



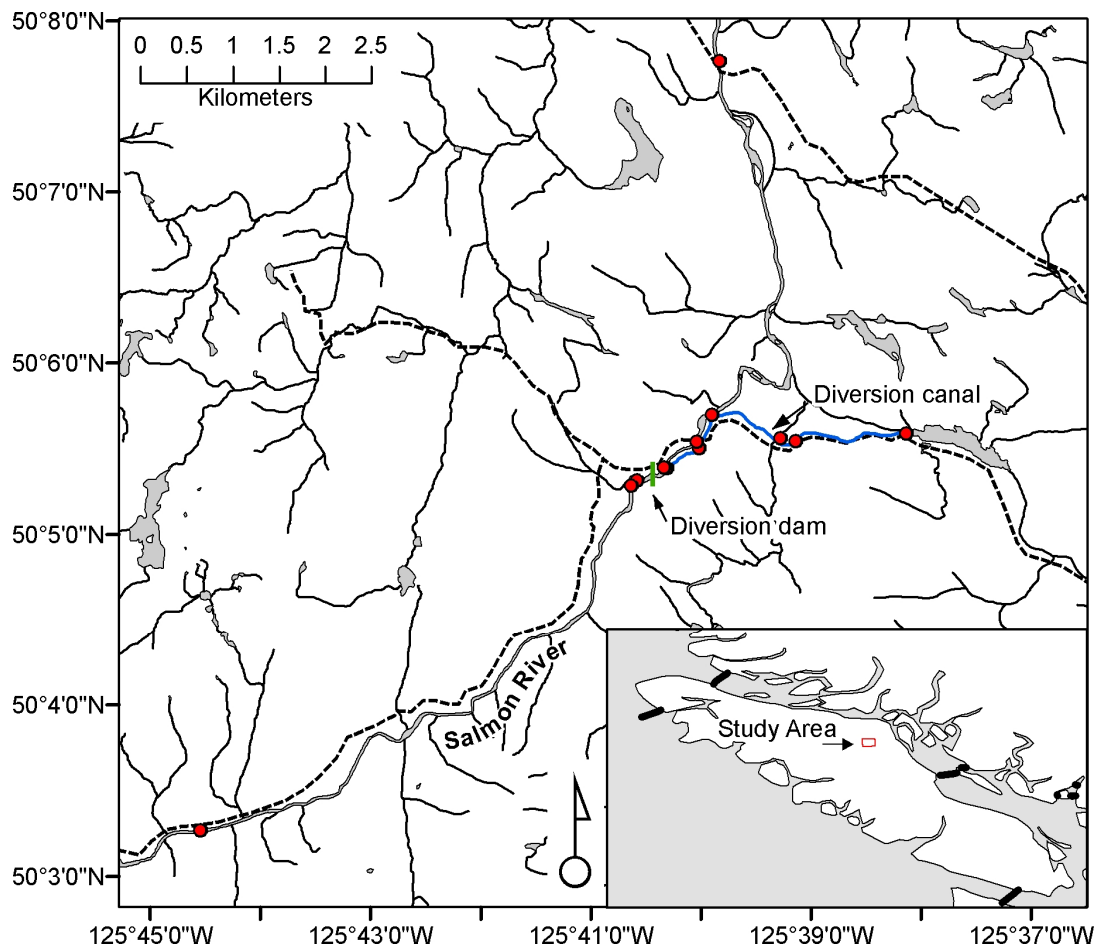
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Salmon River Fishway Assessment Study

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Location of the Salmon River diversion canal and the acoustic receivers deployed during the 2009 field season. Insert shows the location of the Salmon River. The ocean sub-arrays in southern British Columbia are shown as bold lines.



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Acknowledgements

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Executive Summary

The study reported here was done with the assistance of the Department of Fisheries and Oceans, Mainstream Biological Consulting Inc. and on-site BC Hydro personnel. The Salmon River diversion structure potentially poses a physical barrier to upstream migrating adult coho and the functionality of the installed fishway has been questioned. The aim of this study was to investigate the behavior of coho upon reaching the BC Hydro diversion dam. This report is a continuation of the study started in 2008 to examine the migration route of acoustically tagged adult coho salmon reaching the BC Hydro diversion structure located on the Salmon River, Vancouver Island (Lydersen *et al.* 2009).

In the fall 2009, 12 acoustic receivers were installed in the Salmon River, the fishway, Paterson Creek and the BC Hydro diversion canal. Thirty adult coho were gastrically implanted with VEMCO V13 tags, released, and their individual travel patterns from the release site identified using these receivers.

During the ~two month study 2,348 detections were heard and 26 (of 30) tags were detected. The last detection was on 30 Nov 2009, approximately 763 hours after release. Maintenance of the diversion canal prevented diversion of the main river during the study period, eliminating the possibility of adult coho migrating down the canal. Of the thirty coho tagged, none were detected above the fishway. Nine fish were last detected in the fishway, sixteen were last detected on the receivers downstream from the dam, and one fish was last detected on the Paterson Creek receiver.

Fourteen of the thirty tagged fish (47%) were detected in the fishway (compared to 7% in 2008); however, since none were detected above the fishway it is unlikely that upstream passage success was high. Extreme flows during the study period resulted in the burial of two (of three) receivers sited in the main river above the dam, adding a degree of uncertainty to the data interpretation as the exact time of burial cannot be established.

Introduction

The Salmon River is located on the east coast of Vancouver Island, north-west of Campbell River, British Columbia. The watershed is approximately 1300 km² and includes parts of 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 divert water away from the Salmon River in order 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 requirement for fish passage was identified, 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 fishway 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 m³/s of flow to the main Salmon River whenever possible, and the canal (radial arm gate) was required to remain closed during lower flows (<1.73 m³/s; Burt and Roberts 2002).

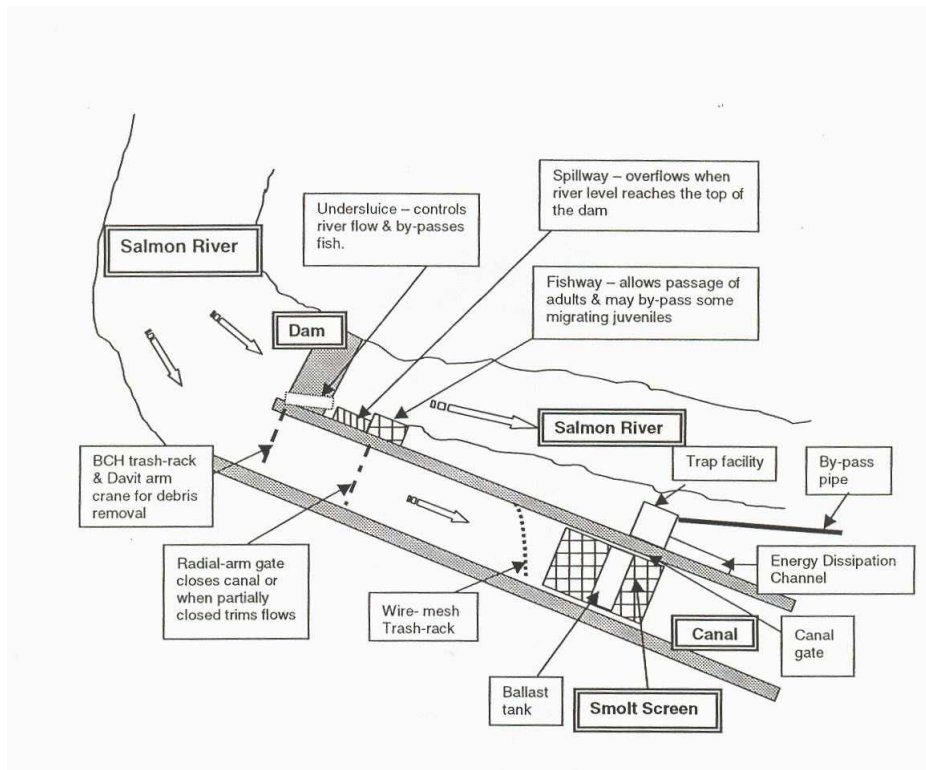


Figure 1. Schematic of Salmon River diversion structure (not to scale; from Hansen 2001).

Currently, fish must enter the small entrance (1.2m high by 0.4m wide) to the fishway slightly downstream of the dam face and sluice gate, which appears to be less attractive than the flows in the main river by the undersluice. 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 trash-racks at the entrance of the fishway 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 fishway and thus tend to pool below the dam face rather than using the fishway (Figure 2). BC Hydro staff open the undersluice 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 during periods where the radial arm gate is open and water is being diverted (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.

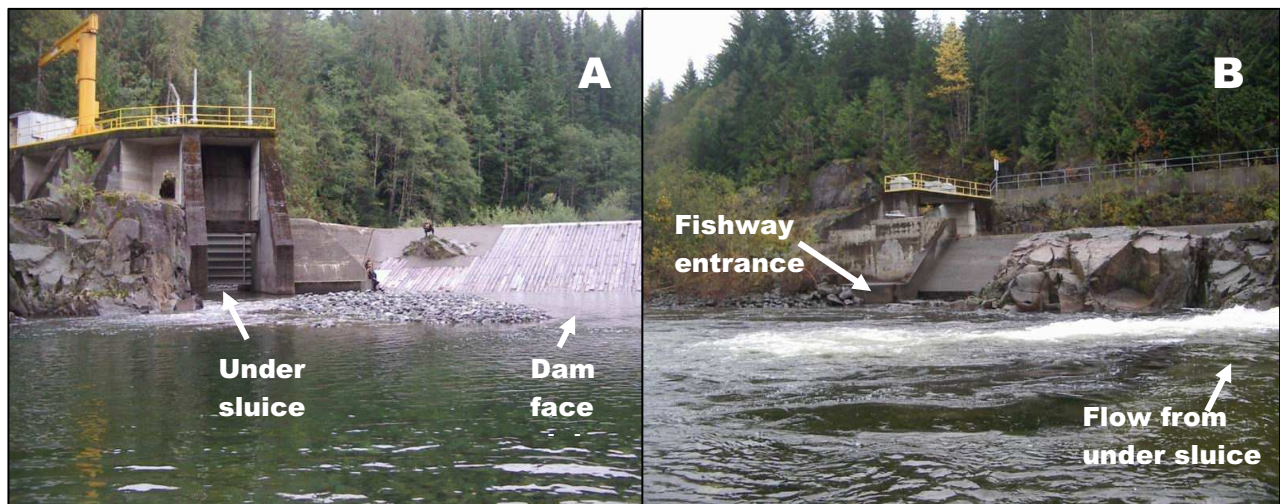


Figure 2. Salmon River diversion structure (photo courtesy of Shannon Anderson).

The intent of this study was to determine the success rate, as well as the passage route, of migrating adult coho upon reaching the diversion structure using a small-scale acoustic telemetry array and gastrically implanting uniquely coded acoustic tags. This allows us to monitor the movements of the coho while building on the results of the 2008 pilot study. However, in 2009 several episodes of extremely high flows were measured (max 477 m³/sec) and impeded the study by moving bedload over top of three acoustic receivers; this made equipment recovery difficult and imposed an uncertainty regarding the period of time some of the receivers were in place and functioning.

Goals and Objectives

The initial objective of this study was to determine the migration route of adult coho that reach the BC Hydro Diversion canal, and establish whether they would: (a) turn around and spawn downstream of the dam, (b) travel up through the fishway or otherwise navigate through the dam structure (through under-sluice gate, or up the far side of the dam face during high flows) and then whether they (c) 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. In particular, the function of the fishway located immediately downstream of the dam has been questioned as the up-migrating Coho appear to have trouble navigating through this site.

Methods

1.1 Salmon River Array

To establish the pattern of movement, three acoustic receivers were installed upstream of the dam in the Salmon River, four in the Salmon River below the dam, two in the diversion canal below the smoltscreen, one in the diversion canal immediately above the smoltscreen and one in the fishway (cover photo and Figure 3). In addition to these 11 receivers, one receiver was placed in Paterson Creek which allows passage from the Salmon River to Paterson Lake at high flows. Unfortunately damage to the diversion canal prevented BC Hydro from diverting flow from the Salmon River to the Campbell system during the time the adult coho were migrating upstream.

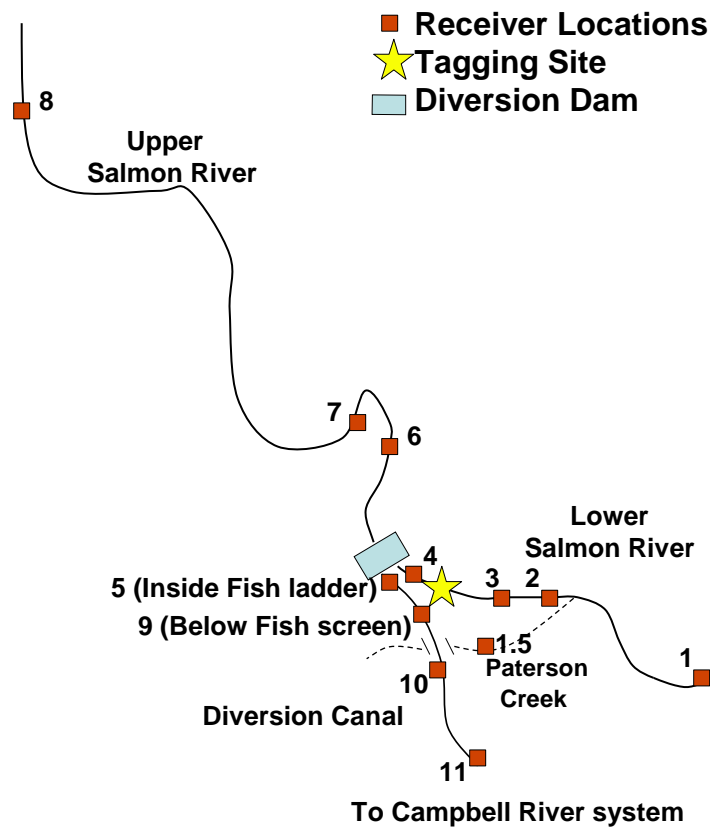


Figure 3. Schematic of acoustic receiver locations on the Salmon River (map not to scale). Receivers 1-8 were in the main river in the expected direction of travel for migrating adult coho; receivers 9-11 were in deployed in the diversion canal; and receiver 1.5 was deployed in Paterson Creek which runs under the diversion canal. The two tagging sites were very close together (<400 m) and are therefore represented as one.

The original design of the array was similar to the layout of the 2008 study with a few alterations:

- 1) A fourth receiver was added in the main river 5.75 km below the dam, close to Marilou Lake at the site of the Memekay main logging road Salmon River bridge.
- 2) An additional receiver was installed in the diversion canal by the bypass pipe that returns fish to the Salmon River.
- 3) One receiver was installed in Paterson Creek, a coho tributary ~ 1km below the dam.
- 4) InStream Fisheries Research Inc replaced the normal trash rack/gate at the top of the fish way with a resistivity counter and panels with narrower openings to ensure fish would only pass through at the counter at the bottom of the fish way rather than being able to pass at any depth (Figure 4). In 2008, an acoustic receiver had been placed in one of the lower chambers, but anchoring proved difficult and this receiver had torn loose. In 2009 the receiver was attached to the resistivity counter inside the fishway, and when InStream removed the resistivity counter it was placed on the trash rack.



Figure 4. The exit of the fishway with the resistivity counter in place and original trash rack panels in place above counter. The modified trash-rack panels designed to prevent passage of fish above the counter can be seen lying on top of the fishway.

Canyon sides along the river and lack of access forced the upper-most receiver to be located 6.2 km from the dam and the furthest down-stream receiver to be located 5 km from the dam. The uppermost site was chosen recognizing that this receiver might be poorly sited because of the presence of large boulders (causing acoustic shadowing) and increased turbulence at high flows.

Due to extreme flows during the study period only eleven of the 12 deployed receivers were recovered by August 2010. Two of the recovered units (receiver 6 and 7) and one which was not recovered (receiver 4) were completely buried under bedload and submerged. Upon retrieval, the data stored on the receivers was uploaded using VEMCO data acquisition software.

1.2 Tagging operations & release of fish

Uniquely coded acoustic tags enable 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.

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 1 μ Pa@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 efficient studies of the movements and survival of fish.

On 28 Oct 2009, adult coho were caught by DFO and Mainstream Biological Consulting Inc, under contract to Campbell River Salmon Foundation, using a beach seine and tangle net below the Salmon River Diversion Dam. Two different sites were used for fishing: below the logging bridge as in 2008 and immediately below the dam (the diversion pool). Fishing below the logging bridge was completed prior to the arrival of the Kintama tagging crew, and a total of only 6 adult coho had been caught. As this site appeared to have less of an abundance of fish, it was decided to move the fishing effort to the diversion pool where an additional 30 fish were caught while Kintama tagged the fish caught below the bridge, 24 of these were tagged. Fish at both sites were

temporarily held in an in-river holding pen which allowed free river flow to the fish and then placed in black, Chinook broodstock bags to reduce stress and allow for continued river circulation. All tagging was completed by Kintama Research with the assistance of DFO staff on site.



Figure 5. Gastric implantation of acoustic tag in adult coho by Heidi Lydersen (Kintama Research) and Barry Peters 2008 (DFO; Photo courtesy of Mainstream Biological Consulting Inc).

Since the Salmon River coho are classified as food fish it is 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 alongside the broodstock bags. 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 5). 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 and included data gathering (length and sex) and scale samples.

This year's water temperature was slightly higher (6.0°C) during tagging than the low temperatures (5.1°C) experienced in 2008 (Lydersen *et al.* 2009), but the resistance of fish to the handling remained low and thereby facilitated the tagging. A total of 30 fish were tagged and none of the fish regurgitated their tags during the >60 min holding period in the brood stock holding bags. The entire tagging event and fish release at the capture site was completed between 13:00-16:00 local time (20:00-23:00 UTC).

1.3 Data

All data files collected from the array underwent Kintama's standard 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. 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.

1.4 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 and planning of the Salmon River

sub-array and tag transmission scheduling in order to allow high detection rates while ensuring the need for relatively low amounts of equipment deployed in the sub-array.

All receiver files were examined and any detections likely to be false (as a result of aliasing or tag collisions) using the acceptance criteria recommended by VEMCO (Pincock 2008) were identified. 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. A few single detections were identified and examined in relation to activity on other receivers; these single detections were all deemed to fit in with movement pattern in the river and were thus retained in the data set. The vast majority of the data consisted of multiple detections closely spaced in time on a given receiver.

Results

1.5 Detections on receivers and residence time

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 detected at each site. Table 3 shows the time of first and last detection, the time in the study area, and location last heard. Location of receivers and names used in Table 1-3 in relation to the tagging site and the BC Hydro diversion dam can be found in Figure 3.

During the Salmon River pilot study, all but four of the uniquely tagged adult coho were detected on the acoustic array. Their time detected in the study area varied from 0:06 hrs to 763:18 hours (compared to 0:42 hrs to 261:51 hrs in 2008).

Table 1. Number of detections based on individual tags and receiver locations. Receivers 1, 2, 3, 4 were located below the BC Hydro dam. Receiver 5 was located in the fishway which was the furthest upstream any coho were detected; none were detected in either the upper Salmon River or the diversion canal. Receiver 1.5 was located in Paterson Creek. Receivers 4 and 6-11 are excluded from the table as they either contained no data (6, 7, 8, 9, 10 and 11) or were not recovered (4). Receiver locations can be seen in Figure 3.

Tag id	Un-detected	Receiver Locations					Grand Total
		Below Dam			Fishway	Paterson Creek	
		1	2	3	5	1.5	
24514				10			10
24515				252			252
24516				12			12
24517	X						1
24518			5		27		32
24519			32				32
24520				74	126		200
24521					108		108
24522			3	21	82		106
24523			1	30	150		181
24524	X						1
24525			3	31	2		36
24526			2	5	20		27
24527	X						1
24528			1		22		23
24529					7		7
24530		1	1	3			5
24531			1	5	124	1	131
24532				14	30		44
24533	X						1
24534				2			2
24535			1	2			3
24536					3		3
24537			1	1			2
24538				2	438		440
24539				12			12
24540				323	210		533
24541			89	1			90
24542				50			50
24543			7				7
Grand Total	4	1	147	850	1349	1	

Table 2. Number of fish detected at each site and percentage of total tagged fish in the Salmon River by the BC Hydro diversion dam, 2009. Receiver 6 and 7 were likely buried during the freshet on the 16th of November when the majority (94%) of fish were no longer detected in the area.

Receiver location	Site location	Number and percent of individual fish detected
1	4 th down river of dam	1 (3%)
1.5	Paterson Creek	1 (3%)
2	3 rd down river of dam	13 (43%)
3	2 nd down river of dam	19 (63%)
4	1st down river of dam	unit not recovered
5	Fishway	14 (47%)
6	1st up river of dam	0? (unit under bedload)
7	2nd up river of dam	0? (unit under bedload)
8	3rd upriver of dam	0
9	Diversion canal (fish screen)	0
10	Mid diversion canal	0
11	End diversion canal	0

Table 3. Time of first and last detection, residence time in study area, and location of final detection site for the 30 adult coho tagged near the BC Hydro diversion canal. Fish were tagged on 28 Oct 2009. Times are reported in UTC.

Tag id	Sex	Time of first detection	Time of last detection	Time in area (hh:mm)	Location last heard
24514	M	2009-10-29 07:27:25	2009-10-29 07:33:58	0:06	3
24515	M	2009-11-02 23:18:55	2009-11-22 08:43:24	465:24	3
24516	F	2009-10-28 23:56:42	2009-10-29 01:17:13	1:20	3
24518	F	2009-10-30 15:02:03	2009-11-05 21:00:19	149:58	5
24519	F	2009-10-29 06:40:05	2009-11-21 11:13:19	556:33	2
24520	F	2009-11-02 03:50:05	2009-11-06 03:53:59	96:03	5
24521	F	2009-10-30 23:19:14	2009-11-12 23:00:14	311:41	5
24522	F	2009-11-05 17:33:37	2009-11-10 01:39:12	104:05	2
24523	M	2009-10-30 01:33:36	2009-11-07 15:34:24	206:00	5
24525	F	2009-10-29 15:05:18	2009-11-09 16:24:20	265:19	5
24526	F	2009-10-30 05:50:31	2009-11-26 17:40:18	659:49	5
24528	M	2009-10-31 17:46:15	2009-11-07 11:51:09	162:04	2
24529	F	2009-10-30 17:14:05	2009-10-30 17:29:39	0:15	5
24530	F	2009-10-30 11:25:38	2009-11-05 10:08:21	142:42	1
24531	F	2009-10-31 18:05:40	2009-11-10 22:09:30	244:03	1.5
24532	M	2009-10-30 20:15:39	2009-11-07 23:48:57	195:33	3
24534	M	2009-10-30 14:41:40	2009-10-30 14:44:26	0:02	3
24535	M	2009-11-01 08:58:47	2009-11-05 12:36:40	99:37	3
24536	F	2009-10-31 16:33:17	2009-10-31 16:38:08	0:04	5
24537	M	2009-10-29 20:11:30	2009-11-06 17:02:50	188:51	2
24538	F	2009-10-31 06:40:55	2009-11-09 01:24:58	210:44	3
24539	M	2009-10-30 06:49:35	2009-11-01 22:30:30	63:40	3
24540	F	2009-10-30 00:24:40	2009-11-30 19:42:59	763:18	5
24541	M	2009-11-03 06:21:10	2009-11-07 03:36:18	93:15	2
24542	F	2009-11-01 14:41:03	2009-11-02 14:44:59	24:03	3
24543	M	2009-11-02 19:10:31	2009-11-03 05:06:25	9:55	2

1.6 Movement of fish in the dam area

During the study, 16 (53%) coho migrated downstream and did not return (receiver 1, 2 or 3 was their last detection site) and one fish was last detected by the receiver located in Paterson Creek (receiver 1.5). Nine fish (30%) were last detected on the receiver in the fishway (receiver 5). No fish were detected above the dam or in the diversion canal. At the date of writing this report, receiver 4 has not been recovered. Figure 6 indicates the movement of the 15 adult coho tagged in 2009 that were detected on multiple receivers.

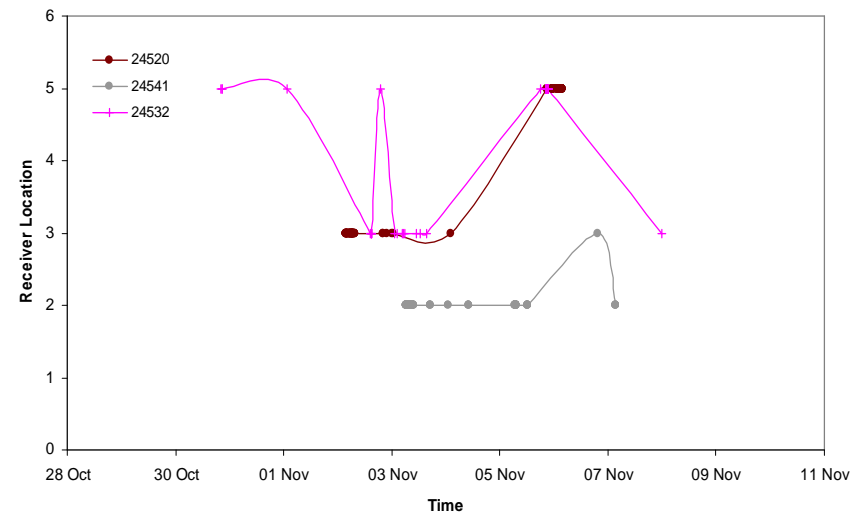
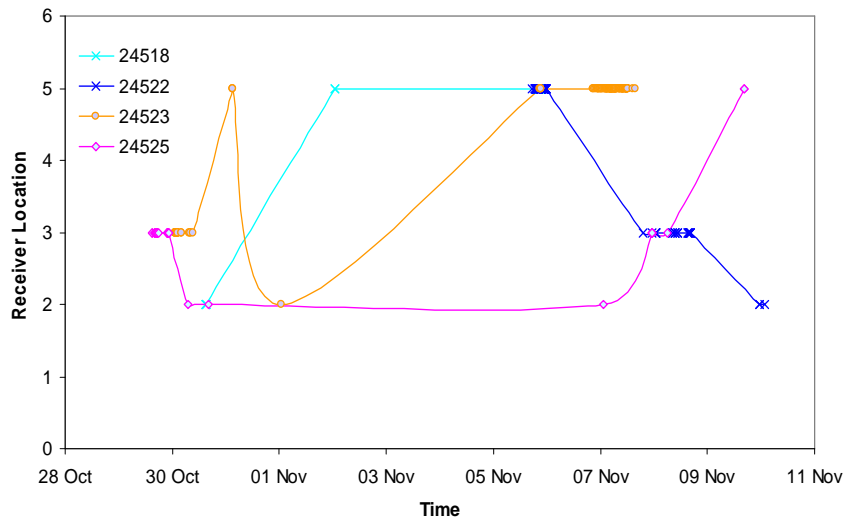
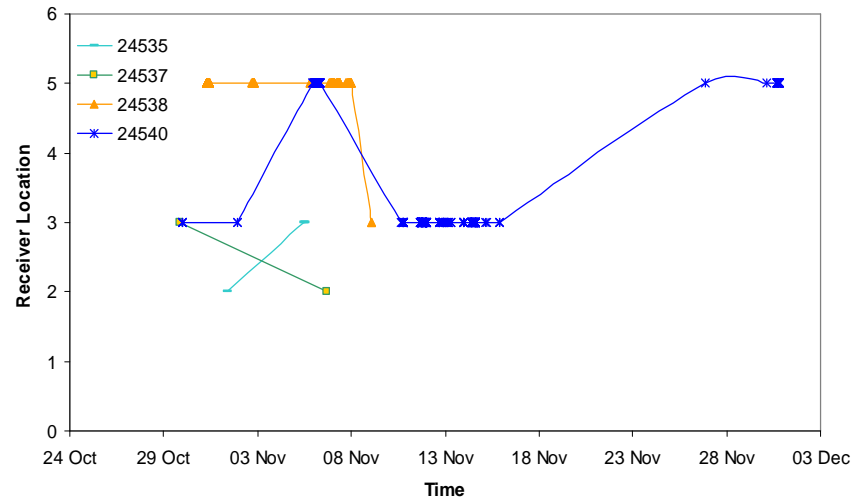
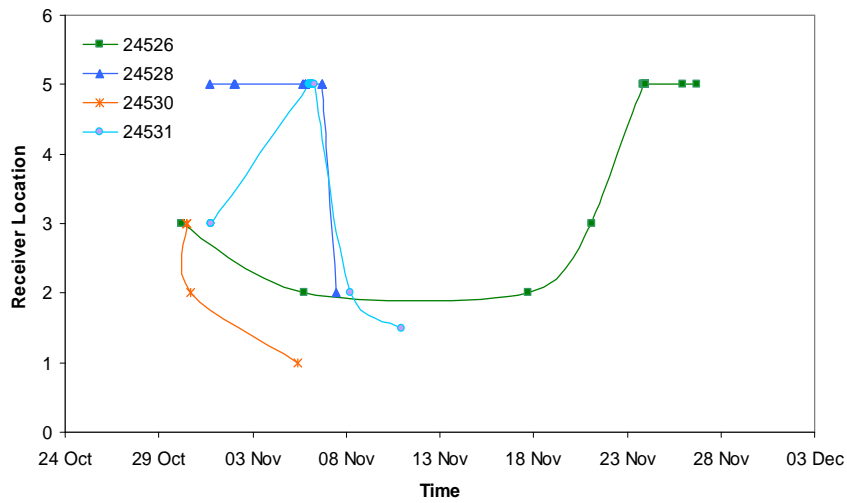


Figure 6. Movement over time of 15 individual fish in dam area. Fish which were only heard on one receiver are excluded from the graphs but identified in Table 1. Receiver locations can be seen on cover photo and Figure 3.

Discussion

1.7 Overview of adult coho movement

Of the 30 fish tagged and released 16 (53%) were noted moving downstream in the main Salmon River, one coho (3%) was last detected in Paterson Creek and 4 (13%) were unaccounted for. This means that at least 57% of the fish that were caught >300m below the dam or pooling by the dam trying to find passage appeared to either have given up their upstream migration or been forced downriver by the high flows. The receivers were in place for a long period of time and as none of these fish returned they may have selected a spawning site further down-river. A total of 14 (47%) unique fish were detected in the fishway, some on multiple occasions (Table 4). This was the last detection site for 9 (30%) tagged adults, while the remaining 5 (17%) that had entered the fishway were subsequently detected down-river.

1.8 BC Hydro operations and fish way activity

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). In neither 2008 nor 2009 was water diverted from the Salmon River to the Campbell river system during the study period as hoped, which meant that all flow came through the study area either by spilling over the dam, through the under-sluice, over the trimming weir in the canal, or through the fishway. Still, the dam poses a physical barrier to the migrating adult salmon and questions regarding the functionality of the installed fishway have been raised. Flow through the undersluice can be managed on-site by a BC Hydro crew independently of diversion need. The following section attempts to link the flow patterns in the river (Figure 7) during the study period to the detections throughout the site – specifically looking at the activity patterns in the fishway (Figure 8). For the fishway to be functional there has to be sufficient water in the canal (upstream of the radial arm gate) to allow passage and not so much water that the head pressure between the chambers inside the fishway exceeds the swimming speed of the adult coho. The under-sluice can, to some degree, help manipulate the flow through the fishway.

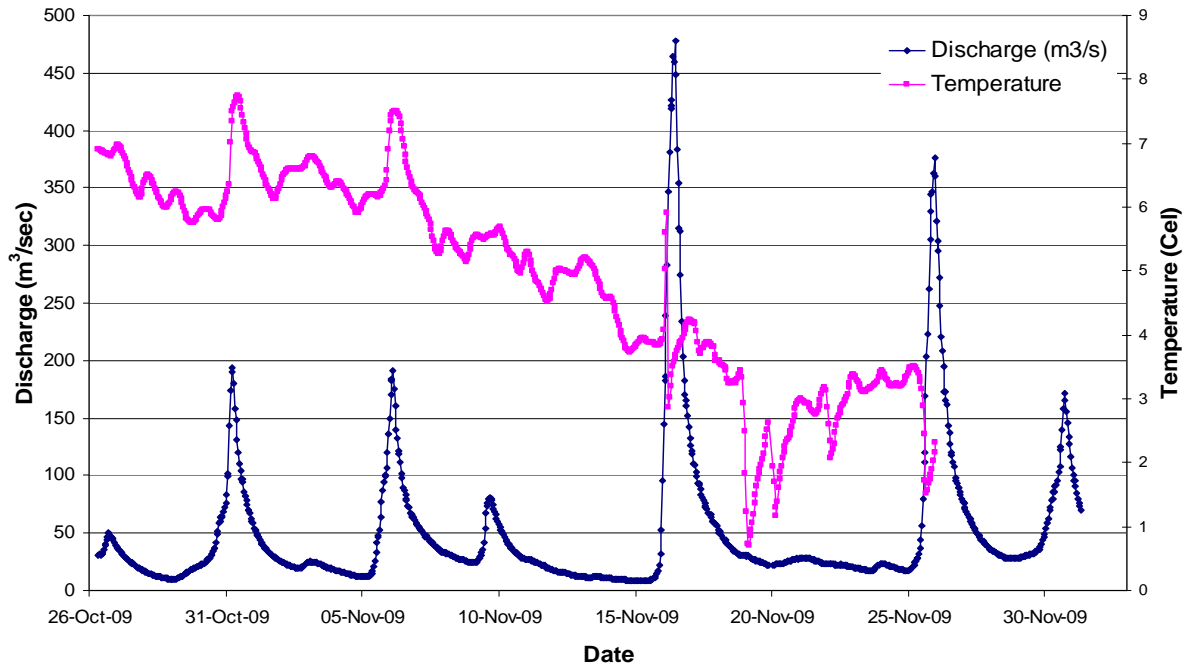


Figure 7. Flow (m³/s) and temperature (C°) in the Salmon River during the period coho were detected near the BC Hydro Diversion Dam. There is no temperature data after 26 Nov as the unit stopped functioning (0:04 UTC).

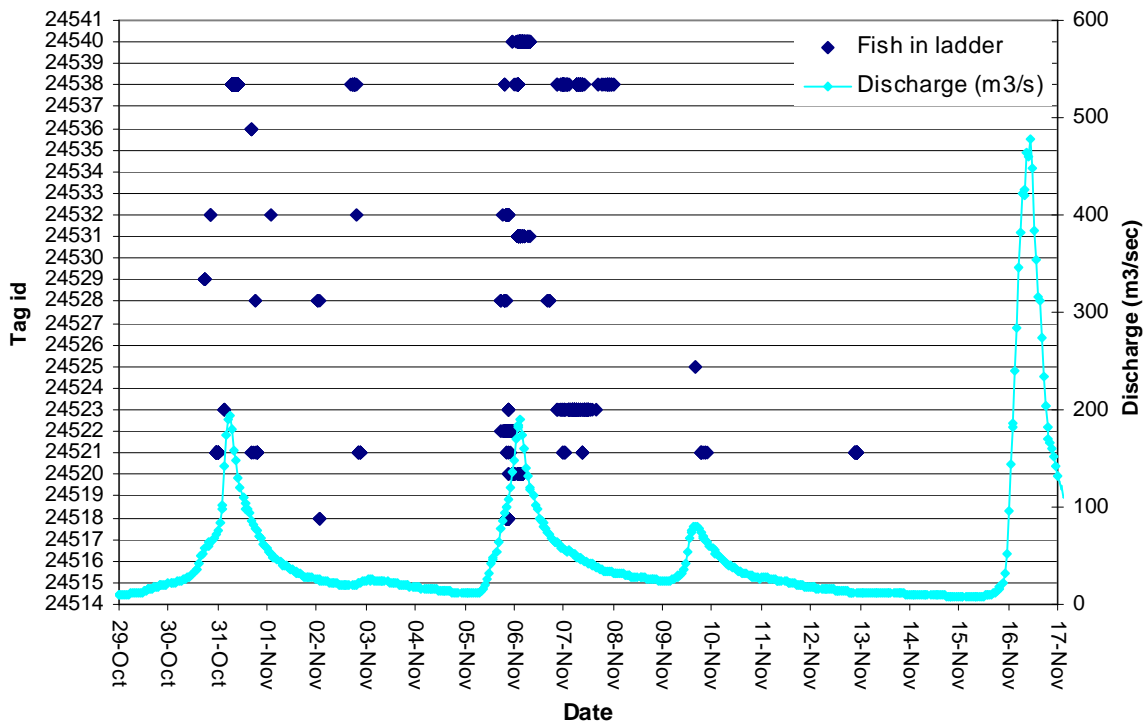


Figure 8. The presence of tagged fish in the fishway relative to the flow of the main river during the 2009 study period.

After the tagging event on Oct 28th, flows started to increase in the Salmon River. By Oct 31st 2010, the flow reached 193 m³/sec, but many tagged fish remained in the area. This is quite different from 2008, where after increased flows following tagging only two fish (of 14) remaining within the study area by day four, yet the 2008 flow in this period only reached ~30 m³/sec. It is interesting to note that the fish remained at the dam for much longer time periods in 2009 (higher flows) than in 2008 (lower flows).

The majority of movement was observed in the Salmon River between Oct 28th and Nov 11th, after which only 5 fish remained in the area. The last detection recorded on the array was on Nov 30th. Six fish were detected on the array only for a brief time period (<24 hours), five were detected in the Salmon River area for 24 to 100 hours, six for 100-200 hours, four for 200-300 hours and five for 300-763 hours (table 3). The majority of the fish stayed in the area for a long time suggesting the desire to continue upstream but being unable to pass the diversion dam.

Table 4. Details on tagged, adult coho that entered the fishway multiple times.

Tag id code	Entry	Exit	# detections	Time in ladder (hour:min)	Approximate flow (m ³ /sec)
24540	05-11-2009 23:06	06-11-2009 07:53	185	08:47	137-121
	26-11-2009 20:04	26-11-2009 20:04	1		90
	30-11-2009 02:58	30-11-2009 19:42	24	16:44	63-150
24523	31-10-2009 03:13	31-10-2009 03:15	3	00:02	143
	05-11-2009 20:59	05-11-2009 21:23	6	00:24	107-120
	06-11-2009 20:53	07-11-2009 15:34	141	18:40	64-39
24532	30-10-2009 20:15	01-11-2009 01:45	4	29:29	64-51
	02-11-2009 19:09	02-11-2009 19:09	1		21
	05-11-2009 17:55	05-11-2009 21:26	25	03:31	86-107

1.9 Function of up-stream receivers

In 2008, only 3 (21%) tagged adult coho were detected in the fishway and for 2 of these (14%) this was the last point of detection. There is no reason to believe that any of the 2008 fish actually continued upstream (or went down the diversion canal) as all 2008 receivers were in

place and functioning; this however is not the case for the 2009 data. The extreme flows in 2009 caused problems at several sites, the most troublesome ones being the locations immediately above the dam and in the diversion pool immediately below the dam:

Receiver 4 (immediately below dam) and anchor was buried below a large quantity of gravel moved by the flows coming over the dam. This receiver remains buried as the site did not get exposed during the low flows in the early fall.

Receiver 6 (first above dam) and associated anchor had been moved and deposited on the side of the river underneath a load of gravel and rocks, and required significant effort to locate and retrieve. This receiver contained no data, but unfortunately we do not know when this receiver was relocated (or how well it could have detected tagged fish after burial). Max flow in 2008 was $\sim 72 \text{ m}^3/\text{sec}$ which caused no problems at this site, but in 2009 flow reached $193 \text{ m}^3/\text{sec}$ within 3 days of the study, and max flow was $477 \text{ m}^3/\text{sec}$ (Nov 16th). Upon retrieval, we were unable to communicate with this receiver. In order to exclude the possibility that the receiver file was empty due to a malfunction of the receiver itself, it was returned to VEMCO for inspection and verification. The error was determined to be an issue with a malfunctioning Bluetooth chip and should not have affected on the performance of the receiver during the study.

Receiver 7 (second above the dam) was buried under a large quantity of gravel (1.5-2 meters deep) and still under water – we were unable to retrieve this receiver on our first two attempts. Later in the summer (2010) this receiver was recovered during extremely low flow but did not contain any detections. Again, we cannot be certain that the receiver was operational during the time the adult coho were in the area.

During the 2008 study flows increased to $88 \text{ m}^3/\text{s}$ while the receivers were deployed in the same manner as in 2009 and these receivers did not move. Although there were three events of flash flows in 2009, the one that happened on November 16-17th reached $477 \text{ m}^3/\text{s}$ and is likely to have caused the movement of the bedload, and by association, the receivers. At this time only two fish (24540 & 24526) were still detected within the study area. Although, we cannot be certain, we believe the upstream receivers were operational during the time period where the majority of the

adult coho should have passed the receivers. Both tags 24540 & 24526 were heard in the fishway following the extreme flow, and as such might have been missed on the two buried upstream receivers if they were to pass them. Receiver 8 (third above dam) should capture any tagged fish going up-river, but this receiver was located in an area suspected to have significant acoustic shadowing due to the amount of rocks, boulders, and riffles at the site. High flows at this site would further decrease the detection efficiency of this receiver. No fish were recorded at site 8, but the receiver was still in place and functioning upon retrieval.

If the two 2008 and nine 2009 fish did not continue up the river, there is still the question of their fate. Anecdotal accounts from BC Hydro crew report otters working the fishway and salmon missing the entrance to the ladder during higher flows, leaving them stranded on the grates covering the pools in the fishway.

Conclusion

Between October 28th and December 2009, the movements of 30 gastrically tagged adult coho in the Salmon River were tracked using an acoustic listening array. The main findings are as follows:

- 87% of the tagged coho were detected on the array.
- None were heard above the Salmon River diversion dam or in the (inactive) diversion canal. However, uncertainty is introduced as two of the up-river receivers were buried by extreme flows during the study period.
- Sixteen of the 30 fish (53.3%) migrated downriver following the tagging, nine fish were last detected by the receiver inside the fishway (30%) and one fish (3%) was last heard on the receiver in Paterson Creek.
- Fish were detected, possibly holding, in the study area below the dam for up to 760 hours (~32 days; Table 3).

The purpose of this study was to build on the initial assessment done in 2008 of the migration behavior of adult coho salmon once they encountered the BC Hydro Diversion Dam on the Salmon River. Both our 2008 and 2009 studies indicate that the majority of acoustically tagged coho failed to travel upstream of the BC Hydro dam, and despite extensive milling (up to 200+ hours in 2008 and 700+ hours in 2009) in the area below the dam, only 14 of the 30 tagged 2009 fish and 2 of the 14 tagged 2008 fish actually entered the fishway.

Recommendations

The results for the 2008 pilot study indicated that the acoustic telemetry system is a promising method of resolving the movements of coho in the Salmon River after release; however, the extreme flows experienced in 2009 posed problems for the telemetry system. The primary problem was the burial of receivers 4, 6, and 7 to a depth of several feet, and the secondary problem was that the high flows would have caused increased turbulence and decreased detection efficiency. In addition, alternative routes could be a possibility in some areas such as Paterson Creek where a flooding of the area surrounding the creek could have allowed fish to migrate outside the normal river channel, and thus in areas not covered by the receiver.

For future studies it would be beneficial to fix receivers on canyon walls above the dam in the summer time when the flow is minimal. It might also improve detection efficiency if a receiver was placed in Paterson Lake in addition to, or instead of, Paterson Creek.

In both the 2008 and 2009 study single groups of tagged fish were released. The allowance for a second tag and release event was in place for 2009, but was prevented by high flows as well as the lack of diversion operation – which was one of the parameters to be tested. It would be useful in future, should the study be repeated, for several groups of 10-20 tagged adult coho to be released at intervals of 5-7 days and their movements monitored.

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