Year	Target	Min	Target	Target	Min
May	2019	12.0	11	1.0	2.9	1.1
June	2019	12.0	10.9	1.4	1.1	1.1
July	2019	18.0	15.8	1.4	1.2	1.1
August	2019	23.0	20.2	1.1	2.7	1.1
September	2019	23.0	20.9	0.8	2.2	1.1
October	2019	12.0	10.8	0.8	6.1	3.6
November	2019	12.0	10.8	1.1	4.0	1.5
December	2019	11.9	10.7	1.1	5.0	2.5
Jan 1-15	2020	11.9	10.7	1.0	5.9	3.6
Jan 15-31	2020	11.9	10.7	1.0	2.9	2.9
March	2020	11.9	10.7	1.0	4.3	1.1
April	2020	12.0	10.8	0.8	3.5	1.1

2.0 Methods

During flow reductions, locations susceptible to stranding risk are assessed during daylight hours by crews of two or four people. Crew size varies depending on the potential stranding risk associated with a particular rampdown. Due to the short duration of most rampdown events and the large amount of habitat potentially affected, only locations that are most susceptible or have been previously identified as high risk are assessed. Therefore, fish stranding numbers presented in this report represent only numbers observed in the index sites, not the entire Lower Coquitlam River area. Areas susceptible to stranding are generally adjacent to the river mainstem and have a flat, un-sloped topography containing numerous potholes and depressions where isolated pools can form (Figure 8). Ephemeral side channels that fill during flow releases and drain completely following gate closures are also highly susceptible to stranding (Figure 9). Areas judged to have no stranding risk are usually steeply sloped river banks that drain rapidly and do not retain any standing water, or areas that have been surveyed repeatedly with no stranding being observed.

Susceptible areas are visually surveyed several times over the course of the rampdown event to assess at what point stranding becomes evident. All isolated pools are assessed for fish and initial attempts at salvaging are conducted with dip nets or seine nets. Fish that are observed to be in danger of stranding, but are not yet stranded can be "pushed" or "chased" out of high risk areas by the survey crews. Another technique employed is the use of shovels to dig out escape channels that open access to the river mainstem, allowing fish a safe passage out of stranding areas. Areas that are difficult to net by hand or are known to strand large numbers of fish are fished overnight with baited minnow traps.

Rampdown site assessments are also linked to dam operations through the three LLO gates and their release stages (Table 2). Timing of site assessments can be correlated with the specific LLO gate flow release stage. For example, during the closure of the second LLO gate, survey crews know to respond to specific index sites which dewater during this stage of the rampdown. LLO gates are classed; LLO1 starting gate = first gate to close, LLO2 second gate = second gate to close, LLO3 = third and last gate to close (Table 2). LLO gate flow reductions can be influenced by rainfall and tributary inputs to varying degrees. For example, the stranding risk at rampdown sites located downstream of Or Creek, (main tributary of the Lower Coquitlam River) is sometimes minimized due to high flows from this tributary which moderates or even eliminates the stage reduction below the confluence.

Survey crews keep in constant contact with BC Hydro gate operators during rampdown events to ensure proper survey timing during dewatering. Prior to initiation of gate changes the rampdown survey crew rendezvous with BC Hydro operating staff to determine rampdown start and finish time. Contact is maintained throughout the gate changes via cell phone and through direct contact at the LLO gatehouse. Remote gate

operation was added to the Coquitlam Dam low level outlet gates in September 2013. The gate movements can also be controlled remotely from BC Hydro's Real Time Operations Center at Fraser Valley Operations (FVO). Fish stranding assessment and salvage crews co-ordinate activities through the operations center and remain in constant contact during ramp down operations. The first remotely controlled rampdown was performed on November 1, 2013.

Table 2 Revised gate adjustment schedule for Coquitlam Dam Low level outlet gates during release reductions. Release varies depending on reservoir elevation. Steps are implemented at 0.5hr intervals. Adapted from BC Hydro. Generation operating order COQ/LBD 4G-24v5. August 30, 2013

Gate	Step	Gate Change		
		From	To	Q m^3sec
LLOG1	1	100%	55%	
LLOG1	2	55%	28%	
LLOG1	3	28%	11%	
LLOG1	4	10%	0%	
LLOG2	5	100%	77%	
LLOG2	6	77%	60%	
LLOG2	7	60%	40%	
LLOG2	8	40%	27%	
LLOG2	9	27%	15%	
LLOG2	10	15%	5%	
LLOG2	11	5%	0%	
LLOG3 (Knife Gate Valve)	12	100%	85%	9.5
LLOG3 (Knife Gate Valve)	13	85%	83%	8.8
LLOG3 (Knife Gate Valve)	14	83%	81%	8.5
LLOG3 (Knife Gate Valve)	15	81%	79%	8.3
LLOG3 (Knife Gate Valve)	16	79%	76%	8.1
LLOG3 (Knife Gate Valve)	17	76%	71%	7.9
LLOG3 (Knife Gate Valve)	18	71%	66%	7.7
LLOG3 (Knife Gate Valve)	19	66%	62%	7.3
LLOG3 (Knife Gate Valve)	20	62%	60%	7.0
LLOG3 (Knife Gate Valve)	21	60%	56%	6.6
LLOG3 (Knife Gate Valve)	22	56%	53%	6.2
LLOG3 (Knife Gate Valve)	23	53%	48%	5.9
LLOG3 (Knife Gate Valve)	24	48%	45%	5.5
LLOG3 (Knife Gate Valve)	25	45%	41%	5.1
LLOG3 (Knife Gate Valve)	26	41%	34%	4.8
LLOG3 (Knife Gate Valve)	27	34%	31%	4.1
LLOG3 (Knife Gate Valve)	28	31%	28%	3.5
LLOG3 (Knife Gate Valve)	29	28%	26%	3.2
LLOG3 (Knife Gate Valve)	30	26%	24%	2.8
LLOG3 (Knife Gate Valve)	31	24%	22%	2.6
LLOG3 (Knife Gate Valve)	32	22%	20%	2.4
LLOG3 (Knife Gate Valve)	33	20%	18%	2.2
LLOG3 (Knife Gate Valve)	34	18%	16%	2.0
LLOG3 (Knife Gate Valve)	35	16%	14%	1.8
LLOG3 (Knife Gate Valve)	36	14%	12%	1.6
LLOG3 (Knife Gate Valve)	37	12%	10%	1.4
LLOG3 (Knife Gate Valve)	38	10%	8%	1.2
LLOG3 (Knife Gate Valve)	39	8%	6%	1.0
LLOG3 (Knife Gate Valve)	40	6%	4%	0.6
LLOG3 (Knife Gate Valve)	41	4%	2%	0.5
LLOG3 (Knife Gate Valve)	42	2%	0%	0.3

Dewatered areas are classified by Reach with index sites lettered A-E, including two to three specific rampdown sub-areas in each index site (Appendix 2 & 3). Rampdown survey areas within each index site are not always contiguous, and may represent a large area of discontinuous but comparable fluvial and river edge characteristics (see Appendix 3 for site maps and descriptions). All sites surveyed typically contain many small depressions and areas where fish and spawning habitat are susceptible to stranding. Isolated pools are examined and their location recorded using a GPS so that they can be located during future rampdown assessments if they are determined to pose a stranding risk. All salvaged fish, both live and dead are enumerated, identified to species and both live and dead fish are returned to areas of the river mainstem not affected by the flow reduction. The age class of stranded fish presented in this document are estimated based on size, but no fork length or weight information is collected.

When evaluating whether fish are stranded or not, a distinction is made between fish stranded in an area that will eventually become effectively dry (resulting in mortalities), and fish that are in temporarily isolated areas that will not dewater. Temporarily isolated areas will remain continually wetted and capable of supporting fish until higher flows return, whether by an increase in flow from the dam, seasonal rainfall or freshet conditions. Fish in these areas could potentially be more susceptible to predation, but follow up surveys in these areas are not performed so it cannot be determined what the survival rate is for fish found in these habitats. These isolated areas may be supported by a number of sources, such as: interstitial flows, bank seepage, tributaries or ground water which help to ensure a supply of oxygen and a degree of temperature regulation. Fish in these areas are not considered stranded and are therefore not included in stranding data.

River stage changes are monitored at two staff gauge sites during the course of each rampdown event (Appendix 1). Stage reductions are determined by survey crews at approximate hourly visual inspections of staff gauges located in Reach 4, (Appendix 3). Couquitlam River stage is also monitored using hourly flow data from the Water Survey of Canada (WSC) gauge located in Port Coquitlam (08MH002) and Or Creek WSC (0MH168) Or Creek is the main tributary to the Lower Coquitlam River and its flow can greatly influence fish stranding downstream, affecting reaches 3, 2b, 2a and 1. These gauges are monitored from the onset of flow reductions to the end of daily salvage operations.

The area of each rampdown site was calculated by estimating the extent of inundation during a full open gate release of all three gates. The full extent of each site is included in the area calculation. Therefore, areas within the rampdown site that do not pose a stranding risk are included in the stranding site area calculation. The total extent of each stranding site is represented as dewatered area in square metres (see Appendix 2 for ramp site descriptions). Survey crews perform area measurements using a hip chain and tape measure, measuring the length and width of each site to determine its areal

extent. For scheduled rampdown events, the area of inundation is not quantified due to the fact that these are base flows and do not inundate areas of the river which are not normally wetted.

3.0 Results

3.1 Scheduled Rampdown Summaries May 2019-June 2020

The rampdown scheduled for January 15, 2020 did not occur due to spilling from Coquitlam Dam, in addition the April 1, 2020 did not occur due to experimental flow releases from the Coquitlam Dam for the Kwikwetlem Sockeye Restoration Program (KSRP) and the November 1, 2019 rampdown did not occur due to heavy rainfall and high river levels in Coquitlam River. In total, only three of the six rampdowns scheduled for 2019-20 under Treatment 2 were undertaken.

3.1.1 Coquitlam Rampdown Summary May 1, 2019

On May 1, 2019 in response to the current Treatment 2 flow regime, the LLO release from Coquitlam Dam was scheduled to be reduced from 3.5 m^3s to 2.9 m^3s. The scheduled rampdown began at approximately 0900hr and was completed by 1130hr. Fish salvage activities continued until 1600hr. This was the first scheduled May flow reduction since 2016, as the previous two years did not occur due to elevated flows from Coquitlam Dam to support Sockeye (*Oncorhynchus nerka*) smolt attraction flows as part of the KRSP.

Upstream of Or Creek in Reach 4 (see Appendix 1), river stage dropped a total of 3.0 centimetres following completion of the flow reduction and had a maximum hourly decrease of 2.0 cm/hr. Downstream of Or creek river stage dropped 3.0 centimetre using the Reach 1 WSC online data. Stranding was observed in 3 of 5 Reaches for a total of 346 fish, all Chum or Coho (*Oncorhynchus kisutch*) fry (Table 3). The total number of dead fish observed was 90 which amounted to a 24% mortality rate. This is the second largest number of stranded fish observed for the May 1 flow reduction and the highest mortality rate observed.

3.1.2 Coquitlam Rampdown Summary June 1-3, 2019

In response to the current Treatment 2 flow regime, the LLO release from the Coquitlam Dam was scheduled to be reduced from 2.9 m^3sec to 1.1 m^3sec for the month of June.

The scheduled flow reductions in June 2019 were performed over 3 consecutive days with flow reductions and dates seen below:

- June 1 2.9 m^3/s - 2.2 m^3/s
- June 2 2.2 m^3/s - 1.5 m^3/s
- June 3 1.5 m^3/s - 1.1 m^3/s

Fish stranding over the course of the 3 days was the largest observed for a single rampdown with a total of 4358 fish stranded (previous high of 3954 in June 2018, Figure 1). In fact, the total of 4358 exceeds the largest amount of stranded fish previously observed in an entire year (4322 in the 2015-16). Field observations suggest river morphology conditions have changed in a few small side channels in Reach 2B, which has led to large scale stranding that was not observed in that reach in the past.

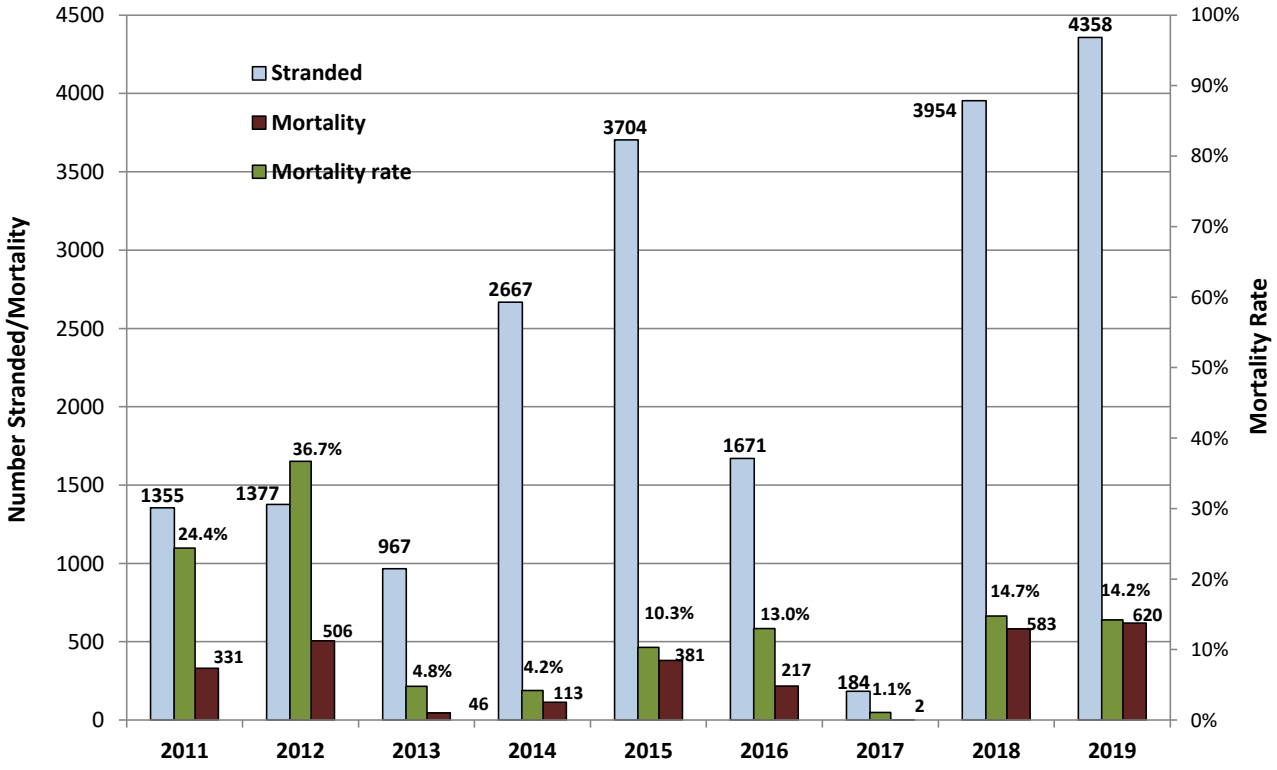

Figure 2 Coquitlam River fish stranding and mortality rate 2011-2019, June scheduled rampdowns.

Of the 4358 fish observed stranded, Coho fry made up the overwhelming majority, accounting for 99.7% of all stranded fish observed. Only 15 fish observed stranded were not Coho fry including: 8 Coho smolts, 4 Northern Pike Minnow, 1 crayfish, 1 sculpin and 1 Three spine Stickleback (*Gasterosteus aculeatus*, Table 3). The mortality rate for all fish was 14.2%, which is slightly above the 2011-2018 mean of 13.8%, but is still lower than any previous rampdowns done over a single day (Figure 1).

3.1.3 Coquitlam Rampdown Fish Salvage September 1, 2019

On September 1, 2019 in response to the Treatment 2 flow regime, the LLO release from Coquitlam Dam was scheduled to be reduced from 2.7 m^3s to 2.2 m^3s. The scheduled rampdown began at approximately 0900hr and was completed by 1030hr. Fish salvage activities continued until 1230hr.

Upstream of Or Creek in Reach 4, river stage dropped a total of approximately 1.0 centimetres following completion of the flow reduction and had a maximum hourly decrease of 1.0 cm/hr. Downstream of Or creek river stage also dropped 1.0 centimetres according to the Reach 1 Water Survey of Canada online data (Appendix 1). No fish stranding was observed in any areas of Coquitlam River.

Table 3 Fish stranding by species, age class and Reach during scheduled rampdowns 2019-2020. Co 0 = Coho fry. Co 1+ = Coho parr/smolt. TSS = Threespine Stickleback. Pk 0 = Pink fry. St 0 = Steelhead fry

			Reach					
Date	**Species**	**Salv/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**
1-May-19	Co 0	s		127	13	30		170
1-May-19	Co 0	m		25	15	14		54
1-May-19	cm 0	s		50	3	33		86
1-May-19	cm 0	m		5	30	1		36
1-Jun-19	co0	s	0	298	866	166	122	1452
1-Jun-19	co0	m		10	103	95		208
2-Jun-19	co0	s	25	550	164	75	26	840
2-Jun-19	co0	m	40	65	241			346
2-Jun-19	co1+	s			1	1		2
2-Jun-19	cray	s			1			1
2-Jun-19	npm	s		4	1			5
3-Jun-19	co0	s	157	234	1008	23	12	1434
3-Jun-19	co0	m		52	7		5	64
3-Jun-19	co1+	s	2					2
3-Jun-19	co1+	m	2					2
3-Jun-19	TSS	s	1					1
3-Jun-19	Cotid	s	1					1
1-Sep-19								0
Total Stranded			228	1293	2440	408	165	4534
Total Salvaged			186	1263	2057	328	160	3994
Total Mortality			42	30	383	80	5	540

3.2 Unscheduled Rampdowns Summaries May 2019-April 2020

3.2.1 *Coquitlam Rampdown Summary February 5-6, 2020*

On February 5, 2020 a rampdown fish salvage was undertaken on Coquitlam River following a full 3 gate LLO spill that had been ongoing since January 21, 2020. The first gate closure was initiated on Wednesday, February 5 at 0900hr when the first of two LLO gates was shut at the prescribed rate. The third and final gate was ramped down on February 6, 2020. A fish salvage/rampdown monitoring crew was on site both days from the beginning of the gate closure until dusk after which fish salvage activities are no longer possible.

In total 106 stranded fish were observed over the two day monitoring period. Fish stranding was dominated by juvenile steelhead and Coho Salmon (Table 4) with a total

of 78 of 106 or 74% represented by these two species; juvenile Coho represented 55% of the total stranded and juvenile steelhead 19% (Table 4). For the period 2002-2019, the average number of stranded fish observed during unscheduled rampdowns is 118. In all a total of 9 species were salvaged, one of which was a non-fish species, a single Coastal Tailed Frog (*Ascaphus truei*) juvenile was salvaged from Reach 3 (Table 4).

The majority of stranded fish were observed on the 2nd and final day of the rampdown with a total of 67 fish or 63.2%. Stranding was observed in every reach of the Coquitlam River and was fairly evenly distributed, with the majority observed in Reach 4 with 31 or 29.2% (Table 4). The mortality rate over the course of the two day rampdown was 31.1% or 33 of 106 fish. This rate is very near double the average mortality rate for unscheduled rampdowns of 17.9% for the 2002-2019 period.

Table 4 Fish stranding by species, age class and Reach during unscheduled rampdowns 2019-2020. Co 0 = Coho fry. Co 1+ = Coho parr/smolt. TSS = Three spine Stickleback. Pk 0 = Pink fry. t 0 = Steelhead fry

			Reach					
Date	**Species**	**Salv/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**
5-Feb-20	co1+	m	1	4				5
5-Feb-20	Rt 1+	m		1				1
5-Feb-20	Crayfish	m	1					1
5-Feb-20	Lmp	m	5					5
5-Feb-20	TSS	m	3					3
5-Feb-20	dace	m		1				1
5-Feb-20	co1+	s		2	1	6		9
5-Feb-20	Rt 1+	s		1		2	1	4
5-Feb-20	Cm0	s		2				2
5-Feb-20	Pk0	s			3			3
5-Feb-20	TSS	s	1					1
5-Feb-20	dace	s	2			1		3
5-Feb-20	CTF	s				1		1
6-Feb-20	co1+	m	5	1				6
6-Feb-20	Rt 1+	m	1	5		1		7
6-Feb-20	Cm0	m	1	2				3
6-Feb-20	Pk0	m		1				1
6-Feb-20	co1+	s				10	28	38
6-Feb-20	Rt 1+	s				7	1	8
6-Feb-20	Cm0	s	1					1
6-Feb-20	Lmp	s	2					2
6-Feb-20	TSS	s					1	1
		Total	**23**	**20**	**4**	**28**	**31**	**106**
		Distribution	**21.7%**	**18.9%**	**3.8%**	**26.4%**	**29.2%**	33

Maximum hourly river stage reduction was 10.0 cm in Reach 4 on the first day (February 5) of the rampdown. Total stage reduction over both days was also highest in Reach 4 with a total reduction of 85.0 centimetres (Appendix 1). River stage decrease downstream of Reach 4 on day 1 was 59.0 centimetres with a maximum hourly decrease of 19.0 centimetres. During day 2 of the rampdown there was enough local rainfall that the river stage did not decrease as much as anticipated downstream of Reach 4. Table 2 shows that the river stage measured in Reach 1 at the WSC gauge dropped only 4.0 centimetres as natural inflows were enough to prevent the river from dropping. This contrasts with a total river stage decrease of 31.0 centimetres in Reach 4 which is only minimally affected by tributary inflow.

4.0 Discussion

4.1 Stranding Risk

As has been the case since Treatment 2 was initiated, the majority of stranding in the Lower Coquitlam River is the result of fish salvages occurring in the month of May and June (including scheduled and unscheduled events). Furthermore, of all rampdown fish salvage events on the Coquitlam River, it is clear that the scheduled June 1 flow reduction has been by far the main contributor to fish stranding. Scheduled rampdowns performed in June have been responsible for 81.2% of all stranding observed on the Coquitlam River since Treatment 2 was initiated. The twelfth full year of rampdown monitoring under Treatment 2 in 2019-2020, had a total of 4807 stranded fish observed, which is more than double the Treatment 2 average of 2348 (Table 5).

River conditions can dramatically impact stranding potential during the June rampdown. June 2017 had the lowest amount of stranding (184) and highest natural inflows for Treatment 2 while 2019 had the most stranding to date (4358) and much lower natural inflows during the flow reduction. In June 2019, the Coquitlam River was at 3.5 m^3/s when the rampdown began and was reduced to 1.1 m^3/s following the flow reduction, while during the 2017 June rampdown the discharge ranged from 5.5 m^3/s to 20 m^3/s throughout the flow reduction period. This demonstrates how the lack of, or abundance of natural inflow downstream of Reach 4 can significantly influence stranding. In the example of the 2017 June rampdown, the Coquitlam River was so high due to rainfall that no stranding assessments took place below Reach 4, which translates into 80-90% of the potential stranding area going unsurveyed. Hence the large drop in fish stranding was a direct result of the increased natural flows during the rampdown.

The June flow adjustment of 2.9 m^3/s to 1.1 m^3/s represents a significant loss of flow volume and river stage in the uppermost reach of the Lower Coquitlam River. While areas downstream of Reach 4 may or may not be significantly impacted at this time of

year from a scheduled flow reduction (depending on freshet and local rainfall), Reach 4 is always very vulnerable. The June flow reduction in Reach 4 is equivalent to 62% of the total flow volume in this section of the Lower Coquitlam River. Reach 4 is above the buffering influence of Or Creek, and has virtually no natural inflow. In addition, its entire length is composed of shallow pools and small channels that attract juvenile fish, so it's at a high risk for stranding. Reach 4 is also the narrowest part of the river and is confined by berms and roadways along its length. These factors result in the river stage elevation decreasing more rapidly and to a greater extent than areas downstream of Or Creek.

Adult Coho Salmon escapement in the Lower Coquitlam River is also concentrated in Reach 4. Typically between 65-75% of all Coho spawning occurs in this Reach (Shick et. al. 2017). This heavy spawning concentration, combined with the fact that May and June represent peak emergence for Coho fry, creates a heightened risk of stranding during rampdowns at this time of year as tens of thousands of Coho fry are emerging from the gravel.

Figure 2 illustrates the increase in the past several monitoring years in the amount of fish stranded on the Coquitlam River under Treatment 2. This increase is influenced by a number of factors, including: the number of rampdown events, seasonal timing of rampdown events, total flow volume decrease, minimum target flow release, as well as survey crews finding more stranding areas and increased efficiency in fish salvage efforts. In addition, during the first year under Treatment 2, the flow releases from the LLO gate at Coquitlam Dam were approximately 20-40% over the target due to a miscalculation in the stage discharge curve at the LLO gate. Therefore, there was consistently more water available and a higher average river stage in the Coquitlam River, likely resulting in a lower stranding risk.

In years 3 & 4 (2011 & 2012) of Treatment 2, the ratio of salvaged fish to mortalities was the second and third worst on record (Table 4), with a 30.6% and 24.3% mortality rate for all stranded fish observed. This is well above average compared to the mean mortality rate of 14.6% for all rampdowns (using 2004-2020 data, Table 5). The high mortality rate in years 3 and 4 was primarily a result of the scheduled June rampdown. The ramping rate established for the June flow reduction called for the entire LLO gate operation to be done in 2 hours which resulted in a rapid decrease of river stage, approximately 15.0-16.0cm in this short period of time.

In light of these high numbers of stranded fish and mortalities during past scheduled flow reductions in June, a decision was made in 2013 to modify the rampdown by extending the flow reduction over two to three consecutive days, and in 2016 this was further modified to three days over a two week period. It was anticipated that a more gradual flow reduction would result in fewer stranded fish, and more importantly, fewer mortalities due to stranding.

The reduction in mortality illustrated in Figure 2 and Table 5 shows the impact of the past nine scheduled flow reductions on this date. The average mortality rate for the June rampdown prior to the 2013 operational change is 24.3%, with a high of 36.7% in 2012, following year 4 the mortality rate has dropped to an average of 12.3% (Table 5). However, the number of fish stranded during the June rampdowns has not decreased over the same period and in fact, the years 2015-2016, 2018-2019 and 2019-2020 have had peak amounts of stranded fish (Table 5).

This staggered flow reduction has dramatically reduced the maximum daily stage elevation drop in Reach 4. Flow reductions in 2011 and 2012 for this gate change dropped flow in Reach 4 approximately 16.0 cm in 2-3 hours with a maximum hourly decrease of 10.0 cm. The maximum decrease this year was 2.0 cm over one hour in Reach 4 on June 2 and 3, 2019 (Table 2).

The act of spreading the flow reduction out over multiple days appears to have had mixed success as the mortality rate has dropped over the past seven years, but the amount of fish stranded has increased (Table 5). Yearly, the number of stranded fish continues to fluctuate based on a number of factors, but the overall amount of stranded fish in June has *not* been addressed through this operational approach.

Table 5 Yearly Reach by Reach comparison of stranded fish during all rampdown events, 2001-2018. T1 = Treatment 1 2001-2008, T2 = Treatment 2 2009-2020.

	Reach 1		Reach 2a		Reach 2b		Reach 3		Reach 4		Total	Total	Total	%
Year	Salv	Mort	Salv	Mort	Salv	Mort	Salv	Mort	Salv	Mort	Strand	Salv	Mort	Mort
2019-20	192	59	1268	172	2057	396	356	111	191	5	4807	4064	743	15.5%
2018-19	139	30	951	11	592	105	1094	343	632	94	3991	3408	583	14.6%
2017-18	4	0	208	27	582	35	228	28	306	7	1425	1328	97	6.8%
2016-17	132	23	459	25	402	100	329	118	597	26	2211	1919	292	13.2%
2015-16	278	172	521	65	147	64	2288	227	461	99	4322	3695	627	14.5%
2014-15	895	36	314	30	663	29	375	20	575	52	2989	2822	167	5.6%
2013-14	0	0	318	12	0	0	428	5	300	32	1095	1046	49	4.5%
2012-13	65	9	143	79	85	24	322	28	847	504	2106	1462	644	30.6%
2011-12	154	9	164	21	3	11	65	88	1071	338	1924	1457	467	24.3%
2010-11	103	6	389	21	39	25	78	13	134	26	834	743	91	10.9%
2009-10	21	0	40	2	0	0	5	0	45	13	126	111	15	11.9%
2008-09	31	5	33	9	49	12	12	0	13	0	164	138	26	15.9%
2007-08	67	6	32	11	199	17	20	1	65	1	419	383	36	8.6%
2006-07	39	14	3	4	47	80	36	4	0	0	227	125	102	44.9%
2005-06	95	0	0	0	1	9	0	7	85	6	203	181	22	10.8%
2004-05	75	2	10	0	13	9	0	0	48	0	157	146	11	7.0%
2001-04	36	4	0	2	0	0	6	1	0	16	65	42	23	35.4%
Total	**2326**	**375**	**4853**	**491**	**4879**	**916**	**5642**	**994**	**5370**	**1219**	**27065**	**23070**	**3995**	**14.8%**
T1	343	31	78	26	309	127	74	13	211	23	1235	1015	220	17.8%
T2	1983	344	4775	465	4570	789	5568	981	5159	1196	25830	22055	3775	14.6%
T1 mean	57	5	13	4	52	21	12	2	35	4	206	169	37	
T2 mean	180	31	434	42	415	72	506	89	469	109	2348	2005	343	

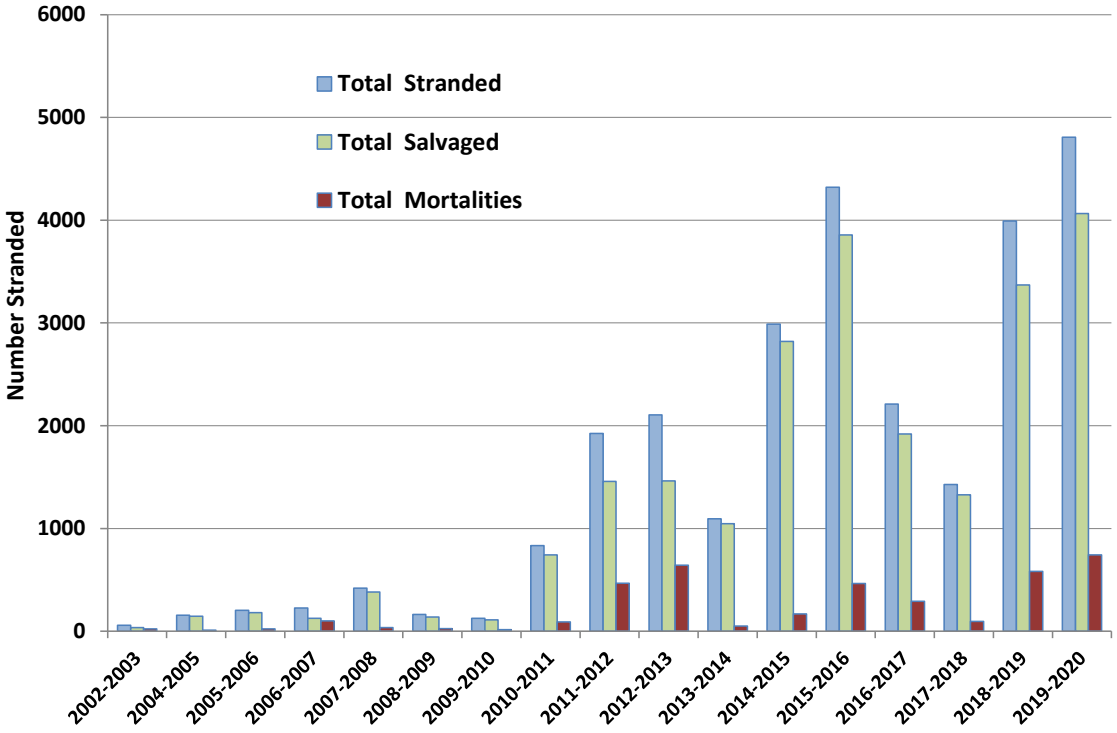

Figure 3 Number of fish salvaged and mortalities for all rampdowns 2002-2020

The fact that the June rampdown reduces the flow of the Lower Coquitlam River by 62% at a sensitive time of year appears to be the central cause of stranding. In addition, the fact that the flow reduction reduces the discharge to a yearly low of 1.1 m^3/s is also problematic. Salmon fry depend on spring (May and June) freshet conditions to provide an increase in flow to accommodate migration within and from their natal grounds (Hartman, 1982). At this time of year, the natural flow pattern for streams and rivers in the South Coast region is to have an increase in discharge, not a severe and rapid reduction. Therefore, the June rampdown represents the opposite of the conditions that migrating fry depend on for survival.

The total decrease in river volume in Reach 4 is also high during the January 15, and November 1 scheduled rampdowns, with a loss of 50%, and 33% of total flow volume respectively (Table 1). This compared to the March 31, April 30 and August 31 scheduled rampdowns which have flow volume decreases of 19%, 17% and 19% respectively. However, during periods of low flow in the Coquitlam River (mid-late summer) even small reductions in flow can have impacts.

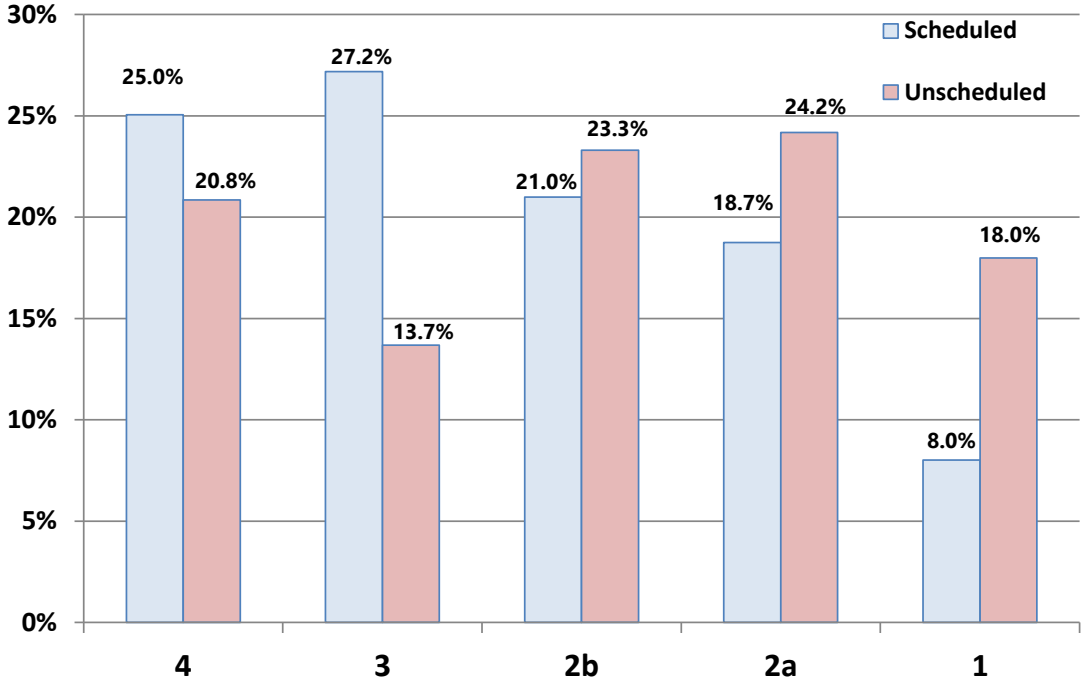

Figure 4. Stranding distribution by Reach, April 2004 – April 2020, highlighting the difference in stranding distribution by Reach between scheduled and unscheduled rampdowns.

Table 6. Stranding results of scheduled rampdowns since the introduction of Treatment 2.

Scheduled Rampdowns

Date	Status	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
15-Jan	Salvaged	-	0	n/s	0	5	10	0	0	31	22	0	0	n/s	**68**
	Mortality	-	0	n/s	0	2	10	0	0	0	0	0	0	n/s	**12**
1-Apr	Salvaged	-	0	n/s	0	1	129	28	48	5	68	n/s	0	n/s	**279**
	Mortality	-	0	n/s	0	0	15	0	14	1	0	n/s	0	n/s	**30**
1-May	Salvaged	-	0	0	n/s	0	100	0	95	310	n/s	n/s	256	n/s	**761**
	Mortality	-	0	0	n/s	0	3	0	21	56	n/s	n/s	90	n/s	**170**
1-Jun	Salvaged	-	20	55	1355	1377	967	2600	3327	1454	184	3371	3738	2895	**21343**
	Mortality	-	0	19	331	506	46	67	381	217	2	583	620	757	**3529**
1-Sep	Salvaged	-	0	0	98	0	0	7	0	n/s	30		0		**135**
	Mortality	-	0	0	82	0	0	0	0	n/s	6		0		**88**
1-Nov	Salvaged	0	0	11	0	0	n/s	0	0	n/s	0		n/s		**11**
	Mortality	0	0	2	0	0	n/s	0	0	n/s	0		n/s		**2**

Other scheduled flow reductions where widespread stranding was observed was during the May 1st rampdown which had the second highest number of total fish stranded since the initiation of Treatment 2 (Table 6). The May 1st rampdown occurs at the peak of Chum and Pink fry emergence when millions of the fry are in the river, many congregating in shallow margins along the river banks which elevates the stranding risk.

However, despite the presence of large numbers of fry during this flow reduction, stranding was nowhere near as problematic as the June 1 flow reductions.

Coho fry have the highest stranding risk due to their year round residence, and habit of congregating in shallow river margins, ephemeral channels and shallow pools (Dunn, 2002, Macnair 2016). All of these factors make them heavily susceptible to stranding. This contrasts with Chum and Pink fry which are the most numerous species when emergence is underway (March-May), but almost immediately migrate out of the river and are absent from the river from June to February and are therefore far less likely to be stranded.

As the results of the spring and summer rampdowns demonstrate, a strong determiner of stranding risk on the Coquitlam River is the time of year at which a rampdown occurs. Rampdowns that occur in the fall and winter months (September 21 – March 21) are the least likely to strand fish. Data on stranding by season and species given in Figure 5 shows that fall and winter rampdowns strand an average of 39 and 41 fish per rampdown respectively, while the average for spring and summer is 64 and 633 fish per rampdown. This seasonal difference is likely due to the reduction of juvenile fish in the system during the fall and winter (compared to spring and summer when millions of fry can be present) and possibly due to colder water conditions in winter which can minimize fish movement (Bustard 2011).

Final river stage elevation is also an important contributing factor as rampdowns occurring from October 1 - January 15 (under Treatment 2) have a higher minimum stage elevation than spring and summer rampdowns. For example, rampdowns in the spring and summer months return to an average discharge of 2.3 m^3/s respectively, while those in the fall and winter return to a discharge flow of 4.7 m^3/s. The higher minimum discharge results in an elevated river stage which keeps sites that are vulnerable to river stages of below 7.90m, measured at WSC at Port Coquitlam, continuously wetted and therefore less at risk of stranding.

Table 7 Stranding and mortality scheduled vs. unscheduled rampdowns 2001-2020

2001-2020	Stranded	Per Ramp	Salvaged	Mortality	Per Ramp	Rate
Unscheduled	5177	118	4264	913	21	**17.6%**
Scheduled	17054	348	14707	2347	48	**13.8%**
Total	**27061**	**291**	**23225**	**3836**	**41**	**14.2%**

Coho juveniles are by far the most likely fish to be stranded over the entire study period, representing 91.6% of all stranded fish between 2004-2020 (Figure 8). In Year 12 Coho fry and smolts represented 95.2% of all stranding observations. Overall, salmonids accounted for 98.7% of all stranded fish for the 2004-2020 period (Figure 8).

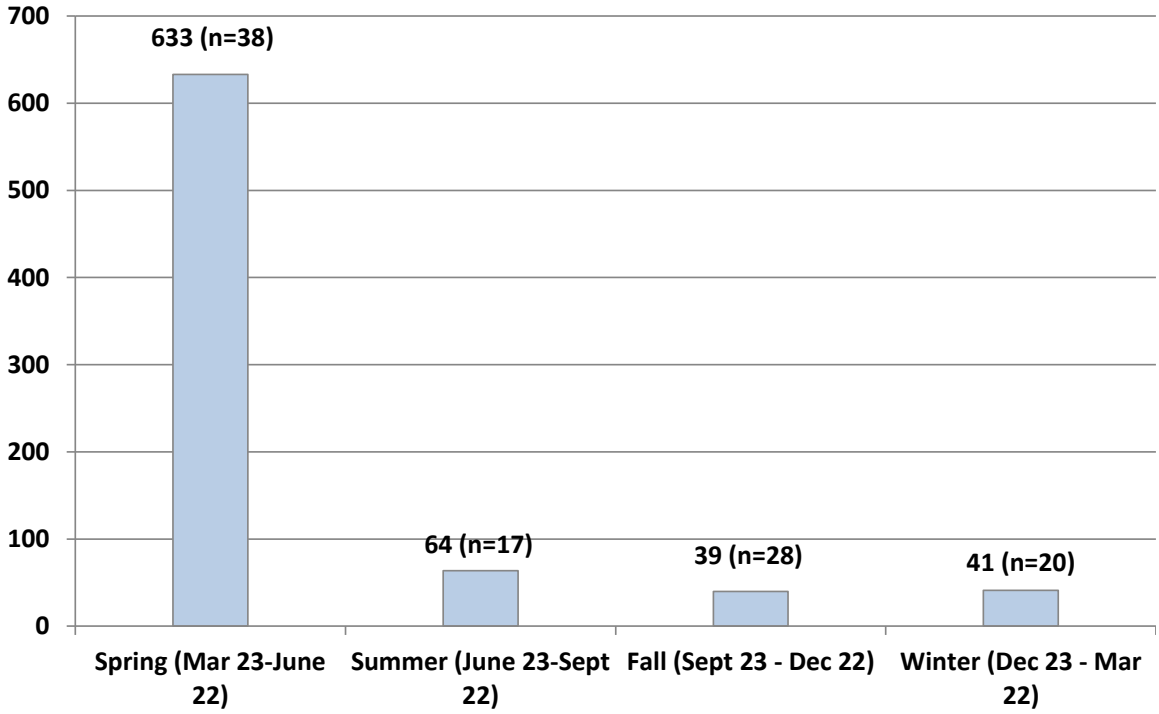

Figure 5 Average number of stranded fish observed per rampdown by season, all fish species 2001-2020. n equals total number of rampdown fish salvage operations per time frame.

In Year 12 stranding was concentrated in the upper reaches of the Lower Coquitlam River with Reach 3 and 4 accounting for 54.5% of all stranding. This trend is the norm under scheduled rampdowns as Reach 3 and 4 typically see 45-75% of all stranding with an average of 63.1% over the Treatment 2 period (Figure 4). Reach 4 is also upstream of the influence of Or Creek which means that any flow reduction, regardless of scale will be guaranteed to reduce the river stage, therefore, a stranding risk always exists in contrast to Reaches 1-3 that can be fed by additional tributary inflow.

The majority of unscheduled rampdowns involve large flow releases. A full 3 gate LLO spill has a release of up to 40-45 m^3/s. Therefore, the stranding impacts tend to extend to the entire river length and be more evenly distributed by reach (Figure 4).

4.2 Redd Stranding

Redd stranding on the Lower Coquitlam River as a result of flow reductions is a risk only during fall salmon spawning and steelhead spawning in the spring. Widespread stranding of redds in the fall only occurs if there is an extended spill event that coincides with peak or near peak spawning period. This has happened on 5 occasions on the Lower Coquitlam River since 2001, stranding an estimated 897 Pink and Chum redds

over the 2001-2020 period (Table 8). Steelhead redd stranding is limited to one or two problem areas on the Coquitlam River. Surveyors have observed repeated stranding in precisely the same spot in eight consecutive years from 2011-2018 (Table 8).

Other than Pink and Chum redd stranding, the relatively low number of redds stranded and the low frequency of events suggests that redd stranding is not a significant concern. The yearly loss of 1-3 steelhead redds compares to a yearly average of 225 created redds over the 2005-2019 period, so the impact of these losses (<1%) is likely to be insignificant. Stranded Chum and Pink redds were not enumerated, but as the average adult escapement numbers is in the 10,000-60,000 range (2017, Schick), it is likely that several thousand redds are created each fall. As such, the loss of a several hundred redds at infrequent intervals over 17 years of study would likely have limited to no effect on Pink or Chum productivity.

Table 8 Redd stranding on Coquitlam River 2001-2018. Steelhead spawning timing March-May, Pink and Chum, September-November

Year	Steelhead	Pink	Chum	Total
2001				
2002				
2003			300	300
2004-2010				
2011	1	30		31
2012	1		300	301
2013	1			1
2014	3		17	20
2015	1			1
2016	2		250	252
2017	2			2
2018	2			
Total	**13**	**30**	**867**	**908**

4.2 Rampdowns and Flow Release Targets

Since the introduction of Treatment 2 there has been no reduction in the total number of unscheduled rampdowns (Table 9). It was anticipated that removal of the temporary dam safety 149m maximum allowable reservoir operating level (in place during Treatment 1 2001-2009) would reduce the number of unscheduled spill events. Under Treatment 1 the Coquitlam River averaged 2.7 unscheduled rampdowns per year, under Treatment 2 the average is also 2.7 unscheduled rampdowns per year for the 2009-2020 period. With respect to the number of full 3 Low Level Outlet Gate spills, again, no reduction has been evident in the past 12 years of monitoring. Of the 26 unscheduled rampdowns since the initiation of Treatment 2, 15 have been full three LLO gate release

rampdowns, the remainder have been due to dam maintenance and for experimental flows designed to attract Sockeye smolt migration.

Table 9 Number of rampdown per year 2001-2020

Monitoring Year	Scheduled	Unscheduled	Total
2019-2020	3	1	4
2018-2019	5	1	6
2017-2018	4	3	7
2016-2017	4	1	5
2015-2016	6	4	10
2014-2015	6	3	9
2013-2014	6	1	7
2012-2013	5	4	9
2011-2012	5	3	8
2010-2011	6	5	11
2009-2010	4	5	9
2008-2009	3	1	4
2007-2008	n/a	5	5
2006-2007	n/a	4	4
2005-2006	n/a	2	2
2004-2005	n/a	3	3
2003-2004	n/a	3	3
2002-2003	n/a	1	1
2001-2002	n/a	1	1
Total	**57**	**51**	**108**
Treatment 2	**4.8**	**2.7**	**7.4**
Treatment 1		**2.7**	**2.7**

4.3 Fish Productivity Impacts

Stranding influence on fish production in the Lower Coquitlam River is likely to be minimal with the exception of Coho fry and possibly steelhead fry. For Pink and Chum fry the impact is negligible. Schick et. al. 2017 reported the estimated average annual outmigrating population for Chum and Pink fry for the 2003-2017 period was 2,248,900 and 958,000 respectively. Contrast this with a total of 79 Chum mortalities and zero Pink mortalities observed during rampdowns for the same period. Coho and steelhead smolt population estimates for the same period averaged 14,479 and 4,242 per year respectively (Schick et. al. 2014). The estimated average number of Coho and steelhead smolt/parr stranded per year due to rampdowns is 17 and 15 respectively, or less than 0.4% of the estimated population. However, in light of the observed impacts on Coho

fry, and to a lesser extent, steelhead fry in the past four monitoring years, there may be cause for concern.

Table 10 Estimated potential impact of rampdowns on Coho fry population in Coquitlam River. Data based on fall Coho fry standing stock estimates (late summer estimate of all Coho fry in the Coquitlam River) for 2011-2017 (Schick et al 2018). Values represent the estimated proportion of the total population of Coho fry that could be eliminated due to rampdowns each year *if* fish salvage activities were not performed.

Year	Coho Fry Standing Stock Est.	Coho Fry Stranded	Stranded as a % of Standing Stock Est.
2011	91367	1420	1.6%
2012	73846	1385	1.9%
2013	70729	975	1.4%
2014	44507	2827	6.4%
2015	36101	3631	10.1%
2016	25424	1961	7.7%
2017	59166	1324	2.2%
Mean 2011-2017	57306	1932	3.4%

As has been shown, Coho fry populations are the hardest hit with respect to stranding. Estimates of total fry productivity (based on fall standing stock estimates for 2011-2017) range from 25,424 to 91,367 with a mean of 57,306 (Table 9, Schick et. al. 2018). Using available data, it is possible to give a rough idea of the impact of stranding on the Coho fry population in the Coquitlam River. For example: If we take the yearly totals for the number of Coho fry observed stranded from 2011-2017 and compare it to the yearly totals of the Coho fry standing stock estimate, this would represent a loss of, on average 3.4% of the Coho fry population each year since 2011, with a high of 10.1% in 2015 (Table 9).

This level of loss has the potential to impact the Coho fry population. Bearing in mind that freshwater mortality can be highly variable and often substantial for juvenile Coho Salmon under natural conditions (Bradford 1995; Nickelson and Lawson 1998). For comparison, summer mortality rates - covering the period June to September - for juvenile Coho ranged from 26% - 56% in a study of three unregulated streams in the Pacific Northwest (Au 1972, Spalding 1995).

This is a rough estimate using only the available fry estimate data, but does provide a useful illustration that can be comparable between years. The impact on steelhead fry does not appear to be as significant; using the average number observed stranded (85) for the 2009-2018 monitoring years and comparing it to the average Treatment 2 standing stock estimate (32,746 for the years 2009-2017), gives a potential loss of <0.01% of the population due to stranding. This is well below potential Coho fry losses and is not likely to have an impact on Coquitlam River steelhead productivity.

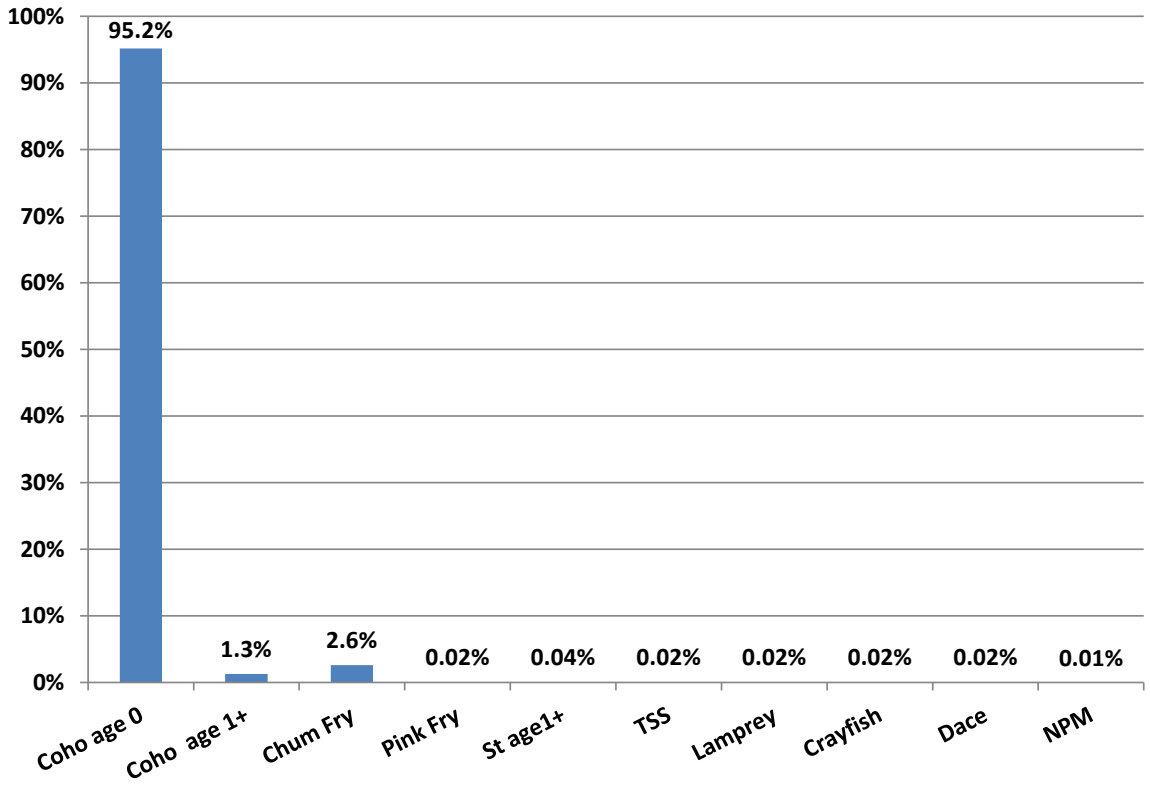

Figure 7 Coquitlam River stranding distribution by species and age class Year 12, May 1 2019-April 30, 2020 all rampdowns.

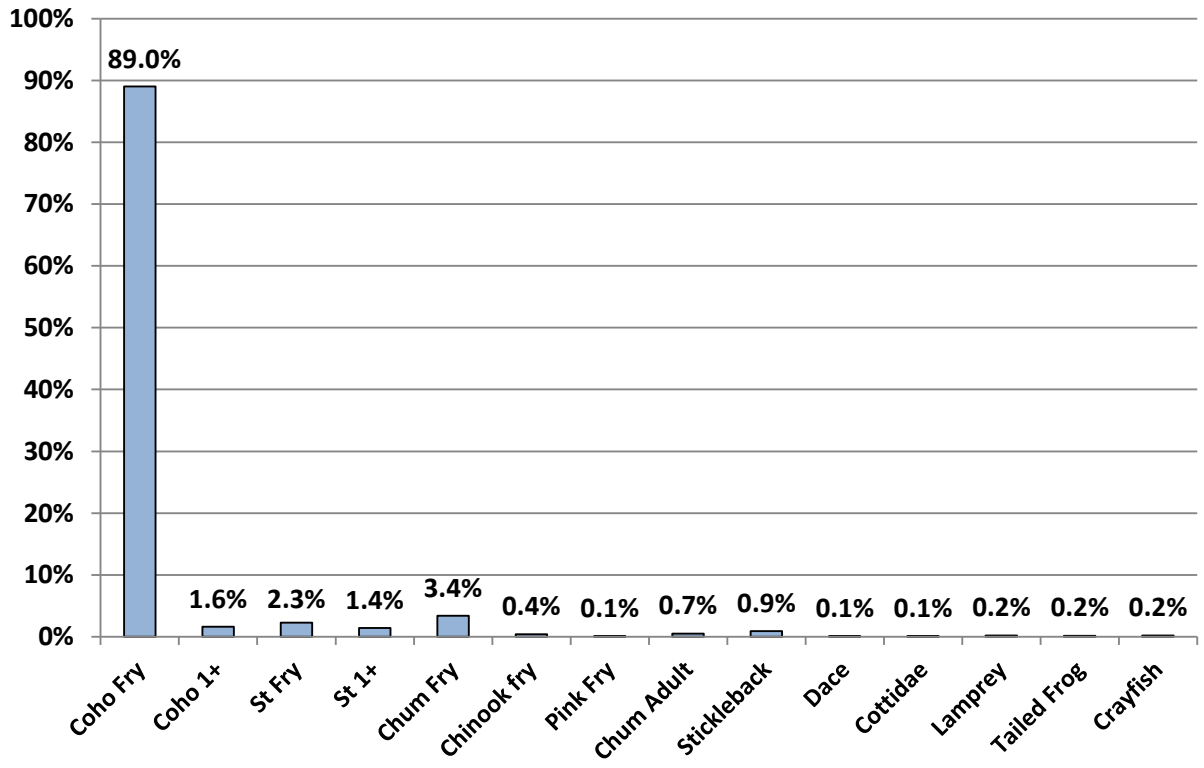

Figure 8 Coquitlam River stranding distribution by species and age class, January 2004-April 2020, all rampdowns.

5.0 Conclusions and Recommendations

The results of the past 12 years of rampdown monitoring clearly indicate that fish stranding and mortalities have increased due to operational changes to the flow regime under Treatment 2. An analysis of the results from Table 5 show that under Treatment 1, survey crews observed an average of 206 stranded fish and 37 mortalities per year, while under Treatment 2 this average has risen to 2348 stranded fish and 343 mortalities per year. The cause of this increase is likely related to two main factors:

1. An increase in the number of rampdowns per year due to the introduction of 6 scheduled rampdowns per year at the Coquitlam Dam. Treatment 1 had an average 2.7 rampdowns per year (all unscheduled), while under Treatment 2 the average has risen to 7.4 per year,

2. An increase in rampdowns at critical time periods for emerging juvenile fish. Scheduled rampdowns in April, May, and June occur at peak emergence for fry in the Lower Coquitlam River, which results in a consistent, yearly increase in the risk of stranding. As discussed in Sec. 4.1, the June rampdown alone has been responsible for 81.2% of all stranding over the past twelve years

The ramping rate established under Treatment 2 appears to be effective at minimizing stranding during both scheduled and unscheduled rampdowns with the exception of the June scheduled rampdown. The June rampdown, could have its ramp rate and operational procedures re-examined and potentially altered to reflect the rivers natural hydrograph. The first step taken towards managing stranding was undertaken in 2013 and has had some promising results as the mortality rate has dropped. Another alteration to the June rampdown protocol was begun in 2016, with the practice of holding the flow for 5 days between each flow reduction thereby spreading out the rampdown and associated salvages over three non- consecutive days. This practice is hoped to reduce stranding risk by giving fry a chance to re-orientate themselves in the river following each flow reduction

In addition, it would be beneficial for this particular rampdown to undergo a reassessment of the minimum target flow. The June reduction does not follow the natural hydrograph of the upper Coquitlam River (WSC Gauge 08MH141). Flows are high and rising during the months of May and June in the upper unregulated Coquitlam River but this is not reflected in Reach 4, where flows drop significantly. A higher minimum flow target for June may likely prevent a significant amount of future stranding.

Having more water available, whether through COQ Dam releases or from tributaries, can potentially reduce stranding. As discussed, during the rampdown in June 2017, discharge never fell below 5.0 m^3/s. This is in contrast to the 2019 Coquitlam River rampdown when the discharge was at 3.5 m^3/s when the rampdown began and fell to

1.1 m^3/s following the flow reduction. The impact of additional water from Or Creek in 2017 meant that many side channels and potential stranding areas containing thousands of fry remained wetted and continued to provide adequate habitat. The impact this additional water had on stranding was significant, with the 2019 rampdown stranding 3954 fish versus only 186 in 2017.

As Table 6 clearly demonstrates, fish stranding under scheduled rampdowns in the Lower Coquitlam River is heavily concentrated in the June rampdown, with regular, but far more limited stranding during the April 1 and May 1 rampdowns. Outside of the June flow reduction, the risk of stranding appears to be minimal during all other scheduled rampdowns downstream of Reach 4. This is largely due to the fact that the scheduled releases under Treatment 2 do not inundate large areas of habitat.

Though the majority of stranding each year is observed during only one scheduled rampdown, it is recommended that all rampdowns continue to be monitored by survey crews during the upcoming monitoring years. The potential for stranding definitely exists, and has been documented on all scheduled rampdown dates. In addition, with the gate operations at the Coquitlam Dam now controlled remotely, it is imperative that a crew be available on site in case of operator error or equipment failure, which has occurred on a few occasions during the past several years.

- Fish salvage crew called out on April 1, 2013 for a scheduled rampdown. Salvage crew did not end up working due to a computer communication error between Fraser Valley Operation Centre (FVO) and Coquiltam Dam operating gate. The gate closure could not proceed until the following day after a BC Hydro crew repaired the problem.

- Due to a miscommunication between staff at FVO, the third and final gate of a full 3 LLOG rampdown was closed on the evening of December 18, 2015 and not the following day as planned. This error meant that salvage crews could not be on site during the final gate closure. This situation likely resulted in a greater than normal amount of stranding and a higher fish mortality rate.

Stranding sites examined under the previous flow regime have been continually re-evaluated under the new Treatment 2 conditions. The results of the twelfth year under Treatment 2 demonstrate that some formerly susceptible areas may now be considered low risk for stranding. Additionally, new areas have been identified during scheduled rampdowns and these new areas have been categorized and included in all rampdown fish salvage surveys. The fluvial morphology of the Lower Coquitlam River will continue to transform as it adapts to the increased annual flow, therefore areas of stranding will continue to shift.

Comparison of rampdown mortality to fish productivity clearly shows, with the exception of Coho salmon fry, the negligible impact that rampdowns appear to have on most fish productivity in the Coquitlam River. Results from the past few years of

monitoring show that greatly elevated Coho fry stranding during scheduled and unscheduled rampdowns at critical time periods is cause for concern. Rampdowns that occur in spring and summer could also require larger rampdown crews and a modified ramp rate in the future to ensure that high numbers of juvenile mortalities do not occur.

With respect to the management questions and hypothesis outlined in the introduction:

H1: *The LB1 WUP interim ramping rate protocol does not strand fish at index sites in the lower Coquitlam River.*

Results to date indicate that fish continue to be stranded under the revised ramping rate protocol. In addition, the risk of fish stranding has increased since the introduction of Treatment 2 flow regime despite careful adherence to the ramping protocol.

Although fish will continue to be stranded regardless of ramp rate, survey crews are well adapted to the conditions of the ramp rate and are able to salvage the majority (>80%) of fish that become stranded. Careful adherence to rampdown rates, minimum flow targets and consistent monitoring of potential stranding sites will continue to be the most appropriate means of reducing fish stranding mortalities while remaining operationally feasible.

Summary of Recommendations

- Stranding of large numbers of Coho fry during the June rampdown will continue to be an issue under the current flow regime. A re-examination of the target flow level of 1.1 should be considered as it falls outside of the natural hydrograph for the Coquitlam River and creates a higher stranding risk.

- Monitoring for fish stranding should be continued in order to ensure that flow release targets are achieved and stranded fish mortalities are minimized. Continued monitoring for fish stranding will also mitigate any LLO gate failures or operator errors.

- Future June 1 scheduled rampdowns should continue to use the modified gate closure operation that was successfully implemented in 2013-present.

- Ensure proper communication with Fraser Valley Operations (FVO) desk during gate closures. This is critical to prevent flow changes happening when salvage crews are not present or available.

- Pay particular attention to the side channel that provides water for the hatchery during rampdowns in January and June-September when releases are less than 3.0 m^3/s as they have the potential to dry up the channel entirely. In 2013 this

situation resulted in the dewatering of the water intake into the hatchery, potentially harming tens of thousands of incubating eggs. In 2015 DFO installed a fail-safe water supply for their hatchery as a back-up in case this side channel dries up again.

- Future rampdowns in June related to Sockeye smolt attraction flows will need to be carefully monitored, particularly if they occur in the spring due to the increased stranding risk associated with the timing, duration and magnitude of these events.

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Appendix 1 Year 12 total daily and hourly Coquitlam River stage reductions by staff gauge all rampdowns.

Coquitlam River stage elevation change during rampdown May 1, 2019

R4 Staff Gauge		WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	
0830	.33	0900	7.86	
0930	.33	1000	7.86	
1030	.31	1100	7.85	
1130	.30	1200	7.83	
1300	.30	1400	7.83	
	3.0		3.0	Max Reduction (cm)
	2.0		2.0	Max Reduction (cm)/hr

Coquitlam River Stage Reduction by Reach June 1-3, 2019.

R4 Staff Gauge		R1 WSC Staff Gauge		**June 1, 2019**
Time	Stage (m)	Time	Stage (m)	
0900	0.31	0900	7.83	
1000	0.30	1100	7.82	
1130	0.27	1300	7.80	
1400	0.26	1500	7.79	
1500	0.26	1600	7.79	
1600	0.26	1800	7.79	
	5.0		4.0	Max Reduction (cm)
	1.5		1.0	Max Reduction (cm)/hr

R4 Staff Gauge		R1 WSC Staff Gauge		**June 2, 2019**
Time	Stage (m)	Time	Stage (m)	
0900	0.26	0900	7.79	
1000	0.25	1100	7.79	
1100	0.23	1300	7.77	
1200	0.22	1500	7.75	
1300	0.22	1600	7.75	
1600	0.22	1800	7.75	
	4.0		4.0	Max Reduction (cm)
	2.0		1.0	Max Reduction (cm)/hr

R4 Staff Gauge		R1 WSC Staff Gauge		**June 3, 2019**
Time	Stage (m)	Time	Stage (m)	
0900	0.22	0900	7.75	
1000	0.22	1100	7.75	
1100	0.20	1300	7.74	
1300	0.18	1500	7.72	
1500	0.18	1600	7.71	
1600	0.18	1800	7.71	
	4.0		4.0	Max Reduction (cm)
	2.0		1.0	Max Reduction (cm)/hr

September 1, 2019

R4 Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	
0830	0.29	0900	7.76	
1130	0.28	1000	7.76	
		1200	7.75	
		1400	7.75	
		1600	7.75	
	1.0		1.0	Max Reduction (cm)
	1.0		1.0	Max Reduction (cm)/hr

February 5, 2020

R4 Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	
0900	1.19	1000	8.75	
1100	0.95	1100	8.73	
1200	0.87	1200	8.54	
1300	0.79	1300	8.48	
1400	0.72	1400	8.36	
1600	0.65	1500	8.27	
		1700	8.17	
		1900	8.16	
	54.0		59.0	Max Reduction (cm)
	10.0		19.0	Max Reduction (cm)/hr

February 6, 2020

R4 Staff Gauge		R1 WSC Staff Gauge		
Time	Stage (m)	Time	Stage (m)	
0900	0.63	1000	8.14	
1000	0.56	1100	8.14	
1200	0.46	1200	8.14	
1400	0.38	1300	8.13	
1600	0.33	1400	8.13	
1700	0.31	1500	8.11	
		1700	8.10	
	31.0		8.0	Max Reduction (cm)
	7.0		2.0	Max Reduction (cm)/hr

Appendix 2 Site descriptions and photographs

Reach 1

Site A1: This area is characterized by dense tree and shrub riparian river margins that contain many depressions that form isolated pools. The substrate is mainly sand/silt and vegetated cover, along with some areas of exposed gravel and cobble.
Total Area: 3800m²

Figure 6 Site A1 showing gravel bar separating river mainstem (left) with isolated pool (right), following rampdown June 1 2012.

Figure 7 Site A1 showing trench dug to allow water from river mainstem to flow into isolated pool.

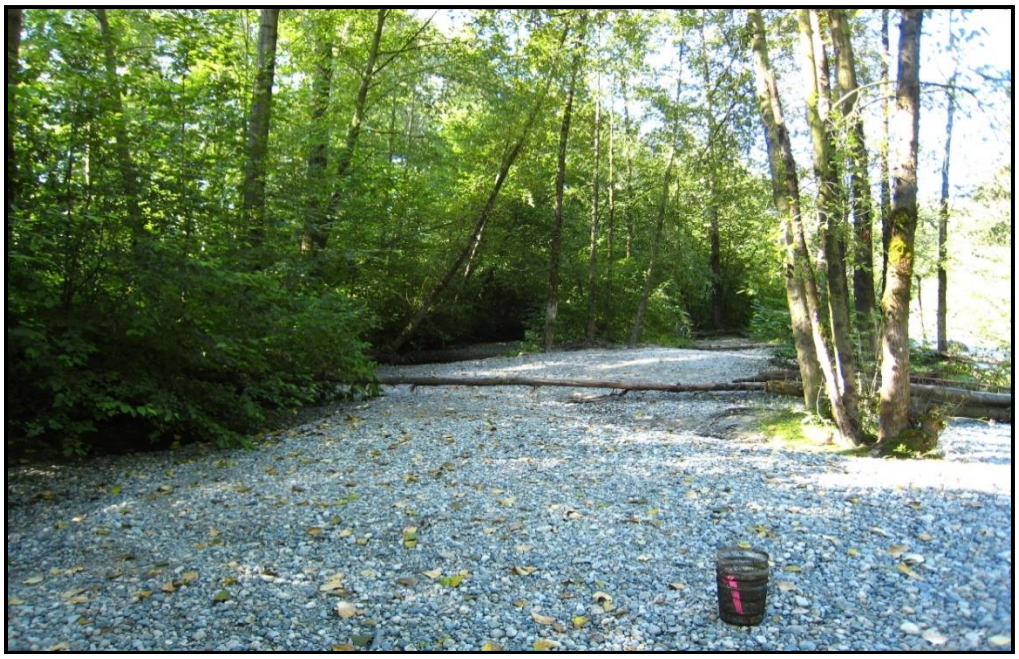

Figure 8 Site A1 showing gravel area on gravel bar fluvial island where fish are regularly stranded

Site A2: These areas are characterized by large expanses of exposed gravel and cobble suitable for spawning adjacent to the river, accompanied by moderately treed areas with numerous depressions that form isolated pools when dewatered. These areas represent a hazard for stranding of both adults, juveniles and redds due to the combination of off-channel habitat and spawning gravel that is wetted during higher flow releases.
Total Area: 19000m²

Site A3: This area is primarily a large gravel and cobble fan with gently sloping topography. There are several areas where large isolated pools form during rampdowns, however this area has a very low risk of stranding.
Total Area: 4800m²

Reach 2A

Site B1: This area is a side channel that is normally wetted except at extremely low flows (below 2.00cms WSC gauge Port Coquitlam). It has a gravel and cobble substrate, however, it rarely completely dewaters, so is only a stranding risk under extreme low flow conditions.
Total Area: 270m²

Site B2: This area is a long narrow partially treed platform with a combined sand/silt, gravel and vegetated substrate. It strands adults, juveniles and redds. This site only becomes inundated during a full three LLO gate release, and is one of the earliest sites to begin dewatering.
Total Area: 3000m²

Figure 9 Site B2, showing isolated pool formed during flow reduction, this site strands juveniles, adults and redds. Substrate is primarily sand/silt.

Site C1: This site is a long side channel composed of gravel and cobble substrate. It drains rapidly and forms many isolated pools that do not retain water well. This site experienced the highest number of stranding during the past two years.
Total Area: 690m²

Site C2: The riparian area is densely covered in shrubs. The substrate is fine silt with some vegetated ground cover. River Morphology changes may also have reduced the risk of stranding at this site.
Total Area: 550m²

Figure 10 View of site C1 side channel that is wetted during single gate openings. This site typically has one of the highest incidences of stranding on the Coquitlam River.

Reach 2B

Site C3: This site is a small side channel composed of gravel and cobble substrate. It drains slowly and forms many isolated pools that do not retain water well. This site experiences only minimal stranding.
Total Area: 60m²

Site D1: This area encompasses two long side channels that completely dewater during the June flow reduction. they are a silt/sand gravel cobble substrate combined with some deeper pools and poses a high risk of stranding.
Total Area: 300m²

Site D2: Parts of this area are densely vegetated with riparian trees and shrubs, though it is primarily a narrow river margin with cobble and boulder substrate and one side channel that nearly dewaters during the June flow reduction. Stranding risk here is high.
Total Area: 80m²

Reach 3

Site D3: This area is a combination of a long, narrow platform with dense trees and shrubs, as well as a small side channel that is permanently wetted. It has a combined sand/silt, gravel and vegetated substrate. Isolated pools form during flow reductions, stranding juveniles which are best removed using minnow traps due to the dense concentration of roots within the pools. Stranding risk here is high.
Total Area: 700m²

Reach 4

Site E1: This area is adjacent to a rearing pond that overflows during dam releases. Juveniles spill from the pond and can become stranded after these overflows. Channel substrate is mainly cobble and gravel intermixed with moderately treed islands.
Total Area: 900m²

Site E2: This area consists of narrow river margins with dense trees and shrubs. Many small isolated pools form close to the river mainstem during gate closure. Observations over the past several years indicate that many of these pools remain wetted year round due to their proximity to the river channel. Stranding risk is high
Total Area: 1800m²

Site E3: This area, situated near the dam face, is densely covered in trees and shrubs. Isolated pools are minimal, but juveniles are sometimes stranded in the area of dense vegetation during dewatering from full 3 LLO gate flow reductions. Moderate risk of stranding.
Total Area: 340m²

Appendix 3 May 2019-April 2020 Coquitlam River rampdown site maps and discreet stranding locations represented by the red dots. Total number of fish stranded not sorted by species.

Figure A
Coquitlam River Stranding Reach 4 and 3.

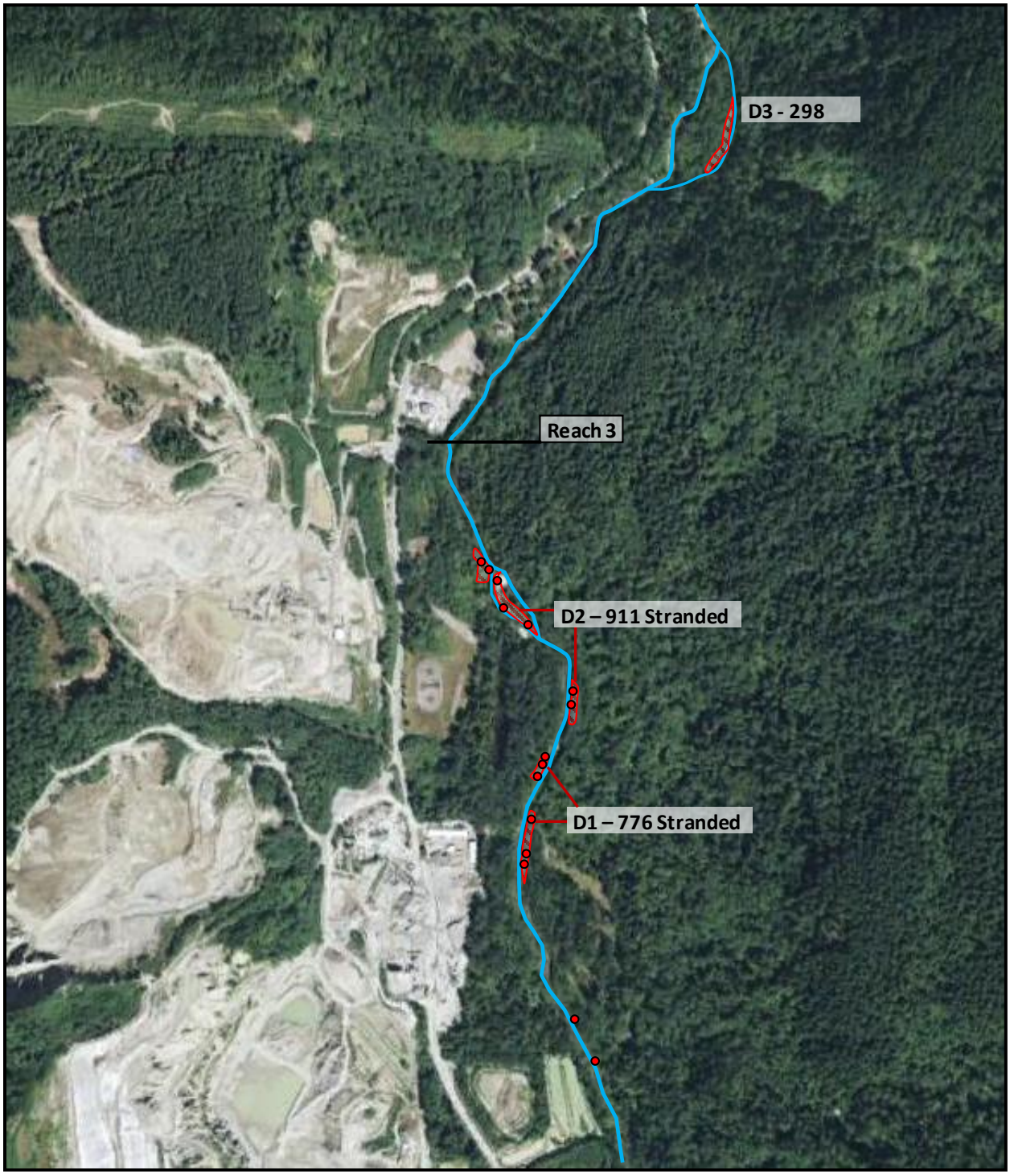

Figure B
Coquitlam River Stranding Reach 3 and 2b

Figure C
Coquitlam River Stranding, Site C, Reach 2a & 2b.

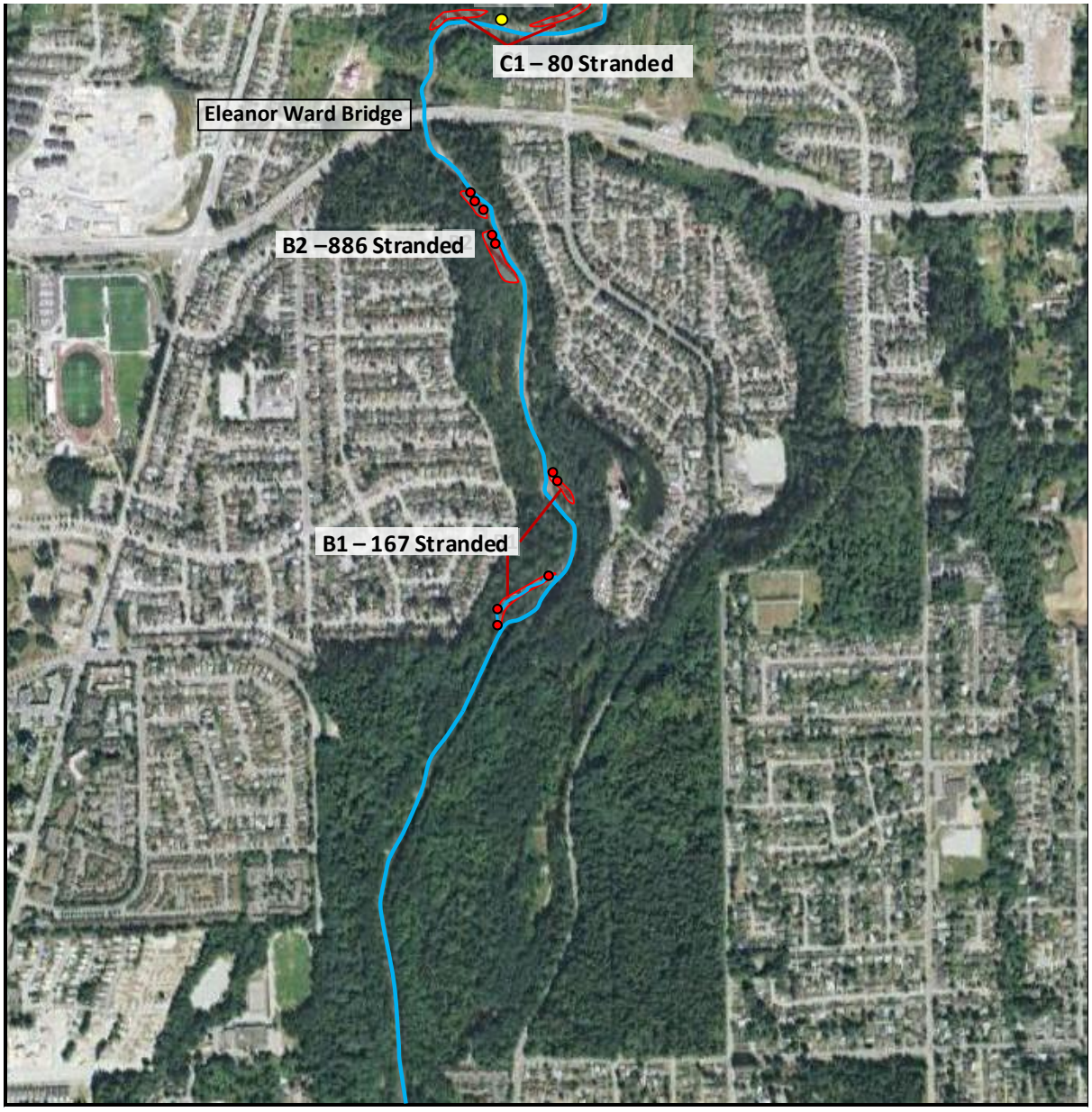

Figure D

Coquitlam River Stranding, Site B & C, Reach 2a.

Figure E

Coquitlam River Stranding, Site A, Reach 1.

Appendix 4 Summary of stranding results from the June 2020 rampdown fish salvage. June 2020 is not part of Year 12 stranding results but is included here for added information.

Coquitlam Rampdown Fish Salvage June 1, 2020

Fish Stranding Summary

In response to the current flow regime (Treatment 2), the low level outlet (LLO) gate release from Coquitlam Dam is scheduled to be reduced from 2.9 m^3sec to 1.1 m^3sec for the month of June. In light of high numbers of stranded fish and mortalities during past scheduled flow reductions on this date, a decision was made in 2013 to extend the flow reduction over three days instead of performing the entire flow reduction over a single day. It was hoped that a more gradual flow reduction would potentially result in fewer stranded fish, and fewer mortalities due to stranding. This extended flow reduction period was first attempted in 2013 and has been successful in reducing stranding mortality when compared to single day rampdowns, however it has not led to a reduction in the number of fish being stranded (which is influenced by several others factors unrelated to the ramping rate (Figure 1).

Adding to the magnitude of the scheduled flow reduction in 2020 was the fact that the normal operating release from COQ Dam for the months of April and May was increased. The increase in flow was part of the Kwikwetlem River Sockeye Program (KRSP), which required a discharge of 6.0 m^3/s in order to attract Sockeye smolt migration from Coquitlam Reservoir. As a result of this flow increase there was a total reduction of approximately 78% of the river volume – from 6.0 m^3/s to 1.1 m^3/s – which required an extended the rampdown period of five days in order to properly manage the stranding risk.

The scheduled flow reductions in 2020 were performed over 5 days with flow reductions and dates seen below:

- June 1 6.0 m^3/s - 4.3 m^3/s
- June 3 4.3 m^3/s - 2.9 m^3/s
- June 5 2.9 m^3/s - 2.2 m^3/s
- June 10 2.2 m^3/s - 1.5 m^3/s
- June 15 1.5 m^3/s - 1.1 m^3/s

This staggered flow reduction has reduced the maximum daily stage elevation drop in Reach 4 dramatically. Flow reductions in 2011 and 2012 for this gate change dropped flow in Reach 4 approximately 16.0 cm in 2-3 hours. The maximum decrease this year was 5.0 cm over one hour in Reach 4 on June 3, 2020 (Table 2).

Over the course of the 5 days of fish salvage a total of 3685 fish were observed to be stranded. Of the 3685 fish observed stranded there was a total 3637 Coho fry, which made up the overwhelming majority of fish accounting for 98.7% of all stranding. In addition, there were 11 Coho smolts, 23 steelhead fry, 11 Threespine Sticklebacks, 3 Signal Crayfish (*Pacifastacus leniusculus*)) and 1 Northern Pike Minnow (Table 1). The mortality rate was 19.4%, which is the highest observed since the switch was made to multiple day rampdown fish salvages, and above the 2011-2019 mean of 13.4%, but is still lower than rampdowns done over a single day period (Figure 1).

The explanation for the high amount of stranding observed is likely due to river conditions during the flow reductions. The increased flow as a result of the KRSP project, along with the accompanying elevation in river stage over such a long period - two months – allowed Coho fry access to many areas of Coquitlam River that they normally could not enter. This lead directly to an increase in stranding area and the number of sites that represent a high risk for stranding.

The act of spreading the flow reduction out over multiple days still appears to have mixed success overall as the mortality rate has decreased in comparison to single day rampdown events, but total stranding observed has not declined (Figure 1).

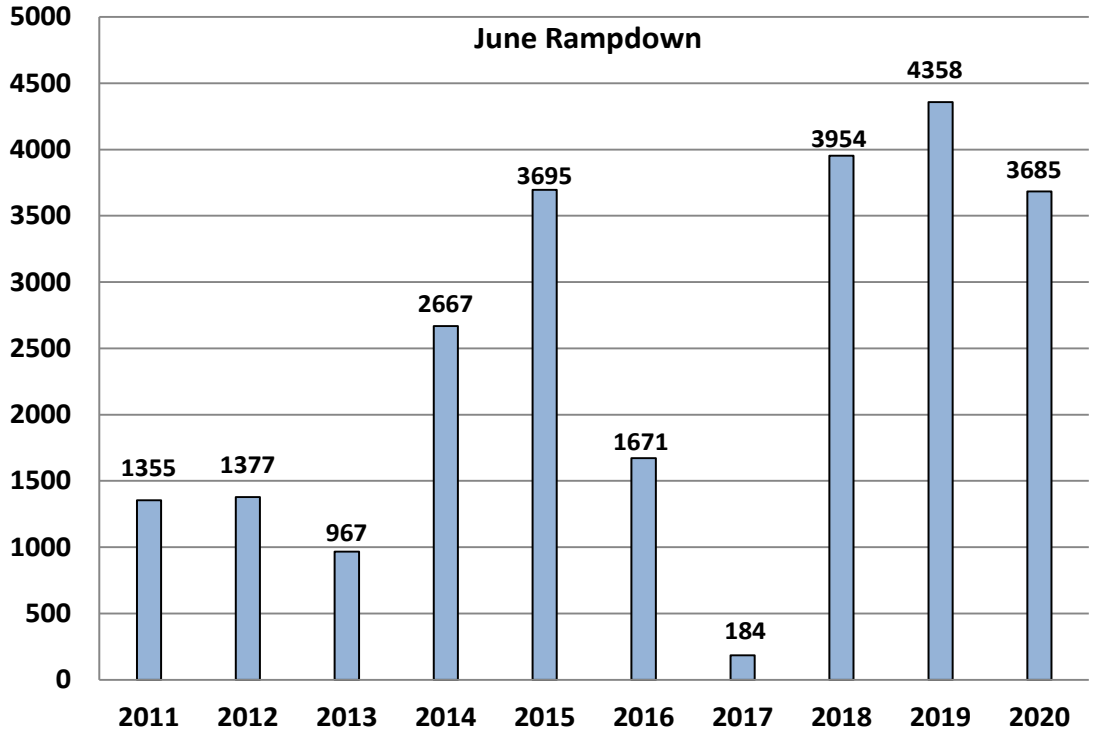

Figure 1 Coquitlam River fish stranding 2011-2020, June scheduled rampdowns only.

Table 11 Coquitlam River Fish salvage and mortalities by Reach June 1, 3, 5, 10 and 15, 2020.

			Reach					
Date	**Species**	**Salvaged/Mort**	**1**	**2a**	**2b**	**3**	**4**	**Total**
1-Jun-20	co0	s	121	289	24	274	87	795
1-Jun-20	co0	m	13	21	9	1		44
1-Jun-20	npm	s		1				1
1-Jun-20	TSS	s					1	1
3-Jun-20	co0	s	176	257	37	181	69	720
3-Jun-20	co0	m		405	43	103		551
3-Jun-20	crayfish	s	1					1
5-Jun-20	co0	s	639	129	26		125	919
5-Jun-20	co0	m	40	13	15		20	88
5-Jun-20	co1+	s	5					5
5-Jun-20	crayfish	s			1			1
5-Jun-20	TSS	s			4			4
10-Jun-20	co0	s	89	76			63	228
10-Jun-20	co0	m	16	14				30
10-Jun-20	co1+	s	6					6
10-Jun-20	TSS	s	6					6
15-Jun-20	co0	s	47	69		17	57	190
15-Jun-20	co0	m	12	7		4	19	42
15-Jun-20	St 0	s					21	21
15-Jun-20	St 0	m					2	2
		Total Stranded	1171	1281	159	580	464	3655
		Total Salvaged	1090	821	92	472	423	2898
		Total Mortality	81	460	67	108	41	757
		Mortality Rate						20.7%

Table 2 Coquitlam River Stage Reduction by Reach June 1, 3, 5, 10 and 15, 2020.

R4 Staff Gauge		R1 WSC Staff Gauge		**June 1, 2020**
Time	Stage (m)	Time	Stage (m)	
0900	0.46	0900	8.02	
1000	0.43	1100	8.00	
1100	0.41	1300	7.97	
1200	0.39	1500	7.96	
1500	0.39	1600	7.96	
1600	0.39	1800	7.96	
	7.0		6.0	Max Reduction (cm)
	1.5		1.5	Max Reduction (cm)/hr

R4 Staff Gauge		R1 WSC Staff Gauge		**June 3, 2020**
Time	Stage (m)	Time	Stage (m)	
0900	0.39	0900	7.96	
1000	0.34	1100	7.95	
1130	0.30	1300	7.90	
1230	0.29	1500	7.88	
1400	0.29	1600	7.88	
1600	0.29	1800	7.88	
	10.0		4.0	Max Reduction (cm)
	5.0		1.0	Max Reduction (cm)/hr

R4 Staff Gauge		R1 WSC Staff Gauge		**June 5, 2020**
Time	Stage (m)	Time	Stage (m)	
0900	0.29	0900	7.88	
1030	0.26	1100	7.87	
1130	0.23	1300	7.85	
1300	0.22	1500	7.83	
1430	0.22	1600	7.83	
1600	0.22	1800	7.83	
	7.0		5.0	Max Reduction (cm)
	3.0		1.0	Max Reduction (cm)/hr

R4 Staff Gauge		R1 WSC Staff Gauge		**June 10, 2020**
Time	Stage (m)	Time	Stage (m)	
0900	0.22	0900	7.97	
1000	0.22	1100	7.97	
1100	0.22	1300	7.96	
1200	0.20	1500	7.93	
1400	0.18	1600	7.93	
1600	0.18	1800	7.93	
	4.0		4.0	Max Reduction (cm)
	2.0		1.5	Max Reduction (cm)/hr

R4 Staff Gauge		R1 WSC Staff Gauge		**June 15, 2020**
Time	Stage (m)	Time	Stage (m)	
0900	0.20	0900	7.92	
1000	0.19	1100	7.92	
1130	0.16	1300	7.94	
1400	0.135	1500	7.92	
1500	0.135	1600	7.91	
1600	0.135	1800	7.91	
	6.5		1.0	Max Reduction (cm)
	1.8		1.0	Max Reduction (cm)/hr