COQMON-7 Monitoring Summary
(2000-2019)

Prepared by:

Jody Schick, Jason MacNair, Jennifer Buchanan and Dani Ramos

September 7, 2020

This summary outlines the steps that led to the development of the Lower Coquitlam River Productivity Monitoring Program (COQMON 7), its overall objectives, management questions and monitoring approach. This summary also describes how changes in flow releases from Coquitlam Dam have influenced downstream flows and how fish productivity has changed between the two flow regimes tested during the monitoring period (Treatment 1: 2000-2008, Treatment 2: 2008-2019). A projection of how extending monitoring beyond 2020 could change our assessment of the impact of each flow treatment on fish productivity is also included.

Development of the Coquitlam Water Use Plan Monitoring Program

The operating strategy of the 2004 Coquitlam-Buntzen Water Use Plan (LB1 WUP) received consensus support from the Consultative Committee (CC) even though there was no agreement on a single preferred dam flow release regime. The consensus agreement was based on the implementation of an adaptive management approach to address uncertainties with fisheries benefits. The adaptive management program included two components: 1) operating under a series of different dam release regimes (flow treatments) and 2) implementing eight monitoring programs and one physical works. The program objective was to ensure there would be sufficient information in place at the end of the planned 15 year review period to better understand the trade-offs between fisheries, domestic water and power generation. The initial design was to compare the two preferred operating alternatives (4FVN and STP5), and to the operations in place at the time (2FV). However, a power analysis completed as part of the WUP process concluded this approach had a low probability of detecting differences in fisheries benefits between the operating alternatives and baseline operations (Higgins *et al*. 2002). The study was reduced to a comparison of six years under baseline conditions (Treatment 1: 2000-2008) and nine years under STP6 (Treatment 2: 2009-2017), a revised version of STP5 to increase the likelihood of detecting differences in productivity within a 15 year period. In 2017, Treatment 2 was extended for an additional 3 years (ending 2020) to increase the level of confidence in the inferences drawn from the study in the lead-up to the Water Use Plan Order Review.

Table 1 outlines the water allocations for Metro Vancouver's domestic water use and Coquitlam Dam releases during Treatment 1 (1998-2008) and Treatment 2 (2008-present). Treatment 1 and 2 discharges are based on releases from the low level outlet gates (LLOG) at Coquitlam Dam. The LLOG releases for Treatment 2 were categorized as either targeted or minimum discharge. Releases use targeted levels as long as there is adequate water supply and switches to minimum releases based on a set of rules set out in the Water Use Plan. Generally, targeted releases for Treatment 2 are higher throughout the year compared with Treatment 1 with the exception of June and July, which were lowered slightly (Table 1.1)

Table 1. Scheduled monthly flow releases from Coquitlam Dam under Treatments 1 and 2 of the Coquitlam River Water Use Plan.

	Reservoir diversion schedule (m^3/s)					
	Domestic water		Coquitlam Dam releases			
			Treatment 1	Treatment 2		
Period	Target	Min		Target	Min	Target species and life stage
Jan 1-15	11.9	10.7	1.0	5.9	3.6	Chinook spawning
Jan 15-31	11.9	10.7	1.0	2.9	2.9	Chinook incubation
Feb	11.9	10.7	1.0	2.9	1.8	Chinook incubation
Mar	11.9	10.7	0.8	4.3	1.1	Steelhead spawning
Apr	12.0	10.8	0.8	3.5	1.1	Steelhead spawning
May	12.0	11.0	1.1	2.9	1.1	Steelhead spawning
Jun	12.0	10.9	1.4	1.1	1.1	Steelhead parr
Jul	18.0	15.8	1.4	1.2	1.1	Steelhead parr
Aug	23.0	20.2	1.1	2.7	1.1	Steelhead parr
Sep	23.0	20.9	0.8	2.2	1.1	Steelhead parr
Oct	12.0	10.8	0.8	6.1	3.6	Chinook spawning
Nov	12.0	10.8	1.1	4.0	1.5	Chinook spawning
Dec	11.9	10.7	1.1	5.0	2.5	Chinook spawning

Study Objectives

The goal of the monitoring programs for the LB1 WUP is to ensure that there is sufficient information in place by the end of the review period to determine the fisheries benefits of two test flows and to enable a better understanding of trade-offs between fisheries, domestic water and power generation. The Lower Coquitlam River Fish Productivity Index Monitoring Program (COQMON-07) was implemented to answer the primary management question: *What are the fisheries benefits associated with each of the proposed test flows evaluated over the review period?* Because the fisheries benefits of the flows may vary among fish species and among life stages of individual species, addressing the following secondary questions will support the management question above:

1. What is the relationship between habitat and fish productivity in the lower Coquitlam River?

2. What are the main factors driving fish productivity in the lower Coquitlam River?

To answer this, a Before – After (BA) experimental design was developed that included monitoring adult escapement, and smolt and fry outmigration. While the development of operating alternatives focused on Steelhead Trout and Chinook Salmon habitat requirements, low Chinook abundance necessitated the use of Coho, Chum and Pink as surrogates for monitoring. Since 2006, night snorkeling surveys were included in the monitoring program to provide estimates of late summer standing stocks of juvenile Coho and Steelhead. Monitoring focused on the 7.5 km downstream of the Coquitlam Dam. This section was expected to have the greatest productive response, which increases the probability that monitoring would successfully detect the effect of the flow treatments. Smolt production was set out as the primary metric for evaluating the fisheries benefits of each flow regime for Coho and Steelhead. We have specifically used mainstem production as the primary metric and excluded production from the four monitored constructed off-channel habitats. This is because 1) flows in off-channel areas are stabilized by groundwater inputs and regulated mainstem intakes and 2) continued maintenance of off-channel areas has a large impact on productive capacity that could obscure flow treatment effects. This is not to say that productivity in these areas is unaffected by mainstem flows, but that effects of mainstem flow and off-channel productivity cannot be completely separated based on the available data. For Chum and Pink, it is the number of outmigrating fry produced per adult spawner.

The study design did not state the amount of change between treatments (effect size) needed to conclude a significant fisheries benefit had occurred but we expect it to be less than the 50% effect size that the power analysis was based on. With this in mind, we include the probability of different effect sizes for Coho and Steelhead. Adult abundance is not used directly as a primary indicator of fishery benefits because of the large role that ocean survival plays in the number of salmon and Steelhead returning to the Coquitlam River. Adult to smolt abundance stock-recruitment analysis was included in the terms of reference as a way to assess fisheries benefits, but a power analysis completed near the start of the project indicated this approach would need a longer time frame than when using smolt production. Adult abundance, or egg deposition estimated based on the number of adults, fall standing-stock and outmigration are useful for assessing how survival between life-stages is influenced by flow treatments or differences in flows within only a specific portion of the year. COQMON-07 includes four monitoring components:

Adult salmon escapement – Chinook, Coho, Chum and Pink adults are counted during weekly surveys of reaches 2-4. Mark-recapture is used to estimate the proportion of fish present that are counted by observers (observer efficiency) as well as to estimate the duration fish are in the surveyed area (survey life). Escapement is estimated using a Hierarchical Bayesian Model (HBM). It expands survey counts to account for that only a portion of fish present are counted, and also that the same fish may be counted during more than one survey. The model also incorporates prior information about spawning run timing that is used to estimate abundance between surveys. This method provides an index of abundance that is likely comparable across years and treatment periods for Pink and Chum. For Coho, estimates are comparable within treatment periods but are less reliable for across-treatment comparisons due bias introduced from a change in survey methods in 2008. Chinook numbers have been high enough to estimate escapement since 2007. While estimates may accurately reflect the relative change in escapement between years, or treatment periods for some species, they may not accurately estimate total escapement because we have had to use published survey life values instead of values specific to the Coquitlam River.

Adult Steelhead escapement – Starting in 2005, the number of returning Steelhead adults has been estimated using weekly or bi-weekly redd surveys during the spring spawning period. The number of redds is used to estimate total escapement and egg deposition using published values for other Pacific north west rivers.

Smolt and fry outmigration – Downstream trapping at three mainstem locations and the outlets of three constructed off-channel habitats is used to estimate Steelhead and Coho smolt production for mainstem reaches 2-4 and constructed off-channel habitats, and Chum and Pink outmigration from the entire study area. We consider the estimates for the mainstem study area (reaches 2-4 combined), with and without off-channel fish to be largely unbiased and sufficiently precise. The precision of reach level estimates is more variable, with generally higher precision for reach 4 and lower precision for reaches 2 and 3. It is important to note that lower precision can increase the number of monitoring years to detect a statistically significant change in productivity if a change has occurred.

Fall fry and parr standing stock – Steelhead fry and parr, and Coho fry in the Coquitlam River Mainstem have been enumerated using snorkel surveys starting in 2006. A number of trials were also conducted to estimate a snorkeler’s observer efficiency (the proportion of fish present that are seen). Initially 12 but later increased to 24 sites were surveyed each year. The survey counts, in combination with observer efficiency estimates, provide relatively accurate estimates of Steelhead age-0 fry, age-1+ parr and Coho fry. This study component was not intended as a key indicator for evaluating flow treatment effects. As such, sampling intensity was not designed to provide the sample level of precision as outmigration monitoring.

Treatment 1 and 2 Flows

Treatment 1 and 2 flow regimes are based on the releases from Coquitlam Dam, not on flows measured downstream at the Port Coquitlam hydrometric station. The influence of dam releases on total mainstem flow is highest in reach 4, which is closest to the dam and above the two major creeks entering the study area (Or and Pritchett Creeks). The relative influence of dam releases versus local inflows is highest June to September when local inflows are at their lowest point. Inflow from these creeks raise flows during fall and winter rain events and during spring freshet. Based on flows at the Port Coquitlam hydrometric station, months with higher minimum releases from Coquitlam Dam during Treatment 2 did increase minimum flows throughout the entire river but has had less influence on average flows (Figure 1). The increases in minimum flows between Treatments 1 and 2 were between 50-300% higher September to April. Minimum flows were relatively unchanged between Treatments 1 and 2 for the June to August period, but this is to be expected given that dam releases were unchanged or minimally changed for these months. Increases in average flow between Treatments 1 and 2 were far lower than for minimum flows for most months and absent during the typically rainy November to January period.

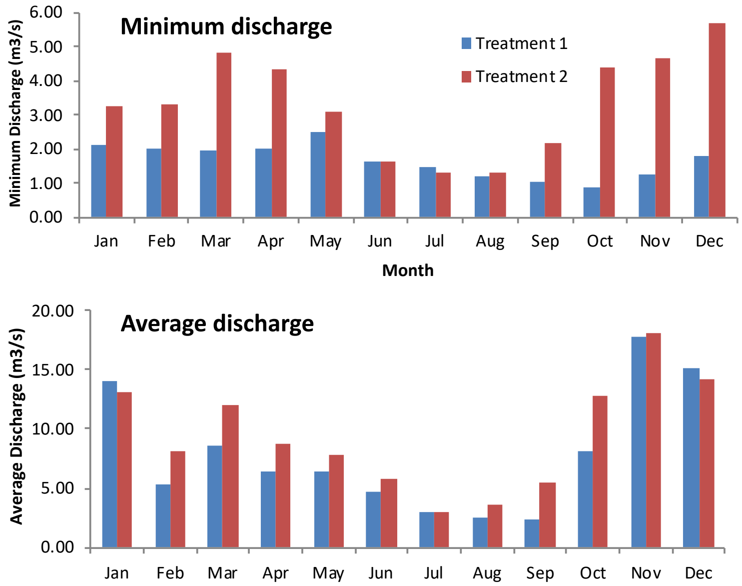

Figure 1. Monthly discharge statistics for the Coquitlam River during Flow Treatment 1 (2000-2008) and Treatment 2 (2009-2019) measured at Port Coquitlam (Water Survey of Canada, stn. 08MH141) including monthly mean and minimum discharge.

Another notable difference between Treatment 1 and 2 was the increase in rampdown events in response to the monthly change in releases from the dam. While unscheduled rampdowns following higher flow events have occurred under both treatment periods, there were from three to six scheduled rampdowns each year during Treatment 2, whereas none occurred during Treatment 1. COQMON-7 was not intended to specifically assess stranding impacts but any impacts would potentially influence the assessment of the fisheries benefits.

Fish Production during Treatment 1 and 2

Analysis to date has focused primarily on the management question of *what are the fisheries benefits of each flow treatment*. There are two parts to this question: 1) has there been a change in fish productivity between Treatment 1 and 2 and 2) if there was a change, was it the result of the flow treatment? On the first question, we have high confidence that productivity increased for Steelhead and Chum, but lower confidence for Coho and Pink. On the second question of whether any increase was caused by the change in minimum flows, the answer thus far is uncertain but possibly no for some species. To conclude that Treatment 2 caused the change with a Before-After (BA) study design relies on the assumption that the only important difference affecting productivity was the change from Treatment 1 to 2 flows. We investigated this assumption by comparing abundance in Coquitlam with other watersheds with similar Treatment 1 abundance trends. The test is whether the between-treatment increase in productivity in the Coquitlam was larger relative to the change in the other watersheds. If so, this would support that Treatment 2 caused the increase. If not, it would suggest the change was due to non-treatment effects. The uncertainty thus far is due to the insufficient precision of the test as well as the comparability of watersheds, and data reliability.

Coho

The mean mainstem smolt production increased from 6,173 during Treatment 1 to 8,193 during Treatment 2 but did not amount to a statistically significant change in abundance (2-tailed t-test, p = 0.11, Figure 2). While this is a 33% increase, the amount of variation in annual estimates within each treatment period was too large to conclude with high certainty (95%) that smolt abundance was statistically different. This is not to say that no change occurred, just that we cannot say with certainty that this result was not due to chance. Maximum smolt yield was similar during each treatment period but minimum yield was lower during Treatment 1 and occurred more frequently (Figure 3). This indicates that freshwater carrying capacity was not increased by the Treatment 2. There was a moderate probability (prob = 0.76) of a 10% or greater increase in abundance. Additional Treatment 2 monitoring may result in a statistically significant difference if the monitoring and current Treatment 2 abundance trends continue. For example, a statistically significant difference (95% certainty) would occur if the results from 2014-2019 were repeated in the next six years. Changes at the reach level suggest the increase in smolt production was the product of increases in the two lower reaches in the study area (reaches 2 and 3); however, none represent statistically significant changes.

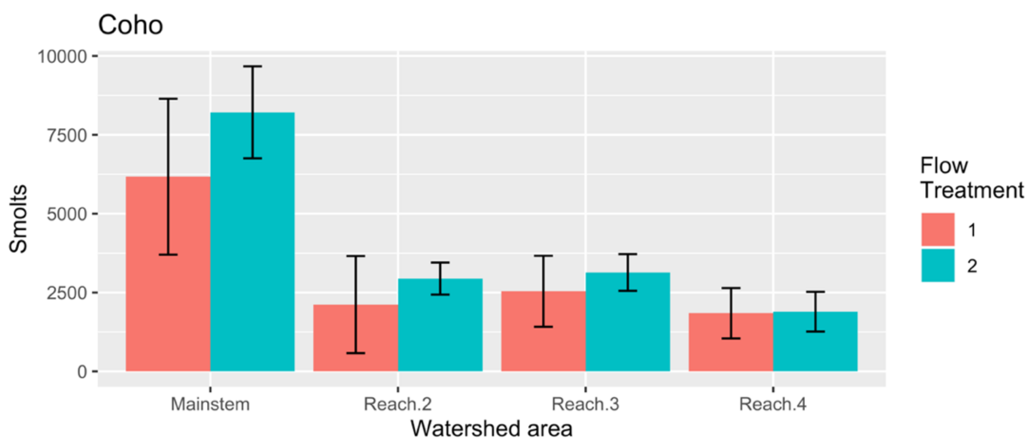

Figure 2. Mean Coho smolt yield and 95% confidence intervals for Treatment 1 and Treatment 2 in the 7.5 km of the Coquitlam River mainstem and reaches 2-4 individually. Only annual estimates for cohorts that reared exclusively under either Treatment 1 or Treatment 2 conditions were included. For Coho, this includes 2000, 2002-2008 for Treatment 1 and 2010-2019 for Treatment 2.

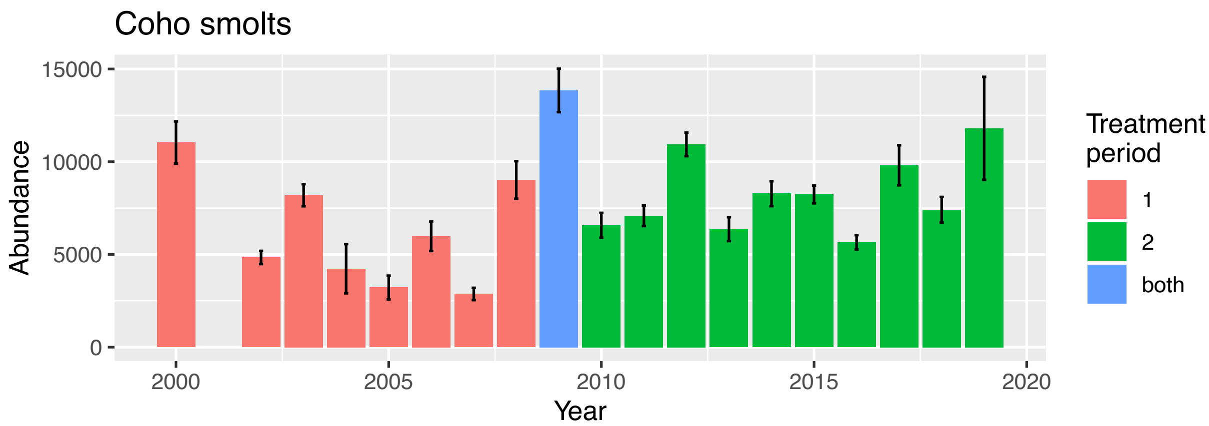

Figure 3. Annual Coho smolt yield and 95% confidence intervals for Treatment 1 and Treatment 2 in the 7.5 km of the Coquitlam River mainstem 2000-2019. Bar colour indicates cohorts that reared exclusively under either Treatment 1, Treatment 2 or both. This includes 2000, 2002-2008 for Treatment 1 and 2010-2019 for Treatment 2.

To assess the assumption that the increase was the result of the flow treatment and no other factors, we compared the between-treatment change in smolt yield in the Coquitlam to three other south coast BC and Vancouver Island watersheds that were moderately correlated with the Coquitlam up to 2009 (correlation coefficient > 0.5). This included the Alouette River (adjacent to the Coquitlam), Sakinaw Creek (south coast BC) and Keogh River (northern Vancouver Island). While the mean between-treatment increase for the Coquitlam was 33%, it was over 42% for the three comparison watersheds; however the broad overlap in the 95% confidence intervals indicates the differences are not statistically different (Figure 4). This does not support the assumption that that Treatment 2 flows caused the increased smolt yield in the Coquitlam and raises the possibility that the increased productivity was the result of non-treatment factors. This could include differences in spawner abundance, which was generally higher during Treatment 2, and regional environmental influences.

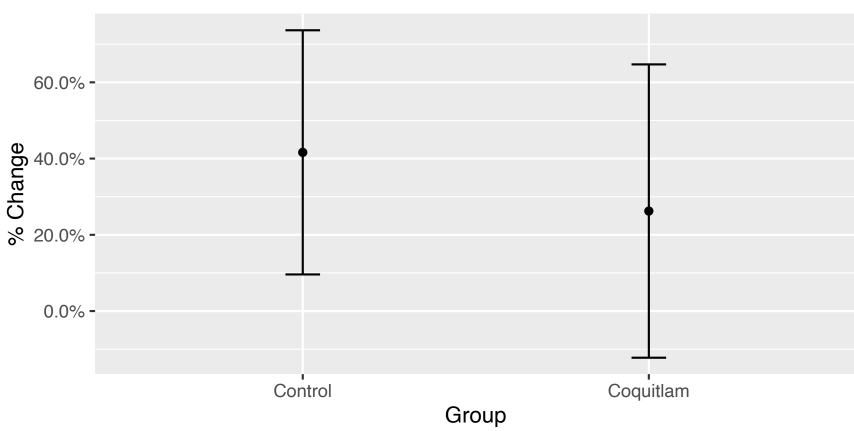

Figure 4. Average percent change in Coho smolt yield from Treatment 1 to Treatment 2 and 95% confidence intervals in the lower Coquitlam River mainstem and three comparison watersheds (Control) that underwent no changes in flow regulation during this time period (Alouette River, Sakinaw Creek, Keogh River). The change in mean abundance was based on cohorts that reared entirely during Treatment 1 and Treatment 2. This includes 2000-2008 during Treatment 1 and 2010-2018 during Treatment 2.

Mean estimated egg-to-fry survival during Treatment 1 and 2 was 1.3% and 0.9% respectively, though they were not significantly different (2-tailed t-test, $p = 0.3$). We are cautious about any between-treatment evaluations reliant on adult escapement estimates, including egg-to-fry. All three years of Treatment 1 survival estimates corresponded to very low escapements, which were likely too low for carrying capacity or density dependant mortality effects to take effect, whereas these effects may have occurred during Treatment 2.

There was moderate support that egg-to-fry survival increased with mean discharge during spawning, possibly due to the increased availability of spawning habitat at higher flows. Mean discharge during spawning (November to January) was the strongest seasonal flow variable predictor of egg-to-fry survival during Treatment 2 ($R^2 = 0.65$). Survival was also influenced, but to a lower degree, by the amount of stranding resulting from the June 1 rampdowns ($R^2 = 0.45$). Survival decreased as the number of fish salvaged alive and dead from this rampdown increased. Even though the flow at Port Coquitlam following the June rampdown was a strong predictor of the number of Coho stranded, ($R^2 = 0.78$), it was a relatively weak predictor of egg-fall fry survival ($R^2 = 0.32$). We only included Treatment 2 years due to the potential bias between treatment periods in the adult estimates used to estimate egg deposition.

Both adult escapement and mean discharge during incubation (February-March) were moderate predictors of egg-smolt survival ($R^2 = 0.68$ and 0.66, respectively). Since the two variables are independent of each other, it is likely by coincidence that both were moderate predictors. Egg-smolt survival decreased as escapement increased and increased with mean discharge during incubation. For both variables, two datapoints with high survival had a large influence on the trends. With these two data points removed, the trend would only persist using adult escapement, suggesting the relationship with adult escapement is less likely to be a spurious result. Analysis in the next reporting cycle will incorporate adult escapement and flow variables (expected fall 2020).

Steelhead

Mean smolt yields for cohorts that reared exclusively under Treatment 1 or Treatment 2 were statistically different (3,716 smolts and 4,798 smolts; respectively; 2-tailed t-test $p = 0.035$). This represents a 30% increase from Treatment 1(Figure 5). The entirety of the increase was due to increased production from reach 4, where production more than doubled during Treatment 2 (Figure 5). There was a high probability (prob = 0.90) of a 10% increase in abundance from Treatment 1 to 2 and a moderate probability (prob = 0.76) of a 20% increase. There was minimal support for a 50% increase (prob = 0.11). Similar to Coho, maximum smolt yield was similar during each treatment period but minimum yield was lower during Treatment 1 and occurred more frequently (Figure 6). This indicates that carrying capacity was not increased by the flow treatment.

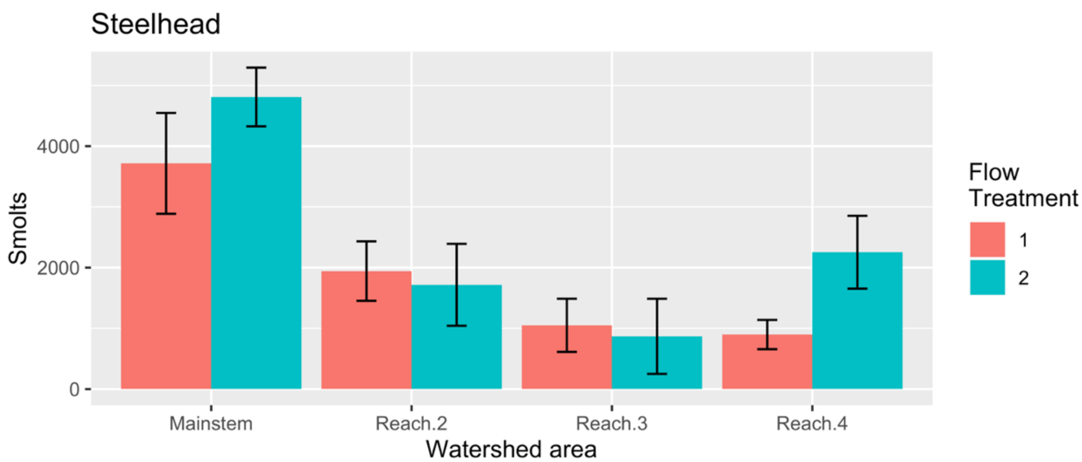

Figure 5. Mean Steelhead smolt yield and 95% confidence intervals for Treatment 1 and Treatment 2 in the 7.5 km of the Coquitlam River mainstem and individually for reaches 2-4. Only annual estimates for cohorts that reared exclusively under either Treatment 1 or Treatment 2 conditions were included. For Steelhead, this includes smolt estimates from 2002-2008 for Treatment 1 and 2012-2019 for Treatment 2.

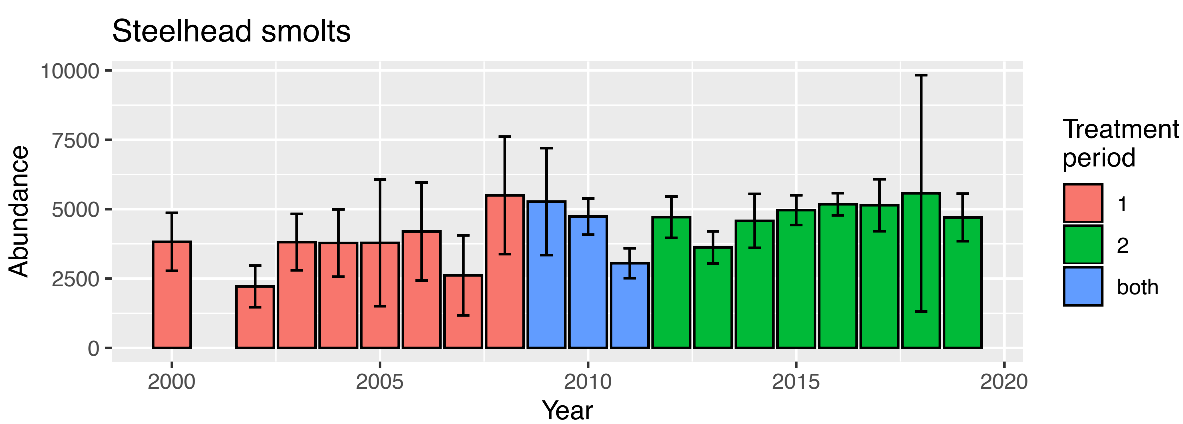

Figure 6. Annual Steelhead smolt yield and 95% confidence intervals for Treatment 1 and Treatment 2 in the 7.5 km of the Coquitlam River mainstem 2000-2019. Bar colour indicates cohorts that reared exclusively under either Treatment 1, Treatment 2 or both. This includes 2000, 2002-2008 for Treatment 1 and 2012-2019 for Treatment 2.

Using the same method as for Coho to evaluate the assumption that the increased smolt yield was due to the flow treatment and not other factors, we compared the relative increase in smolt yield in the Coquitlam River to a comparable watershed to help distinguish between flow treatment effects and regional changes in productivity. Unfortunately, we were limited to using only the Alouette River for this comparison. Other rivers with Steelhead smolt monitoring were not compared either due to dissimilar abundance trends during Treatment 1 (Keogh-northern Vancouver Island correlation coefficient < 0.05) () or underwent changes in flow regime that coincide with the treatment changes (Cheakamus). Since monitoring on the Alouette ended in 2014, the comparison includes only three Treatment 2 years once cohorts reared under both treatments were excluded. Similar to Coho, this analysis suggest there was no support that the between-treatment productivity increased more in the Coquitlam than the Alouette River. This is due to smolt yield increasing by 74% (though a highly uncertain estimate) compared to the 30% increase for the Coquitlam. Considering the potential biases in the Alouette data, we view these results as raising the possibility that the flow treatments were not responsible for some or all of the increase in production but does not confirm this. Resolving this requires comparisons with other watersheds and/or alternative analysis that removes or accounts for the potential bias from the Alouette data. A recommencement of smolt outmigration monitoring on the Alouette (224th Street location) could also help resolve this uncertainty.

Average fall abundance of fry was 70,963 for Treatment 1 and 41,555 for Treatment 2 thought this difference was not significant (t-test $p = 0.15$). Any decrease in fry abundance did not translate to lower age 1+ parr abundance in the fall, which was similar between Treatments 1 and 2 (age 1+ parr 8,812 and 8,827; respectively; t-test $p = 0.96$). There was no significant difference in egg-fall fry abundance from Treatment 1 to 2 (survival = 7.7% and 5.8%, respectively, p = 0.15).

All of the seasonal flow variables and adult abundance were relatively poor predictors of egg-fall fry survival during Treatment 2. The strongest variables were adult abundance ($R^2 = 0.34$) and mean discharge during incubation ($R^2 = 0.28$). What is notable from this analysis is that the number of days during August that flows at Port Coquitlam are below 20% of the mean annual discharge (MAD) has very low predictive ability on survival ($R^2 = 0.09$). Low flows during August rearing was raised as a concern by some in the WUP consultative committee. Similar to Coho fry, the next version of this analysis will include adult escapement in combination with a flow variable.

Chum

The primary metric for evaluating fisheries benefits for Chum is the number of outmigrating fry per spawner or egg-fry survival. There was strong support that more fry were produced per adult spawner during Treatment 2 than Treatment 1 as flow treatment was a significant factor in the fry per spawner relationship, ($p<0.05$). More fry were produced per adult during Treatment 2 than during Treatment 1, even when accounting for spawner abundance (Treatment 2 line higher Treatment 1, Figure 7). Egg-fry survival also increased from 10.2% in Treatment 1 to 25% in Treatment 2 (two-tailed t-test, $p < 0.01$). For some years, the Chum egg-fry survival estimates exceeded published values for this species suggesting some or all estimates may be biased high. The most plausible source of this bias is an underestimate of Chum escapement as opposed to an overestimate of Chum fry, given that observer efficiency of adult surveys remains uncertain. This would have little impact on the between-treatment comparison as long as any bias applies equally to Treatment 1 and 2.

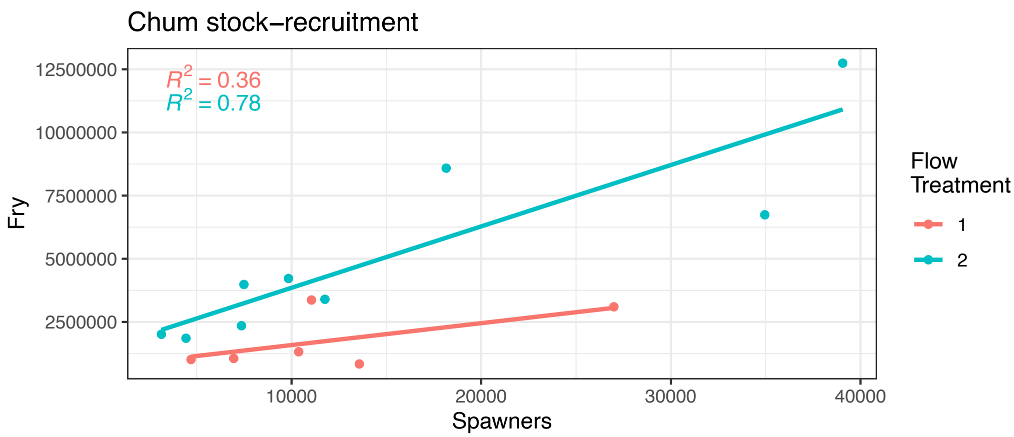

Figure 7. Adult spawner to fry stock-recruitment relationship for Chum Salmon during flow Treatment 1 (2000-2007 adult brood years) and Treatment 2 (2008-2016, 2018 adult brood years) from 7.5 km of the Coquitlam River.

As for Coho and Steelhead, it's unclear whether the increased fry per adult during Treatment 2 was due to the flow treatment. To date, we have not fully assessed support for the assumption that the increase in fry per spawner was the result of the flow treatment, in part due to a lack of comparable data from watersheds that did not experience changes in flow regulation.

There was strong support that the number of days flows are above 70 m^3/s during the incubation period (December – February) be used as a predictor of egg-fry survival ($R^2 = 0.80$). Survival increased with the number of days when flows were above 70 m^3/s. There was no support that flow during spawning (October-November) had a meaningful impact on survival. We excluded the 2004 escapement year from the analysis largely because flows during the 2004-2005 winter were far higher and high flows more frequent than all other years that led to unique impacts on survival. However, the low survival for 2004-2005 winter suggests that while higher flows during incubation may increase survival, there may be a a point when it reduces survival.

Pink

Mean egg-fry survival was 8.1% during Treatment 1 and 27% during Treatment 2 (2009-2015 brood years only) but was not statistically different due to the very high variability during Treatment 2. Estimated adult Pink returns to Coquitlam River ranged from 2,867 to 5,418 during Treatment 1 and 9,327 to 34,280 during Treatment 2. Pink fry estimates ranged from 150 to 320 thousand during Treatment 1 and from 110 thousand to 6 million during Treatment 2. The increased fry abundance during Treatment 2 was a result of higher spawner abundance, most likely caused by improved ocean survival of the 2013 and 2015 cohorts rather than changes in freshwater conditions considering a near identical increase in fry outmigration occurred on the Cheakamus River and from 2006 onward on the Alouette as well (Figure 8). Similar to Chum, the high egg-fry survival during Treatment 2 exceeded published values for other streams suggesting some or all estimates were biased high. At this point, we do not know how credible these results are for comparing treatment effects. The change to lower adult returns in 2015 and 2019 improved the comparability of survival estimates between Treatments 1 and 2. If monitoring were extended past 2020, there would then be sufficient Treatment 2 estimates to estimate mean survival without the 2011 and 2013 brood years, which are the two that are most likely biased high.

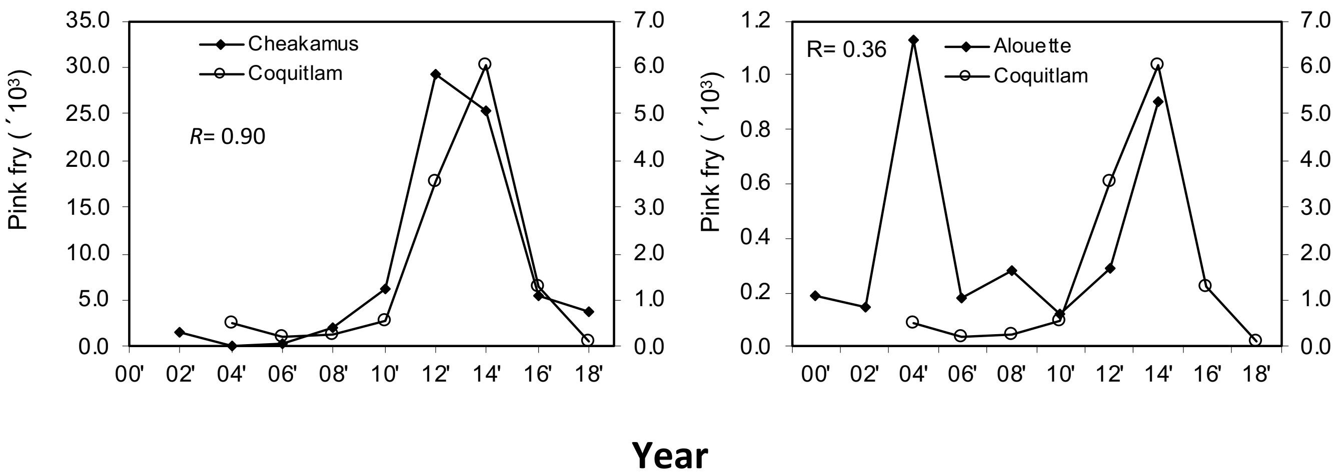

Figure 8. Annual fry outmigration estimates in the Coquitlam River versus that in the Cheakamus River during 2002-2018 and Coquitlam River versus the Alouette River during 2000-2014. Values for the Coquitlam are given on the right-hand axis, and values for the Cheakamus and Alouette are given on the left-hand axis.

There was weak support for a linear, escapement-to-fry, stock-recruitment relationship during Treatment 1 ($R^2 = 0.36$) but strong support for one during Treatment 2 ($R^2 = 0.75$, Figure 9). This figure also illustrates the order of magnitude difference between Treatments 1 and 2 in both juvenile and adult estimates, and the weakness of this data for comparing treatment effects due to non-overlapping adult estimates. Ideally, stock recruitment relationships for each treatment period should span a similar range in adult escapement, as was the case for Chum.

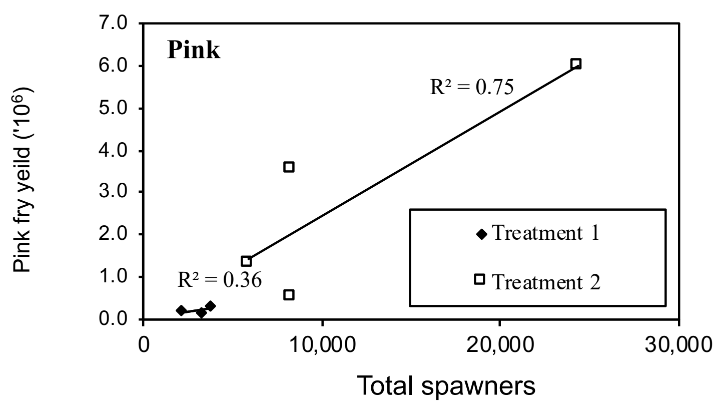

Figure 9. Preliminary escapement-fry stock-recruitment relationship for Pink Salmon during flow Treatment 1 and Treatment 2 (2009-2015) from 7.5 km of the Coquitlam River. Note that Pink Salmon spawn every other year in the lower Fraser River watershed.

Conclusion

Study results suggest that the production of Coho, Chum and Pink Salmon as well as Steelhead have been higher in the Lower Coquitlam River during Treatment 2 compared with Treatment 1, but only statistically higher for Steelhead and Chum. For Chum, this reflects a doubling of the egg-fry survival. For Coho and Steelhead, the average increase was approximately 30% above Treatment 1 levels but there is also uncertainty about the amount of the increase, particularly for Coho. Egg-fry survival possibly increased for Pink but it is unclear how much this was influenced by the substantially higher adult escapement during Treatment 2. While higher Pink escapement is encouraging, it may have more to do with higher marine survival, than to a change in freshwater productivity.

We are less certain about whether the increases were a product of the Treatment 2 flows or other factors, such as higher adult escapement or regional environmental changes. If the assumption that these differences were the result of the flow treatment then this supports a conclusion that increased production is a fisheries benefit of Treatment 2 flows. However, support for this assumption varies by species and is generally uncertain at this point. For Coho, a rise in smolt yield in other watersheds raises the possibility that the increase was not the result of the flow treatment. This is also the case for Steelhead, but the analysis is weaker due to comparing the Coquitlam to only one other river. For Chum and Pink, the absence of comparable productivity data from other watersheds prevents this analysis. Reducing the uncertainty will depend on finding suitable watersheds with reliable and comparable data to compare with the Coquitlam and/or using alternative analytical approaches to control for some non-treatment effects. These two steps will be completed by the fall of 2020. Additional control stream data depends on the availability of Washington State fisheries data given that comparable data from BC is already included. We are optimistic that alternative analysis will reduce this uncertainty for some species. There is a possibility that for some decision makers neither approach will successfully address this uncertainty ahead of the order review.

We have a weak understanding of the main drivers of productivity and how flows influence productivity at this time. We are still developing the alternate analysis and expect our preliminary findings to change as flow variables are evaluated while accounting for the influence of adult escapement. This will be complete by the fall of 2020. The number of abundance estimates is at the minimum to reliably compare the influence of multiple factors and will likely require extending monitoring beyond 2020 for reliable findings.

Current answers to the primary management question:

What are the fisheries benefits associated with each of the proposed test flows evaluated over the review period?

Coho – Mean smolt yield likely increased from Treatment 1 to Treatment 2 (mean increase 33%). Maximum smolt capacity was relatively unchanged between treatments but there was a higher number of years with abundance near the maximum carrying capacity during Treatment 2. It remains unclear at this time whether the increased productivity was the result of the Treatment 2. Similar abundance trends in comparable watersheds raises the possibility that the increase was due at least in part to non-treatment factors.

Steelhead – Mean smolt yield very likely increased from Treatment 1 to Treatment 2 (mean increase 30%). Maximum smolt capacity was relatively unchanged between treatments but there was a higher number of years with abundance near the maximum carrying capacity during Treatment 2. It remains unclear at this time whether the increased productivity was the result of Treatment 2. Similar abundance trends in the Alouette raises the possibility that the increase was due at least in part to non-treatment factors.

Chum – Egg-fry recruitment increased significantly from Treatment 1 to Treatment 2, even when accounting for the number of adult spawners. While we lack information to confirm that this change was the result of the flow treatment, there is no information suggesting otherwise.

Pink – Egg-fry recruitment possibly increased from Treatment 1 to Treatment 2 but this may be a product of the up to 10-fold higher spawner abundance during Treatment 2. Because of this, we do not consider this a useful indicator of fisheries benefits until Treatment 2 includes years with comparable spawner abundance to Treatment 1.

We have not yet completed the analysis to fully address the secondary management questions:

1. What is the relationship between habitat and fish productivity in the lower Coquitlam River?
2. What are the main factors driving fish productivity in the lower Coquitlam River?

Key Uncertainties

1. Were the increases in productivity from Treatment 1 to 2 caused by the change in minimum flows or were they the product of other factors (i.e. spawner abundance, environmental change)? This is addressed by:
   - Covariate analysis to assess which hydrologic or other variables best explain the year-to-year variability in productivity.
     - Benefits: can be developed and tested without additional monitoring; useful for determining the main drivers of productivity.
     - Limitations: no guarantee of success; reliable results may require additional monitoring; monitoring frequency for ST may be too coarse to reliably identify main drivers.
   - Compare results with abundance trends in comparable watersheds in the region.
     - Benefits: Can provide the strongest support of flow treatment effects.
     - Limitations: Reliable data from comparable watersheds may not be available.
   - Continued monitoring on the Coquitlam River
     - Benefits: Improved power of covariate analysis and watershed comparisons; possibility of monitoring a year with highly informative flow or other characteristics.
     - Limitations: No guarantee this will address the uncertainties.

2. The secondary management questions were not yet addressed. Addressing these involve all of the study components listed previously and includes the same benefits and limitations.

3. What are the effects of variances to Treatment 2 flows? A number of variances to Treatment 2 flows have been approved in recent years or are under consideration including: higher spring releases to encourage Sockeye outmigration; reduced late summer flows to maintain Metro Vancouver allocations; and higher fall release to increase Sockeye spawner attraction. This is addressed by:

- Continued Coquitlam River monitoring for life-stages present during flow variance period. It may be possible to reduce monitoring components depending on the timing of the variance.
  - Benefits – provide preliminary information about effect of variances on productivity; test whether Treatment 2 effects are maintained with different minimum flows; improved contrast in flow conditions would improve covariate analysis.

- Limitations – Results could be informative for generating hypotheses but are unlikely to be statistically significant depending on type of analysis; cost of continued monitoring.

4. Is sufficient information in place to understand the trade-offs between fisheries, domestic water and power generation? The uncertainties listed above reflect the views of the consultant. It is ultimately the level of certainty that First Nations/stakeholders/regulators/BCH require to make decisions about future flows that is most important. The level of certainty for the series of questions we use to address the primary management question varies:
    - Has productivity increased? Certainty: moderate to very high
    - Was the increase in productivity caused by Treatment 2? Certainty: low to moderate
    - What is the relationship between habitat and productivity? Certainty: unknown, not yet assessed
    - What are the main factors diving fish productivity? Certainty: low to moderate, preliminary assessments

References

Higgins, P.S., J. Korman, and M.J. Bradford. 2002. Statistical power of monitoring inferences derived from experimental flow comparisons planned for Coquitlam-Buntzen Water Use Plan. B.C. Hydro internal report. Burnaby, B.C. 20 p.