Wahleach Project Water Use Plan

Herrling Island Chum Spawning Success Monitor

WAHMON#3

Herrling Island Chum Spawning Success Monitor

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LGL Limited

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EXECUTIVE SUMMARY

This report summarizes results from the fourth year (2008-09) of a proposed five-year program to monitor pink (*Oncorhynchus gorbuscha*) and chum (*O. keta*) salmon spawning success in the Herrling Island sidechannel on the lower Fraser River, located approximately 25 km west of Hope, British Columbia. The primary objective of the study was to assess the effectiveness of operational measures at BC Hydro’s Wahleach Generating Station (WAH GS) at minimizing spawning in marginal areas and subsequent fry stranding. A secondary objective was to assess the risk of stranding of adult spawners associated with the recommended operations. An addendum to the terms of reference recommended that post-spawning assessments of egg distribution and development be initiated in 2007-08. Water Licence requirements stipulate that under normal operating conditions the WAH GS will curtail generation to zero for a 2-h period every 24 hours between 15 September and 30 November, while at all other times the WAH GS can generate at maximum capacity.

From 13 October to 18 November 2008, spawning behaviour of chum salmon was observed at two index sites in the Herrling Island sidechannel. Peak daily counts (live + carcasses) were 360 fish at site 1 on 18 November and 20 fish at site 2 on 21 October. Low water levels in late October and early November restricted access to three spawning “fingers” in site 1 and appeared to reduce the proportion of fish spawning in marginal areas that are susceptible to dewatering. Approximately 12 chum salmon were observed spawning in a new area located downstream of site 1 on 18 November. No adult chum salmon were observed stranded at either index site in 2008. Two hydrometric stations monitored stage height and water temperature in the sidechannel from October 2008 through May 2009. Fourteen redds were identified and marked at site 1: 8 were complete, 1 was still active, and 5 were incomplete (and presumed abandoned). Six out of eight complete chum salmon redds were estimated to have dewatered at least once between egg incubation and fry emergence, while only three redds were estimated to have dewatered more than once. No chum salmon fry were observed stranded during visits to site 1 on 6 March and 23 April 2009.
INTRODUCTION

The Wahleach hydroelectric facility is part of the BC Hydro Coastal Region and is located approximately 25 km west of Hope and 100 km east of Vancouver (Figure 1). The facility came into service in 1952 and includes the Boulder Creek Diversion Dam, Jones Lake (Wahleach) Reservoir, Wahleach Dam, and Wahleach Generating Station (WAH GS). Water from Jones Lake Reservoir enters an intake structure on the west side of the reservoir and is carried through a 4.2-km long tunnel and a 500-m long penstock to the WAH GS on the south bank of the Fraser River. Additional water is supplied to the reservoir by the diversion of Boulder Creek into Jones Lake Reservoir. The Boulder Creek Diversion Dam is located 400 m east of Wahleach Dam. The WAH GS is a high-head station with a maximum sustained generating capacity of 63 MW. Historically, the Wahleach hydroelectric facility has provided an average of 245 GWh per year and contributed approximately 0.67% of BC Hydro’s hydroelectric generation (BC Hydro 2004). Discharge from the WAH GS enters the Herrling Island sidechannel of the Fraser River.

The Herrling Island sidechannel is 10 km long and located on the south (left) bank of the Fraser River approximately 25 km downstream of Hope, BC (Figure 1). The WAH GS tailrace is located 2.5 km downstream from where the Fraser River enters the sidechannel. The sidechannel is fed by water from the Fraser River during freshet (May to August), tributary streams during periods of high rainfall, groundwater, and discharge from the WAH GS (Parsonage and Leake 1999). Historical hydrometric data shows that the mean daily discharge for the Fraser River near Hope peaks in mid-June at approximately 7,000 m$^3$/s, but is typically around 2,000 m$^3$/s from mid-to-late October (Figures 2 and 3). The WAH GS typically operates to meet local peak electricity load. This results in daily fluctuations in flows in the Herrling Island sidechannel between August and May, a period when the Fraser River does not typically affect sidechannel flows except through groundwater contributions (BC Hydro 2005).

Fish species known or believed to spawn in the Herrling Island sidechannel include: chum salmon ($Oncorhynchus keta$), pink salmon ($O. gorbuscha$), coho salmon ($O. kisutch$), cutthroat trout ($O. clarki$) and white sturgeon ($Acipenser transmontanus$; Parsonage and Leake 1999). In lower Jones Creek, which drains into the Fraser River immediately upstream of the Herrling Island sidechannel, chum salmon spawn from late September to mid-December with peak spawning occurring from mid-late October (Greenbank and Macnair 2007, 2008). Chum salmon were observed spawning in the Herrling Island sidechannel from late October to mid-November in 2005, 2006, and 2007 (Smith 2006, 2007, 2008). Eggs incubate from late October through early May, and fry out-migrate from mid-March to late May. Upon emergence, chum salmon fry migrate directly to the estuary. Accumulated thermal units (ATU) used to predict the duration of incubation phases for chum salmon include: 300-350 ATU for the eyed stage, 475-525 ATU for the hatch stage, and 900-1,000 ATU for the emergent stage (Shepherd 1984). Annual chum salmon escapements in the Herrling Island sidechannel were once estimated to be between 2,000 and 10,000 adults (Hancock and Marshall 1985). Peak counts of chum salmon in the sidechannel were 279 in 2005, 304 in 2006, and 275 in 2007 (Smith 2006, 2007, 2008).

Past studies (BC Hydro 1998; McLean 1998; Parsonage and Leake 1999) have shown that fluctuations in water levels in the Herrling Island sidechannel due to operational conditions at the WAH GS may contribute to:
(1) Extensive dewatering of shallow riffles and gravel bars in the sidechannel;  
(2) Partial or full dewatering of chum salmon redds;  
(3) Stranding of spawning adult chum salmon; and  
(4) Stranding of outmigrating juvenile chum salmon in isolated pools or dewatered areas.

Figure 1. The Wahleach hydroelectric facility which includes the Boulder Creek Diversion Dam, Jones Lake (Wahleach) Reservoir, Wahleach Dam, and Wahleach Generating Station (WAH GS).
In response to these issues, the Wahleach Water Use Plan consultative process was initiated in September 2000 “to develop recommendations defining a preferred operating alternative using a multi-stakeholder consultative process” (Anonymous 2003). A Consultative Committee report and draft Water Use Plan (WUP) were submitted to the Comptroller of Water Rights in December 2003, and the Wahleach WUP was accepted and implemented in January 2005 (BC Hydro 2004). One of the recommended operational changes for the WAH GS was meant to limit
spawning use in marginal areas (i.e., those areas that are at risk to be subsequently dewatered during operations or maintenance) and therefore reduce stranding during fry out-migration. Specifically, this recommendation stipulated that from 15 September to 30 November, BC Hydro would curtail generation at the WAH GS to zero for a two-hour period every twenty-four hours. At all other times, BC Hydro could generate at maximum capacity and there was no constraint on the rate of change of flow from the powerhouse.

The potential effectiveness of these operational changes was uncertain because the behavioural response of spawners to flow reductions was poorly understood. As a result, the Consultative Committee recommended that all operational changes be monitored for their effectiveness (BC Hydro 2005). It was hypothesized that the amount of salmon habitat would decrease in the Herrling Island sidechannel as a result of decreased flows through the WAH GS; however, spawning success (as measured by egg-to-fry survival) was expected to increase as a result of the operational changes. Management questions pertaining to the potential affects on salmon and their habitat in the Herrling Island sidechannel that needed to be addressed included:

(1) Will the recommended operational measures keep spawning away from marginal areas?
(2) Will the operational measures in the fall result in stranding of adult spawners?
(3) Will the operational measures in the fall result in minimal fry stranding in the spring?

Based on these management questions, it was proposed that the following hypotheses be tested in relation to the effectiveness of the recommended operational measures:

(1) H₁: Suspending Wahleach generation for 2 h daily during the spawning period does not deter spawning in marginal areas;
(2) H₂: Suspending Wahleach generation for 2 h daily during the spawning period does not result in stranding of spawning adults; and
(3) H₃: Suspending Wahleach generation for 2 h daily during the spawning period does not eliminate fry or redd stranding caused by operations.

The primary objective of this study was to assess the effectiveness of the WAH GS operational measures at minimizing spawning in marginal areas and subsequent fry stranding in the Herrling Island sidechannel. A secondary objective was to assess the risk of stranding of adult spawners associated with the recommended operations. To meet these objectives, three study components were utilized for this monitoring program. The behavioural response of adult spawners was monitored before, during, and after daily outages at index sites within the Herrling Island sidechannel. An adult stranding risk assessment was conducted by monitoring the area of habitat dewatered or cut off from mainstem flow due to WAH GS operations, the number of spawners stranded in affected habitat, and the rate of stage change at each index site as related with stranding risk. And lastly, a redd and fry stranding assessment was conducted using water level data collected at hydrometric stations and redd depths measured at the index sites.

In the first year of this study (2005), chum salmon were observed spawning at two main sites within the Herrling Island sidechannel between 24 October and 16 November (Smith 2006). During WAH GS outages, eight chum salmon were found stranded in dewatered areas within the sidechannel and 21 chum salmon were found stranded in isolated pools. Forty-six percent (n = 35) of redds were estimated to have dewatered at least once. In 2006, high inflows into the
sidechannel from 3-11 November combined with historic lows on the Fraser River in October may have confounded results from the redd and fry stranding portion of the study (Smith 2007). Chum salmon were observed from 30 October to 20 November 2006. Two adult chum salmon were observed stranded in a dewatered area during a WAH GS outage, and 88% of completed redds were estimated to have dewatered at least once prior to emergence. In September 2007, 15 pink salmon were observed stranded in dewatered areas during a WAH GS outage. At the same time, pink salmon were observed abandoning their redds as water levels decreased; and fish returned to these marginal areas once WAH GS discharges were restored.

Key measures to describe adult spawning behavioural responses to WAH GS outages proved difficult to ascertain from 2005 to 2007 due largely to observer limitations, water conditions, and high spawning densities at the index sites. As a result, an addendum was made to the terms of reference of this monitoring program in December 2007 recommending that additional assessments and mapping of pink salmon egg distribution take place after peak spawning periods for the 2007 and 2009 runs. Relative to direct observation of spawning adults, embryo sampling has the potential to better assess whether WAH GS operational changes result in lower spawner densities in marginal habitats than in stable habitats. On 22 January 2008, pink salmon embryos (471 alevins and 1,196 dead eggs) were sampled using a hydraulic sampler in different elevation bins along two transects at a site located 1.5 km downstream of the WAH GS. Embryos were found in the highest elevation bins along the right bank of the sidechannel indicating that WAH GS operations did not prevent spawning in marginal areas. However, due to small sample sizes in each elevation bin, large variability in the number of embryos collected at each site, and sampling for embryos several weeks after eggs hatched, it was difficult to determine whether WAH GS operations affected the distribution or success of pink salmon spawning in 2007.

This report summarizes results from the fourth year (2008-09) of a proposed five-year monitoring program.

**METHODS**

LGL Limited (Sidney, BC) partnered with the Cheam First Nation (Rosedale, BC) to conduct the Fall 2008 field work and complete four primary tasks:

1. Monitoring the behavioural response of chum salmon before, during and after WAH GS outages at the index sites;
2. Recording the total area of spawning habitat either dewatered or cut off from the mainstem flow due to WAH GS operations;
3. Recording the number of stranded spawners in the affected habitat; and
4. Monitoring the wetting of redds using recorded water levels data and tracking known redd elevations.

**Index Sites for Monitoring Salmon**

Adult chum salmon were monitored at two index sites in 2008 (Figures 4 and 5). These sites were monitored in 2005, 2006, and 2007, and were initially selected based on information collected during earlier BC Hydro field studies (BC Hydro 1998; McLean 1998; Parsonage and Leake 1999).
Figure 4. Aerial photograph of the Herrling Island sidechannel showing the Wahleach Generating Station (WAH GS), two hydrometric stations, and two index sites used to monitor chum salmon spawning activity in 2008-09.
Figure 5. Location of chum salmon redds observed at site 1 in the Herrling Island sidechannel from 21 October to 18 November 2008. Six temporary staff gauges (rebar 1-6) and a new chum salmon spawning area are also shown.

Hydrometric Data

Fraser River at Hope

Hourly Fraser River stage height and discharge data was collected at a gauging station near Hope, BC, from September 2008 through May 2009 (Lauren Wick, Environment Canada, personal communication).

Herrling Island Sidechannel

As part of a separate contract with BC Hydro, Via-Sat Data Systems, Inc. (North Vancouver, BC) installed and operated two hydrometric stations in the Herrling Island sidechannel (Figure 4). The uppermost station (station 1) was located on the left bank approximately 2.5 m
downstream from the inlet of the sidechannel and 50 m upstream from WAH GS tailrace. The lowermost station (station 2) was located on the left bank approximately 2.5 km downstream from the WAH GS tailrace. Each hydrometric station consisted of a Model PT2X pressure transducer (0-5 PSI) from Instrumentation Northwest Inc. (Kirkland, WA). The pressure transducers logged water level and water temperature at 15-min intervals. Water levels at each station were referenced to local datum (pressure transducer) as 0.000 m. Locations were selected in consideration of vandalism avoidance, effectiveness through ranges of expected water levels, and stability. Raw data collected from the stations is stored digitally at BC Hydro.

Water level in site 1 was also recorded at six temporary staff gauges (1.3 cm dia. rebar) located in each of the three spawning fingers (Figure 5).

Discharge at the Wahleach Generating Station

Hourly discharge (m$^3$/s) from the WAH GS was recorded from October 2008 through May 2009 (Dave Hunter, BC Hydro, personal communication).

Adult Spawning Behaviour Observations

The initial goal of this assessment was to observe spawning behaviour over a minimum of 10 consecutive days and over a continuous 10-h period each day (~1700-0300 hours) during the 2-week peak spawning period at each index site. Typically, peak load discharge from the WAH GS drops off around 2200 hours nightly, which should have coincided with the planned 2-h WAH GS outage. Given this scenario, daily observations would describe the effects of an outage from 2200 to 0000 hours. This plan allowed 3 h for water levels in the sidechannel to recede and stabilize, and an additional 2 h for monitoring while the WAH GS discharges were restored.

However, during the 2008 field study, WAH GS outages typically occurred during the day (~1200-1500 hours), and thus the sampling schedule had to be adjusted accordingly. Attempts were made to visit the index sites prior to the daily outage, observe spawning behaviour at a site as water levels dropped, and then re-visit each index site during the outage and before WAH GS discharges were restored.

Adult spawners were enumerated at each site before and during WAH GS outages and their specific activity (migrating, holding, spawning) and location (thalweg, left/right bank) were documented. Each redd received a unique identification code (date-site-#, GPS location) and was marked with a flag-taped rock. Redds were measured for depth before and during the WAH GS outage and described based on their status (false, partial, full) and composition (sand, gravel, cobble). Redd depths were measured from the substrate surface at the lowest point in the redd pit to the water surface (Figure 6). Additionally, the river depth of the undisturbed substrate adjacent to reds was measured. The crew also tried to estimate the amount of dewatered area and area cut-off from mainstem flow during outages. Results from this assessment were intended to test the hypothesis (H$_1$) that suspending Wahleach generation for 2-hours daily does not deter spawning in marginal areas.
Figure 6. Schematic of a redd depicting the location of egg pockets in the gravel matrix. Redd depth was measured from the water line to the river substrate at the deepest section of the redd pit. Undisturbed bed depth was measured from the water line to the river substrate at a location near the redd that has not been influenced by spawning activity.

Pink salmon do not return in significant numbers to the Fraser River during even-numbered years so no egg distribution mapping was conducted in 2008. Egg distribution mapping was not conducted on chum salmon in 2008 due to low spawning densities and the absence of sites where redds at different elevation bins could be sampled.

Adult Stranding Risk Assessment

During low-water conditions following WAH GS outages, the crew documented the number of adult salmon found in isolated pools or dewatered areas at each index site. The condition (live, pre/post-spawn moribund, pre/post-spawn mortality) and location of stranded fish was recorded. Results from this assessment were used to test the hypothesis (H2) that *suspending Wahleach generation for 2-hours daily does not result in stranding of spawning adults*. Analysis of these data was qualitative based on the incidence of pre-spawn or recently spawned adults that were stranded due to WAH GS operations. Since moribund adults are susceptible to stranding they were not considered representative of the target population of this study and thus were excluded from this assessment. Adult stranding assessments were only required in the first two years of this study (2005/06); however, related observations were documented in 2007 and 2008.

Redd and Fry Stranding Assessment

River bed and redd depths collected during the spawning behaviour monitoring assessment were tracked against water level recordings from the hydrometric stations operated in the sidechannel. Results from this assessment were used to test the hypothesis (H3) that *suspending Wahleach generation for 2-hours daily does not eliminate fry or redd stranding caused by operations*. For each redd identified at the index sites that was measured for depth on more than one occasion, the following analyses were performed:
(1) Redds were classified as complete, active, or incomplete. A redd was complete if fish were observed spawning and/or there was evidence over consecutive site visits that the redd pit had been filled in. Active redds were ones where spawning was still occurring or fish were still present on a redd but the pit had not yet been filled by the end of the sampling period. A redd was classified as incomplete if the pit was not filled in and consecutive site visits indicated no further spawning activity.

(2) A redd was considered dewatered when the undisturbed bed depth was zero. By this definition, eggs in a dewatered redd were not necessarily exposed to air. Stage height of the sidechannel where individual redds dewatered was estimated using one of two methods:
   a. Regression analyses of paired bed depth and water level measurements collected before and during WAH GS outages; or
   b. If a redd was observed dewatered during field observations, stage height at the hydrometric station at the corresponding time was used.

(3) The frequency of dewatering events was calculated as the number of times during the incubation and emergence periods when the stage height at a particular hydrometric station was at or below the depth where a redd was considered dewatered.

(4) The duration of dewatering events was calculated as the length of time in hours that each dewatering event lasted; and

(5) The extent of redd dewatering was determined based on timing – dewatering events were categorized as either egg stranding during incubation (October 2008 – 31 March 2009) or fry stranding over emergence (1 April – 5 May 2009). These periods were based roughly on outmigration data for pink and chum salmon fry in nearby Jones Creek (Macnair 2005; Greenbank and Macnair 2007, 2008).

RESULTS

Hydrometric Data

Fraser River at Hope

From 1 October 2008 to 15 May 2009, discharge of the Fraser River at Hope ranged from 601 to 4,732 m³/s and stage height ranged from 2.97 to 6.34 m (Figure 7). Fraser River stage height was below average in October and early November 2008, at or slightly above average through mid-December, and for the most part lower than average through mid-April (Figure 8). Stage height increased dramatically and was above average from mid-April to mid-May 2009. Based on the findings of Parsonage and Leake (1999), the only period when the Fraser River exceeded 4.96 m at Hope and directly influenced water levels in the sidechannel occurred during emergence from 21 April through May 2009.
Figure 7. Stage height and discharge of the Fraser River at Hope, BC, from 1 October 2008 to 15 May 2009. The dashed line indicates the stage height (4.96 m) above which Fraser River discharge directly influenced water levels in the Herrling Island sidechannel in 2006.

Figure 8. Stage height of the Fraser River at Hope, BC, from 1 October 2008 to 15 May 2009 relative to historical data (Environment Canada 2009).
Herrling Island Sidechannel

From 1 October 2008 to 5 May 2009, stage height of the Fraser River in the Herrling Island sidechannel ranged from 0.02 to 1.14 m at station 1 and -0.01 to 1.52 m at station 2 (Figure 9). Average daily water temperatures ranged from 1.7 to 12.9 °C at station 1 and from 1.1 to 12.3 °C at station 2 (Figure 10). Water levels at temporary staff gauges in the first and second fingers (rebar 1-5) of site 1 were relative insensitive to changes in water level recorded at hydrometric station 1, particularly when water levels at station 1 were less than 0.6 m (Figure 11).

Figure 9. Hourly stage height of the Fraser River measured at two hydrometric stations located in the Herrling Island sidechannel from 1 October 2008 to 5 May 2009.

Figure 10. Average daily water temperature of the Fraser River measured at two hydrometric stations located in the Herrling Island sidechannel from 1 October 2008 to 5 May 2009. Accumulated thermal units (ATUs) at station 1 from 13 October to 5 May are also shown.
Figure 11. Water level and wetted width at six temporary staff gauges located in the three spawning fingers of site 1 relative to water level at hydrometric station 1, 2008-2009.

Discharge at the Wahleach Generating Station

Discharge at the WAH GS ranged from 0.0 to 12.8 m³/s between 1 October 2008 and 15 May 2009 (Figure 12). Extended periods of WAH GS outages occurred from 2-8 October (128 h), 9-14 October (101 h), and 24-27 October (58 h), just prior to the main arrival of chum salmon in the spawning fingers. Water levels in the spawning fingers were noticeably lower during WAH...
GS outages on 21 October (Photos 1-4). WAH GS outages from 1-3 November (62 h), and 15-17 November (48 h) occurred during the main spawning period. During emergence from 1 April to 15 May 2009, the WAH GS operated for only 12 h (5-6 April).

![Discharge graph](image)

Figure 12. Discharge at the Wahleach Generating Station (WAH GS) from 1 October 2008 to 15 May 2009.

**Adult Spawning Behaviour Observations**

**Site 1**

During the first field visit on 13 October 2008, four live chum salmon were observed in relatively deep water at the lower end of site 1 (see Appendix A for a summary of field observations). Moderate numbers of chum salmon were observed at the lower end of site 1 during subsequent visits on 17 October (14 fish), 21 October (43 fish), and 4 November (175 fish). Chum salmon counts at site 1 peaked at 360 fish on 18 November.

Access to the three spawning fingers was limited during low water prior to 4 November, particularly during WAH GS outages (Figure 13; Photo 5). The accumulation of gravel at the mouth of a small tributary at the lower end of site 1 may also have hindered access to the spawning fingers (Photos 6 and 7). No chum salmon were observed in the spawning fingers until 4 November. The proportion of fish observed in the spawning fingers increased from 0% on 21 October (0 of 43) to 36% on 11 November (90 out of 250) and 64% on 18 November (230 out of 360).

On 18 November, 12 chum salmon were observed spawning along the left bank of the sidechannel approximately 50 m downstream of site 1 and 300 m upstream of the WAH GS outlet (Figure 5). No fish were observed at this location in the previous three years. Redd depths
ranged from approximately 34-60 cm; however, it was difficult to identify individual redds (or count fish) due to the depth at this site.

The only noticeable change in behaviour during WAH GS outages occurred on 11 November when four chum salmon were observed swimming downstream from the third spawning finger to the tailrace pool as water levels decreased (Photo 8). At the same time, three partial redds were observed in the third spawning finger, presumably abandoned due to the drop in water level.

Site 2

On 21 October, approximately 20 fish were observed spawning at site 2 near the mouth of an unnamed creek that drains into the sidechannel along the left bank (Photo 9). As in previous years, fish at this site were actively spawning in water greater than 50 cm deep and the redds were not at risk of dewatering.

WAH GS Tailrace

No chum salmon or redds were observed in the immediate vicinity of the WAH GS tailrace on 21 October.

![Stage height and discharge graph](image)

Figure 13. Stage height of the Fraser River at Hope, stage height of the Herrling Island sidechannel (stations 1 and 2), and WAH GS discharge from 13 October to 20 November 2008.

**Adult Stranding Risk Assessment**

No adult chum salmon were observed stranded at sites 1 or 2 in 2008.
Redd and Fry Stranding Assessment

Fourteen chum salmon redds were identified at site 1 on 21 October (2 redds) and 11 November (12 redds; Figure 5; Appendix B). Of these, eight were classified as complete, one was still active when last observed, and five were incomplete (presumably abandoned prior to completion). One of the incomplete redds was observed dewatered during the WAH GS outage on 21 October.

Of the eight complete redds, six were located in the first (left bank) spawning finger and two were in the middle spawning finger. None of the complete redds were observed dewatered (i.e., bed depth = 0.0 m) in the field. Pit depths ranged from 0.10 m to 0.30 m and bed depths ranged from 0.06 m to 0.21 m. Weak linear relationships (based on only 3 data points) between water levels at station 1 and bed depths were used to estimate the water level at station 1 where each redd was predicted to dewater (Appendix C). Based on these data, six out of eight (75%) complete redds were estimated to have dewatered at least once, while only three out of eight (37.5%) were estimated to have dewatered more than once (Figure 14). Amongst the six complete redds that dewatered at least once, there were a total of 169 dewatering events: 126 (75%) during egg incubation and 43 (25%) during fry emergence (Figure 14). Redds dewatered 5 to 90 times during egg incubation and 1 to 23 times during fry emergence (Figure 15). The cumulative length of time that individual redds were dewatered ranged from less than 1 h to 1,482 h.

In the spring of 2009, two visits were made to site 1. On 6 March, water levels in the sidechannel were low (mean = 0.554 m at station 1) and the WAH GS discharged at an average of 8.5 m$^3$/s (Photo 10). Fourteen live fry (presumably chum salmon) were observed at the lower end of site 1. There was no evidence of redd or fry stranding, and there was open access to the tailrace pool from the three spawning fingers for outmigrating fry. On 23 April, water levels were extremely high (mean = 0.741 m at station 1) and visibility was poor as the sidechannel was heavily inundated by surface flows from the Fraser River (Photo 11). No fish were observed during this visit.

![Graph of redd ID and number of dewatering events]

Figure 14. Frequency of dewatering events for eight complete chum salmon redds that were monitored at site 1 from egg incubation (Nov/08) through fry emergence (May/09).
DISCUSSION

Adult Spawning Behaviour Observations

Several steps are involved in the process of spawning, including the selection of a redd site, site preparation, courtship behaviour, egg release and fertilization, egg burial, and defending the redd. Depending on their timing, flow fluctuations may influence one or more of these spawning stages. The life expectancy of a chum salmon once it reaches the spawning grounds was 8.8-15.2 d in Big Beef Creek, Washington (Koski 1975) and 7-10 d in the lower Columbia River (Tiffan et al. 2005). The life expectancy of female pink salmon averaged 10.8 d (range: 6.6-20.6 d) in Sashin Creek, Alaska (McNeil 1962) and was less than 15 d in Lake Creek, Alaska (Fukushima and Smoker 1998). However, it may take only 30-40 h to complete a chum salmon redd that can contain 4-6 nests (Helle 1981; Schroder 1982; Tautz and Groot 1975). Since fish can begin the spawning process in a relatively short time period (i.e., less than a day), and new fish may arrive daily on the spawning grounds over most of the run, it is reasonable to expect that daily flow fluctuations will not prevent the development of redds in marginal areas. Although daily flow fluctuations do not completely prevent the development of redds in marginal areas, they may reduce the level of redd development and associated egg deposition.

In late October and early November 2008, water levels at site 1 in the Herrling Island sidechannel were low due to lower than average Fraser River water levels combined with extended periods of WAH GS outages (Figure 13). Low water levels in the sidechannel influenced chum salmon spawning behaviour in several ways. First, access to the spawning fingers at site 1 was relatively restricted until early November (Photos 1-8), so the first fish were not observed in the spawning fingers until 4 November. Similar water conditions were observed in 2006 (Smith 2007). Second, prior to 18 November, the majority (64-100%) of chum salmon were observed spawning in deeper areas at the lower end of site 1 and thus avoided spawning in marginal areas along the fringes of the spawning fingers. The spawning behaviour of fish in
these deeper areas did not appear to change significantly during WAH GS outages. And third, chum salmon were observed spawning in a new area located downstream of site 1, presumably because access to their primary spawning area was restricted during low water (Figure 5). The substrate (largely sand and rock) in this new area was not ideal for chum salmon spawning.

The only time fish behaviour was noticeably affected by a WAH GS outage occurred on 11 November when four chum salmon were observed with their backs exposed to air as they swam downstream and away from their partial redds in the third spawning finger (Photo 8).

**Adult Stranding Risk Assessment**

No adult chum salmon were observed stranded in the sidechannel in 2008. At both sites 1 and 2, there was very little risk of adult stranding during WAH GS outages because the majority of fish spawned in deeper water.

**Redd and Fry Stranding Assessment**

It was difficult to determine whether suspending WAH GS discharge for 2 h or more daily eliminated redd or fry stranding in 2008-09. Low water levels in the sidechannel in late October and early November were the result of low water levels in the Fraser River combined with periods of WAH GS outages. These conditions restricted access to the spawning fingers and reduced the proportion of fish spawning in the marginal areas of site 1. This was supported by the fact that only three out of eight (37.5%) complete redds were estimated to have dewatered more than once from egg incubation through fry emergence (Figure 14). In addition, no (complete) redd or fry stranding was observed in the field during visits to site 1 in October/November 2008 or March/April 2009.

Potential impacts of flow fluctuations on the developmental phases of salmon will vary with the timing, magnitude, and duration of the fluctuations as well as with characteristics of the affected site. Water-level reductions over a salmonid redd may cause a cessation of inter-gravel flow and drainage of water from gravel, changes in water temperature, desiccation, reduced dissolved oxygen concentrations, settling of gravel, and increased concentration of biotic wastes (Neitzel and Becker 1985). Studies have shown that incubating salmon eggs are considerably more tolerant of dewatering than alevins that have not yet emerged from the substrate (Becker et al. 1982; Becker et al. 1983; Neitzel and Becker 1985). McMichael et al. (2005) reported that Chinook salmon (*O. tshawytscha*) redds could be expected to tolerate dewatering periods as long as 8 h, whereas fry survival would be expected to be significantly impacted if redds were dewatered for even 1 h. Given the relatively low frequency and short duration of dewatering events for the majority of complete redds monitored in 2008-09, it is reasonable to assume that the dewatering events did not significantly impact the survival of eggs and emerging fry.

There are several potential sources of uncertainty in the redd and fry stranding assessment. The relationship between water levels at station 1 and water levels at site 1 was assumed to be linear. This was not necessarily the case, as water levels in the spawning fingers appeared to be buffered from changes in water levels observed at station 1 (particularly when station 1 measured less than 0.6 m; Appendix C). This was likely due to the input of sub-surface water from the Fraser.
River and upwelling, which is typical of preferred chum salmon spawning habitat (Salo 1991). In addition, only three data points collected on two different days (11 and 18 November) were used to estimate the relationship between water levels at station 1 and bed depths at site 1.

As in previous years, it was more difficult to locate, mark, and sample redds in deep water (i.e., greater than 45 cm) than in shallow water. Since redds located in deep water were less likely to dewater than redds in shallow water, the redds used in the dewatering analysis were not likely representative of all redds in the index site. The sampled redds were likely biased “shallow” and thus the frequency (and duration) of dewatering events was likely biased high (and long).

Attempts were made in the spring of 2009 to visit site 1 during low water conditions when redd or fry stranding might be observed. Although Fraser River water levels were low during the 6 March visit, the WAH GS had been operational since 2 March, so water levels in the sidechannel were moderate and stable. In addition, few if any chum salmon fry were outmigrating at the time. During the 23 April visit, the WAH GS was not operational but the sidechannel was inundated with turbid water from the Fraser River. A more suitable time for a site in 2009 would have been in early-mid April when water levels in the sidechannel were low (WAH GS was not operational and station 1 measured less than 0.1 m), visibility was good, and fry were present.

CONCLUSIONS AND RECOMMENDATIONS

Recommendations to improve the results of future studies include:

- Continue to monitor temporary staff gauges located in the spawning fingers at site 1 during spawning and emergence.

- Measure redd and bed depths over a range of Fraser River water levels, sidechannel water levels, and WAH GS discharges, in order to better estimate the relationship between water levels at hydrometric station 1 and index site 1.

- Visit site 1 at least once during emergence when water levels are low, visibility is good, and chum salmon fry are present, in order to ground-truth results from the redd/fry stranding assessments.

- Continue egg distribution mapping in 2009/10 with consideration of the 2007/08 recommendations, namely:
  a. Hydraulic sampling should be conducted during the eyed stage 350-400 ATU for pink, 300-350 ATU for chum). Thus, it is critical that ATUs be calculated inseason and used to determine the appropriate sample period.
  b. To better determine whether egg deposition and survival rates vary across elevation bins, more than two sites per elevation bin should be sampled.

One mitigative measure recommended in previous studies was to confine off-road vehicle activity at site 1 to areas where there was no spawning activity. After the 2007-08 study, a concrete barrier was placed across the access road leading to site 1 which prevents vehicles from...
easily accessing the area. As a result, no off-road vehicles were observed in the sidechannel in 2008-09.

Once data collection for the 2009/10 study has been completed in May 2010, results from the entire 5-year study will be summarized in a final project report. As specified in the original terms of reference, results will be assessed by weight of evidence based on the incidence of adult stranding, proportion of spawners observed that use habitat subsequently lost due to operations, and behaviour observations detailing responses to operational measures. Together with results from the egg distribution and mapping component conducted for pink salmon in 2007 (and proposed for 2009), the study’s three management questions and recommendations for operational changes or other mitigative options will be addressed. Year 5 analyses will further expand on hypothesis testing by acknowledging that daily WAH GS outages do not completely prevent marginal spawning, but may act to reduce it with associated benefits to fish production.

REFERENCES


Greenbank, J., and J. Macnair. 2007. Fish productivity monitoring in lower Jones Creek, 2005-06. BC Hydro, Burnaby, BC.


Parsonage, K., and A. Leake. 1999. A summary of fisheries assessments and observations on Wahleach Reach (Wahleach Slough) sidechannel. BC Hydro, Power Supply Environment, Burnaby, BC.


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PHOTO PLATES
Photo 1. Top end of the 1st spawning finger at site 1, 21 October 2008 (1014 hours). This photograph was from the left bank of the sidechannel when the WAH GS was discharging 12.0 m³/s.

Photo 2. Top end of the 1st spawning finger at site 1, 21 October 2008 (1400 hours). This photograph was taken from the left bank of the sidechannel when the WAH GS was discharging 0.0 m³/s.
Photo 3. Top end of the 2nd spawning finger at site 1, 21 October 2008 (1055 hours). This photograph was taken from the left bank of the sidechannel when the WAH GS was discharging 12.0 m$^3$/s.

Photo 4. Top end of the 2nd spawning finger at site 1, 21 October 2008 (1357 hours). This photograph was taken from the left bank of the sidechannel when the WAH GS was discharging 0.0 m$^3$/s.
Photo 5. A chum salmon swimming downstream through the only channel connecting the spawning fingers at site 1 to the tailrace pool, 21 October 2008 (1351 hours). This photograph was taken from the right bank when the WAH GS was discharging 0.0 m$^3$/s.

Photo 6. Lower end of site 1 showing a small tributary draining into the sidechannel along the left bank, 21 October 2008 (1351 hours). This photograph was taken from the right bank (looking towards the left bank) when the WAH GS was discharging 0.0 m$^3$/s.
Photo 7. Lower end of site 1, 21 October 2008 (1349 hours). This photograph was taken from the left bank (looking upstream) when the WAH GS was discharging 0.0 m$^3$/s.

Photo 8. Top end of the 3$^{\text{rd}}$ spawning finger at site 1, 11 November 2008 (1518 hours). Note the partial redd in the foreground and chum salmon in the background that are swimming to deeper water during a WAH GS outage. This photograph was taken from the right bank (looking downstream) when the WAH GS was discharging 0.0 m$^3$/s.
Photo 9. Site 2 in the Herrling Island sidechannel, 21 October 2008 (1153 hours). This photograph was taken from the left bank (looking downstream) when the WAH GS was discharging 12.1 m³/s.

Photo 10. Lower end of site 1, 6 March 2009 (1301 hours). This photograph was taken from the left bank (looking upstream) when the WAH GS was discharging 8.5 m³/s.
Photo 11. Upper end of site 1, 23 April 2009 (1259 hours). This photograph was taken from the left bank (looking downstream) when the WAH GS was discharging 0.0 m$^3$/s.
## Appendix A. Summary of field observations in the Herrling Island sidechannel, 2008–2009.

<table>
<thead>
<tr>
<th>Date</th>
<th>Site</th>
<th>Time</th>
<th># fish</th>
<th>Comments</th>
<th>Time</th>
<th># fish</th>
<th>Comments</th>
<th>General observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>13-Oct</td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>Fish in deeper water at lower end</td>
<td>10:00</td>
<td>19</td>
<td>14 live (partially fungused), 5 carcasses, all fish at lower end</td>
<td>Limited access to fingers - low water</td>
</tr>
<tr>
<td>17-Oct</td>
<td>1</td>
<td>14</td>
<td>7</td>
<td>7 active redds in deep water at lower end</td>
<td>13:30</td>
<td>43</td>
<td>38 live, all in deep, none in fingers, 1 CM struggled to deep water during SD</td>
<td>No fish in fingers - low water</td>
</tr>
<tr>
<td>17-Oct</td>
<td>2</td>
<td>10</td>
<td>4</td>
<td>4 active redds in deep water along left bank</td>
<td></td>
<td></td>
<td>No risk of redds dewatering</td>
<td></td>
</tr>
<tr>
<td>21-Oct</td>
<td>1</td>
<td>10:00</td>
<td>19</td>
<td>14 live (partially fungused), 5 carcasses, all fish at lower end</td>
<td>13:30</td>
<td>43</td>
<td>38 live, all in deep, none in fingers, 1 CM struggled to deep water during SD</td>
<td></td>
</tr>
<tr>
<td>21-Oct</td>
<td>GS</td>
<td>11:30</td>
<td>0</td>
<td>No fish/redds in WAH GS tailrace area</td>
<td></td>
<td></td>
<td>No risk of redds dewatering</td>
<td></td>
</tr>
<tr>
<td>21-Oct</td>
<td>2</td>
<td>11:40</td>
<td>20</td>
<td>Fish in deep water, visibility poor, appear to be spawning</td>
<td></td>
<td></td>
<td>2 people fishing for trout. No risk of redds dewatering.</td>
<td></td>
</tr>
<tr>
<td>4-Nov</td>
<td>1</td>
<td>13:00</td>
<td>175</td>
<td>Only a handful of fish in fingers, majority spawning in deep areas</td>
<td></td>
<td></td>
<td>2 people fishing for trout. No risk of redds dewatering.</td>
<td></td>
</tr>
<tr>
<td>10-Nov</td>
<td>1</td>
<td>9:40</td>
<td>&gt;200</td>
<td>CM in fingers and at lower end</td>
<td>14:30</td>
<td>250</td>
<td>Significant dewatering in 3rd finger; fish moved away from redds to deep water</td>
<td></td>
</tr>
<tr>
<td>11-Nov</td>
<td>1</td>
<td>9:40</td>
<td></td>
<td>Too turbid to count fish accurately; active spawning taking place</td>
<td></td>
<td></td>
<td>3 non-spawning CM in lower end of small tributary; little spawning in marginal areas relative to previous years</td>
<td></td>
</tr>
<tr>
<td>18-Nov</td>
<td>1</td>
<td></td>
<td></td>
<td>Spawning nearing completion</td>
<td>12:00</td>
<td>360</td>
<td>240 live + 120 carcasses</td>
<td></td>
</tr>
<tr>
<td>6-Mar</td>
<td>1</td>
<td>12:20</td>
<td>0</td>
<td>Significant algae in 1st and 2nd fingers; no signs of redds being dewatered</td>
<td></td>
<td></td>
<td>No evidence of stranding; carcasses have drifted into tailrace pool</td>
<td></td>
</tr>
<tr>
<td>23-Apr</td>
<td>1</td>
<td>12:30</td>
<td>0</td>
<td>Very turbid water, visibility 1”; no fish observed</td>
<td></td>
<td></td>
<td>WAH GS operational; 14 live fry presumably chum at lower end</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Fraser heavily inundating all 3 fingers</td>
<td></td>
</tr>
</tbody>
</table>
Appendix B.  Chum salmon redd data collected from 21 October to 18 November 2008.

<table>
<thead>
<tr>
<th>Date</th>
<th>ID</th>
<th>Condition</th>
<th>Composition</th>
<th>Fish on redd?</th>
<th>At risk?</th>
<th>Time1</th>
<th>Pit1(m)</th>
<th>Bed1(m)</th>
<th>Time2</th>
<th>Pit2(m)</th>
<th>Bed2(m)</th>
<th>finger</th>
<th>bank</th>
<th>loc.</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-Nov</td>
<td>011103</td>
<td>complete</td>
<td>cobble/gravel</td>
<td>no</td>
<td>no</td>
<td>9:51</td>
<td>0.15</td>
<td>0.12</td>
<td>13:55</td>
<td>0.10</td>
<td>0.10</td>
<td>1</td>
<td>right</td>
<td>upper</td>
<td>Fish were on redd yesterday</td>
</tr>
<tr>
<td>18-Nov</td>
<td>011103</td>
<td>complete</td>
<td></td>
<td>no</td>
<td>maybe</td>
<td></td>
<td></td>
<td></td>
<td>12:23</td>
<td>0.14</td>
<td>0.14</td>
<td></td>
<td></td>
<td></td>
<td>Filled in</td>
</tr>
<tr>
<td>11-Nov</td>
<td>011104</td>
<td>partial/active</td>
<td>cobble/gravel</td>
<td>no</td>
<td>no</td>
<td>9:56</td>
<td>0.29</td>
<td>0.17</td>
<td>13:58</td>
<td>0.20</td>
<td>0.12</td>
<td>1</td>
<td>left</td>
<td>upper</td>
<td>May have spooked fish off redds during approach</td>
</tr>
<tr>
<td>18-Nov</td>
<td>011104</td>
<td>complete</td>
<td></td>
<td>no</td>
<td>maybe</td>
<td></td>
<td></td>
<td></td>
<td>12:25</td>
<td>0.12</td>
<td>0.12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-Nov</td>
<td>011105</td>
<td>partial/active</td>
<td>cobble/gravel</td>
<td>yes</td>
<td>no</td>
<td>10:00</td>
<td>0.24</td>
<td>0.21</td>
<td>13:59</td>
<td>0.16</td>
<td>0.15</td>
<td>1</td>
<td>left</td>
<td>middle</td>
<td>Not likely to dewater</td>
</tr>
<tr>
<td>18-Nov</td>
<td>011105</td>
<td>complete</td>
<td></td>
<td>no</td>
<td>no</td>
<td></td>
<td></td>
<td></td>
<td>12:29</td>
<td>0.15</td>
<td>0.15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-Nov</td>
<td>011106</td>
<td>partial/active</td>
<td>cobble/gravel</td>
<td>yes</td>
<td>no</td>
<td>10:05</td>
<td>0.35</td>
<td>0.17</td>
<td>14:03</td>
<td>0.28</td>
<td>0.12</td>
<td>1</td>
<td>right</td>
<td>lower</td>
<td>Deep redd pit</td>
</tr>
<tr>
<td>18-Nov</td>
<td>011106</td>
<td>complete</td>
<td></td>
<td>no</td>
<td>maybe</td>
<td></td>
<td></td>
<td></td>
<td>12:37</td>
<td>0.14</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
<td>Filled in</td>
</tr>
<tr>
<td>11-Nov</td>
<td>011107</td>
<td>partial/active</td>
<td>cobble/gravel</td>
<td>yes</td>
<td>no</td>
<td>10:09</td>
<td>0.29</td>
<td>0.16</td>
<td>14:05</td>
<td>0.18</td>
<td>0.10</td>
<td>1</td>
<td>right</td>
<td>lower</td>
<td>Deep redd pit</td>
</tr>
<tr>
<td>18-Nov</td>
<td>011107</td>
<td>complete</td>
<td></td>
<td>no</td>
<td>maybe</td>
<td></td>
<td></td>
<td></td>
<td>12:40</td>
<td>0.13</td>
<td>0.09</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11-Nov</td>
<td>011108</td>
<td>partial/active</td>
<td>cobble/gravel</td>
<td>no</td>
<td>no</td>
<td>10:17</td>
<td>0.43</td>
<td>0.23</td>
<td>14:06</td>
<td>0.31</td>
<td>0.15</td>
<td>1</td>
<td>right</td>
<td>lower</td>
<td>Deep pit, probably spooked fish of redd</td>
</tr>
<tr>
<td>18-Nov</td>
<td>011108</td>
<td>incomplete</td>
<td></td>
<td>no</td>
<td>no</td>
<td></td>
<td></td>
<td></td>
<td>12:44</td>
<td>0.26</td>
<td>0.16</td>
<td></td>
<td></td>
<td></td>
<td>Still a pit; abandoned?</td>
</tr>
<tr>
<td>11-Nov</td>
<td>011109</td>
<td>partial/active</td>
<td>rock/gravel</td>
<td>yes</td>
<td>yes</td>
<td>10:26</td>
<td>0.24</td>
<td>0.08</td>
<td>14:08</td>
<td>0.12</td>
<td>0.00</td>
<td>1</td>
<td>left</td>
<td>lower</td>
<td>Bed dewatered, not redd</td>
</tr>
<tr>
<td>18-Nov</td>
<td>011109</td>
<td>incomplete</td>
<td></td>
<td>no</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td>12:49</td>
<td>0.25</td>
<td>0.07</td>
<td></td>
<td></td>
<td></td>
<td>Abandoned?</td>
</tr>
<tr>
<td>11-Nov</td>
<td>011110</td>
<td>partial/active</td>
<td>cobble/gravel</td>
<td>yes</td>
<td>yes</td>
<td>10:29</td>
<td>0.27</td>
<td>0.11</td>
<td>14:08</td>
<td>0.24</td>
<td>0.10</td>
<td>1</td>
<td>left</td>
<td>lower</td>
<td>10 m d/s redd #9</td>
</tr>
<tr>
<td>18-Nov</td>
<td>011110</td>
<td>complete</td>
<td></td>
<td>no</td>
<td>yes</td>
<td></td>
<td></td>
<td></td>
<td>12:52</td>
<td>0.11</td>
<td>0.11</td>
<td></td>
<td></td>
<td></td>
<td>Filled in</td>
</tr>
<tr>
<td>11-Nov</td>
<td>011111</td>
<td>partial/active</td>
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<td>maybe</td>
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<td>14:11</td>
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<td>lower</td>
<td>Fish in deep water</td>
</tr>
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<td>lower</td>
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<td>upper</td>
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<td>lower</td>
<td>2 fish actively spawning but not at risk</td>
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Appendix C. Relationship between bed depth at chum salmon reds in site 1 and water depth at hydrometric station 1.