BC hydro

Puntledge River Project Water Use Plan

Puntledge River Adult Fish Passage During Pulse Flow Releases (Year 1) *FINAL*

Reference: Puntledge MON#1

Puntledge River Water Use Plan Monitoring Program: Adult Fish Passage During Pulse Flow Releases

Study Period: May 2007 to February 2008

Carleton University
Department of Biology and Institute of Environmental Science
and
Esther Guimond

Puntledge River 2007 Summer Run Chinook Radio and Electromyography Telemetry Study

INTERIM REPORT

May 2007 – February 2008

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Puntledge River 2007 Summer Run Chinook
EMG and Radio Telemetry Study

Report Prepared for BC Hydro as a reporting requirement for the Water Use Planning Process for the Puntledge River.

Executive Summary

In 2007 we conducted a study on adult fish passage during pulse flow releases in the Puntledge River as part of the BC Hydro Water Use Planning Process. Our research efforts focused on summer Chinook salmon. Using a combination of radio telemetry and electromyogram (EMG) telemetry we evaluated the behaviour and fate of fish in response to the pulsed flows and overall to provide information on the migration biology of this imperiled population. All fish that were tagged with transmitters were also non-lethally biopsied to obtain blood and gill tissue. In addition, each transmitter was also affixed with a thermal logger which was downloaded if the transmitter was recovered. Fish were tracked frequently by walking the river bank. In addition, we deployed a number of temporary and permanent telemetry arrays throughout the river based on the distribution of fish. The summer of 2007 was somewhat of an anomaly inthat there was a large amount of snowpack. Hence, there was a need to spill water at rates and durations inconsistent with those that were prescribed as part of the WUP. In total, there were only three pulses and we were able to monitor fish behaviour and activity before, during, and after these events. We intended to use 2 release groups of 28 fish for the telemetry studies of which 20 were to be conventional tags and 8 were to be EMG tags. We deviated from this plan due to low numbers of fish and a need to ensure adequate numbers of fish for hatchery production. Seven fish were tagged with EMG transmitters on June 29; 9 with EMG transmitters on July 06; and 32 with radio transmitters on July 17 (10 of the radio tagged fish were transported to Comox Lake to attempt to locate spawning grounds and were not included in the study carried out on the Puntledge River). A total of 3 pulses were delivered on July 04-05 (lasted 48 h), July 11-26 (384 h), and August 01-02 (48 h). Preliminary results indicate that pulse flows did not induce statistically significant movement among tagged fish, although the data were suggestive that fish were moving more in response to the pulses. Only 5 tagged fish successfully migrated beyond the diversion dam; 13 fish held below the diversion dam, but successfully moved beyond Nibs Falls; 5 fish were last tracked between Stotan Falls and Nibs Falls; while 15 fish failed to pass through Stotan Falls. Physiological biopsies revealed that fish condition varied across the three tagging sessions. Fish that arrived at Reach C and subsequently tagged and sampled during the first release were found to have less calcium and magnesium than the second release group while fish tagged and sampled during the first and second release had significantly more glucose and higher gross somatic energy values. No physiological variable was found to be significantly indicative of fate, as no differences were found among fish that did not spawn, possibly spawned, and spawned. However, migratory behaviour was correlated with several physiological variables. Stepwise linear regression indicated that the maximum distance traveled upstream by individual fish was influenced by a combination of calcium and potassium and explained 56 % of the observed variance in migratory distance. However, when the first release of fish was omitted from the model, a combination of 7 variables (potassium, calcium, glucose, magnesium, sodium, AST, and gross somatic energy) accounted for 82 % of the observed variance in the model. Multiple regression also revealed that the number of times that an individual fell back was explained (59%) by a

combination of triglycerides, calcium, AST, glucose, and phosphorous. Data from the 16 thermal loggers that were retrieved are currently being analyzed and with the EMG data will be used to parameterize a bioenergetics model which will enable us to develop reach, flow, and temperature specific estimates of energy expenditure using data from 2007 and future years. Collectively, our preliminary analyses suggest that fish condition upon arrival in the river seems to affect individual migratory behaviour. This paradigm provides new insight into the impacts of the hydropower infrastructure, operations, and other barriers (i.e., Nibbs and Stotan Falls). Based on our knowledge gained in 2007, we intend to expand the use of fixed telemetry stations in future years. In addition, we propose to install thermal loggers throughout the system in key habitats where fish hold in an effort to determine if fish are able to seek out thermal refugia while holding in the river.

Context

In 2003, the Puntledge River Water Use Plan consultative committee (PUN WUP CC) recommended several operational changes to BC Hydro's Puntledge River facilities. As per the recommendations, several operational changes will require monitoring to ensure that anticipated benefits are properly documented and that the recommended operational constraints are followed. The monitoring program includes a number of components. However, the focus of this proposal is on the "Assessment of Adult Fish Passage During Pulse Flow Releases (Section 2)". Essentially, this will be a three-year study (over five years) to assess the benefits of pulse flows on the migration of summer run chinook salmon during July and August.

The Fish Ecology and Conservation Physiology Laboratory at Carleton University was awarded a contract to execute Section 2 of the WUP TOR. Because of innovations in the fields of biotelemetry and field physiology, there are new tools for monitoring fish responses to pulse flows. As such, the Cooke lab proposed a number of modifications to the WUP TOR. It is important to note that the study addressed all of the core questions (i.e., the primary monitoring indicator is the distance chinook salmon travel before/after a pulse flow) but did so with techniques that were better able to detect such behaviours. Specifically, we used electromyogram (EMG) biotelemetry to assess fine scale changes in fish behaviour and swimming activity. In addition, we assessed fish condition upon arrival in the Puntledge River. These data will be essential for interpreting the influence of other factors (e.g., elevated water temperatures, ocean conditions) on fish behaviour and survival. Such information is essential for understanding the effectiveness of the pulsed flows and in illuminating other possible strategies for reducing the period that Chinook salmon spend in the Puntledge River relative to upstream holding (i.e., the lake) or spawning areas.

At the end of year 1, we proposed to revisit and re-assess our successes and failures prior to determining the most logical monitoring strategy for future years. Here, we provide a preliminary analysis of our findings from year 1 and propose a number of minor modifications for year 2.

Objectives

The key management question is: Do pulse flow releases during July and August stimulate and facilitate the upstream migration of adult summer run chinook Salmon and steelhead trout in Reach C of the Puntledge River? As noted in the TOR, run sizes of steelhead are sufficiently low to preclude direct research on them at this time. Hence, the data for Chinook will be assumed to be representative of steelhead. For the purposes of the monitoring program, it is assumed that improved passage conditions will benefit summer run chinook salmon and steelhead trout at the population level. These benefits may be realized through a) increased survival and spawning success due to reduced migration stress, and/or b) improved access to underutilized spawning and rearing habitats upstream.

The primary objective of the monitoring program is to assess the benefits of pulse flow releases to the upstream migration of adult summer run chinook salmon and steelhead trout in Reach C of the Puntledge River. As such, one ecological hypothesis1 will be examined: H1: The pulse flow releases improve fish passage in Reach C. After reviewing existing literature, the Puntledge River WUP Fish Technical Subcommittee used expert judgment to propose that a 12 m3•s-1 pulse flow over 48-hours, would provide sufficient flow for fish to overcome the physical and behavioural obstructions (i.e., falls and powerhouse discharge respectively), and thus reduce the duration and the assumed cumulative stress of migration. The monitoring program examined this conclusion by comparing fish passage (i.e., the distance migrated upstream) during pulse and non-pulse periods. The migratory response of Chinook salmon to previous pulse flows suggests that flow conditions can induce upstream migration, though the response varies among pulses.

Currently, the environmental cues that stimulate adult salmonids to migrate and the conditions that enable them to pass partial migration barriers are not well understood. A number of factors are believed to stimulate salmonid migration, including flow conditions, water temperature, light intensity, turbidity, changes in barometric pressure and olfactory cues. A combination of environmental factors may produce 'optimal conditions' to elicit a migratory response. The role of flow conditions in this combination of cues is uncertain, and the monitoring program will provide information to reduce this uncertainty. The proposed physiological assessments will also enable us to include an understanding of the fish condition (e.g., energetic status, thermal ecology, hormone titres) on migration as well.

For clarity, the hypotheses are stated as the alternate hypotheses. Analyses will test the null hypotheses of no effect or difference. During summer, the 12 m3•s-1 pulses should also discourage recreational activities, which may affect migration behaviour. The EMG telemetry will enable the research team to quantify fish behaviour and activity relative to different intensities of recreational activity during the monitoring period (i..e., before, during, and after the pulse flows).

Summary of Methods used in 2007

As outlined in the TOR, fish were captured for tagging at the lower Puntledge River hatchery. Monitoring focused on the migration of summer run chinook salmon during the July and August pulse flows using radio telemetry (as per Komori Wong Environmental and Bigsby 2003, Taylor and Guimond 2004). The movements of tagged fish were intended to be monitored over the 5 weekly pulses in summer. However, in 2007, there were only three pulses and they differed in magnitude and duration (due to high snow pack). Fish movements were tracked intensively during all three pulses. Movements during pulse and non-pulse periods were compared to evaluate the benefits of pulse flows (see below).

Telemetry work will be supplemented with snorkel counts at locations with difficult passage (in a complimentary project – data will be integrated for the final report). We supplemented this work by also releasing Chinook salmon with EMG transmitters. These devices provide fine-scale information on fish activity, energetics, and behaviour. In addition, all fish carrying radio transmitters (conventional and EMG) had a thermal logger attached to the transmitter to reconstruct the migration history of migrants. All tagged fish were also non-invasively biopsied prior to release (blood sample and gill tissue).

The original TOR determined that in each year of monitoring, 2 groups of 25 adult summer run chinook salmon would be randomly selected from the lower Puntledge hatchery raceway and tagged. We intended to use 2 groups of 28 – of which 20 were to be conventional tags and 8 were to be EMG tags. We deviated from this plan due to low numbers of fish and a need to ensure adequate numbers of fish for hatchery production. Seven fish were tagged with EMG transmitters on June 29; 9 with EMG transmitters on July 06; and 32 with radio transmitters on July 17 (10 of the radio tagged fish were transported to Comox Lake to attempt to locate spawning grounds and were not included in the study carried out on the Puntledge River). A total of 3 pulses were delivered on July 04-05 (lasted 48 h), July 11-26 (384 h), and August 01-02 (48 h).

Upon capture (i.e., netted from DFO holding facility at lower fishway), all fish were placed in a water-filled trough and sampled (via caudal puncture) for blood (1.5 ml). In addition, a small gill biopsy was collected (3 mm off the tips of 5 to 8 filaments; Cooke et al. 2005). A previous study has determined that this method of non-lethal biopsy does not alter survival or behaviour of sockeye salmon. We also used a non-invasive fat probe (Crossin and Hinch 2004) to assess energy density. All physiological samples were processed and stored in LN2 until analysis at our laboratory.

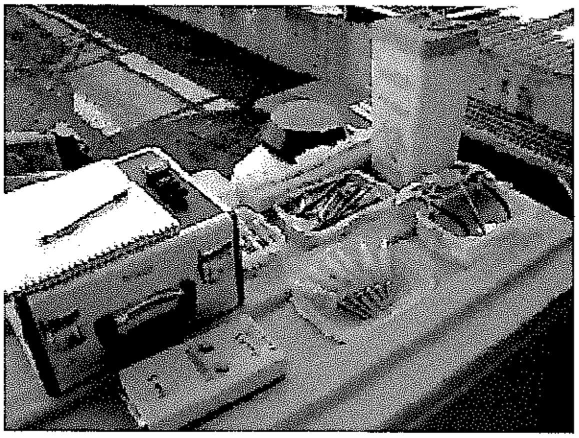

Photo 1. Physiological sampling materials.

For fish being tagged with conventional tags, a Lotek model MCFT-3A radio tag was inserted into the stomach of captured fish following the procedures outlined in Korman et al. (2002). For fish requiring EMG tags, fish were anesthetized following physiological sampling (as described above) in clove oil (60 ppm). Fish were then transferred to a surgical table continuously supplied with a maintenance does of anesthetic (30 ppm). Surgery followed the methods outlined in Cooke et al. (2004). Briefly, a small incision was made in the coelom. Sharpened rods were used to place gold electrodes in the axial musculature of the fish. The transmitter was then inserted into the coelom and the wound closed with PDS II suture material prior to being placed in a recovery tank. For all fish (conventional and EMG), fork length and sex of tagged fish was recorded. After a brief (2 hour) recovery period in DFO fishway holding pen, tagged chinook were released prior to the pulses. Ideally, the release timing would ensure that there is sufficient time to examine the initial migratory response of released fish, and fish migration during a 2-day, base flow control period immediately prior to the pulse. Hence, migration during the control period would not be confounded with the initial migratory response following release. However, due to the limitations with fish, not all tagging was conducted in accordance with this protocol. There was also inconsistent delivery of pulses so it was not possible to the magnitude or duration of a pulse. We maintained close communication with BC Hydro environmental staff to obtain their input re study design given these challenges.

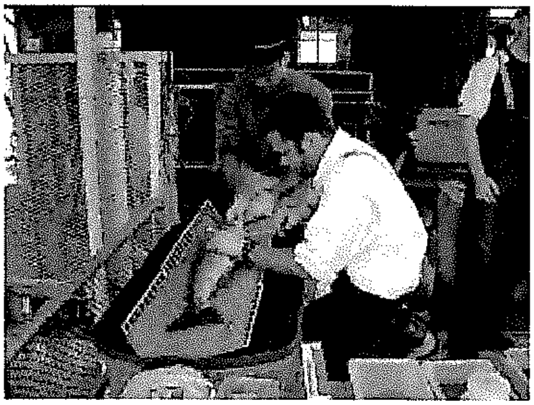

Photo 2. Dr. S. Cooke (foreground) and R. Sunder implanting an adult female summer run Chinook with an EMG transmitter.

The location (river kilometer or GPS location) of tagged fish were tracked with mobile receivers. Each mobile tracking session involved an attempt to locate all tagged fish.

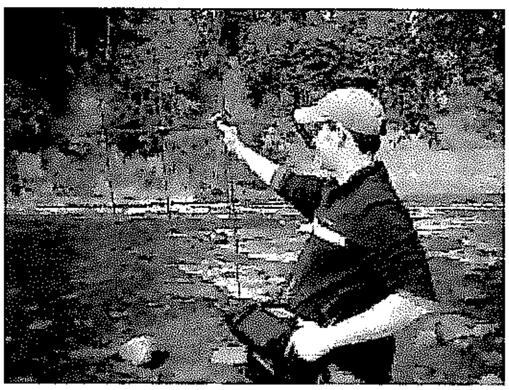

Photo 3. C. Hasler manually tracking tagged fish.

Reach C was accessed by foot. Mobile tracking sessions were grouped into four components and included both conventional and EMG telemetry. (a) Specific pulse tracking: Specific tracking sessions were timed such that the distance migrated during each control and pulse flow treatment period could be calculated. For each study pulse, a minimum of seven mobile tracking sessions would be required to obtain this information. Tracking sessions covered reach C. (b) Tracking within pulse periods: Twice daily (morning and evening) tracking sessions during the control and pulse periods provided additional information on the timing of fish movements within a given period. Eight such tracking sessions occured for each study pulse. Tracking sessions covered Reach C. (c) Continuous tracking at falls: Determining the exact time and corresponding discharge (measured at Gauge 6 or 8) when chinook pass key migration barriers is important to help determine the conditions that facilitate passage. Manual tracking from components (a) and (b) above will provide information on fish movements at a 12-hour time-scale. This time scale is sufficient when flows are held relatively constant near 5.7 or 12 m3•s-1 (Fig. 2-4 TOR). However, this time scale is insufficient during the ramp-up and ramp-down phases of the pulse flow. EMG telemetry was therefore used to provide important information on fish activity during the periods of ramp-up and ramp-down. If fish migrate during these 2 periods, the 12-hour time scale data would not be able to determine the exact discharge at which fish passed. Continuous manual tracking at key migration obstructions during changes in discharge were used to yield this information. Continuous tracking covered the area immediately upstream and downstream of Nibs and Stotan Falls with the tacking crew moving frequently between these areas. Fixed telemetry receivers, an alternative to continuous manual tracking at these two falls, were used to obtain strategic information where appropriate. We used as many as three fixed stations at a time.

Photo 4. An automatic tracking array at the lower fish hatchery.

(d) Spawning period tracking (NOTE: this component of the study was completed as part of the complimentary BCRP proposal awarded to Comox Valley Project Watershed Society for 2007; lead biologist, Esther Guimond).

Interpretation of results for fish migration during pulse flows can be challenging because several physiological and environmental factors other than flow can affect migration. However, we included an assessment of physiological status which will enable use to evaluate the role of physiological condition (e.g., energetics, hormonal status) on behaviour and survival (e.g., Cooke et al. 2006). Previous pulse flow studies on the Puntledge River (Komori Wong Environmental and Bigsby 2003, Taylor and Guimond 2004) and a study with Atlantic salmon in Europe (Thorstad and Heggberget 1998) suggest that pulse flows influence migration, though results can be inconclusive and the patterns can be difficult to interpret. The key monitoring result for this program is the distance migrated during the control vs. pulse periods as well as changes in activity patterns. Results will be presented such that the distance migrated between each tracking period and during each pulse and control period is presented for individual tagged fish (such analyses are ongoing).

Interim Findings

Pulse flows did not induce statistically significant movement among tagged fish (Table 1; Figure 1). When movements prior to each pulse were compared to movements after the pulse was complete, fish were not found to move further upstream, or downstream in relation to pulse times. The statistical analysis had reasonably low power and because the data are suggestive of increased movement during pulse 3, but decreased movement during pulse 2. It is possible that the detailed EMG activity will yield more insight. Relatively few fish moved upstream during the pulses (pulse 1: 1/7; pulse 2: 1/14; 8/33). Distance traveled upstream during pulse 2 was higher than during the other pulses, and a higher proportion of fish moved upstream during this time. However, the pulse was 336 hours longer than the other two pulses as a result of the high snowpack.

Table 1. The mean distance traveled (km), standard error, sample size, and p value calculated using a two-way paired student t-test ($\alpha = 0.05$).

Pulse	Conditon	Mean Distance Traveled (km)	Standard Error	Sample Size	*p* value
1	Before	0.33	0.26	7	0.35
1	After	0.04	0.14	7	
2	Before	0.01	0.05	15	0.28
2	After	-0.11	0.10	14	
3	Before	0.11	0.05	33	0.06
3	After	0.33	0.10	33	

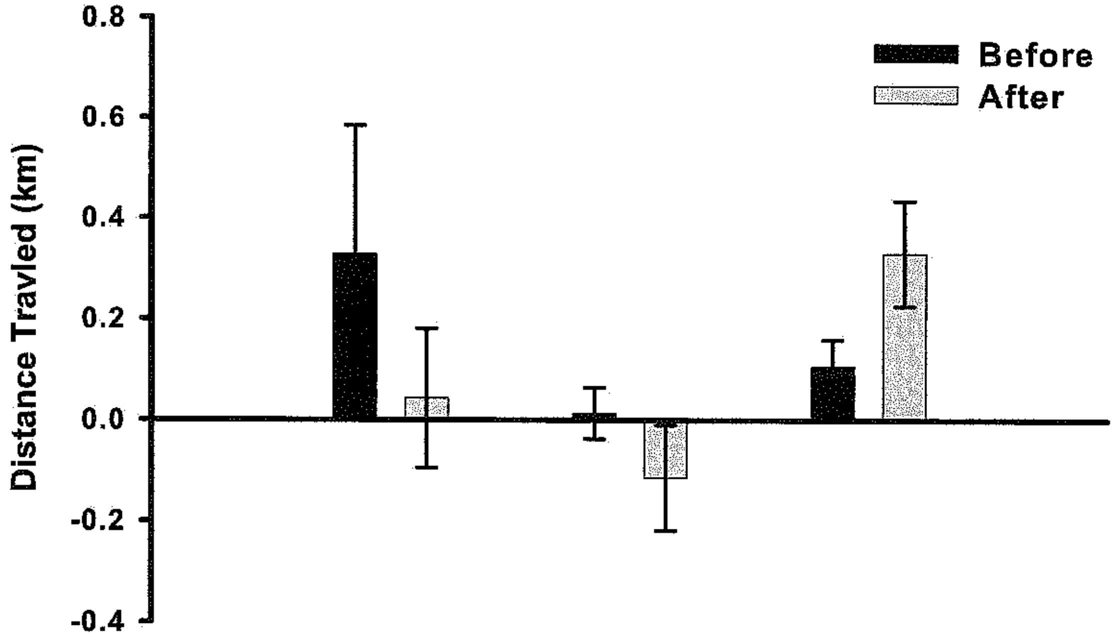

Figure 1. The mean (whiskers represent standard error) distance traveled (km) for Chinook salmon before and after pulsed flows.

Tagged fish movement was likely influenced by natural and artificial barriers present in the diversion reach. Only 5 tagged fish successfully migrated beyond the diversion dam; 13 fish held below the diversion dam, but successfully moved beyond Nibs Falls; 5 fish were last tracked between Stotan Falls and Nibs Falls; while 15 fish failed to pass through Stotan Falls.

Though natural and artificial barriers likely prevented fish from reaching the diversion dam, spawning was observed in some fish. The 5 tags recovered from fish that successfully passed beyond the diversion dam were found on gravel beds, indicating possible spawning. Interestingly, some tags of fish that successfully passed through Stotan Falls were found near spawning gravel beds as well, and it is likely that approximately 13 more fish were able to spawn during 2007. Overall, of 38 fish that were tracked throughout the study, 18 likely were able to move to areas of Reach C that would have provided suitable habitat for spawning.

EMG transmitters allowed for the quantification of activity and energy use as fish moved upstream. Activity levels (and energy use) were found to be significantly different across individuals, indicating that fish could not be aggregated together. We are continuing with exploratory analyses and multivariate techniques to identify common behavioural strategies that could be grouped for analysis. Preliminary results show variation among individual fish in regards to energy use prior to, during, or after pulse flows (e.g., Figure 2). Further analysis is still being completed to assess whether flow and/or temperature significantly affected energy use. These data will be merged with information from the thermal loggers and flows to yield reach, flow, and temperature dependent estimates of energy expenditure. Such information can be used to model energy use of fish relative to different

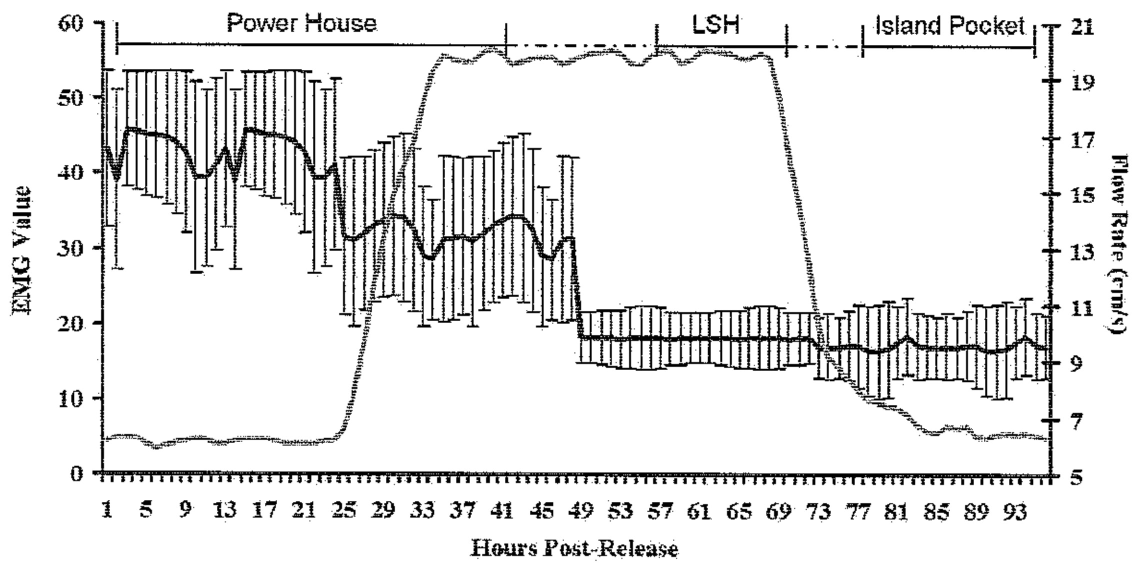

Figure 2. The mean (whiskers represent standard error) EMG value for Chinook salmon number 29 before and after the first pulse flow (black line) and the water flow measured at gauge 6 (blue). The physical location of the fish along Reach C is also given (solid line indicates known location, dotted line indicates unobserved transition between known locations).

At the time of tag implantation, blood and gill samples were collected and energy density readings were obtained. By doing so, we were able to assess two things: the physiological condition of fish at the time of entering Reach C, as well as physiological correlates to migratory behaviour (maximum distance traveled; number of fall backs) and fate (occurrence of spawning).

Fish condition varied relative to time of arrival at the hatchery (and thus for our different release groups; See Table 2,3). Fish that arrived at Reach C and subsequently tagged and sampled during the first release were found to have less calcium and magnesium than the second release group (Table 2) while fish tagged and sampled during the first and second release had significantly more glucose and higher gross somatic energy density values than fish released in the third group (Table 2).

Table 2. Condition of summer Chinook salmon relative to time of release. Data reported include means, standard errors, and sample sizes for physiological variables vs. time of release. Results from an ANOVA with a Tukey-Kramer post-hoc test (α = 0.05) are also given; rows with dissimilar letters are significantly different (NS = non significance).

Physiological Variable	Release Date	Mean	S.E.	n	Comments
Total Protein	June 29	42.7	1.7	7	
(g/L)	July 6	47.0	1.6	9	NS
	July 17	46.4	1.1	21	
AST (U/L)	June 29	1309.9	155.5	7	
	July 6	1173.9	137.1	9	NS
	July 17	1065.5	89.8	21	
Cholesterol	June 29	11.5	0.9	7	
(mmol/L)	July 6	12.7	0.8	9	NS
	July 17	10.4	0.5	20	
Triglycerides	June 29	2.1	0.4	7	
(mmol/L)	July 6	3.2	0.4	9	NS
	July 17	3.0	0.2	20	
Glucose	June 29	7.0	0.5	7	**a**
(mmol/L)	July 6	7.0	0.5	9	**a**
	July 17	5.3	0.3	21	**b**
Sodium	June 29	163.3	2.8	7	
(mmol/L)	July 6	163.3	2.5	9	NS
	July 17	164.9	1.2	20	
Potassium	June 29	3.1	1.3	7	
(mmol/L)	July 6	5.1	1.2	9	NS
	July 17	3.2	0.8	20	
Chloride	June 29	138.0	2.3	7	
(mmol/L)	July 6	134.3	2.1	9	NS
	July 17	135.5	1.4	20	
Calcium	June 29	2.8	0.1	7	**a**
(mmol/L)	July 6	3.2	0.1	9	**b**
	July 17	2.0	0.1	21	**a b**
Phosphorous	June 29	3.4	2.1	7	
(mmol/L)	July 6	3.5	1.9	9	NS
	July 17	4.9	1.3	20	
Magnesium	June 29	1.1	0.1	7	**a**
(mmol/L)	July 6	1.4	0.1	9	**b**
	July 17	1.4	0.0	21	**b**
GSE	June 29	9.5	0.2	7	**a**
(MJ/kg)	July 6	9.4	0.1	9	**a**
	July 17	8.8	0.1	19	**b**

Table 3. Statistical output table for one-way ANOVA with physiological variables vs. time of release. Significance marked in bold.

Physiological Variable	F Ratio	DF	*p value*
Total Protein (g/L)	1.84	2, 34	0.174
AST (U/L)	0.97	2, 34	0.388
Cholesterol (mmol/L)	3.09	2, 33	0.059
Tryglycerides (mmol/L)	2.47	2, 33	0.099
Glucose (mmol/L)	**6.73**	**2, 34**	**0.003**
Sodium (mmol/L)	0.19	2, 33	0.829
Potassium (mmol/L)	0.95	2, 33	0.397
Chloride (mmol/L)	0.72	2, 33	0.496
Calcium (mmol/L)	**3.72**	**2, 34**	**0.035**
Phosphorous (mmol/L)	0.30	2, 33	0.744
Magnesium (mmol/L)	**9.74**	**2, 34**	**< 0.001**
GSE (MJ/kg)	**9.14**	**2, 32**	**< 0.001**

No physiological variable was found to be significantly indicative of fate (Table 4,5).

Table 4. Physiological correlates of migratory fate for Chinook salmon. Means, standard errors, and sample sizes of physiological variables vs. time of release. Results from an ANOVA with a Tukey-Kramer post-hoc test (α = 0.05) are also given; rows with dissimilar letters are significantly different (NS = non significance).

Physiological Variable	Release Date	Mean	S.E.	n	Comments
Total Protein	Did not Spawn	47.1	1.2	17	
(g/L)	Possibly Spawned	45.0	1.3	15	NS
	Spawned	44.0	2.2	5	
AST (U/L)	Did not Spawn	1227.4	98.12	17	
	Possibly Spawned	995.87	104.5	15	NS
	Spawned	1261.4	180.9	5	
Cholesterol	Did not Spawn	11.9	0.6	17	
(mmol/L)	Possibly Spawned	10.4	0.6	15	NS
	Spawned	11.0	1.2	4	
Triglycerides	Did not Spawn	2.9	0.3	17	
(mmol/L)	Possibly Spawned	2.8	0.3	15	NS
	Spawned	2.7	0.6	4	
Glucose	Did not Spawn	6.2	0.4	17	
(mmol/L)	Possibly Spawned	5.9	0.4	15	NS
	Spawned	6.1	0.7	4	
Sodium	Did not Spawn	163.0	1.7	17	
(mmol/L)	Possibly Spawned	163.3	1.8	15	NS
	Spawned	172.3	3.5	4	
Potassium	Did not Spawn	4.7	0.8	17	
(mmol/L)	Possibly Spawned	3.2	0.9	15	NS
	Spawned	0.9	1.7	4	
Chloride	Did not Spawn	134.4	1.5	17	
(mmol/L)	Possibly Spawned	136.1	1.6	15	NS
	Spawned	139.8	3.0	4	
Calcium	Did not Spawn	3.2	0.1	17	
	Possibly Spawned	2.9	0.1	15	NS
	Spawned	3.1	0.1	5	
Phosphorous	Did not Spawn	5.4	1.3	17	
(mmol/L)	Possibly Spawned	3.1	1.4	15	NS
	Spawned	3.6	2.8	4	
Magnesium	Did not Spawn	1.3	0.0	17	
(mmol/L)	Possibly Spawned	1.3	0.0	15	NS
	Spawned	1.3	0.1	5	
GSE	Did not Spawn	9.2	0.1	17	
(MJ/kg)	Possibly Spawned	9.0	0.1	14	NS
	Spawned	9.0	0.3	4	

Table 5. Statistical table of one-way ANOVA with physiological variables vs. spawning fate.

Physiological Variable	F Ratio	DF	*p value*
Total Protein (g/L)	1.13	2, 34	0.335
AST (U/L)	1.57	2, 34	0.222
Cholesterol (mmol/L)	1.56	2, 33	0.226
Tryglycerides (mmol/L)	0.08	2, 33	0.920
Glucose (mmol/L)	0.10	2, 34	0.907
Sodium (mmol/L)	3.10	2, 33	0.059
Potassium (mmol/L)	2.30	2, 33	0.120
Chloride (mmol/L)	1.33	2, 33	0.279
Calcium (mmol/L)	2.61	2, 34	0.088
Phosphorous (mmol/L)	0.74	2, 33	0.485
Magnesium (mmol/L)	0.82	2, 34	0.922
GSE (MJ/kg)	1.16	2, 32	0.327

Migratory behaviour was correlated with a number of physiological variables. Using stepwise linear regression, maximum distance traveled was regressed on the linear combination of calcium and potassium (Table 6). The equation containing these variables accounted for 56 % of the observed variance in maximum distance traveled from release (Table 6). However, when the first release of fish was omitted from the model, a combination of 7 variables (potassium, calcium, glucose, magnesium, sodium, AST, and GSE) accounted for 82 % of the observed variance in the model (Table 7).

Table 6. Summary of the relationship between physiological indicators and maximum migrated distance (forward loading, stepwise linear regression, p to enter equal to 0.250).

Release Date	Parameter	Probability to Enter	Parameter Estimate	R^2	DF	F Ratio	*p* value
Combined	Potassium	0.006	-0.44	0.21	1	13.17	0.001
	Calcium	0.035	-2.64	0.32	1	5.78	0.022
	Full Model			***0.31***	***2, 33***	***7.50***	***0.002***
Release 1 omitted	Potassium	0.011	-0.33	0.23	1	5.65	0.028
	Calcium	0.013	-5.64	0.41	1	13.33	0.002
	Glucose	0.091	0.66	0.48	1	4.23	0.054
	Magnesium	0.182	-7.01	0.52	1	5.13	0.035
	Sodium	0.042	0.30	0.61	1	8.30	0.010
	AST	0.161	0.00	0.65	1	2.56	0.126
	GSE	0.156	1.39	0.68	1	2.18	0.156
	Full Model			**0.68**	**7, 19**	**5.83**	**0.001**

Migratory behaviour was also assessed with respect to the number of fall backs experienced by an individual fish. Using stepwise linear regression, number of fall backs was regressed on the linear combination of triglycerides, calcium, AST, glucose, and phosphorous (Table 7). The equation containing these 5 variables accounted for 59 % of the observed variance.

Table 7. Summary of the relationship between physiological indicators and the number of fallbacks (forward loading, stepwise linear regression, p to enter equal to 0.250).

Parameter	Probability to Enter	Parameter Estimate	R^2	DF	F Ratio	*p* value
Triglycerides	0.049	-0.88	0.12	1	12.69	0.011
Calcium	0.081	2.05	0.21	1	7.32	0.002
AST	0.078	0.00	0.29	1	2.64	0.115
Glucose	0.216	-0.22	0.33	1	2.36	0.135
Phosphorous	0.237	-0.05	0.36	1	1.48	0.233
Full Model			**0.35**	**5, 29**	**3.06**	**0.023**

Sixteen thermal loggers were recovered from tagged fish post-mortem. These loggers contained the ambient water temperatures of the river every 2 hours during each day post-release and allowed us to dissect the thermal history of the tagged fish's upstream migration (Figure 3 and 4). Once thermal logger temperatures are compared to actual in-river temperatures, thermal habitat use and/or use of thermal refuges will be possible.

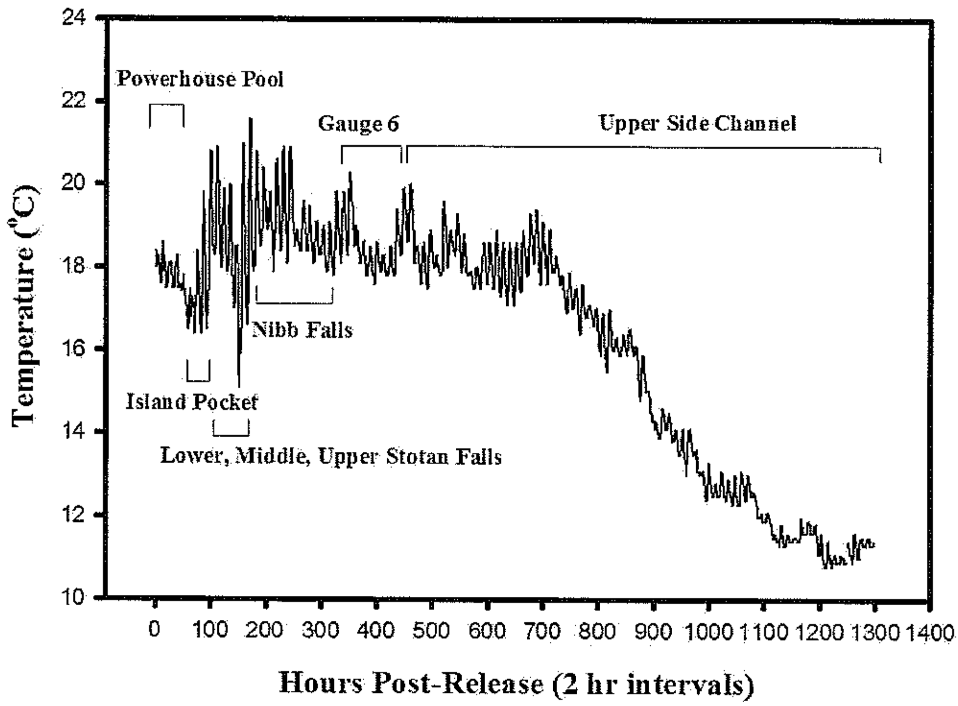

Figure 3. Thermal history of fish "61" with locations based on telemetry data.

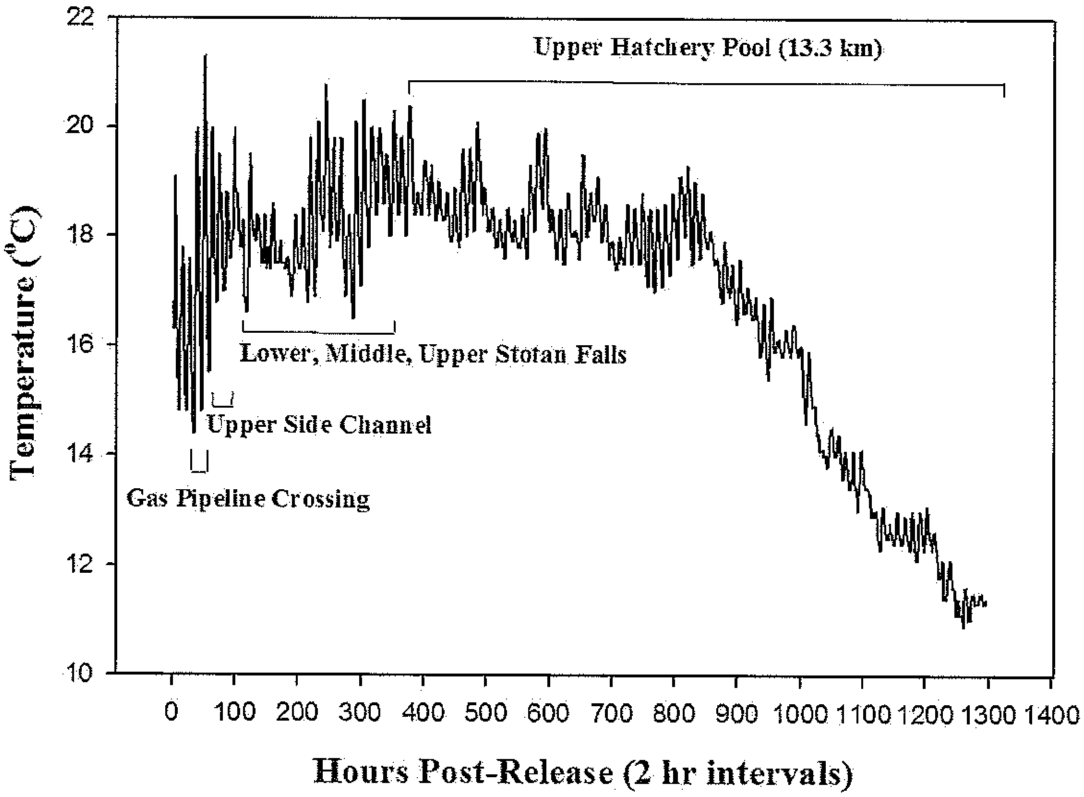

Figure 4. Thermal history of fish "28" with locations based on telemetry data

In previous reports, Stotan Fall has been identified as a key barrier to migration of summer-run Chinook salmon. To assess this, we identified the amount of flow at Stotan flows during time periods when both EMG- and radio-telemetered fish were ascending the falls. We then compared these flow values to a Poisson generated distribution (random) based on flows measured during the time period when fish were ascending Stotan Falls (July 15th to August 10th). Marginally, fish were ascending Stotan at lower flows (11.13 cm/s; S.E. = 0.69; Figure 5) than would be expected if fish were ascending the falls at random (12.25 cm/s; S.E. = 0.37; Figure 5).

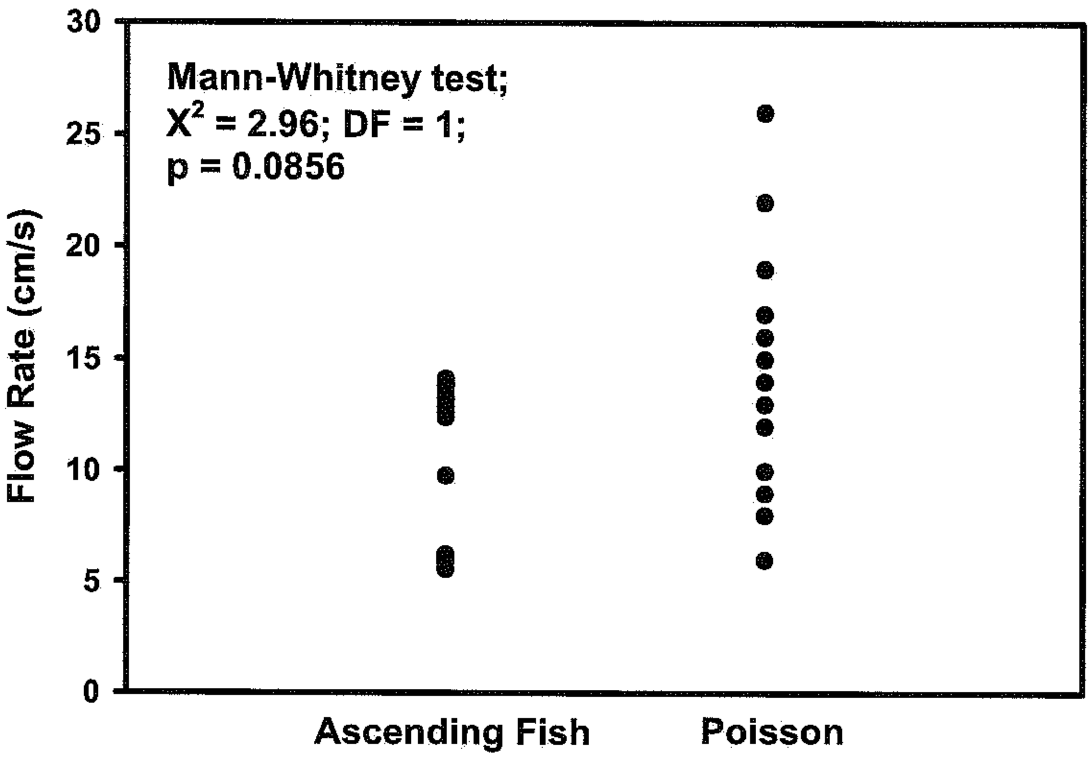

Figure 5. The hourly flow rate (cm/s) measured at Stotan Falls during the time periods when fish were ascending the falls compared to a Poisson generated flow distribution based on the flows measured during periods when fish were ascending (July 15th to August 10th).

Summary of the key additions to the TOR and an evaluation of their success in year 1 with comments on year 2

1. Inclusion of EMG telemetry to assess fine scale energetic and behavioural responses to pulse flows.

We successfully implanted EMG transmitters into 16 chinook salmon. We have developed surgical holding and release strategies to minimize stress and enhance survival. We acknowledge the support provided by the DFO stock enhancement staff at the Puntledge River Hatchery. Data have been incorporated into MS Access and can now be queried to test the core hypotheses and address other questions. Such analyses are ongoing and will be particularly relevant for across-year comparisons.

2. Non lethal biopsy to assess the physiological and energetic condition of fish at time of entry into reach C.

We successfully obtained non-lethal biopsies for all fish (EMG and radio) that were tagged and released in 2007. Blood samples were analyzed for nutritional and stress indicators. We are still awaiting results on several hormones and gill sample analyses (for gill ATPase activity). The data were just recently obtained (assays are time consuming) and analyses continue. We feel that this component of the study is particularly useful as it has the potential to provide information on the "background" condition of fish arriving in the Puntledge River and independent of any hydropower impacts.

3. Use of thermal loggers applied to fish to reconstruct thermal histories of migrants.

We successfully applied thermal loggers to all telemetered fish in 2007. We were able to retrieve a large proportion of loggers and these have yielded individual thermal traces. This information will be useful for future energetics modeling that will incorporate EMG data. We propose to continue with this approach.

4. Use of physiological and energetic information to assess the costs of residency in reach C (from EMG telemetry and recovery and examination of carcasses).

Ongoing – This component of the study is ongoing and will be most relevant to an overall "final" assessment in year 3 where we evaluate the energetic costs of residency in different reaches and relevant to different flow and thermal environments. In year 1 we identified several areas where fish were holding. In year 2, we will use this information to identify additional sites for the deployment of fixed stations.

5. Use of physiological and energetic information to assess passage difficulty at Nibbs and Stotan Falls (from EMG telemetry).

Ongoing – We strategically located telemetry logging receivers at Stotan Falls. By strategically orienting antennas, we will be able to reconstruct the timing of ascent and the relative difficulty/costs. Based on year 1 we will be able to better identify periods for which we can focus on intensive manual tracking.

6. Use of physiological and energetic condition to assist with interpretation of behavioural patterns.

Ongoing – We are conducting exploratory analyses and the data from thermal loggers, EMG transmitters, and physiological assays will collectively be used to understand the patterns of ascent/delay in Reach C.

Revised Schedule

As per the TOR, monitoring will occur in three years over a five year period (year 1 was 2006 and did not include monitoring). Therefore, the proposed field work will occur in year 2 (2007), year 3 (2008) and either year 4 (2009) or 5 (2010) depending on run size strength and guidance from DFO and BC Hydro staff. In total, there will be 3 years of monitoring. Section 2.3 in the TOR describes the general timing for each task. The weekly timing for pulse flow releases during July and August may not be finalized until two weeks prior to the release. Indeed, in 2007, the timing provided was more on the order of days as a result of high water levels. We have communicated with DFO hatchery staff and although the numbers of fish expected in 2008 are not exactly "high" (nor has it been for the last 6+ years), by working closely with hatchery staff and stock assessment biologists, we should be able to obtain adequate numbers of fish. We propose to have our team on the ground even earlier to take advantage of the early timed arrivals. There are no significant deviations in the budget. Although we have several tags that we have recovered and can redeploy, it is our hope to increase the sample size rather than reduce the number of tags purchased in 2008 in an effort to increase statistical power. The only budgetary change is related to inflation. We will continue to operate on a fixed price basis which enables us to allocate resources in a manner to best address project objectives and to reflect the fact that we do not have the capacity to generate regular invoices for specific expenditures.