Stave River Project Water Use Plan

Limited Block Load as Deterrent to Spawning

Implementation Year 7

Reference: SFLMON#4

Report on the 2011 Limited Block Load as Deterrent to Spawning

Study Period: 2011

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STAVE RIVER LIMITED BLOCK LOAD AS DETERRENT TO SPAWNING

Escapement Analysis and Reporting (2012)

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FINAL DOCUMENT

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EXECUTIVE SUMMARY

This report consists of the second biannual installment of the analysis of limited block loading as a deterrent to spawning of chum salmon adults in the lower Stave River below Ruskin Dam. Expanding on earlier limited block loading observations which explored detailed sets of hypotheses surrounding spawning deterrence at high elevation redd locations, we collated annual Inch Creek Hatchery - Fisheries and Oceans Canada lower Stave River chum salmon spawner escapement as a relative index of spawner abundance. We evaluated the hypothesis that chum escapement has not changed since the introduction of the fall limited block loading strategy as a part of the Lower Stave Water Use Plan. An initial report tabled in 2010 found no statistically significant weight to two predictors (brood escapement and discharge variation) of future escapement but noted that the analysis was based upon only two years of escapement affected by limited block loading operations.

Based on the limited time series with an added two years data a multiple regression model comparing variation in the hourly discharge and brood year abundance during the fall limited block loading period (1999 - 2007) is not significantly correlated to the number of Ocean 4 age chum spawners which returned during 2003-2011 escapements. The additional data strengthened the relationship ($r^2 = 0.61$) that the abundance of brood spawners and discharge explains on the variation in the abundance of future spawners.

The Ruskin operational profiles before and after the fall limited block loading strategy were implemented are somewhat different with the major difference being that the average discharges during the spawning period post-WUP (2004-2011) were significantly higher than those recorded before limited block loading was implemented (1999-2003). A comparison of spawner broods affected by limited block loading shows that average escapement for those years where the limited block loading strategy was in effect (2008 – 2011) was significantly lower

than for the preceding year’s escapements (2003 – 2007) with a different operational regime.

Overall declines in escapement in the Stave River appear to parallel reduced annual commercial catches and a declining trend in whole river escapement estimates from the Cheakamus River.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

1.1 Background

Since 1980, a number of initiatives have been undertaken to improve the escapement of lower Stave River chum salmon adults downstream of Ruskin Dam. The number of adult chum returning to the river has experienced a 7-fold increase from its 1960-1984 average of just 44,000 individuals (Figure 1). These initiatives have included a hatchery release program to supplement smolt out-migration, a Fraser River exploitation reduction program, and a habitat restoration program which more than doubled the area of spawning habitat in the lower river. Since 1990, Fisheries and Oceans Canada with BC Hydro and other partners have worked to rehabilitate ~60,000 square metres of salmon spawning habitat by recontouring and re-grading the gravel beds below Ruskin Dam (Mike Landiak – DFO, pers. comm.). In addition to these activities, a flow regime was implemented by BC Hydro that restricted the fluctuation of downstream water levels during the chum spawning and incubation periods (Bailey 2002). The objective of the regime was to minimize the risk of adult and redd stranding. However, these restrictions implemented in 1999 were costly in a power generation capacity as they removed considerable flexibility in plant operations which was previously used to match periods of peak power demand.

During the WUP process, an alternate plant operating strategy was proposed. This strategy was designed to take advantage of the initial test digging behaviour and subsequent egg laying patterns of chum salmon and utilize this to minimize the risk of redd stranding. This in turn reintroduced some flexibility in power generation during the spawning and incubation periods. The underlying premise of the strategy was to maintain a relatively high base water level during the spawning and incubation periods such that most of the available spawning habitat was continuously usable and relatively free from the risk of future stranding during the incubation period. Hydraulic simulation modeling found that a constant release of 100 m^3/s was sufficient for this purpose as it allowed most of the spawning habitat to be underwater by at least 10 cm and was sustainable during the spawning and incubation periods in most years. Above the 100 m^3/s base release, all restrictions to generation were removed, allowing plant releases to vary as needed to meet power demands and manage the supply reservoir levels. Because of the contoured banks of the river, a direct result of habitat restoration efforts, the Consultative Committee (CC) accepted the notion that such variable flows would not severely impact the spawning population. Stave River hydraulic modeling indicated that the vast majority of the spawning habitat was located below the 100 m^3/s watermark, and field observations indicated that the variability in velocities would be within tolerance limits of the population. In fact, the CC adopted the view that variability in flows above 100 m^3/s would in the long run be beneficial to fish production, the rationale being that pulsed flows would deter chum salmon from spawning in habitats that are susceptible to dewatering during incubation (Failing 1999).

Studies that support the assertion that peaking flows (in this case flows between100 m^3/s and 325 m^3/s for periods of 4 or more hours) can deter spawning appear limited but are documented. Of three publications referenced, two were reported from the Columbia River (Bauersfeld 1978, Chapman et al. 1986), and the other in New Zealand (Hawke 1978). All of these studies were concerned with Chinook salmon spawning. At the time of project inception, whether these results could be extended to other Pacific salmonids was unknown. In the absence of data to the contrary for WUP purposes it was assumed that this was indeed the case and the concept of ‘partial peaking’ was adopted as part of the Combo 6 WUP operating strategy recommended by the CC, provided that a monitor was carried out to verify results.

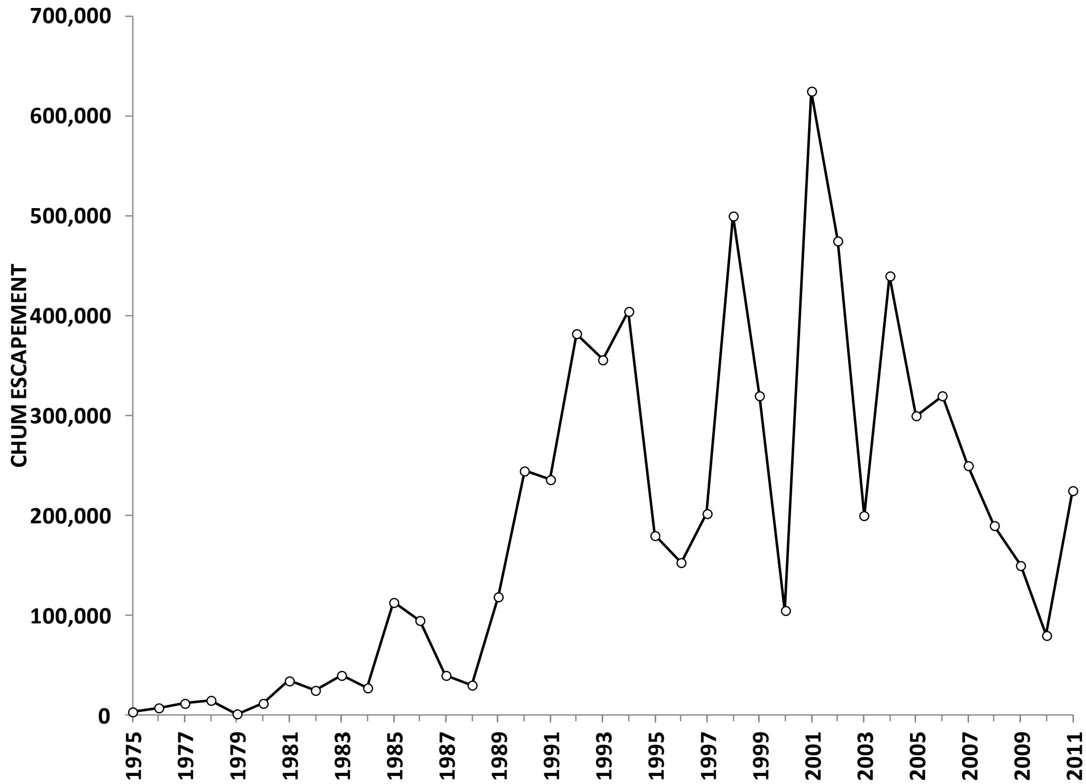

Figure 1. Inch Creek Hatchery (Fisheries and Oceans Canada) adult chum salmon spawning escapement estimates for the lower Stave River, 1975 through to 2011. Annual counts are based on weekly aerial surveys conducted during the late September through early December spawning period.

1.2 Management questions

The key management question addressed by this monitor is whether the limited block loading strategy adopted in the WUP is as successful in maintaining healthy chum salmon populations as was the pre-WUP ‘full’ block loading strategy. Given that the escapement of chum salmon to the Stave system appears to have the potential to reach full capacity (220,000 spawners; Bailey 2002), an increase in average escapement post WUP operations is not expected, largely because of the limiting effects of redd super-imposition on potential fry yield. Instead a more suitable indicator of success would be that average adult spawner escapement does not reduce over time (allowing for external influences: exploitation/marine survival) and that juvenile fry production remains constant over time.

Operating conditions similar to limited block loading operations were imposed immediately after the WUP discussions in 1999, however there were some periods of unrestricted fall peaking and spilling (> 100 m^3/s for > 12 hrs) during the spawning period from 1999 through to 2003 and spilling during a portion of 2006 and 2009 (Table 1). For periods after 2003 (excluding 2006 and 2009 spills) to present, fall limited block loading operations have been implemented without unrestricted fall peaking operations. Given the historic age structure of the spawner population which is comprised of 22.7% Ocean 3, 68.2% Ocean 4, and 8.9% Ocean 5 spawners (Data on file: Inch Creek Hatchery), the first of the dominant Ocean 4 cohort of spawners from the 1999-2003 broods returned during the fall of 2003 through 2007 (Table 2). Post-WUP (mostly pure block loading) Ocean-4 returns would have returned to the lower Stave River after 2008.

Table 1. List indentifying the pre- (prior to 2004) and post- (2004 to present) water use plan operation schedules for BC Hydro's Ruskin facility during the Fall Block Loading period (15 October – 30 November) and concurrent chum salmon incubation period.

Ruskin WUP Operation
(1.1) Fall Block Loading (15 Oct – 30 Nov) - min tailwater of 1.8 m (~70 100 m^3/s) (1.1.1) Discharges from RUS less than or equal to 100 m^3/s To avoid impacting habitat for spawning salmon, discharge from RUS GS may be held constant or increased during the period 15 October – 30 November. Once flows are increased, they may not be decreased while discharge is less than 100 m^3/s. An increase may be initiated only once every 7 days or more and must be conducted over a period of 4 hours or less. (1.1.2) Discharges from RUS greater than 100 m^3/s To keep salmon from spawning in habitat above 100 m^3/s, discharge from RUS GS must be reduced to 100 m3/s every 12 hours or less. The duration of the flow reduction must be 1 hour or greater and may include ramp down time. Ramp down rates are restricted to 113 m^3/s or less every 30 minutes.
Ruskin PRE WUP Operation (previous to 2004)

(i) At all times maintain a minimum tailwater elevation of 1.57 m immediately downstream of Ruskin Powerhouse.

(ii) During the salmon spawning period, between 15 October and 30 November, discharges from RUS must be blocked (no load factoring) on a weekly basis.

During this period the block release can be changed once a week and must remain at that loading for the duration of the week unless an agreement can be reached with DFO and MELP or an emergency is encountered. Between 15 October and 31 October RUS can be block loaded between 10 MW (~50 m^3/s) and 40 MW (~140 m^3/s) and for the month of November RUS can be block loaded between 20 MW (85 m^3/s) and 40 MW. DFO and MELP have to be notified prior to setting block loads between 40 MW and 60 MW (200 m^3/s) during the spawning period (15 Oct - 30 Nov). Loads above 60 MW must be negotiated with DFO and MELP before implementation.

(iii) During the fish incubation period from 1 December to 15 May, for one hour every day, a flushing flow equal to or higher than the maximum blocked release during the spawning period has to be provided.

Table 2. Lower Stave River chum salmon cohorts and the WUP limited block loading operations as deterent to spawning. The years with spawners from pre-WUP broods (yellow), and those years post-WUP (green) with spawner broods which expreienced block loading conditions during both spawning and incubation.

Brood year	Ocean 3 returns	Ocean 4 returns
1999	2002	2003
2000	2003	2004
2001	2004	2005
2002	2005	2006
2003	2006	2007
2004	2007	2008
2005	2008	2009
2006	2009	2010
2007	2010	2011
2008	2011	2012
2009	2012	2013
2010	2013	2014
2011	2014	2015
2012	2015	2016

Pre WUP - Some continual peaking during spawning

Post WUP - Mostly pure block loading, with short durations of continual peak flow

* Pre 2007 adult returns affected by some continual peaking during spawning

* Post 2007 mostly pure block loading operations

Success of the limited block loading operating strategy may not be solely defined by changes in adult escapement numbers. There are risks associated with manipulating daily fluctuations in water level, and one of the most important is the loss or persistent relocation of quality spawning habitat. With changes in flow come changes in local water depth and velocity. Though chum salmon are capable of spawning over a wide range of depths and velocities (particularly in crowded conditions), there are limits to what they can tolerate and they will avoid unsuitable hydraulic conditions if they persist. In considering the limited block load strategy, the CC assumed that within the range of daily fluctuation, hydraulic conditions in mid-channel spawning grounds and key gravel bars would remain within acceptable tolerance limits. This however, has not been verified, and is based primarily on anecdotal information. If, after further investigation, this is not found to be the case the expected benefits of the new operating strategy for spawning chum salmon may not be fully realized. It is possible that if the impact of high flows is severe and detrimental to spawning in these areas then the negative effects on chum spawning in this lower Stave River may outweigh the benefits of block loading efforts.

It should be noted that during this seasonal manipulation of flow there are other risks associated with daily flow fluctuations. The most important of these from a chum salmon perspective is that the daily flow fluctuations could potentially strand adult fish that have yet to spawn. This issue is beyond the scope of the present study and is reported separately in other WUP monitors (Troffe and Ladell 2007).

1.3 Impact hypothesis

This monitoring study focuses on a general test of the partial block loading strategy in terms of its success on sustaining annual escapements of chum salmon. The null hypotheses can be stated as follows:

H_0: Chum salmon escapement at the lower Stave River does not change following introduction of the partial block loading strategy during the spawning period.

1.4 Key water use decisions affected

The key water use decision linked to this monitor is whether to continue with the limited block loading strategy, modify it, or to abandon it if found to be detrimental to spawning success. The limited block loading strategy has never been previously applied in British Columbia and only reported as utilized in a fish conservation capacity in a few circumstances throughout the Pacific Northwest. Its success in BC with chum salmon has yet to be evaluated. If found successful in maintaining high adult yields, this type of operation could be continued on the Stave River system, and perhaps be expanded to other similar watersheds if found not to impact the availability of stable, high quality spawning habitat. Conversely, if the monitor finds that the reproductive success of chum salmon has been significantly negatively impacted, then the strategy will likely have to be modified if possible or even abandoned all together should the impact be considered too great.

2.0 METHODOLOGY

Troffe and McCubbing (2010) analyzed annual (1999 to 2009) Inch Creek Hatchery - Fisheries and Oceans Canada Stave River chum salmon spawner escapement and discharge variability to explore the hypothesis that chum escapement has not changed since the introduction of the fall partial block loading strategy. Their report expanded on the limited block loading observations from Troffe et al. (2008) which explored detailed sets of hypotheses surrounding spawning deterrence at high elevation redd locations.

2.1 Variance in river discharge and brood year size compared with subsequent adult returns

The 1999-2011 hourly averaged Ruskin Facility generation discharges during the fall Limited Block Loading period (October 15th through November 30th) were collated and the annual average and standard deviation was calculated. The average discharge was used as a relative index for the amount of generation, and the standard deviation was used as an index of variability in hourly discharge. The variability in discharge for a given years spawning period was then compared to the abundance of the brood year class and resultant spawner escapement estimates for the dominant cohort which returned to the lower Stave River four years later (e.g. 1999 discharge variability and 1999 brood estimate linked to 2003 spawner counts). A multiple regression analysis was then used to examine the range of influences Ruskin operational discharge and brood abundance may have on the future abundance of returning ocean aged 4 spawners. All variables were natural log transformed and assumptions of linearity, normality, and equality of variance were examined before regression analysis. All statistical analyses were performed according to procedures outlined in Zar (1984).

2.2 Escapement comparisons among populations

The average spawner escapement before and after 2007 (first cohort unaffected by pre-block load operations) and onward through to 2014 was compared to those years before the limited block loading strategy was implemented. Overall escapement trends were also compared to total coast wide commercial chum catch estimates and another southern BC proximate population (Cheakamus River). Troffe and McCubbing (2010) compared Stave River chum escapement to other regional chum escapement data sets (Alouette and Coquitlam Rivers). This was not done in the present study. Alouette River chum escapement estimates have been found to be inaccurate (Scott Cope, pers. comm.) and annual FRCC-ARMS Hatchery fish fence counts are unlikely to reflect true escapement. In the case of Lower Coquitlam River, chum escapement was not directly measured. Rather it was inferred from smolt counts (Decker et al. 2009).

Escapement data for adult chum salmon on the Stave River system tends to be highly variable from year to year (*see:* Figure 1 and Bailey 2002). Testing of the limited block loading hypothesis should be more effective as more data is gathered and potentially additional determinants built in to the model. This analysis should not be relied upon on its own as an assessment of the operating strategy's value, rather used as part of a weight-of-evidence approach.

3.0 RESULTS

3.1 Discharge profiles 1999-2011

Operating conditions similar to blocking loading operations were imposed immediately after the WUP discussions in 1999, however there were some periods of unrestricted fall peaking and spilling (> 100 m^3/s for > 12 hrs) during the spawning period from 1999 through to 2003 (Figure 2) and spilling during a portion of 2006 (Figure 3) and 2009 (Figure 4). For spawning periods after 2003 (excluding 2006 and 2009 spills) to 2011, fall block loading operations have been implemented without unrestricted fall peaking operations (Figures 3 & 4).

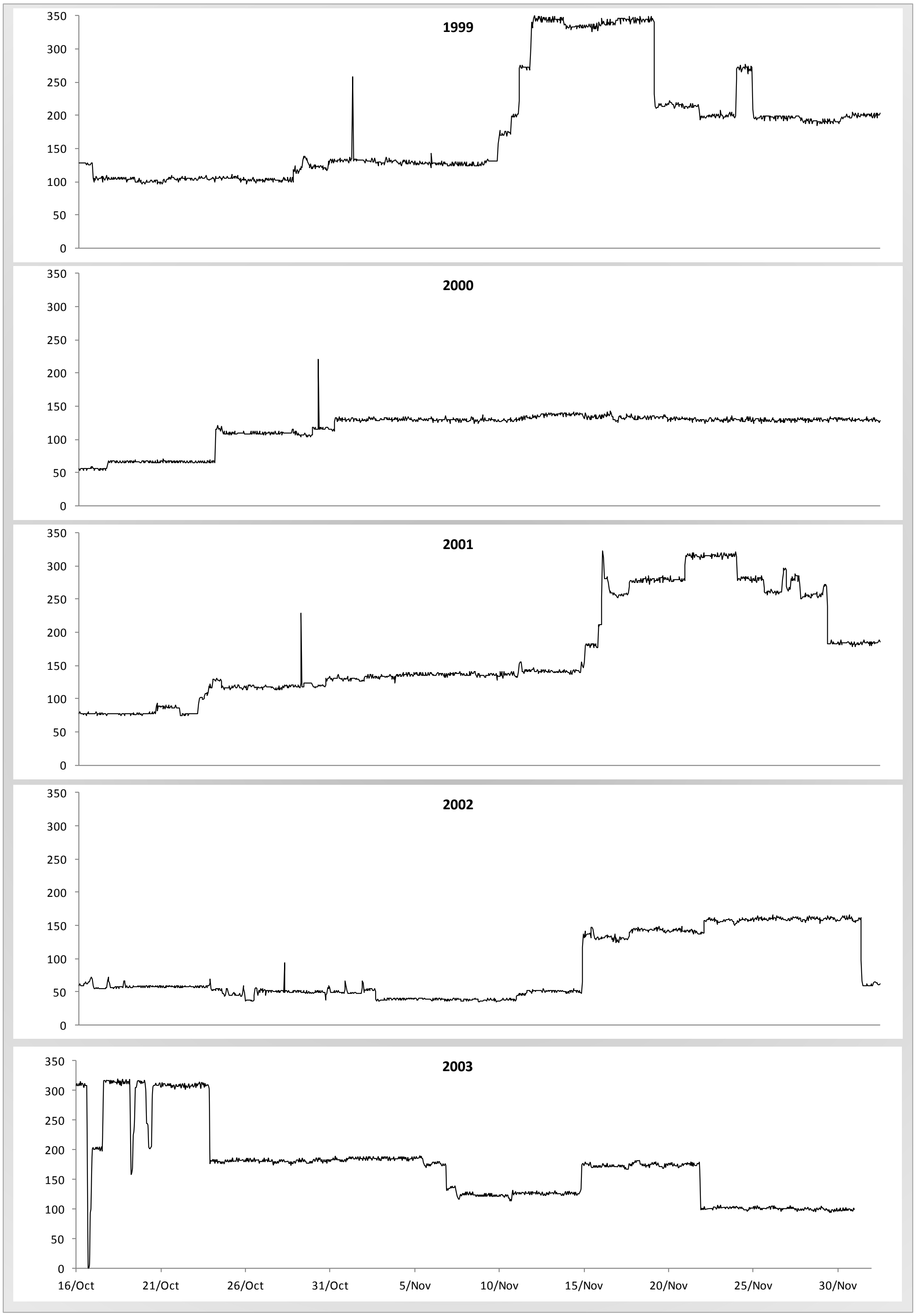

Figure 2. Hourly Ruskin discharge (m^3/s) profile during chum spawning season (October 15 – November 30) for years 1999 – 2003 (pre-WUP operations).

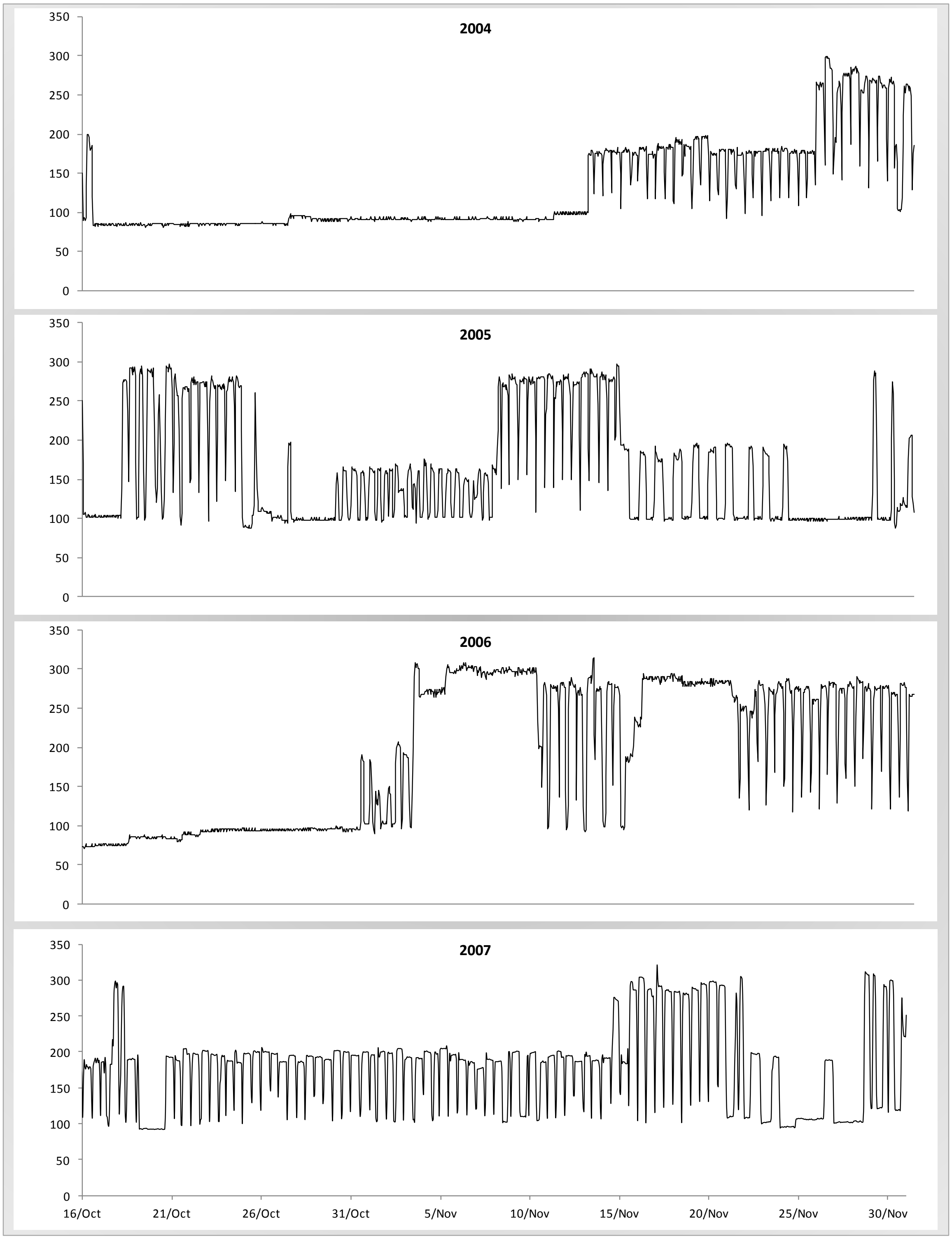

Figure 3. Hourly Ruskin discharge (m^3/s) profile during chum spawning season (October 15 – November 30) for years 2004 – 2007 (post-WUP operations).

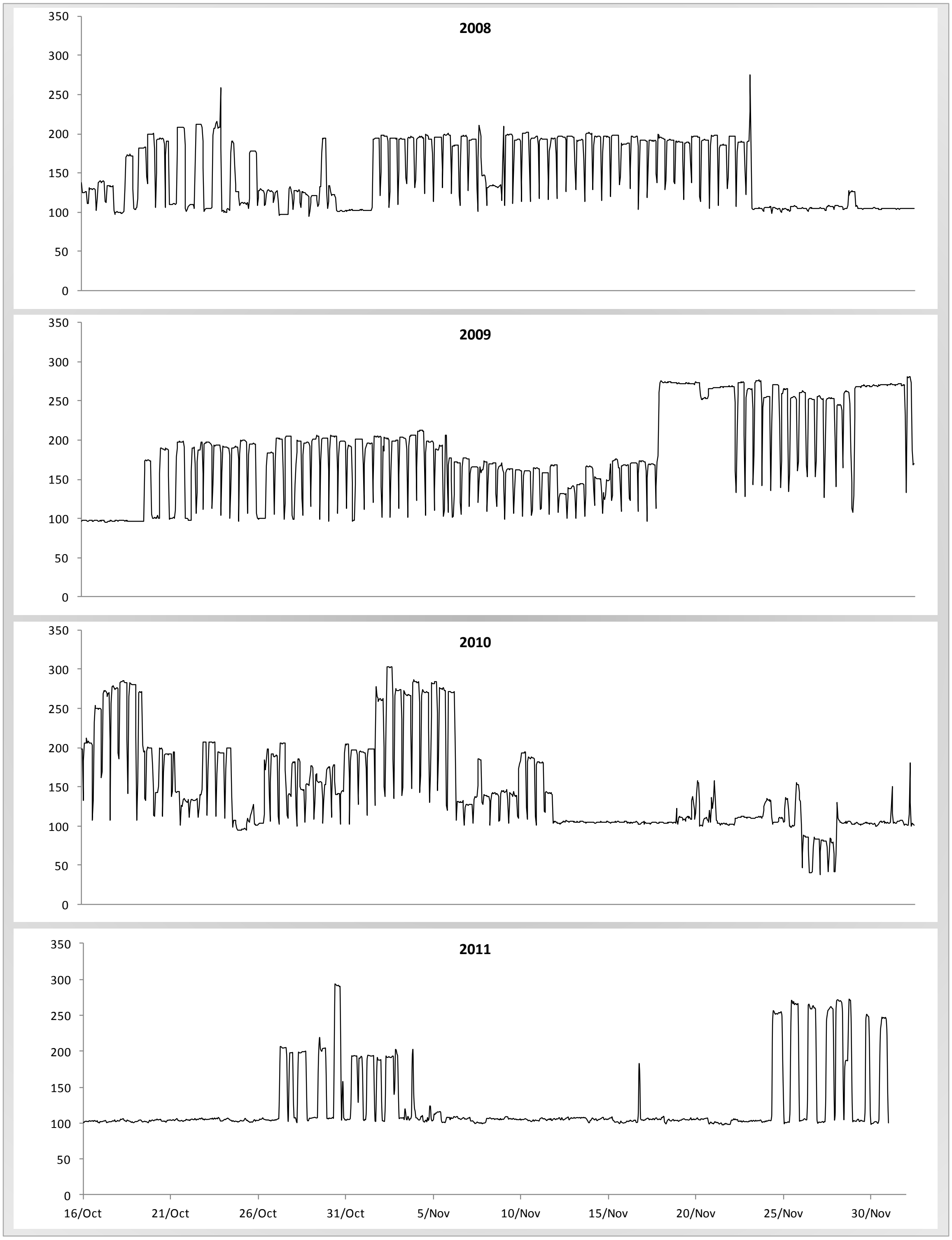

Figure 4. Hourly Ruskin discharge (m^3/s) profile during chum spawning season (October 15 – November 30) for years 2008 – 2011 (post-WUP operations).

3.2 Average discharge and variance

There is a significant difference between the average spawning period discharges observed before and after WUP operations, (145.3 ± 73.2 m^3/s; 1999-2003 vs. 160.3 ± 66.4 m^3/s; 2004-2011) with discharges from the 2004-2011 fall limited block loading operations being higher than those observed prior to WUP implementation (ANOVA - $\rho<0.001$ (Figures 6 & 7). The lowest average chum spawning period discharges were observed during the pre-WUP fall block loading operations in 2002 (84.2 ± 48 m^3/s) and the highest average discharges were recorded post-WUP during 2006 (196.5 ± 90 m^3/s) (Figure 6).

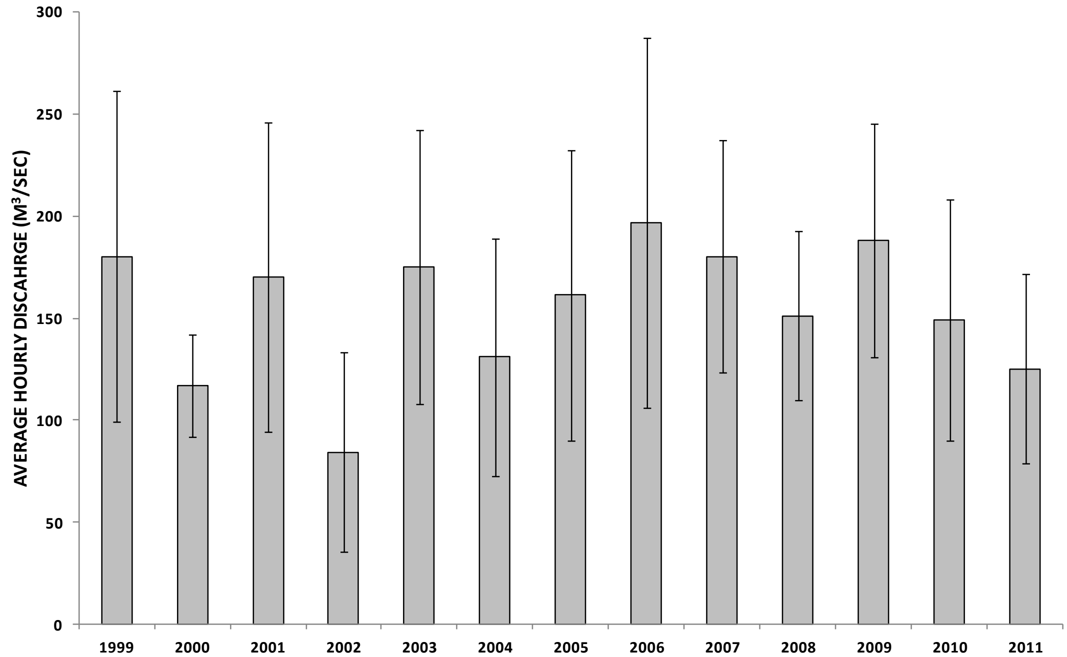

Figure 5. Average hourly (±S.D.) Ruskin discharge profile during chum spawning season (October 15 – November 30) for years 1999-2011.

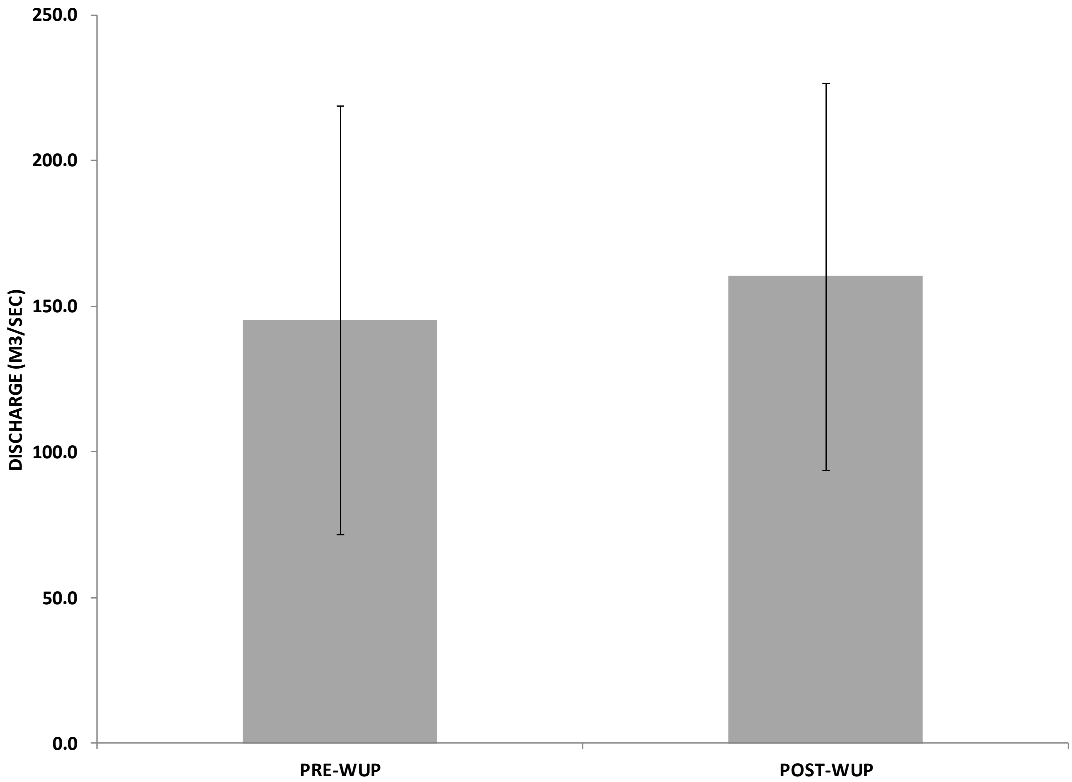

Figure 6. Average hourly (±S.D.) Ruskin discharge during chum spawning season (October 15 – November 30) for years pre-WUP (1999-2003) and post-WUP (2004-2011).

3.3 Escapement estimates

Escapement estimates for lower Stave River chum over the last decade have been highly variable and estimates ranged from a low of 80,000 spawners during 2010, to over 625,000 spawners during 2001 (Figure 1, Appendix I). Chum adult returns for the period spanning 1999-2011 averaged 295,909 but with high variance of ± 160,372 (SD). Eight of the 13 years since 1999 have had escapement estimates above the calculated 220,000 spawner habitat capacity estimated by DFO (DFO Inch Creek Staff and Matt Foy, pers comm.). Average chum spawner escapement for adult progeny of the post-WUP brood (2008 – 2011) was significantly lower (161,250) than for adult returns (302,000) affected by the full block loading operations (1999 – 2003). Hatchery supplementation to the lower Stave River by Inch Creek Hatchery (DFO) was terminated after 1998 and it is estimated that 1999-2003 returns received between 30,000 to 65,000 hatchery raised progeny distributed among the Ocean 3-Ocean 5 cohorts (Bailey 2002, Stu Barnetson pers comm.).

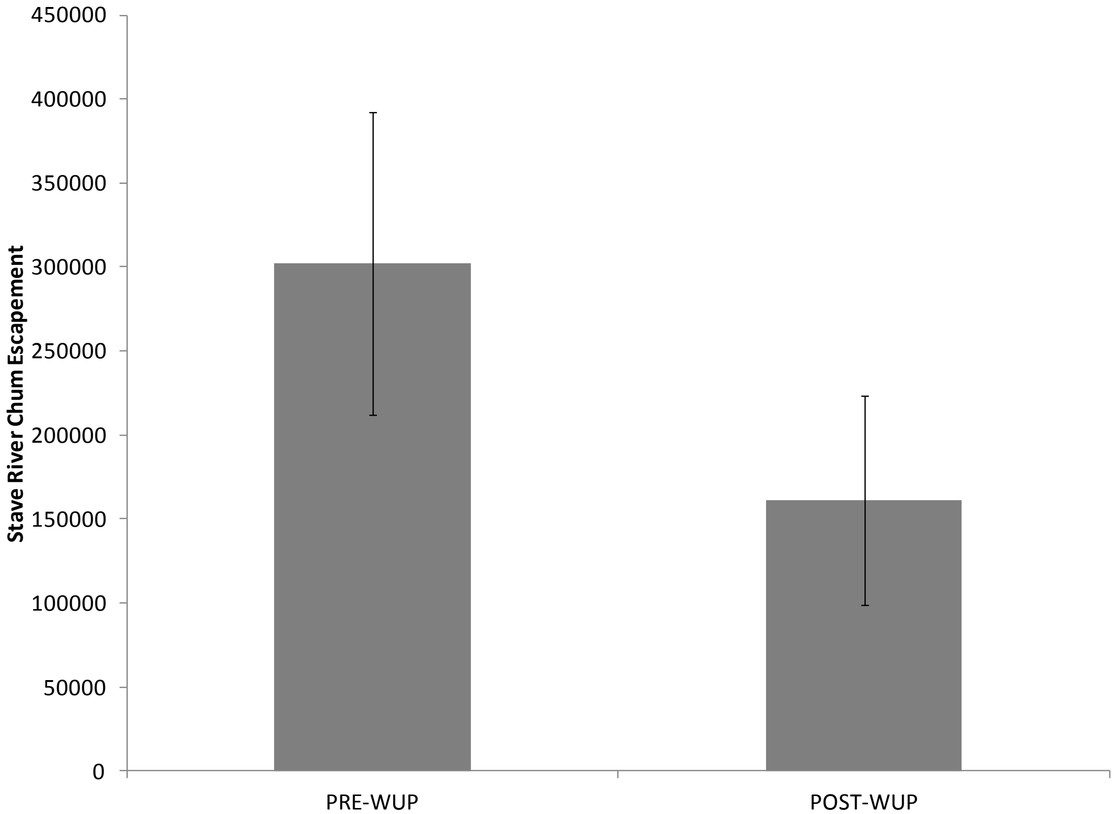

Figure 7. Average (± SD) escapement of chum salmon to the Stave River before (2003 – 2007) and after Water Use Plan implementation (2008 – 2011 Ocean 4 returns)

3.4 Variance in discharges and brood versus future escapement

To test the relative potential influence that discharge and brood strength has to future spawner escapement a multiple regression analysis was performed after a simple linear regressions comparing discharge variation or brood abundance to future escapements suggested that there could be a weak positive relationships (r^2=0.54 ; 0.06 respectively) between these factors and the resulting future escapements (Figure 8) The dataset was natural log transformed and tested for the assumptions of linearity, normality, and equality of variance. Scatter plots of the transformed data and residuals demonstrated that a linear relationship was appropriate and that variance was approximately equally among variables. The skewness and kurtosis of the transformed dataset ranged within -1 to +1 suggesting normality.

Correlation and multiple regression analyses were conducted to examine the relationship between chum escapement and two potential predictors, discharge and brood escapement. Table 3 summarizes the descriptive statistics and analysis results. Variation in discharge is negatively and significantly correlated with the criterion, indicating that higher scores on this variable tend to have lower future spawner abundance. The multiple regression model with both predictors produced $R^2 = .609$, $F = 4.68$, $p = .0596$. As can be seen in Table 3, brood escapement had positive but non-significant regression weight, indicating that it did not contribute to the multiple regression model. The discharge variance has a significant negative weight (opposite in sign from its correlation with the criterion), indicating those years with higher discharge variation would be expected to have lower future spawner abundance (a suppressor effect).

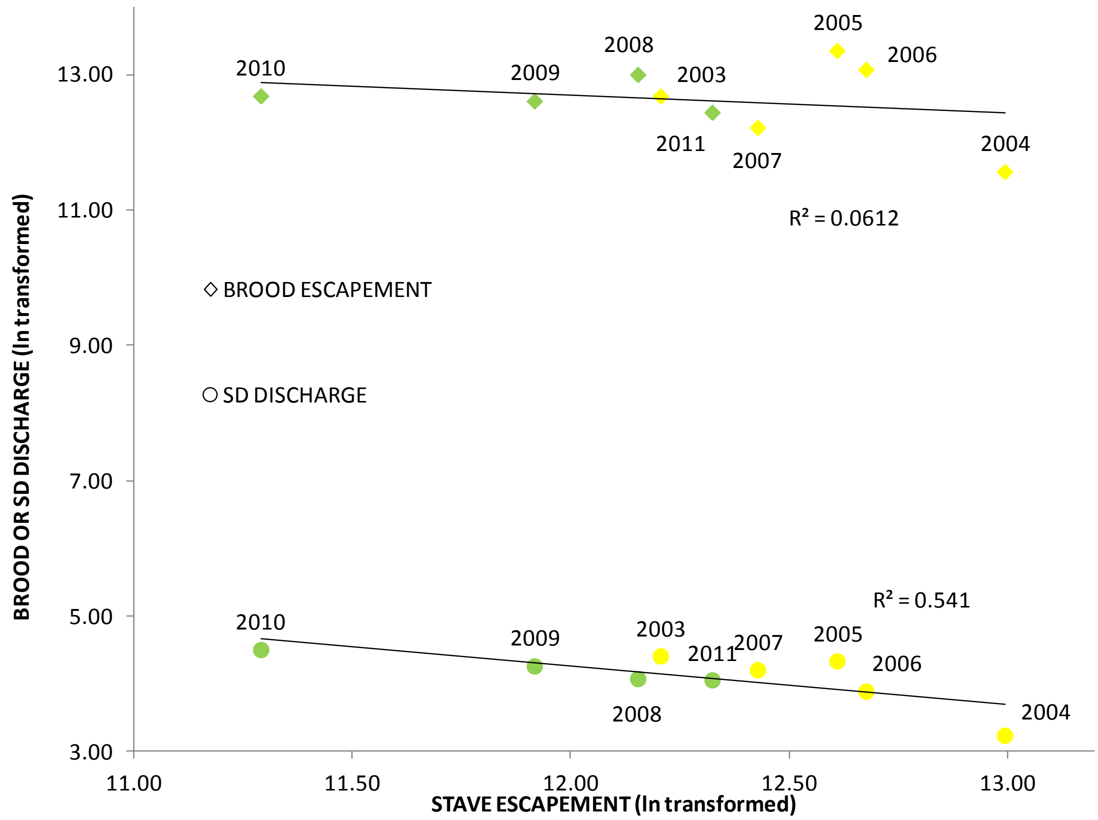

Figure 8. Comparison of natural log transformed brood abundance (diamonds) and standard deviation of hourly averaged Ruskin discharge (circles) during fall limited block loading compared to resultant lower Stave River chum salmon (Ocean Age 4) escapement estimates. Yellow markers (2003 – 2007) indicate escapement years prior to limited block loading. Green markers (2008 – 2011) show chum counts influenced by limited block loading

Table 3. Summary statistics, correlations and results from the regression analysis of brood escapement size and the variance in Ruskin fall limited block loading operational discharges influencing future spawner abundance.

Multiple regression model	Value
r^2 (model fit)	0.61
Adjusted r^2 (model fit)	0.48
ρ - value	0.0596
Discharge S.D: ρ - value; standardized β	0.03 ; -0.94
Brood cohort: ρ - value ; standardized β	0.34 ; 0.34

3.5 Escapement comparisons among other chum populations

The lower Stave River chum escapement estimates have been highly variable over the last decade and averaged more than 295,000 (SD) spawners annually (Figures 1 and 10). Other south coastal chum populations show similar proportional escapement variability. The relative standard deviation for 2001 – 2011 chum escapements in the Stave (54%) is lower than that seen in a nearby watershed, Cheakamus River (62%) (Figure 10). Historic coast-wide total commercial chum catches from British Columbia reported by DFO during 1996-2011 have also been highly variable (CV = 76%) ranging from a low of 109,020 (2010) to a high of over 4.4 million fish in 1998 (Figure 10; Appendix I); (DFO Commercial catch statistics 2011; McCubbing et al. 2012; Troffe et al. 2007-2009).

Lower Stave River chum estimates compared to Cheakamus River estimates (Figure 11) or historic coast-wide DFO commercial catch (Figure 12) show a non-significant relationship. Given the calculated capacity of 220,000 spawners it could be speculated that during the last decade the lower Stave River population has been near or exceeding theoretical production capacity, while the smaller systems are operating below production capacity (Figure 10; Appendix I).

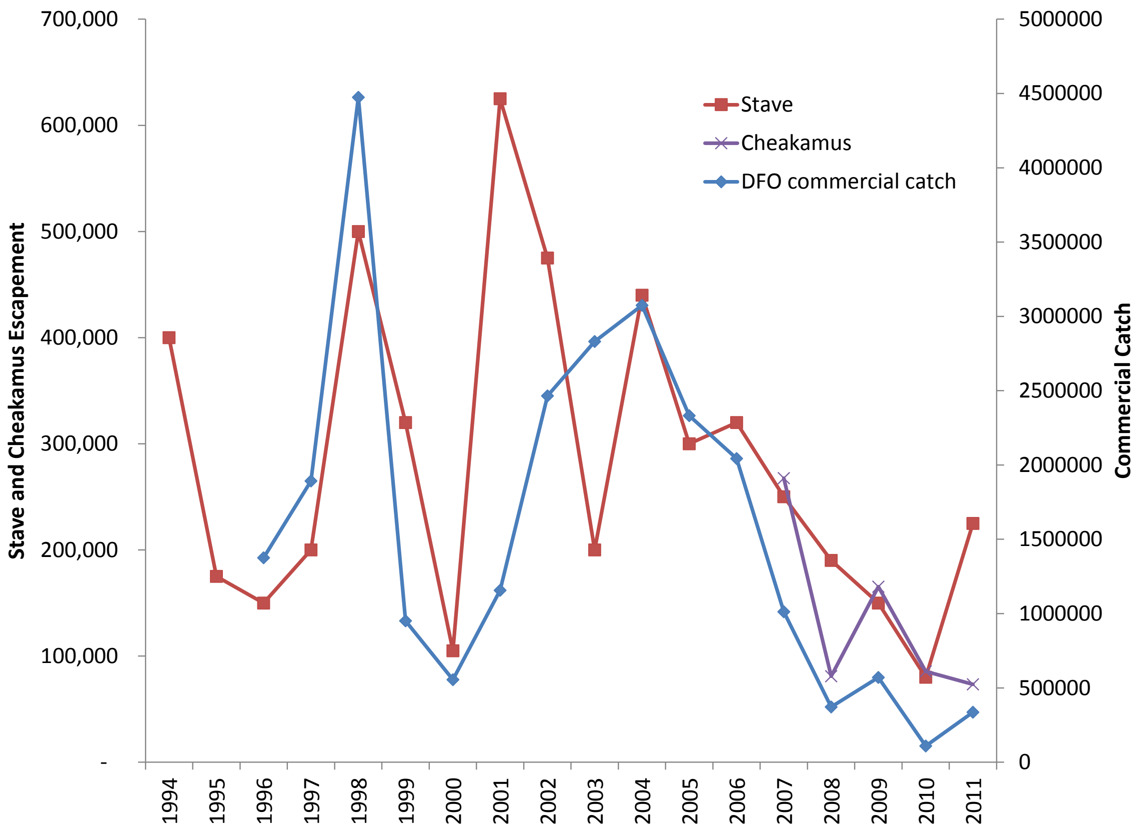

Figure 9. Annual chum adult salmon escapements from the Stave River (1994 – 2011), Cheakamus River (2007 – 2011) and DFO coast-wide commercial catch records (1996 – 2011).

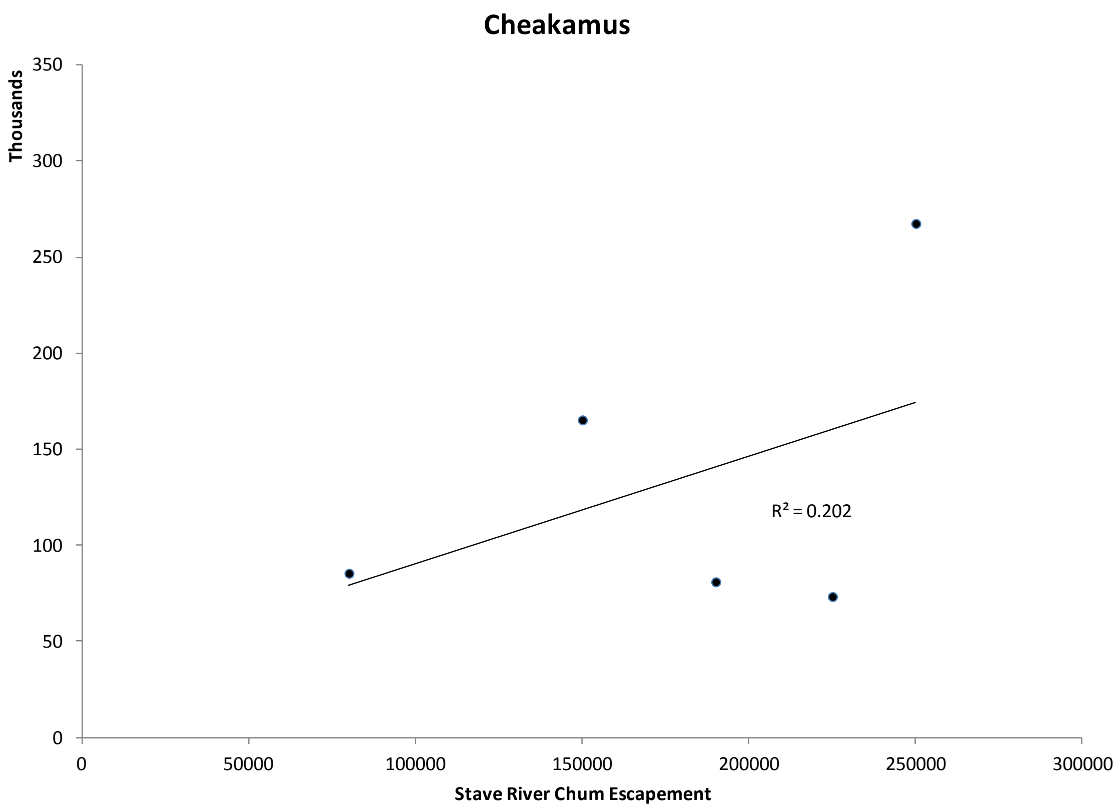

Figure 10. Cheakamus River full river escapement estimates versus lower Stave River chum escapement estimates (2007-2011 dataset).

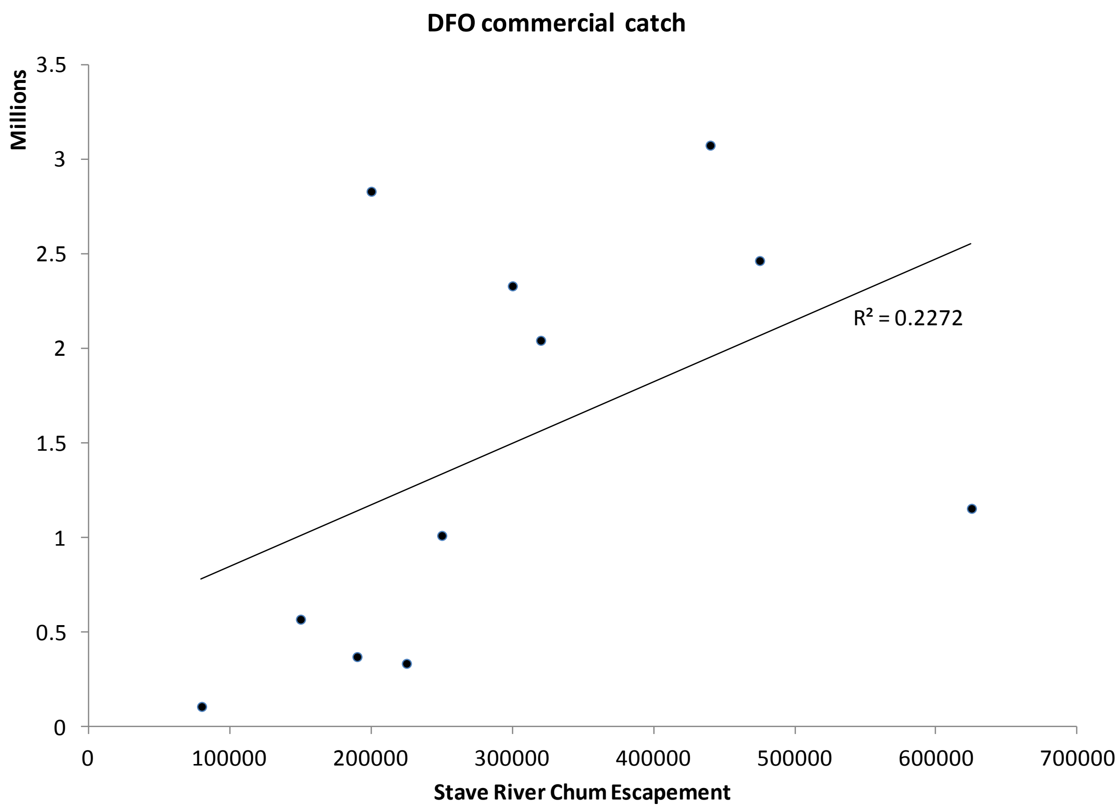

Figure 11. DFO commercial coast wide harvest estimates of chum salmon in British Columbia versus lower Stave River chum escapement estimates (2001-2011 dataset).

4.0 DISCUSSION

There have been a few surveys exploring long term chum salmon escapements in rivers with regulated discharges; however, some recent behavioural observations suggest that given appropriate habitat, chum salmon can be resilient to reasonable variations in river discharge. Troffe et al (2008) suggested that the variances in discharge from the fall limited block loading operation appear partially successful at reducing spawning chum salmon from utilizing sub-optimal high elevation spawning habitat in the lower Stave River. A preliminary analysis of chum escapement and Ruskin discharge completed by Troffe and McCubbing (2010) found no significant relationship between chum escapement and predictors but was based upon only 2 years of post-WUP return data. In another recent study, Tiffan et al. (2010) observed that when water velocities below Bonneville Dam on the Columbia River were less than 0.8 m/sec during elevated discharges, female chum salmon stayed close to their redds but exhibited reduced digging activity as water velocities increased. When velocities exceeded 0.8 m/sec, females that remained on redd sites exhibited increased swimming activity and digging virtually ceased. When velocities became unsuitable chum salmon left redd sites and occupied nearby refuges with suitable velocities, but returned to their redds after discharges returned to base levels.

Previous examination of chum data (Troffe and McCubbing 2010) analyzed seven years of escapement (2003 – 2009) and its relationship to escapement and variation in discharge for the requisite Ocean 4 brood years (1999 – 2005). The multiple regression model for these predictors showed no significant relationship for the model nor either predictor. For this report two additional years (2010 & 2011) of escapement data were added to the time series. The additional data points weakened the relationship between brood year abundance and future Ocean 4 escapement (r^2 = 0.06) but slightly strengthened the regression between brood year discharge variation and future escapement (r^2 = 0.54). Although the multiple regression model was not statistically significant (ρ =

0.0596) the results suggest the additional data has strengthened the model considerably. Within the model, discharge variance had a significant negative weight indicating that years with higher discharge variation would be expected to have lower future spawner abundance. Limited block loading which starts in 2004 is characterized by more stable and slightly lower annual flow variation. The coefficient of variation for annual flow over the spawning period ranged from 0.22 to 0.58 in the pre-WUP years. After block loading operations were implemented in 2004 the annual flow CV range tightened from 0.27 to 0.46 with the highest CV occurring in 2006 when an unrestricted spill happened.

The Ruskin discharge profile for the chum spawning period (October 15 – November 30) pre- and post-WUP remain significantly different with the addition of the 2010 and 2011 profiles. Post-WUP discharges (2004-2011) were significantly higher than those recorded pre-WUP (1999-2003).

The average post-WUP escapement (161,250) is significantly lower than the average pre-WUP escapement (372,857). This result requires several caveats on interpretation. Troffe and McCubbing (2010) were unable to make a pre/post WUP comparison of escapement because of the low number of post-WUP data points (2 years – 2008 & 2009). This analysis compares seven years of pre-WUP chum returns with 4 years (2008 – 2011) of post-WUP returns. Furthermore, chum escapement in the Stave River had been declining since 2004 which was well before WUP affected adults returned to the river. The trend pattern seen in the Stave River is broadly mirrored in the DFO commercial catch data. Post-2003 commercial chum catch data is highly correlated ($r^2 = 0.85$) with Stave River escapement.

The results of this analysis which incorporates two additional years of data over what was reported by Troffe and McCubbing (2010) remain inconclusive with respect to determining what effect limited block loading has upon adult chum escapement in the lower Stave River. Evaluation of two predictors identified in the prior reporting indicates that annual variance in discharge at Ruskin Dam during the chum spawning period (October 15 – November 30) may have some impact upon the escapement of future Ocean 4 chum adults. Additional year's data should increase the power of regression analyses carried out here. Previous WUP monitors indicated that fry and adult stranding were difficult to tie solely to discharge and that the tidal influence from the Fraser River plays an important role (Troffe and Ladell 2007; Troffe and McCubbing 2009). Adult stranding during operational drawdown during normal block loading operations was low (~ 0.4%) but increased by a factor of two when spilling occurred. Fry stranding during the spring block loading period was not only related to discharge but also to the timing of chum emergence and the frequency of operational drawdowns.

The escapement of chum from the Stave River is undoubtedly affected by a variety of factors over and above brood escapement and discharge from the dam. Annual commercial exploitation rates, marine survival, homing rates and terminal losses due to angling activities in approach waters, FN catches, poaching and natural deaths are all parameters that have some influence on escapement. Chum salmon escapement in the lower Stave River has been in general decline since 2004. This broad decline in numbers appears to be coincident with declines in other chum rivers (Cheakamus) and with an overall decrease in annual commercial catch reported to Fisheries and Oceans Canada. The ability to separate out Stave escapement trends due to Ruskin operational changes from other intrinsic parameters remains, at this point, difficult. The addition of supplementary data to the time series through to the end of this monitor may help further resolve trends in the data set and assist in identifying other predictors of escapement to test the success of the partial block loading strategy on chum escapement.

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6.0 APPENDIX I – Historic chum salmon estimates

Year	Commercial catch[1]	Stave R.	Coquitlam R.	Alouette R.[2]	Cheakamus R.
2001	1155873	625000			
2002	2465308	475000	18900		
2003	2831447	200000	21300	10727	
2004	3075055	440000	29000		
2005	2331637	300000	33150	76191	
2006	2043946	320000	53600	150734	
2007	1012674	250000	12500	16502	267574
2008	372250	190000	18200	71980	81000
2009	570052	150000	26000	153882	165318
2010	109020	80000	4000	41312	85461
2011	336720	225000	35000	25042	73337

[1] Coast wide catches sourced from: http http://www.pac.dfo-mpo.gc.ca/stats/comm/summ-somm/index-eng.htm - accessed August 29, 2012

[2] Annual FRCC-ARMS Hatchery fish fence counts, S. Alouette River (data courtesy of FRCC-ARMS) used as indicator of relative chum escapement.