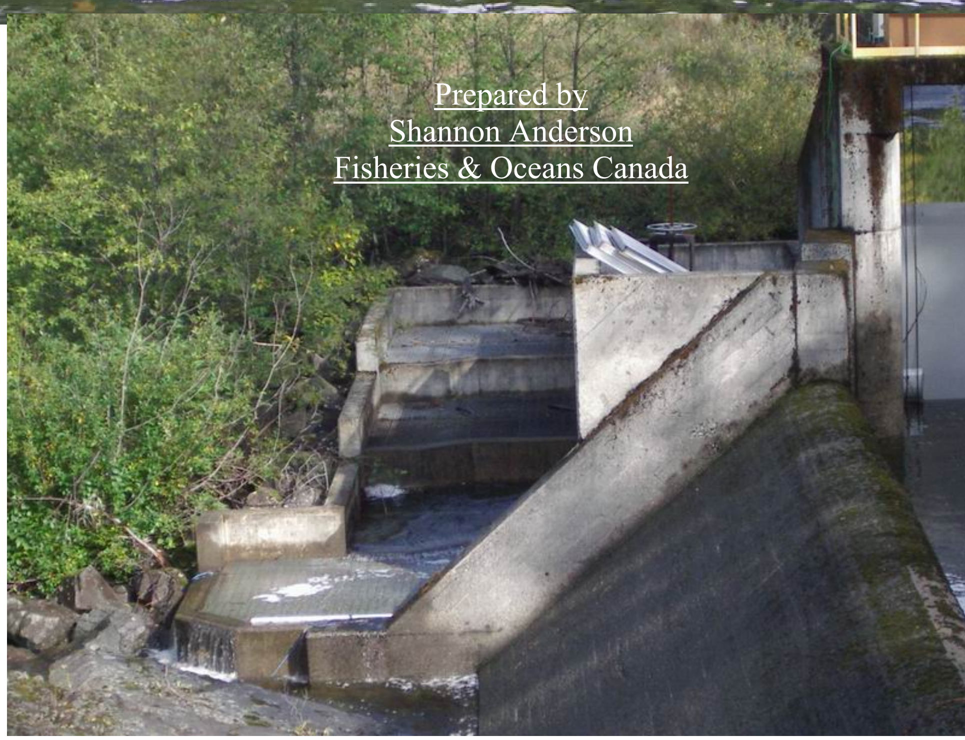
Salmon River Adult Fish Passage Assessment Study
Project #07.CBR.04



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For
BCHydro
Bridge Coastal Fish and Wildlife Restoration Program
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Executive Summary

The Salmon River is amongst the largest watersheds on Vancouver Island with a drainage area in excess of 1200km^2. The 5.6m BCHydro diversion dam may interrupt access for upstream migrating adult salmonids to over 50km of mainstem and tributary habitat in 268km^2 of watershed upstream. The upper Salmon River has valuable Coho spawning and rearing habitat (Craig et al. 1998, Wong, R. and V. Komori. 1999) that will become increasing important with the effects of global climate change. Utilization of the entire accessible watershed is important to the biodiversity of Coho populations; access to headwater habitats will be key to salmonid survivals through warming periods. These higher elevation habitats will warm the least and retain the most snow, as well as provide some protection against the increased intensity of winter storm discharges. This pilot study was initiated to determine if the returning Coho adults found the Fishway structure, if they successfully transited the diversion facility, under what flow conditions, and if possible understand the period of delay for upstream migrants. The results from the resistivity counter and the acoustic tagging program do provide some insight into the relationship of the migrating Coho to the changes in the Salmon River discharge; the configuration of the undersluice gate opening, mainstem flows and diversion flows are all important considerations in how the Coho behave. Mainstem discharges to 30m^3/sec, with the undersluice gate opening to nearly 1 meter, resulted in net upstream Coho migration, however with the undersluice gate decreased to 0.15m Coho were attracted to the fishway, but net upstream counts were negative during most flows. Only a few appeared to successfully move upstream through the fishway when the discharge to the lower river was 10-12 m^3/sec (adjusted by subtracting diversion canal flows from mainstem above the diversion). The acoustic tag information mirrors the resistivity counter finding. This appears to point to some obstruction, whether velocity or behavioural, within the fishway itself even at fairly low downstream discharges. Surface water level differences, from the canal to river downstream, and turbulence within the fishway will require further investigation.

The 2008 study has established a foundation of information, communications, procedures and logistics that will be built on with the continuation of this study. Through understanding the limits or bottlenecks, if any, to upstream migration of both Coho and steelhead adults at the Salmon River diversion dam we can better formulate practical solutions to adult upstream fish passage.

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Introduction

The Salmon River drains a watershed of nearly 1300 km^2, flowing into Johnstone Strait at Kelsey Bay, 90km from its headwaters, on the east coast of Vancouver Island. (Fig. 1). A diversion dam (5m high, 73m long) and canal were constructed in 1958, 54.2 km upstream from the mouth (Burt and Robert, 2002) to supply water, when available and required, for hydroelectric generation in the Campbell River watershed (Fig. 2). The Salmon River above the diversion dam drains a watershed area of 268 km^2 (http://scitech.pyr.ec.gc.ca/waterweb/fullgraph.asp). Diverted Salmon River water flows 14km through a series of flumes, channels and lakes to Lower Campbell River, providing generating capacity for both the Ladore and John Hart facilities. Maximum diversion capacity of the canal is $42.5m^3$/second (m^3/sec), to a water license maximum of 493.4 million cubic meters annually.

A 1971 inspection identified a rock and debris jam in the steep walled canyon 38km from tidewater and about 12km downstream of the diversion dam (BCRP Vol 2. 2000). In 1975-76 BC Fish and Wildlife Branch blasted the rocks, removing this barrier to migrating salmonids. In 1986 a screen was installed in the concrete canal section 500m downstream of the intake to intercept smolts entrained in the diverted water, redirecting them back into the Salmon River. The Sayward Fish and Game Club initiated a program of Coho fry stocking to the lakes and streams upstream of the diversion in 1989 using broodstock collected in the lower river. Fish migration upstream of the diversion dam was only possible when flows were favourable for passage through the undersluice gate at the dam up until the construction of a fishway at the diversion in 1992 (BCRPVol 2 2000). The fishway is a concrete 8 step structure with submerged slots, spanning an elevation of about 2.25m, sill slab to slab (0.3m each step). The top of the trimming wall at the site is 4.25m above the top sill of the fishway, at higher flows water cascades over the dam and trimming weir. (Fig. 3). The discharge at which water flows over the dam and canal walls depends on the setting of the undersluice and radial arm gates

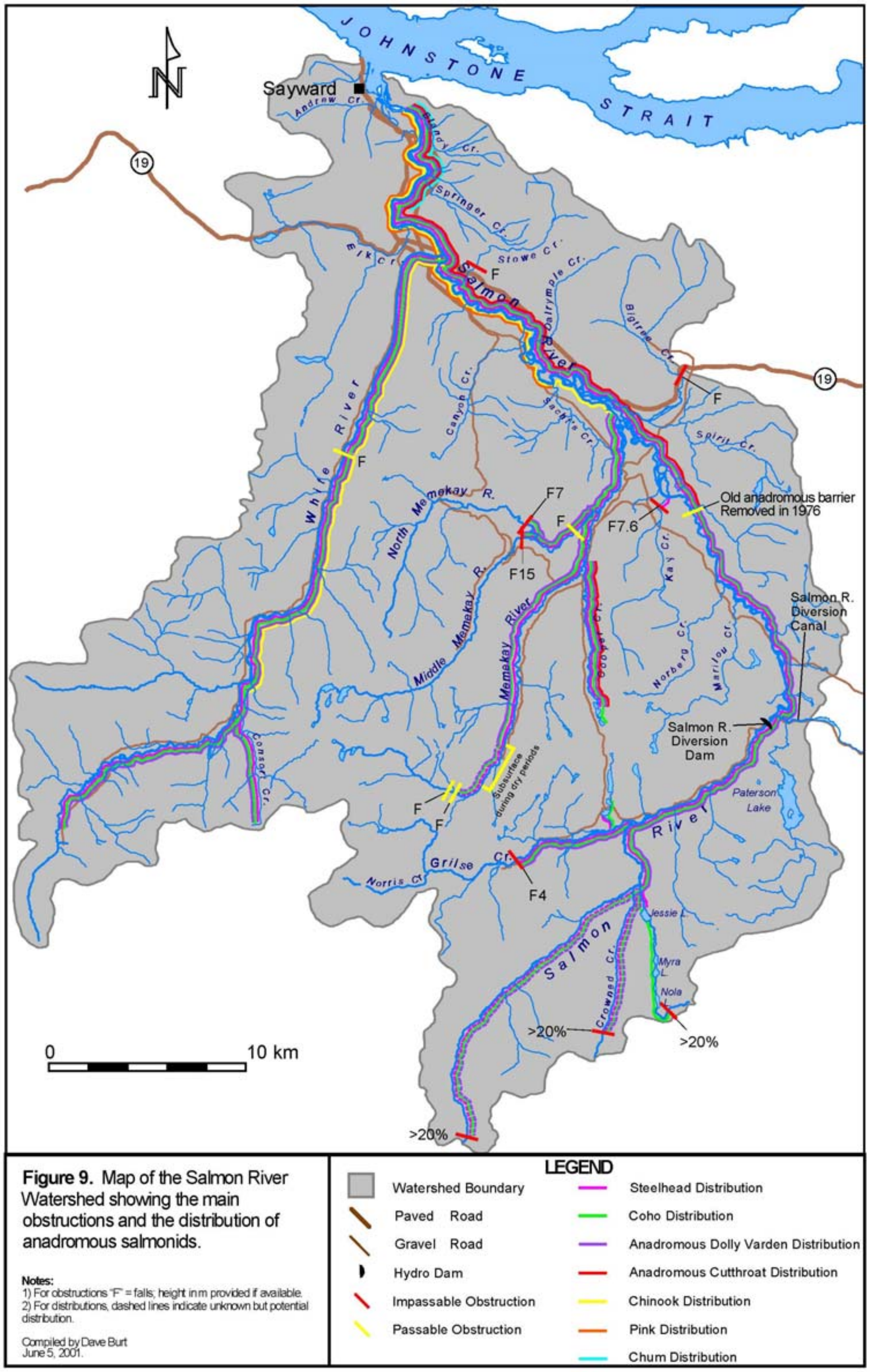


Figure 1. Salmon River Watershed 1300km^2- from Burt and Robert 2002

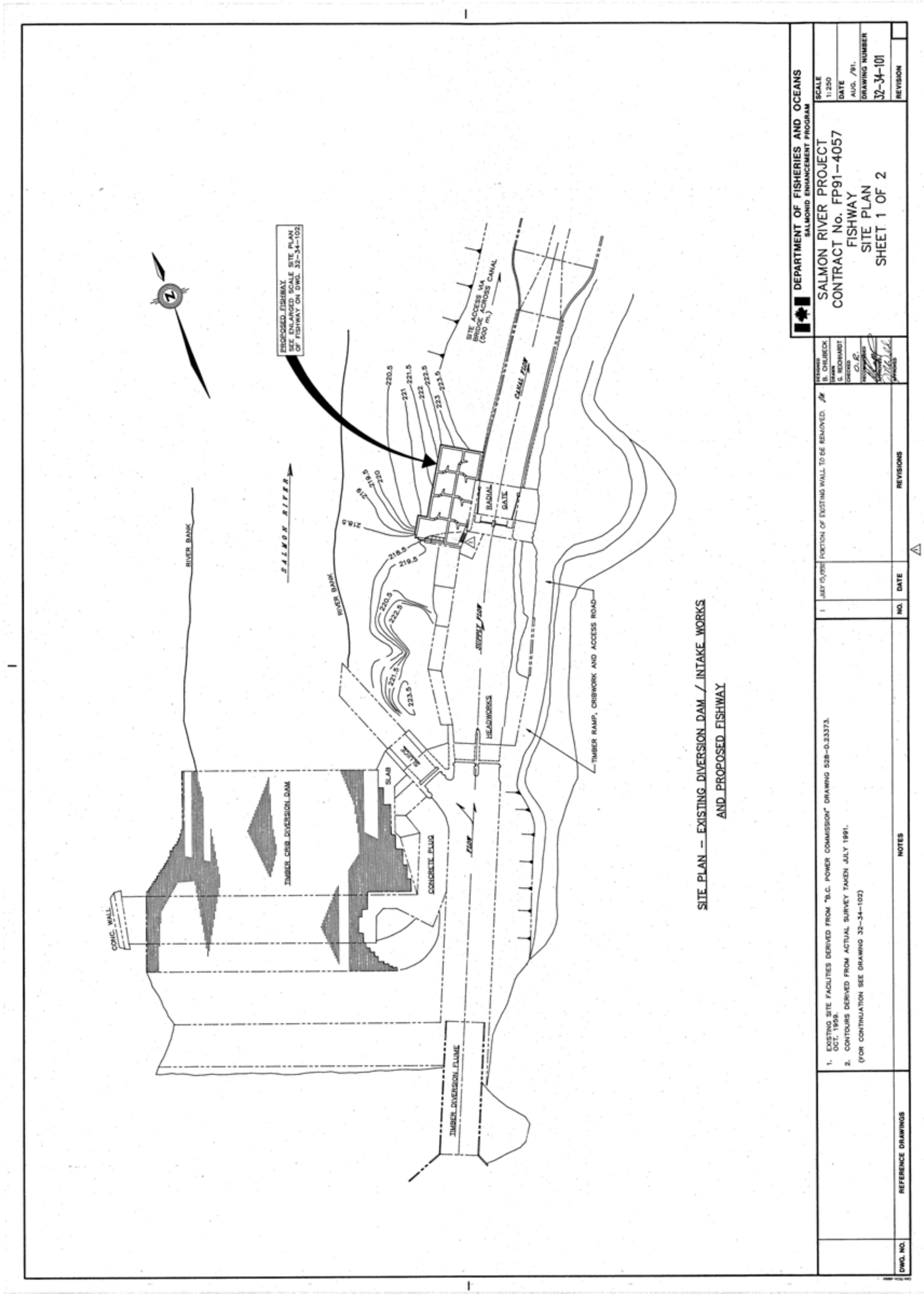


Figure 2. Salmon River Diversion facility drawing (DFO)

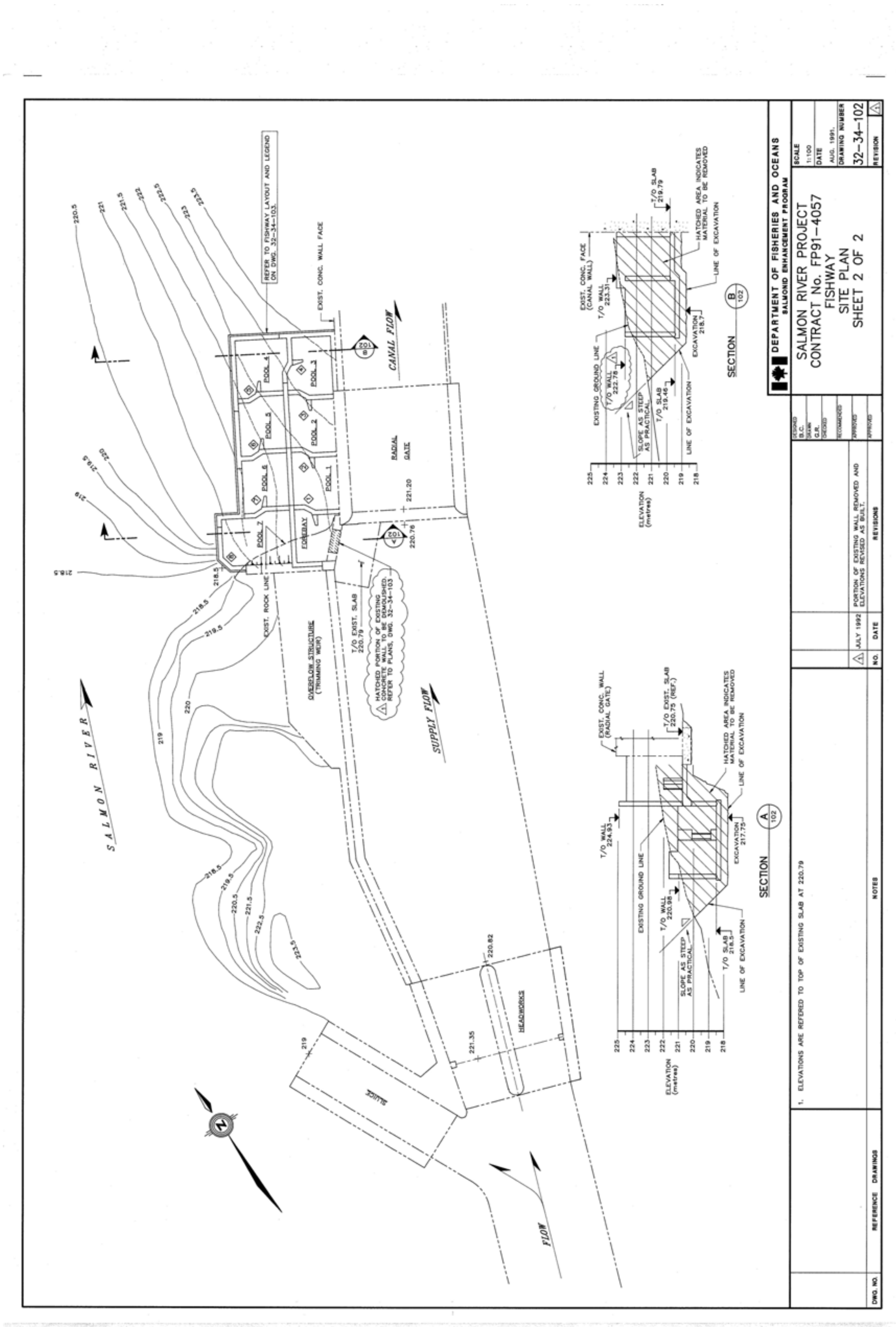


Figure 3. Fisheries & Oceans Canada (DFO) Fishway design site plan view with sections, showing steps and total elevation change, river to canal, canal wall is 4m above top cell entrance

Modifications were done in 1999 to improve the screen efficacy, especially for fry and parr that could pass through the original mesh (Burt and Robert 2002). Additionally, the screen is only functional at screening juvenile salmonids when the diversion is less than 15m^3/sec or 2m water level in the canal, (much below the capacity of 42.5m^3/sec) as the screen begins to lift off the bottom of the canal, resulting in fish passing through the diversion canal to the Campbell system. This also becomes an issue at lower diverted flows if debris builds up on the screen, causing it to lift. The result is limits to the diversion capacity during the periods when the screen must be in; typically periods of fish migration when the temperature is over 5.5C. Both adult Coho and steelhead, and juvenile Coho have been observed in the canal and the lakes leading to the Campbell system, as well as in the reservoirs themselves (juveniles).

The habitat upstream of the diversion has been assessed on a number of occasions (Burt and Robert 2002, Wong, R. and V. Komori. 1999, Craig et al. 1998). All the assessment studies have rated the upper reach as valuable steelhead and Coho habitat. Observations and juvenile surveys in recent years have identified naturally produced fry in the area (Pellett 2008), suggesting that adults are successfully accessing the upper watershed. However, it is unknown if or when the Coho and steelhead adults successfully migrate through the fishway or the undersluice gate, or if some that reach the diversion eventually spawn below the diversion, or end up downstream in the diversion canal.

The Water Use Plan (WUP) for the Campbell River system, completed in 2004 (not yet signed by the Comptroller of Water Rights June 2009), has identified an operational period for the screen as April 1 through December 31. Recently (fall 2008) the time frame was amended, allowing the screen to be locked out of fishing position when water temperatures reach 4.5C for 3 days, as the screen is susceptible to damage from ice build up. Also included in the WUP is the provision of 30 m^3/sec diversion flows during screen operation – only if the structure is improved such that migrating fish are not negatively impacted. The impact of this increased flow on adult passage through the fishway was not considered. Burt and Robert (2002), in their report to BCHydro reviewing existing information on the Salmon River for the WUP, identified a data gap as to the effectiveness of the adult fishway. Concerns were raised regarding the attraction flows to the fishway entrance being insufficient, resulting in the returning adults keying on the stronger flows from the dam undersluice, as well as over the dam and trimming wall, possibly tiring and delaying their upstream migration. Additionally BCRP Strategic Plan Vol. 2 states the impacts of the Salmon River diversion dam includes entrainment of adults at the diversion screen.

In summer and early fall the undersluice gate is generally open nearly one meter, which allows a substantial flow (upstream mainstem discharge to about 7 m^3/sec) to move through with no head pressure to increase velocity. At present BCHydro is required to supply a minimum of 1.7m^3/sec to the Salmon River downstream during periods when the natural flow is available. BCHydro has been supplying in excess of this requirement, generally providing the WUP flows of 4.0m^3/sec. As the undersluice is closed down to 0.15-20m later in the fall, providing the 4.0m^3/sec, the head pressure and small gate setting creates a velocity barrier to the fish. BCHydro staff has adjusted the undersluice flows when adult Coho have been observed holding in the pool downstream of the diversion dam in an effort to facilitate fish access to the upper Salmon River.

Coho have been observed very early in the Salmon River, when the river discharge is typically less than 2m^3/sec. Broodstock capture by the Sayward Fish and Game Club, for both Chinook and Coho generally occurs before mid-September in the lower river and over the past 2 Fall migrations Coho have been observed at the diversion dam (about 50km upstream from brood capture sites) in mid September, with most Coho observed after a late September/early October rain event.
The Salmon River is a very flashy system, discharge can go from less than 5 m^3/sec to 297 m^3/sec in a matter of hours (October 7, 2007) in response to rain events and come back down to 25 m^3/sec within a day.

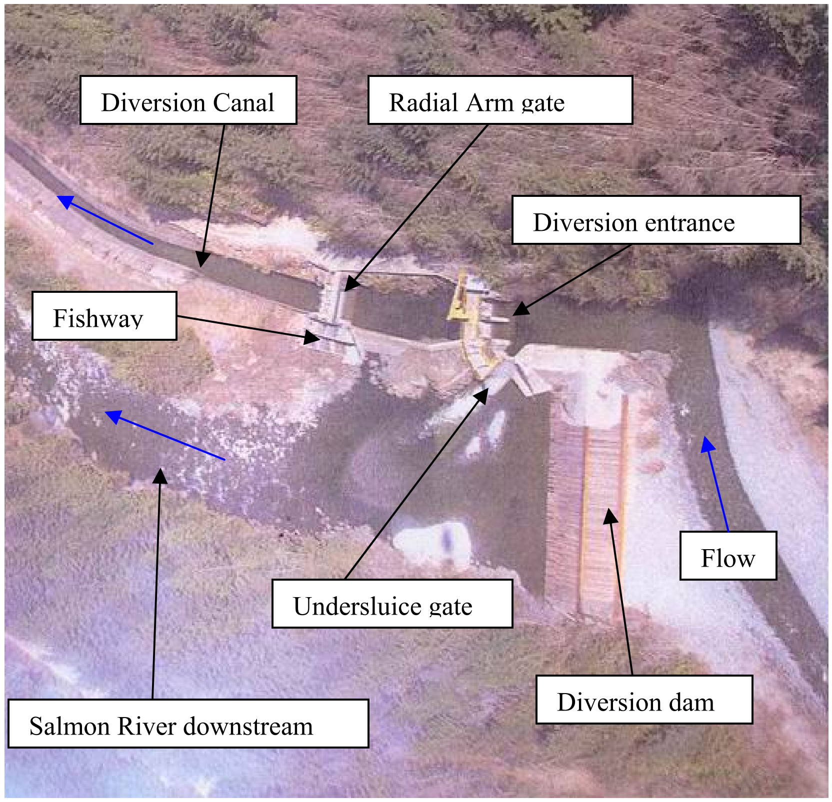
Goals and Objectives

- Assess fish passage at the diversion dam and fishway to determine if the performance of the structure is acceptable and/or if design and/or operational changes are required to improve passage.
- Cover the period of adult Coho migration (as practical) September to December
- Track fish spatially and temporally to determine residency and migration patterns and relate, if possible to mainstem flows, diversion canal operation, fishway performance and undersluice settings
- Pilot the use of acoustic telemetry on the system to ensure applicability and practicality for future projects
- Pilot the use of a resistivity counter on the system to ensure applicability and practicality for future projects
- Gather as much observational data as possible to complement the technology applications
- Establish an annual late summer program of Coho juvenile density and biomass surveys on habitats both up and downstream of the diversion structure
- Document river and canal flows during adult migration
- Recommendations – further studies, operations or infrastructure changes

Study Area

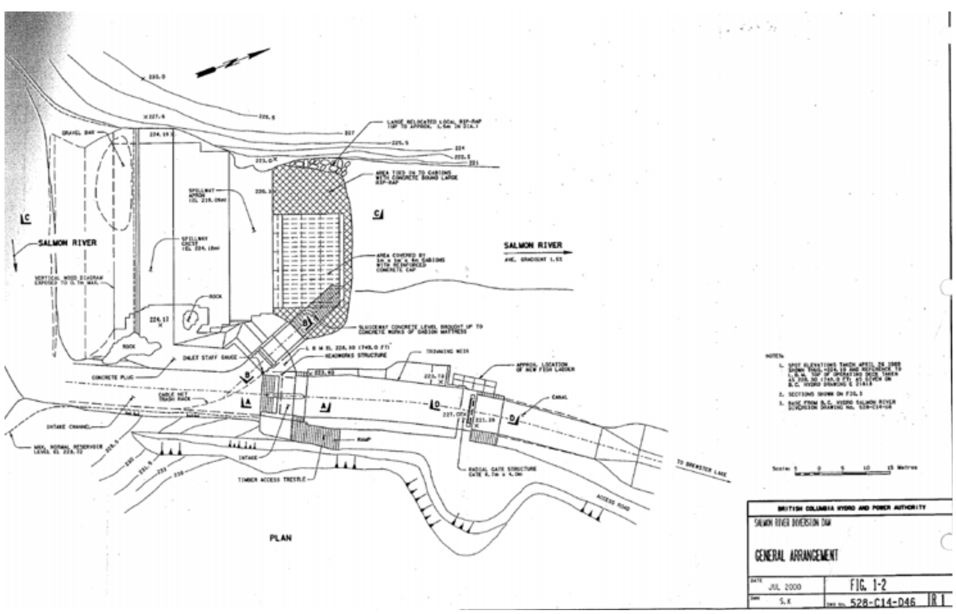
Site Coordinates: **50.05.28.02 N 125.40.29.95 W**

The Salmon River Diversion Dam and Canal structure are located more than 50km from the mouth of the Salmon River. The site is accessed from Campbell River by traveling north on Highway 19 about 15km to the Menzies Bay Main (MBM) logging road turnoff, then a further 30km west to the bridge over the Salmon River, (the road reference becomes the Salmon River Main –(SRM) west of Brewster Lake). The flume from the Salmon River diversion parallels the SRM for about 6km (about 3km concrete lined) flowing into Brewster Lake. From Brewster the diversion flow travels a further 5km through Gray, Whymper and Fry Lakes entering Lower Campbell Lake downstream from the Strathcona Dam. The diversion site consists of the timber crib dam and concrete diversion canal, flow and debris control structures, the adult fishway (Fig. 4-5) and a screen across the canal 500m downstream of the diversion dam.



a)

Figure 4. a) Aerial view of Salmon River BCHydro diversion facility - dam at centre, mainstem Salmon River approaching the diversion structure from right side, flow through both the undersluice to the river downstream and into the canal through the radial arm gate. Fishway is adjacent to radial arm gate – 8 cells visible. 2008 April 23. River Discharge 6.0m^3/sec, canal ~1-2 m^3/sec (photo BCHydro) Below b) BCHydro plan view of Salmon River diversion structure – view is 180 degree rotation of photo with river approach from upper left.



b)

Figure 5. Upstream entrance to the diversion canal, looking downstream. Mainstem discharge (1.7m^3/sec in this photo) all carried through undersluice (1m open) to the left of photo. Shows relative sill height of canal entrance and trash rack on canal.

Methods

In order to assess the efficiency and effectiveness of the fishway and/or to determine other options for adult passage at the Salmon River Diversion structure Fisheries & Oceans Canada (DFO) proposed to capture and tag returning adult Coho in the vicinity and track them – temporally and spatially relative to the facilities and river discharges.

With input from a number of sources, DFO staff evaluated a variety of available technologies to determine the technology best suited to the system. This included acoustic and radio receivers and tags, counters such as resistivity, infrared and pulsar, dual beam sonar (DIDSON), and underwater cameras. The most promising applications were the acoustic tagging and resistivity counter combination, having local expertise available for both technologies (Kintama Research Corporation and Instream Fisheries Research). The shortfall from the non-marking technique (resistivity) is the inability to follow individual fish to determine how and when they accessed certain areas of the site, however with this ‘passive’ monitoring more fish under more conditions, and timings, could be assessed.

The cost and concern for vandalism of the DIDSON precluded its use (at least 2 would have been required, preferably 3 at a cost of over $100,000 each). Juvenile Coho density surveys, both up and downstream of the diversion in late summer were also added to provide more understanding of both the habitat condition and use by Coho juveniles.

All field activities on the Salmon River, both on and off BCHydro facilities, were preceded by a risk assessment, leading to the development of comprehensive safety plans. Daily safety meetings were held to ensure understanding and compliance with the safety plans and recognize any additional risks at the specific sites. Activities requiring BCHydro equipment lockout were identified early in the project, and all personnel working in these areas were required to have Workplace Protection – Category B and local component training for the Salmon River Diversion Dam site.

Coho fry survey

In late August and September 2008 DFO staff undertook 3 days of a juvenile survey in the Salmon River watershed based on sites sampled and reported in a previous report surveying potential habitat of Coho salmon in the upper Salmon River Watershed (Craig et al. 1998). Four sites upstream of the diversion and 2 downstream were established and sampled using beach and pole seine removal methods, sampling the juveniles for length, weight and scale samples, (Appendix A, Fig.6) to add to the understanding of the productivity from available habitat, densities, biomass and life history. Each site was sketched and position recorded on GPS. All Coho were measured (mm) and up to 3 of each length were damp blotted and weighed (0.01g) using an OHaus Scout Pro, model SP202 (Fig. 7 & 8).

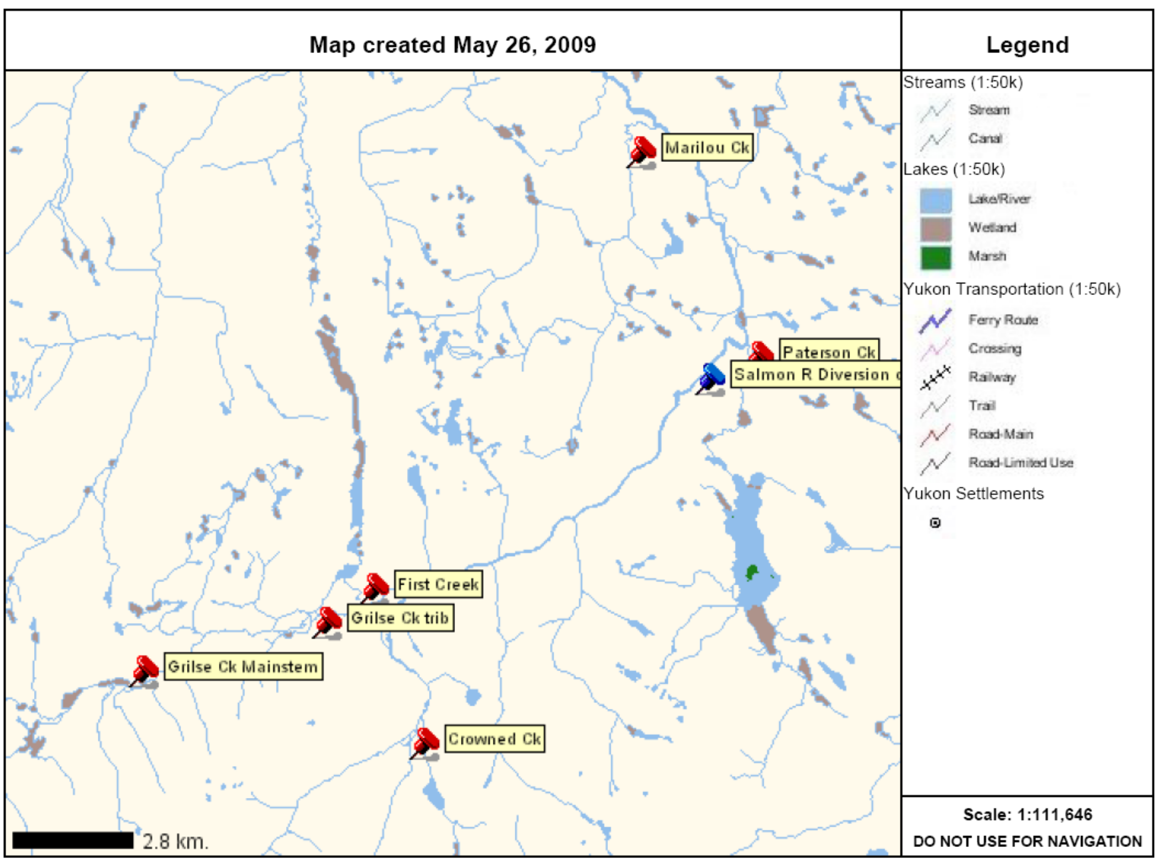


Figure 6. Juvenile sampling sites, approximate positions, on the Salmon River 2008

Figure 7. DFO staff beachseining for juveniles on Grilse Creek Tributary - G02 August 08.

Figure 8. DFO staff - David Ewart and Pieter van Will sampling Coho fry at Grilse Creek tributary August 08

Alkaseltzer or Bromoseltzer (approximately 1 tablet or dose per 4 litres water) was used as anesthetic. Fish were placed in a recovery bucket with a battery powered aerator after sampling and only returned to the site after all seining and sampling was complete. Total areas and populations estimates were calculated with the computer program supplied with the methodology supplied by DFO stock assessment, (Appendix

A). The average lengths and weights for each site were calculated taking a weighted mean of all the recorded data. Scale samples were taken from the larger fish in the sample, placed on scale books and submitted to DFO Ageing Lab for analysis.

The length and age data collected provide the frequency of each size which can be used to describe the population. Only the 0+ fish (Brood 2007) are used in the calculations of Kurtosis and Skew which measure the shape of the length frequency distribution. A distribution without a strong central peak will have a negative kurtosis, a strongly peaked distribution will have a positive kurtosis. Skewness refers to the relative size of the tails of the distribution on either side of the peak. A longer tail of small fish will give a negative skewness and a longer tail of large fish (often seen in juvenile Coho data) will give a positive skewness.

We are interested in the skewness of the distribution: we think that a positive skewness may indicate that the Coho are at or close to the carrying capacity of the habitat (S. Baillie pers communication).

Additional sites will be added in future years, for a target of 10 sites total, 5 above and 5 below the diversion. These sites will be monitored annually to provide additional information on juvenile rearing densities. The Ministry of the Environment (MoE) has ten sites sampled annually for the past decade by electrofishing, (through B.C. Conservation Federation (BCCF) and BCHydro BCRP funding) focusing on juvenile steelhead/rainbow habitat (Pellett, 2008) on the mainstem Salmon River and major tributaries. The DFO focus was on off channel habitats and smaller drainages more typical of Coho habitat. Comparisons year to year, relating to discharge, operation of the diversion canal and adult escapement numbers and observations will follow with subsequent sampling, and tying into the data gathered by MoE, but is outside the scope of this report.

Onsite observations

Site visit observation templates were provided to BCHydro and DFO staff that regularly visited the site to record water levels, fish presence, and activities such as gate adjustments or debris removal. This template as well as a photographic summary of activities are provided in Appendix B and C. Photographs were taken on most site visits, generally recording the conditions at the diversion pool, undersluice flow, the fishway canal and radial arm gate downstream, as seen in Figures 9 and 10, as well as recording the temperature, gate settings, diversion operation and discharges and fish presence at the site.

Figure 9. Coho adults - dark shapes - holding at the diversion dam pool. October 8, 2008. Discharge $16m^3$/sec, undersluice open 0.91m.

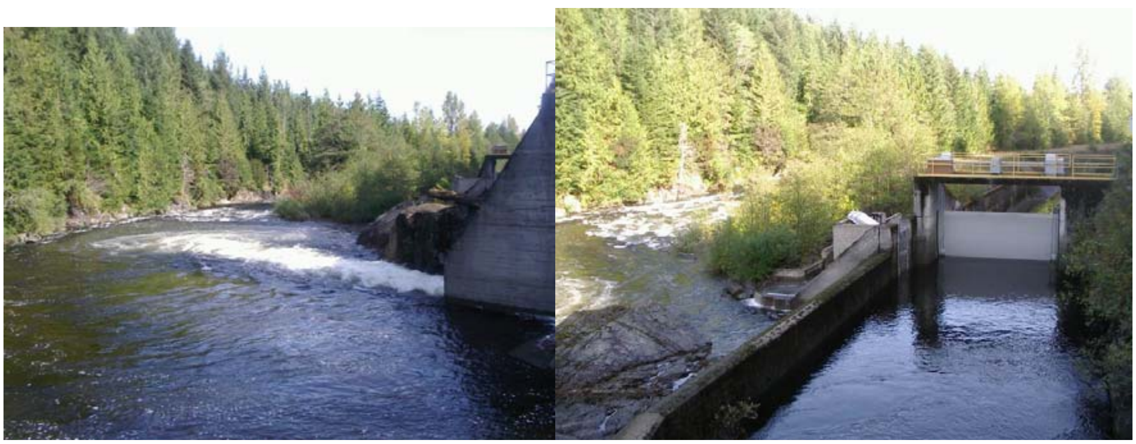


Figure 10. October 8, 2008- undersluice open 0.91m. $16m^3$/sec all through undersluice and fishway, no diversion flow.

Resistivity Counter

September 22nd, Instream Fisheries Research Inc. (IFR), installed the Logie 2100C resistivity counter (Aquantic, Scotland), grate and tubes, specifically designed and configured to the lowest fishway cell. At this time the fishway was dry, all water passing through the undersluice at the diversion dam. Details on the resistivity specifications, operation, and data download procedure are included in IFR final report (Appendix D). The counter detects changes in resistance when a fish passes across an array of three electrodes. The occurrence is recorded and analyzed to confirm that it was a fish, and then additional information is recorded and stored; time, direction of travel and peak signal size. IFR was onsite regularly to check for debris buildups and data download and analysis. On October 25th one of the grates over the lowest fishway cell was removed to allow debris to pass over the walls and not block the counter tubes. As no power is available onsite a series of batteries and solar panels were relied on; there was one period of 5 days missed due to a battery malfunction. The resistivity counter was operational from October 4th through to December 2nd.

Acoustic Tagging Survey

A small scale pilot acoustic tagging study was designed, implemented and reported by Kintama Research Corporation (Kintama). An array of receivers on the mainstem Salmon River near the diversion dam was set up to determine the migration route(s) of tagged adult Coho that reach the vicinity of the diversion dam, giving the direction and timing of fish movement (Appendix E). An arrangement of acoustic receivers, (Vemco VR2 waterproof data loggers) was placed in the Salmon River on September 24, 2008. Each receiver was wrapped with a floatation collar to maintain an upright orientation of the hydrophone, tied to an anchor chain and tethered to shore with wire line. Sites were marked and GPS information recorded. Three receivers were deployed above the diversion in the mainstem Salmon River, one in the fishway, one in the diversion canal, one at the downstream outlet of the canal and four in the Salmon mainstem below the diversion- including one in the diversion pool (Fig. 11). The diversion canal is only opened when watershed conditions allow, and BCHydro power generation is required. Due to concerns of vandalism in the dry canal, the canal receiver was removed and deployed again November 4th, as soon as possible after diversion flows commenced, (November 1st).

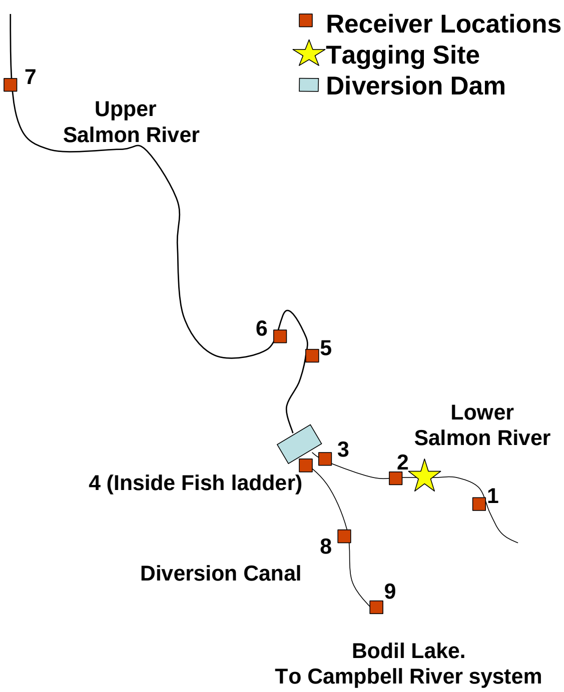


Figure 11. Acoustic receiver placement schematic on the Salmon River Fall 2008 Lydersen et al. 2009.

Kintama determined that use of the uniquely coded Vemco V13-1H acoustic tags (13 mm in diameter, 36 mm long, weighing 11 g in air, power output of 153 dB re 1µPa@1m)

gastrically implanted into the adult Coho stomach would produce a signal that would be picked up by the receivers.
Site visits to the Salmon River Diversion site were made weekly by DFO staff to determine fish presence and identify opportunities for adult capture and tagging. Weather predictions and Water Survey of Canada (WSC) discharge data for the Salmon River above the diversion (#hd08015) on the BCHydro website (http://www.bchydro.com/about/our_system/hydrometric_data/vancouver_island.html) were checked to ensure crews could access the water safely to capture fish.

On Monday October 27th DFO staff observed 60-70 Coho adults holding under the SRM bridge over the Salmon River. With rain predicted within 48 hours crews were organized for adult capture while the river flows were low enough for effective seining, and safe for personnel instream.

On October 28th five staff from DFO and Mainstream Biological Consulting (MBC), captured 14 Coho adults using a beachseine (61m long x 6m deep, 14cm mesh) and two sinking tangle nets, (15m x 2.4m with 14cm mesh). Discharge in the river was $5m^3$/sec with no flow through the diversion canal. The tangle nets were joined together and strung across the mainstem at a riffle site about 100m downstream of the logging bridge (Fig. 12). The beachseine was set using a small inflatable raft with one person aboard and two ashore at the top end holding the upstream end of the net. A rope from the other end of the net was walked downstream on the left bank then midway across the river to pull the raft downstream, launching the net from the raft. The raft was then pulled to shore about 30m downstream of the original launch site, the upper crew walking down the left bank to close off the net (Fig. 13). Large boulders at the upstream end caused some delays in deploying the net; however the tangle net at the downstream end was very effective in catching the fish. Eleven males and 3 females were caught and placed in a net pen for tagging (Fig. 14). All 14 fish were in very good condition, coloured up but with no visible fungus or injuries (Fig. 15-16).

Figure 12. Tangle net spanning riffle downstream of Coho capture site, October 28 2008.

Figure 13. Closing up the Beachseine, October 28th, during capture of adult Coho for marking

Figure 14. Captured Coho waiting tagging in net pen (S. Anderson photo)

Figure 15. MBC staff holding well coloured clean male, well developed kype. This site is over 50km from tidewater. Oct 28/08. (S.Anderson photo)

Figure 16. Coho holding in net pen. October 28 08. (Mainstream Biological Consulting photo)

The application of the acoustic tags was done right at the net pens with no anesthetic applied (see Appendix E for explanation). The cool water (5C) kept the fish fairly docile, and efficient handling times of less than one minute per fish streamlined the operation. Each fish was taken out of the net pen and the nose-fork length, sex and the tag number were recorded. The fish was held belly-side up and the V13-1L tag was quickly inserted down the esophagus, through to the stomach using a food grade, flexible plastic tube and plunger (Fig. 17). The fish were then placed into individual broodstock holding bags for 30-60 minutes to monitor for regurgitation of the tags, then released at the capture site. Receivers were removed and downloaded in early December 2008.

Figure 17. Heidi Lydersen of Kintama Research inserting acoustic tag. Fish held by Barry Peters DFO. (Mainstream Biological Consulting photo)

Results

Coho fry survey

This was the first year of sampling specifically for Coho fry in late summer. Of the six sites sampled, five on August 19-20 and another on September 17, 2008, Coho juveniles were found at five.

Summarized fry survey data are shown in Table 1, with calculated biomass for each site in illustrated in Fig. 17, along with the expected biomass from alkalinity levels. Alkalinity levels are used by the BC Ministry of Environment as a predictor of expected biomass. For the Salmon River 224.5g/100m^2 is the expected biomass for juvenile steelhead, based on an alkalinity of 16.5mg/l (formula 35*(alkalinity mg/l)$^{0.663}$, -Ptolemy pers comm). Coho biomass estimates for the Salmon River are 448g/100m^2, predicted as twice the Steelhead value (R Ptolemy pers comm). It is likely the role alkalinity plays in food production that provides the correlation between alkalinity and fish habitat productivity. The condition coefficient, K, is a measure of the relationship of weight to length (Groot, C. and L. Margolis. 1991) and generally used as an indication of fitness for juvenile salmonids. The K calculated on coho fry ranged from 0.98 at Marilou Creek to 1.07 at Paterson Creek with the other sites in between (smaller K indicates thinner fish). The detailed length weight data indicate Marilou Creek coho fry did not have a mean K over 1.0 until they reached over 44mm whereas all other sites were at K>1.0 around 40mm. The length frequency charts for each site are illustrated in Fig.18. The fry sampled in this survey were quite small for late summer rearing. Marilou Creek, the furthest downstream of the diversion, had the smallest average size at 44.2mm and less than a gram in weight, but had the highest biomass at 288.5g/100m^2 (Paterson Creek was sampled a month later so is not used in the comparative biomass results). Grilse Creek tributary, over 11km upstream of the diversion, had the next highest biomass at 277.31, but average size of the fish was larger, length 47.7mm and weight 1.36g. The numbers used to generate these mean sizes weights and biomass included all fish caught at each site.

The age information from scale smears collected has been included (Table. 2) as well as in the length frequency charts to illustrate the year class breakdowns in each site, and indicate the fry used for the calculations of kurtosis and skew.

A positive skewness, where the central peak is shifted to the smaller size range (to the left on the x-axis), is illustrated by Marilou, Grilse and First Creek Creek charts, with a longer tail on the larger sized fish. These three sites also have fairly strong peaks, kurtosis ranging from 1.049 to 3.69, Paterson Creek is only very slightly positively skewed at 0.096, Grilse Creek mainstem is the only site with a slight negative skew. Both Paterson and Grilse Creek mainstem had more uniform distribution, and weaker defined peaks with negative kurtosis values.

Table 1. Salmon River Coho juvenile survey data from August and September 2008

Beach and Pole seine removal fry survey August 19-20, *September 17 2008								
		Downstream of Diversion			Upstream of Diversion			
		Marilou Creek	*Paterson Creek		First Creek	Grilse Trib	Grilse Mainstem	Crowned Creek
Date		Aug 20 08	Sept 17 08		Aug 20 08	Aug 19 08	Aug 19 08	Aug 19 08
Population estimate		360.9	107.5		107.4	264.4	101.0	0.0
	SE	5.6	3.0		2.5	6.8	0.1	0.0
Total Area m2		123.6	64.6		86.7	137.3	311.5	66.3
Area >10cm m2		115.8	54.3		77.2	129.9	274.1	55.5
fry/m2		3.1	2.0		1.4	2.0	0.4	0.0
fry/100m2		311.7	198.0		139.1	203.5	36.8	0.0
Coho size mm		44.0	54.4		50.3	47.7	49.8	
Coho weight g		0.9	1.8		1.6	1.4	1.3	0.0
Mean Condition Coefficient* K		0.98	1.04		1.07	1.06	1.04	
Biomassg /100m2		288.5	365.4		216.2	277.3	48.6	
Alkalinity (16.5) 2x sthd biomass (MoE) predictor g/100m2		448	448		448	448	448	448
Kurtosis		3.69	-0.78		0.56	2.90	-0.56	
Skew		1.73	0.10		0.96	1.30	-0.15	
Temperature		13.2	13.6		15.2	13.0	15.6	14.0
Distance from Salmon River diversion (km + or -)		-9.8	-2.4		10.3	11.2	11.8	13.2
*Fulton Condition Coefficient formula K=(W/(Ln^3))*10^5 , W = weight -grams Ln is nose-fork mm								

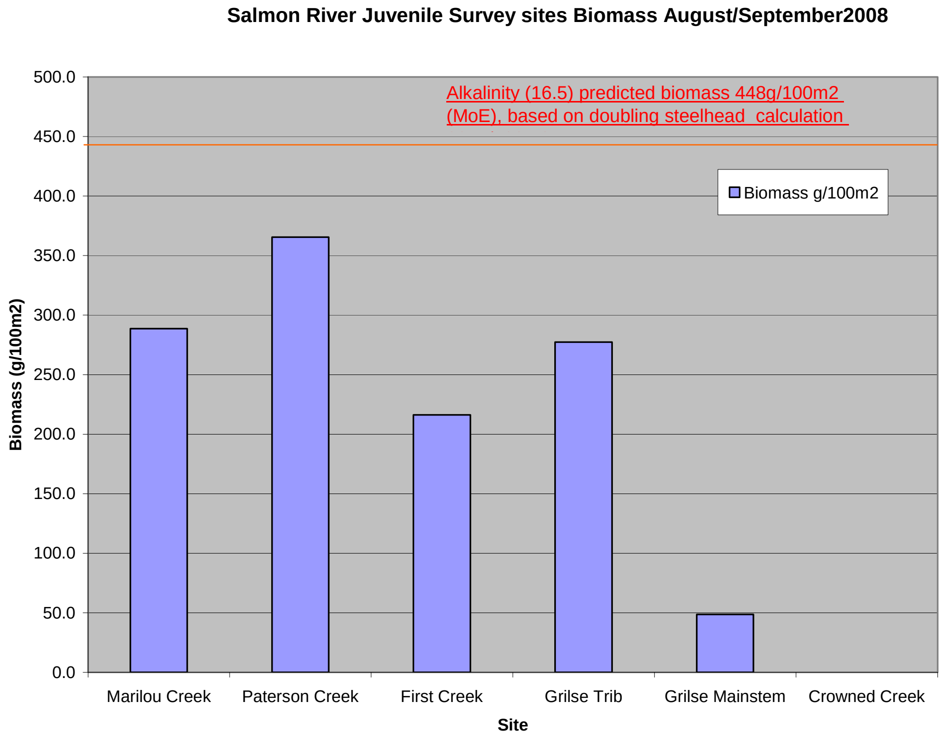


Figure 18. Biomass/100m2 for Salmon River juvenile survey sites, with biomass predicted by alkalinity of 16.5mg/l=224.5g/100m^2 times 2 for coho fry= 448g/100m^2. (MoE)

Table 2. Percentage of Age 0 and 1+ Coho at Salmon River juvenile sampling sties 2008, August and September .

SITE	% AGE 0	% AGE 1+
Marilou Creek	100%	0
Paterson Creek	99%	2
First Creek	98%	2
Grilse Creek Tributary G02	91%	9
Grilse Creek mainstem	98%	2
Crowned Creek	0	0

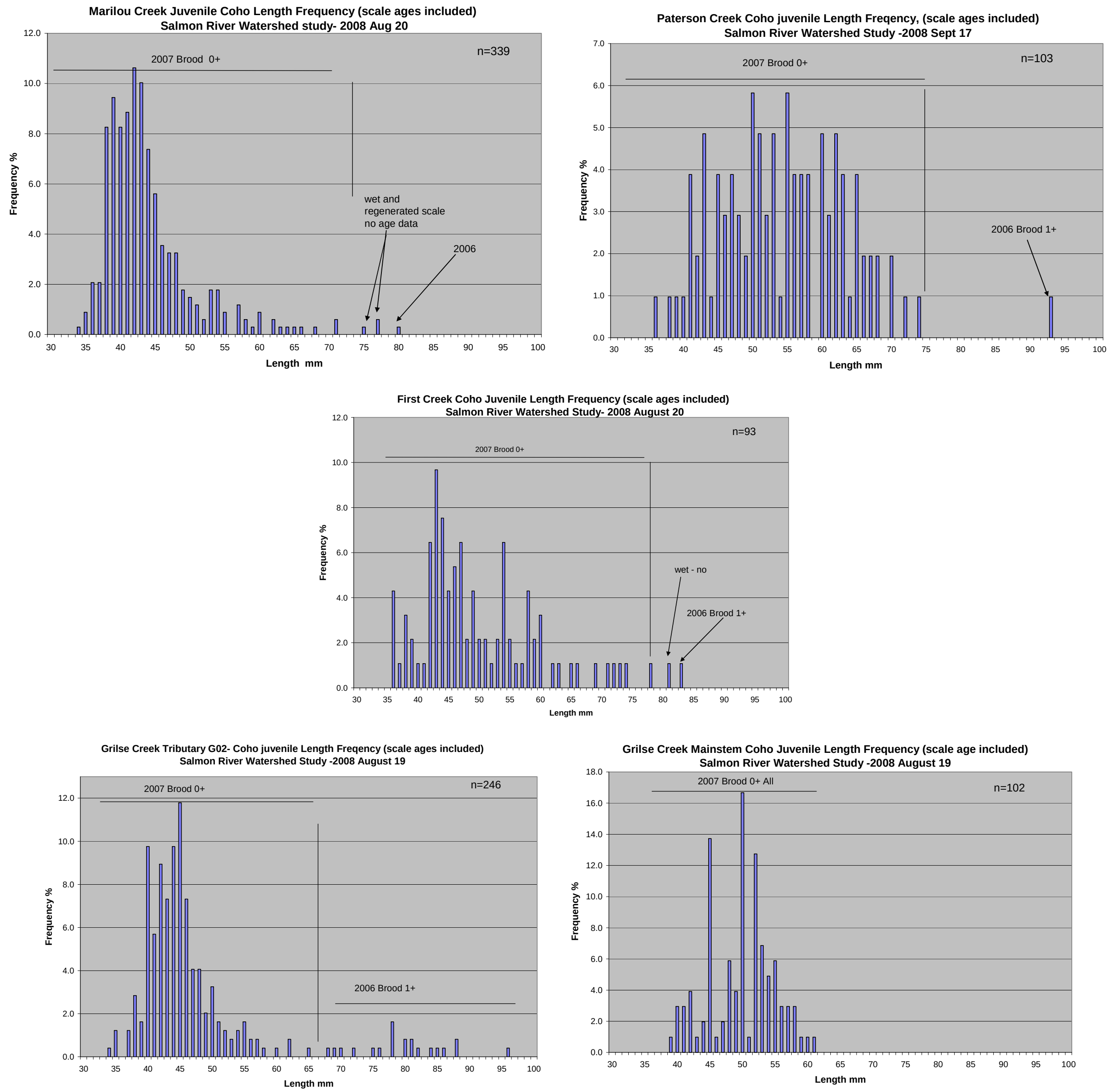


Figure 19. Frequency distribution of Coho juvenile length for the 5 sites sampled, 2008. Top 2 charts are sites below the diversion, 3 lower sites above.

Onsite observations

DFO and BCHydro personnel reported observations and activities at the Salmon River diversion site on the provided template form, contributing valuable information on the conditions, timing of adult migration and reconnaissance for fish capture and tagging opportunities. This diary information is included in Table 3. Undersluice gate settings, discharge and diversion operation over the period of the study is reported in Fig. 20.

The discharge for the Salmon River near the diversion, for most of the summer months is around 1 m^3/sec, quite low for a river of this size, and easily flowing through the undersluice gate when it is open about one meter (Fig. 21). Coho were observed holding in the lower river near Sayward in early September. A storm in late August bumped the Salmon mainstem flow to 7m^3/sec likely drawing these fish upstream as an estimated 40 Coho were observed in the pool upstream of the diversion on September 24th indicating the adults move up early on quite low water (Fig. 22).

Early (October 8) flows of 16 m^3/sec brought Coho to the diversion pool, 75-100 were observed holding, the undersluice at this time was still open to nearly 1.0m. A week later there were no fish in the diversion pool, and a few under the logging road bridge. During this period the diversion canal was closed, river discharge had dropped to 7m^3/sec, and the undersluice remained open 0.91m until October 15/16 when it was reduced to 0.15m. Generally the gate setting is decreased in anticipation of the higher fall flows that bring large debris that can get jammed in the gate. Adult Coho were observed continually at either the diversion pool site or at the logging bridge from early October until November 28 when there were still 20 fish at the diversion dam pool. During higher flows visibility was decreased at both the diversion dam pool and the bridge pool.

Table 3. Salmon River observation diary Fall 2008

					Fish				
Date	08HD015 River Discharge m3/sec	Water Temp C	Diversion Discharge m3/sec	Under sluice open (cm)	Salmon R bridge	diversion pool	WSC pool	Crew	Comments
24-Sep-08	0.9	10.1	0				25	Kintama, Mainstream, S Anderson K Wilson, M Grant	Lock out and local component training Testing netting process, Installing hydro acoustic receivers
8-Oct-08	16	7.3	0	91		75-100	Few present	S Anderson E Fortkamp	2 dead Coho on fishway screen top, 3 otters in diversion pool
14-Oct-08	7	7.5	0	91	15	0	Not inspect	R Senger, S Anderson	no flow thru fishway, all through undersluice
16-Oct-08	5	6.6	0	15	15	0		S Anderson B Pechter	Solar panel in at resistivity, flow thru fishway
24-Oct-08	6	12.5	0	20			Not inspect	M Grant	bottom section of fishway blocked at resistivity counter- water spilling out screen surface - require removal of screen to clear
27-Oct-08	5	5	0		70	0		B Peters S Anderson	Pre check for tagging capture.
28-Oct-08	5	5	0		60		Not inspect	B Peters S Anderson Mainstream Biological Kintama,	Beachseine with raft, 2 tangle nets at bottom riffle, 15 caught, 14 tags applied, 11 male, 3 female
29-Oct-08	4.5	5.8	0	20		30		M Grant	
31-Oct-08	28	7	0					M Grant	10 Coho swimming on top of fishway lowest step, -BCHydro photos Resistivity plugged
1-Nov-08									Diversion opened
6-Nov-08	26	5.5	12.7	15		15		M Grant	
7-Nov-08	28	5.8	14		visibility poor	30	Not inspect	D Ewart, S Anderson	Diversion flow 1.8m Staff gauge at screen, screen off lower fishway step, overspill at trimming wall
14-Nov-08	20	5.3	12			0		Al McLean	no fish observed (phone conversation)
19-Nov-08	11	4.5	5.4		visibility poor	40	Not inspect	B Peters, S Anderson	Staff gauge at fishway entrance =1m water level, fish at diversion pool clean, dark and red, circling
20-Nov-08			0						Diversion Closed
28-Nov-08	8.7	4.2	0	50		20	Not inspect	S Anderson J Anderson	Staff gauge WL 0.8m at Fishway, smolt screen and trash rack out of canal

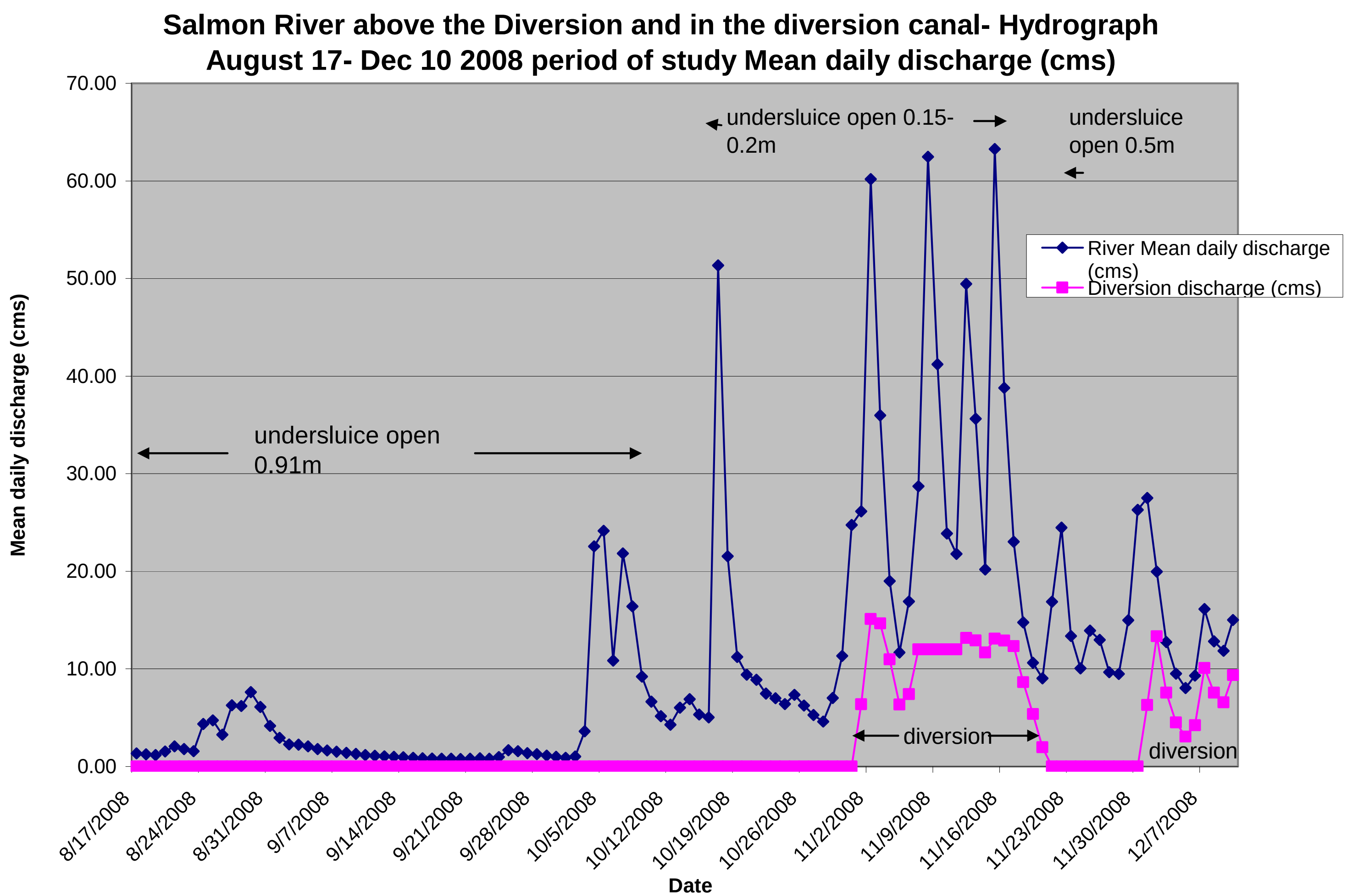


Figure 20. Environment Canada Water Survey of Canada Discharge data for Salmon River mainstem upstream of the diversion and the diversion canal (08HD015and 08HD020) August 17- December 10, 2008, period of study and undersluice gate openings recorded. Note steep increases in response to rain events

Figure 21. Salmon River diversion structure looking upstream - undersluice gate open to 0.9m September 24 2008, mainstem flow less than 1m^3/sec. All of the river flow is passing through the undersluice.

Figure 22. Coho adults observed in the WSC pool upstream of the diversion dam September 24, 08. Undersluice open to 0.91m, mainstem river flow 0.9m^3/sec

Resistivity Counter

(**Appendix D comprehensive report**)
The net daily upstream counts from the data were considered the measure of fish passage success through the fishway at the diversion. The first fish were recorded on October 4th, when the mainstem river discharge reached nearly 15m^3/sec. The fishway had been dry to this time due to low flows all being carried through the undersluice. Peak fish movements were recorded in October with daily mean flows 10-20m^3/sec. Hourly flow data indicates Coho moved on the falling hydrograph, around 12-16m^3/sec. It is also important to note that the undersluice gate was open to nearly one meter during the first 2 weeks of October when the net upstream counts were highest (Fig. 23). As the counter is in the lowest section of the fishway it is possible to determine the time and discharge that the fish entered the fishway, but not the time they spent resident in the fishway before passing upstream, or returning downstream. October counts of successful fish passage were 79 fish, from recordings of 268 upstream and 189 downstream counts.
In late October the removal of one of the screens over the lowest cell of the fishway allowed some fish to migrate overtop, without being counted as upstream migrants, but potentially being picked up in the counter if they retreated back downstream, this would account for the net downstream count of 216 fish over the sampling period (Fig. 24 -25).

The diversion canal was opened November 1-20, closed for a period, then reopened December 1st (refer to Fig. 20 above). Discharge curves were adjusted to account for the amount of water left in the mainstem river (WSC 08HD015 – WSC 08HD020), and fish passage related to this number ((Fig. 26- 27). Although mainstem attraction flow is less there is the still head pressure at the top of the fishway with the diverted flows.

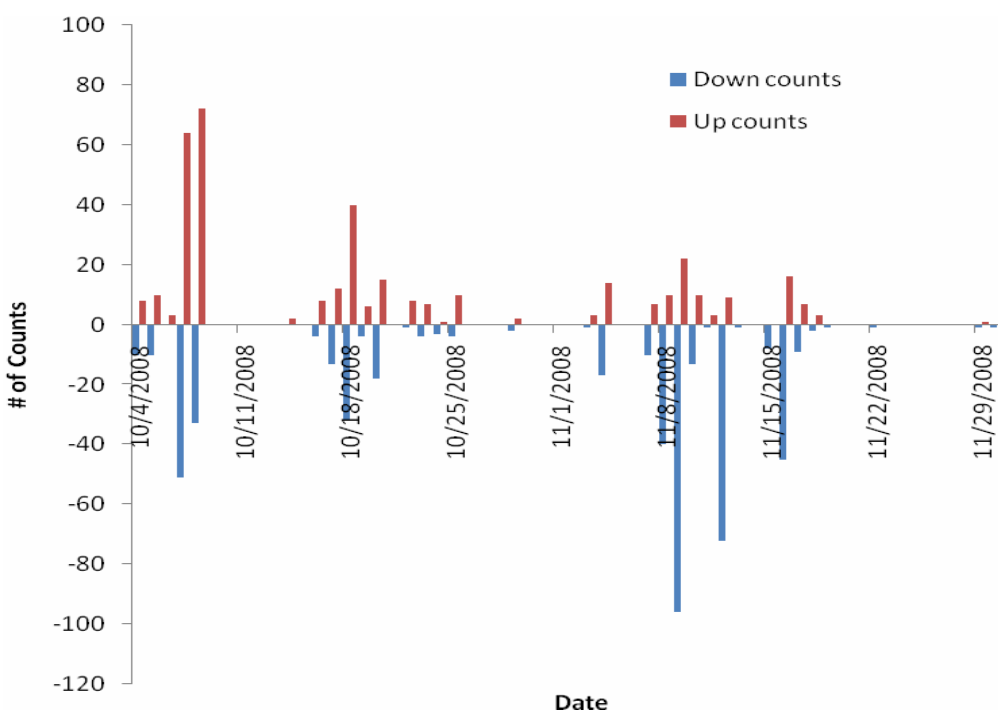


Figure 23. Daily up and down counts as recorded by the resistivity fish counter on the Salmon River fishway, fall October – December 2008 (McCubbing 2009, see Appendix D)

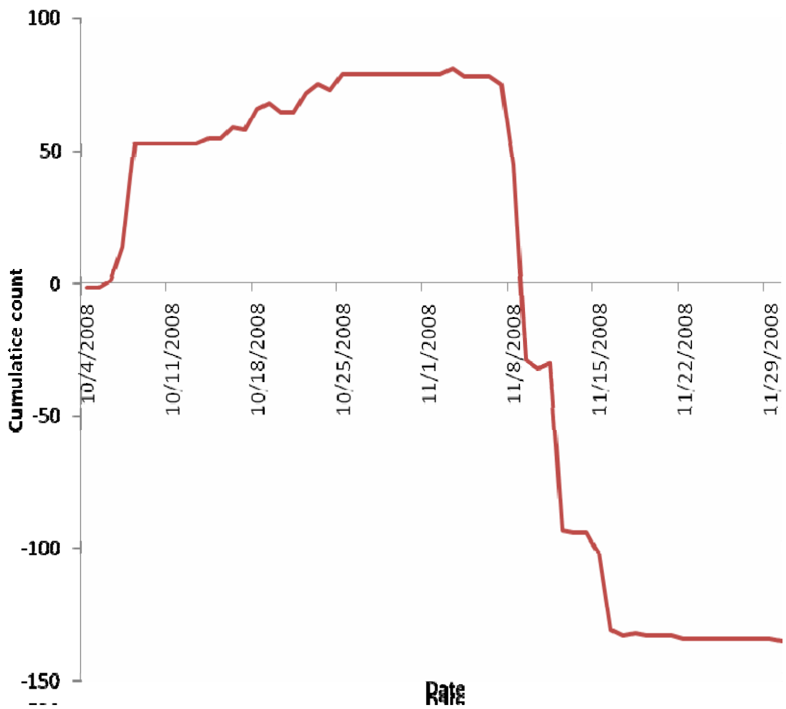


Figure 24. Cumulative net fish count at the Salmon River fishway, fall 2008. (McCubbing 2009, see Appendix D)

Figure 25. View of entrance to Salmon River fishway with mainstem in background. Screen is off lowest cell of fishway, where Coho could have bypassed resistivity counter both up and down.

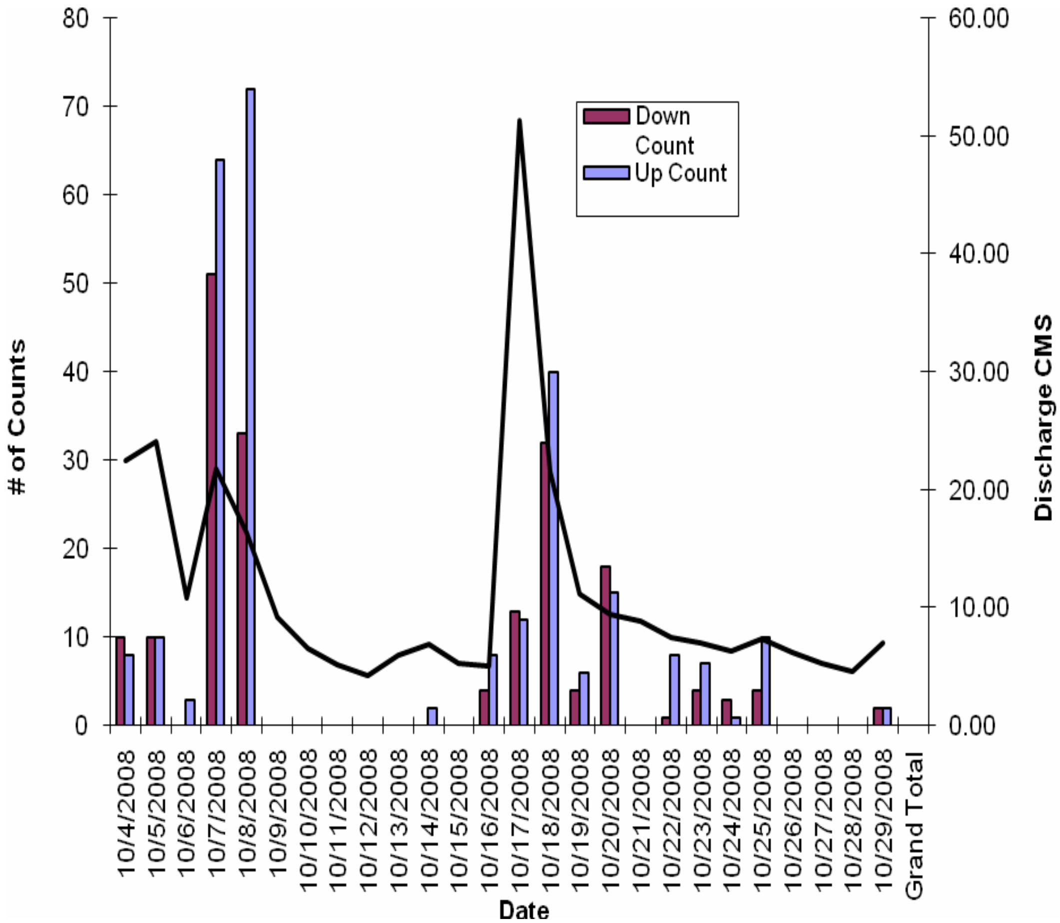


Figure 26. Daily up and down count of Coho salmon in the Salmon River Fishway compared with average daily river discharge in m3/sec, during October 2008 (McCubbing 09 see Appendix D)

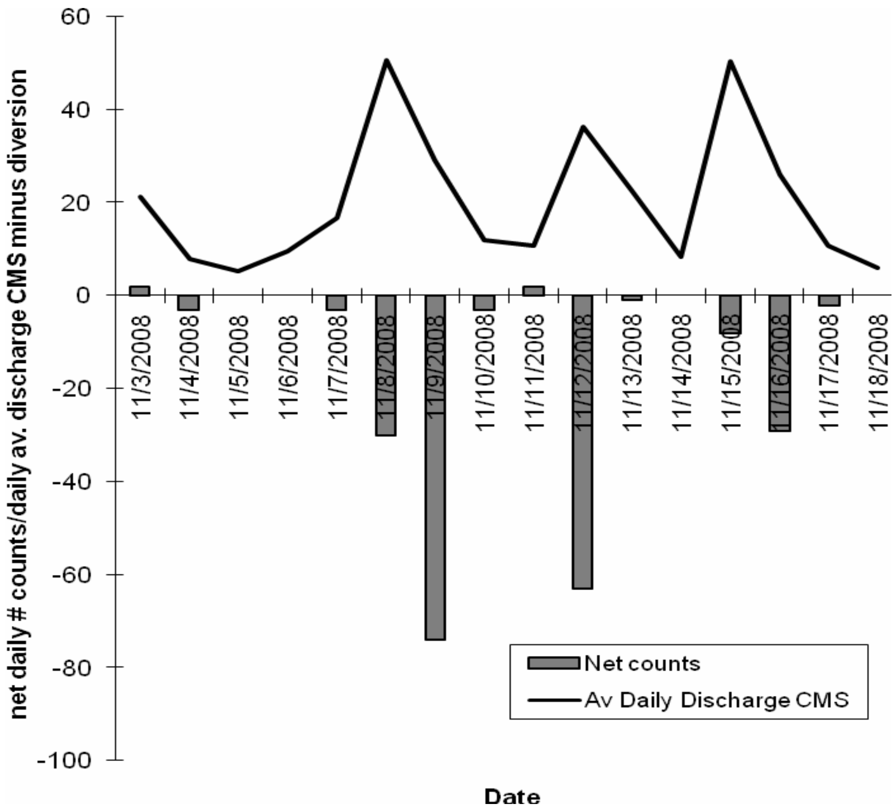


Figure 27. Net daily count of Coho salmon in the Salmon River fishway compared with average daily river discharge in m3/sec, during November 2008 (McCubbing 2009, see Appendix D)

The graphics in Figure 26 and 27 are set up differently but both illustrate the pattern of Salmon River discharge to net counts of the fish passing through the resistivity counter – reconciling up and down counts.

Acoustic Tagging Survey

The Salmon River flows in the fall of 2008 were much lower than those experienced in fall 2007, allowing crews to safely capture adults for tagging downstream of the diversion. Even so (mainstem Salmon River flows at 5m^3/sec -October 28) the seining was a challenge – both from the logistics of getting a crew together on short notice, and capturing fish). The fish were placed in a net pen until Kintama Research staff arrived to tag the fish. Three days after tagging BCHydro opened the diversion (Nov 1, 2008).

Nine of the ten deployed receivers were recovered December 4th. Upon retrieval, the data stored on the receivers was uploaded using VEMCO data acquisition software. All 14 tags were recorded at the receiver near the Salmon River Main bridge, just upstream of the tagging and release site (Receiver #2) (Table 4). Unfortunately the receiver at the diversion dam pool (#3) was not recovered – possibly debris had torn it from its anchor during high flows. (Refer to Figure 11 for relative receiver placement).

Table 4. Acoustic receivers; sites and number (and percentage) of tagged fish recorded (Lydersen et al 2009 Appendix E)

Receiver location	Site location	Number and percent of individual fish detected
1	3rd down river of dam	11 (78%)
2	2nd down river of dam	14 (100%)
3	1st down river of dam	Unit Not Recovered
4	Fish Ladder	3 (21%)
5	1st up river of dam	0
6	2nd up river of dam	0
7	3rd upriver of dam	0
8	Mid diversion canal	0
9	End diversion canal	0

The tagged fish were detected in the area of the 3 receivers for varying periods, ranging from just over 5.5 hours to nearly 11 days (261.51hrs) (Table 5).

Table 5. The approximate time in study area, and the first and last detection of the 14 adult Coho tagged in the Salmon River by the BC Hydro diversion canal. Fish were tagged on 28 Oct 2008 and the receivers were recovered on 4 Dec 2008. Times are reported in UTC. (Lydersen et al 2009 Appendix E.)

Tag id	Sex	First detection	Last detection	Time in area (hr:min)	Location last heard
24087	M	28-Oct-2008 21:39	31-Oct-2008 11:03	61:23	1
24088	M	28-Oct-2008 21:49	29-Oct-2008 3:31	5:42	1
24089	M	28-Oct-2008 22:11	31-Oct-2008 10:15	60:03	1
24090	M	28-Oct-2008 22:26	30-Oct-2008 1:28	27:02	1
24091	F	28-Oct-2008 22:32	06-Nov-2008 6:31	199:58	1
24092	M	28-Oct-2008 21:44	31-Oct-2008 13:01	63:17	1
24093	M	28-Oct-2008 21:52	29-Oct-2008 3:27	5:34	1
24094	M	28-Oct-2008 22:15	30-Oct-2008 2:18	28:03	1
24095	M	28-Oct-2008 22:26	08-Nov-2008 20:18	261:51	2
24096	M	28-Oct-2008 22:37	02-Nov-2008 0:45	98:07	4
24097	F	28-Oct-2008 21:46	01-Nov-2008 22:12	96:25	4
24098	F	28-Oct-2008 21:53	29-Oct-2008 14:34	16:40	2
24099	M	28-Oct-2008 22:17	02-Nov-2008 7:32	105:14	2
24100	M	28-Oct-2008 22:28	31-Oct-2008 23:38	73:10	1

Nine of the tags were last detected at the array receiver farthest downstream, three at the logging bridge site and two in the fishway. For details on the movement and tracking of the tags see the full report in Appendix E, Figures 5-8. None of the tagged fish were recorded at receivers in the canal or upstream on the Salmon River.

Movement and analyses of tagged Coho

The hydrographs, summarizing flows in the mainstem Salmon River above the diversion, in the diversion canal, the net flow downstream to the mainstem and water temperature, are shown in Figure 28 for the period after Coho were tagged to the date of the last detection (October 28- November 9, 2008).

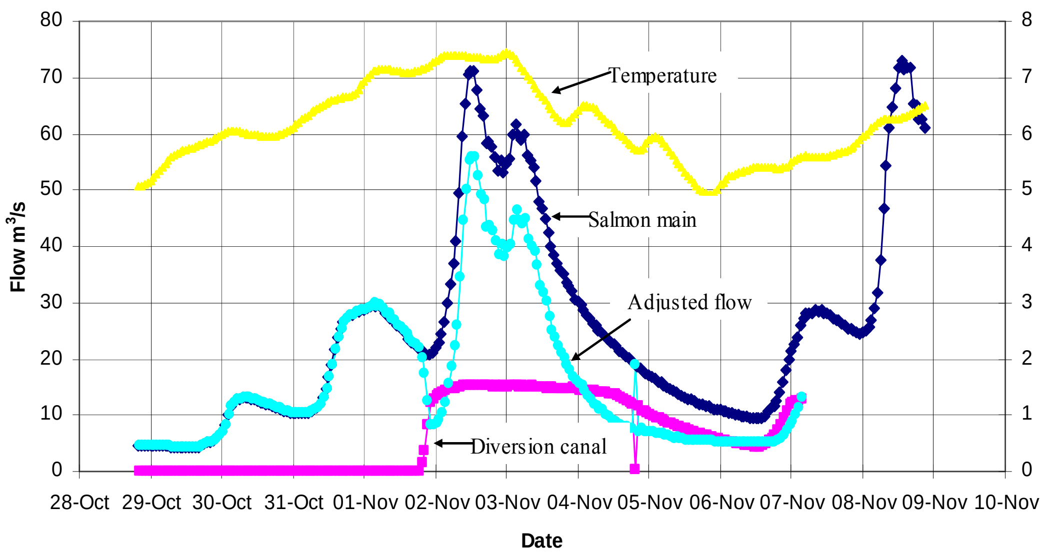


Figure 28. Discharge summary of the Salmon River. Flow (m^3/s) and temperature (C) in the Salmon River and Diversion Canal during the period tagged Coho were detected near the BC Hydro Diversion Dam. There is a gap in the flow data for the diversion canal between the 7 Nov (3:22) and the 12 Nov (20:32). "Salmon main" refers to the flow above the dam and "Adjusted flow" is an approximation of the flow in the river below dam. The first hydrometric reading from the diversion canal, indicating flow, was on the 1 Nov 2008 at 19:32. . (Lydersen et al 2009 Appendix E)

Only 3 tagged fish were detected in the fishway (Fig. 29), all at flows of 10-15m^3/sec to the river downstream.

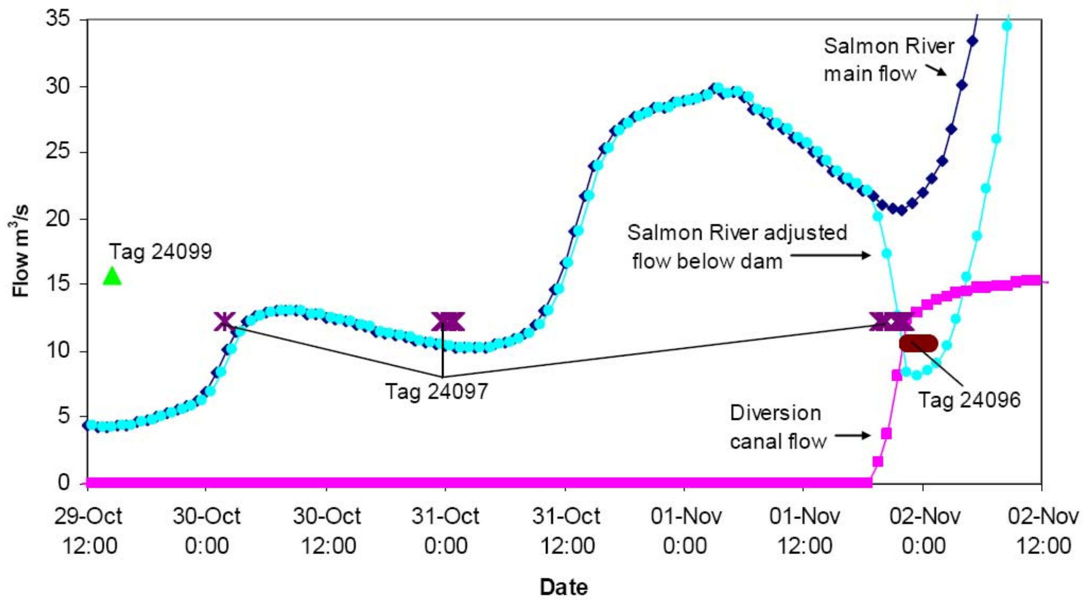


Figure 29. From Appendix E - (Lydersen et al. 2009) A close-up showing the flow in the Salmon River, diversion canal and adjusted flow in river below dam during the time adult Coho were detected in the fish ladder. Fish 24099 was only detected once and subsequently heard downstream. Fish 24096 had one period of continuous detection in the fish ladder. Each tag is shown as a different symbol

Discussion

The upper Salmon River has valuable Coho spawning and rearing habitat (Craig et al.l , Wong, R. and V. Komori. 1999) that will become increasing important with the effects of global climate change. Utilization of the entire accessible watershed is important to the biodiversity of Coho populations, and the access to headwater habitats will be key to salmonid survivals through warming periods. These higher elevation habitats will warm the least and retain the most snow, as well as provide some protection against the increased intensity of winter storm discharges.

By understanding the limits or bottlenecks, if any, to upstream migration of both Coho and steelhead adults at the Salmon River diversion dam we can better formulate practical solutions to adult upstream fish passage.

Coho fry survey

Annual surveys of the 6 established sites, both up and downstream of the diversion, (4 more sites are scheduled to be added in 2009) provide comparative data year to year, as well as within year differences on the habitats used by Coho juveniles in the Salmon River watershed. This will include relative densities and biomass, as well as potentially developing a link to the timing of mainstem flows and diversion operation during the upstream migration of the parent Coho. More detailed comparisons could also use the information from MoE (Pellett 2008) steelhead surveys to link spring spawner upstream migration success.

The Coho fry sites surveyed in 2008 result from adults that faced migration through the diversion facility in October and November 2007. Extended periods of high flows with discharge (>10m^3/sec) for much of the adult Coho migration period created challenging conditions.

Coho adult passage upstream of the diversion was confirmed with fry presence in all except one site sampled, and the MoE electrofishing survey from September 17-23 also confirms Coho fry presence in most sites (Pellett 2008). In general the sites upstream of the diversion had lower densities and larger size than downstream habitats surveyed. The average weights of the fish were small for late summer at 0.93g in downstream of the diversion at Marilou Creek and 1.3-1.5g upstream of the diversion.

Biomass calculations indicate similar productivities at 4 of the 5 sites that had Coho fry, but with very different populations. The Coho fry in Marilou Creek being about 60% of the size of fry from First Creek (1.55g), a small tributary of Grilse Creek. The estimated biomass capacity of the Salmon River, as reported by MoE from the alkalinity model, is around 225g/100m^2 for steelhead, which translates to 448g/100m^2 for coho (R Ptolemy pers comment). Stock Assessment staff in DFO use the density of Coho populations in specific sites as an indicator of the number of parental spawners (Appendix A), and also use the relative sizes of fry, using only young of the year, (0+) to reflect the 'seeding' level of the stream. For this methodology it is the frequency distribution of the fry sizes not the average size used to indicate healthy populations. Data gathered in 2008 may indicate that the Coho are at, or close to the carrying capacity of the habitat in some of the habitats surveyed in 2008. Marilou Creek for example had the most common size being 43mm, the smallest at 34mm and the largest of the 0+ fry at around 73mm, a 9mm spread towards the smaller fish and 30mm toward the larger which could indicate the habitat is fully seeded, and there are few food and other resources available (S. Baillie, DFO pers comm.). Marilou Creek also had the smallest size and highest density of Coho fry, 0.98g and 311 per 100m^2 respectively. The site sampled on Grilse Creek, more than 20km further upstream, had Coho fry ranging in size from 39mm to 61mm, the highest frequency length, 50mm, at the very centre of the distribution, indicating more than necessary resources are available to the fish and the habitat is under-seeded. Paterson Creek also illustrates the latter trend. Paterson was sampled a month after the other 5 sites, the fry were 10mm longer than Marilou Creek, the other site downstream of the diversion, possibly indicating the rapid growth of Salmon River Coho in late summer. Sampling all sites over a 4 day consecutive period in late August/early September of 2009 will help to clarify whether there are differences in the Coho habitats, growth and densities relative to being up or downstream of the diversion structure.

Temperatures recorded at the sampling sites ranged from 13C to 15.6C. Brett (1952) reported optimum growth efficiency in salmonids at water temperatures ranging from 10-15C. Mainstem Salmon River temperatures reported from the WSC gauge, (08HD015) just upstream of the diversion does indicate for 2008 that the temperature only reaches these levels in late June through to early October. The daily average temperature in the mainstem Salmon River on August 19 was 16.9C, the 20th was 15.2C. On September 17th when Paterson Creek was sampled the Salmon River was 12.3C. The summer of 2007 showed a similar temperature pattern with daily average temperatures only breaking through 10C from late June through to late September.

Adults accessing the upper river via the undersluice gate in late September, as we observed in both 2007 and 2008, would, if they spawned in early October be much further developed than the Coho migrating later in the fall. Winter temperatures in the Salmon River range from 0C to 4C, which slows developing eggs. For example, in 2008 if spawning occurred October 1 the Coho fry would be emerged in early June; those Coho still holding at the diversion in late November could be delayed a month or more, whether they ended up spawning up or downstream of the diversion. Summing the 'degree days', the average daily temperature, is used to predict egg to fry development. This may explain the size range of the 0+ Coho fry sampled in August 2008 in the Salmon tributaries (from 44mm in Marilou to 50 in First Creek and Grilse Mainstem), as well as the relatively small size of the 1+ Coho (from 68 to 96mm), especially in the Grilse Creek tributary. Placing temperature loggers in the sites up and downstream will provide some indication if groundwater influence is also a factor in growth of Coho fry.

Combining this with scale and size samples from outmigrating Coho smolts sampled at the diversion screen in the spring of 2009 there will be even better understanding if the Coho juveniles in the Salmon River spend one or two winters in freshwater, or if the length attained by late summer is an indicator of either smolt survival or life history determination. Scale samples collected from the returning adults, those used for tagging in 2009 will also offer key life history information.

Observations from fall 2007 and 2008

Adult Coho were sited from late September through late November, with fish already above the diversion by September 24th, holding in the WSC pool with mainstem flows around 1m^3/sec. Early migrating adults were able to swim through the undersluice gate (about 0.9m opening) on the decreasing hydrograph after higher discharges has brought them upstream (the fishway is dry during these periods of lower flow). Later in the season, with the undersluice gate lowered to 0.15 -0.2m the Coho were still attracted to the undersluice discharge, as well as flows over the dam and trimming weir. Coho adults cycled through the pool immediately downstream of the diversion dam on the side of the river opposite the fishway entrance, with sporadic forays into the high velocity discharge from the undersluice. During higher discharge, over 20m^3/sec (although this number does depend on the undersluice gate setting) flows would be through the fishway, the undersluice and over the trimming weir and dam. Coho were observed jumping at the waters spilling over the rocks near the fishway entrance, at the water over the face of the dam as well as the flows on the far left bank of the dam structure. Details on the conditions at the site, the flow patterns through and over the diversion structures indicate the Coho adults are attracted to the higher velocity and free spilling waters throughout the Fall.

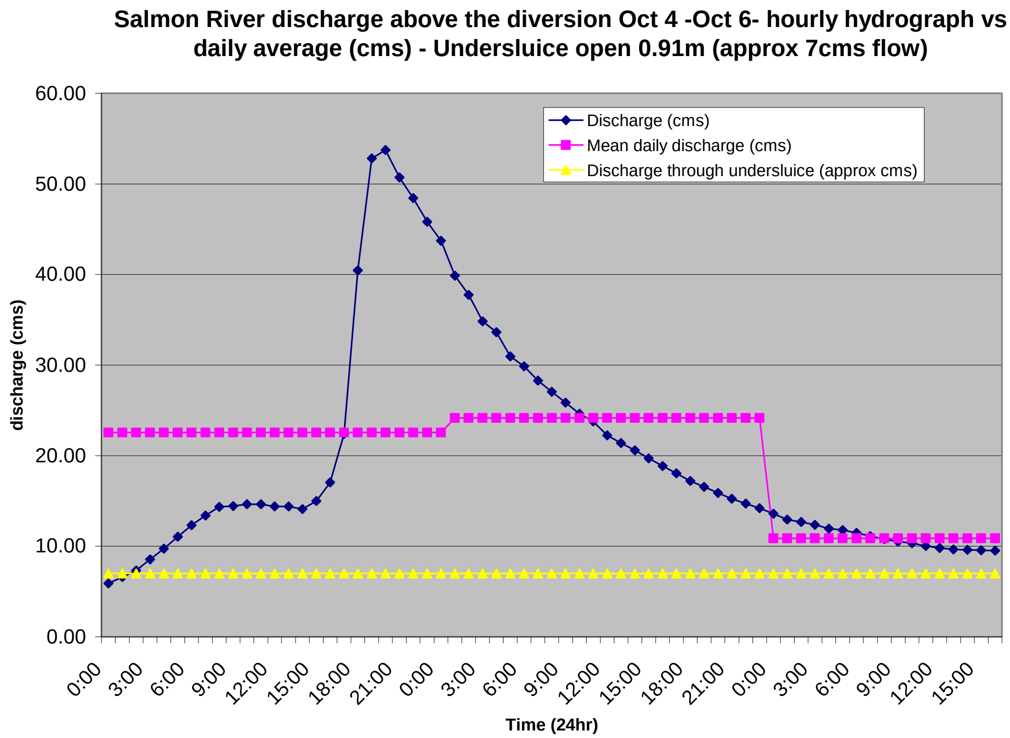
Resistivity counter and Acoustic tags

The results from the Resistivity counter and the acoustic tagging program do provide some insight into the relationship of the migrating Coho to the changes in the Salmon River discharge. The complications of the site result in a number of scenarios that the migrating salmon face. For the late September through to October 4th the flows all passed through the undersluice gate (0.91m), the fishway was dry so no fish pass the installed counter. With increases in flow, around 15m^3/sec, the fishway and the undersluice both provided attraction flows, and at the lower discharges in October there was a net upstream migration through the fishway of 79 fish. The undersluice was open nearly a meter until October 18th, resulting in lower water levels in the canal which feeds the fishway, possibly improving fish passage. After October 18th the undersluice gate was decreased, providing BCHydro's required license flows downstream to the mainstem Salmon River, and preventing larger debris jams in the gate opening during high flow events. This results in more water through the fishway on lower discharges, and higher canal water levels compared to the same discharge with the higher gate setting. The charts shown in Figure 28 a) and b) indicate the rapid increases and decreases of discharge over storm events, and the relative changes in the water carried through the undersluice. The average daily flows may not always be an indicator of the magnitude swings in flow the Coho adults experience over a daily migration; continued monitoring will provide details on the hourly discharge, canal water levels, and the velocity of water within the fishway.

The passive technology of the resistivity counter provides data on the entire migration timing as well as use of the fishway during the various complex flow patterns at the Salmon River site, but not of the timing and movement of individual fish, or where they go after passing through the fishway.

One of the questions posed for this study was "Do the Coho adults find the fishway entrance, and if so, is there a limited range of flows?" We have determined from both the resistivity and acoustic tagging that the fish do find the fishway, and there is some indication that the mainstem discharge, undersluice settings and diversion operation all have some influence. The range of flows that resulted in net upstream counts of fish passage varied from 30m^3/sec with the undersluice open to 0.9m, to 10-12m^3/sec at the 0.15m opening (mainstem - diversion flows). The expanded study in Fall 2009 will grant further opportunities to determine the passage limits, and if there are combinations of water flow operations that may aid or impede the Coho.

With the placement of the resistivity counter in the lowest cell in the fishway the adult Coho were enumerated entering quite effectively through most of October. Data indicates Coho were more likely to enter the fishway on the falling hydrograph when discharge had decreased to 10-20m^3/sec, after a rainfall. Placing the counter at the top end of the fishway could determine the number of fish that successfully navigate through the fishway, as opposed to the data from fall 2008 which provided data on the flows that the fish enter the fishway, or leave the fishway back through the bottom, but not those that actually make it through to the canal. The time/date stamp on each upstream passing will be correlated to the discharge recorded for that hour, adding to understanding of the flows encountered for successful transiting. Monitoring the water levels at the upstream fishway exit to the canal will help to round out the data, and add to the understanding of the flow limitations, if any, through the fishway.



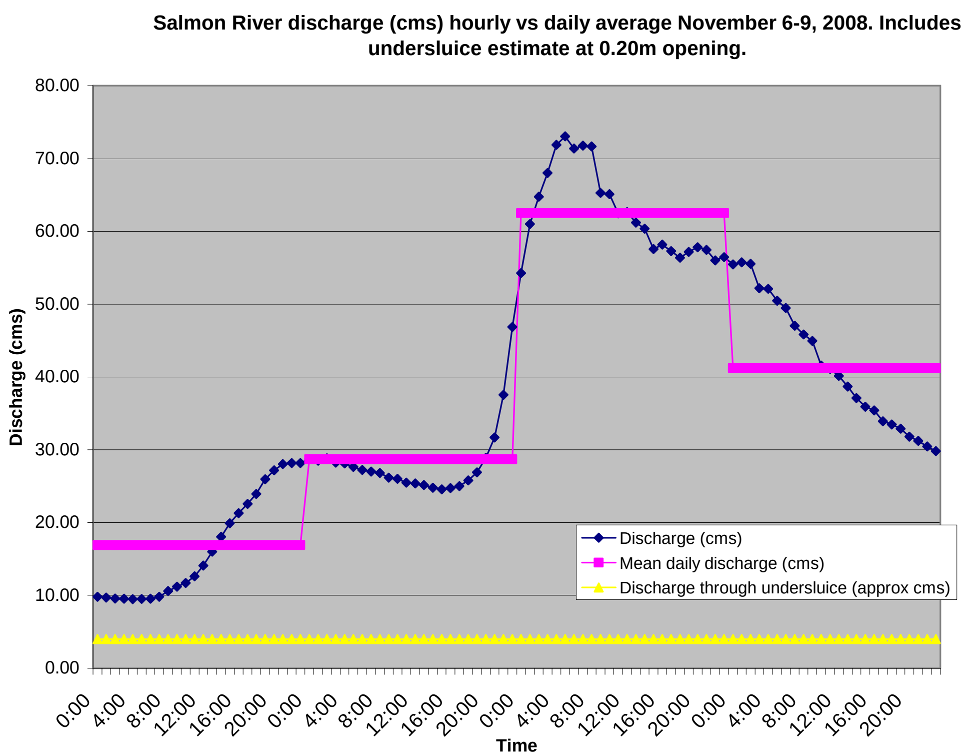


Figure 30. Salmon River discharge showing the hourly and daily averages, as well as the undersluice gate settings discharge estimates for 2 periods. a) October 4-6 and b) November 6-9 2008

Acoustic tagging

Capture and tagging

With only 14 caught of the estimated 60-70 fish observed holding October 28th, the beachseining and tangle netting procedure needs some improvements. Adding a second tangle net assembly upstream would likely improve the efficiency of catch, although capture at the diversion canal pool would be the most effective. The area at the diversion dam is only accessible through BCHydro property and it was determined that any activity at this site would require full lockout. BCHydro was as accommodating as possible in trying to schedule staff to supervise the lockout, however with weather and flow conditions so changeable, and the requirement to get all the rest of the crews assembled (contract staff for capture and tagging and DFO staff) on short notice, seining the logging bridge pool was the only practical and safe option. Flows were around $5m^3$/sec with a weather forecast calling for increasing rain within 24 hours. Any discharge over $10m^3$/sec in the river would be difficult to seine in, and the flows in the Salmon can stay above that discharge level for extended periods. This year, 2008, flows from October 30 through to early December seldom dropped to less than $10m^3$/sec, so it was timely the seining and tagging took place on October 28th. From observations over the past two fall migration periods we have noted that Coho adults move into the pool under the bridge after a high water event, and move up again to the diversion canal when the flow increases again (the assumption being they are the same fish, and moving upstream, and in general the numbers seem to match).

The tagging operations went extremely smoothly, the fish were in very good shape at capture and handling was a minimum. No anesthetics were used and the fish appeared to recover immediately. Tag retention was 100% for the holding period and all tags were detected in the receiver at the release site indicating the sending and receiving signals were working. The acoustic receivers covered all the areas of interest, the lower river, canal, fishway and upper river and tags were detected in 3 of the lower receivers recovered.

The canal receiver, initially installed in September and removed due to concerns of vandalism during non-diversion periods, was not reinstalled for a few days after the diversion flow was opened, which may have lead to tagged fish passing. In the next round of this study Kintama has recommended fixing the receiver to the canal walls so that it would be less likely damaged or vandalized, and be able to be left in place for the duration of the study. It is very unfortunate that the receiver in the diversion pool was not recovered – it would likely have added important details on the holding patterns in the vicinity of the dam and fishway. A more robust anchoring system will be designed for future projects at the site.

Results of this pilot project should be expanded with increased tags to cover more of the migration period and additional receivers downstream for the 2009 Coho migration as 2008 results showed the Coho moved back downstream after tagging. Placing a receiver in Paterson Creek, the first tributary downstream of the diversion is also recommended.

Results of both adult studies from fall 2008 indicate the fishway is accessed during downstream mainstem flows of 10-$15m^3$/sec, but there appears to be some blockage, whether behavioural or velocity, which limits the Coho access to the upstream exit. It is interesting to note the consistency of flow when the acoustic tags were recorded in the Fishway, and that one fish tried 3 different times over a period of 3 days, all at the same flows (10-12m^3/sec) and at the same time, near midnight. It was illustrative that only 3 of 14 fish were recorded in the Fishway, and none recorded upstream in the mainstem, or downstream in the canal. Increased numbers of tagged fish, and better secured receivers for the duration of migration and BCHydro operations will be important to the future studies. Reconciling the water level in the diversion canal and resulting velocities within the fishway may offer some rationale for the apparent lack of successful passage. This should be investigated further in fall 2009, both from the fishway design specifications and from onsite measurements of velocity.

This study was intended to pilot the various technologies, and ensure that they worked, and to identify challenges and work the bugs out before implementing a more comprehensive plan design for Fall 2009. The 2008 study has established a foundation of information, communications, procedures and logistics that will be built on with the continuation of this study.

Recommendation

1) Continue annual Coho fry surveys in the Salmon River Watershed, both up and downstream of the diversion, sampling 10 total sites up and downstream of diversion
2) Set resistivity counter in top cell of fishway to detect fish exiting to the canal – at present set up only counts fish in and out of lower section – need to understand the success rate of passage – and timing to discharge and diversion operation.
3) Investigate potential for 2 resistivity counters – one at top and one at bottom to track fish entering and successfully passing to canal.
4) Run acoustic tagging program in Fall 2009, with 50 tags applied to track Coho in diversion area.
5) Have acoustic receivers in position and recording for entire migration – identify potential methods and sites for attaching receivers so they are less vulnerable to vandalism.
6) Add additional acoustic receivers downstream of Paterson Creek confluence to capture downstream movement of tagged adults as well as within Paterson Creek.
7) Model and measure the hydrology of the Fishway to determine any physical limits of velocity.
8) Investigate debris deflectors at canal entrance to Fishway to reduce potential obstructions in Fishway and/or effects on resistivity counter operation
9) Install Water level data recorders in the canal and in the diversion pool to assess what magnitude of head influences fish passage, if any
10) Provide data and reporting to the Salmon River Diversion Committee and contribute to the BCHydro Fish Passage Framework Decision process.

Acknowledgements

BCHydro's Bridge Coastal Fish and Wildlife Restoration Plan provided the funding for this project, as well as liaison for project and safety planning with BCHydro staff .

BCHydro's John Hart Generating Station staff was invaluable assisting with project development, safety planning and personnel onsite for Workplace Protection supervision and lockout procedures. As well additional thanks to the BCHydro staff that provided data through filling out the Logbook forms whenever they were onsite.

As this was a pilot project there was much planning and adjustments to the project as it progressed and continued. The consultants involved Kintama Research Corp, Instream Fisheries Research Inc. and Mainstream Biological Consulting Inc. supplied professional and enthusiastic support as well as the ability to react on short notice to program requirements.

South Coast Fisheries & Oceans Canada was key in supporting the project. Personnel assisting throughout the project with field work, meetings, logistics, advice, reporting and planning included:

Oceans and Habitat Enhancement Branch -
- Resource Restoration
- Habitat Management
- Salmon Enhancement

Resource Management-
- Stock Assessment
- Fish Management

The establishment of the Salmon River Fish Passage Working group, comprised of BCHydro, Fisheries & Oceans Canada, Ministry of the Environment, and the Sayward Fish and Game Club allowed opportunities for ideas and information to be presented, discussed and exchanged.

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Appendices

Appendix A Coho Fry Surveys Work Statement

COHO FRY SURVEYS
WORK STATEMENT
KENT SIMPSON STOCK ASSESSMENT SOUTH COAST DFO

We are now assessing Coho stocks throughout the coast and in the Skeena and Fraser watersheds by determining the density and size of the juveniles prior to overwintering. Densities are difficult to interpret since they are so dependent on the habitat of the sampling site. However, it is becoming apparent that the change in densities at the same site from one year to the next often reflects changes that have occurred in the number of parental spawners. We think the size of the fry may also tell us whether the stream is capable of supporting more than the observed number of fry, that is whether the spawning was sufficient to fully 'seed' the stream. The size attribute that does this is not the average size (which strongly depends on the density of the fry) but how the sizes are distributed. If you plot the number of Coho of each size, eg. 50mm, 51mm, 52mm etc., you will get a length frequency distribution starting out with no really small fry, going to a peak number somewhere near the average size and declining down to no really large fry. Its the skewness that appears to be an important indicator: is the length interval between the smallest fry and the most common size smaller than between the most common size and the largest fry? If it is not significantly smaller, ie. if there is little skewness, there may be excess food and other resources for all and the stream may be under-seeded. Secondly, knowing the size of the fry allows us, in relativer terms at least, to estimate how well they will survive in the coming winter. That, in combination with the density estimate, tells us how the size of the smolt run next spring is likely to change.

SELECTING A STOCK AND SAMPLING SITE

Stock assessments by our Division are usually directed at wild (ie. not enhanced) stocks so this may be your first criterion. Second, the stock should be in a stream section (reach) that is small enough to allow a density estimate to be made, usually where it can be sealed off with barrier nets. Third, the habitat in the site should not have so much cover like deep water, extremely deep overhanging banks or thick woody debris that you are unlikely to capture most of the Coho with the gear you have. However, it should be a site where you have some expectation that Coho occupy. It would not be useful to pick a long riffle because few if any Coho will be there. In short, pick Coho habitat that you can sample. Most Coho occupy pools and backwaters where the current is not strong, where there is at least 10cm depth and where they have some cover like large woody debris, overhanging banks, overhanging vegetation or aquatic vegetation. Try not to pick the best Coho habitat in the stream either - we want a reach that is representative of the Coho habitat in the stream.

The reach should normally be about 30m long but the upper and lower bounds will depend on factors such as:

- the expected catch (determined by looking for fry or trying a few pole seine scoops). A catch of 120 to 500 is ideal.
- locations of spots that can best be sealed with barrier nets. For example, avoid putting a barrier net in the middle of a pool - its usually difficult and its not a good idea to arbitrarily divide a habitat type occupied by Coho.

Once the site has been selected it should not be changed later unless the reach has changed (eg. pools filled in) or you have found a another Coho habitat site that you are able to sample much better. Do not expand or contract the reach at later samplings in response to the catch you expect and do not change a site to obtain better Coho habitat (unless the old site is no longer Coho habitat).

Record the site in enough detail so someone not familiar with the area can find it. Flag the upper and lower boundaries of the site and preferably mark it more permanently than that, e.g. tree paint.

GETTING A DENSITY ESTIMATE

A list is attached of the equipment and supplies you will need to obtain the estimate and sample the catch. The density estimate consists of getting estimates of the number of Coho in the reach and of the area of water they occupy.

1. The Abundance Estimate

a) Seal the reach off using barrier nets. Avoid overhanging banks which are almost impossible to seal. Riffles are usually easy and it doesn't matter if you divide them since few Coho will be there. Use ropes or sticks to keep the top of the net up and hold the bottom down with rocks or sticks. You will probably have to periodically clean these nets of leaves during the session.

b) Select the gear. Unless the reach is entirely accessible to beach or pole seining, you should use a shocker in conjunction with netting. Netting and shocking complement each other since they are more efficient with different sizes of fish (shocking is better for larger fish). However, shock in moderation by only shocking those areas that couldn't be reached by netting. Shocking may kill or drive fish into deep cover, artificially reducing catches in subsequent passes. Typically, we beach seine if possible and 'clean up' remaining areas like riffles and stream banks with pole seining and/or shocking or we pole seine and shock. We seldom use more than 120 seconds of shocker time in each pass.

c) Fish the reach with the selected gears. Record the amount of effort you expend: the number of beach seine sets and/or pole seine sweeps and the number of seconds of shocking. This is pass 1 of at least 3 and it is critical to expend the same effort each time, so balance the effort. Too little effort and the next catch may not be substantially less and another pass will have to be done. Too much effort is unnecessary and the very low catch you may get in pass 2 makes it less likely that the pass 3 catch will be smaller yet - which causes some analytical problems (this will become clearer below). We normally pace ourselve to get a catch in Pass 2 which is a quarter to a third of the Pass 1 catch and our Pass 3 catch is very small or zero. It is entirely dependent on the site and the number of Coho but we almost never beach seine a pool more than once per pass and may make 10-20 pole seine sweeps in a 30m reach and perhaps shock for up to 300 seconds (seldom more than 120 sec, as note above).

If you are netting and shocking, do the netting first. Fish with the current when pole seining (more fish are caught if the water is muddy) and against the current when shocking (you need to see). You may have to wait for the water to clear before shocking. If so, process the netting catch while the water clears. If you can shock immediately, the third person can start processing the netting catch while the other two are shocking. Do not release any fish until all the passes are finished. Keep an eye on them in the buckets and change their water periodically. Do not keep large sculpins, trout or char in with the fry or fry will disappear.

d) Repeat the same fishing at least twice more. Arrange your sampling and other tasks so you give as much time as possible for the fish to settle down between passes. Use the same effort in the second and third passes. This is critical - guard against slackness in later passes. Your effort should not vary because of poor, even zero, catches. If the Coho catch has not declined 'significantly', so the third pass catch is still more than 20% of the first pass catch or if one of the catches was higher than the previous one, you should do more than three passes. This is particularly true if the last catch is greater than its predecessor because no estimate is then possible with the data at hand. If you do not have time, it is acceptable to stop the session with a catch that is higher than its predecessor but only if the catch is very small (say less than 5).

Examples:

Catches				Comments
Pass 1	Pass 2	Pass 3	Pass 4	
155	43	6	Not needed	Good est.
155	95	28	"	Fairly good est.
155	95	53	21	Pass 4 gives a much better est.
155	176	47	15	The 3 pass estimate would have
been				poor.
155	43	47	15	No est. possible after 3 - need 4
49	0	2	?	No est. possible after 3 but with such low numbers it would be acceptable to stop at 3. [The analyst can later force an estimate by making the catch zero in an imaginary fourth pass.]
1	0	1	?	Probably wouldn't do a fourth

2. Estimating the Area of Habitat

Run a 50m surveyor's measuring tape between the lower and upper boundaries of the reach and tie it off. Use another tape, a 30m is sufficient, to measure the width of the stream at points along the first tape. Two widths are recorded at each point: the total stream width and the width of water which is greater than 10cm deep. The latter is measured because it is the most meaningful for Coho since it excludes riffles and other shallows which they seldom inhabit. The 10 cm depth is usually estimated by seeing where the water comes to on the wader boot. The length on the upstream/downstream tape must be recorded with the two widths and a statement of the habitat type. Here is an example:

Length	Total Width	Width >10cm	Type
2.1(lower end)	3.1	2.7	P(bottom)
5.2	4.6	3.4	P
7.3	6.2	6.0	P
7.5	9.9	8.5	P
12.9	9.5	1.5	P(top)
15.1	3.7	2.1	G
18.0	3.3	0.9	R(bottom)
20.8	3.1	1.1	P(bottom)
24.1	5.8	5.2	P
26.9(up end)	1.4	0	P(top)

This describes a reach that is 24.8m long (26.9 minus 2.1) and consists, going upstream, of a pool, glide, riffle and pool. The lower pool is 10.8m long (12.9-2.1), the glide is 5.1m long (18-12.9), the riffle is 2.8m long and the upper pool is 6.1m long. Measure as many points as required to be able to draw a reasonable map: take widths where a habitat type (riffle, glide or pool) changes, where the amount of shallow water changes relative to deeper water, and where there are sudden width changes. The fourth measurement is an example of a rapid width change: by defining it exactly where it occurred, between 7.3 and 7.5m, a much more accurate area can be calculated than if the next measurement was at 12.9m. Sometimes side channels or isolated side pools are more easily measured separately by noting their length and a few widths or an estimated average width. If the side pools or channels are small, we may just estimate what percent of their area is >10cm deep.

Your results are interpreted better if the reach is photographed. Take as many photos as necessary to show all the major parts of each reach (usually 2 or 3). Note them on the data sheet (see below).

There may be a relationship between Coho productivity and water temperature and conductivity. If you have a temperature/conductivity meter ensure that it is calibrated periodically and take a reading above each site (away from the water disturbances). Do not have the meter recording near an active electrofisher. If you do not have an electronic meter, please take a thermometer reading.

SAMPLING THE CATCH

1. The Data Sheet. An example data sheet is attached. Note that water level is usually a subjective assessment of whether the creek is high, low or normal for the time of sampling. Leave blank if you don't know. Under the top part there are three main columns which can be used in several ways. At least for Pass 1, we usually have one for netted Coho, one for shocked Coho and one for other species (showing catches by each gear in the same column). Use them any way you like but we suggest that you also keep the shocked catches separate from netted catches (combine pole and beach seine catches however). Enter at the top of the main column the pass number, the species or 'Spp' (Coho, other, or all) and the effort or 'E' (see the legend at the bottom of the form). The first sub-column shows the fork lengths in mm. The tens digits are put in by you based on the size range of the catch. The second sub-column is used for tallies of the lengths (see below). And the third sub-column can be used for several things: recording other species if a separate main column is not used, recording scale book grid numbers for lengths at which scales have been sampled, or for weights. At the bottom of the form you should record: (1) where you took photos of the reach and in what direction (upstream, downstream, cross-stream); and (2) the number(s) of the scale book(s). The codes, 1 - 3, for the scale books are only used in the rare event that more than one book is used per session (see below).

2. Preparation. Prepare the anaesthetic bath and test one fish to see how quickly it is anaesthetized, 20 seconds is about right. We use about 3L in the bath. Fully label the scale book and prepare the data sheet.

3. Lengths. All salmon, trout and char must be measured. Coho in particular cannot be sub-sampled for lengths because the shape of their length frequency distribution is sensitive to errors in selecting a random sample of the total catch. Take each fork length (tip of nose to fork of tail) using the measuring boards and record on the data sheet as a tally mark in the appropriate row (see example). If three crew are available, we have two measuring and one recording with one of the measurers taking weights or scales when necessary.

4. Weights. If time permits, wet weights can be recorded in the second column. Blot the fish lightly with absorbent towels or sponges beforehand. We do not usually weigh the fish but when we do, we get a maximum of 3 weights per mm size class (ie. row).

5. Scale Samples. It is important to take scales for aging from any Coho that could be yearlings. We do not normally take scales from Coho under 70 mm fork length on the coast if it is after August. A typical sample will be about 5% of the total but this will vary. Start by selecting a minimum size which is giving something higher, say 10%, and adjust this size cutoff (usually upward) as the distribution of length tallies becomes apparent. If two size groups are developing as you measure, adjust the minimum scale sampling size to capture all the larger fish and especially the fish in the overlap length range between the two. All Coho above the minimum size should have scales taken.

Fully label the scale book. Using a scalpel, scrape a sample from the side, just behind the dorsal fin and above the lateral line and, without turning the scalpel over, slide the scale smear onto the grid square in the scale book using a pencil. Spread the scales around the square using the pencil. Wipe clean the scalpel and pencil. Record the grid number in the appropriate mm size class row on the form. If you use more than one scale book, indicate which book the grid number is for, either by using the book codes, 1-3, associated on the bottom of the form with each book number, or by drawing a dividing line in each row where a grid number refers to a new book. We seldom need more than one book, however.

(EQUIPMENT AND SUPPLIES

Barrier nets (2-4) - maximum mesh size that will stop fry, usually about 5/16" stretch mesh
- about 10m x 1m
- we don't use floats (too bulky) and use light chain or leadline on the bottom

Rope, about 1/4" dia. - for tying barrier nets, etc.
Beach seine - 40ft x 6ft is a versatile size
Pole seine - 2 man type
Backpack electrofisher, with anode pole, cathode, batteries (2), and rubber gloves (3pr) - recommend a paddle type cathode (a rat-tail is not preferred) and a ring-type anode. Cover the ring with netting so fish can be scooped by the shocker person.
Charger for shocker batteries
Pole scoop - used by the shocker assistant to scoop fish. We use a kitchen sieve lashed to a light pole 5-6ft long.
Sieves (2) - kitchen sieves for scooping fish
Buckets (5) for holding fish - 3-5 gal with holes drilled about 4" from the top or with screen windows so water can be replenished.
Chest waders
Polaroid sunglasses - essential for shocking
Anesthetic tray - a plastic wash basin, about 18"x12"
Anesthetic
Measuring boards (2)
Scalpels (4 or more)
Scale books, preferably with a book number and grid numbers 1-50 (allow 1.5 per site)
Pencils
Data forms (allow 2 per site)
Clipboard, legal size
Weigh scale (optional), with batteries and tray
Towels or sponges for blotting fish being weighed
Camera with high speed (eg. ASA 400) film
Survey measuring tapes, 50m and 30m (one each)
Waterproof notebook, ring binder type, with waterproof pages
Tally counter
Packs (3) for barrier nets, beach seine and other gear
Container for sampling utensils. We use a Tupperware box that fits inside the plastic anesthetic tray when packed.
Thermometers (2-3), or
Conductivity/temperature meter
GPS unit

Appendix B Salmon River Diversion

Salmon River Diversion Acoustic Tagging Survey
Activity Log Book 2008

BCHydro Staff Contractor DFO Technician
(circle option that applies)

Date: ______________**Time**: PDT /PST _____________
Crew Name(s):____.
River Discharge (m3/sec estimate) _______________________
Diversion Canal (m3/sec estimate) _________________?changed to ______
Weather : Clear Cloudy Rain Snow Wind
Lock out required Yes No
Purpose of Site Visit: (ie check site conditions, open/close/adjust radial arm gate, clear debris, monitor screen, check monitoring equipment)

Observations
Sketch for detailed observations notes next page

1. Debris build up on diversion trashrack
   - Clear Some debris Lots of debris ?Passable
2. Debris Fishway at diversion canal
   - Clear Partly BlockedMostly Blocked Passable?
3. Adult Salmon observed Yes No (Diversion pool, canal –btwn trash rack and fishway, canal below radial arm gate, upstream of canal entrance, under log bridge etc)
   - Where? ____________________# __________,
   - Where? ____________________# __________,
   - Where? ____________________# __________,
   - Where? ____________________# __________,
   - (or note on sketch next page)_________________

Activity Open Undersluice? Debris cleaning or Fish passage

a. Did fish go through?
b. Undersluice opened to __________inches
c. Undersluice opened for _________minutes

Additional Comments –fish attempting to go over dam etc,

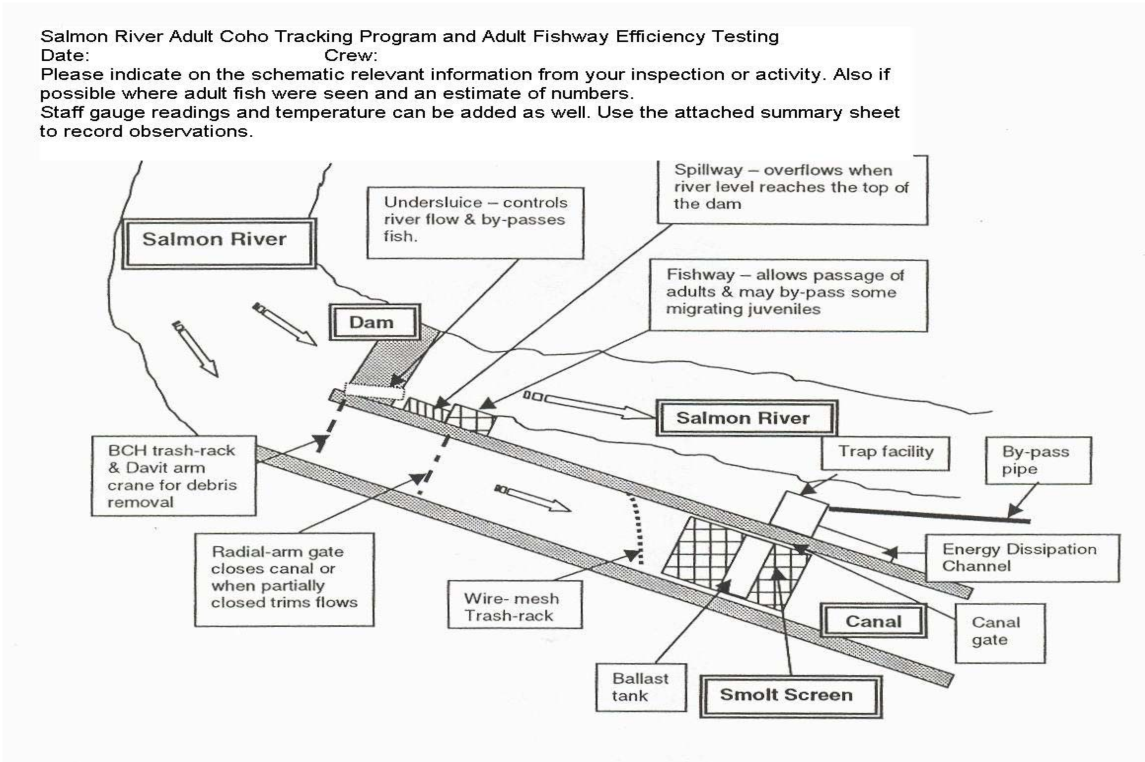

Figure 1. Schematic of structures at the Salmon River diversion dam and canal.

From Hanson L. 2001. Additional Salmon River smolt screen modifications and facility improvements report to B.C.Hydro. Letter to Allister Mclean of BC Hydro from BC Conservation Federation, March 19, 2001

Appendix D. Salmon River (BC Hydro) Diversion Coho Salmon Fishway Passage Study 2008-Resistivity Counter Evaluation. Instream Fisheries Research Inc.

Salmon River (BC Hydro) Diversion

Coho Salmon Fishway Passage Study 2008

Resistivity Counter Evaluation.

Prepared

by

D.J.F. McCubbing and Lloyd Burroughs

February 2009

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ABSTRACT

Adult coho salmon migration through the fishway at the Salmon River BC Hydro diversion was monitored in 2008 by a resistivity counter. In early October (through 15th) the undersluice gate was set high at 91cm and thus the flows down the header canal and fishway were likely much less than gauged above the dam. In fact discharge levels in the Salmon River precluded fishway operation due to low flows prior to October 4th with all the discharge passing through the undersluice gate and the fishway remaining dry. During this period fish may have passed upstream without the need to use the fish by passage via the undersluice gate.

Fish passage was recorded into the lower cell of the fishway from October 4th through the last day of sampling on December 1st. Evidence of successful fish passage was collected under medium and low flow conditions in October when river discharge above the diversion dam was measured at less than 14 CMS. After October 15th the undersluice gate was lowered to approximately 20-25cm with a corresponding but un-gauged increase in the proportion of discharge passing through the fishway. From this time and through November complete passage of fish through the fishway was not confirmed. Changes to the fishway allowed passage of coho salmon into and out of the fishway without the need to pass through the sensor units. These changes were required due to debris issues which blocked the sensor units in late October for a period of a few days. As a result we monitored many fish passing downstream but few upstream migrants. These data do however indicate that many fish or a few fish made several failed attempts to make fishway passage and that flows in excess of 16CMS passing down the fishway/header overspill and undersluice gate may have been problematic.

Further evaluations on spring freshet of passage issues are yet required to confirm these initial findings and for steelhead trout. Plans to evaluate passage at the upstream end of the fishway should be implemented and velocity/discharge metering within the fishway undertaken.

ACKNOWLEDGEMENTS

Financial support for this project was provided by the Department of Fisheries and Oceans through a grant from BC Hydro Bridge Coastal Fish and Wildlife Restoration Program. Shannon Anderson (DFO) assisted in with contract monitoring and data interpretation. River discharge and temperature data were provided by Chris Beers (BC Hydro) while local on-site support was provided by Mike Grant.

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1.0 INTRODUCTION

1.1 Site Study Area

The Salmon River watershed is located on the east coast of Vancouver Island, north west of Campbell River, BC, flowing eastward towards Johnstone Strait at Sayward. The watershed drains and area in excess of 1300 km^2 with an approximate main river length of length of 87.4km (Hansen 2004). A wide variety of salmonids frequent this watershed including coho salmon (Oncorhynchus kisutch), anadromous steelhead and resident rainbow trout (O.mykiss), cutthroat trout (O.clarki clarki), chinook salmon (O.tshawytscha), chum salmon (O.keta), and pink salmon (O.gorbuscha) as well as Dolly Varden, (Salvelinus.malma), Ptolemy *et al* 1977.

BC Hydro operate a water diversion canal on the upper Salmon River during high water periods, typically in the spring during snow melt and for shorter periods in the fall during rain or rain on snow storm events (Ladell and McCubbing 2005). The diversion canal entrance is located at the BC Hydro (BCH) diversion dam and accessed along the Menzies Mainline of ~~Weyerhaeuser Ltd~~., ~~North Island Timberlands~~, north of Campbell River (Figure 1).

Top of Form

Bottom of Form

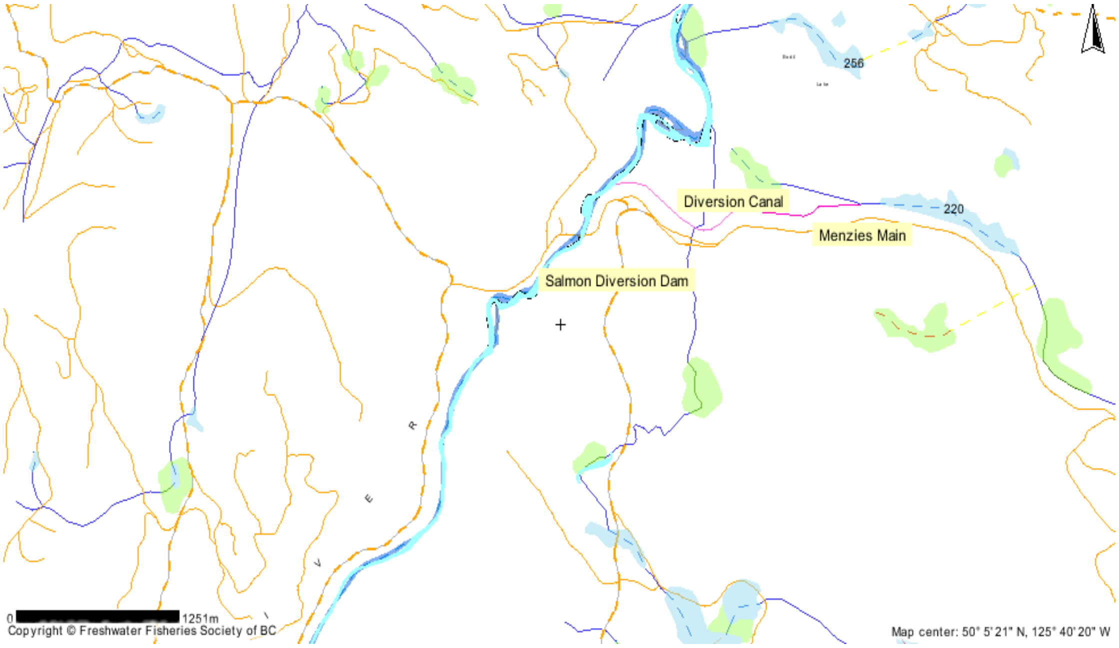

Figure 1. Location of Salmon River Diversion.

The diversion canal and dam were constructed in 1958 approximately 58km from the river mouth (Hansen 2004) at which time passage for anadromous salmonids was restricted by a natural barrier downstream of the dam site (Ptolemy *et al* 1977). After removal of this obstruction in 1977 by the Ministry of Environment and subsequent stocking of the upper watershed with steelhead trout and coho salmon, two improvements to assist fish passage were retrofitted into the existing structures. These included a large horizontal screen used to divert smolt and adult fish passing down the diversion back into the Salmon River, rather than into the Campbell River watershed and a fishway to assist passage of adults past the diversion dam (see Figure 2).

Figure 2. Downstream view of the diversion fishway, radial arm gate and Salmon River during fall 2008 at approximately 9CMS flow with the diversion closed (photo by S.Anderson).

1.2 Adult Fish Passage and site operations

During diversion operations and since 2000, BC Hydro must maintain a minimum flow of 4 cubic meters per second (CMS) to the Salmon River below the diversion whenever possible (note: natural flows may occur which are lower). Water may pass the site via the under-sluice gate, or via the fishway, or a combination of both depending on the discharge and the height at which the under-sluice gate is set.

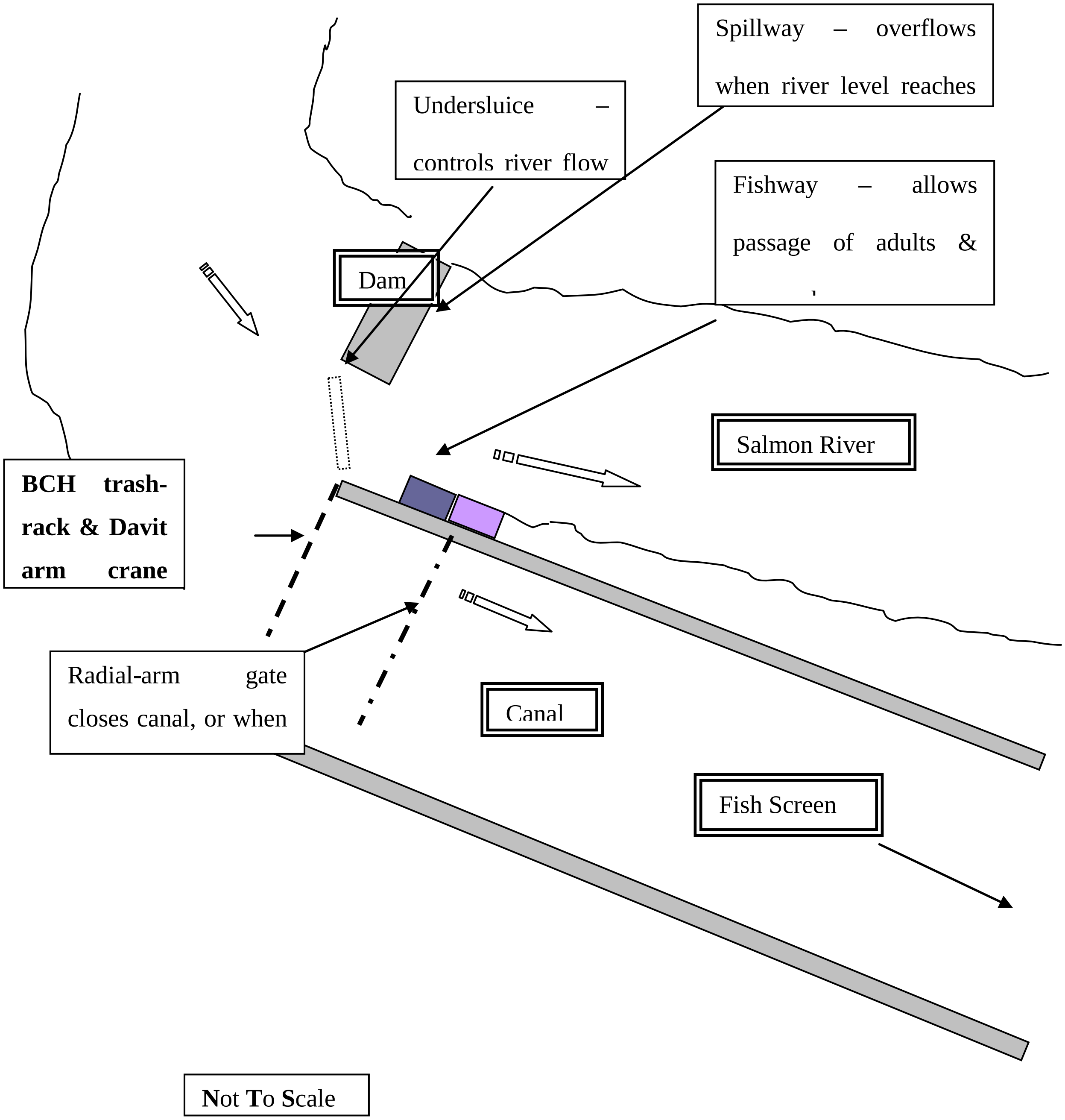

Figure 3. Schematic drawing of structures at the Salmon River diversion dam and fish screen facility (After Hanson 2001).

During operations in the fall of 2009, the undersluice gate was open at three different settings. Prior to October 15th, the gate was set open at 91cm. At this time either all or a significant portion of the river flow passed through this gate, the remainder passing down the diversion canal header and the fishway. The undersluice was reduced to 15-20cm open on October 15-16th at which time a greater proportion of the discharge would have passed down the canal header and the fishway creating increased "head" for the fishway. The diversion was not operating at this time. On November 1st, the diversion canal was opened and so the head in the canal was reduced for any given discharge through late November when the undersluice gate was raised to 50cm. The exact head levels in the fishway entrance area were not recorded continuously so can only be estimated in relative terms based on the above information.

During medium and high water flows, water will pass through the fishway, under the under-sluice gate and depending on river height over the canal header overspill and/or over the main dam. During diversion operation up to 15CMS will be diverted down the canal via the open and trimmed radial arm gate located immediately downstream of the upstream end of the adult fishway. A small portion of this is diverted with any fish via the horizontal screen back into the Salmon River, the remainder being diverted through the canal and a series of small lakes to Lower Campbell Lake, providing generation capacity at both Ladore and John Hart generating stations.

Observations of fish passage past the diversion structures and fish holding below the dam have been made by InStream Fisheries Staff between 2003 and 2008 during routine maintenance of the horizontal screen. These include passage of coho salmon through the fishway at below canal full capacity, likely passage of fish over the main diversion dam under high flow conditions, and conditions which appear suitable for fish passage via the undersluice gate on low flow with the gate out of the river flow. Observations of steelhead and coho holding below the dam (Figure 4) were also routinely recorded in operations reports (Troffe and McCubbing 2003, Ladell and McCubbing 2004 - 2008) although in many cases these were transient and the fate of holding fish ultimately unknown.

Figure 4. Coho salmon holding below the diversion dam under low flow conditions, October 10th 2003 (Photo from IFR archives).

1.3 Project Objectives

The following objectives were set for operation and analysis of counter data and with respect to the behaviour of coho salmon in the diversion dam fishway.

- Provide electronic counts of fish ascending the fishway.
- Report on counter performance where possible including;
- Sizing ability
- Count efficiency
- Reliability
- Species identification
- Evaluate the effects of discharge in the Salmon River on fish passage at the fishway.
- Suggest guidelines to counter operation and modifications (if required) to equipment set up post 2008 migration season.

2.0 METHODS

The Salmon River diversion dam fishway operated continuously for 60 days, from October 4th to completion of monitoring on December 2nd 2008, although flows within the fishway varied greatly during this period. The purpose of this program was to enumerate the passage of adult coho salmon migrating upstream through the fishway to spawn. Enumeration of fish was achieved through the operation of an electronic counter through which fish pass to enter the lower cell of the fishway unhindered. Fish enumeration operations were concluded on December 2nd, 2008 as access to the site was likely to become limited due to forecast heavy snowfalls although at this time no fish were observed in the locality and the fishway was operating.

2.1 Counter Design, Installation and Operation

The Logie 2100C electronic counter (Aquantic Ltd, Scotland) is a resistivity counter, which detects the passage of fish across an array of three electrodes. The counter electronics continually monitors the resistance of the water above the counting array (bulk resistance) and calibrates for minor environmental changes in this resistance every 30 minutes. When a fish passes through the electrode array, a change in resistance occurs, as a fish is more conductive than the water it displaces. This change of resistance is recorded and analyzed by the counter using a firmware algorithm to determine if it fits a typical fish pattern. Should the counter assess that a fish has passed over the array (based on this comparison), the time, direction of travel and peak signal size (change of resistance measurement) of the fish event, is recorded and stored for later downloading and analysis (see Aprahamian et al 1996 for more details of counter design and operation).

The design of sensors used in the Salmon River fishway is similar to that used on the Bonaparte Kloiya and Seton dam fishways and is a departure from more traditional applications of the Logie 2100C resistivity counter, although other generic counters have utilized similar in-river applications, particularly in Scotland (Nicholson et al 1995). As with previous applications the counter requires three electrode sensors (Aprahamian 1996, McCubbing et al 1999, McCubbing 1999) to determine when fish passage occurs, in which direction and of what size. In this case the sensor electrodes are created as rings and placed in insulating plastic tubes of 37.5cm diameter at 25cm intervals from the center of the tube. The tubes were approximately 100cm long. Insulated wires connect the tubes with the Logie 2100C unit. The two experimental tubes were installed in a grid which separated the lower cell of the fishway from the river. The tubes were mounted flush with the downstream end of the grid.

On September 22nd 2008, the resistivity counter, grate and tubes were installed in the last cell of the fishway. No flow was recorded in the fishway or the canal entrance to the diversion through October 4th at which time river discharge increased from an previous daily average of <3CMS to >22.5 CMS.

2.2 Data Download

Data collected was stored as buffer files (on the counter) and downloaded on a regular basis remotely via a modem and on site by field staff. The data contains the date of download, settings of the counter, and dummy fish data, followed by fish records. The fish records contain a date, time, conductivity, channel of count, direction of travel (up or down) and estimated Peak Signal Strength (PSS)

Example fish record:

.

Date	Time	Conductivity	Channel	Direction	PSS
25/10/2009	9:46:23	NR	1	U	98

In addition to these data, additional graphical representations of each record can be collected. These we refer to as "Trace data" and offer the operator and opportunity to further evaluate the incoming signal to which the counter algorithm assigns a counter record. Additional equipment (laptop computer) is required to capture these data and thus opportunities may be limited where power sources are restricted.

2.3 Data Analysis

Counter data analysis was under taken for all periods when the counter was operating. The total number of fish enumerated by the counter was assessed from the counter records. Total upstream escapement for each counting period (day or part thereof), was estimated from the following equation, developed from McCubbing 2003:

1) UPEt = UP c – DOWNc,

where

UPc is the total up count for each size class of fish each sample day

DOWNc is the total down count for each size class of fish each sample day

UPEt is the calculated upstream escapement for each size class of fish during time period t.

A series of daily results from the counter can thus be evaluated. By incorporating a calculated efficiency from video validation verification of counts an upstream escapement estimate can be calculated from the equation:

2) UPE = UPEt /E *100 + UPEt+1 /E+1 *100 + …. through time T

where

E is the calculated or substituted counter efficiency

UPE is the calculated upstream escapement over time T.

2.4 Discharge Monitoring and Operations

River discharge and temperature data were collected at Environment Canada Water Survey of Canada (WSC) site # 08hd015 upstream of the diversion dam and WSC #08hd020 (discharge only) in the diversion canal downstream of the smolt screen. Tables of this data was provided by BC Hydro. Data were made available as hourly and daily records. Discharge was recorded in cubic meters per second and temperature in degrees Celsius.

Within the monitoring period, the Salmon River diversion was operated from November 1st through November 22nd. During these operations of the diversion canal, the net discharge which remained in the Salmon river was calculated as the average daily (or hourly) discharge in the Salmon river above the dam, minus the measured discharge in the canal.

3.0 RESULTS

We evaluated the ability of coho salmon successfully passing through the fishway at the Salmon River diversion as indicated by a net daily upstream count on the fish counter. It should be noted that fish which enter the fishway, but fail to complete their passage may in some cases remain in the fishway above the counter for an extended period of time prior to being enumerated passing downstream. As such net daily counts are a general indication of fish passage and direction but may not in all cases be a good indicator of actual daily successful completion of passage into the diversion canal. However total net upstream fish observed over a period of time is likely to indicate an escapement of fish above the fishway. Furthermore after a debris laden storm event on October 25th, a cover grate on the lower fishway cell was removed allowing fish to enter or leave the cell on high water without passing through the fish counter. This was undertaken to avoid debris blocking the counter tubes as happened on October 26th through 28th. In addition, we cannot comment on the fate of fish once they pass above the fishway.

3.1 Resistivity Counter Data Analysis and Peak Signal Size (PSS)

Peak signal sizes of up counts were plotted against size category for fish passing through the counter in two periods, October and November, 2008 (Figure 5), to provide data for species allocation. In October the majority of fish were assigned a size class of 127, the maximum the counter can assign. At this time the gain setting was set to 300. The lack of smaller up counts (7 of 211) indicates larger coho salmon represented the majority of fish passage with the smaller counts perhaps being coho jacks. A similar pattern was recorded for downstream migrants.

On November 3rd the gain setting on the fish counter was reduced to 100 in an attempt to provide some relative sizing of coho adults in light of the lack of smaller signals. The counter threshold was set to 30 below which data were not recorded to avoid background noise interference in operations. Evaluation of counts in November indicated a median PSS value of 90 with a normal distribution (Figure 6).

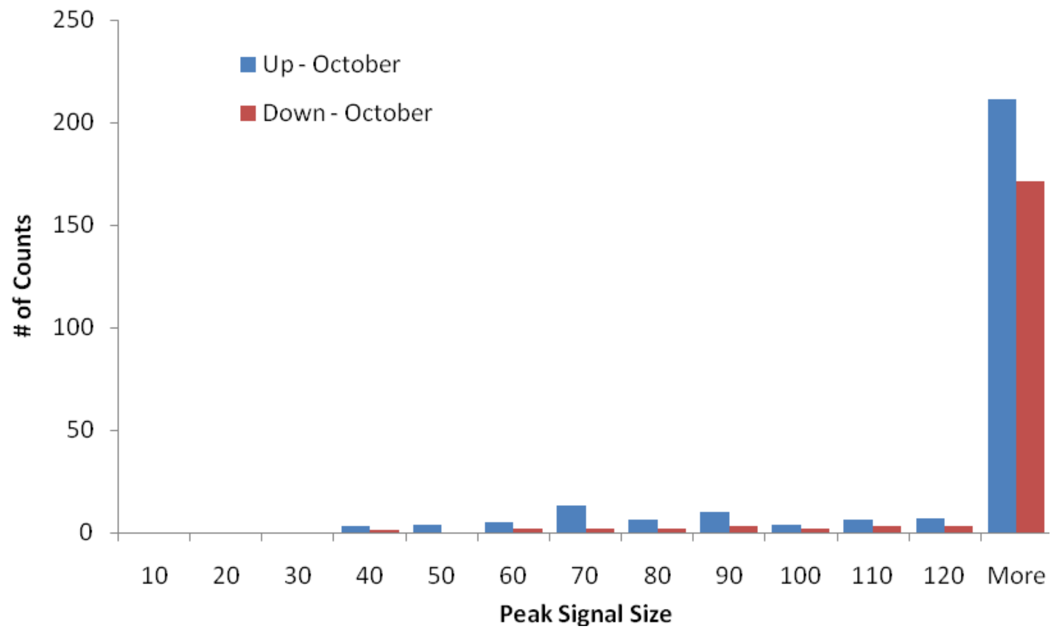

Figure 5. Peak signal size of fish enumerated at the Salmon River fishway, October 2008, gain set at 300.

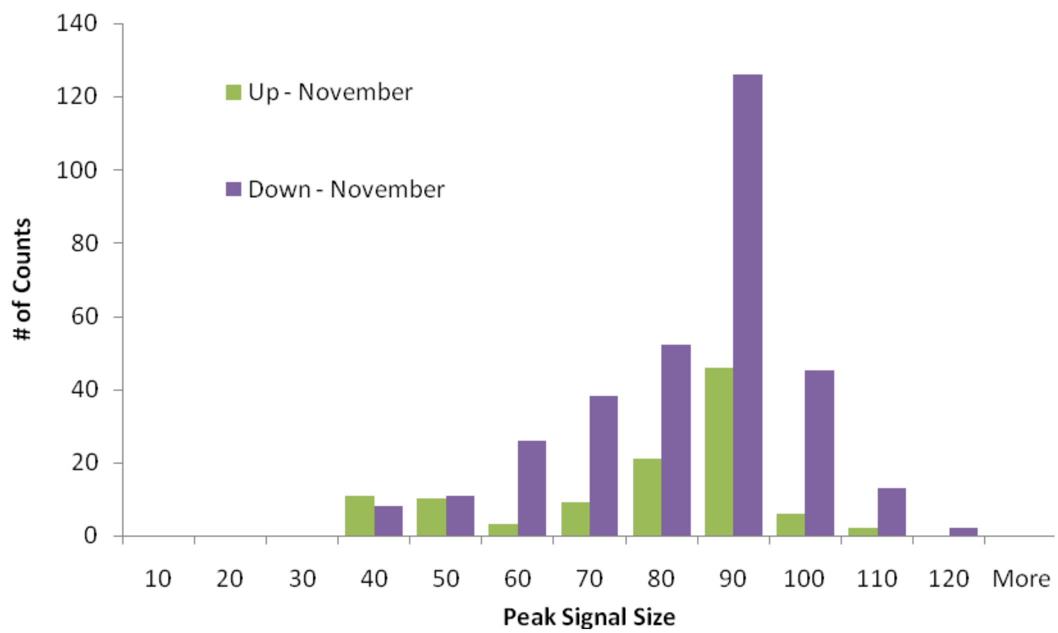

Figure 6. Peak signal size of fish enumerated at the Salmon River fishway, November 2008, gain set at 100.

3.2 Coho Salmon Enumeration

Fish counter operations for coho salmon enumeration started on September 24th. The fishway was dry at this time with the undersluice gate open and this likely allowed fish passage therefore no fish were recorded through October 3rd. On October 4th fish movement was recorded as the river discharge increased and the fishway started to operate. The first upstream count was recorded at 11:09am at which time discharge in the river was 14.65 CMS with a river water temperature of 10.5^0 C.

Typical count efficiencies for "Crump Weir" (triangulated full river span structure) style and tube style resistvity counters are around 90%, +/-5% SD (Nicholson 1995, McCubbing et al 1999, McCubbing et al 2003). Examination of limited graphical "trace" data from the Salmon River fishway in 2008, indicated fish were unlikely to pass through the counting tubes without being correctly assigned as up/down counts based on typical trace type.

Video validation with infra red night illumination, was attempted but results were inconclusive due to fish passage during periods of high debris load, at night in turbid water and following flood events in which the camera mount was moved and thus not functional. In addition passage appeared skewed to channel (tube) 1, where as the video camera was aimed at the upstream end of tube 2. Fish were however observed on video in the fishway circling above the counter tubes on October 16th presumably having entered either through the tubes.

For the purposes of this report, we assume the counter is 100% efficient and that all upstream and downstream fish were correctly enumerated. These assumptions, while known to be incorrect, allow us to develop a baseline evaluation of the counter operations. Future operations will include more rigorous validation methodologies based on the lessons learned in 2008.

Daily fish movement in an upstream and downstream direction was calculated for each day (Figure 7, Table 1) from October 4th through December 2nd except the period of 30th of October through November 3rd when a battery malfunction resulted in no counter records being recorded (Table 1). Data after September 29th will not be a complete count as fish could access the fishway under high flows (>12CMS in the Salmon River) by passing over the retaining wall and through the open cover grid (Table 2).

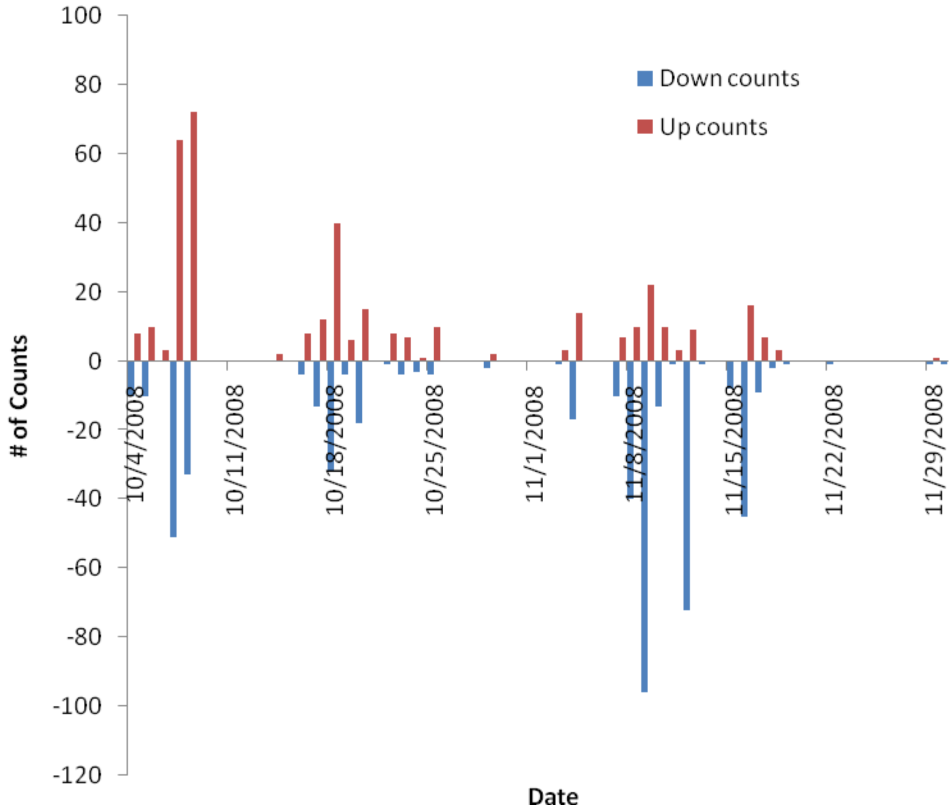

Figure 7. Daily up and down counts as recorded by the resistivity fish counter on the Salmon River fishway, fall 2008.

Table 1. Summary of daily fish counter data at the Salmon River fishway, fall 2008.

Date	Total Down	Total Up	Net Count	Net Cumulative Count	Daily Average CMS	Daily Av Water Temp
10/4/2008	-10	8	-2	-2	22.55	6.5
10/5/2008	-10	10	0	-2	24.16	5.9
10/6/2008	0	3	3	1	10.87	5.2
10/7/2008	-51	64	13	14	21.85	5.5
10/8/2008	-33	72	39	53	16.40	5.8
10/9/2008	0	0	0	53	9.21	6.5
10/10/2008	0	0	0	53	6.64	6.9
10/11/2008	0	0	0	53	5.16	6.6
10/12/2008	0	0	0	53	4.28	6.3
10/13/2008	0	0	0	53	6.03	6.3
10/14/2008	0	2	2	55	6.90	5.8
10/15/2008	0	0	0	55	5.33	5.4
10/16/2008	-4	8	4	59	5.04	5.6
10/17/2008	-13	12	-1	58	51.35	6.1
10/18/2008	-32	40	8	66	21.54	6.5
10/19/2008	-4	6	2	68	11.24	6.1
10/20/2008	-18	15	-3	65	9.42	6.5
10/21/2008	0	0	0	65	8.89	6.1
10/22/2008	-1	8	7	72	7.48	6.5
10/23/2008	-4	7	3	75	6.99	6.3
10/24/2008	-3	1	-2	73	6.40	6.4
10/25/2008	-4	10	6	79	7.34	6.4
10/26/2008	0	0	0	79	6.24	5.5
10/27/2008	0	0	0	79	5.28	5.1
10/28/2008	0	0	0	79	4.61	5.3
10/29/2008	-2	2	0	79	7.02	5.9
10/30/2008				79	11.34	6.0
10/31/2008				79	24.74	6.1
11/1/2008				79	26.16	6.8
11/2/2008				79	60.19	7.2
11/3/2008	-1	3	2	81	35.98	7.3
11/4/2008	-17	14	-3	78	19.00	6.5
11/5/2008	0	0	0	78	11.67	5.9
11/6/2008	0	0	0	78	16.91	5.2
11/7/2008	-10	7	-3	75	28.70	5.5
11/8/2008	-40	10	-30	45	62.49	5.8
11/9/2008	-96	22	-74	-29	41.21	6.5
11/10/2008	-13	10	-3	-32	23.88	6.9
11/11/2008	-1	3	2	-30	21.78	6.6
11/12/2008	-72	9	-63	-93	49.45	6.3
11/13/2008	-1	0	-1	-94	35.64	6.3
11/14/2008	0	0	0	-94	20.20	5.8
11/15/2008	-8	0	-8	-102	63.28	5.4
11/16/2008	-45	16	-29	-131	38.80	5.6
11/17/2008	-9	7	-2	-133	23.03	6.1
11/18/2008	-2	3	1	-132	14.76	6.5
11/19/2008	-1	0	-1	-133	10.63	6.1
11/20/2008	0	0	0	-133	9.05	4.7
11/21/2008	0	0	0	-133	16.88	4.4
11/22/2008	-1	0	-1	-134	24.47	4.5
11/23/2008	0	0	0	-134	13.36	4.4
11/24/2008	0	0	0	-134	10.05	4.4
11/25/2008	0	0	0	-134	13.93	4.6
11/26/2008	0	0	0	-134	12.96	4.5
11/27/2008	0	0	0	-134	9.66	3.8
11/28/2008	0	0	0	-134	9.48	3.9
11/29/2008	-1	1	0	-134	14.99	4.2
11/30/2008	-1	0	-1	-135	26.30	4.5
12/1/2008	-2	3	1	-134	27.51	4.6
12/2/2008	-1	0	-1	-135	19.98	4.7

Table 2. Summary of fish counter operations fall 2008.

Date	Operations	Days
24 Sept - 3 Oct	No water in fishway	10
4 Oct - 29 Oct	Complete count	26
30 Oct - 3 Nov	No count (power outage)	5
3 Nov - 2 Dec	Partial Count	29

Fish counter data indicated that fish movement into the fishway occurred most days, but that the majority of fish enumerated, either in an upstream or downstream (likely recycling fish not kelts) direction occurred in just a few days over the sampling period. Of the 376 up counts and 511 down counts recorded, 80% of up counts and 90% of down counts were recorded in just 14 of the 56 operational days.

The daily cumulative count was then calculated from October 4th through December 2nd except the period of 30th of October through November 3rd when a battery malfunction resulted in no counter records being recorded (Figure8). During the period October 4th through October 25th a total 268 up counts and 189 down counts were enumerated for a net upstream migration of 73 fish. While this indicates positive escapement, the large number of down counts relative to the net escapement is high and unusual in fishway applications of this technology.

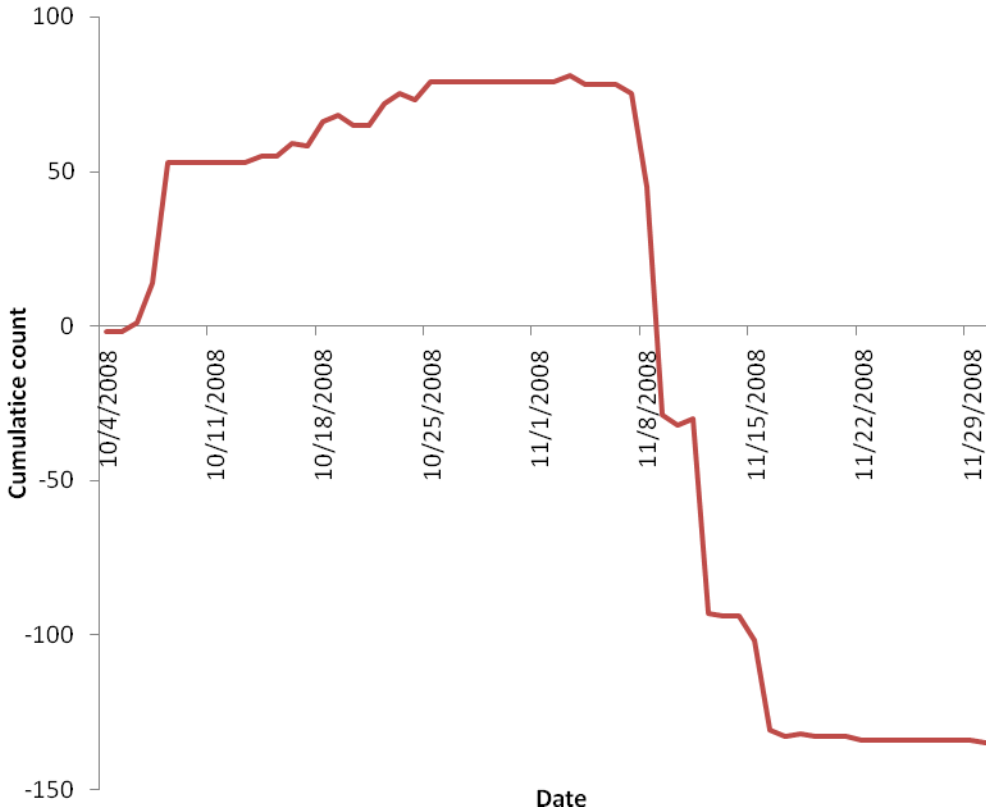

Figure 8. Cumulative net fish count at the salmon river fishway, fall 2008.

After the fishway grid was removed on October 26th, some fish may have passed into and out of the fishway under higher flows without being enumerated. The data collected from October 3rd through December 2nd indicated that a net downstream count of 216 fish was recorded in this time period. This is likely explained by fish passing into the fishway over the overspill separation wall during elevated discharge but returning to the river from the fishway via the fish counter tubes as it is unlikely that outmigrant kelts were present in the river at this time.

3.3 Discharge and Upstream Fish Passage.

There is some evidence of fish passage being affected by river discharge levels and perhaps temperature. During October the diversion canal was not operating and thus the discharge passing down the river was that recorded above the fishway and diversion dam. In these circumstances peak fish movement was recorded in the fishway during periods of increased river discharge, particularly when average daily flow was above 10CMS but below 20CMS (Figure 9). Preliminary examination of hourly records indicates that greatest upstream fish movement was recorded when flows were in the range of 12-16CMS on a falling discharge curve.

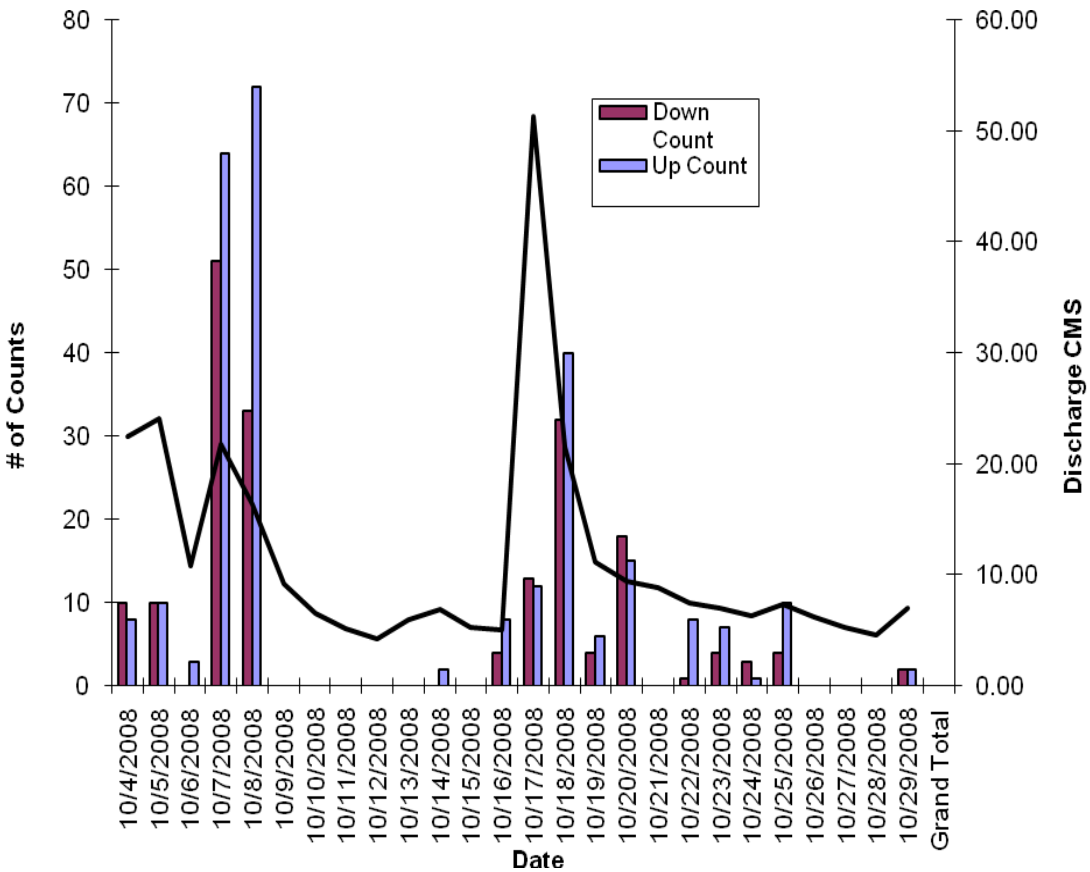

Figure 9. Daily up and down count of coho salmon in the Salmon River fishway, compared with average daily river discharge in CMS, during October 2008.

Examples of this behavior were particularly evident on October 8th and 18th. The exact time of successful passage however cannot be established as the counter was at the lowest cell of the fishway and fish may stay resident in the fishway cells for an unknown period after entrance and before they exit upstream.

Examination of data compared to discharge in November once the diversion canal was operating requires a different approach. In this time period, the discharge available for upstream migration is the net discharge remaining in the river. This can be calculated by substracting the daily discharge in the canal from total discharge above the diversion dam. During the period Nov 7th through 11th, no discharge data were remotely recorded in the canal, however site visits indicted the canal was running at close to capacity during this period and the discharge was thus assumed to be in the region of 12CMS.

On first examination, upstream fish passage appeared very limited during November with net daily counts generally negative in value (Figure 10). We assume that fish were successfully navigating the fishway, although in unknown numbers, based upon October fish movement data. During November fish may have entered the fishway via the overspill in the lower fishway cell or through the counter tubes. Similarly, fish exited either via the upstream end of the fishway, via the counter tubes or via the overspill. The high net count in a downstream direction was markedly increased during several periods (Figure 10.) compared to October and indicates many fish either entered the fishway via the overspill, failed to navigate the fishway and left via the counter tubes or that a significant number of kelts utilized the fishway for outmigration. These days of high net down count appeared to be co-incident with days when net river discharge exceeded 20CMS.

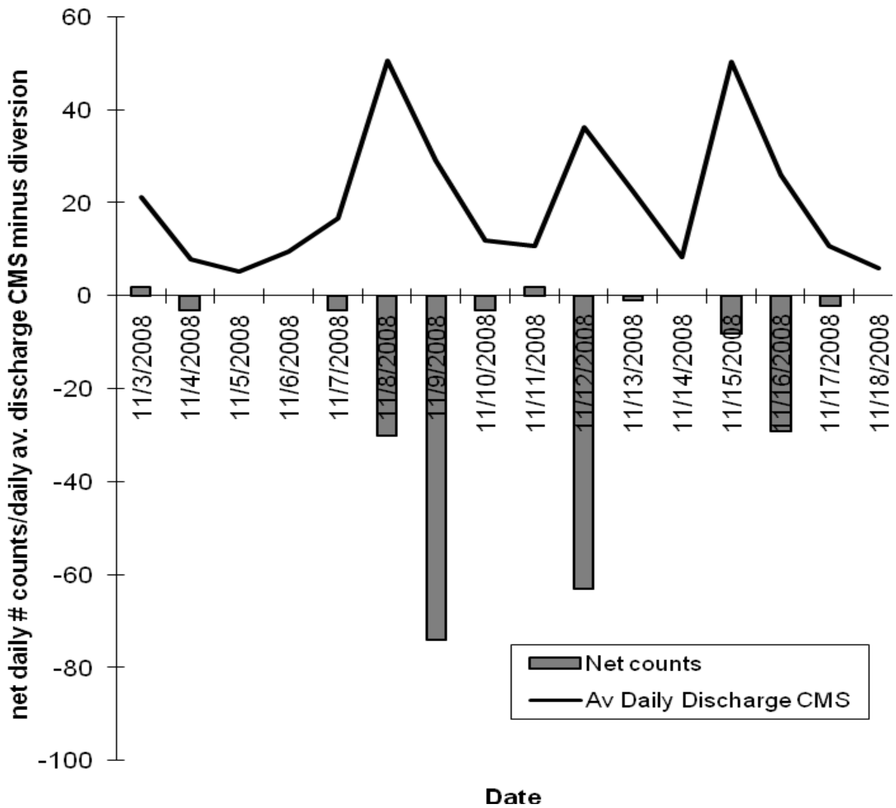

Figure 10. Net daily count of coho salmon in the Salmon River fishway, compared with average daily river discharge in CMS, during November 2008.

Daily average water temperature varied considerably through the study period as well as daily (Figure 11). Generally water temperatures were greater in periods of higher water discharge and lower during the night. Temperatures were highest during the day at the start of the study (>11C) and lowest at the end of the study during the night, (<4C). Fish passage through the counting tubes generally appeared to coincide with periods of elevated temperatures, but occurred across the range of 6C through 9C. These relationships are complicated as elevated temperatures were often linked with elevated flows and complete fishway passage could not be confirmed so the effect on temperature on the successful migration upstream cannot be established at this time.

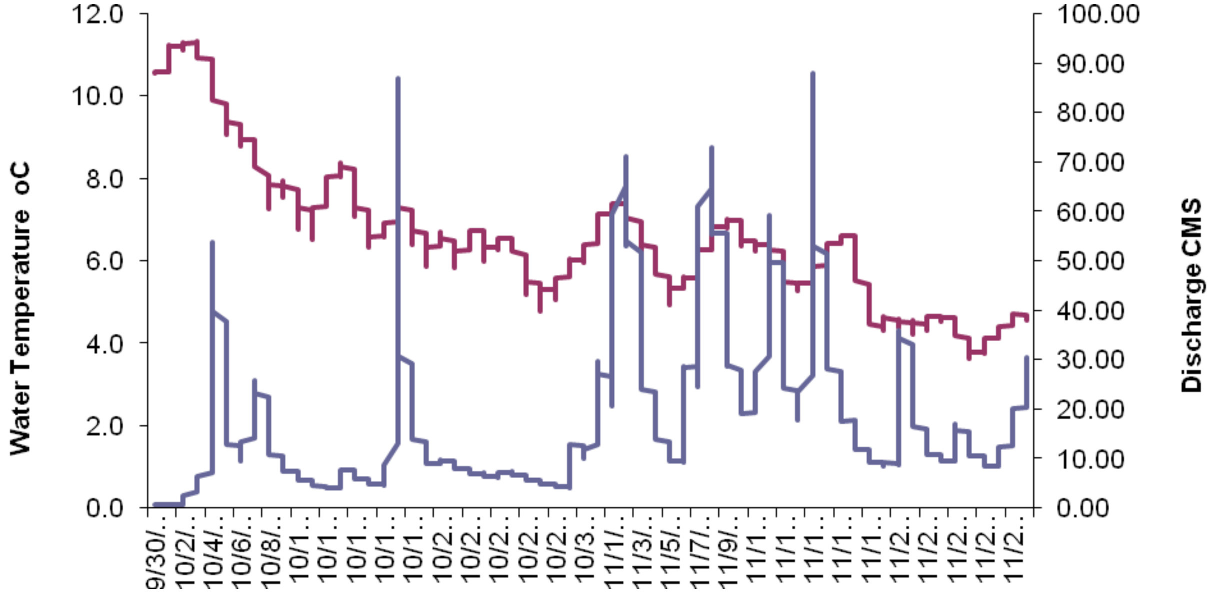

Figure 11. Daily fluctuations in temperature (red bar) and discharge (blue bar) data at the Salmon River upstream of the diversion dam, October 1st through November 30th 2008.

4.0 DISCUSSION

In this study a resistivity fish counter (Logie 2100C) was utilized to gather information on fish passage through the Salmon River diversion fishway during the coho migration period. The counter sensor units comprising of paired electrodes in two tubes were located in the lower cell of the fishway between fishway and the river. This location was selected to confirm that fish had found the fishway entrance and at what flows they were attracted to this passage option around the diversion dam. The location was also less likely than an alternate location at the fishway intake to suffer from debris build up during flood events or dewatering during low flows both of which can create counter noise events.

The operation of the fish counter was in the main successful with just one period of outage (5 days) resulting from a battery failure in the power system. Video validation was attempted but due to debris loads, turbidity and the behavior of fish, few validated records were recorded. Graphics data collected indicated both typical and non-typical fish event records likely resulting from fish behavior and the velocity in the counting tubes. This may have affected overall counter efficiency but without complete graphics records and or video validation, this cannot be fully evaluated at this time.

The fish counter was operated between mid September and early December. During this period the fishway operated from October 4th, after the first fall rains, continuously through December 2nd when the enumeration electronics were removed. Fish passage was recorded into the lower cell of the fishway on the first day that water was present in the diversion canal header (Oct 4th) and some attempts at passage were recorded in the final week of operations, although these were low in number compared to the periods of peak fish movement on October and November.

Over the entire period of operations, the number of down counts recorded exceeded the number of up counts at the sensor units which is unusual in this type of situation (McCubbing 2003). This can be explained by the operational change made on October 29th. On this date the lower fishway cell cover grid was removed to allow debris to float out of the fishway, rather than block the counter sensor tubes as occurred on October 26th for three days. This change allowed fish to pass upstream or downstream at elevated flows (~16CMS) without being enumerated. Based on the recorded data it appears that while fish did enter the fishway by swimming over the dividing wall, they had a tendency to leave the fishway by the counter tubes. This resulted in a large net negative count in November which could only otherwise be explained by kelted post spawner outmigrants, none of which were observed at this time. As a primary aim of the project was the intention to establish if and when fish made passage through the fishway, the results are interesting despite the uncertain number of total fish enumerated making passage. Clearly fish did enter the fishway in November but it appears that for many fish, or a few fish on many occasions, “drop back” or recycling occurred through the lower cell. This behavior appears validated by the acoustic tagging component of this work, that indicated three fish entered the fishway in late October, but none of these were detected on the upstream arrays indicating passage through the fishway was likely incomplete.

Evaluation of the conditions during which fish located the fishway entrance indicted that there was a preferred discharge for attempted passage. These conditions occurred when the diversion canal header was wetted and the flows down the Salmon River were below 20CMS. At flows in excess of this we tended to enumerate large numbers of downstream counts, indicating a possible problem in the fishway. In our view based on visual examination, this problem is most likely to be a velocity barrier issue in the upper reaches of the fishway at high river discharge. The upstream exit in the fishway consists of a 4ft by 24 inch slot which can be closed with a manual sluice gate. When the canal is full a head of approximately 2.3m or more feeds the fishway creating excessive velocities through this slot into the first fishway cell. In these instances it is possible access through the fishway and into the canal is limited. It appears that this does not block all passage in coho salmon, as on a number of occasions passage likely was possible when the canal header was not full. The effect on migration delays however may be significant and some fish may abandon efforts after one or more failed attempts particularly in periods of extended high-water.

5.0 SUMMARY

During the study period, the resistivity counter installed at the lower end of the Salmon River diversion dam fishway was successful in demonstrating that coho salmon adults were able to locate and enter the fishway and at a variety of discharges. However, in October data collected indicated an apparent large number of fish recycled between the lower fishway cell and the river, an atypical behavior compared with other similar fishway counters we have examined. There also appeared to be a preferred flow during which upstream passage was greater than downstream passage and fish presumably ascended the fish way successfully. This flow window was limited to below 16 CMS. Discharges of greater than 16CMS (with the diversion closed) appeared problematic for fish passage with reduced fish movement and reduced successful migration through the entire fishway, resulting in some negative count days.

During November when fish had access to the fishway via the lower cell overspill (grid removed due to debris issues), downstream movement peaked at discharges in excess of 20CMS (river discharge minus diversion flows). As in October this likely indicates a possible flow barrier in the fishway at elevated discharges as debris issues were not observed. Visual observations indicate the orifice between the fishway forebay and the first cell of the fishway, which is regulated by a sluice gate may be the problem. Velocities within this area at full or overflowing canal head discharges appear very high and should be evaluated.

In summary we recommend several additional investigations which should confirm or refute these initial findings and allow investigators to determine if modifications and or additional fish passage requirements are necessary at this location to assist fish passage. These are:

- Additional monitoring with a resistivity counter at the upper end of the fishway to confirm fish passage (perhaps combined with lower cell monitoring)
- Validation of counter efficiency with video to be repeated and expanded.
- Monitoring of steelhead trout passage issues during spring freshet and canal operations.
- A repeat of either acoustic tag tracking of migratory adults and/or additional evaluation through radio tag evaluation (see McCubbing 2003) in the fishway to determine possible velocity barriers.
- Flow monitoring in the fishway to evaluate canal head to inter-cell velocity relationships
- Examination of undersluice operating height during periods of lower discharge when canal is not operational.
- Improved power source to allow for graphics and video data recording.

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Appendix E. Salmon River Fishway Assessment Study :Kintama Research

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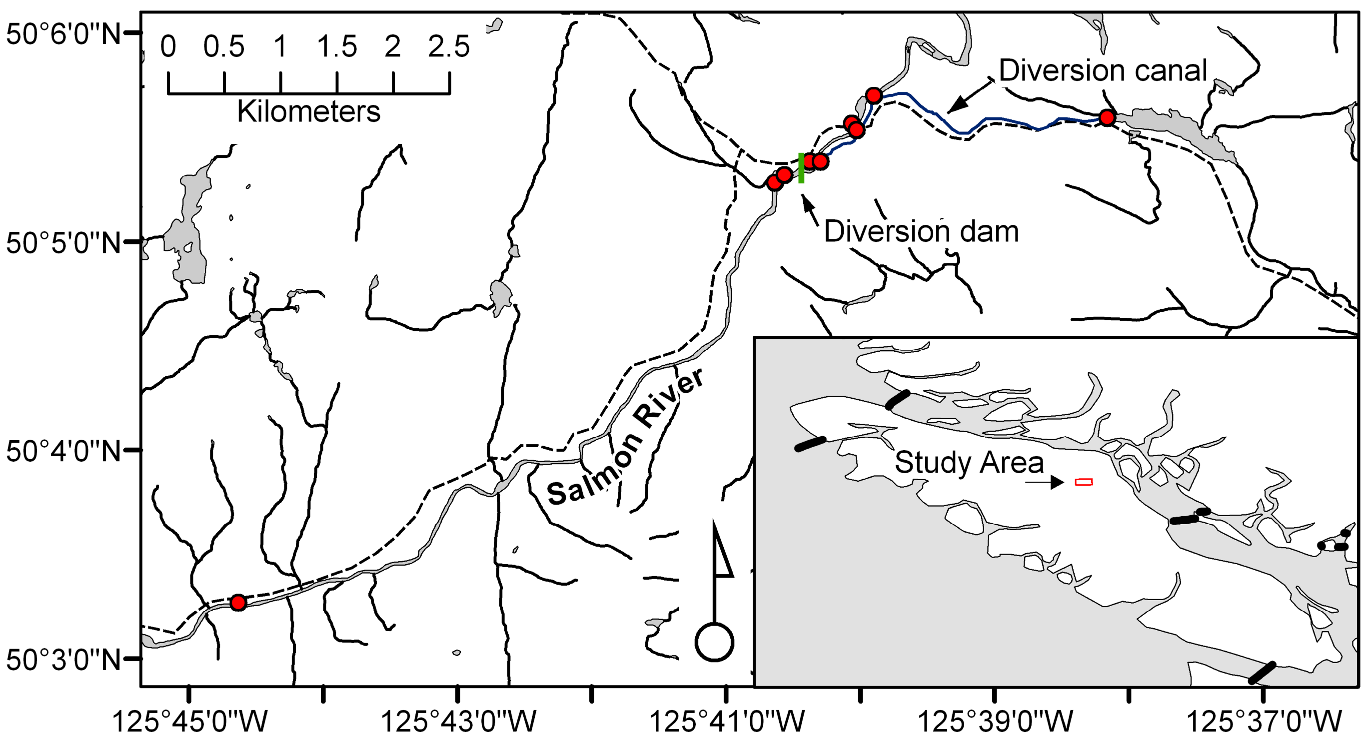
Salmon River Fishway Assessment Study

Prepared by

H. Lydersen, S. Williams, A. Porter, M. Jacobs, Y.K. Muirhead, and D.W. Welch

DFO Contract No: F1103-080071; Final Report 28 February 2008



Location of the Salmon River diversion canal and the acoustic receivers deployed during the 2008 field season. Insert shows the location of the Salmon River. The POST ocean arrays in southern British Columbia are shown as bold lines.

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Acknowledgements

Financial support for this pilot study was provided by DFO through the BC Hydro Bridge Coastal Fish and Wildlife Restoration Program. Considerable field assistance was provided by Shannon Anderson and Barry Peters of DFO and the staff from Mainstream Biological Consulting Inc. Lastly, we would like to thank Andrew Sauter from Hydrology and Technical Services, BC Hydro, for providing the flow and temperature data, and Mike Grant, also BC Hydro, for assisting us on-site at the Salmon River diversion dam.

Executive Summary

A study investigating migration route of acoustically tagged adult coho salmon reaching the BC Hydro diversion structure located on the Salmon River, Vancouver Island, was conducted by Kintama Research. The study was done with the assistance of Department of Fisheries and Oceans, Mainstream Biological Consulting Inc. and on-site BC Hydro personnel.

The diversion structure potentially poses a physical barrier to upstream migrating adult coho and the functionality of the fish ladder has been questioned. The aim of this pilot study was to establish both the functionality of an acoustic array in the Salmon River for future years as well as investigating the behavior of coho upon reaching the BC Hydro diversion dam.

In the fall 2008, nine acoustic receivers were installed in the Salmon River, fish ladder, and BC Hydro diversion canal; fourteen adult coho were gastrically implanted with Vemco V13 tags and their individual travel patterns from the release site identified.

During the two and a half months the receivers were deployed, 2,549 detections were heard and all fourteen tags were detected. The last detection was on 8 Nov 2008, approximately 260 hours after release.

Of the fourteen coho tagged, none were heard above the dam or in the diversion canal. Two fish were last detected in the fish ladder, nine were last heard on the receiver farthest downstream from the dam, and three fish were last heard on the second-last downstream receiver.

Three of the fourteen tagged fish (21%) were detected in the fish ladder; however, since none were detected above the fish ladder it is likely that successful upstream passage through the fish way is less than 7%.

Introduction

The Salmon River is located on the east coast of Vancouver Island, west of Campbell River, British Columbia. The Salmon River watershed is approximately 1300 km^2 and includes parts of the Strathcona Provincial Park (Burt and Roberts 2002). Species inhabiting the Salmon River include resident cutthroat and rainbow trout populations, anadromous cutthroat, steelhead, coho, Chinook, chum, and pink salmon (Ptolemy *et al.* 1977). Due to snowmelt, the river flows are high from May through July, and lower during the summer months, as is typical for a BC coastal basin.

The Salmon River mainstem is 87.4 km long and flows into Johnstone Strait at Sayward (Hansen 2004). In 1958, the Salmon River BC Hydro diversion canal was built approximately 58 km from the river mouth (Hansen 2004). The aim was to increase water flow available to the BC Hydro power stations located below Elk Falls in the Campbell River system (Ladore and John Hart Generating Stations). At the time of construction no additional fish passage was required, as the main river below the dam was naturally obstructed by several large boulders which, in combination with bedrock load and debris, formed an effective barrier for migrating salmon (Ptolemy *et al.* 1977).

In 1977, the Ministry of Environment (MOE) removed the obstruction below the BC Hydro dam and in 1986 and 1987 the upper watershed was stocked with steelhead and coho (Hansen 2004). In 1986, MOE also installed a fish screen in the diversion canal, with a 457 mm diameter bypass pipe, 400 m downstream of the canal headwaters; this was an attempt to prevent the downstream migrating Salmon River smolts and upstream migrating adult salmon from inadvertently migrating into the Campbell River system by rerouting them back into the Salmon River (see schematic – Figure 1). In 1992, the Department of Fisheries and Oceans (DFO) installed a seven step fish ladder to facilitate upstream migration at the dam. Prior to this, any upstream travel had been through the under sluice used to control the flow in the river or, during high flows, up the bank next to the over spilling dam face (M. Grant, BC Hydro, personal communication, 24 Sept 2008).

Starting in 2000, BC Hydro was required to provide 1.73 m^3/s of flow to the main Salmon River whenever possible, and the canal was required to remain closed during lower flows (<1.73 m^3/s; Burt and Roberts 2002).

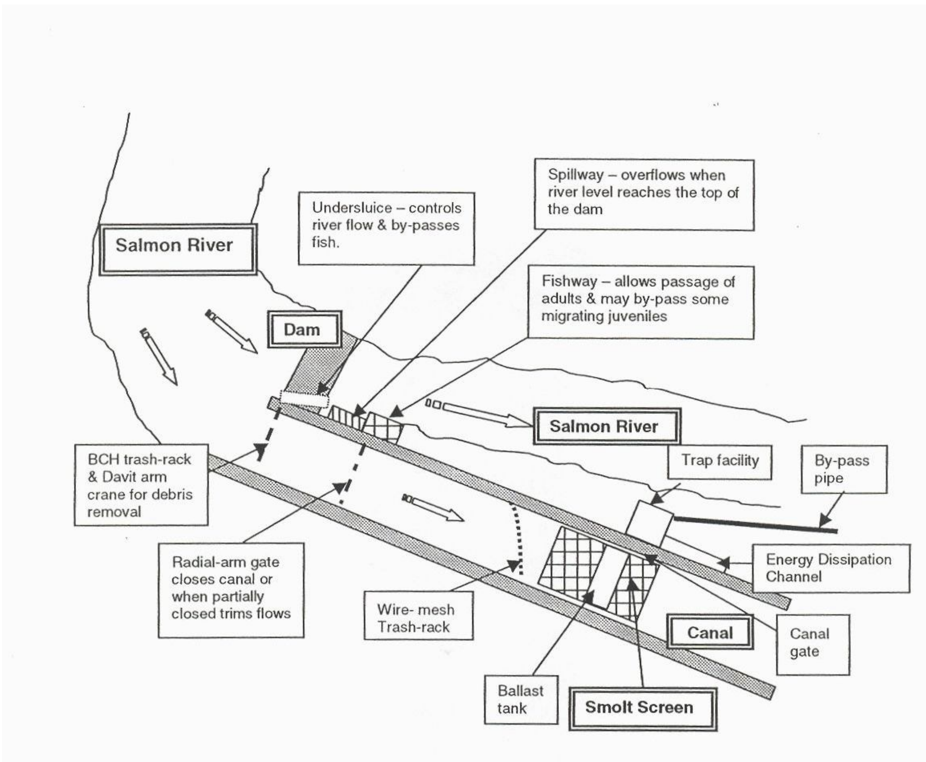

Figure 1. Schematic of Salmon River diversion structure (not to scale; from Hansen 2001).

Currently, fish must enter the small entrance (1.2m high by 0.4m wide) to the fish ladder slightly downstream of the dam face and sluice gate, which appears to be less attractive than the flows in the main river. When the canal is open, fish using the fishway must first maneuver up the ladder and then exit into the full flow of the diversion canal to continue to swim upstream. The trashracks at the entrance of the fish ladder and the entrance to the diversion canal gather debris and can present an additional challenge for successful upstream migration. The migrating salmon appear to be attracted to the spills over the dam, or the flows through the undersluice, rather than the comparatively minor flow exiting from the fish ladder and thus tend to pool below the dam face rather than using the fish ladder. BC Hydro staff open the under-sluice gate when they observe adult coho holding below the dam, and depending on the discharge and head at the sluice the fish might then be able to travel upstream through the gate. Although both adult coho and smolts have been observed in the upper Salmon River, the success rate of adults navigating the dam structure is not known. Adult coho have been reported below the smolt screen in the diversion canal which eventually leads to the Campbell River system (M. Grant, BC Hydro, personal communication, 24 Sept 2008). This anecdotal information suggests that some coho are unable to continue upriver once they have entered the canal.

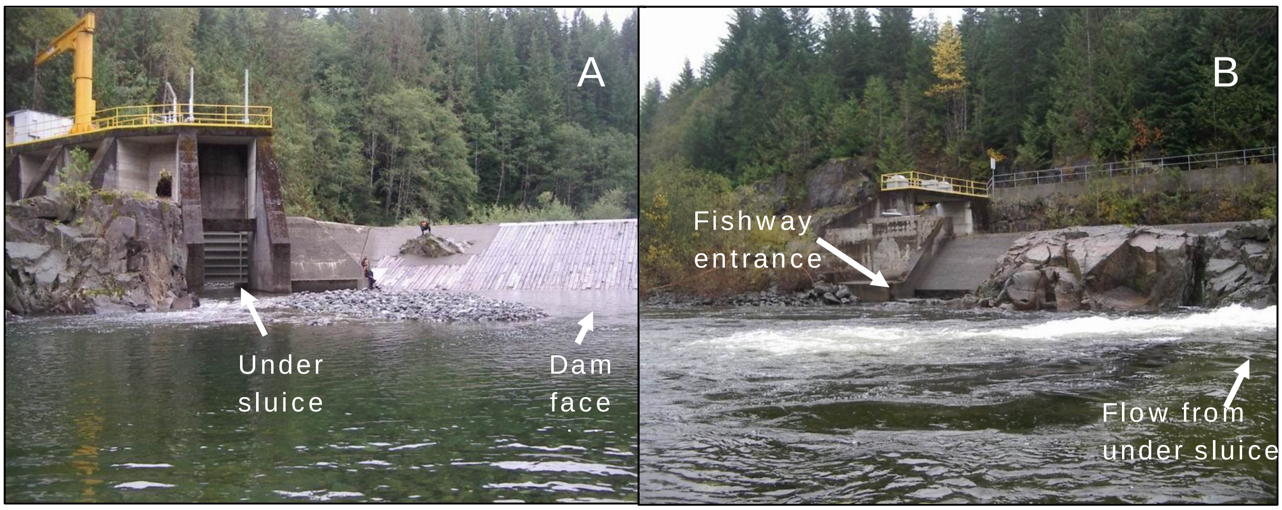

Figure 2. Picture A shows an open sluice gate during low flows. Picture B shows the entrance to the fishway downstream from the sluice gate during higher flows; the turbulence caused by the concentrated flow through the sluice gate can easily be seen.

The intent of this pilot study was to determine the success rate, as well as the passageway, of migrating coho through the diversion structure using a small-scale acoustic telemetry array and gastrically implanting uniquely coded acoustic tags in adult coho to monitor their movements.

Goals and Objectives

The initial objective of this pilot study was to determine the migration route of adult coho that reach the BC Hydro Diversion canal, whether they would: (a) turn around and spawn downstream of the dam, (b) travel up through the fish ladder or otherwise navigate through the dam structure (through under-sluice gate, or up the far side of the dam face during high flows) and (c) whether they continue upstream in the Salmon River or (d) go down the diversion canal and thus ultimately leave the watershed and enter the Campbell River system. To establish the pattern of movement, three acoustic receivers were installed upstream of the dam in the Salmon River, three below the dam, two in the diversion canal, and one in the fish ladder (Figure 3 and 5).

Furthermore, the uniquely coded acoustic tags enabled a closer inspection of the behavior of individual fish in relation to river flows and dam operations. A timeline of the movement of each specific fish can be constructed as the acoustic receivers record ID code, date and time of each detection.

Methods

Instrumentation and Array Design

Acoustic telemetry is in principle similar to radio telemetry, but has an advantage as radio tracking does not work when the tags are in deep or highly conductive water; as a result, radio tracking is not feasible in estuarine or salt water. In contrast, acoustic telemetry can in principle provide a seamless system to monitor both movements and survival in both freshwater and the ocean. The basic design principle of these units is essentially a waterproof data logger, which detect the presence near the receiver of an appropriately programmed acoustic tag. The unit verifies the accuracy of the received transmission and, if the detection passes a checksum test transmitted as part of the acoustic code, is logged to non-volatile flash memory along with the date and time of the detection. Because of the characteristics of the checksum encoded as part of the tag's transmission, the acoustic code is identified with high accuracy, and "false positives" (detection of an incorrect tag code) are rare.

POST array

The POST array is a large scale marine acoustic tracking network which extends from Northern Oregon, throughout coastal British Columbia, and up to southeast Alaska (see www.post.coml.org for more information).

The POST array consists of many Vemco VR2 (temporary) and VR3 (permanent) acoustic receivers deployed in key locations. These units are able to detect animals implanted with POST tags which transmit unique ID codes at a frequency of 69 kHz. Kintama Research uses special designed flotation collars and anchoring systems to deploy the units in the river or on the ocean bottom down to a maximum depth of 300m. They are deployed in specific locations with set spacing to provide maximum detection efficiency. The goal is to completely cover the areas travelled between the beach and the shelf break as well as within several rivers (currently, the lower Fraser, Columbia mainstem, and Snake Rivers have year-round coverage).

As the adult coho tagged in this study were solely monitored in the vicinity of the Salmon River, the marine POST array is not described in further detail here.

Salmon River Array

For the study reported here, a temporary acoustic array was designed and deployed in the Salmon River above and below the BC Hydro dam as well as in the diversion canal using Vemco VR2 acoustic receivers.

The original design of the array consisted of three evenly spaced receivers sited above the dam, three evenly spaced receivers sited in both the diversion canal, and in-river below the dam, and one receiver sited within the fish ladder. At the time of deployment changes were made to the original layout due to the inaccessibility of some of the desired receiver locations. Canyon sides along the river forced the positioning of the upper-most receiver to be located 6.2 km from the dam (straight-line GPS measurement; Figure 3). During the array deployment BC Hydro informed Kintama Research that the diversion canal would likely be closed off for a significant amount of time, leaving the canal dry. As significant vandalism and theft had recently occurred in the area, it was decided that a second deployment trip would need to be scheduled to install the receivers in the diversion canal, rather than leaving them exposed for an indeterminate period of time. However, one receiver was installed at the end of the diversion canal by Bodil Lake Main bridge crossing as there was sufficient water to cover the receiver in this location. Once notification was given that the diversion canal had been opened (1 Nov 2008) a second deployment trip was made to the Salmon River (4 Nov 2008) and one more receiver was installed midway in the canal.

On 3 Nov 2008, Don McCubbing (InStream Fisheries Research Inc) recovered a receiver located inside the fish way. High currents had torn the receiver from its anchor, but fortunately the floatation collar kept it floating and the water levels at this time were sufficiently high to keep the receiver trapped inside the fish way where it continued to log data. A replacement receiver was installed approximately 24 hours later.

The Salmon River array was formed by a series of 10 detection sites, each comprised of an individual receiver (Figure 3). Tagged adult coho would travel past these sites during their migration upstream to spawn. The data collected off the array would make it possible to determine the direction and movement of the fish after being released below the BC Hydro diversion dam.

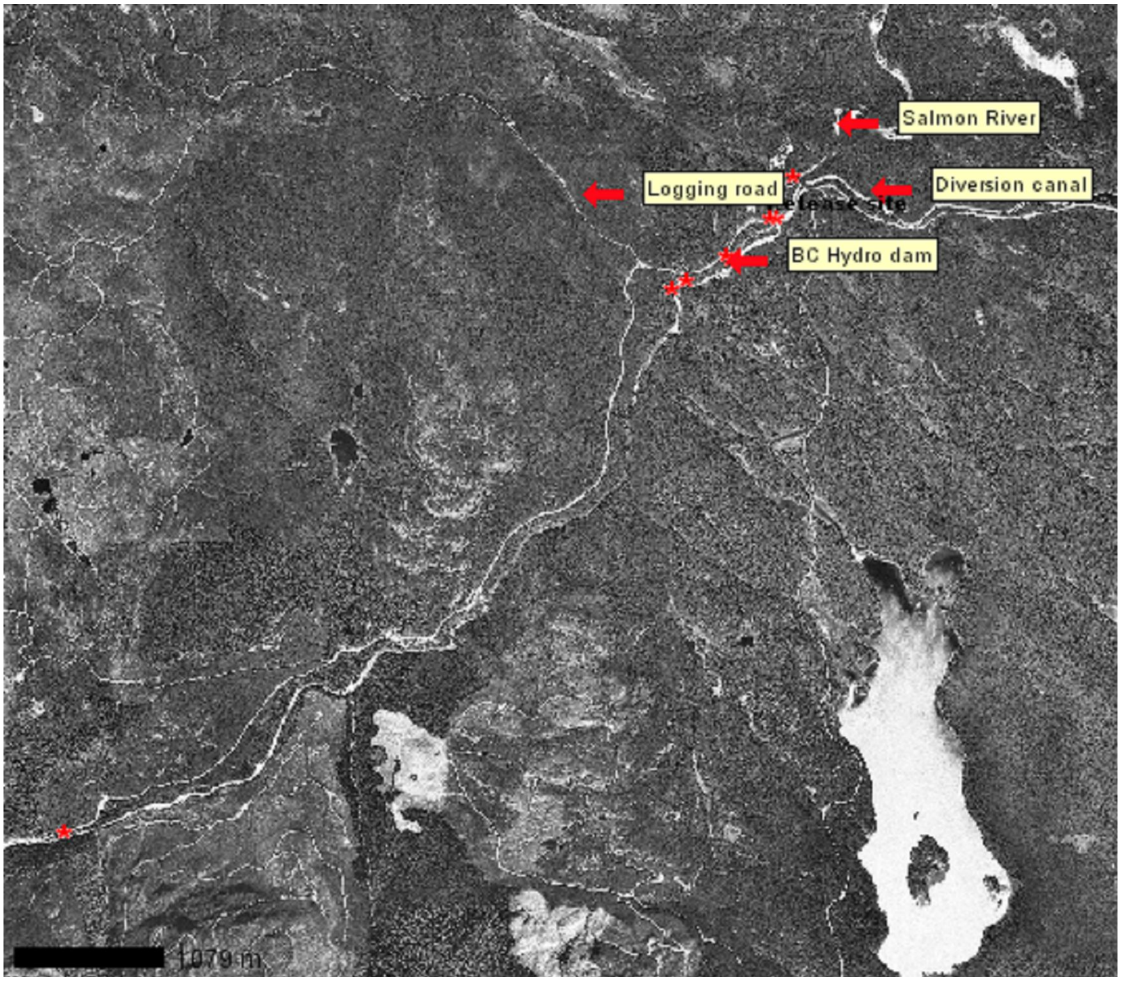

Figure 3. Aerial photo of Salmon River study area showing location of receivers.

To study the adult coho movements, Vemco V13-1H acoustic tags (13 mm in diameter, 36 mm long, weighing 11 g in air, power output of 153 dB re 1µPa@1m) were gastrically implanted into the fish's stomach. These tags were programmed with the POST code map, an acoustic code map and associated transmission schedule developed by Kintama Research to allow highly efficient studies of the movements and survival of fish. Nine of the ten deployed receivers were recovered on 4 December 2008. Upon retrieval, the data stored on the receivers was uploaded using VEMCO data acquisition software.

Tagging Operations & Release of Fish

On 28 Oct 2008, adult coho were caught by Mainstream Biological Consulting Inc, under contract to DFO, using a beach seine and tangle net below the Salmon River Diversion Dam. Fishing was completed prior to the arrival of the Kintama tagging crew, and a total of 14 adult coho had been caught. The fish were temporarily held in an in-river holding pen which allowed free river flow to the fish. All tagging was completed by Kintama Research with the assistance of DFO and Mainstream staff on site.

Since the Salmon River coho are classified as food fish it was not possible to sedate them using MS222 (Tricaine Methanesulfonate) which is commonly used in aquaculture and fisheries studies. MS222 requires significant holding time in order to clear the fish for consumption and the intent for this study was to only hold the coho for a brief period to monitor for tag regurgitation. Clove oil was considered for use as an anesthetic, but since recent papers have called attention to a possible interference between clove oil and the olfactory system by potentially masking the chemical cues the migrating salmon need to navigate the river (Woody *et al.* 2002), it was decided to tag fish without the use of any anesthetic.

To minimize fish handling, tagging was done in the river by the netpen. Individual fish were lifted out of the water, turned belly-side up, and the V13-1L tag was quickly inserted into the stomach using a food grade, flexible plastic tube and plunger (Figure 4). Once the tag was inserted, the fish were put into a holding bag to monitor for tag regurgitation. The tagging procedure took less than one minute per fish.

Low water temperatures (5.1°C) decreased the resistance of fish to the handling and thereby facilitated the tagging. None of the 14 fish regurgitated their tags during the 30-60 min holding period in the brood stock holding bags. The entire tagging event and fish release at the capture site was completed between 14:30-16:00 local time (21:30-23:00 UTC).

Figure 4. Gastric implantation of acoustic tag in adult coho by Heidi Lydersen (Kintama Research) and Barry Peters (DFO; Photo courtesy of Mainstream Biological Consulting Inc).

Data Analysis

All data files collected from the array underwent quality assurance and quality control procedures. System data recorded in the file header from the receiver were reviewed, and the data files checked for gaps or inconsistencies. As the first receiver deployed in the fish ladder (location 4) was removed on 3 Nov 2008 around 19:00 (UTC) and the replacement receiver was not installed until 4 Nov at 19:45, there was a data gap of approximately 24 hours for the this site. Finally, all records of tag detections were checked against a list of known tags codes used in the Salmon River study and put through the standard "false detection screening" described below.

False Detection Screening

If a tag transmission arriving at an acoustic receiver meets certain criteria, the tag code is recorded by the data acquisition firmware; otherwise, internal counters are incremented to record how many possible transmissions were received, but the transmission itself is not recorded. A key point to note is that all component pulses must be received in order for the tag to be detected;

a drop out of even one pulse is sufficient to cause the receivers to reject the transmission from a tagged fish. A substantial amount of effort went into designing Kintama Research's array geometry and tag transmission scheduling in order to allow that high detection rates were possible while ensuring sufficient tag life and the need for relatively low amounts of equipment deployed in the array.

All receiver files were examined and any detection likely to be false (as a result of aliasing or tag collisions) using the acceptance criteria recommended by VEMCO (Pincock 2008) were identified and excluded. Detections met the first of two criteria if there was at least one short interval (<0.5 hour) between successive detections of a given ID code on a receiver and if there were more short intervals between detections than long ones (>0.5 hour). Detections that did not meet the first criteria were then examined individually to determine if there was possible collision activity on the receiver (i.e. two or more tags transmitting at the same time). Collision of tag ID codes was considered likely if there was another tag detected within five minutes on either side of the detection in question. This screening excluded a small number of sporadic detections (0.078%) and the vast majority of the retained data consisted of multiple detections closely spaced in time on a given receiver or sub-array.

Results

Summaries of the coho salmon detections on the Salmon River array are presented in Tables 1 through 3. Table 1 shows the number of detections of each tag at each receiver location. Table 2 shows the number of unique ID codes heard on each site. Table 3 shows the time of first and last detection, the time in the study area and location last heard. Figure 5 shows location of receivers and names used in Table 1-3 in relation to tagging site and the BC Hydro diversion dam.

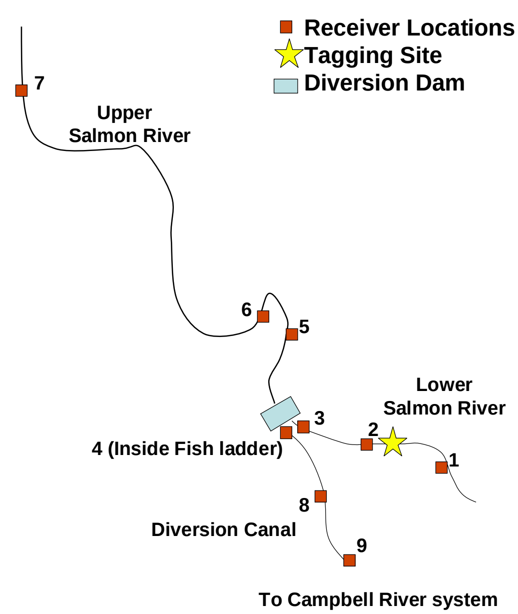

Figure 5. Schematic of acoustic receivers locations on the Salmon River (map not to scale). Receivers 1-7 were in the expected direction of travel for migrating adult coho, while receivers 8-9 are deployed in the diversion canal.

Table 1. Number of detections based on individual tags and receiver locations. All data (including false positives) are reported here. Receivers 1-7 were in the expected direction of travel for migrating adult coho, while receivers 8-9 were deployed in the diversion canal. Receiver 4 was located in the fish ladder which was the furthest upstream any coho were detected; none were detected in either the upper Salmon River or the diversion canal.

	Receiver location									**Total**
Tag Id	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
21054*	0	1	NR	0	0	0	0	0	0	1
21367*	0	1	NR	0	0	0	0	0	0	1
24087	1	43	NR	0	0	0	0	0	0	44
24088	10	17	NR	0	0	0	0	0	0	27
24089	1	18	NR	0	0	0	0	0	0	19
24090	346	7	NR	0	0	0	0	0	0	353
24091	42	149	NR	0	0	0	0	0	0	191
24092	1	136	NR	0	0	0	0	0	0	137
24093	35	17	NR	0	0	0	0	0	0	52
24094	331	17	NR	0	0	0	0	0	0	348
24095	86	86	NR	0	0	0	0	0	0	172
24096	0	162	NR	217	0	0	0	0	0	379
24097	1	112	NR	199	0	0	0	0	0	312
24098	0	28	NR	0	0	0	0	0	0	28
24099	0	219	NR	1	0	0	0	0	0	220
24100	9	258	NR	0	0	0	0	0	0	267
Total tag detections	863	1269	NR	417	0	0	0	0	0	2549

*False positives

NR - Not Recovered at date of writing

Table 2. Number of fish heard at each site and percentage of total tagged fish in the Salmon River by the BC Hydro diversion dam, 2008.

Receiver location	Site location	Number and percent of individual fish detected
1	3rd down river of dam	11 (78%)
2	2nd down river of dam	14 (100%)
3	1st down river of dam	Unit Not Recovered
4	Fish Ladder	3 (21%)
5	1st up river of dam	0
6	2nd up river of dam	0
7	3rd upriver of dam	0
8	Mid diversion canal	0
9	End diversion canal	0

Table 3. The approximate time in study area, and the first and last detection of the 14 adult coho tagged in the Salmon River by the BC Hydro diversion canal. Fish were tagged on 28 Oct 2008 and the receivers were recovered on 4 Dec 2008. Times are reported in UTC.

Tag id	Sex	First detection	Last detection	Time in area (hr:min)	Location last heard
24087	M	28-Oct-2008 21:39	31-Oct-2008 11:03	61:23	1
24088	M	28-Oct-2008 21:49	29-Oct-2008 3:31	5:42	1
24089	M	28-Oct-2008 22:11	31-Oct-2008 10:15	60:03	1
24090	M	28-Oct-2008 22:26	30-Oct-2008 1:28	27:02	1
24091	F	28-Oct-2008 22:32	06-Nov-2008 6:31	199:58	1
24092	M	28-Oct-2008 21:44	31-Oct-2008 13:01	63:17	1
24093	M	28-Oct-2008 21:52	29-Oct-2008 3:27	5:34	1
24094	M	28-Oct-2008 22:15	30-Oct-2008 2:18	28:03	1
24095	M	28-Oct-2008 22:26	08-Nov-2008 20:18	261:51	2
24096	M	28-Oct-2008 22:37	02-Nov-2008 0:45	98:07	4
24097	F	28-Oct-2008 21:46	01-Nov-2008 22:12	96:25	4
24098	F	28-Oct-2008 21:53	29-Oct-2008 14:34	16:40	2
24099	M	28-Oct-2008 22:17	02-Nov-2008 7:32	105:14	2
24100	M	28-Oct-2008 22:28	31-Oct-2008 23:38	73:10	1

Movement of Fish in the Dam area

During the Salmon pilot study, all the uniquely tagged adult coho were detected on the acoustic array. Initially they were all heard on receiver 2, which was approximately 20 m from the tagging and release location.

Post-surgery their time in the entire study area varied from 5:42 hrs to 261:51 hrs; during this period nine coho migrated downstream and did not return (receiver 1, furthest downstream was last detection site), three fish were last heard by receiver 2 (upstream from receiver 1, close to tagging site) and were not detected elsewhere. Two fish were last heard on the receiver in the fish ladder (receiver 4). No fish were detected above the dam or in the diversion canal. At the date of writing this report, receiver number 3 (immediately below the dam face) has not been recovered. Figure 6-9 indicate the movement of the 14 adult coho tagged in 2008.

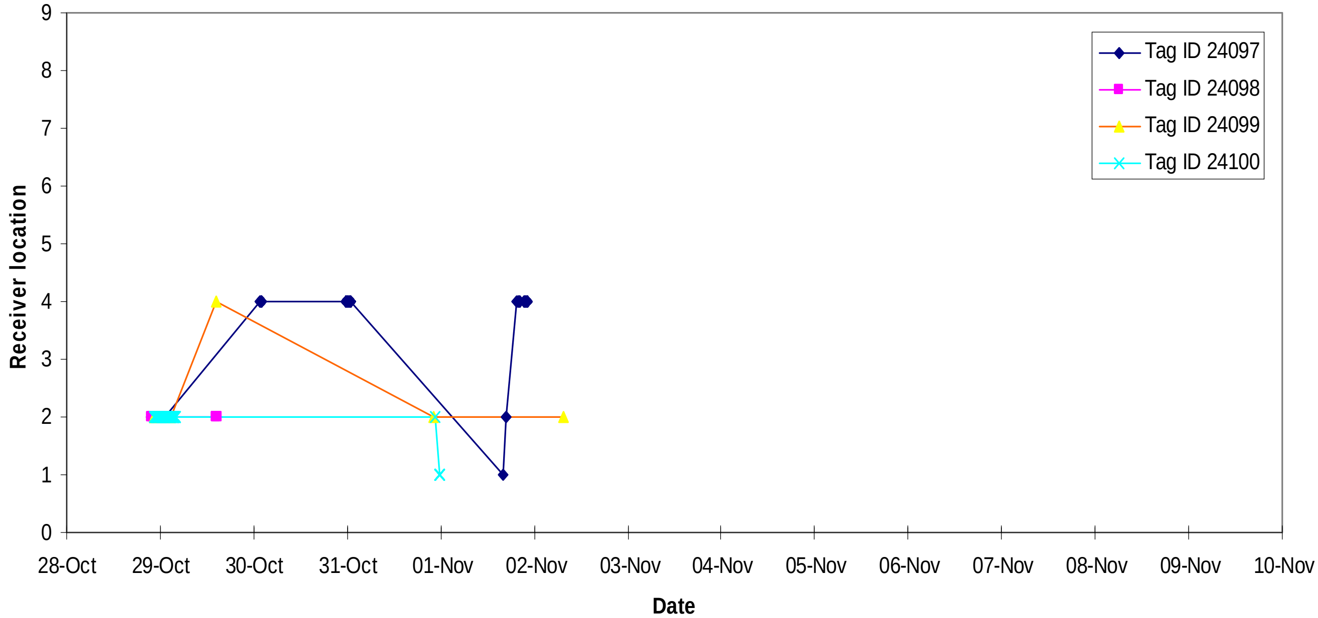

Figure 6. Movement over time of four individual fish in dam area. The array stayed in place until 4 Dec 2008. Receiver locations can be seen in Figure 5.

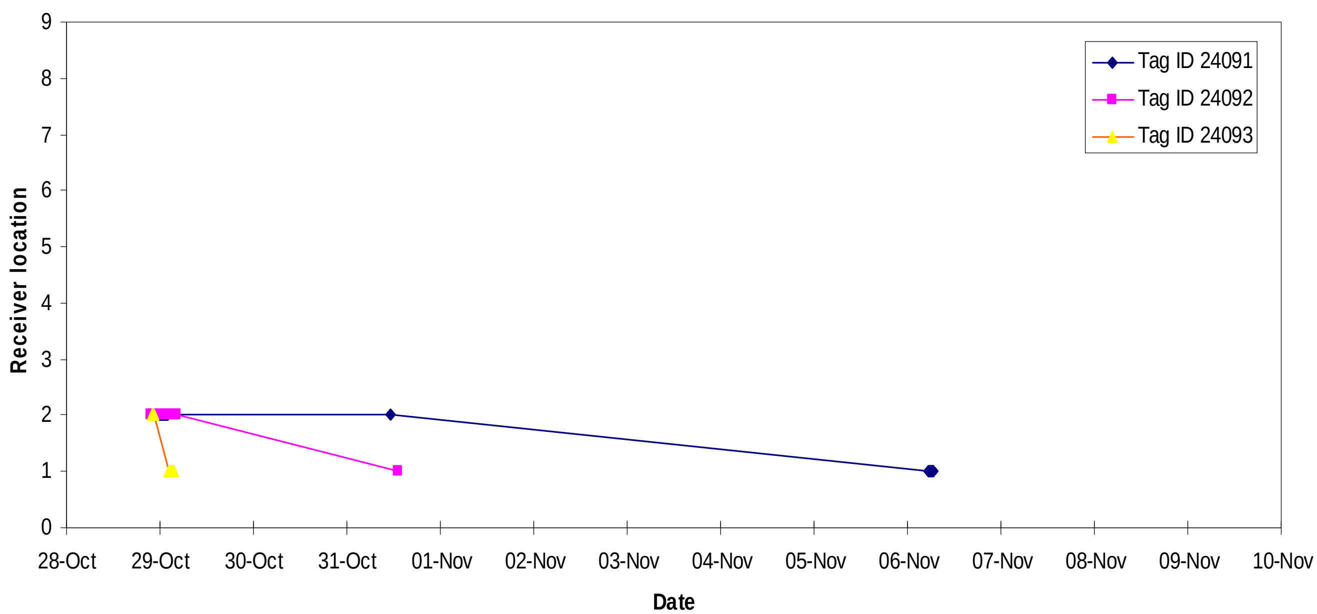

Figure 7. Movement over time of three individual fish in dam area. The array stayed in place until 4 Dec 2008. Receiver locations can be seen in Figure 5.

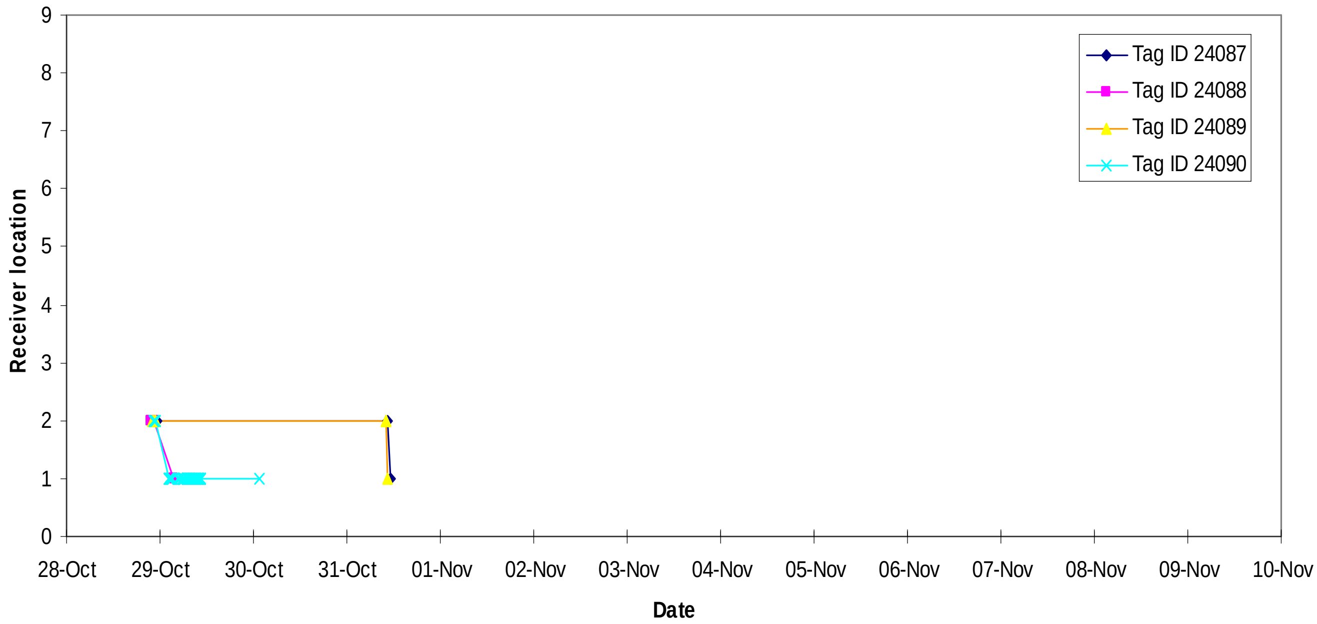

Figure 8. Movement over time of four individual fish in dam area. The array stayed in place until 4 Dec 2008. Receiver locations can be seen in Figure 5.

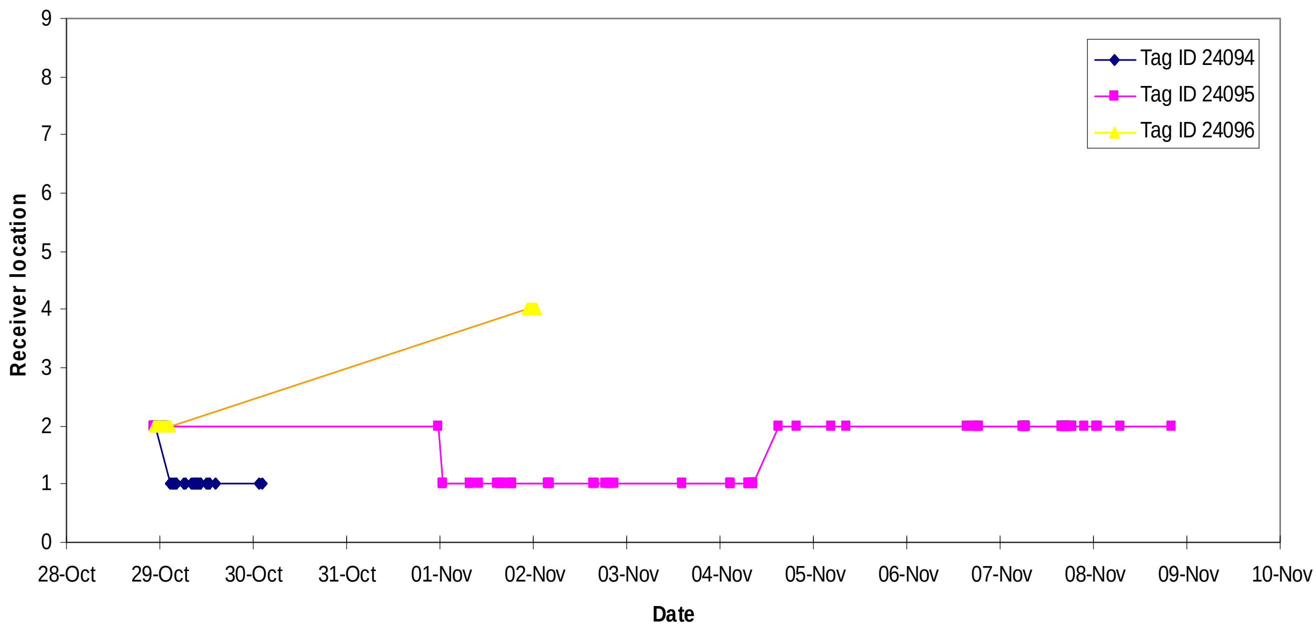

Figure 9. Movement over time of three individual fish in dam area. The array stayed in place until 4 Dec 2008. Receiver locations can be seen in Figure 5.

Discussion

Effect of BC Hydro Operations

The most significant effect of the BC Hydro operation on the Salmon River is the change in hydrology below the dam depending on draw of water to the Campbell River system (Burt and Roberts 2002). The dam poses a physical barrier to the migrating adult salmon and questions regarding the functionality of the installed fish ladder have been raised. The following section attempts to link the flow patterns in the river during the study period to the detections throughout the site – specifically looking at the activity patterns in the fish ladder.

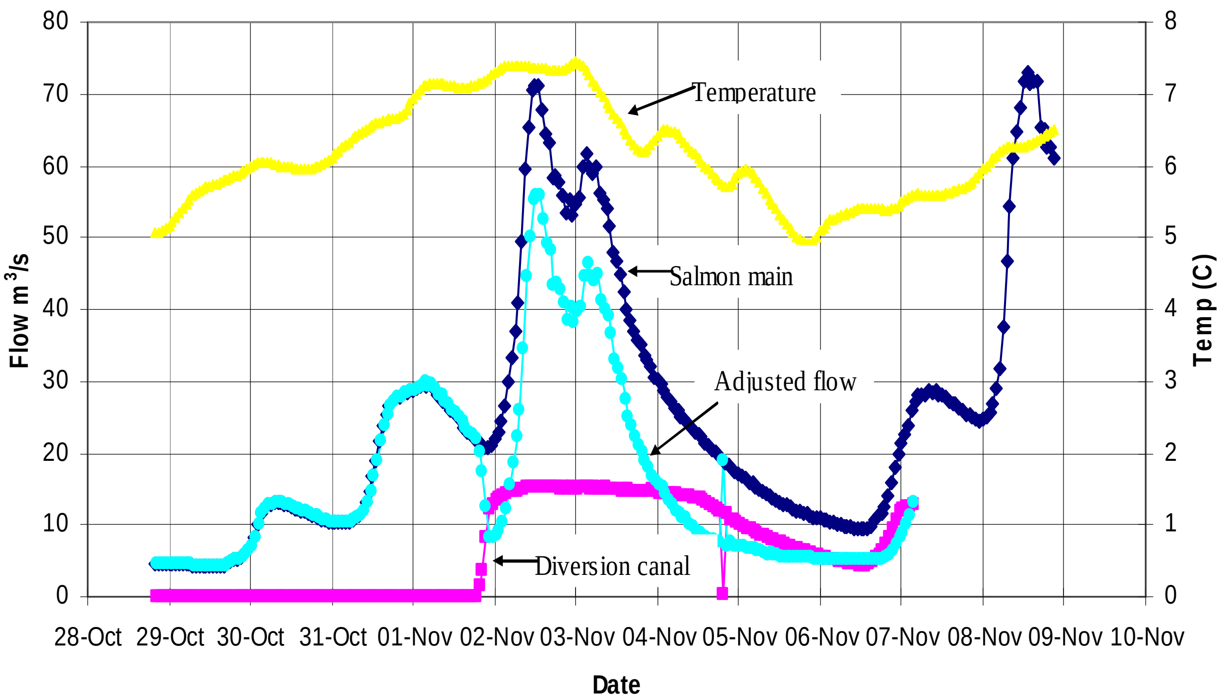

Figure 10. Flow (m^3/s) and temperature (C°) in the Salmon River and Diversion Canal during the period coho were detected near the BC Hydro Diversion Dam. There is a gap in the flow data for the diversion canal between 7 Nov (3:22) and 12 Nov (20:32). "Salmon main" refers to the flow above the dam and "Adjusted flow" is an approximation of the flow in the river below dam. The first hydrometric reading from the diversion canal, indicating flow, was on 1 Nov 2008 at 19:32 (UTC).

Further analyses of the movement of coho

By 31 Oct 2008, three days after tagging, nine fish were still heard in the main river below the dam. As flow started to rapidly increase on the 31 Oct; five fish (24087, 24089, 24092, 24095, and 24100) appeared to either have given up their upstream migration or were forced downriver by the increased flows. This behavior was inferred from their movement pattern, with the last detection of these fish being on receiver 1. The BC Hydro diversion canal was not open at this time.

Fish 24094 was able to remain in the detection area below the dam (receiver 1) during the high flows, which peaked at 70.7 m^3/s above dam and approximately 55.9 m^3/s below the dam, and then worked its way back upriver (receiver 2) once the flow decreased to approximately the same level at which the fish had initially moved downriver.

Fish ID 24099

The first fish (ID 24099) in the fish ladder was detected on 29 Oct at 14:29 as a single detection: the flow at this time was 4.31 m^3/s. It apparently did not travel through the fish ladder and was subsequently heard downstream again. Fish 24099 was not recorded at the fish ladder again.

The following three fish described here were detected inside the fish ladder and the sections detail their movements in relation to the flow and temperature of the river. Figure 10 and 11 attempt to clarify a possible relationship between the presence of fish in the fish ladder and the flow of the river.

Fish ID 24097

The second fish (ID 24097) detected in the fish ladder was detected approximately 11 hours later at 1:45 on 30 Oct. By then the flows in the river had increased to approximately 10 m^3/s (8.35 m^3/s at 1:00 and 10.14 m^3/s at 2:00).

30/10/2008 1:45-1:58 25 detections flow: approximately 10.0 m^3/s.

The flow then increased to 13.1 m^3/s.

30/10/2008 23:33-23:59 38 detections flow: approximately 10.4 m^3/s.

31/10/2008 0:31-0.58 43 detections flow: approximately 10.3 m^3/s.

Following these three periods in the fish ladder 24097 was detected down river as the flow continued to rapidly increase. The maximum flow reached during this freshet was 29.9 m^3/s.

Once the flow decreased, fish 24097 moved into the fish ladder for the fourth time on the 1st of November, shortly after the opening of the diversion canal. This time period also coincides with the temperature rising above 7°C for the first time during the study period. Fish 24097 entered the fish ladder once the flow in the river below the dam dropped to approximately 20 m^3/s and was detected for two hours and 35 min (93 detections).

It is interesting to note that fish 24097 entered the fish ladder and was detected at 19:37 on the 1st of Nov at essentially the same time as the first hydrometric reading after opening the diversion canal (19:32 on 1 Nov). Hydrometric data is recorded once an hour. An email from BC Hydro, Mike Grant, states the diversion canal was opened at 19:00 UTC, which means the fish entered the fish ladder within 37 minutes of the opening of the canal.

Fish ID 24096

Once the flow decreased on 1 November, fish 24096 also moved into the fish ladder shortly after the opening of the diversion canal. This time period also coincides with the temperature rising above 7°C for the first time during the study period.

Fish 24096 was detected continuously for two hours and ten minutes (217 detections) in the fish ladder and then was not heard again. This fish was first detected in the fish ladder at 22:34 on the 1st of Nov. This coincides with the timing wherein the flow in the diversion canal for the first time is higher than the flow in the main river below the dam. At 22:00 the main flow above the dam is measured as 20.7 m^3/s and at 22:32 the diversion flow is measured as 12.3 m^3/s, leaving approximately 8.4 m^3/s in the main river below the dam.

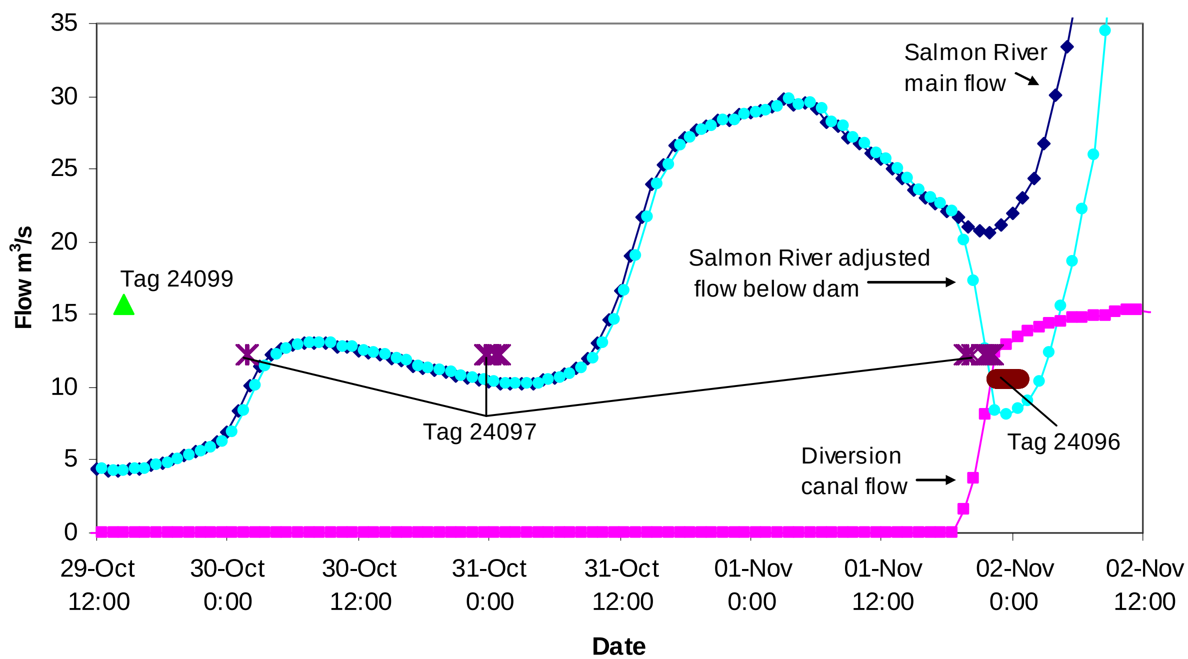

Figure 11. A close-up showing the flow in the Salmon River, diversion canal, and adjusted flow in river below dam during the time adult coho were detected in the fish ladder. Fish 24099 was only detected once and subsequently heard downstream. Fish 24097 had four periods of detection in the fish ladder at approximately equal flow rates. Fish 24096 had one period of continuous detection in the fish ladder. Each tag is shown as a different symbol.

Since the diversion canal was opened on Nov 1st and two of the fish (24096 and 24097) were detected in the fish ladder immediately after the opening of the diversion canal as their last site of detection, it does pose the question of their fate. Anecdotal accounts from BC Hydro crew report otters working the fish ladder and salmon missing the entrance to the ladder during higher flows, leaving them stranded on the grates above the pools in the fish ladder. It is unlikely that the fish travelled upstream, as the first two of three receivers above the dam are fairly close, and the detection efficiency of the receivers should be high. The receiver midway in the diversion canal was not put in place until 4 Nov at 18:00, while the receiver at the end of the diversion canal was in place throughout the study period. It seems unlikely that coho exiting the fish ladder during these flows (12.3 m^3/s and 13.5 m^3/s) were missed by the single receiver located at the end of the diversion canal.

Array Performance

The layout of the acoustic array and programming of the tags was designed to provide high detection of tagged fish moving through the study area. However, a number of factors can reduce this detection rate, including the following:

- Incomplete coverage by receivers (i.e., some river locations might provide poorer than expected coverage because of local topography);
- Environmental noise (e.g, heavy rainfall, wind creating waves, interference between two or more tag transmissions, machinery); and,
- Acoustic absorption due to high levels of particulates in the environment.

Conclusion

Between October 28th and December 4th 2008, the movements of 14 gastrically tagged adult coho in the Salmon River were tracked using an acoustic listening array. The main findings from this pilot study are as follows:

- 100% of the tagged coho were detected on the array.
- None were heard above the Salmon River diversion dam or in the diversion canal. This places a reasonable bound on the successful upstream passage rate as <7%.
- Nine of the 14 fish (64.3%) migrated downriver following the tagging, two fish were last detected inside the fish ladder and three fish were last heard on the second receiver downstream of the dam.
- Fish were detected, possibly holding, in the study area below the dam for up to 260 hours (Table 3).

Summary & Recommendations

The purpose of this pilot study was to provide an initial assessment of the migration behavior of adult coho salmon once they encountered the BC Hydro Diversion Dam on the Salmon River, as well as assessing the performance of the acoustic array.

Our 2008 study shows that the acoustically tagged coho failed to travel upstream of the BC Hydro dam, and despite extensive milling (200+ hours) in the area below the dam only three of the fourteen tagged fish actually entered the fish ladder.

Recommendations

The results for the 2008 pilot study indicate that the acoustic telemetry system is a promising method of resolving the movements of coho in the Salmon River after release. For future studies it is recommended that more receivers be added downstream of the diversion dam to increase the area covered below the release site and help identify the extent of the movements of the fish that travel downstream. Initially the tagging site was intended to be immediately below the dam, in which case there were would have been two receivers located downstream of tagging site rather than one. However, due to high flows and inaccessibility of the desired tagging area, the tagging was done under the logging bridge just downstream of receiver #2. Standardizing the site below the logging bridge as the favored tagging site in future years would allow for the array design to be adjusted accordingly to optimize the information gathered.

The 2008 study indicated that less than 7% (<1 in 14) of adult coho travel upriver from the BC Hydro diversion dam. The 14 fish in this study were all released at approximately the same time and subject to the same environmental conditions. In order to give a closer estimation of the proportion of adult coho migrating past the dam a larger study is required. It would be useful to the study if there was an allowance for several tagging days (5-7 days apart) where groups of 10-20 tagged adult coho could be released and monitored under various conditions.

Due to the possibility of theft in the area, the installation of receivers in the diversion canal posed a concern as the canal was kept dry for a period of time after the initial deployment trip which would have left the receivers exposed. It would be preferable if permission could be obtained to drill into the concrete and mount the receivers directly onto the concrete floor at the beginning of the study period. Alternatively, increased coordination with BC Hydro could possibly allow installation of receivers immediately prior to opening the diversion canal. It might be beneficial to add one more receiver below the Bodil Lake Main Bridge, past the end point of the concrete diversion canal, in a location where the receivers would be submerged even without any water being present in the canal. This would ensure the presence of two receivers on this route if, for some unforeseen reason, the canal should be opened prior to the installment of receivers within the actual canal.

The results for the Salmon River in 2008 match Kintama Research's prior experience elsewhere that properly designed acoustic telemetry studies can reliably address questions concerning the movement and fate of adult coho in the Salmon River using relatively modest numbers of tagged animals.

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Appendix F Financial Statement

Project #: 07.Cbr.04				Actual Final			
INCOME	**BCRP**	**Other (Cash)**	**Other (in-kind)**	**BCRP**	**Other (cash)**	**Other (in-kind)**	**Obligations**
Total by Source	$62,952.50		$19,525.00	$56,657.25	$0.00	$49,800.00	
Grand Total Income (BCRP + Other)		**$82,477.50**			**$106,457.25**		
EXPENSES	**BCRP**	**Other (Cash)**	**Other (in-kind)**	**BCRP**	**Other (cash)**	**Other (in-kind)**	**Obligations**
Project Personnel							
Biologist project supervisor (contractor)	$4,500.00			$690.00			$0.00
Bio-Technician (contractor)	$3,500.00			$600.00			$0.00
Resistivity counter - all found Instream Fisheries research				$23,645.50			$9,677.30
Hydro acoustics - Kintama Research all found - 15 tags/receivers labour reporting	$900.00			$24,675.00	$0.00		0
Labor to download data Monitoring of receivers	$900.00			$0.00			0
DVSM monitoring video Labor to download and review video tapes	$4,320.00			$0.00			0
Biotech DFO			$750.00	$0.00			0
Biologists field component DFO includes 0708observations, juvenilie sampling			$4,000.00			$27,300.00	0
Eng tech DFO			$900.00			$0.00	0
Biologist to analyze acoustic data	$1,200.00					$0.00	0
WPP training (fishway BCHydro property)	$900.00			$0.00		$0.00	0

BCHydro staff- maintenance technicians filling out summary forms/observations -1hour/trip max	$0.00		$450.00	$0.00			0
BCHydro manipulation of flows – if req'd to determine thresholds for fish passage			$1,200.00				0
Adult capture seine (Mainstream bio 2 days + volunteers onshore)	$5,400.00		$4,500.00	$2,789.80			0
DFO inkind time safety meetings,reporting, updates						$22,500.00	0
DFO fish tech support - Quinsam Hatchery	$0.00		$3,000.00				
Labour to date	$21,620.00	$0.00	$14,800.00	$52,400.30	$0.00	$49,800.00	$9,677.30
Material and Equipment	**BCRP**	**Other (Cash)**	**Other (in-kind)**	**BCRP**	**Other (cash)**	**Other (in-kind)**	**Obligations**
TV monitor	$150.00			$0.00			
Battery packs and wiring	$600.00			$0.00			
Underwater lights	$300.00			$0.00			
Acoustic transmitters (50)	$20,000.00			$0.00			
Acoustic Receivers purchased 2	$10,800.00			$3,393.11			
DVMS 400	$4,500.00						
underwater video camera	$1,000.00						
Video cable	$300.00						
Portable hard drive	$350.00						
Aluminum tunnels	$1,000.00			$0.00			
VHF radios	$0.00		$400.00	$0.00			
Hardware for receiver placement	$300.00			$0.00			
Vehicle +fuel	$607.50			$0.00			
Vandal Proof housing for DVMS	$800.00		$0.00			$0.00	
Jet boat operation/adult capture	$0.00		$600.00				
Repairs to net, equipment	$500.00		$0.00	$328.94			
Travel costs	$0.00		$0.00	$534.90			
Totals Material/Equip to date	**$41,207.50**	**$0.00**	**$1,000.00**	**$4,256.95**	**$0.00**	**$0.00**	

Administration	BCRP	Other (Cash)	Other (in-kind)	BCRP	Other (cash)	Other (in-kind)	Obligations
Office space, equip, supplies	$50.00		$25.00			$0.00	
Photocopies and printing	$0.00		$225.00			$100.00	
camera	$0.00		$500.00			$0.00	
GPS	$0.00		$375.00			$0.00	
Field supplies - paper	$25.00		$0.00			$50.00	
Communications Book keeping			$1,200.00			$0.00	
Courier etc	$50.00		$100.00				
Totals Admin	$125.00	$0.00	$2,425.00	$0.00	$0.00	$150.00	
Total Expenses BCRP	**$62,952.50**	**$0.00**	**$18,225.00**	**$56,657.25**	**$0.00**	**$49,950.00**	**$6,295.25**
Grand Total Expenses (BCRP + others)		**$81,177.50**			**$106,607.25**		
Spent BCRP				$56,657.25		Required	**$9,677.30**
						overage	$3,382.05
Balance (Grand Total Income - Grand Total Expenses		**$0.00**					
BCRP Balance (surplus)							Instream F

* Any unspent BCRP financial contribution to be returned to: BC Hydro, BCRP
6911 Southpoint Drive (E14)
Burnaby, B.C. V3N 4X8

Red font indicates original budget items – that were not used Alternate technology and strategies applied

$56,657.25			$62,952.50	$56,657.25	$6,295.25	holdback
		Remaining obligation to Instream Fisheries Research			$9,677.30	actual owe
					-$3,382.05	proj deficit

Appendix G Performance Measures – Actual Outcomes

This study is designed to provide information and direction on the issue of adult fish passage at BCHydro's Salmon River diversion. As such measurable performance measures are not part of the project, this report represents the outcomes to date. The actual outcomes and recommendations from this study will be carried forth and a larger scale BCRP study in 2009/10 may provide specific operational or infrastructure changes at the site.

Appendix H Confirmation of BCRP recognition-Participation in Meetings

This BCRP project was not publicized through the press, other than the BCHydro press release in Spring 2008 identifying the project. The location and type of monitoring equipment in such remote sites would be susceptible to vandalism.
BCHydro and DFO staff met frequently to discuss safety planning. The Safety Plan was developed and modified as required to reflect project scope and any changes or activities identified over the past 6 months.
Updating of information gathered during the project was presented at meetings attended by DFO, BCHydro (local and regional staff, and BCRP representative), MoE, and local community group representatives.