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

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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, in Reach B (headpond reach), and in the Comox Lake tributaries. Four groups of chinook were tagged using two types of radio transmitters: seven electromyogram (EMG) tagged fish were released on 29 June and a further nine on 6 July, while 22 conventional radio-tagged fish were released on 17 July. 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. 2008 for more detail). An additional 10 conventionally tagged chinook were released directly into Comox Lake on 18 July. Manual tracking was conducted daily at the commencement of the study (initial tag releases) and at approximately 12 hour intervals between 8 July and 3 August. The daily tracking interval was gradually increased after 8 August. Three pulse flows were delivered on July 4-5 (48 hr duration), July 11-26 (384 hr), and Aug 1-2 (48 hr).

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 significant obstacle to migration with 23% and 22% respectively, of the combined EMG and conventional tagged chinook reaching this area unable to progress further. The mean delay time caused by Stotan Falls was 312 hours (95% CI 193 – 431),

compared with 269 hours (95% CI 255 – 283) at Nib Falls, suggesting that the former poses a greater impediment to migration. However, individual fish were not consistent in their rates of ascent of the two sites. Snorkel surveys and visual monitoring events conducted at Stotan Falls failed to provide further insight into potential migration difficulties at this site. The diversion dam also posed a significant impediment to migration with 70.6% of the tagged chinook that reached this site failing to proceed further.

Five radio tagged chinook (2 EMG and 3 conventional tagged) successfully migrated into Reach B but did not proceed further into Comox Lake. These fish remained in the headpond until the spawning period. Of the 10 tagged chinook that were released in Comox Lake in July, 8 chinook dropped below the Comox Dam to spawn in the headpond, while the remaining two chinook were located in the Upper Puntledge River in October. Recovered temperature data from 2 of the 10 thermal loggers in chinook that held in Comox Lake indicates that fish seemed to prefer holding at a temperature of about 16 ^{o}C.

Radio telemetry results from the fixed station at Stotan Falls did not evince any pattern that might suggest that human recreational activities in the area, as represented by sunshine levels, influenced migration timing and duration. Similarly, diurnal movement was not significantly influenced by periods of sun and cloud.

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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.

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 hypolimnion of 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 radiotagged 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).

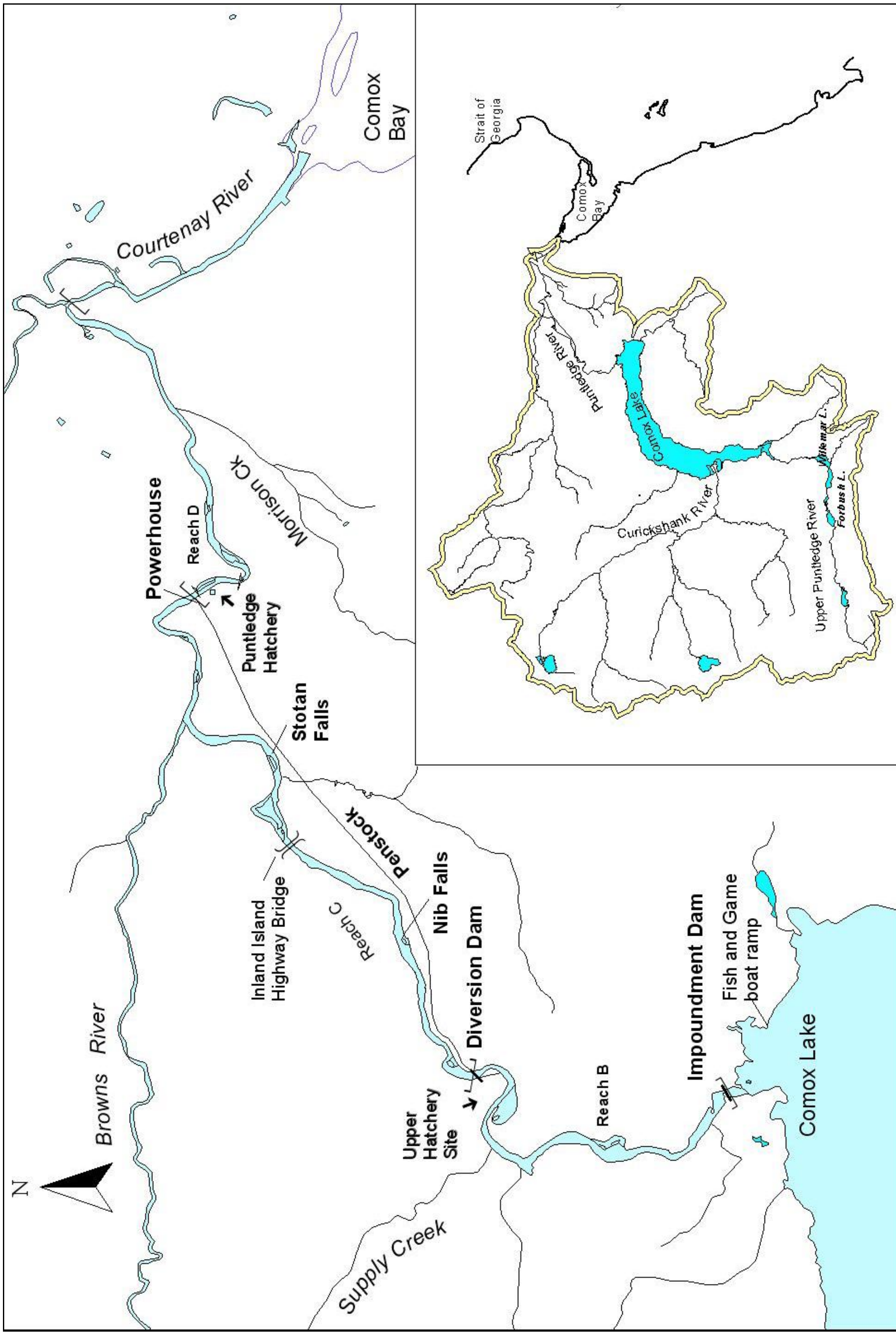


Figure 1. Puntledge River showing major features and areas monitored during the 2007 telemetry study, including Reach C, B and Comox Lake tributaries (inset map).

3 METHODS

3.1 Tagging

Summer chinook arriving at the lower Puntledge hatchery were diverted at the lower fence into hatchery raceways commencing June 18, 2007. Summer chinook arriving before this date were allowed to continue their migration in the river upstream of the barrier fence. On June 29 and July 6, seven and nine 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 17, thirty-two summer chinook were fitted with conventional Lotek model MCTF-3A radio transmitters. 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 anesthetized in clove oil (60 ppm) and then transferred to a surgical table continuously supplied with a maintenance dose of anesthetic (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). 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 returned to an empty hatchery raceway for recovery and transported to Comox Lake on the following 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. Each mobile tracking session attempted to locate all tagged fish in Reach C and Reach B. In addition, continuous tracking using one fixed telemetry receiver (Lotek SRX 600) and 3 directional antennas covered the area immediately upstream and downstream of Stotan Falls. The fixed station operated from July to mid August and provided more detailed information on timing of arrival and frequency and timing of attempts to move past this location.

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). In Reach B, tracking was less frequent, but usually occurred on a weekly basis from early August until the end of October. One tracking session was conducted by helicopter on October 5, 2007 in the upper watershed (Cruickshank and Upper Puntledge rivers). The survey covered the areas of Reach B, the Cruickshank River and major tributaries (Eric, Rees and Comox creeks) and the Upper Puntledge River (including Willemar and Forbush Lakes).

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 10, 16, 27 and Aug 15.

[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.

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 following provides a brief summary of movement of tagged chinook in response to pulse flows. The BCRP telemetry study also monitored fish behaviour and movement after the completion of the pulse flows and provides migration behaviour results and responses in Reaches C, B and A (Comox Lake). The following analysis is derived from the manual telemetry tracking results.

The delivery of pulse flows in 2007 differed from that outlined in the PUN WUP Monitoring Program Terms of Reference, due to a heavy snowpack and a requirement for BC Hydro to spill water into early summer. Instead of five weekly 48 hr pulse flows in July and August at 12 m^3/s, only 3 pulse flows were delivered. The first 48 hr pulse flow was higher in magnitude (18-20 m^3/s) whereas the second pulse flow was longer in duration (16 days) and was punctuated with a 96 hr spill with discharges exceeding 20 m^3/s (Figure 2). The third pulse flow on Aug 2-3 was a typical pulse flow as per the Monitoring Program Terms of Reference.

Movement of the first group of EMG tagged chinook from the Powerhouse Pool was rapid, with 71% (5 of 7) moving upstream prior to the first pulse flow on the 4th and 5th of July. Only one of these fish continued to move during the pulse and one chinook failed to move either before or after the pulse. Comparison of pre and post pulse distances travelled did not reveal any significant differences (Hasler et al. 2008; paired t-test, $\alpha=0.05$, $p=0.35$). Similarly, the movement patterns associated with the first pulse flow using Liddell's exact test (Liddell 1983) showed no significant effect due to the increase in flow ($R = 1.22$, $p = 0.97$).

The second release of EMG tagged chinook displayed a similar degree of initial movement with seven of the nine (78%) released moving from the Powerhouse Pool before the second pulse release. Snowmelt prolonged the duration and magnitude of the discharge during the second pulse release. Unfortunately, we did not assess the pattern of movement prior and subsequent to this period (approximately 11 July to 26 July). However, Hasler et al. (2008) again found that the distances travelled did not correlate to increased flow (p=0.07).

Chinook tagged with conventional transmitters were released on the 17th of July, during a period of increased flows associated with the second pulse (average flow on the date of release was 13.7 cms) which was shortly before a series of peaks in the hydrograph resulting from snowmelt (Figure 2). This level of discharge was approximately twice those on the release dates of the EMG groups, 6.3 cms and 7.2 cms). Initial movement was proportionally less at the higher flow, with nine of 21 functioning tags noted as having moved in the first two days following release (43%).

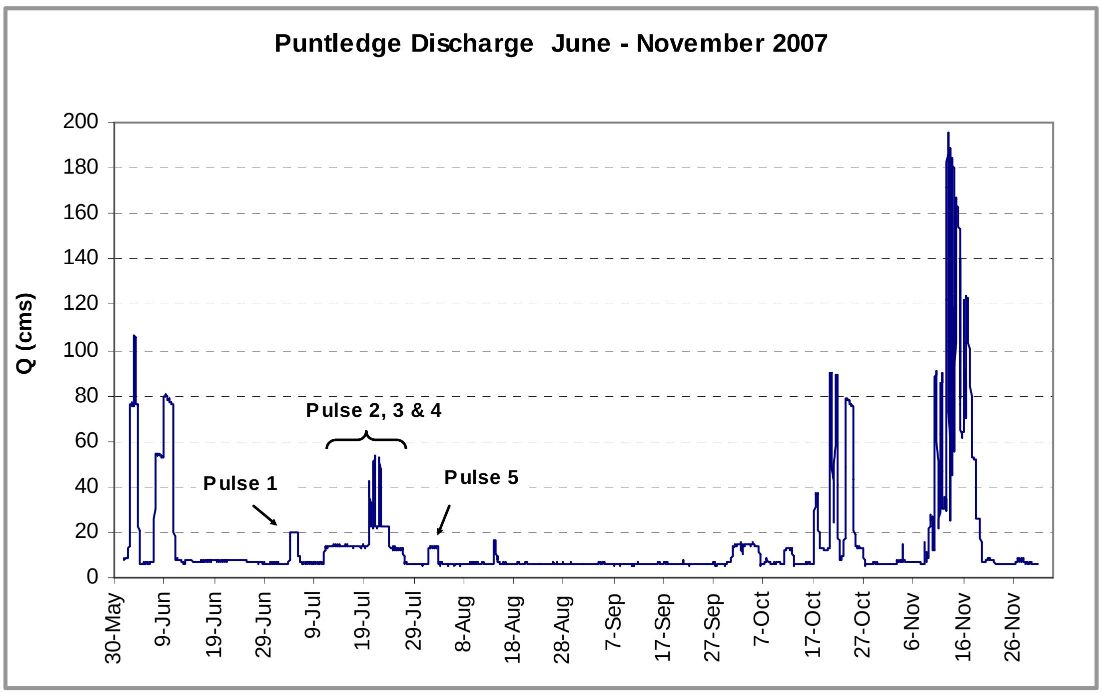


Figure 2. Hourly discharge for the Puntledge River at Gauge 6 below the diversion dam (WSC Gauge No. 08HB084).

By the date of the third pulse release (1 August) 14 EMG tags and 19 conventional tags were considered to be still operating in live chinook. Again, the distance moved in response to the pulse, measured by Hasler et al. (2008) was not significant (paired t-test $p=0.06$). The pattern of movement before and after the pulse was also not significant (Liddell exact test $R=7$, $p=0.07$). However, both the degree and configuration of migration could be considered to be responsive to the second and third pulse flows at a lower level of significance ($\alpha=0.10$).

We examined the possible influence of flow on migration of both EMG and conventionally tagged chinook through areas of the river that excluded the influence of Stotan and Nib Falls. Both are known to create a substantial challenge to migration. The effect of the falls on success of migrants is examined in the following section (Sec 4.2). Movement in areas below, between and upstream of these areas, and the approximate timing, was determined from mobile telemetry. Mean flow (m^3/s) was calculated for the period of movement and assessed as a covariant with the distance moved and rate of movement. However, efforts to define a significant relationship between chinook movement and Puntledge River hydrology, based on Gauge 6 data, were unsuccessful. Linear regression of flow, including log transformation of mean flow, on the above variables did not explain more than 1% of the total variability (best fit rate of movement versus log flow $F1,37 = 0.375$, $P = 0.54$, $r2 = 0.01$).

4.2 Progress of migration downstream of, and through Stotan and Nib Falls

The fate of chinook tagged with EMG and conventional transmitters is summarized in Table 1. A limited number of both tag types failed to move upstream from the Powerhouse Pool (8%), although when combined with fish that did not migrate successfully through lower Reach C (6.8 – 9.2 km) the total represents a disturbing initial loss of 21% of chinook. Both EMG tags and conventional tags encountered difficulty in passing through Stotan Falls, with 31% of EMG tagged chinook reaching this area unable to progress further. The cumulative total of chinook constrained below 9.2 km was 44%. The failure rate for EMG tags was extremely high (36%) at this point in the river (Table 1). Similarly, although attrition was much less for conventional tags (13%), this area again posed a barrier as it has in previous studies (Taylor and Guimond 2006).

Snorkel surveys and visual monitoring events conducted at Stotan Falls failed to provide further insight into potential migration difficulties at this site. Counts of chinook in the pools below the middle fish ladder (9.4 km) and below the upper fish ladder (9.6 km) were low on any given snorkel survey, and were slightly higher at the upper than the middle ladder pool (Table 2). Due to the difficulty of observing the upper ladder, technicians were stationed at the middle ladder only, and they did not record any visual evidence (i.e. leap attempts, etc.) of fish migrating through the ladder during these sessions (the low numbers of chinook counted below this ladder supports these results). Even if snorkel counts are underestimated, there did not appear to be large numbers of chinook stacking up below the ladders.

The second most difficult obstacle to migration was Nib Falls, also historically a choke point in the Puntledge River. Here, two out of nine EMG tagged chinook and three of 14 conventionally tagged fish were unable to migrate further. Overall losses at this point in the river were 22% (Table 1). Snorkel data was not available for the pool below the main fish ladder and technicians did not monitor this site. Observations reported in Taylor and Guimond (2004) indicated that chinook encountered difficulty approximately 40 m downstream of the middle fish ladder and at the fish ladder itself with several unsuccessful leap attempts being recorded.

Table 1. Furthest extent of migration for Chinook tagged with EMG and Conventional radio transmitters, showing number of fish to fail to pass specific points in the system, proportional losses from total tags applied and site specific estimates of failure to proceed.

		EMG			Conventional			Combined tags		
Furthest upstream progress	**Distance (km)**	**# of fish**	**% of total releases**	**failure rate at this site**	**# of fish**	**% of total releases**	**failure rate at this site**	**# of fish**	**% of total releases**	**failure rate at this site**
Powerhouse pool	6.8	0	0.0%	0.0%	3	13.6%	13.6%	3	8%	7.9%
Mortality/regurgitation Reach C1 (6.8-9.2 km)	8.6	2	12.5%	12.5%	3	13.6%	15.8%	5	13%	14.3%
Stotan Falls	9.2	5	31.3%	35.7%	2	9.1%	12.5%	7	18%	23.3%
Nib Falls	11.7	2	12.5%	22.2%	3	13.6%	21.4%	5	13%	21.7%
WSC Gauge 6	12.7	1	6.3%	14.3%	0	0.0%	0.0%	1	3%	5.6%
Upper Hatchery Pool	13.3	4	25.0%	66.7%	8	36.4%	72.7%	12	32%	70.6%
Comox Dam tailrace pool	16.9	2	12.5%	-	3	13.6%	-	5	13%	-

Table 2. Number of chinook counted at three locations in the Puntledge River during four separate snorkel surveys conducted during the WUP Steelhead Production monitoring program.

Location of snorkel count	10-Jul	16-Jul	27-Jul	15-Aug
Below Diversion Dam	34	35	71	60
Upper Stotan Falls (9.6 km)	4	1	6	0
Mid Stotan Falls (9.4 km)	2	0	0	0

A third location that has been known to constrain migration of summer chinook is the diversion dam. In 2007, four of six EMG tagged chinook and eight of eleven conventionally tagged chinook that arrived at the diversion dam (or Upper Hatchery pool) failed to proceed further (Table 1). This represents a combined failure rate of 70.6% at this site, and is higher than results from the three previous telemetry studies for this site (Table 1). Even when using a cut-off date of Sept 6 when the fishway at the diversion dam was closed on to prevent fall chinook access into the headpond, the failure rate was still high (69%) with 7 of 10 fish failing to proceed further.

There has been speculation on the manner in which these areas block fish passage in previous reports (Taylor and Guimond 2006), but previously, calculation of a number of relevant statistics has been deferred due to the fact that failure to progress provides incomplete information for the calculation of means, variances etc. Therefore, estimates of, for example, holding time would not include these data and be biased. Event-time analysis (more commonly referred to as survival analysis) permits incorporation of incomplete, or censored data into such estimates (Castro-Santos and Haro 2003 provide an example of event-time analysis applied to smolt passage through a hydroelectric facility bypass sluice). Data used in this analysis was provided as a summary of the telemetry database compiled as part of the WUP program (C. Hasler, Carleton University). The following material is derived from mobile telemetry data.

Progress of chinook through Stotan and Nib Falls is illustrated in a Kaplan-Meier probability plot of time before passage (Figure 3). This figure illustrates the sequential movement of Chinook past the two areas with more rapid movement through Nib depicted by the steeper slope. The mean delay time caused by Stotan Falls was 312 hours (95% CI 193 – 431), compared with 269 hours (95% CI 255 – 283) at Nib Falls, suggesting that the former poses a greater impediment to migration. However, we cannot assess this statistically, since the sample population at Nib exclusively comprises successful fish from Stotan. Paradoxically, migration failure through Nib Falls is proportionally similar (Table 1) to that through Stotan, while the passage time appears to be lower.

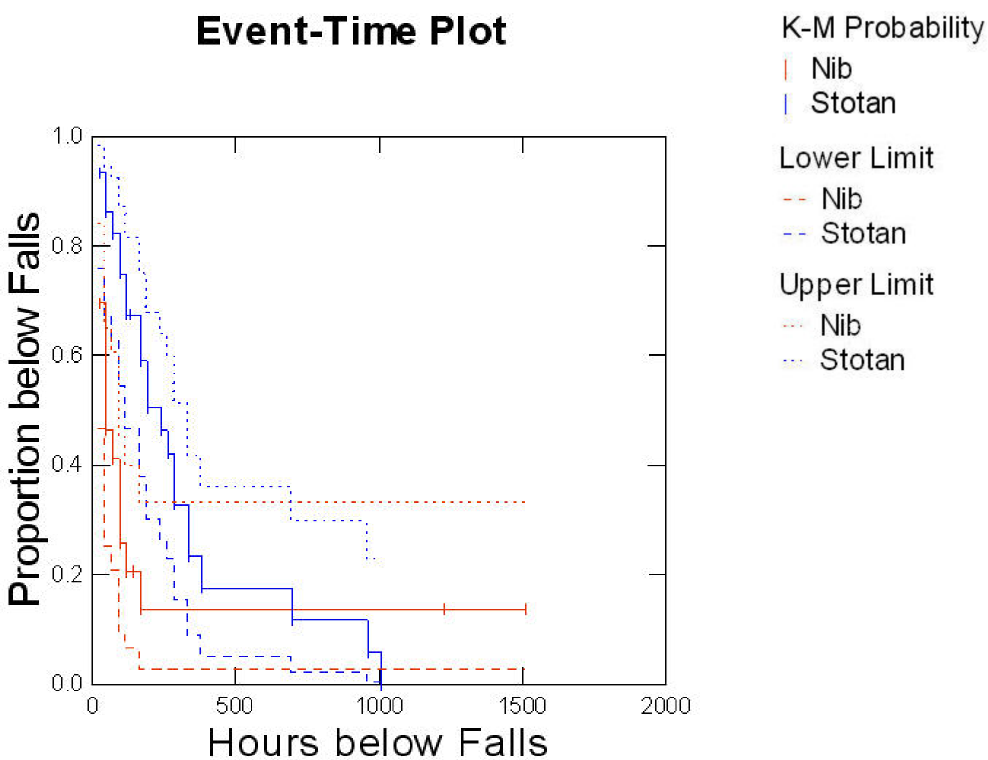


Figure 3. Kaplan-Meier probability plot of time before passage through Stotan and Nib Falls.

Table 3 contrasts the quantiles of timing associated with passage through the two areas. At Stotan, a quarter of migrants required 96 hrs or less before being able to ascend the fish ladder, while three out of four fish were able to pass upstream after 336 hours. The delay was shorter at Nib, with one in four fish moving through in 24 hours and half of those reaching the falls continuing upstream within 48 hours. A more detailed picture of movement through these areas is provided in Tables 4 and 5, which list the Nelson-Aalen (N-A) cumulative event-time function for successful passage.

Table 3. Probability quantiles of the length of time (hrs) that chinook are delayed in their passage through Stotan and Nib Falls.

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

Table 4. Summary of chinook migration through Stotan Falls fish ladder.

Fish below Stotan	Number Passing Upstream	Time (hrs)	N-A Cumulative Success Rate	Standard Error	95.0% Confidence Interval	
					Lower	Upper
0	2	24	0.067	0.047	0.000	0.159
26	2	48	0.144	0.072	0.003	0.285
23	1	72	0.187	0.084	0.022	0.352
22	2	96	0.278	0.106	0.071	0.485
20	2	120	0.378	0.127	0.128	0.627
16	2	168	0.503	0.155	0.199	0.807
14	2	192	0.646	0.185	0.283	1.008
12	1	240	0.729	0.203	0.332	1.127
11	1	264	0.820	0.222	0.384	1.256
9	2	288	1.042	0.272	0.509	1.576
7	2	336	1.328	0.339	0.664	1.992
4	1	384	1.578	0.421	0.752	2.404
3	1	696	1.911	0.537	0.859	2.964
2	1	960	2.411	0.734	0.973	3.850
1	1	1008	3.411	1.240	0.980	5.842

Table 5. Summary of chinook migration through Nib Falls.

Fish below Nib	Number Passing Upstream	Time (hrs)	N-A Cumulative Success Rate	Standard Error	95.0% Confidence Interval	
					Lower	Upper
23	7	24	0.304	0.115	0.079	0.53
15	5	48	0.638	0.188	0.269	1.007
9	1	72	0.749	0.219	0.32	1.177
8	3	96	1.124	0.308	0.521	1.727
5	1	120	1.324	0.367	0.605	2.043
3	1	168	1.657	0.496	0.685	2.629

Comparison of the cumulative successes over time indicates that upstream passage at Nib Falls is initiated more rapidly, with approximately equal proportions of chinook moving upstream after 48 hrs at Nib, versus 192 hours at Stotan. Since estimates at Nib are measured from previously successful migrants, it is possible that experience at Stotan confers added ability to negotiate obstructions. Conversely, fish that successfully negotiated Stotan Falls may have innately superior physiological migratory ability. Hasler et al. (2008) suggests that migratory behaviour was tied to physiological condition upon entry into the Puntledge River. The physical characteristics of the sites may also be important, although this is not illuminated by snorkel surveys or visual monitoring. While Nib Falls appears to provide similarly difficulty to passage, in terms of fish mortalities (Table 1), conditions here may allow for greater frequency of successive attempts to move upstream. However, specific success at the two obstructions may also be influenced by the prevalent suite of environmental conditions over the period of fish passage at each site. This is suggested by the lack of consistency in performance of successful fish at the two sites, as indicated in the following analysis.

The time required to successfully move upstream form Stotan Falls was divided into fast and slow categories using the lower confidence limit for the middle quantile (120 hrs) calculated from the event-time analysis for Stotan (Table 3). Table 6 identifies the fish that were considered to be fast by this criterion. A two sample t-test confirms that the fast group is significantly faster than the others (t-test, $\alpha=0.05$, $t=-5.14$ $p<0.001$). The time required to ascend Nib Falls is listed for the same fish in Table 6. At this site the mean time to ascend the falls, calculated from event–time analysis, was lower than at Stotan: half of all fish managed to progress within 48 hrs (Table 3). Although the fish in the fast category at Stotan did fairly well, their delay time was not significantly less compared with the others (t-test, $\alpha=0.05$, $t=-0.21$ $p=0.418$). It appears that rate of progress of specific fish is inconsistent between the two sites. Also, three of the fish that moved quickly through Stotan, failed to progress past Nib (Tags 27, 53 and 70). If Stotan has a deleterious effect on chinook, then this appears to be highly variable, since 42% of the slow fish at Stotan recorded the fastest times (24 hrs) at Nib (Table 6).

Table 6. Number of hours before successful ascension of Stotan and Nib Falls, by specific fish: initial categorical grouping based on Stotan timing only.

	Stotan[1]		Nib	
	Tag #	**Hrs**	**Tag #**	**Hrs**
Fast	27	120		
	36	48	36	48
	38	120	38	24
	45	72	45	96
	49	24	49	48
	53	24		
	61	96	61	96
	62	48	62	24
	70	96		
Others	22	384	22	120
	23	240	23	72
	26	264		
	28	336	28	24
	30	168	30	168
	31	696	31	24
	33	288	33	96
	41	336	41	24
	50	168	50	24
	54	288	54	24
	58	192	58	48
	65	192	65	48
			46	48

[1] Two fish, tags 37 and 46 were considered to be outliers with times of 960 and 1008 hrs respectively. Subsequently Tag 46 ascended Nib in a fast time.

Further clarification of aspects of the movement of fish through these areas would require a control group of radio-tagged fish to be released upstream of Stotan Falls. This would permit statistical comparison of rates of movement and degree of success between previous success at Stotan and the control. No significant difference at an acceptable level of power for the test would permit extrapolation of results to previous year's data.

It is possible that tagged fish behave different than untagged fish. The timing of the telemetry study and release of radio tagged fish into Reach C precludes us from comparing their response to untagged fish released at the same time. Summer chinook broodstock capture and collection of study animals commences around mid June. Therefore fish that have already bypassed the lower hatchery before mid June have been exposed to different environmental conditions, cooler river temperatures and different discharges than those fish released between the end of June and mid July. An underwater video camera at the lower Hatchery fishway and diversion dam fishway could provide a means of determining migration success of untagged fish through Reach C. However, the current set-up is inadequate due to the ability of chinook to by-pass the lower hatchery camera at high river discharges through a flood channel on the left bank of the river. BC Hydro currently releases ~85 m^3/s into Reach C for a kayak pulse flow event, typically around the beginning of June. It is also common for Hydro to spill water into the river during high Comox Lake inflows and snow melt events in the Spring. In 2007, at least 211 summer chinook passed the lower hatchery between March 1 and June 18 undetected. Addressing this bypass issue at the lower hatchery fence would provide an opportunity to more accurately assess the migration success of untagged "early" (prior mid June) summer chinook migrants through Reach C.

4.3 Movement of fish in Reach B

A total of 5 radio tagged chinook released at the lower Puntledge hatchery successfully migrated into the headpond. The earliest fish was located in the headpond on July 25, while the other 4 fish were located between the 3rd and 8th of August, following the last pulse flow. The diversion dam fishway was operated such that access into the headpond was permitted until September 6, to prevent Fall chinook access into the headpond. At least 10 radio tagged fish (and between 30-40 untagged adults from observations made from a vantage point above the pool) were located in the diversion dam pool when the fishway was closed. In fact, these tagged fish had been holding in this pool between the date of the last recorded tagged migrant into the headpond (Aug 8) and the fishway closure date (Sept 6). It is unclear why these tagged fish were not motivated to migrate through the fishway during this 4 week period while 20 untagged summer chinook were counted passing through the fishway during this time. One suggestion was that pulse flows may also positively influence fish holding in the diversion pool to migrate through the fishway. However, a preliminary analysis on the data of chinook migration at the diversion dam from video surveillance records revealed no more chinook moving during a pulse flow (12-16 m^3/s) than during normal base flows (4-8 m^3/s) (Figure 4).

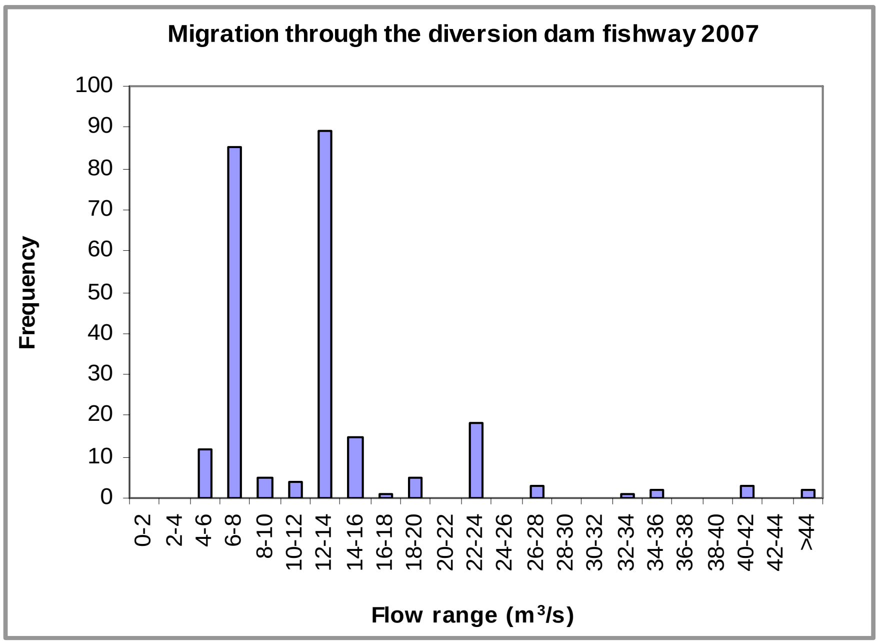


Figure 4. Frequency of summer chinook migration through the diversion dam fishway at flow ranges from Reach C discharge, measured at Gauge 6, (WSC Gauge No. 08HB084), 600 m downstream.

The 5 tagged fish recorded in the headpond did not proceed further into Comox Lake and their signals were located at 2 main holding areas - the impoundment dam tailrace (km 16.9) and a deep eddy pool upstream of the recent spawning habitat restoration site (km 14.7). These holding pools are near the only two suitable spawning sites for chinook in the headpond – a small historic spawning area 200 m below the impoundment dam (km 16.7) and the new reconstructed spawning habitat at the outlet of Supply Creek (km 14.5).

However, the location in which fish were holding before spawning began did not appear to influence the habitat these fish selected for spawning. In other words, a fish holding at km 16.9 did not necessarily spawn at 16.7 despite the proximity of this spawning habitat. In some cases, fish were tracked back and forth between the eddy pool and the tailrace, or the lower and upper spawning platform. This may have been due to the fact that all tagged fish were male and hence were more active in their search for mates.

4.4 Movement of fish released into Comox Lake

Of the 10 tagged chinook that were released directly into Comox Lake on July 18, all but one fish (tag 39) remained in the lake until the onset of spawning. Fish #39 was first recorded in the headpond, below the impoundment dam, on Aug 22, where it remained until October 5. However, a temperature profile recorded from a logger recovered in this carcass after spawning, shows that it likely dropped down around Aug 6, or was holding above the impoundment dam in the upper 6 m of the lake (Figure 5). Signals from 7 of the remaining 9 lake released fish were recorded in the headpond on October 5, although 5 of these were located a few days earlier. The last 2 tagged fish were located in the Upper Puntledge River during a helicopter survey on October 5: one tagged fish was detected at the mouth, and another further upstream at the outlet of Willemar Lake.

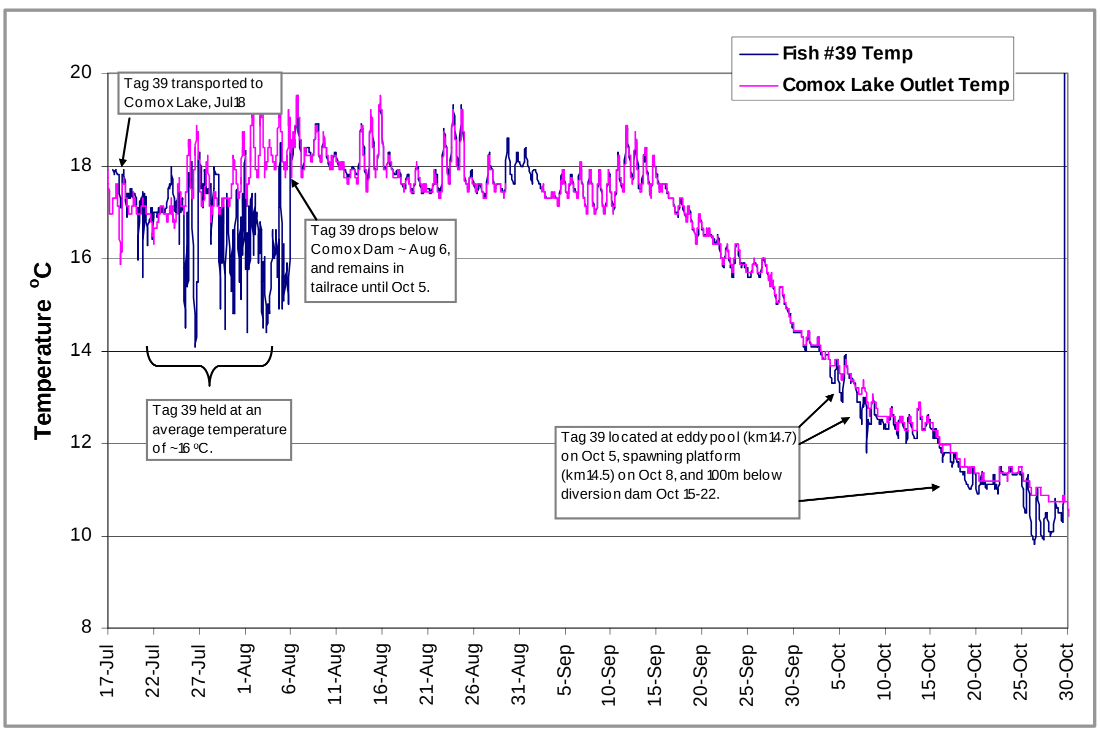


Figure 5. Temperature history of fish #39 relative to Comox Lake outlet temperature between July 17 (transmitter insertion) and October 30, 2007 (transmitter recovery).

From October 2 - 15, five of the eight tagged fish in the headpond were tracked on the Supply Ck spawning platform, one fish was tracked at the upper relic spawning area and one fish was tracked at both locations. The signal from the eighth fish was received in the vicinity of the impoundment dam on Oct 4, but not detected again for the remainder of the tracking period. In addition to the tagged fish, an estimated 75 adult chinook were observed spawning at the Supply Ck spawning platform while ~25 fish were counted at the upper spawning habitat. Several attempts were made to capture a visual record on the physical condition of chinook that held in Comox Lake during the summer. One fish was finally observed after it dropped below the diversion dam to spawn at the BC Conservation Foundation (BCCF) habitat restoration site adjacent the diversion dam. Compared to other fish in the area, it was silver bright and much more active.

Recovered temperature data from 2 of the 10 thermal loggers in chinook that were transported to Comox Lake indicates that fish seemed to prefer holding at a temperature of about 16 ^{o}C (Figure 5 and Figure 6). Fish #44 remained in the lake during the entire summer, dropping below the impoundment dam at the end of September to spawn, while fish #39 dropped down below the dam in early August. This temperature preference correlates to a depth of about 8-10 m based on a temperature profile of Comox Lake completed by the provincial Ministry of Environment on August 9, 2007 (Figure 7).

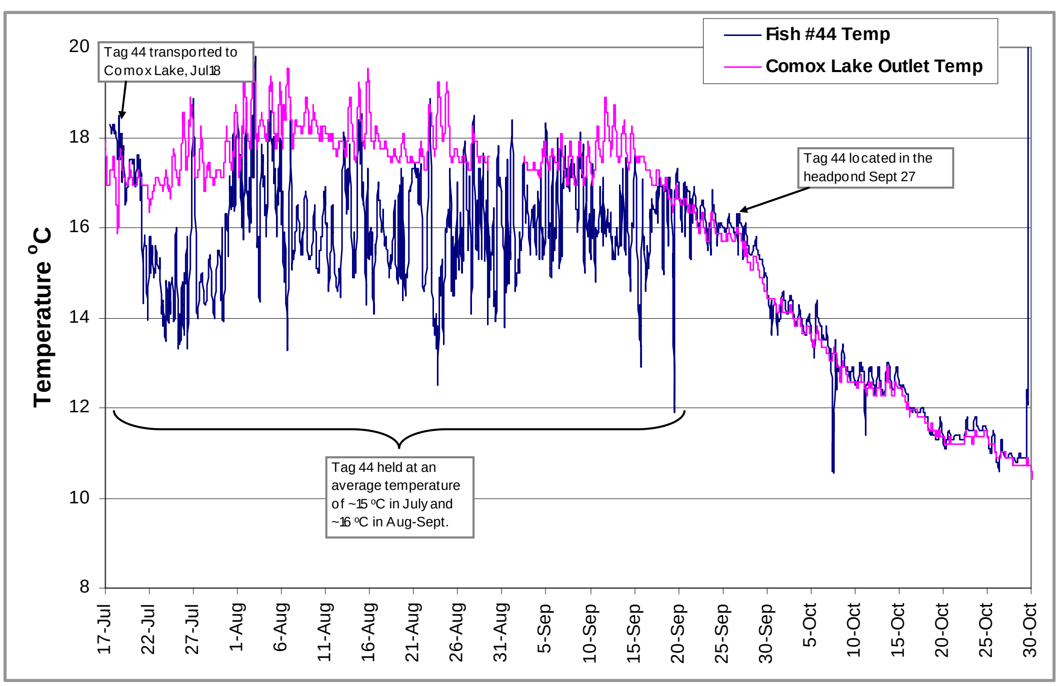


Figure 6. Temperature history of fish #44 relative to Comox Lake outlet temperature between July 17 (transmitter insertion) and October 30, 2007 (transmitter recovery).

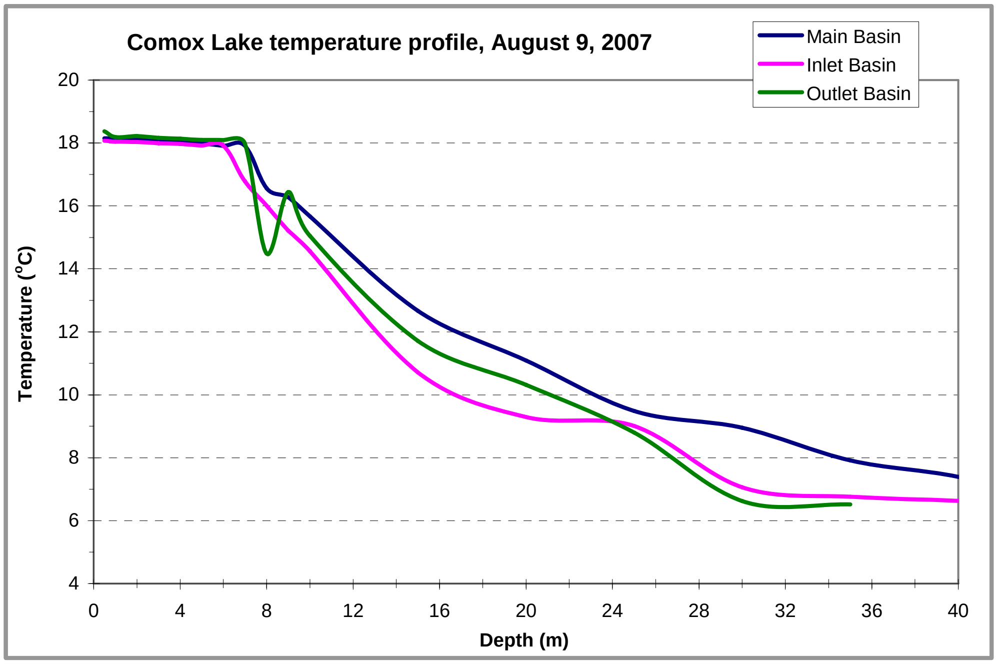


Figure 7. Temperature profile for Comox Lake inlet basin (near Upper Puntledge River), main basin (centre of lake near Cruickshank River), and outlet basin (centre of lake), measured on August 9, 2007 (BC MOE data).

5 FIXED STATION RADIO-TELEMETRY AT STOTAN FALLS

Exact timing of fish passage through Stotan Falls was based on the spacing and power levels of signals from EMG and conventional tags recorded from the three antennas at the fixed telemetry site. An example is illustrated in Figure 8, where passage is clearly defined (28 July at 11:11) and subsequent signals comprise reflections and signal bounce. Unfortunately, few of the records were as clear cut and Tag 36 (Figure 9) displayed an erroneous signal record from antenna 1 that was potentially due to an incorrect date setting in the receiver (C. Hasler pers. comm.).

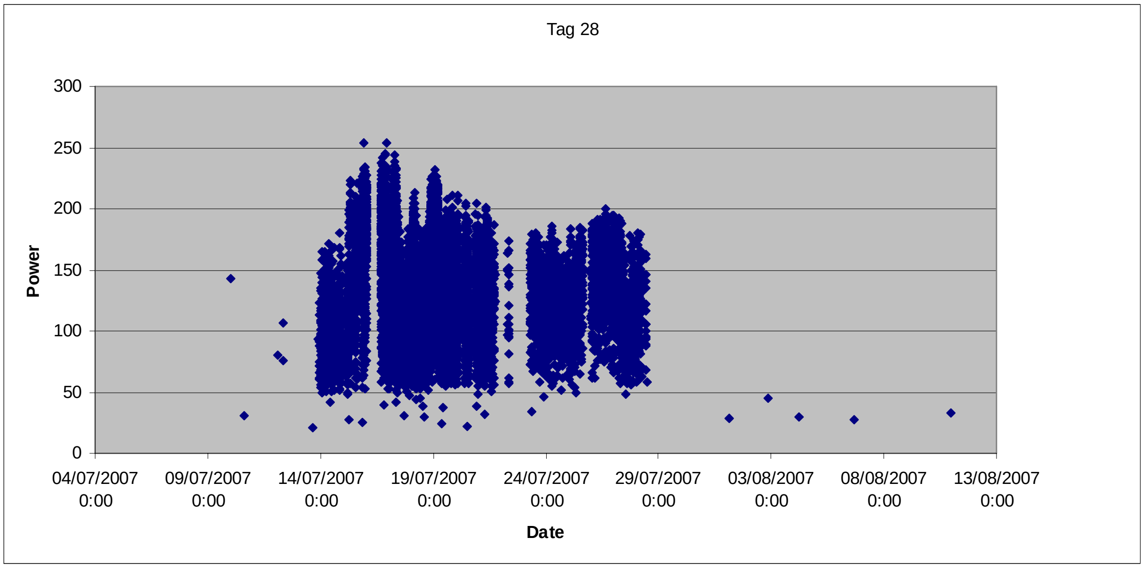


Figure 8. Telemetry of EMG Tag 28 from antenna 3.

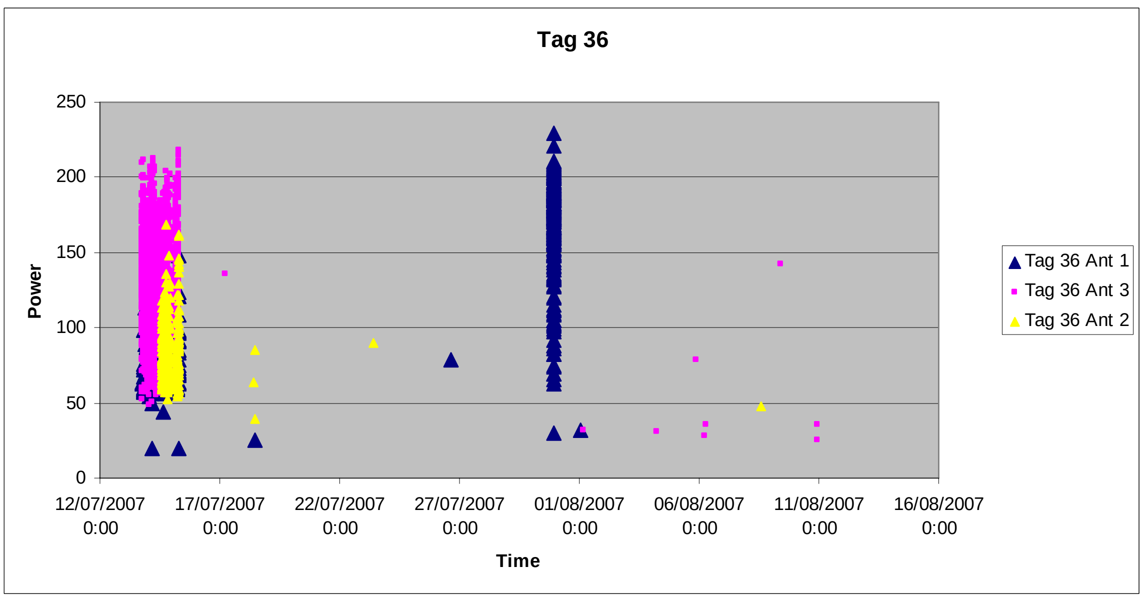


Figure 9. Telemetry of EMG Tag 36 from antennas 1, 2 and 3 illustrating an incorrect series of records in late July.

Consequently, passage times could not be extracted from the database without careful manual scrutiny and the manual tracking records were useful in narrowing down the appropriate time frame. However, in most cases the time of passage could be determined fairly clearly (i.e. within an hour or so).

The dates of passage are listed in Table 7 with the corresponding data on flows at Gauge 6 (timing corrected for the delay to reach Stotan). Mean flows and median flows were calculated over the time period from 4 hours before passage to 4 hours after. Means and medians can be compared to assess the degree of change in flow over this period and the percentage change relative to the first data point in the time series is listed. Only 5 of 23 tagged fish had a passage time associated with either rising or falling flows. Appendix E illustrates the timing of passage and associated flow rates for these fish.

Table 7. Exact time of passage of EMG and Conventional tags through Stotan Falls, based on fixed station telemetry, with associated hydrological and meteorological variables. Flow data represent the period 4 hrs before and after passage. Light levels are D=dark, C=cloudy and S=sunny.

Tag #	**Date**	**Time**	**Mean flow**	**Median flow**	**Flow rate of change**	**Sunshine hours**	**Light level**
EMG							
22	02/08/07	21:22	10.72	13.01	-27.4%	13.2	D
23	21/07/07	8:17	31.50	22.63	-56.3%	0.7	C
26	26/07/07	21:06	10.68	12.43	-18.4%	12.5	D
27	15/07/07	23:30	14.06	14.08	-0.8%	12.1	D
28	28/07/07	11:11	5.99	6.01	2.8%	6.3	C
30	15/07/07	20:18	14.09	14.08	-1.4%	12.1	C
31	06/08/07	23:33	6.07	6.12	7.4%	14.0	D
33	18/07/07	21:01	13.73	13.69	2.9%	2.9	D
36	17/07/07	5:58	13.72	13.71	-2.1%	11.4	C
Conventional							
37	11/08/07	0:34	6.27	6.26	-0.1%	7.9	D
38	25/07/07	10:00	12.72	12.69	-2.9%	14.9	S
41	01/08/07	16:33	13.48	13.45	-3.3%	14.6	S
45	26/07/07	19:15	11.16	12.49	-5.4%	12.5	C
46	11/08/07	0:35	6.27	6.26	-0.1%	7.9	D
49	25/07/07	15:26	12.60	12.60	-2.7%	15.1	S
50	26/07/07	23:59	9.91	10.79	-39.7%	12.5	D
53	01/08/07	16:35	13.48	13.45	-3.3%	14.6	S
54	01/08/07	15:43	13.43	13.43	-1.2%	14.6	S
58	01/08/07	5:15	10.42	12.75	112.3%	14.7	C
61	01/08/07	12:15	12.64	13.38	0.7%	14.6	S
62	08/08/07	20:09	6.05	6.05	-3.7%	8.7	C
65	01/08/07	16:38	13.48	13.45	-3.3%	14.6	S
70	06/08/07	2:36	5.96	5.96	-3.2%	14.4	D

Most fish ascended Stotan at flows between 12 and 14 cms (47.8%). The second most numerous group (26.1%) were successful between 6 and 8 cms and almost all of the remainder (21.7%) ascended at 8 to 12 cms. One fish, EMG 23, moved upstream just following an abrupt peak flow due to snowmelt (Appendix E).

Conditions under which fish moved were characterized by light conditions measured in the hour of movement and characterized as Dark, Cloudy or Sunny. A general picture of conditions associated with movement was also compiled from sunshine hours. Total sunshine hours were tallied for the day of passage for fish that moved in the afternoon and during the hours of darkness. The previous day's sunshine hours were calculated for fish that moved in the early morning. The majority of chinook (16 out of 23) moved in the late evening or during darkness (Table 7). These comprised 39.1% of the total in darkness and 30.4% under cloudy conditions. The remaining 30.4% moved during sunshine. The association between sunshine and the patterns of movement recorded by the fixed station at Stotan Falls is illustrated in Appendix F.

The yellow bands shown in combination with the telemetry for each fish represent contiguous periods where more than 9 hours of sunshine was recorded each day. Neither the EMG (tags 22 to 36) nor conventional tags (tags 37 to 70) demonstrated movements that were associated with a particular level of sunshine. The telemetry records display gaps that suggest movement of the fish beyond the range of the antennas, but these were not consistently found to occur during sunny periods. For example, EMG tag 28 had a total of 4 breaks, 50% of which occurred during sunny periods, as did conventional tag 54. If an increased incidence of movement out of detection range occurred due to human disturbance, we might expect that sunny periods would contain a disproportionate share of these events due to the increase in recreation levels during sunny weather. This does not appear to be borne out by the data. However, additional analysis is required to eliminate movement events that occurred at night, when human activities would be greatly reduced. This could be done by examining all telemetry events for the upstream antenna 3 (in a majority of cases there was good agreement between the downstream and upstream antennas). Gaps in the tag records would be classified as night or day events and the latter then tabulated with respect to sunny or cloudy periods. Additional work would be required to identify gaps resulting from removal of the receiver at Stotan for battery charging. These occasions are noted in field records (C. Hasler pers. comm.).

This type of analysis was performed for passage timing (the exact time that a fish was presumed to have successfully ascended the falls), as opposed to all movement events beyond the range of the antennas. The time periods that were cloudy versus sunny are listed in Table 8. Fish movement was compared with these periods to determine if movement occurred at night more often then in the day during sunny weather.

Table 8. Periods when sunshine hours fell below 9 hours daily (cloudy) versus > than 9 hours daily (sunny).

	Cloudy	Sunny
Dates	1 – 3 July	4 – 6 July
	7 – 8 July	9 – 16 July
	17 – 23 July	24 – 26 July
	27 – 28 July	29 July – 6 Aug
	7 – 12 Aug	13 – 15 Aug
	16-Aug	

During sunny periods, 6 fish moved at night versus 10 in the daytime: daytime included early morning and evening periods. In the cloudy periods, 3 fish moved in the night versus 4 by day. Comparison of these frequencies using contingency tabulation indicates that diurnal movement was not significantly influenced by periods of sun and cloud (Fisher exact test 2 tail $p = 0.615$).

Fixed station telemetry did not reveal an overall migration pattern that would support human disturbance as a contributing factor based on the indirect relationship between sunny conditions and recreational use of the Stotan area. In order to directly assess the degree to which activities such as swimming impinge on the migration of chinook at Stotan fishway, comparison between migration success with average summer utilization of the area and in the absence of such activities would be required. There are two approaches, of which the second is the more robust to bias.

The first method would track tagged chinook over a period when weather conditions are conducive to the types of activities that may influence fish migration timing and success. At some predetermined time, public access to the area would be prevented and the rate at which successful ascents are recorded would be determined for the remaining fish. A higher rate of successes in comparison with the initial (human activity) group would indicate some effect due to the presence of humans. There are several problems with this approach. The pre and post closure subjects are not randomly selected, therefore, fish that are the first to move may represent specimens that are physiologically more fit. Failure to move before the area is closed may demonstrate a response based on the initial exposure to the area i.e. failures may reduce the strength of the fish so that attempts to migrate are subsequently more prolonged, even in the absence of human activity: interestingly the above comparison of Stotan and Nibs rates of success does not support this possibility. One positive in this approach would be the shorter time frame for the experiment which would increase the likelihood of consistent conditions of discharge and sunshine.

The second approach would require the release of two groups of fish. Ideally, these would be randomly selected from a pool of fish collected at the same time. Practically, holding the second group until their turn would not likely be feasible and may have some adverse effect on their performance. Irrespective of the periodicity of collection of specimens, these should be as similar as possible e.g. all males, all within a predetermined size range, no visible wounds etc. The first, control, group would be exposed to normal levels of activity at Stotan based on public response to warm sunny weather. The second group would have human activity curtailed soon after reaching the fish ladder. Design of a robust experiment is complicated by the need to control for as many variables as possible in comparing a control and experimental group. Factors such as flow may be important, and potentially, comparisons should be made within a range of 12 – 14 m^3/s which seems to maximize successful ascent of Stotan. Sunshine hours would also have to be as similar as possible for the two groups, although the effect of light conditions on migrating fish is less than clear. Ideally similar weather would last for the duration of both experimental periods. An important factor would be the period over which the Stotan area could be closed to the public. Previous work has shown that 50% of fish require between 120 and 336 hours before successfully ascending Stotan. Therefore, to maximize the length of time that the experimental group has to produce a sufficient number of successes would require closure of at least 5 days, depending on the sample size available. Power analysis would be necessary to predict the numbers of fish that would have to successfully migrate to avoid type II errors in comparing the results: low power would result in the potential for assuming no statistical difference when in fact there was some effect due to activity levels. A large sample size may be requires for a trial of this nature and it is unlikely that this experiment could be run in conjunction with the requirements of the current pulse flow program. In the event that sufficient subjects could be provided, then pulse flows would have to be curtailed for the duration of the trials, as indicated above regarding consistency of flows.

6 RECOMMENDATIONS

1. More effort should be placed on trying to recover temperature loggers from radio tagged carcasses following the spawning period, and from mortalities during the study. This data will provide valuable information on the thermal history of each tagged fish's upstream migration. When compared to actual river temperatures (from temperature loggers placed at strategic locations between Comox Dam and the lower hatchery), they may provide clues to the use of thermal habitats or refuges.

2. 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.

3. Further investigate the flood channel at the lower hatchery fence (left bank) to confirm whether fish are using this channel to bypass the fence, determine the discharges required for access, and develop a plan to discourage fish from using this route.
4. Explore migration routes through Nib Falls to determine whether fish are using alternate sites for migration than the areas observed as posing some difficulty in previous studies. A fixed station at this location would provide additional data.

5. Compare the migration rate of tagged Chinook through Nib Falls using a tagged control group released upstream of Stotan Falls.

7 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; D. Epps (BC MOE) for Comox Lake temperature profile and BC Hydro for discharge data. Thanks also to Brent Mossop (BC Hydro) for drawing attention to the potential application of survival analysis

8 REFERENCES

Bengeyfield, W. and W. A. McLaren. 1994. Puntledge River gravel placement feasibility study. Global Fisheries Consultants Ltd. White Rock, B.C. and McLaren Hydrotechnical Engineering, Coquitlam, B.C. for: Environmental Resources, B.C. Hydro, Burnaby 43 p.

BC Hydro 2003. Consultative committee report: Puntledge River water use plan. Prepared by the Puntledge River water use plan consultative committee.

Castro-Santos, T. and A. Haro. 2003. Quantifying migratory delay: a new application of survival analysis methods. Can. J. Fish. Aquat. Sci. 60: 986–996.

Ecodynamic Solutions Inc. 2007. Puntledge River WUP: Steelhead Productivity Study 2007. unpublished data.

Hasler, C.T., R. Sunder, M.D. Donaldson, S.J. Cooke and E. Guimond. 2008. Puntledge River 2007 summer run chinook radio and electromyography telemetry study. Interim report prepared for BC Hydro, Burnaby, BC

Hourston, W. R. 1962. Brief outlining the need for fish protective facilities at the Puntledge River hydroelectric development. Dept. Fisheries Canada, Pac. Area, Brief presented to Dr. H. F. Angus, Commissioner, Puntledge River Inquiry, 35 p. + app.

Liddell, F.D.K. 1983. Simplified exact analysis of case-referent studies: matched pairs; dichotomous exposure. Journal of Epidemiology and Community Health 1983;37:82-84

Taylor, J.A. and E. Guimond. 2004. Puntledge River summer sun chinook radio telemetry study 2003. Prepared for: Fisheries and Oceans Canada, Habitat and Enhancement Branch, Nanaimo, B.C.

Taylor, J.A. and E. Guimond. 2006. Puntledge River 2005 summer run chinook radio telemetry study. Prepared for Fisheries and Oceans Canada, Nanaimo, BC. and BC Hydro, Burnaby, BC.

Personal Communications

Caleb Hasler University of Carleton, Ottawa, Ontario

APPENDICES

APPENDIX A: BCRP Financial Statement

Project #: 07.Pun.04

INCOME	BUDGET BCRP	BUDGET Other (Cash)	BUDGET Other (in-kind)	ACTUAL BCRP	ACTUAL Other (cash)	ACTUAL Other (in-kind)
Total by Source	$45,060.00	$0.00	$25,465.00	$45,060.00	$0.00	$25,465.00
Grand Total Income (BCRP + Other)	**$70,525.00**			**$70,525.00**		
EXPENSES						
Project Personnel						
biologist - Project Coordination	$7,200.00			$8,651.40		
Technicians	$19,600.00			$13,420.50		
Statistician	$5,194.00			$11,550.00		
DFO (Biologist)			$4,000.00			$4,000.00
DFO (Technicians)			$8,400.00			$8,400.00
Communications	$1,800.00			$1,800.00		
Material and Equipment						
Construction of fixed receiver stations	$2,500.00			$1,493.86		
Radio Transmitters	$3,150.00			$2,883.20		
Rental of Lotek receivers			$10,500.00			$10,500.00
camera, GPS rental	$300.00			$0.00		
Boat Rental			$250.00			$250.00
Misc field, safety supplies, permits	$500.00			$178.14		
Travel	$720.00			$650.25		
Adiministration						
Office space, equip, supplies						
Photocopies and printing						
Production of As-built Drawings						
Admin Fees (10%)	$4,096.00		$2,315.00	$4,062.74		$2,315.00
Total Expenses	**$45,060.00**	**$0.00**	**$25,465.00**	**$44,690.09**	**$0.00**	**$25,465.00**
Grand Total Expenses (BCRP + others)	**$70,525.00**			**$70,155.09**		
Balance (Grand Total Income - Grand Total Expenses	**$0.00**			**$369.91**		
BCRP Balance (surplus)	**($370)**					

* 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 # 07.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 in the Comox Valley Echo announcing the Puntledge River Radio Telemetry Project, August 14, 2007

Comox Valley Echo Tuesday, August 14, 2007 A3

Monitoring the success of summer Chinook migration

Do substantial increases in water flow during the summer months help Chinook salmon move above river obstacles as they go up the Puntledge River? BC Hydro is providing significant funds for two studies to find out.

The 2005 Puntledge River Water Use Plan provides for 17 two-day fish migration pulse flows throughout the year. BC Hydro provides monitoring funds to determine if they are working, and to obtain other useful information to see if modifications need to be made when the plan is reviewed.

There are two ongoing studies that focus on the five migration pulse flows in July and August that target Summer Chinook. The first study, that will take place over three seasons, will hopefully determine if BC Hydro's summer pulse flow releases are beneficial to these historically significant Puntledge River fish populations.

Using radio telemetry, Carleton University will closely monitor the movements of radio-tagged fish over the five pulse flow periods.

Historically, summer-run chinook salmon and steelhead are the only fish populations to have traveled past Nib Falls and Stotan Falls. The goal of the second study, in close collaboration with the first study, is better understand the nature of Chinook migration after the summer pulses and once they reach the Upper Puntledge River and access Comox Lake Reservoir.

"Increased spawning success can be attained if these fish reach their pre-spawning habitat in Comox Lake Reservoir and their historical spawning habitat in the Puntledge River, below the Comox Dam," says CVPWS Contract Biologist, Esther Guimond.

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. The cost of the Water Use Planning study is $90,000 per year. In addition, BC Hydro Bridge Coastal Fish and Wildlife Restoration program has provided funding to the Comox Valley Project Watershed Society with one year funding, of $45,000, to support these programs.

These partnership projects involve Fisheries and Oceans Canada, BC Hydro, Comox Valley Project Watershed Society and Carleton University.

APPENDIX D: Photos

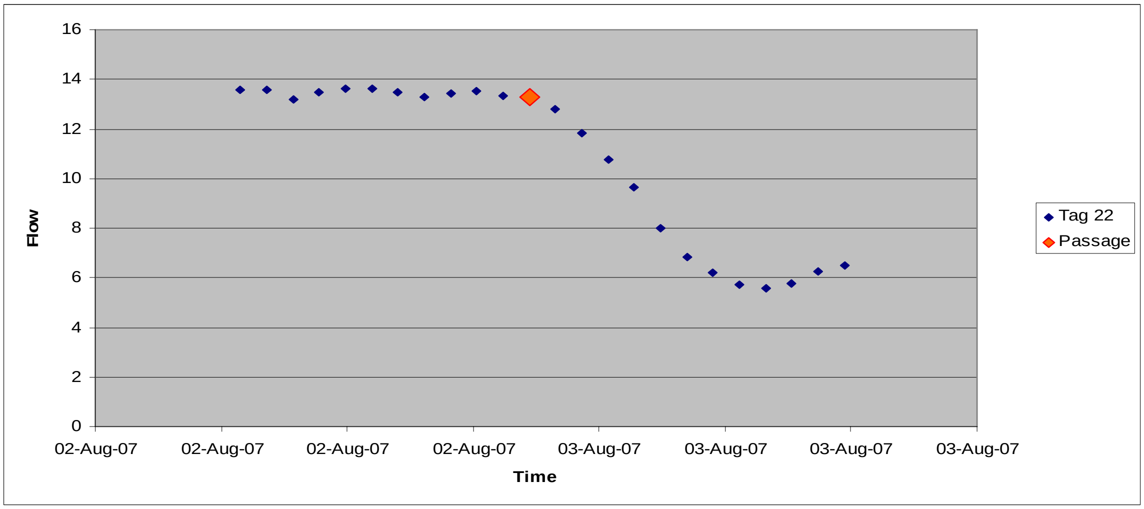
Photo 1. Conventional Lotek MCTF radio telemetry transmitters with temperature loggers attached on the end.

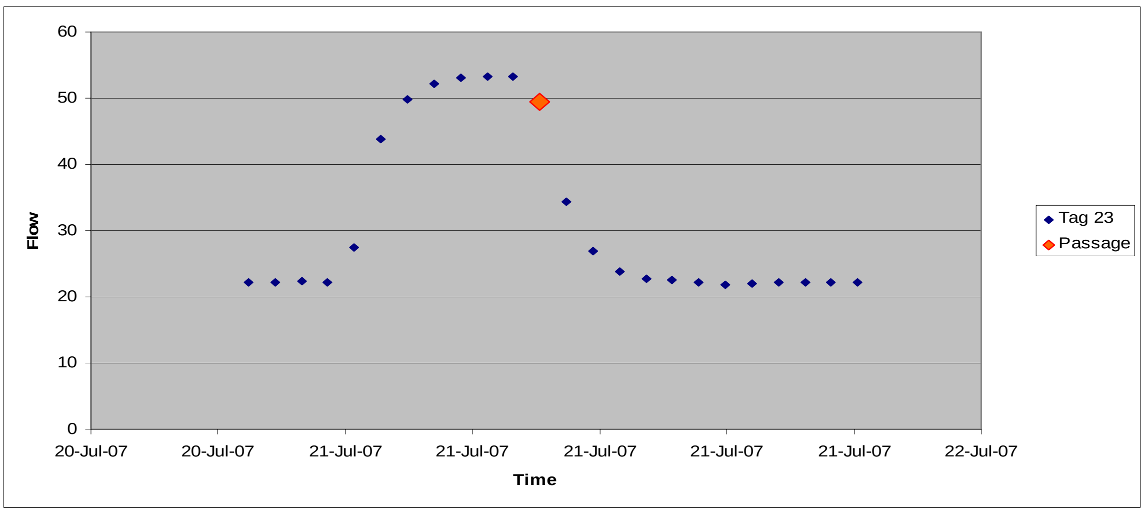
Photo 2. Collection of a blood sample via caudal puncture on a summer chinook adult prior to transmitter insertion.

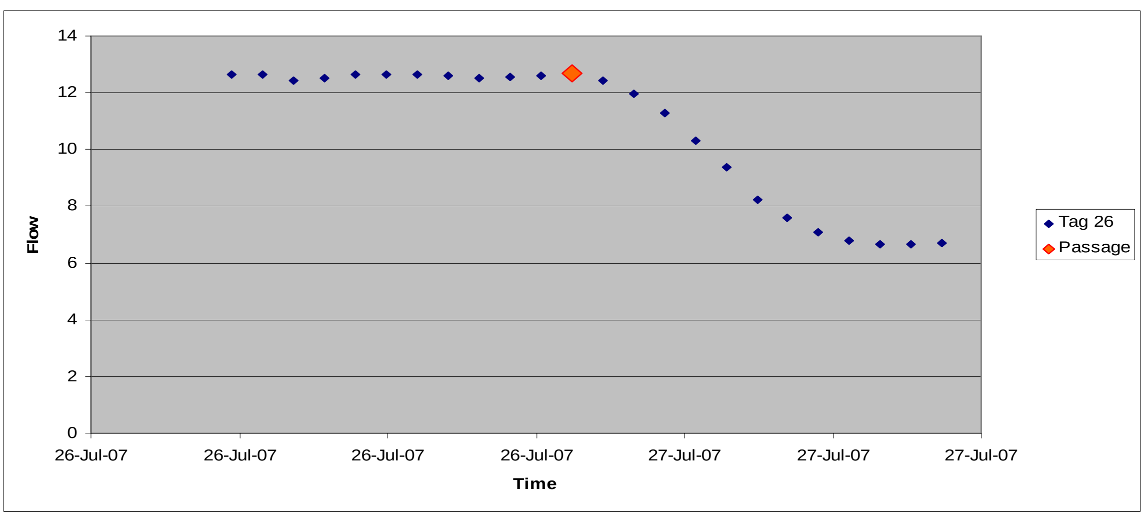
Photo 3. Radio tracking by helicopter in the Cruickshank River, October 5, 2007.

Photo 4. Recovery of an electromyogram (EMG) radio tagged chinook carcass in November 2007. Note antenna protruding from abdomen.

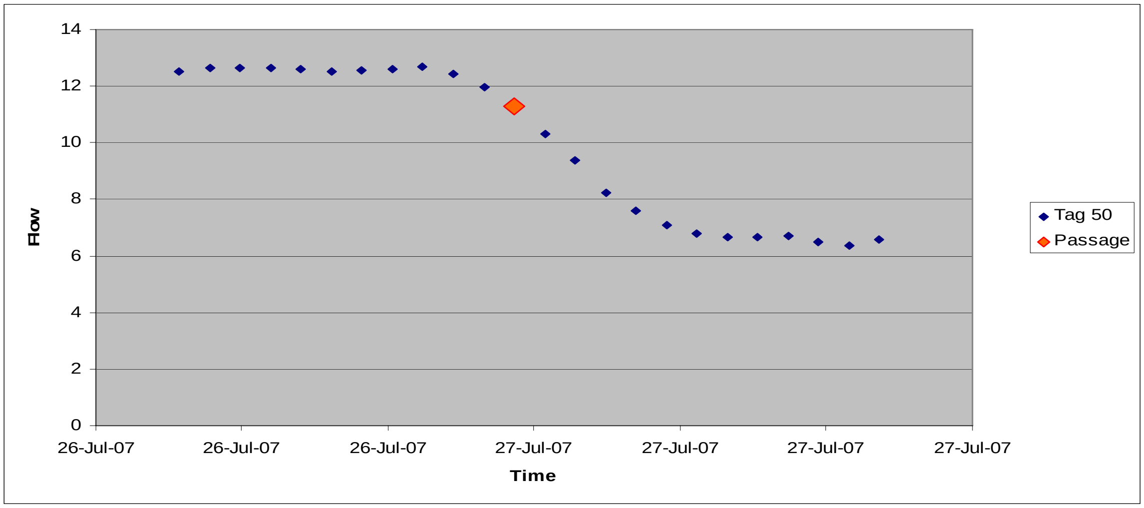
APPENDIX E. Flow (m^3/s) over the 8 hour period encompassing passage time.

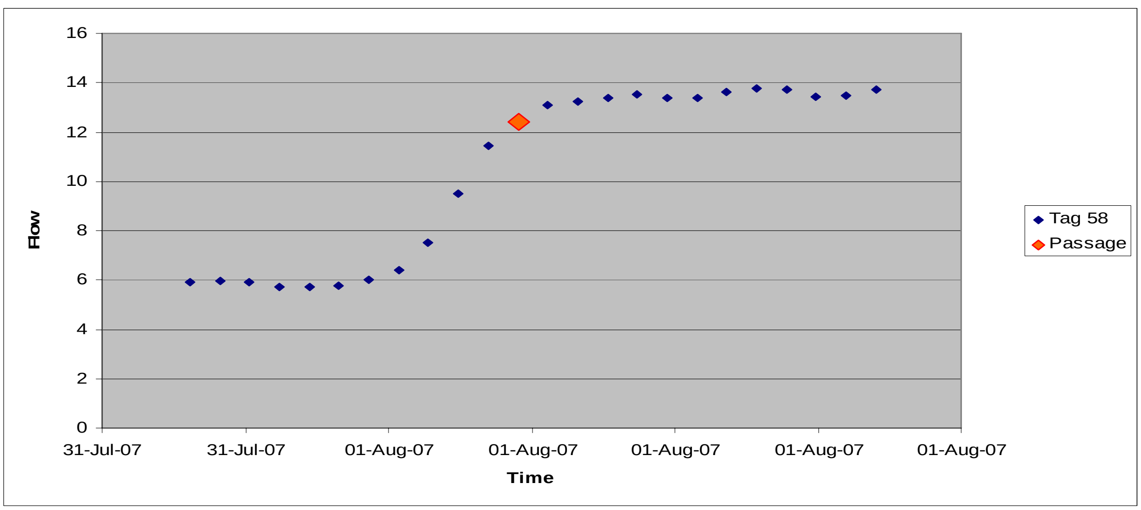




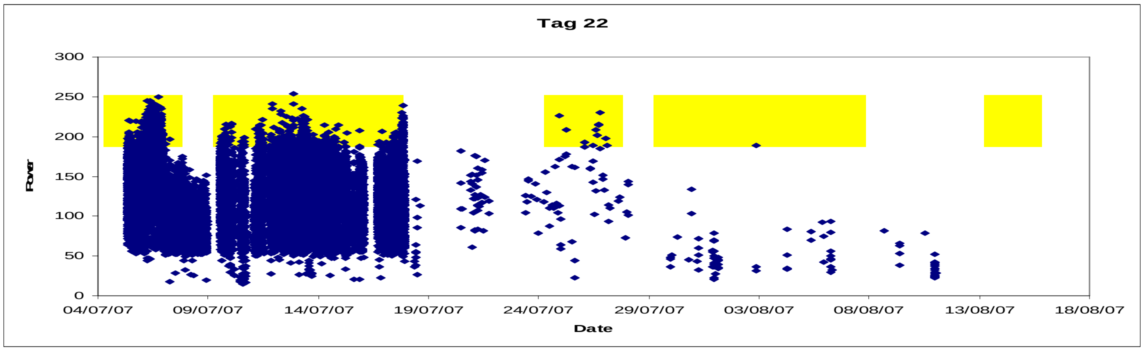


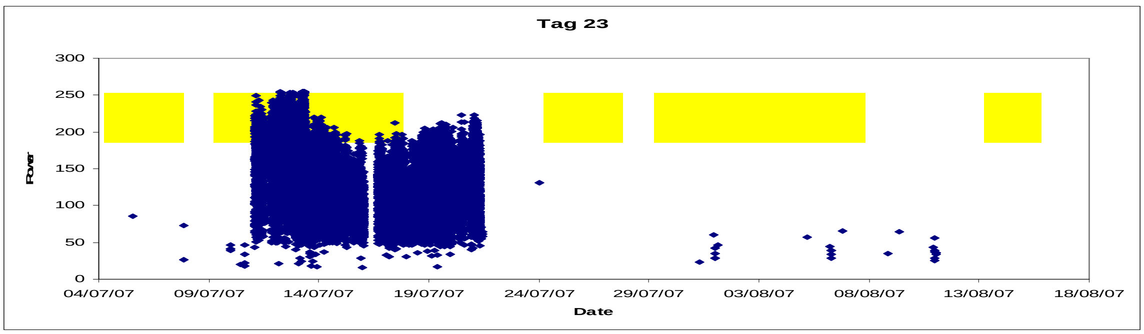
APPENDIX E Cont'd

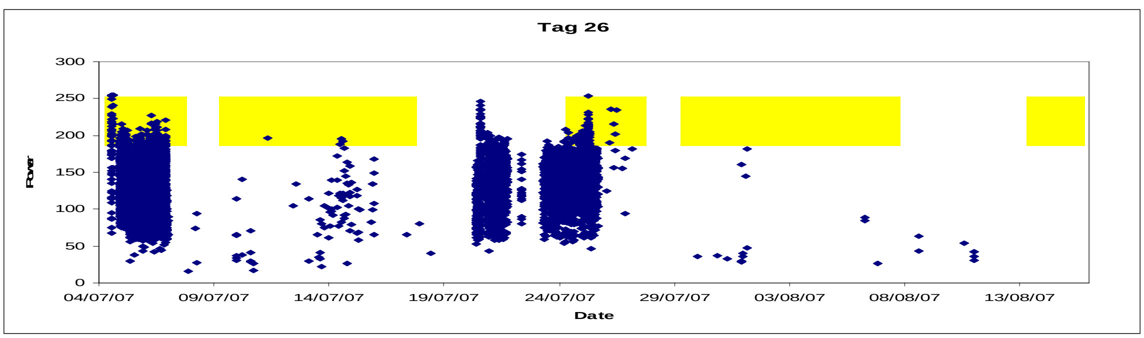


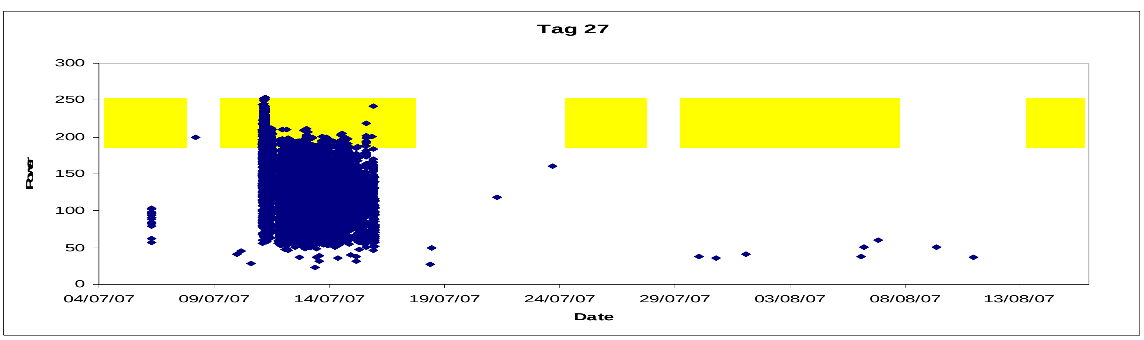


APPENDIX F. Fixed station telemetry records overlain on the incidence of contiguous days with at least 9 hours of sunshine (yellow bands).









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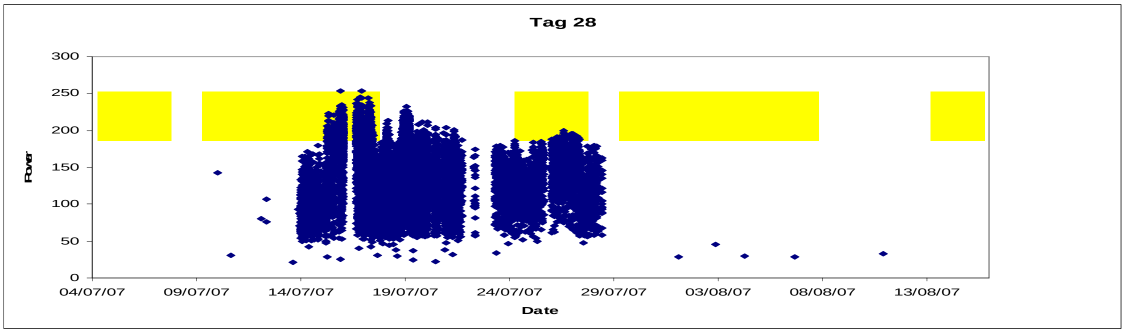

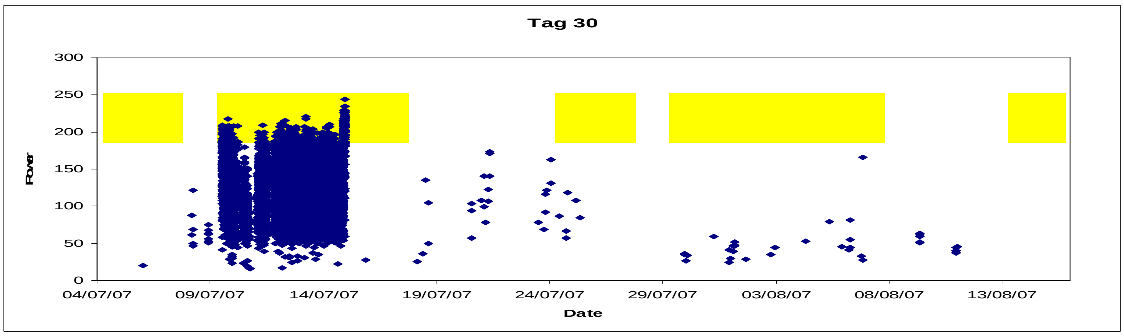

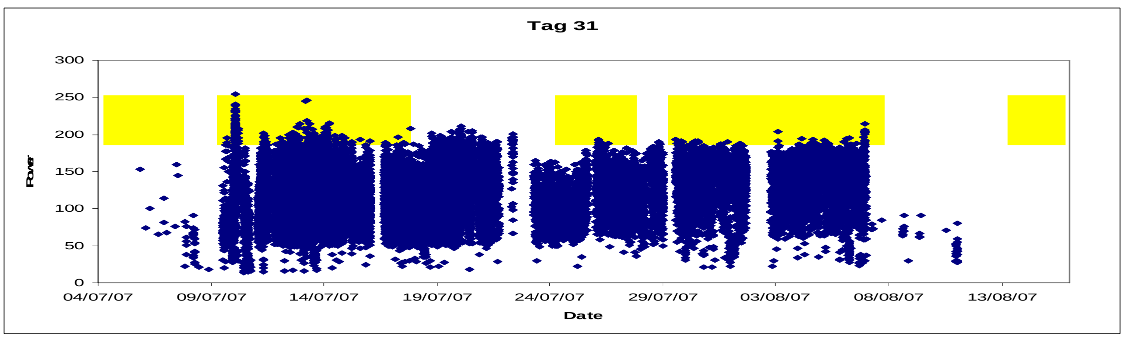

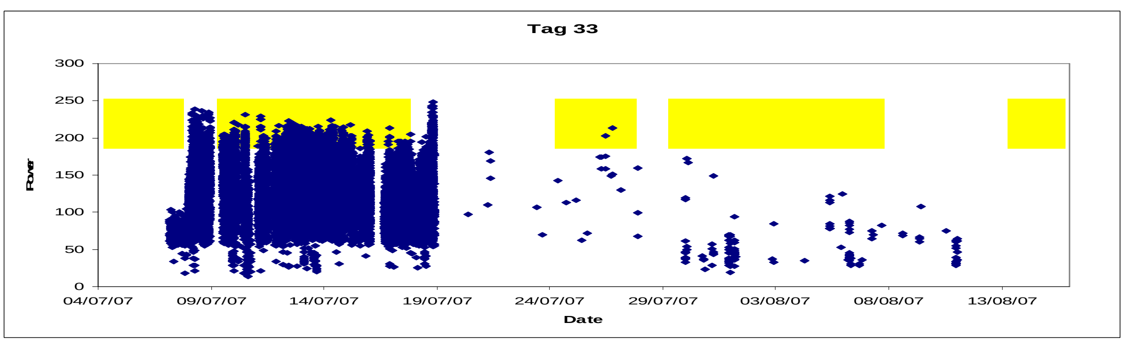

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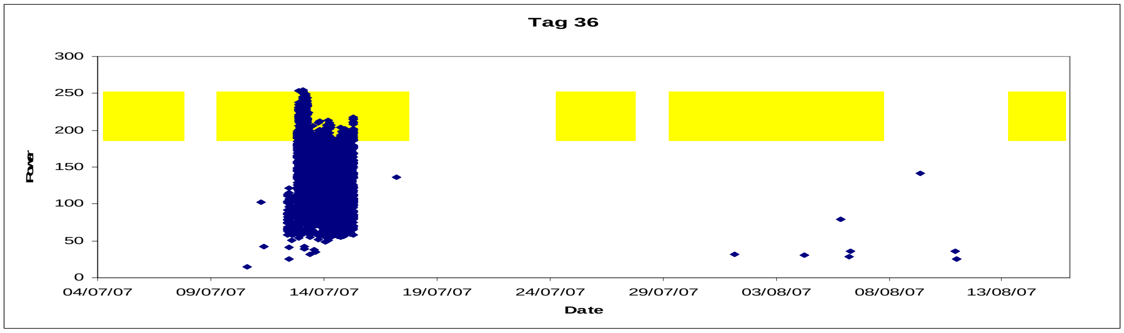

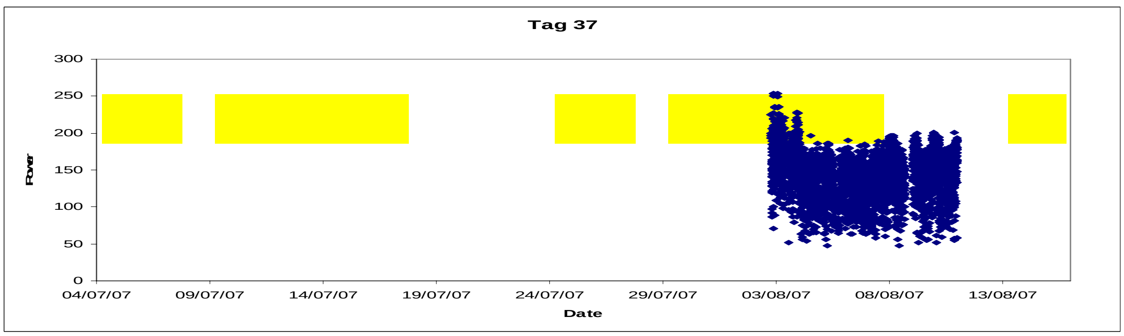

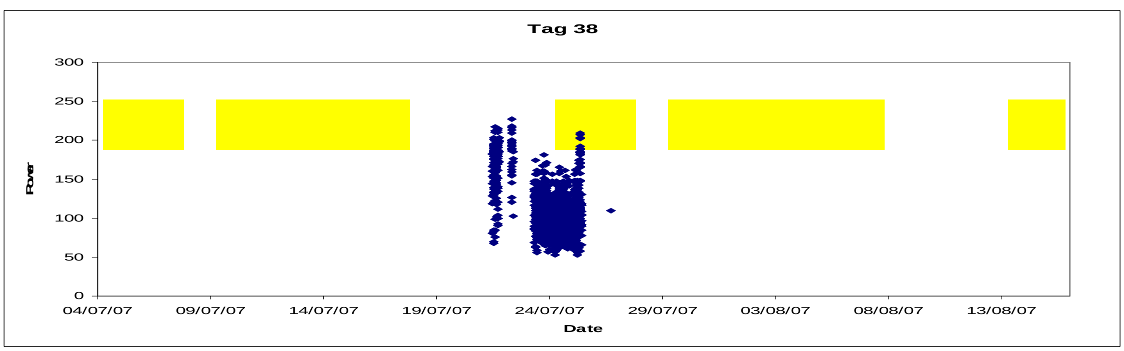

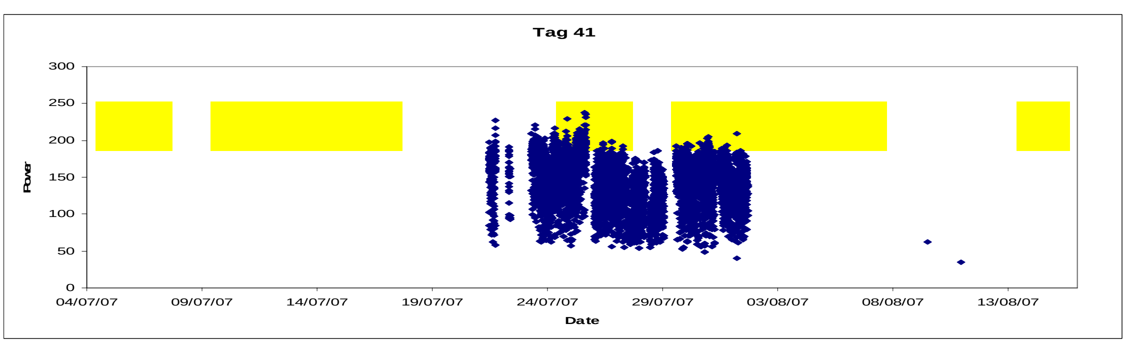

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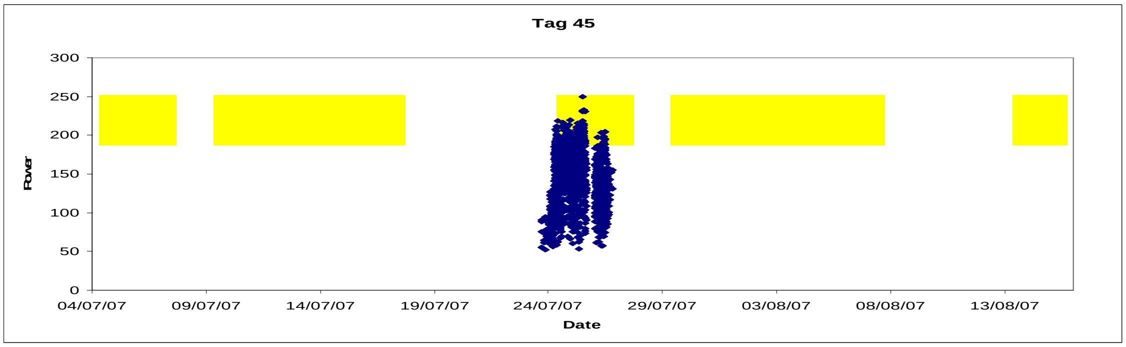

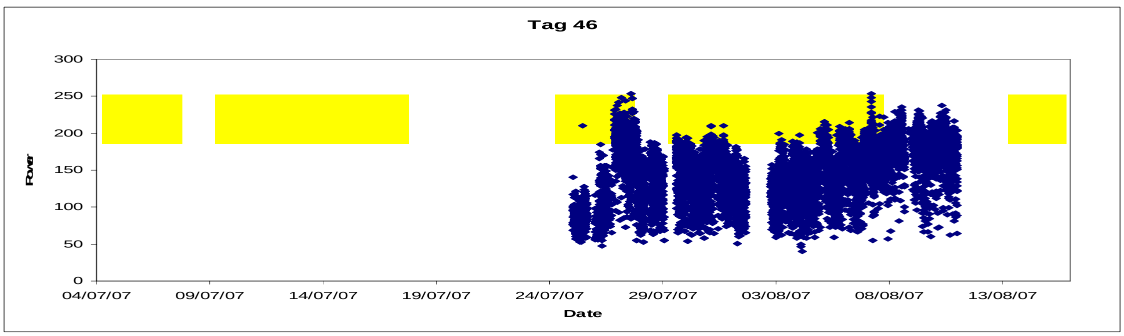

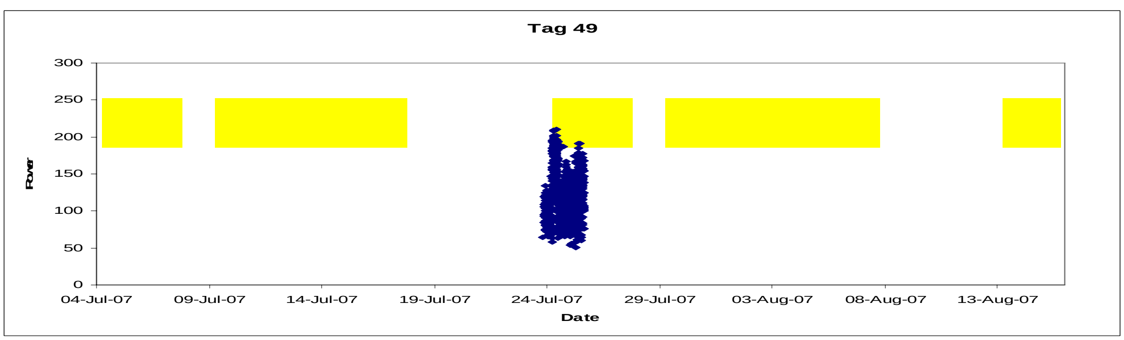

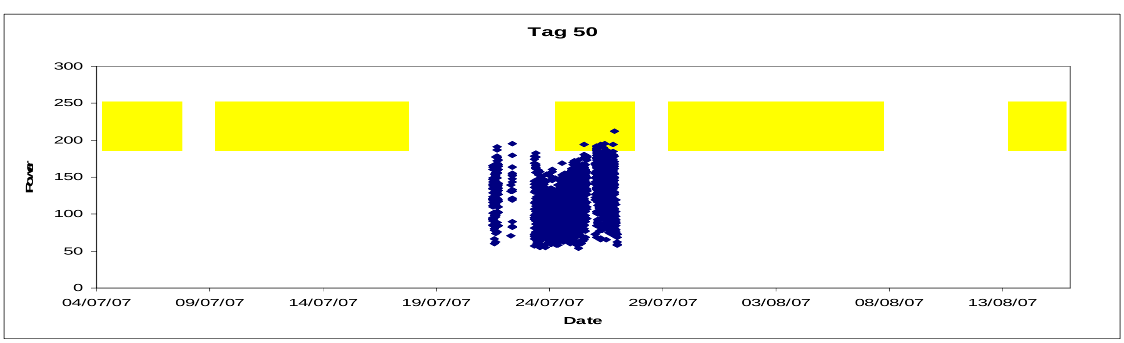

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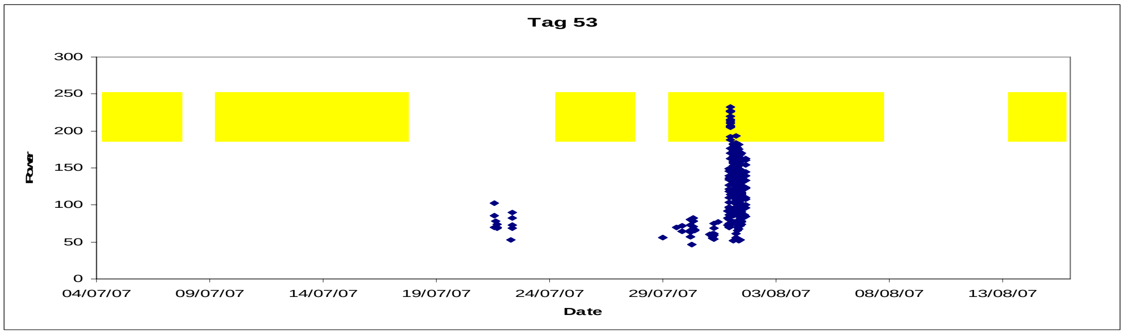

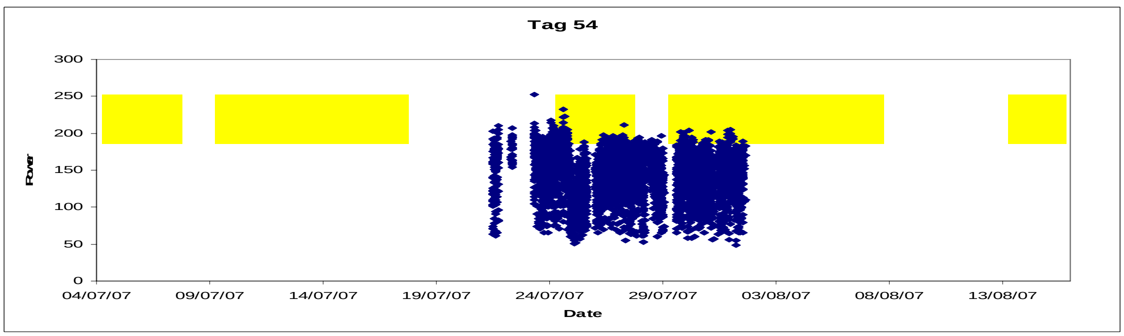

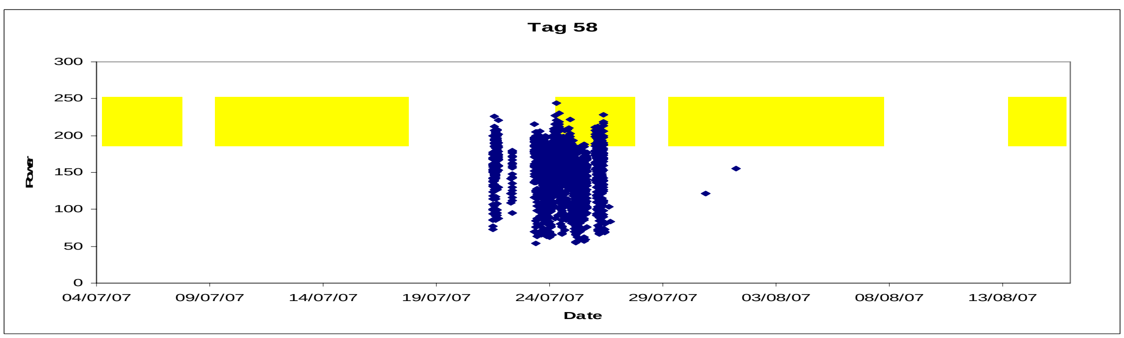

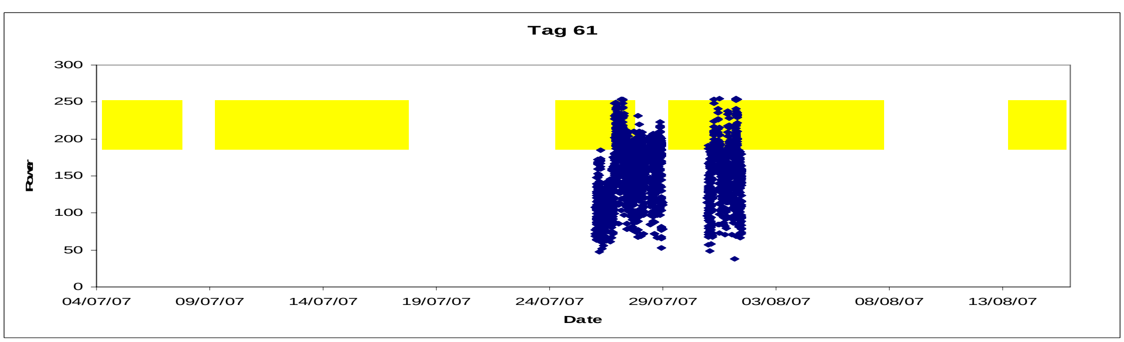

APPENDIX F Cont'd