Puntledge River Radio Telemetry Study on Summer Chinook Migration in the Upper Watershed 2008

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Prepared for:

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EXECUTIVE SUMMARY

In 2005, BC Hydro initiated the Puntledge River Water Use Plan (PUN WUP). One of the key recommendations was the release of 5 pulse flows in Reach C during the months of July and August to improve summer chinook and steelhead migration. In 2007 a WUP radio telemetry study was initiated to assess the benefits of these pulse flows on chinook migration as per the WUP Monitoring Program. This monitoring program, which will extend over three years, is being conducted by a team of DFO staff, private consultants, and the Fish Ecology and Conservation Physiology Laboratory at Carleton University. A complimentary study, funded by BC Hydro's Bridge Coastal Fish and Wildlife Restoration Program (BCRP), also focuses on the migration behaviour of chinook during pulse flows as well as behaviour post-pulse flows, and during the spawning season until late October. The main objective of this secondary telemetry study, which is the focus of this report, is to document the migration behaviour, success and survival to the completion of spawning of Summer-run chinook salmon. Results from both studies will potentially be used to develop a long-term strategy to rebuild the Puntledge Summer-run chinook stock to historical escapement levels.

The BCRP radio telemetry study tracked the movement of radio-tagged adult summer chinook in Reach C, and specifically at two known choke points - Stotan and Nib Falls, and in Reach B (headpond reach). Four groups of chinook were tagged using two types of radio transmitters: three electromyogram (EMG) tagged fish were released in the river at the Lower Puntledge Hatchery on 30June and a further eight on July 7, while 16 conventional radio-tagged fish were released on July 21. These fish were released at the lower Puntledge Hatchery and tracked in Reach C and Reach B using fixed stations and mobile receivers (see Hasler et al. 2009 for more detail). An additional 10 conventionally tagged chinook were tagged and released directly into Comox Lake on July 25. Manual tracking was conducted daily at the commencement of the study (initial tag releases) and at approximately 12 hour intervals between 1July and 3August. The daily tracking interval was gradually increased after 3August. Five 48-hour pulse flows were delivered on July 2-3, July 9-10, July 16-17, July 23-24 and July 30-31.

Overall, the results indicated no statistically significant movement of radio-tagged chinook in response to the pulse flows ($\alpha = 0.05$). Both Stotan and Nib Falls represented a minor obstacle to migration in 2008, compared to other years, with 11% and 19% respectively, of the combined EMG and conventional tagged chinook reaching this area unable to progress further. Fish at Stotan Falls showed more rapid transit and

greater successes in 2008 versus 2007 with a mean time before ascending the falls of 151 hours (95% CI 102.6 – 198.7). However, there was no significant difference in rate of movement between Stotan and Nib Falls in 2008, with a mean delay time of 178 hours (95% CI 112.4 – 244.0) at Nib Falls.

One radio-tagged chinook (EMG) successfully migrated into the Upper Hatchery and was later spawned. Another conventional tagged chinook entered Reach B but did not proceed further into Comox Lake. Nine of the 10 tagged chinook that were released in Comox Lake on July 25 returned to Reach B around the beginning of October. Recovered temperature data from thermal loggers in 3 of these fish indicated a wide range of temperatures encountered, and an overall temperature preference for holding at around 15 ^{o}C.

With the help of snorkel survey counts in Reach C and video surveillance at the diversion dam fishway, the success rate of early migrating summer chinook (not radio-tagged) in reaching the diversion pool/Upper hatchery was estimated at 96% compared to only 26% in the later arriving radio-tagged summer chinook. Commencement of the WUP summer chinook migration study earlier in the season may provide valuable insight into the greater success of early summer chinook migrants.

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1 INTRODUCTION

The migration of adult summer chinook salmon in the Puntledge River was first assessed using radio telemetry in 2002 during the Puntledge Water Use Planning process (PUN WUP). The study examined the migratory response of radio-tagged summer chinook to an experimental pulse flow in Reach C (Komori Wong Environmental and Bigsby 2003). Discharge in Reach C was ramped up from 5.7 m^3/s (200 cfs) to 17.5 m^3/s (610 cfs) between 29 Jul and 2 Aug at a rate of ~ 2.9 m^3/s (100 cfs) every 24 hours. The first year of telemetry results suggested that the pulse flow stimulated migration. Subsequently, the WUP Technical and Consultative Committee (CC) recommended 5 pulse flow releases in the months of July and August for summer run chinook salmon and summer run steelhead trout migration as outlined in the CC report (BC Hydro 2003). As per the recommendations of the PUN WUP CC, several operational changes to BC Hydro's Puntledge Facilities require monitoring to ensure that anticipated benefits are properly documented and that the recommended operational constraints are followed. A WUP study to assess the benefits pulse flows have on the migration of summer chinook and steelhead during July and August was initiated in 2007. This three year study is being conducted by a team of DFO staff, private consultants, and the Fish Ecology and Conservation Physiology Laboratory at Carleton University.

A complimentary study, funded by BC Hydro's Bridge Coastal Fish and Wildlife Restoration Program (BCRP), also focuses on the migration behaviour of chinook during pulse flows as well as behaviour post-pulse flows, and during the spawning season until late October. The main objective of this secondary telemetry study, which is the focus of this report, is to document the migration behaviour, success and survival to the completion of spawning of Summer run chinook salmon. Results from both studies will potentially be used to develop a long-term strategy to rebuild the Puntledge Summer run chinook stock to historical escapement levels. This report summarizes results from 2008.

1.1 Background

Hydroelectric generation on the Puntledge River dating back to 1912, and, more specifically, following expansion of the facilities in the 1950s, changed river discharges in Reach C from a more natural flow regime to a constant regulated flow throughout most of the year (BC Hydro 2003). A decrease in both the average flow and in the variability of flow below the diversion dam, as well as an increase in the rate of flow changes during the summer period has affected the ability of summer chinook to migrate though Reach C, and more specifically, to ascend Stotan and Nib Falls. A historic review of activities on the Puntledge River found that remedial work on these falls began in 1923 and continued sporadically until 1977 (Bengeyfield and McLaren, 1994). The intention of the work was to improve access for summer chinook. These works inadvertently benefited other species previously not capable of ascending these falls. Radio-telemetry studies conducted in the last 5 years indicate that Stotan Falls and to a lesser degree, Nib Falls, combined, may account for as much as 30% in the failure of tagged fish to progress upstream (Taylor and Guimond, 2006). In addition to the obstacles of Stotan and Nib Falls, the diversion dam and impoundment dam further delay migration and further limit the number of summer chinook salmon successfully migrating to the upper watershed.

In 1955, during the first year of operation of the expanded hydro facility, adult summer-run chinook salmon were delayed at the tailrace pool of the powerhouse, a phenomenon not previously recorded during the four decades of operation of the facility by Canadian Collieries (Hourston, 1962). The higher flows through the penstock (1000 m^3/s versus 300 m^3/s prior to expansion), combined with cooler temperatures from the powerhouse and lower flows in the mainstem “diversion” reach (Reach C) inadvertently attracted adult salmon to the tailrace pool. Chinooks that attempted to swim up the tailrace would suffer from exhaustion or serious injury and often died before spawning. Other fish delayed in the tailrace pool became susceptible to poaching and predation. Those fish that managed to reach the spawning grounds were often observed with injuries, and covered in fungus. Currently, the degree to which the Powerhouse tailrace pool continues to delay summer chinook migration in Reach C remains unclear.

The rebuilding of the summer chinook stock to pre-hydro expansion escapement levels has not yet been achieved despite 50 years of efforts. A loss of spring freshet flows, lack of suitable spawning habitat, and either reduced or delayed access to Comox Lake are key Hydro facility ‘footprint impacts’ that have yet to be fully addressed. While present stock and habitat enhancement and rehabilitation projects are making significant progress towards this goal, it is clear that ensuring prompt and unimpeded access for summer chinook to their historical holding and spawning grounds (i.e. headpond and Comox Lake) is most critical to the success of their recovery.

Although significant improvements have been made at the Hydro Diversion and Impoundment Dam fishways, there may always remain a measurable impact on fish migration that can not be fully compensated. The telemetry study will potentially identify other access problems in the river that can compensate for Hydro footprint impacts. For instance, at other areas of concern, such as Stotan and Nibs Falls, access might be improved to partially compensate for delayed access past the Hydro dams and Powerhouse tailrace. It is expected that improved spring and early summer access into the cooler range of temperatures available in Comox Lake, will result in increased survival and spawning success, and therefore result in higher productivity of the stock.

1.2 Goals and Objectives

The objectives of the BCRP radio telemetry study on summer chinook migration in the Puntledge River watershed are threefold:

1) Monitor the movement of adult summer chinook past Stotan and Nib Falls in Reach C. These two obstacles have been identified in past radio telemetry studies on Puntledge summer chinook migration as having significant influence on the success of these fish in reaching the upper river (Taylor and Guimond 2006).
2) Track the movement of radio-tagged summer chinook in the headpond reach and in the Comox Lake tributaries. This will provide information on whether adult chinook are able to access Comox Lake through the sluice gates when lake level and discharge conditions are favourable, and determine if early summer-run chinook adult migrants hold in the cooler depths of Comox Lake during the summer to escape high temperatures prior to fall spawning either in the lake tributaries or below the Comox Dam.
3) A release of a group of up to 10 radio-tagged adult summer chinook into Comox Lake will provide a means of assessing survival of adults holding in the Lake and allow field staff to observe the physical condition of fish that hold in the lake until spawning. It is anticipated that additional fish tagged in the lower river will successfully migrate into the Lake and provide additional information on lake survival.

2 STUDY AREA

The radio telemetry study on summer chinook migration in the Puntledge River watershed tracked the movement of radio-tagged chinook in 3 key reaches as follows:

i. Between the diversion dam and the Powerhouse (Reach C) and more specifically at two known areas of difficult migration in the reach – Stotan and Nib Falls (Figure 1);
ii. Reach B also known as the headpond reach between B.C. Hydro's diversion dam and the Comox Lake impoundment dam (Comox dam);
iii. and in Comox Lake tributaries, specifically the Cruickshank and Upper Puntledge Rivers (Figure 1 inset).

The Puntledge River Watershed encompasses a 600 km^2 area west of the city of Courtenay (Figure 1). The lower Puntledge River flows from Comox Lake in a north-easterly direction for 14 km where it joins with the Tsolum River. From this point downstream the river is called the Courtenay River, which flows for another 2 km into the Strait of Georgia. The Lower Puntledge River is divided into 3 distinct reaches. Reach B, also known as the headpond, is located between the Comox impoundment dam and the diversion dam, approximately 3.7 km downstream. This is a low gradient reach (<0.01%) characterized by deep, slow moving water which is a result of backflooding from the diversion dam. The average channel width is about 60 m and ranges between 35 and 105 m (Bengeyfield and McLaren, 1994). The substrate composition in this reach ranges from mud to large gravel and cobble with a small percentage of boulder. Discharge through the reach is controlled by BC Hydro which normally operates at a target discharge of 33 m^3/s in order to maintain a power output of 24 MW and provide a minimum instream flow of 5.7 m^3/s below the diversion dam. Reach C extends downstream of the diversion dam for 6.5 km to the Powerhouse. It is higher gradient and dominated by smooth bedrock with sections of cobbles and boulders. Two major waterfalls (Nib Falls and Stotan Falls) are located in this reach.

The Cruickshank and Upper Puntledge Rivers are the largest of the Comox Lake tributaries. The Cruickshank River (drainage area = 213 km^2) is a snow-fed system of moderate to high gradient with approximately 30 km of accessible habitat for salmon and trout. The mainstem contains large areas of spawning gravel, particularly in the lower to middle reaches. The Upper Puntledge River (drainage = 92 km^2) is warmer and lower gradient with several small lakes (Willemar and Forbush).

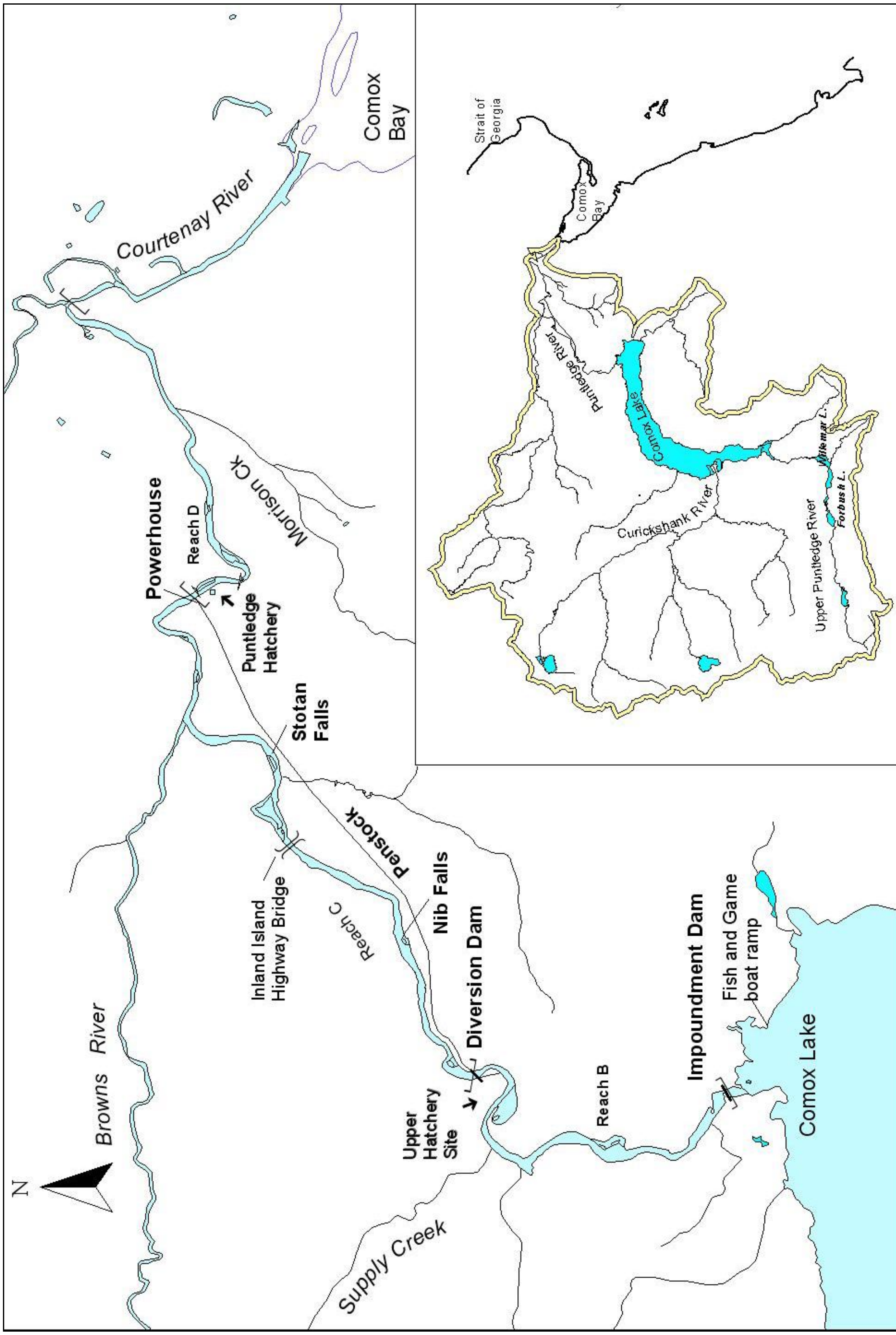


Figure 1. Puntledge River showing major features and areas monitored during the 2007 telemetry study, including Reach C, B and Comox Lake tributaries (inset map).

3 METHODS

3.1 Tagging

Summer chinook arriving at the lower Puntledge hatchery were diverted at the lower fence into hatchery raceways commencing June 4, 2008. Summer chinook arriving before this date were allowed to continue their migration in the river upstream of the barrier fence and were collected at the Upper Hatchery. On June 30 and July 7, three and eight chinook respectively were fitted with electromyogram (EMG) transmitters. These devices provide fine-scale information on fish activity, energetics, and behaviour (Hasler et al. 2008). On July 21, sixteen summer chinook were fitted with conventional Lotek model MCTF-3A radio transmitters. Another 10 chinook were radio-tagged (conventional) on July 25 for release into Comox Lake.

Fish were netted from the hatchery raceway and transferred to a water-filled sampling trough that was continually supplied with freshwater. For fish requiring EMG tags, fish were anaesthetized in clove oil (60 ppm) and then transferred to a surgical table continuously supplied with a maintenance dose of anaesthetic (30 ppm). EMG transmitters were surgically inserted as per the methods described in Hasler et al. (2008). For fish requiring conventional tags, transmitters, coated with vegetable oil, were inserted orally into the stomach of each fish using a hollow plastic applicator.

Fork length and sex of tagged fish was recorded, and all fish were non-invasively biopsied (prior to transmitter insertion). Due to the low numbers of summer chinook and the need to ensure adequate numbers of fish for hatchery production, transmitters were applied to male fish only, since they typically arrive at the hatchery in higher proportion than females. A blood sample (1.5 ml) was collected via caudal puncture from each tagged fish, as well as a small gill biopsy (3 mm off the tips of 5 to 8 filaments; Hasler et al. 2008). A non-invasive fat probe was used to assess energy density (Hasler et al. 2008). All physiological samples were processed and stored in liquid nitrogen until analysis by the University of Carleton team. In addition, all fish carrying radio transmitters (conventional and EMG) had a thermal logger attached to the transmitter to allow reconstruction of the migration history of each fish (i.e., determining if they migrated into Comox Lake).

Fish destined for release into the Puntledge River were transported to a recovery pen located beside the barrier fence fishway at the lower Hatchery. After a brief (2 hour) recovery period in the fishway holding pen, the pen was opened to the river so that tagged chinook could swim out on their own. Fish destined for release into Comox Lake were placed in a transport tank after tagging, then transported to Comox Lake on the same day. The fish were released into the lake adjacent the Courtenay and District Fish and Game Clubhouse, 850 metres from the impoundment dam (Figure 1).

3.2 Tracking

The location (river kilometer) of tagged fish was tracked with a portable Lotek SRX 400A and/or SRX 600 Telemetry Receiver. During each mobile tracking session, technicians travelled along the river and attempted to locate all tagged fish in Reach C and Reach B. In addition, continuous tracking using three multiple antenna fixed telemetry stations (Lotek SRX 600 receivers) covered a large area of the river, particularly the areas upstream and downstream of Stotan and Nib Falls (Hasler et al. 2009). One station was located on a bluff upstream of the powerhouse, one at Stotan Falls (used in 2007), and a third just upstream of mid Nib Falls. The fixed stations operated from July to early August and provided more detailed information on timing of arrival and frequency and timing of attempts to move past these locations.

In Reach C, tracking was conducted twice/day July to early August, and then from 1-3 times/week until the end of spawning (end of October). Recovery of transmitters continued sporadically throughout the winter when conditions permitted. EMG tags ceased transmitting signals around the end of September (90 day battery life), therefore fish/tags could not be located or recovered during the spawning period. In Reach B, tracking was less frequent, but usually occurred on a weekly basis from early August until the end of October. Surveys in the upper watershed (Cruickshank and Upper Puntledge rivers) were considered unnecessary when 9 of the 10 radio-tagged fish released in Comox Lake returned to Reach B in early October.

In addition, technicians were stationed at the fish ladders in Stotan and Nib Falls, periodically observing adults migrating up the ladders and recording leap attempts, success, and migration routes. These two activities (tracking and visual monitoring) were supplemented with snorkel surveys in the river, particularly at locations of difficult passage (in pools directly below Stotan and Nib Falls). Snorkel counts (and associated costs) were completed under the WUP Steelhead Production monitoring program.[1] The distribution and relative abundance of tagged and untagged fish was documented during snorkel counts. This information was used to support results from the telemetry study and also provided immediate information on numbers of fish congregating below the fish ladders in order to schedule visual monitoring events. Snorkel counts were conducted July 8, 11, 29 and Aug 1.

3.3 Communications

A Communications Plan conducted by staff of Comox Valley Project Watershed Society informed the public about the Puntledge River Summer Chinook Radio Telemetry Study through notices in local newspapers, an article in the *Watershed News,* displays, and a guided tour during BC Rivers Day (Appendix C). More detailed reporting of the Community Outreach Program associated with this and three other BCRP projects in the Puntledge River watershed is summarized in a separate report.

4 RESULTS AND DISCUSSION

4.1 Movement of fish in Reach C

The delivery of pulse flows in 2008 differed slightly from that outlined in the PUN WUP Monitoring Program Terms of Reference, due to a requirement for BC Hydro to spill water into early summer. Five weekly 48 hr pulse flows were delivered in July and all but the first pulse flow (July 2-3) were between 12 – 14 m^3/s, whereas the first pulse was 29 – 62 m^3/s (Figure 2). Also, the Water License (WL) requirement that the pulse flow be greater than the powerhouse discharge was not met in 3 of the 5 pulse flow events. This requirement is to provide greater attraction flow through Reach C compared to the tailrace discharge, for fish holding in the powerhouse pool. During these 3 WL

[1] Snorkel counts for the steelhead stock assessment under the WUP Steelhead Production monitoring program, were being conducted at the same time as the summer pulse flows, therefore costs for snorkel counts were covered under the Steelhead Production monitoring program and data was provided to the Telemetry study crew.

violations, tailrace discharge exceeded discharge in Reach C. Notwithstanding these variations, pulse flows did not stimulate fish movement (Hasler et al. 2009).

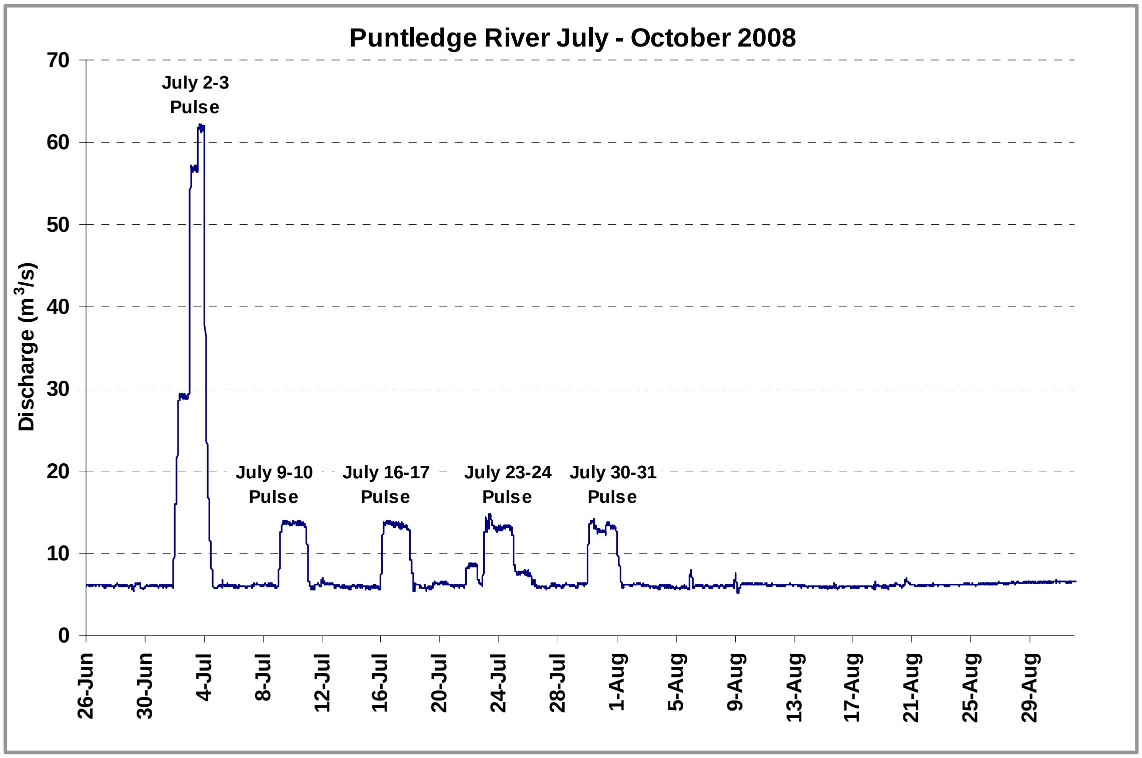


Figure 2. Discharge for the Puntledge River (15 min intervals) at Gauge 6 below the diversion dam (WSC Gauge No. 08HB084). Pulse flows are indicated.

Within 9 days of tagging fish with conventional tags (21 July) 7 fish had dropped downstream below the barrier fence, and only one of these fish resumed its upstream migration and successfully reached the diversion dam pool. Conversely, none of the EMG tagged chinook dropped below the barrier fence after release in the river, despite the greater stress imposed on the EMG fish (surgical implanting of tags) versus the conventional tagged fish (oesophageal insertion). Handling of the fish at the higher temperatures was likely accountable for the fall-back of fish in the conventional tagged group. Fish tagged at the higher water temperatures also exhibited indicators of stress in their plasma (Hasler et al. 2009). Mean and max temperatures recorded in the river at the barrier fence during the conventional tagging in 2008 were 18.9 ^{o}C and 19.5 ^{o}C (Figure 3) compared to 17.5 ^{o}C and 17.9 ^{o}C in 2007.

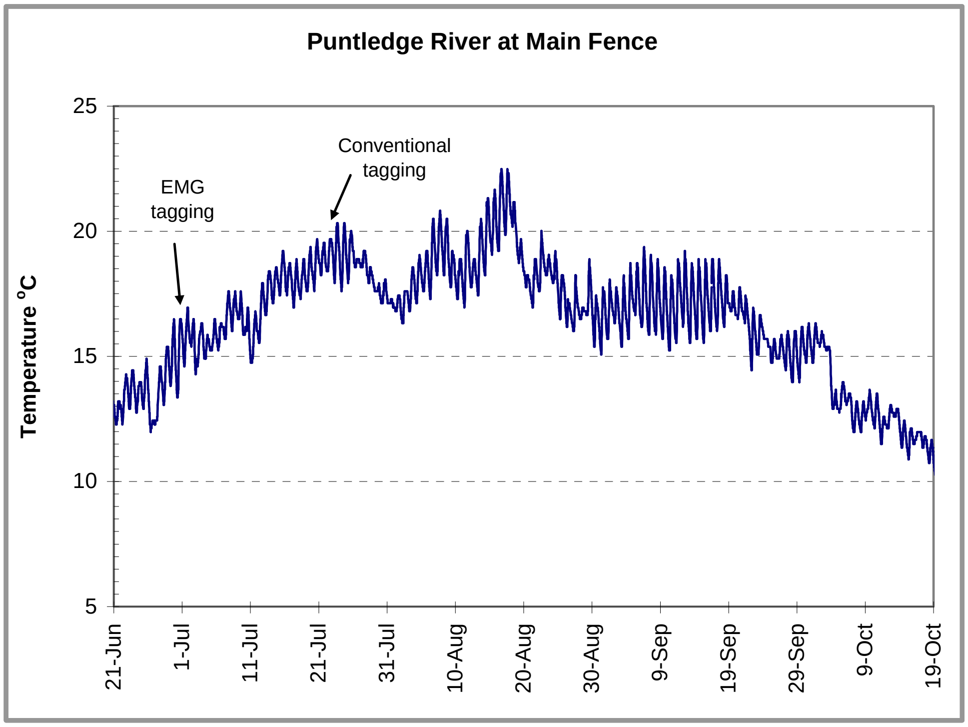


Figure 3. Puntledge River temperature (15 min intervals) recorded at the barrier fence at the Lower Puntledge Hatchery using Onset Tidbit temperature loggers.

Results provided by the fixed station receivers located at the Stotan and Nib Falls areas enabled time of passage through the falls to be more accurately assessed in comparison with mobile tracking sessions. These data records were made available by researchers from the Fish Ecology and Conservation Physiology Laboratory at Carleton University, who are conducting a concurrent program under the Puntledge River Water Use Plan (PUN WUP).

Fixed station signal power levels recorded from the radio tags at short time intervals were graphed to illustrate migration patterns at each site and used to assess time of movement to and above the falls. Although three antennae were installed for each receiver, the pattern of signal reception was very similar from each and the upstream facing antenna generally provided sufficient information to construct movement patterns: information from the other antennae as well as data from additional fixed tracking sites (Pipeline and Bluff) was used to confirm time of arrival and movement from the falls, if required. Examples of the migration graphs are shown in Figure 4. The first (top) of these shows Tag 135 arriving at Stotan around mid-day on 27 July and completing

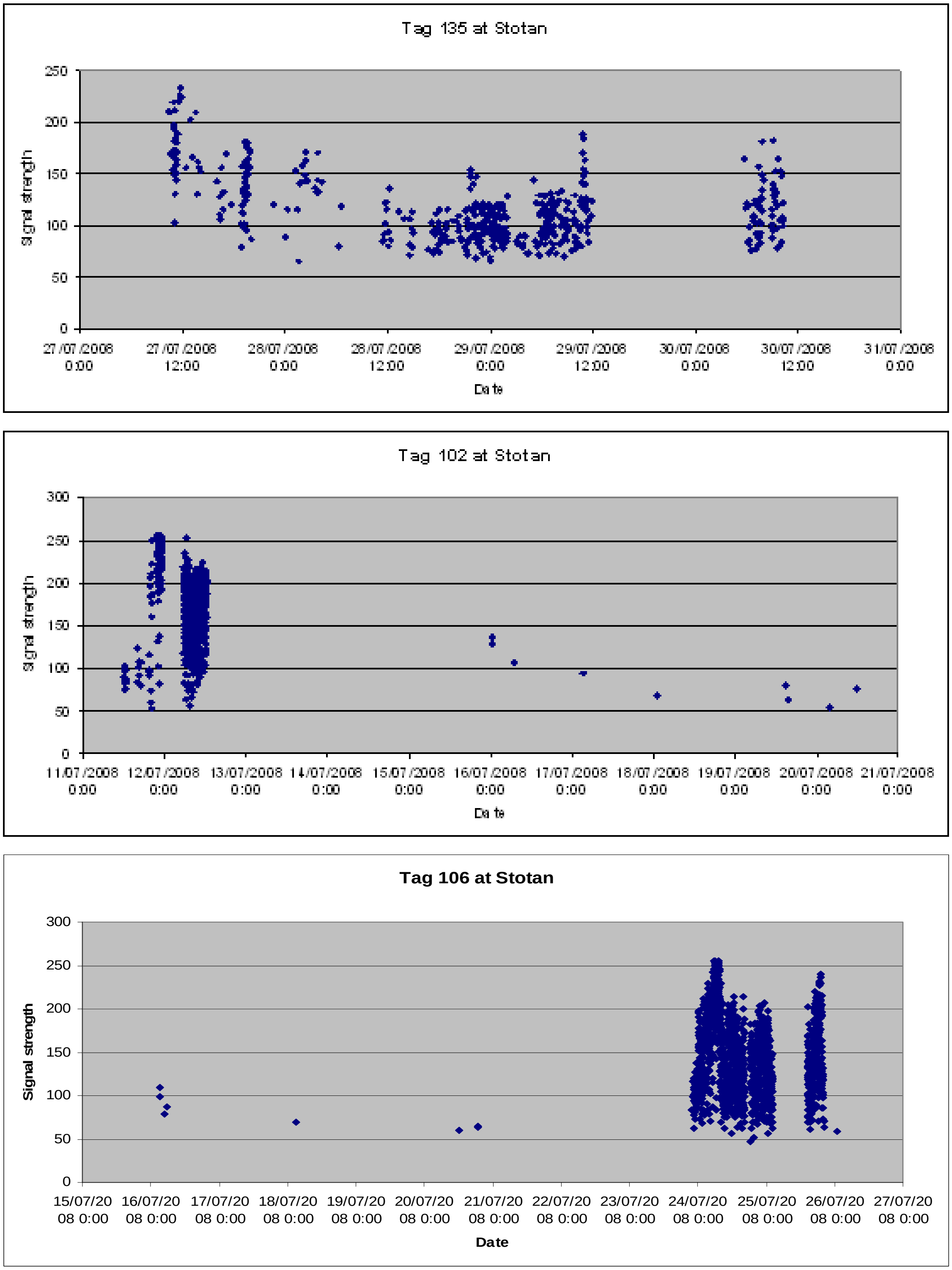


Figure 4. Examples of patterns of movement recorded by the Stotan Fixed Station receiver.

passage through the falls three days later on 30 July. This pattern tended to be typical of most tags. The second graph (middle) shows Tag 102 nearing the falls on 11 July around noon and quickly passing upstream by noon on the following day. The additional single records were gauged to be reflective signals and disregarded with respect to passage time, which was recorded as 24.5 hours. Finally, Tag 106 (bottom) came into range of the receiver on 16 July but was not judged to be making a concerted attempt to move upstream until the main body of the record in late evening of 23 July. Passage was completed shortly after on 26 July just after midnight.

Unfortunately, not all the tag records were clear-cut. Tag 26 was found to have been generated only one specific record at 4:11 pm on 24 July. Tag 134 was not recorded passing through Stotan Falls by the fixed receiver and found only on one date at this location by mobile tracking. Similarly, tags 132, 135 and 136 were not picked up by the Nib Falls fixed receiver: this receiver may have been non- operational or dismantled during the period that they attempted to move past Nib. Additionally, Tag 20 attempted to negotiate Stotan Falls around 23 July and failed to progress. Subsequently, it did reach 11.7 km up river on 19 August but was not tracked by the fixed receiver as it passed through Stotan, nor by the fixed receiver at Nib falls upon arrival. For this tag, the initial continuous record from the Stotan fixed receiver was used for the survival analyses: data from the second successful attempt was not available even from the mobile tracking series and could not be included. In the cases of Tags 132, 135 and 136 the less precise mobile tracking data was substituted since a continuous record was not available. For very short passage times encountered with Tags 26 and 134, where only one mobile location record was available, a nominal timing value of 24 hours was used in the survival analyses.

In 2007, a total of 38 chinook, implanted with EMG and conventional tags, were tracked in the Puntledge River (Guimond and Taylor 2008). Combined, 22% of these fish failed to reach Stotan Falls, the first major area of passage difficulty in the river. Subsequently, 23% of all tagged chinook failed to successfully negotiate Stotan Falls. Similarly, 22% of chinook did not progress over the second major choke point, Nib Falls. The probability quantiles for the progress of fish over the falls indicated that a quarter of migrants required 96 hours or less to ascend Stotan, while at the other extreme, 25% of fish needed 336 hours (Table 1). At Nib Falls, the delay was shorter with one in four fish moving through in 24 hours and half of those reaching the falls continuing upstream within 48 hours.

In contrast, of 27 tagged chinook released in 2008, only 19 fish reached Stotan (30% failure rate in the lower river). However, further progress was remarkably improved at this site with only 11% failing to move past the falls: one of these fish was tracked to 9.6 km, representing the top of the Stotan area but then returned downstream and was considered not to have successfully migrated through the site. Three of the chinook that moved above Stotan did not reach Nib Falls, but 13 of the other 16 were successful in continuing their migration beyond this point (19% failure rate).

Table 1. Probability quantiles of the length of time (hrs) that chinook were delayed in ascending Stotan and Nib Falls in 2007.

	STOTAN			NIB		
Probability	Delay Time	95.0% Confidence Interval		Delay Time	95.0% Confidence Interval	
		Lower	Upper		Lower	Upper
0.25	96	48	168	24	24	48
0.50	240	120	336	48	24	96
0.75	336	264	960	120	72	-

Rate of movement was much greater at Stotan than in the previous year with a mean time before ascending the falls of 151 hours (95% confidence interval 102.6 – 198.7) only half of the mean of 312 hours recorded in 2007. A delay of only 28 hours was recorded for the fastest 25% of migrants and a median delay of 154 hours in 2008 was observed versus 240 hours in the previous year (Table 2).

Table 2. Probability quantiles of the length delay (hrs) experienced by chinook in ascending Stotan and Nib Falls in 2008.

	STOTAN			NIB		
Probability	Delay Time	95.0% Confidence Interval		Delay Time	95.0% Confidence Interval	
		Lower	Upper		Lower	Upper
0.25	28	23	119	39	12	145
0.50	154	28	227	145	39	288
0.75	238	154	323	288	145	-

The situation was reversed at Nib Falls, where the greater success rate in 2008 did not translate into faster ascension times. The mean delay was 269 hours on average in 2007, but this was substantially influenced by an outlier of 1008 hours. In 2008, the mean was 178 hours (95% confidence interval 112.4 – 244.0) and the quantiles of passage indicate that 25% of the fish required 39 hours to ascend compared with only 24 hours in 2007. Similarly, the slowest 25% needed 145 hours or more versus 120 hours in the previous year (Table 2).

A more detailed look at the progress of tagged fish through the Falls areas is available using the Nelson-Aalen (N-A) estimator of cumulative hazard (Table 3). This accounts for the increasing difficulty of successfully moving upstream as time below the falls increases and is tracked as each individual successfully ascends: censored (unsuccessful) fish are incorporated into the calculation of difficulty.

Table 3. Nelson-Aalen estimates of cumulative hazard for chinook migration past Stotan and Nib falls in 2008.

Fish below Stotan	Number passing upstream	Time (hrs)	N-A Cumulative Successes	Standard Error	95.0% Confidence Interval	
					Lower	Upper
19	1	22.5	0.05	0.05	0.00	0.16
18	1	24.0	0.11	0.08	0.00	0.26
16	1	24.5	0.17	0.10	0.00	0.36
15	1	25.5	0.24	0.12	0.00	0.47
14	1	28.4	0.31	0.14	0.04	0.58
13	1	30.4	0.39	0.16	0.07	0.70
12	1	71.9	0.47	0.18	0.12	0.82
11	1	92.6	0.56	0.20	0.17	0.95
10	1	118.7	0.66	0.23	0.22	1.10
8	1	153.9	0.79	0.26	0.28	1.29
7	1	203.6	0.93	0.29	0.35	1.50
6	1	211.0	1.09	0.34	0.43	1.76
5	1	227.1	1.29	0.39	0.53	2.06
4	1	237.9	1.54	0.47	0.63	2.46
3	1	296.1	1.88	0.57	0.76	3.00
2	1	323.0	2.38	0.76	0.89	3.87
1	1	354.7	3.38	1.26	0.92	5.84
Fish below Nib	**Number passing upstream**	**Time (hrs)**	**N-A Cumulative Successes**	**Standard Error**	**95.0% Confidence Interval**	
					Lower	**Upper**
16	1	12.0	0.06	0.06	0.00	0.19
15	1	20.8	0.13	0.09	0.00	0.31
14	1	25.7	0.20	0.12	0.00	0.43
13	1	39.2	0.28	0.14	0.01	0.55
12	1	72.0	0.36	0.16	0.04	0.68
10	1	84.6	0.46	0.19	0.09	0.83
9	1	118.5	0.57	0.22	0.14	1.00
8	1	145.1	0.70	0.25	0.20	1.19
5	1	250.3	0.90	0.32	0.26	1.53
4	1	265.5	1.15	0.41	0.35	1.95
3	1	288.0	1.48	0.53	0.45	2.51
2	1	304.5	1.98	0.73	0.56	3.40
1	1	384.2	2.98	1.24	0.56	5.40

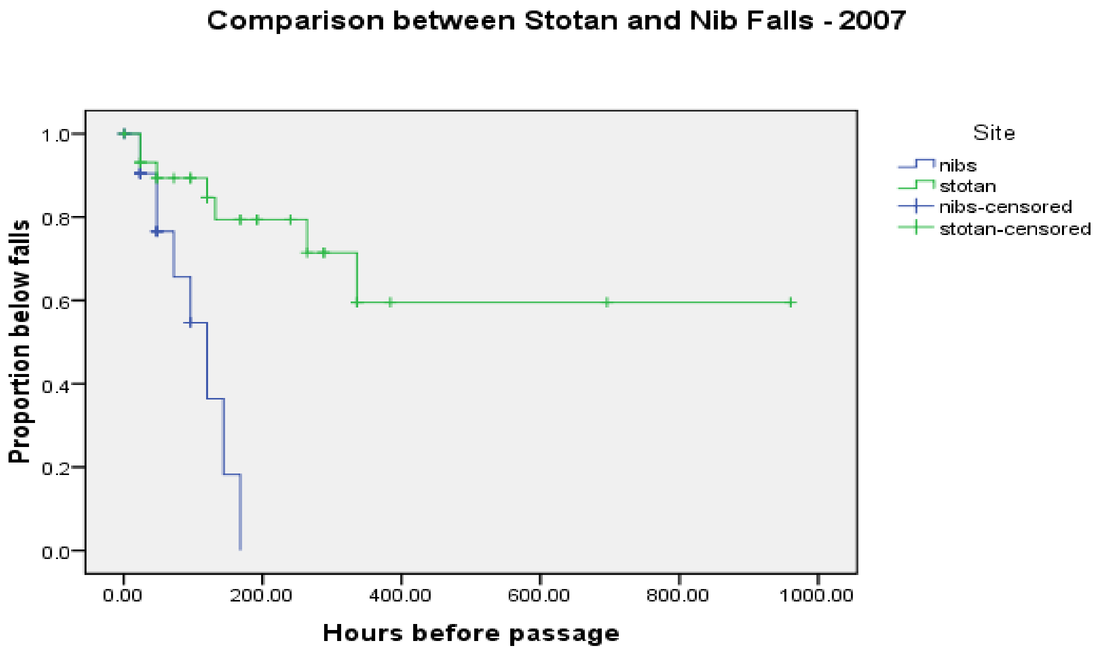
Comparing the proportion of successes for a given number of hours below the falls in these tables, we can see that passage rate was faster at Stotan than Nibs in agreement with the quantiles presented in Table 2. The following section provides a test of this comparison.

4.2 Statistical comparisons between sites, years and tag types

We combined the data sets from 2007 and 2008 to enables comparisons between the two sites as well as years of the study using the Kaplan-Meier (K-M) probability estimator (Kaplan and Meier 1958). The data used to construct survival curves are provided in Appendix D, along with the mean and median statistics for the two river sites organized by year and tag type. The survival trends are illustrated in plots of the Kaplan-Meier probability estimates of time before passage delay experienced by fish moving through the Stotan and Nib choke points. Comparisons were based on the Breslow test statistic, a generalized form of the Wilcoxon test (Gehan 1965).

The pattern of migration success at Stotan versus Nib falls in 2007 was clearly different, (Figure 5) with upstream passage at Nib Falls initiated more rapidly, and with greater successes (fewer censored data). The distribution of K-M probabilities was significantly different in this year (Breslow chi square value = 5.33, p = 0.02).

In 2008, probabilities of successful passage were very similar at both sites and the plots show parallel migration trends. There was no significant difference between the sites in this year (Breslow chi square value = 0.26, p = 0.61). The specific parameters of the estimates for both sites are provided in Table 4.



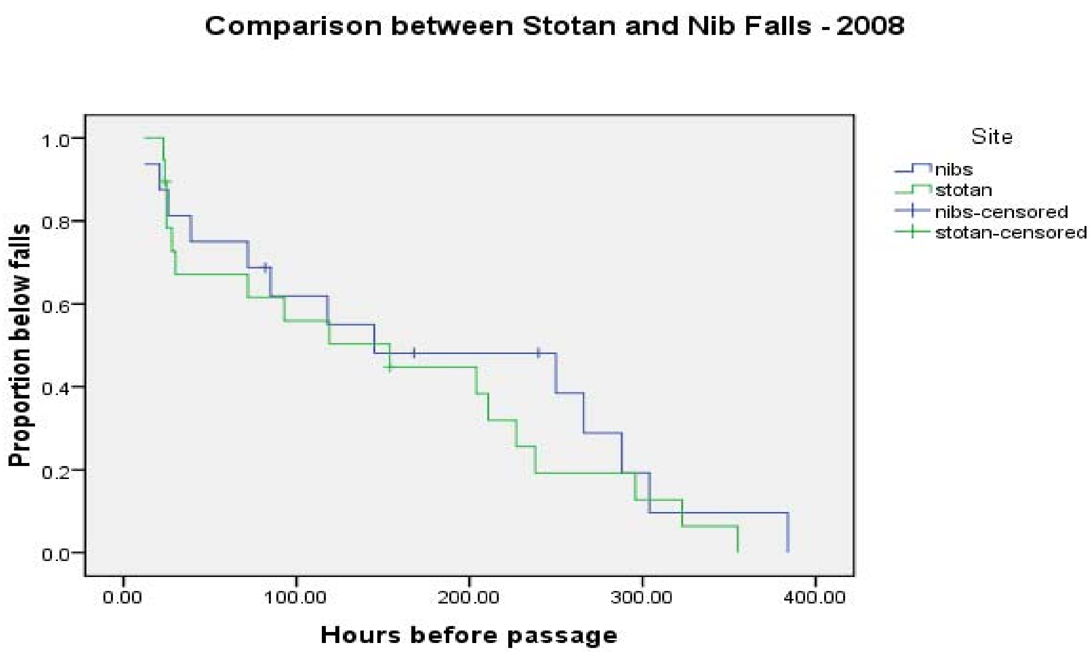


Figure 5. Kaplan-Meier probability plots of time before passage through Stotan and Nib Falls comparing timing of successful passage at the two sites in 2007 and 2008.

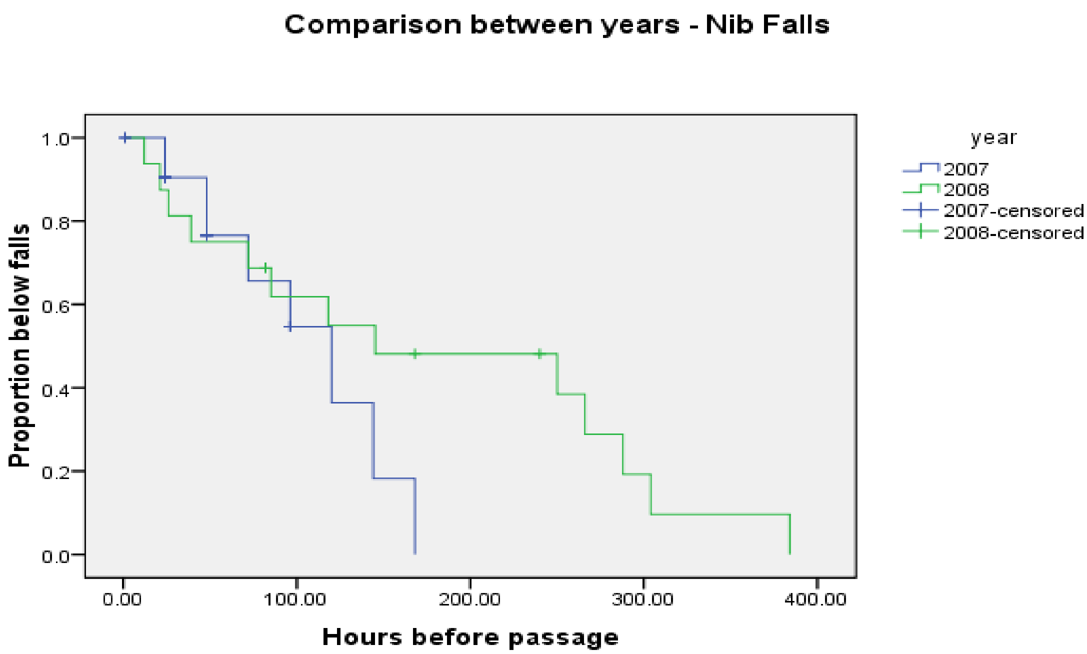
Table 4. Means and medians for time before passage

Year	Site	Mean[a]				Median			
		Estimate	Std. Error	95% Confidence Interval		Estimate	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound			Lower Bound	Upper Bound
2007	Nibs	106.1	14.5	77.6	134.6	120	29.6	62.1	177.9
	Stotan	648.6	101.0	450.7	846.5	.	.	.	.
	Overall	512.3	86.9	341.9	682.6	336	130.2	80.8	591.2
2008	Nibs	178.2	33.5	112.4	243.9	145	102.8	0.0	346.4
	Stotan	151.5	27.8	97.1	205.9	154	64.0	28.7	279.3
	Overall	164.1	21.2	122.5	205.8	145	58.0	31.3	258.7
Overall	Overall	280.7	45.9	190.7	370.7	211	50.3	112.5	309.5

a. Estimation is limited to the largest survival time if it is censored.

Comparisons between the two sites over the two years of the study for both tag types are illustrated in Figure 6 with parameter estimates given in Appendix D. At Nib Falls, early successes were associated with similar probability levels in both years, with greater divergence as the delay time for some fish increased in 2008 (Figure 6). However, this was not sufficient to create a significant difference between the distributions (Breslow chi square value = 0.054, p = 0.82). The situation at Stotan Falls is clearly different between the years, showing more rapid transit and greater successes in 2008 versus 2007. The distributions here were significantly different (Breslow chi square value = 9.56 p = 0.002).

Finally we examined the progress of the two tag types, using combined data over the two study years. The plots of time before passage are shown in Figure 7 and means and medians are provided in Appendix D. Neither Stotan nor Nib provided a differential degree of difficulty to EMG versus conventional radio tags (Stotan Breslow chi square value = 0.68 p = 0.41, Nib Breslow chi square value = 0.03 p = 0.86). Consequently, inferences drawn from the EMG tagging program regarding migration success and timing through the choke points of Stotan and Nib Falls can be reliably extrapolated to, at least, conventionally tagged chinook, if not the wider population of summer escapement.



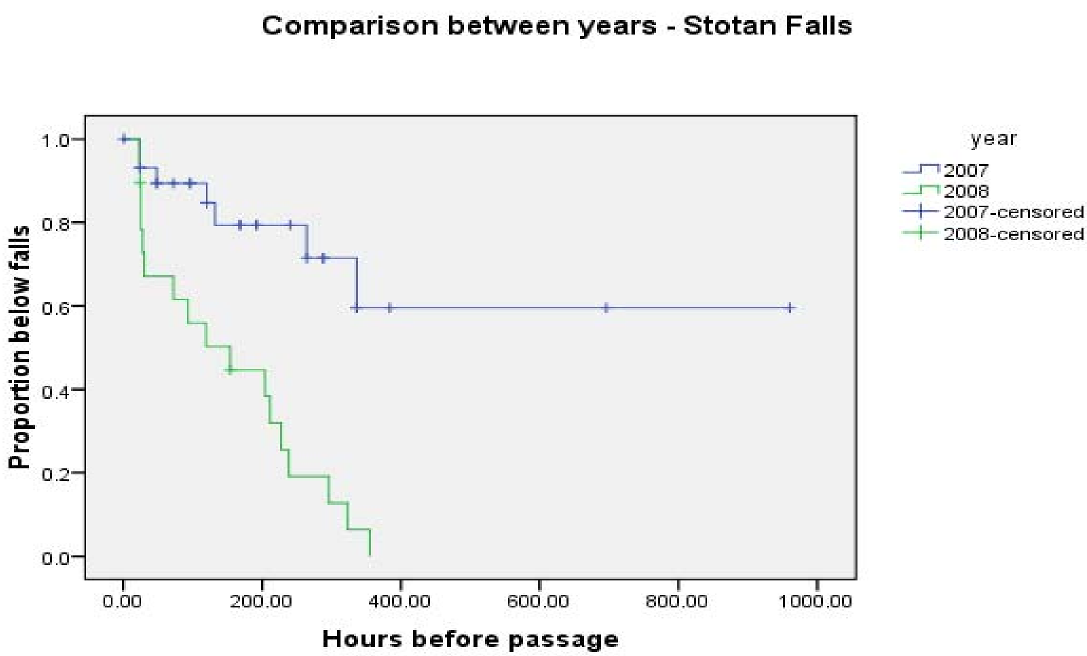
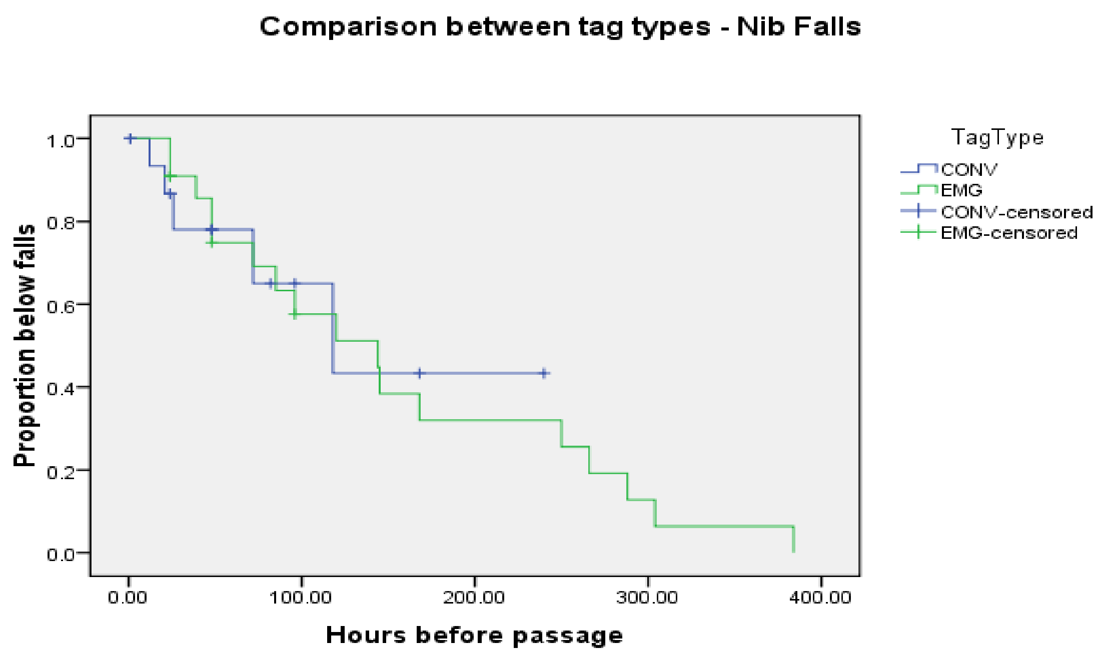


Figure 6. Kaplan-Meier probability plots of time before passage through Stotan and Nib Falls comparing timing of successes in 2007 versus 2008.



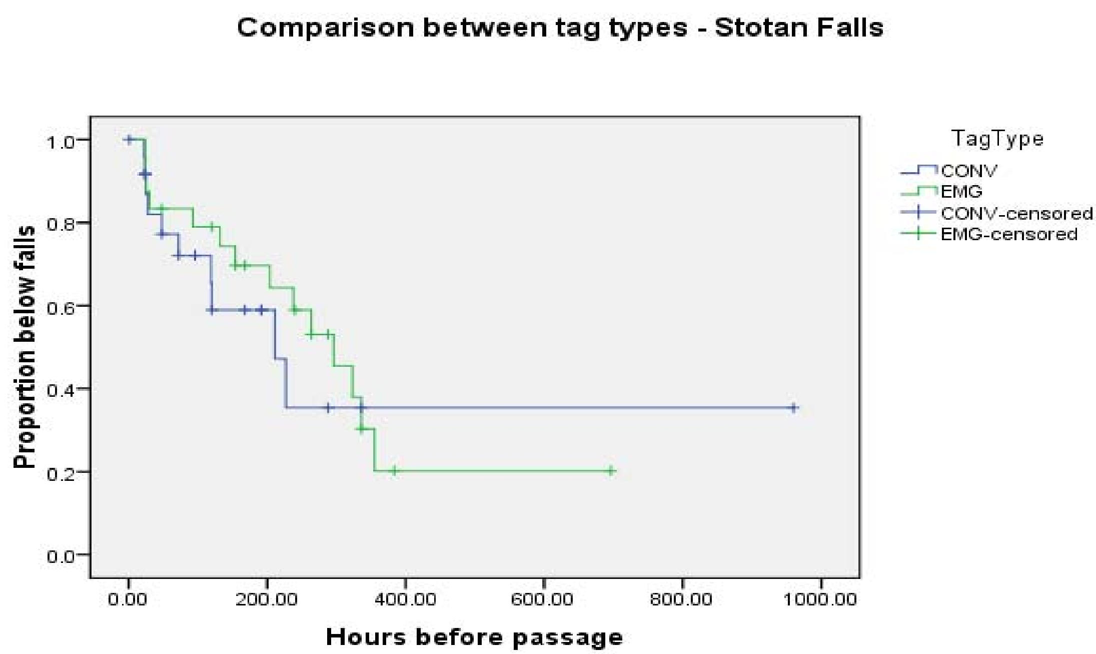


Figure 7. Kaplan-Meier probability plot of time before passage through Stotan and Nib Falls illustrating similarity in timing of successes between EMG and conventional tag types at both sites.

In earlier studies on the Puntledge River, Stotan and Nib Falls areas were identified as similar in degree of difficulty to passage of chinook, and it was found that many of the tagged fish were unable to progress upstream past these points (e.g. Taylor and Guimond 2004 and Taylor and Guimond 2005). On average, over the 2003 to 2008 programs, 19% of chinook that reached Nib Falls failed to migrate further, compared to 17% at Stotan. However, it appears that Stotan Falls has greater associated variability in terms of impediment to migration success expressed through the delay experienced by fish in migrating through the area. In 2008 Stotan closely resembled Nib Falls, unlike in the previous year (Figure 5). The difference may be due to physiological condition of the fish or in physical parameters such as river temperature. The results of the 2007 EMG radio-tagging program (Hasler et al. 2008) suggest that condition upon entry into the Puntledge River influences migratory behaviour. In 2008 (Hasler et al. 2009), high temperatures appeared to affect physiological variables in chinook; fish were in poorer condition with respect to levels of sodium and chloride in blood plasma on the third sampling day. In the first study, the maximum distance traveled upstream by individual fish was influenced by a combination of calcium and potassium. Subsequently, no statistical relationships could be derived to explain the degree of variation in maximum distance achieved upstream during 2008, although some relationships between physiological condition and fate were found. It is hoped that additional data gathered on temperature will add to our understanding of these areas, through future energetics modeling that will incorporate EMG data to provide reach, flow and temperature specific estimates of energy expenditure.

4.3 Observations of non-tagged chinook migration

There is speculation that early migrating chinook (i.e. adults that arrive in the river between early May and late June) have a greater success of migrating through Reach C and negotiating the Stotan and Nib falls areas compared to later migrants (i.e. adults arriving in the month of July. Due to design flaws, these 'early' fish can potentially bypass the barrier fence at the lower hatchery during high river flows (flows likely exceeding 75-80 cms at Gauge 8). In 2008, early summer chinook migrants were observed entering the mouth of the Puntledge River (at the 5th Street bridge) on a DIDSON sonar imaging unit, around May 18. River discharge (Gauge 8) exceeded 80 cms on several days between May 24 and June 1, and again for a brief period on June 21-22 and July 2-3. Since the barrier fence was closed to migration on June 4th, we can assume that the majority of non radio-tagged chinook in Reach C counted during snorkel surveys in Reach C (Table 5) had arrived before this date, although some fish may have also bypassed the barrier fence during the last spill on June 21 and 22 and during an abnormal pulse flow release on Jul 2 and 3.

On the final snorkel survey date (Aug 1) a total of 162 chinook were counted between the powerhouse pool and the diversion dam (i.e. Reach C) plus there were 86 untagged chinook that had entered the Upper Puntledge Hatchery. If the number of radio-tagged chinook in this reach is subtracted from the in-river and hatchery counts, because these fish were released into the system later in the summer, the total estimate of early summer chinook migrants in Reach C on Aug 1st was 142. Therefore, the total number of early migrants that were above the lower fence is 228 (i.e. the addition of the 86 untagged chinook at the Upper Hatchery plus the 142 in the river). Of this total, 218 of these fish or 96% were either holding in the diversion pool or were already captured at the Upper Hatchery suggesting that early migrating chinook (i.e. summer chinook that enter Reach C prior to July 4th) have a high success rate migrating above Stotan and Nibs Falls. Most of these fish appear to have reached the upper section of Reach C before river temperatures and recreational activity increased (Table 5).

Table 5. Number of chinook counted at three locations in the Puntledge River during four separate snorkel surveys conducted during the 2008 WUP Steelhead Production monitoring program.

Location of snorkel count	8-Jul	11-Jul	29-Jul	1-Aug
Diversion Dam pool (13.3 km)	65	69	130	135 [b]
Diversion to Stotan (13.2 – 9.7 km)	66	64	44	14
Upper Stotan Falls (9.6 km)	50	7	0	7
Mid Stotan Falls (9.4 km)	2	2	0	0
Stotan to Powerhouse (9.3 – 6.9 km)	5	9	1	1
Powerhouse pool (6.8 km)	5	2	2	5
Total Snorkel Count	**193**	**153**	**177**	**162**
Radio-tagged fish in Reach C (6.8-13.3 km) [a]	10	11	21	20
Total Count (Untagged)	**183**	**142**	**156**	**142**
Number of CN that accessed Upper Hatchery	8			86
Total Count (early migrants)	**191**			**228**

[a] Radio-tagged fish may or may not have been observed by snorkelers
[b] 3 of the fish observed were radio-tagged

Radio-tagged fish released into the lower Puntledge between June 30 and July 21 had a success rate of only 26% (7 of 27 radio-tagged fish) reaching the diversion pool or Upper Hatchery. Using a similar evaluation for non radio-tagged early adult migrants, the peak swim counts and Upper Hatchery captures on July 8th and Aug 1st were compared to determine the success rate of adult migration to the top of Reach C between the two dates (it was assumed that Reach C was a closed system during this period). There were a combined total of 191 early chinook in the river and in the Upper Hatchery on July 8th. On Aug 1st there were a total of 228 fish. Based on this comparison, the migration success rate between the two dates (ie. 228/191) exceeds 100% suggesting that, although visibility during swim counts was between 8-11 meters on Jul 8 and Aug 1, and the effort was similar, swim count accuracy was not the same. This may be related to differences in adult distribution or migration activity. However, in spite of this discrepancy, chinook arriving at the Lower Hatchery in June appear to have a significantly higher success rate migrating up to the diversion pool than chinook arriving in July.

The influence of tagging and handling on the behaviour and migration success of tagged fish has not been factored into the above estimate, but should be further investigated. From our experience in 2008, it is clear that handling fish at high river temperatures can have an adverse effect on their ability to resume migration once returned to the river. Overall, only ~50% of the radio-tagged fish released at the Lower Hatchery successfully reached the diversion dam pool / Upper hatchery based on the earlier results of 5 years of telemetry studies (2002 – 2007).

A modification to the WUP Migration Study Terms of Reference has been proposed to examine the migration rate of a group of early summer chinook migrants in 2009 (fish that arrive at the barrier fence by late May/early June). The barrier fence will be modified to prevent these early fish from accessing the river upstream during freshet and kayak pulse flows, and allow collection of chinook at the Lower Hatchery. Tagging of an early group of summer chinook will provide an excellent opportunity to compare physiological condition, migration behaviour, fate and thermal biology compared to the later fish at warmer temperatures. It is also expected that surgical and handling stress on the fish will be lower earlier in the season. The information gained form this study will be extremely useful in developing and evaluating future summer chinook conservation strategies.

4.4 Movement of fish in Reach B

Only 1 radio-tagged chinook released at the Lower Puntledge Hatchery successfully migrated into the headpond, just prior to the spawning period. Tag #15 (conventional tag) had been holding in the diversion pool since July 29 until its signal was lost on Sept 26. It was confirmed in Reach B at the spawning platform on Oct 7. Chinook access into the headpond was closed for much of the summer to allow Puntledge Hatchery to collect early summer chinook migrants at the Upper Hatchery. As many as 6 tagged chinook (3 EMG and 3 Conv.) were recorded in the diversion pool during this closure, and one fish entered the Upper Hatchery on July 31. Once access into the headpond was opened on August 22, approximately 65 chinook, in addition to the one radio-tagged fish, were counted passing through the fishway at the diversion dam.

4.5 Movement of fish released into Comox Lake

Of the 10 tagged chinook that were released directly into Comox Lake on July 25, all fish remained in the lake until the onset of spawning (early October). Manual tracking on Oct 01 located 2 radio-tagged fish in the Comox Dam tailrace, while a survey on Oct 07 located 7 more fish, two of which had dropped below the diversion dam. One week later, only two of the radio-tagged "lake" fish remained in Reach B at the new spawning platform. The tenth fish may have survived also, and migrated up into the Cruickshank or Upper Puntledge river systems, but a tracking survey to verify this was not attempted.

Recovered temperature data from 3 of the 10 thermal loggers in chinook that were transported to Comox Lake indicates that fish encountered a wide range of water temperatures, likely corresponding to a range of water depths the fish occupied in the lake (Figure 8). Although the preferred holding temperature was ~15 ^{o}C, temperatures ranged from 8.5 – 19 ^{o}C. For example, Fish #122 held for extended periods at ~10 ^{o}C compared to Fish #124 which was recorded only sporadically at this temperature, and Fish #120 did not encounter temperatures below 11.8 ^{o}C. Based on a temperature profile of Comox Lake completed by the provincial Ministry of Environment on August 9, 2007, the temperature range recorded by fish in 2008 roughly corresponds to a depth of about 8-30 m depending on location within the lake basin (Figure 9).

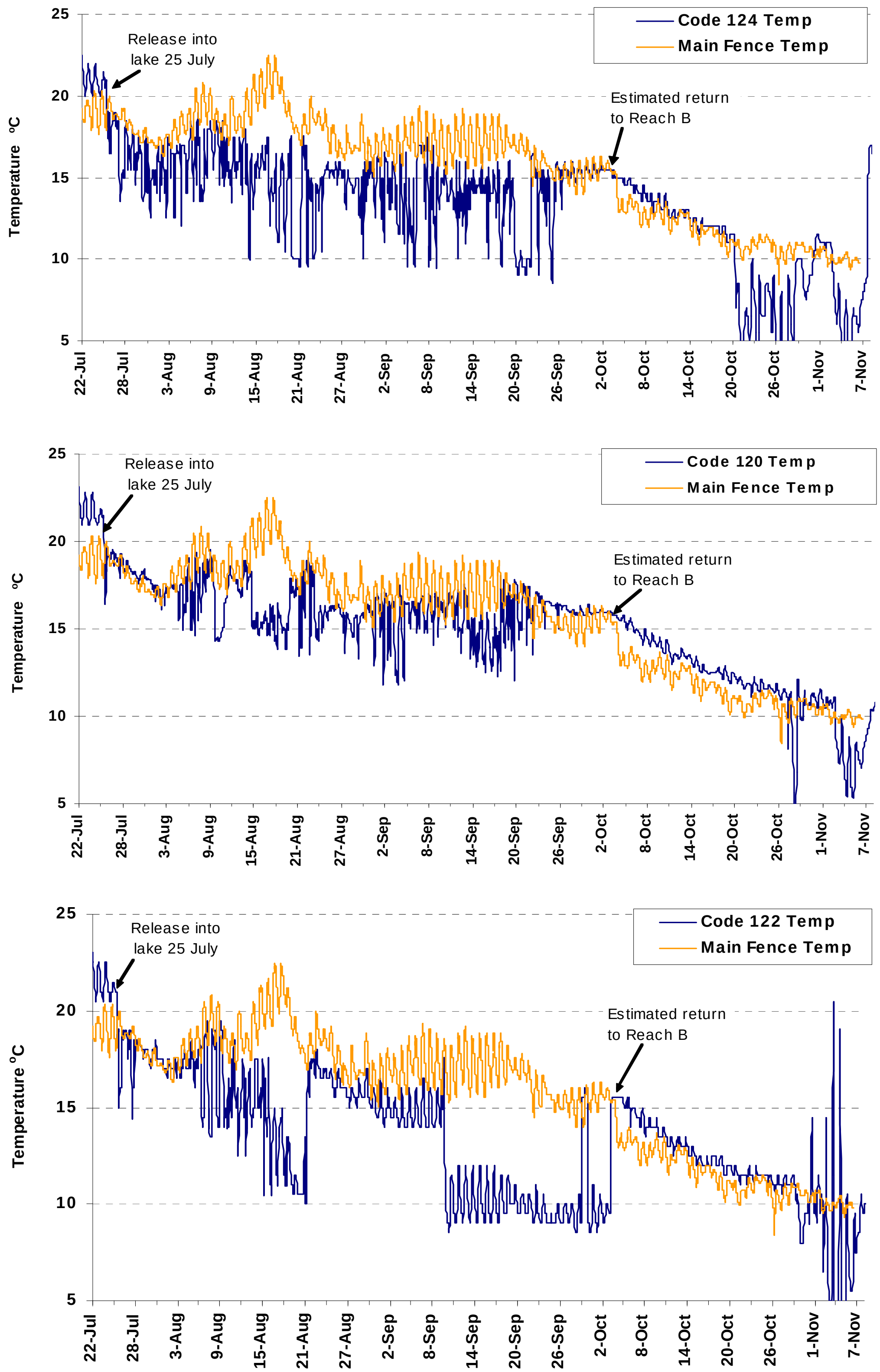


Figure 8. Temperature history of Fish #124, 120, and 122 released in Comox Lake on July 25, 2008, relative to the Puntledge River temperature measured at the lower hatchery barrier fence.

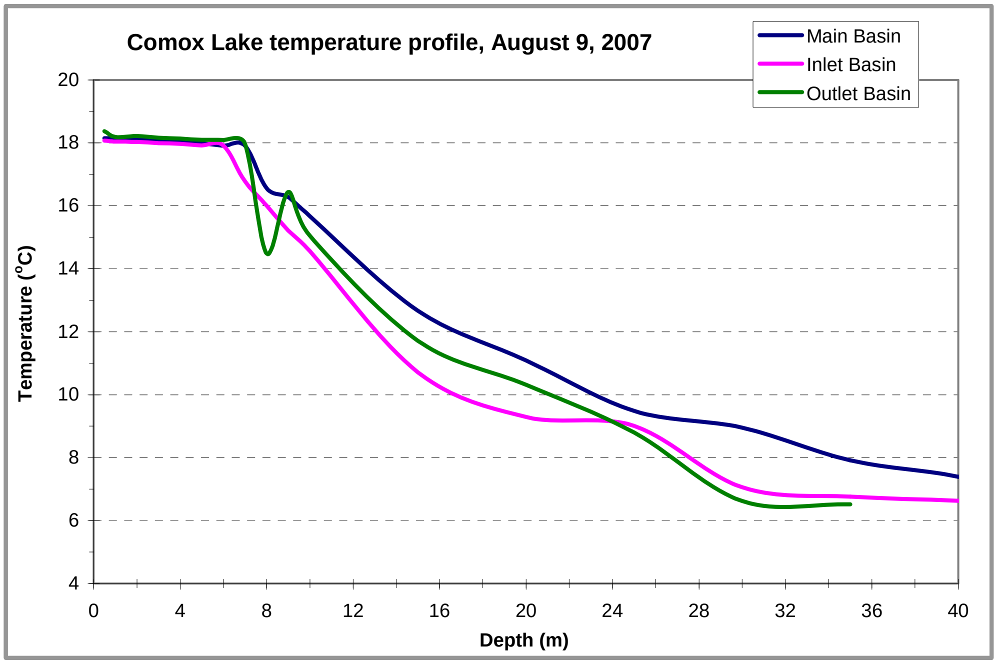


Figure 9. Temperature profile for Comox Lake inlet basin (near Upper Puntledge River), main basin (centre of lake near Cruickshank River), and outlet basin (centre of lake), measured on August 9, 2007 (BC MOE data).

5 RECOMMENDATIONS

1. Tagging of a group of early summer chinook migrants (fish that arrive at the lower hatchery in late May/early June) and tracking prior, during and following freshet flows with mobile and fixed station receivers will provide valuable comparative information to telemetry data that has been collected in the past seven years.

2. Summer chinook access upstream of the barrier fence during freshet/kayak pulse flows should be addressed so that the early component of the summer chinook population can be accurately enumerated. Operation of the video cameras at the lower and upper hatchery should commence by early May to ensure the commencement of the summer chinook migration is not missed.

3. Operation of a DIDSON acoustic camera at the 5th Street bridge could provide additional information on survival and rate of travel of summer chinook in the lower 6 km of the river.

4. Collect more detailed temperature profile data from Comox Lake between July and September to accompany temperature data from thermal loggers in fish that hold in the lake during the summer.

6 ACKNOWLEDGEMENTS

We are grateful for the financial support for this study from BC Hydro Bridge Coastal Fish and Wildlife Restoration Program (BCRP), and technical support from Fisheries and Oceans Canada. Special thanks are also given to Puntledge Hatchery staff for their assistance in capturing, holding and radio tagging summer chinook; University of Carleton for technician support, telemetry equipment use and data sharing; Ecodynamic Solutions for conducting snorkel surveys during the study; T. Sweeten (DFO) for providing river temperature data; and BC Hydro for discharge data.

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APPENDICES

APPENDIX A: BCRP Financial Statement

Project #: 08.Pun.04

INCOME	BUDGET BCRP	BUDGET Other (Cash)	BUDGET Other (in-kind)	ACTUAL BCRP	ACTUAL Other (cash)	ACTUAL Other (in-kind)
Total by Source	$35,990.00	$0.00	$34,100.00	$35,990.00	$0.00	$34,100.00
Grand Total Income (BCRP + Other)	**$70,090.00**			**$70,090.00**		
EXPENSES						
Project Personnel						
Biologist - Project Coordination	$8,000.00			$7,308.00		
Technicians	$12,600.00			$8,112.50		
Statistician	$2,968.00			$3,045.00		
DFO (Biologist)			$4,000.00			$4,000.00
DFO (Technicians)			$10,500.00			$10,500.00
Communications	$3,150.00			$3,150.00		
Material and Equipment						
Construction of fixed receiver stations	$700.00			$0.00		
Radio Transmitters	$3,000.00			$2,866.50		
Rental of Lotek receivers			$10,500.00			$10,500.00
Rental of video surveillance equip.			$6,000.00			$6,000.00
Receiver servicing	$500.00			$0.00		
Boat Rental	$250.00			$0.00		
Misc field, safety supplies, permits	$300.00			$201.59		
Travel	$600.00			$518.50		
BC Wild Workshop & expenses	$650.00			$450.00		
Administration						
Office space, equip, supplies Photocopies and printing Production of As-built Drawings Admin Fees (10%)	$3,272.00		$3,100.00	$2,565.21		$3,100.00
Total Expenses	**$35,990.00**	**$0.00**	**$34,100.00**	**$28,217.30**	**$0.00**	**$34,100.00**
Grand Total Expenses (BCRP + others)	**$70,090.00**			**$62,317.30**		
Balance (Grand Total Income - Grand Total Expenses	**$0.00**			**$7,772.70**		
BCRP Balance (surplus)	**($7,773)**					

* Any unspent BCRP financial contribution to be returned to:

BC Hydro, BCRP
6911 Southpoint Drive (E14)
Burnaby, B.C. V3N 4X8

APPENDIX B - Performance Measures

Project # 08.Pun.04

Performance Measures – Target Outcomes												
			Habitat (m^2)									
Project Type	**Primary Habitat Benefit Targeted of Project (m^2)**	**Primary Target Species**	Estuarine	In-Stream Habitat – Mainstream	In-stream Habitat – Tributary	Riparian	Reservoir Shoreline Complexes	Riverine	Lowland Deciduous	Lowland Coniferous	Upland	Wetland
Impact Mitigation												
Fish passage technologies	Area of habitat made available to target species	Summer chinook and steelhead		**3.7 km**	**>8 km**							
Drawdown zone revegetation/stabilization	Area turned into productive habitat											
Wildlife migration improvement	Area of habitat made available to target species											
Prevention of drowning of nests, nestlings	Area of wetland habitat created outside expected flood level (1:10 year)											
Habitat Conservation												
Habitat conserved – general	Functional habitat conserved/replaced through acquisition and mgmt											
	Functional habitat conserved by other measures (e.g. riprapping)											
Designated rare/special habitat	Rare/special habitat protected											
Maintain or Restore Habitat forming process												
Artificial gravel recruitment	Area of stream habitat improved by gravel plmt.											
Artificial wood debris recruitment	Area of stream habitat improved by LWD plcmt											
Small-scale complexing in existing habitats	Area increase in functional habitat through complexing											
Prescribed burns or other upland habitat enhancement for wildlife	Functional area of habitat improved											
Habitat Development												
New Habitat created	Functional area created											

APPENDIX C: Confirmation of BCRP Recognition

Article on the BCRP Summer Chinook Radio Telemetry Study, appearing in the ***Comox Valley Project Watershed News***, January 2009.

For a full copy of the Newsletter, see *"Comox Valley Project Watershed Society's Community Outreach – Communications Plan: Final Report 2009"*

Summer Chinook Migration Study

Summer chinook migration in the Puntledge River is being closely monitored through a combination of two radio telemetry studies with funding from BC Hydro's Water Use Planning Monitoring Program and the Bridge Coastal Fish and Wildlife Restoration Program (BCRP).

The first study monitors summer chinook migration in the Puntledge River in response to 5 pulse (higher flow) releases of water below the diversion dam during July and August. The purpose of the study is to determine if these summer pulse flows are beneficial to these historically significant Puntledge River fish populations.

The goal of the second study, conducted in close collaboration with the first, is to better understand summer chinook migration after the pulse flows, and once they reach the upper Puntledge River (above the diversion dam) and access the cooler water temperatures in the Comox Lake Reservoir.

Historically, summer-run chinook salmon and steelhead were the only fish populations to have traveled past Nib Falls and Stotan Falls. Summer chinook that are successful in accessing the lake are more likely to survive to spawn.

Fitting chinook with radio transmitter.

These two studies involve a collaboration of researchers from Carelton University, DFO scientists, the Puntledge River Hatchery, BC Hydro, Comox Valley Project Watershed Society and a local biologist. The results from the migration assessment will be essential in guiding future operations and restoration activities in the Puntledge River. Such activities are important to rebuilding these important Puntledge River fish populations back to sustainable and viable levels.

Stotan Falls, Puntledge River.

APPENDIX D: Passage through Stotan and Nib falls combined 2007 and 2008 data.

Summary of Migration Success by Year

Site	Year	Total N	N of Events	Censored N	Censored Percent
Nibs	2007	23	9	14	60.9%
	2008	16	13	3	18.8%
	Overall	39	22	17	43.6%
Stotan	2007	30	7	23	76.7%
	2008	19	17	2	10.5%
	Overall	49	24	25	51.0%
Overall	Overall	88	46	42	47.7%

Comparison of years - Means and Medians for Time before Passage

		Mean[a]				Median			
				95% Confidence Interval				95% Confidence Interval	
Site	Year	Estimate	Std. Error	Lower Bound	Upper Bound	Estimate	Std. Error	Lower Bound	Upper Bound
Nibs	2007	106.1	14.5	77.6	134.6	120	29.6	62.1	177.9
	2008	178.2	33.5	112.4	243.9	145	102.8	0.0	346.4
	Overall	158.9	23.3	113.3	204.6	120	32.6	56.1	183.9
Stotan	2007	648.6	101.0	450.7	846.5	.	.	.	.
	2008	151.5	27.8	97.1	205.9	154	64.0	28.7	279.3
	Overall	366.0	70.3	228.2	503.7	264	45.9	174.1	353.9
Overall	Overall	280.7	45.9	190.7	370.7	211	50.3	112.5	309.5

a. Estimation is limited to the largest survival time if it is censored.

Comparison of tag type - Means and Medians for Time before Passage

		Mean[a]				Median			
				95% Confidence Interval				95% Confidence Interval	
Site	Tag Type	Estimate	Std. Error	Lower Bound	Upper Bound	Estimate	Std. Error	Lower Bound	Upper Bound
Nibs	CONV	143.4	31.9	80.9	205.9	118	43.3	33.2	202.8
	EMG	156.4	26.7	104.1	208.7	144	45.1	55.7	232.3
	Overall	158.9	23.3	113.3	204.6	120	32.6	56.1	183.9
Stotan	CONV	417.4	117.8	186.4	648.3	211	63.7	86.1	335.9
	EMG	309.8	54.5	203.0	416.6	296	47.9	202.2	389.8
	Overall	366.0	70.3	228.2	503.7	264	45.9	174.1	353.9
Overall	Overall	280.7	45.9	190.7	370.7	211	50.3	112.5	309.5

a. Estimation is limited to the largest survival time if it is censored.

APPENDIX E. Photos

Photo 1. Three Lotek Electromyogram (EMG) transmitters and one Conventional MCTF 3A transmitter with temperature loggers attached.

Photo 2. Oral insertion of a conventional radio transmitter in a summer chinook.

Photo 3. Barrier fence in the Puntledge River at the Lower Hatchery showing the bypass channel created on the left bank, accessible by summer chinook during freshet flows. Photo taken during a discharge of 77 cms (measured at Gauge 8).