Wahleach Project Water Use Plan

Herrling Island Chum Spawning Success

Implementation Year 6 Reporting

Reference: WAHMON-3

A Synthesis of the Herrling Island Side Channel Spawning Success Monitoring

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EXECUTIVE SUMMARY

Wahleach Generating Station (WAH GS) outages cause dewatering of marginal areas throughout the Herrling Island Side Channel. During the salmon spawning and incubation period from September to April these outages lead to:

- adult Pink (*Oncorhynchus gorbuscha*) and Chum (*Oncorhynchus keta*) Salmon stranding and mortalities;
- Pink and Chum Salmon redd dewatering with unknown outcome past the eyed egg stage; and
- stranding and mortalities of Pink and Chum Salmon fry.

The highest probability for all of the above stated dewatering effects can be found during medium water levels (3.9-4.3 m) of the Fraser River main stem (Hope Station) when:

- No direct flow from the Fraser River main stem buffers the water level fluctuations caused by WAH GS outages;
- Adult Pink and Chum Salmon can access marginal spawning areas in the Herrling Island Side Channel when the WAH GS is operating and subsequently these marginal areas fall dry during WAH GS outages.

The Fraser River main stem affects the water levels in the Herrling Island Side Channel directly at water levels of >4.96 m at the Hope hydrometric station. At these high water levels the side channel is inundated by Fraser River main stem flow and WAH GS outages do not dewater marginal areas.

At very low Fraser River water levels (<3.9 m), marginal areas are less frequently accessible for spawning when the WAH GS is operating and thus WAH GS outages do not lead to adult standing or redd dewatering.

Temporary exclusion fences have been used in the Herrling Island Side Channel to prevent fish from spawning in marginal areas. These exclusion fences were most effective when high flows or predators such as bears did not breach them. During high water periods of direct inundation by Fraser River main stem flows, the temporary exclusion fences erected from 2010 to 2013 were breached. More permanent and structurally sound exclusion fence designs would be less likely to breach, and may be a more reliable option. While the previously deployed exclusion fencing has shown promise in preventing adult spawners from accessing marginal areas, the effectiveness of such fencing to prevent juvenile fish from entering marginal areas is unknown. For juvenile exclusion fencing the mesh size would likely need to be much smaller and consequently panels would need to have a much higher resistance to current and would be easily plugged. In conclusion, exclusion fencing can block access to marginal areas for adult Pink

and Chum Salmon but it should be considered unlikely that exclusion fencing would be well suited to prevent access to marginal areas for juveniles of the two species.

Re-contouring of the Herrling Island Side Channel as a measure to reduce the amount of area that dewaters during WAH GS shutdowns has been recommended in the past. However, the Herrling Island Side Channel is currently one of only two proven areas for White Sturgeon (*Acipenser transmontanus*) spawning in the Lower Fraser River (Triton 2013). Given the sensitive status of this species and the lack of detailed knowledge about its spawning habitat requirements, this option should not be pursued. It would also be very difficult to obtain regulatory approval for this type of instream work. All assumptions about the status and protection of Lower Fraser White Sturgeon are based on direct input from Erin Stoddard (Ecosystem Biologist and White Sturgeon Specialist, BC Ministry of Forest, Lands and Resource Operations) on the writing of the sturgeon chapter.

In conclusion, the suspension of flows through the WAH GS that were meant to dissuade Pink and Chum Salmon from entering marginal areas for spawning do not work. The only reliable way to prevent Pink and Chum Salmon dewatering mortalities at the adult, embryonic and fry stages would be to replace those outages with a less fluctuating flow regime especially throughout the Pink and Chum Salmon spawning period from mid-September to early December. If this option is not feasible, the annual installation and maintenance of the previously used type of exclusion fencing should be continued and should be complimented by pilot studies on the effectiveness of sturdier exclusion fencing.

BACKGROUND

Setting

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, British Columbia (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 Side Channel of the Fraser River.

The Herrling Island Side Channel 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 side channel. The side channel 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). The WAH GS typically operates to meet local peak electricity load. This results in daily fluctuations in flows in the Herrling Island Side Channel between September and April, a period when the Fraser River does not typically affect side channel flows except through groundwater contributions (BC Hydro 2005).

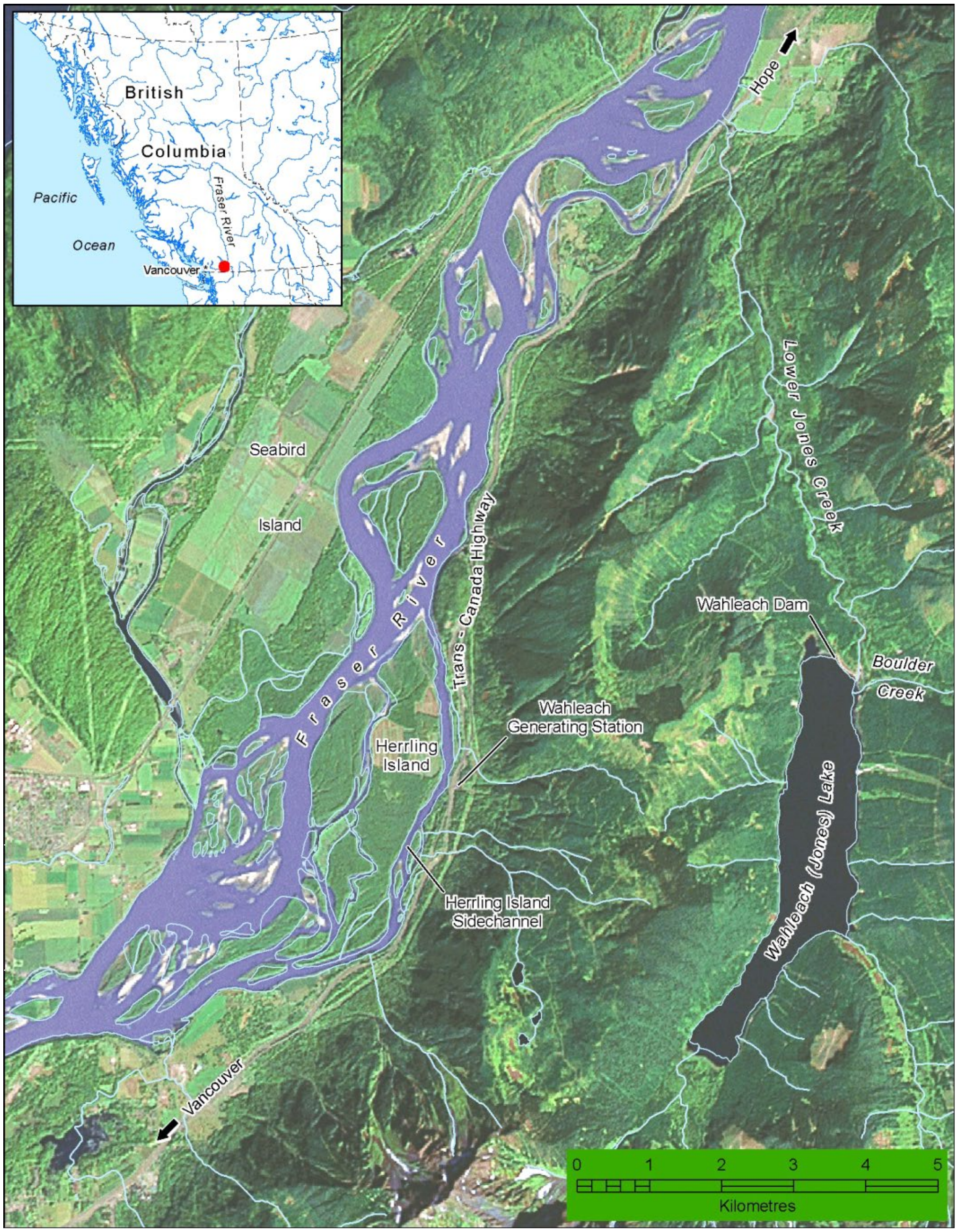


Figure 1 The Wahleach hydroelectric facility which includes the Boulder Creek Diversion Dam, Jones Lake (Wahleach) Reservoir, Wahleach Dam, and Wahleach Generating Station (WAH GS).

Mean daily discharge for the Fraser River near Hope typically peaks in mid-June at 7,200 m^3/s, ranges from 1,510 to 1,750 m^3/s in October-November, and is lowest in February and March (847-848 m^3/s). Mean daily water level peaks at 7.5 m in mid-June, ranges from 4 to 4.5 m in October-November and is lowest February and March (3.5-3.7 m) (Figure 2). Via-Sat Data Systems Incorporated (North Vancouver, BC) installed and operated three hydrometric stations in the Herrling Island Side Channel from 2005 to 2013. The stations logged water level and water temperature at 15-min intervals. Based on the data from these stations, water level changes in the Herrling Island Side Channel could be compared to water levels in the Fraser River main stem. Typical daily average water levels for the Herrling Island Side Channel are shown in Figure 3.

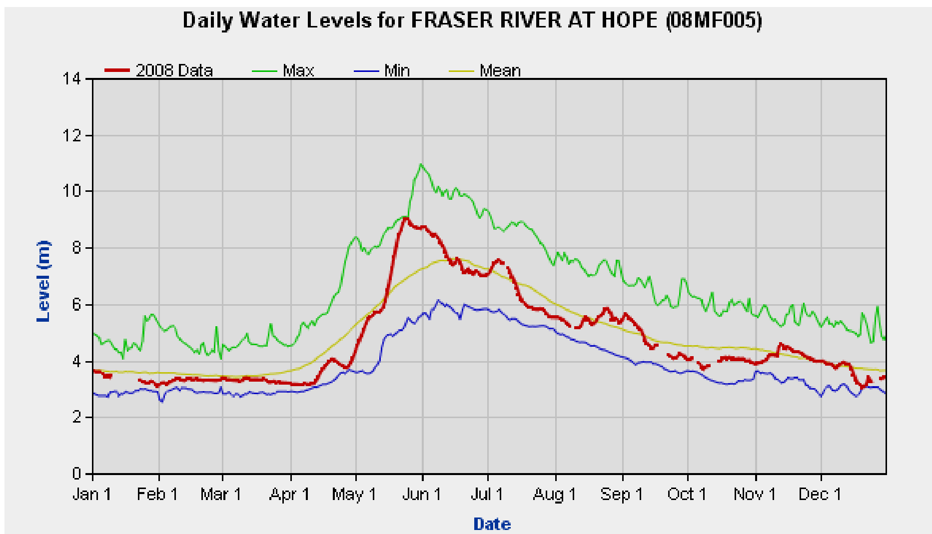


Figure 2 Mean daily water level of the Fraser River at Hope, BC, 1996-2008 (EC 2009).

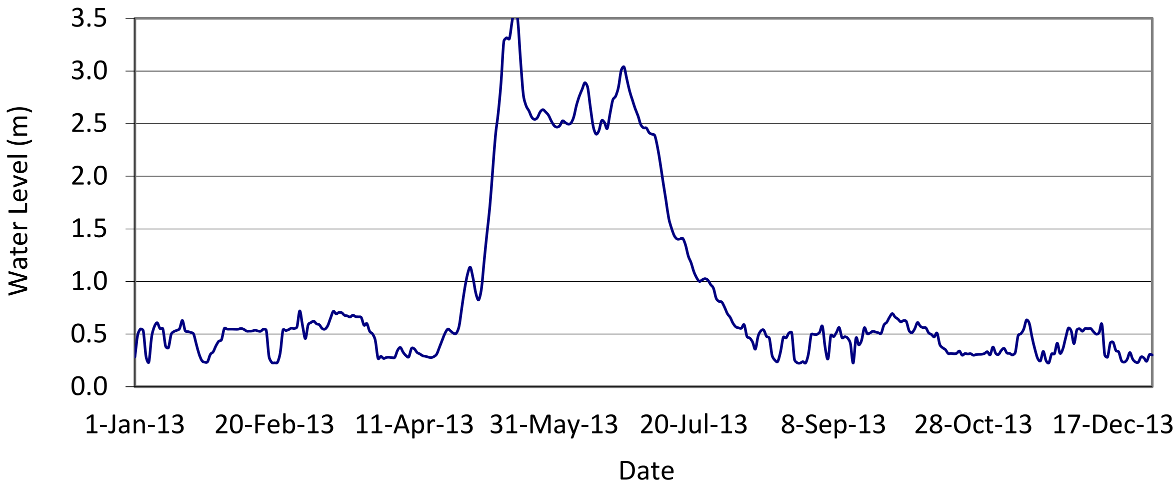


Figure 3 Mean daily water levels for the Herrling Island Side Channel at Station 1 for 2013 (Data Source: Via-Sat data Systems Incorporated)

From September to the end of April, water levels in the side channel fluctuate by a maximum of approximately 0.6 m and are mainly influenced by WAH GS outages and run-off from tributary creeks. During the freshet, when Fraser River main stem flow inundates the side channel, water levels in the side channel can increase by 3 m. This scenario occurs when the Fraser River water level at Hope rises above 4.9 m.

The typical low water period in the Herrling Island Side Channel from September to April (Figure 3) coincides with the typical spawning, incubation and short juvenile rearing period of Pink (*Oncorhynchus gorbuscha*) and Chum (*Oncorhynchus keta*) Salmon. The low water period in the side channel also coincides with a period when the mean daily water levels in the Fraser River at Hope are typically below 4.9 m (Figure 4).

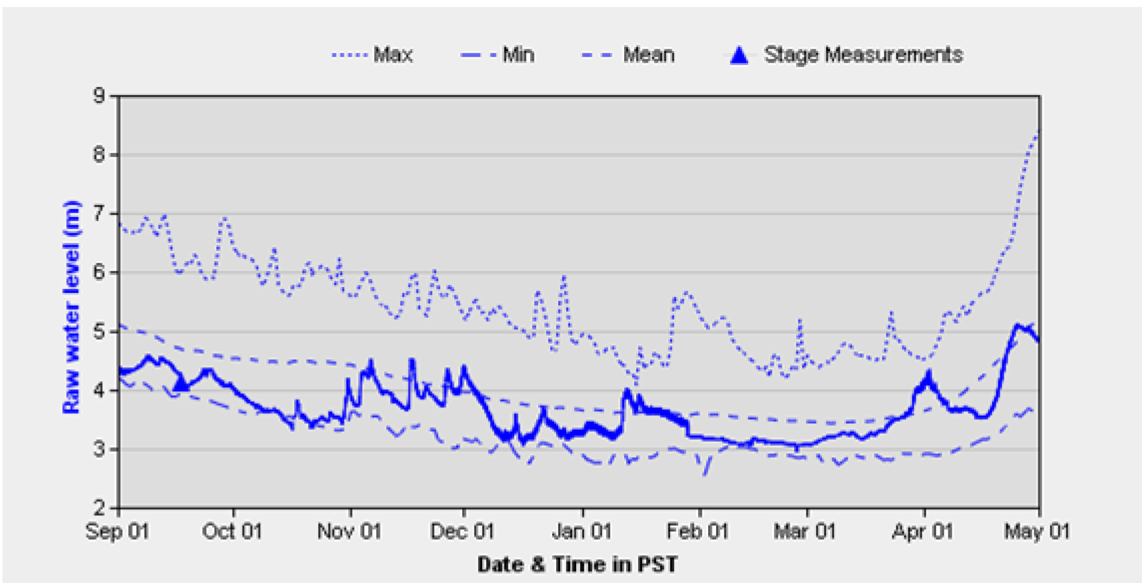


Figure 4 Water levels of the Fraser River at Hope, BC, from 1 September 2009 to 30 April 2010, relative to historical data (Environment Canada 2010).

During periods when the Fraser River does not inundate the side channel, discharge and water levels in most of the Herrling Island Side Channel vary substantially due to abrupt changes in WAH GS discharge (see Figure 5 for an example of how water levels in the side channel changed from 1 September to 31 October, 2013). Fluctuations in water levels also change the wetted width within the side channel (for an example please see Figure 11 later in this report).The details and effects of changes in water levels and wetted width for adult salmon spawning and stranding, as well as redd dewatering and juvenile stranding are explored in detail later in this report.

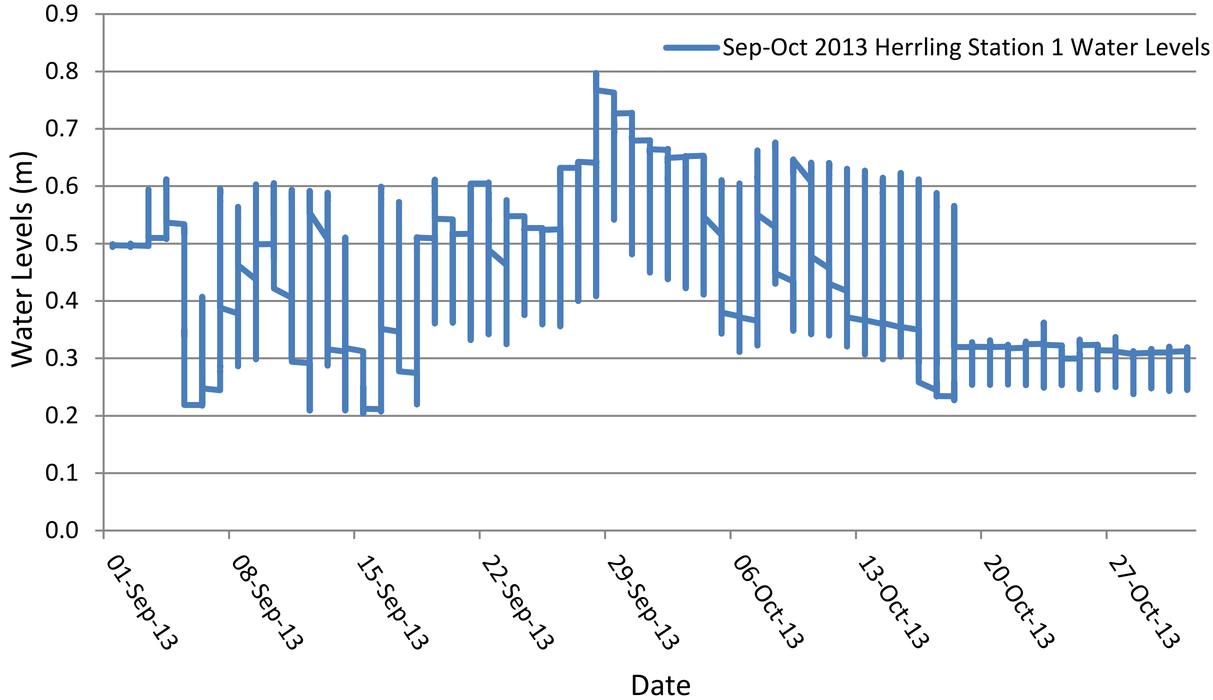
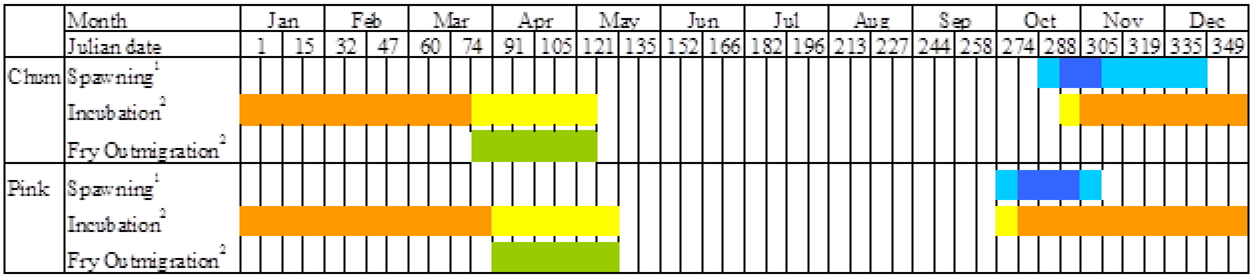


Figure 5 Water level of the Herrling Island Side Channel (Station 1, ~50 m upstream of the WAH GS outflow) during the Pink Salmon spawning period, 1 September to 31 October 2013 (Data Source: Via-Sat data

Fisheries Setting

Fish species known or believed to spawn in the Herrling Island Side Channel include: Chum (*Oncorhynchus keta*), Coho (*O. kisutch*), and Pink (*O. gorbuscha*) Salmon; Cutthroat Trout (*O. clarkii*) and White Sturgeon (*Acipenser transmontanus*) (Parsonage and Leake 1999). Two Chinook Salmon (*O. tshawytscha*) were observed in the side channel in the fall of 2009; however no redds were confirmed (M. McArthur, BC Hydro, personal communication). In lower Jones Creek, which drains into the Fraser River immediately upstream of the Herrling Island Side Channel, Chum Salmon spawn from late September to mid-December with peak spawning occurring from mid-late October (Greenbank and Macnair 2007, 2008) (Figure 6). Chum Salmon were observed spawning in the Herrling Island Side Channel from mid-late October to mid-November from 2005 through 2008 (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).



[1] Based on observed adult escapement in Lower Jones Creek (MacNair 2005).
[2] Based on observed fry outmigration from Lower Jones Creek (MacNair 2004).

Marginal Spawning; Main Spawning; Marginal Incubation; Main Incubation; Main Fry Outmigration

Figure 6 Periodicity chart for Chum and Pink Salmon in Lower Jones Creek (adapted from Figs. 2 & 3 in BC Hydro 2005, Wahleach Water Use Plan Monitoring Terms of Reference).

Annual Chum Salmon escapements in the Herrling Island Side Channel were estimated to be between 2,000 and 10,000 adults in the early 1980s (Hancock and Marshall 1985). Peak counts of Chum Salmon in the side channel were 279 in 2005, 304 in 2006, 275 in 2007, 360 in 2008 and 387 in 2009 (Smith 2006, 2007, 2008, 2009, 2010). Although the escapements of 2,000-10,000 Chum in the early 1980s cannot be directly compared with the peak counts from 2005 to 2009, in “Area Under The Curve” (AUC) estimates of fish populations, total escapements are typically two to three times higher than the peak counts for the enumeration period. It can therefore be inferred that the total Chum Salmon escapements to the Herrling Island Side Channel decreased by a factor of two to ten times from the early 1980s to the period from 2005 to 2009.

Pink Salmon spawn in Lower Jones Creek from early October to early November with fry outmigrating from early April to mid-May (Greenbank and Macnair 2007, 2008). In BC, Pink Salmon eggs typically hatch from late December to late February (Bonar et al. 1989). Alevins remain in the gravel for several weeks while their yolk sacs are absorbed. Fry emerge from the gravel as early as late February, but peak emergence is typically during April or May. Incubation phases include: 350-400 ATUs for the eyed stage, 550-650 ATUs for the hatch stage, and 900-950 ATUs for the emergent stage (Shepherd 1984). Peak counts of more than 3,000 Pink Salmon were observed in the Herrling Island Side Channel in 2009 (Smith 2010). Historic escapement estimates or peak counts for Pink Salmon spawning in Herrling Island Side Channel were not found.

WAH GS FLUCTUATIONS, FISHERIES IMPLICATIONS AND THE WATER USE PLAN

Numerous studies carried out in the Herrling Island Side Channel (BC Hydro 1998; McLean 1998; Parsonage and Leake 1999; Smith 2006, 2007, 2008, 2009, 2010) have shown that fluctuations in water levels in the Herrling Island Side Channel due to operational conditions at the WAH GS contributed to:

(1) Extensive dewatering of shallow riffles and gravel bars in the side channel;
(2) Partial or full dewatering of Pink and Chum Salmon redds;
(3) Stranding of spawning adult Pink and Chum Salmon; and
(4) Stranding of outmigrating juvenile Pink and Chum Salmon in isolated pools or dewatered areas.

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 2005). 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 Side Channel 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 effects on salmon and their habitat in the Herrling Island Side Channel that needed to be addressed included:

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

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

Hypothesis 1 Suspending Wahleach generation for 2 h daily during the spawning period does not deter spawning in marginal areas;

Hypothesis 2 Suspending Wahleach generation for 2 h daily during the spawning period does not eliminate fry or redd stranding caused by operations.

Hypothesis 3 Suspending Wahleach generation for 2 h daily during the spawning period does not result in stranding of spawning adults

HERRLING ISLAND SIDE CHANNEL PINK AND CHUM SALMON SPAWNING SUCCESS MONITORING

Adult Stranding, Stranding Mortality and Redd Dewatering Assessments

From 2005 to 2009, Smith (2006, 2007, 2008. 2009, 2010) and co-workers carried out a program to monitor initially Chum Salmon and later Chum and Pink Salmon spawning success in the Herrling Island Side Channel. In the following paragraphs results from each of those five years of monitoring are summarized.

2005 Chum Salmon: The maximum daily count for Chum Salmon was 289 fish (Smith 2006). In general, Chum Salmon were observed spawning at two main sites within the Herrling Island Side Channel between 24 October and 16 November. During WAH GS outages, eight Chum Salmon were found stranded in dewatered areas within the side channel 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.

2006 Chum Salmon: In 2006 (Smith 2007), high flows from the main stem Fraser into the side channel 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 spawning from 30 October to 20 November 2006 with a peak daily count of 349 fish. 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.

2007 Pink Salmon: In 2007, the monitoring period started earlier to assess the effects of WAH GS outages on Pink Salmon spawning. In September 2007, the highest daily count of Pink Salmon in the Herrling Island Side Channel was 1,184 fish (Smith 2008). Fifteen of these 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.

2007 Chum Salmon: The highest daily count for Chum Salmon in 2007 was 281 fish. Stranding and redd dewatering during the Chum spawning period in October and November did not occur. Due to the influx of water from the Fraser River, water levels in the Herrling Island Side Channel changed very little during WAH GS outages. High turbidity levels also made it difficult to count and assess the behaviour of Chum Salmon.

2008 Chum Salmon: In 2008, the highest daily count for Chum Salmon in the Herrling Island Side Channel was 360 fish. Low water levels in late October and early November 2008 restricted access of Chum Salmon to the spawning “fingers” in site 1 (Smith 2009) and other marginal areas. Likely due to the low water levels, Chum Salmon were observed spawning in a new area downstream of site 1 in November 2008. Due to the low water marginal areas could not be accessed by Chum Salmon for spawning and therefore no adult Chum Salmon were observed stranded in 2008. In addition, in 2008 Chum Salmon fry stranding surveys were carried out in the spring and no Chum Salmon fry were observed stranded during visits to site 1 on 6 March and 23 April 2009.

2009 Pink Salmon: As in 2007, monitoring in 2009 started in September to assess WAH GS outage effects on Pink Salmon. The number of Pink Salmon spawning during the 2009 survey was higher than in 2007 (Smith 2010). Pink Salmon were observed spawning throughout the Herrling Island Side Channel and peak counts of approximately 3,000 fish occurred on 27 September and 3 October. In general, the majority of Pink Salmon were observed spawning in shallow water of <0.2 m depth. Therefore it was not surprising that a total of 192 redds were observed dewatered during WAH GS outages. In addition, 30 live Pink Salmon were stranded and 200 fish died, most likely due to stranding.

2009 Chum Salmon: In 2009, 15 Chum Salmon were observed stranded, 16 pre-spawn mortalities were attributed to stranding based on their location and flows and 3 Chum Salmon redds were observed dewatered.

Table 1 Summary tables for observed Pink and Chum Salmon strandings, stranding-based mortalities and redds dewatered at least once during WAH GS outages. In 2005, 2006 and 2008 the side channel was not surveyed in September during Pink spawning (Data Source: Smith 2006, 2007, 2008, 2009, 2010). Due to their two year life cycle on the odd years, Pink Salmon return in even years in very small numbers to the Fraser River and were therefore not observed in 2006 and 2008. In 2005 the project started past the Pink spawning period.

		2005	2006	2007[1]	2008	2009
Pink	Percentage of run covered (%)	-	-	11	-	11
	Max daily count (N)	-	-	1,185	-	3,000
	Stranded (N)	-	-	15	-	30
	Mortality (N)	-	-	0	-	200
	N or % of redds dewatered	-	-	0	-	192
Chum	Percentage of run covered (%)	20	20	5	20	10
	Max daily count	286	349	281	360	
	Stranded	29	2	0	0	15
	Mortality	0	0	0	0	16
	N or % of redds dewatered	35 or 46%	88%	0	75%[2]	3

In 2007, the Herrling Island Side Channel received flow from high water levels in the Fraser River mainstem in October and November. Therefore water levels did not drop based on WAH GS outages.

[2] The 75% was based on the redds selected to be observed, number of total redds that were dewatered at least once was unknown in 2008.

Egg and Juvenile Survival and Density Assessments

Assessment of 2007 Brood Year Eggs and Alevins: Key measures to describe adult spawning behavioural responses to WAH GS outages proved difficult throughout the first three years of the study from 2005 to 2007 based on observer limitations, water conditions, and high spawning densities at the index sites. As a result, an addendum was made to include additional assessments and mapping of Pink Salmon egg distribution for the 2007 and 2009 runs. Embryo sampling has the potential to assess whether WAH GS operational changes result in lower spawner densities in marginal habitats than in stable habitats. In 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 outlet into Herrling Island Side Channel. Embryos were found in the highest elevation bins along the right bank of the side channel 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.

Assessment of 2009 Brood Year Eggs and Alevins: Using the same hydraulic sampler as in 2008, Pink Salmon embryos were collected along four transects in November of 2009. For the pooled results from all transects, the density of embryos in non-marginal (never dewatered) areas of the side channel was significantly higher than in areas that were classified as marginal, as shown in the example of Transect 1 on the top panel in Figure 7 (Smith 2010). Contrary, the percentage of live embryos was not significantly different between marginal and non-marginal areas (bottom panel in Figure 7).

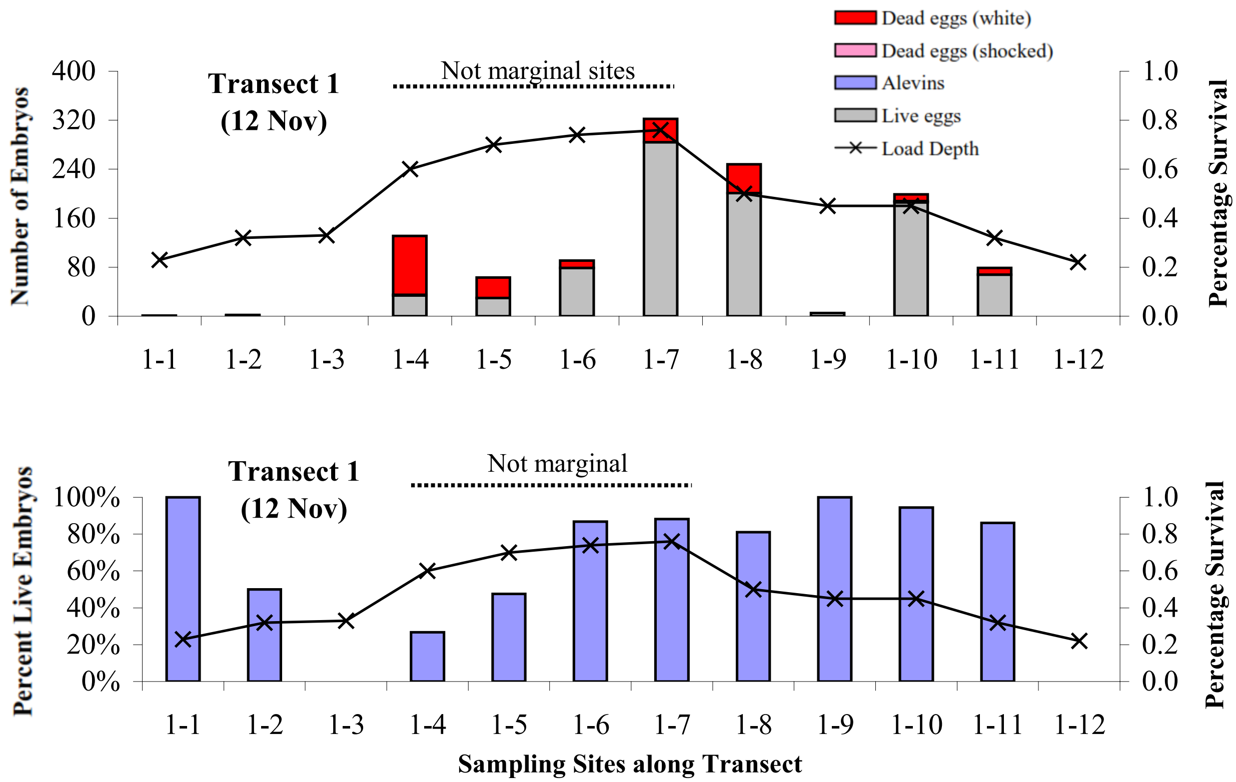


Figure 7 The top panel shows the number of Pink Salmon embryos (grey bar=live eggs, red bar=dead eggs) in 12 sampling sites along Transect 1 on 12 November 2009 in relation to the water depth (black line). The bottom panel shows the percentage of embryos that were alive (Source: Smith 2010).

In 2009, Pink Salmon therefore appeared to be spawning less in the frequently dewatered marginal areas when compared with the consistently submersed non-marginal areas while survival of the eggs did not appear to be affected early on by the frequent dewatering of the redds. In conclusion, while marginal areas were used less frequently in 2009 for spawning than non-marginal areas, the offspring of Pink Salmon that spawned marginally were not affected by redd dewatering early on in a year when over 200 adult Pink Salmon were stranded and 192 redds became dewatered during WAH GS outages (Smith 2010). The fact that a redd dewatered did not necessarily mean that the embryos were exposed to air, as Pink Salmon egg pockets were typically buried 20-30 cm beneath the substrate. Also, ova sampling was conducted while embryos were at the eyed stage, a period when they are less sensitive to the effects of dewatering. Survival rates in marginal areas may be substantially lower during the swim-up and emergence periods when embryos are more sensitive to dewatering. In addition, embryos sampled later would also be exposed to more dewatering events and potential periods of freezing than those sampled earlier. It is therefore recommended that embryo survival surveys be conducted in January and February to assess the rate of survival in marginal versus non-marginal areas of the Herrling Island Side Channel.

Juvenile or Salmon Fry Stranding Assessments

Chum and Pink Salmon fry stranding surveys in the spring following emergence from the gravel, and preceding the downstream migrations of the fry into the ocean, were carried out only twice. The first time occurred on 14 April 2008 (Smith 2008), when approximately 50 live and two dead fry were observed stranded. Likely those fry were composed of juvenile Pink and Chum Salmon since both species were observed spawning in the fall of 2007. The second time occurred on 23 April 2009, when flow from the Fraser River main stem inundated the Herrling Island Side Channel, and no fry were observed stranded. Fry in 2009 would have been Chum Salmon only, since no Pink Salmon spawning was observed during the fall of 2008, an off year for Pink Salmon in the Fraser River. Based on these results it can be assumed that WAH GS outages cause fry strandings and subsequent fry mortalities, but more studies in March and April are needed to quantify the occurrence of these strandings and mortalities.

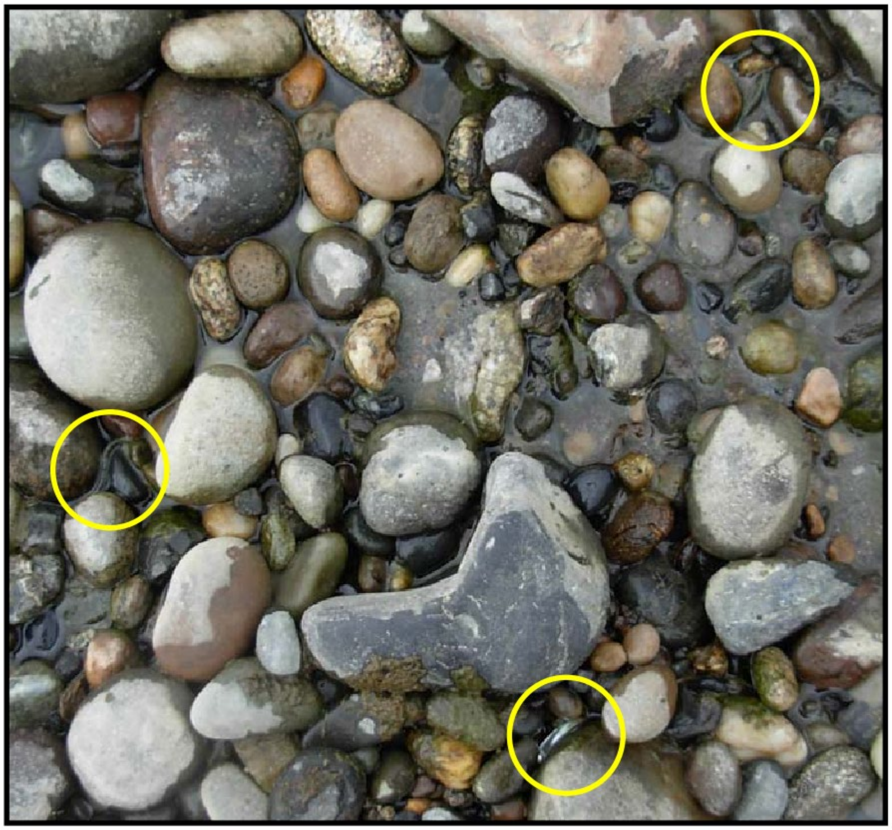


Figure 8 Stranded fry (yellow circles) observed on 14 April 2008 during a WAH GS outage.

GENERAL PARAMETERS AFFECTING PINK AND CHUM STRANDING, STRANDING MORTALITY AND REDD DEWATERING

WAH GS Discharge

During WAH GS outages, water levels at Stations 1 and 3 in the Herrling Island Side Channel can decrease from 0.6-0.08 m, depending on the decrease in WAH GS discharge and water levels in the main stem Fraser River. During periods when Fraser River water levels range from 4.0-4.3 m (Hope Station), as experienced in 2009, the Fraser River does not contribute flow directly into the side channel; and indirect percolation into the side channel is likely also lower. Consequently, very large and quick drops in water level of 0.5-0.6 m were observed in 2009 at side channel Stations 1 and 3 (Figure 12, red and black line). Drops in stage height at side channel Station 2 were buffered by Fraser River backwatering at the downstream end of the side channel (Figure 9, blue line).

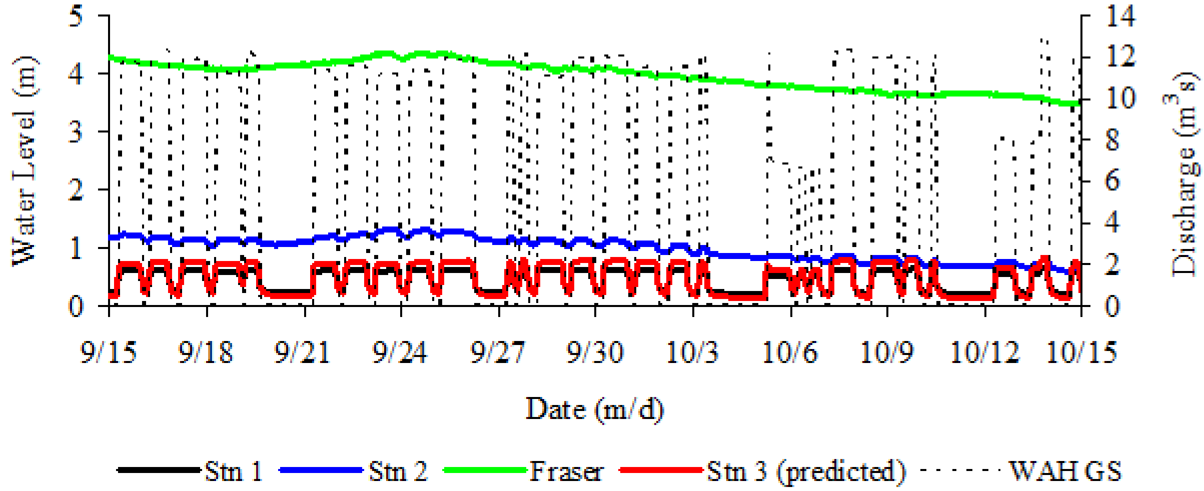


Figure 9 Water level of the Herrling Island Side Channel (stations 1 and 2) and WAH GS discharge during the Pink Salmon spawning period, 15 September to 15 October 2009.

Although the WAH GS outages under the WUP were suggested to be no longer than 2 h in a 24 h period during the spawning period from September to the end of November, outages lasted up to 20 h during the spawning period (for example, see 21 Sep, 27 Sep, 4 Oct, 12 Oct in Figure 9), and during the incubation period from December to March. As an example, the frequency and the duration of WAH GS outages and redd dewatering events were summarized for Pink Salmon redds from September 2007 to April 2008 (Figure 10). Of the 330 dewatering events over this period, only 15% were 2 h or shorter in duration, while the remaining 85% were longer than 2 h in duration. On 12 occasions, the WAH GS outages lasted longer than three days.

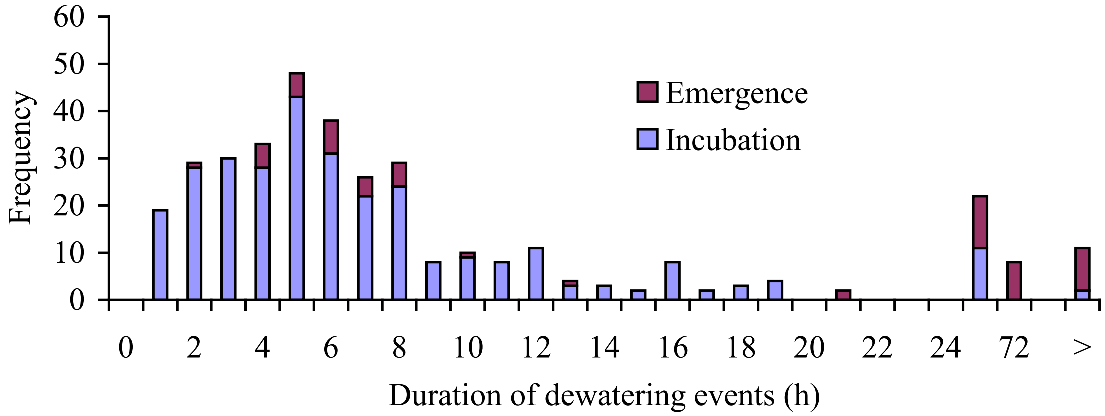


Figure 10 Duration of dewatering events for 11 Pink Salmon redds that were monitored from incubation through emergence in the Herrling Island Side Channel, September 2007 to April 2008 (Source: Smith 2008).

As a consequence of the WAH GS outages, the wetted area of the Herrling Island Side Channel typically decreased (see Figure 11 for an illustration of the 21 September 2007 WAH GS outage). In this instance, the wetted area was reduced by approximately 65% during the WAH GS outage. WAH GS outages caused water levels to decrease at a maximum rate of approximately 15 cm/h (based on data collected by Via-Sat data Systems Incorporated in the Herrling Island Side Channel). Salmon holding or spawning in the dewatered areas either managed to escape into deeper water or were stranded if the channel morphology did not allow for egress.

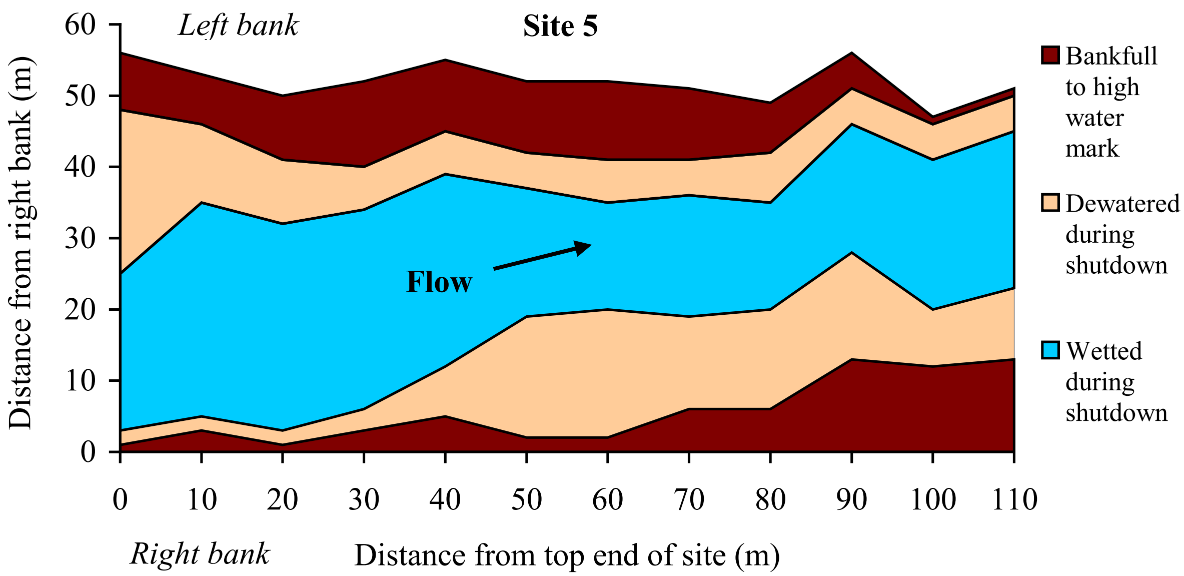


Figure 11 Amount of habitat in a 110-m long section of the Herrling Island Side Channel located in Site 5 that was dewatered during the WAH GS outage on 21 September 2007 (Smith 2008).

Fraser River Stage Height and Backwatering or Flow through the Side Channel

The critical Fraser River water level at which flows in Herrling Island Side Channel are directly affected was estimated in 2006 to be 4.96 m at the Hope Station (Figure 12). At or above this level, the side channel was flooded by Fraser River surface water, which buffered decreases in stage height caused by WAH GS outages (as experienced during the Chum Salmon spawning period in October and November of 2007).

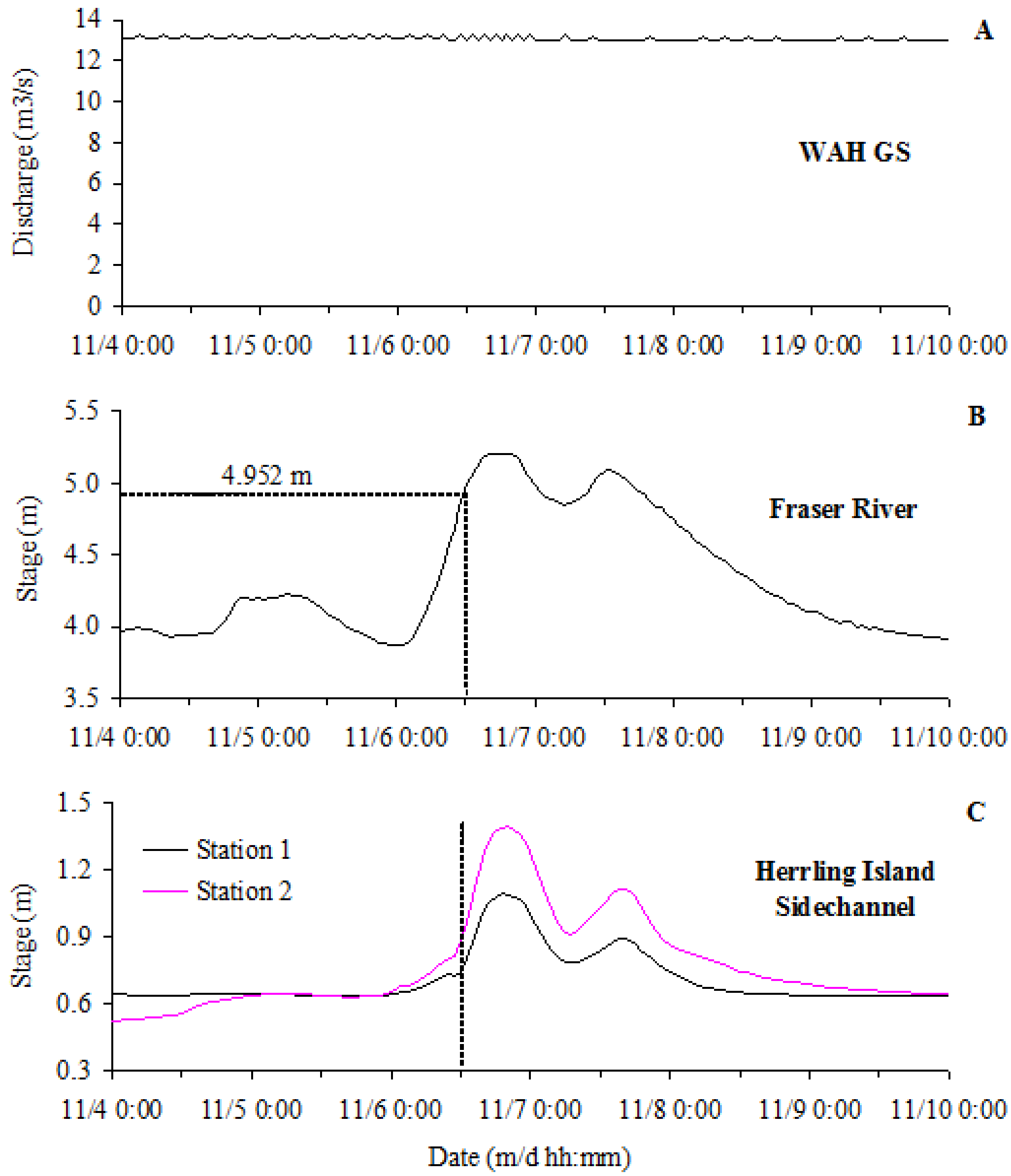


Figure 12 WAH GS discharge (Panel A), Fraser River stage height at Hope (Panel B), and Herrling Island Side Channel stage height measured at hydrometric Stations 1 and 2 (Panel C), 4-10 November 2006.

Even below the 4.96 m stage height of the Fraser River at Hope, Fraser River stage height influences the stage height in the Herrling Island Side Channel indirectly through subsurface percolation. Stranding-related mortality and redd dewatering were found most often to occur during medium stage heights (3.9-4.3 m at the Hope Station). At these Fraser River stage heights, as experienced in 2009 (Figure 9), Pink and Chum Salmon can access marginal and shallow-water areas for spawning, and subsequently these areas dewater during WAH GS outages. At very low Fraser River stage heights (<3.8 m), as seen in October and November of

2008 (Figure 13), many of the marginal areas that would be submersed at higher stages cannot be accessed by fish for spawning. Fish instead have to spawn in deeper areas that are not dewatered during WAH GS outages.

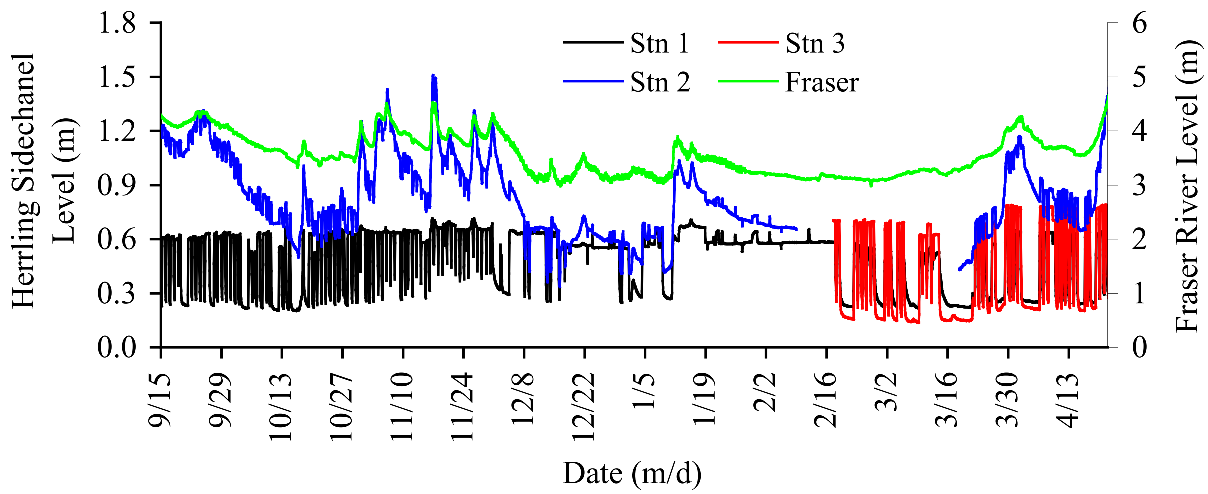


Figure 13 Hourly water levels of the Fraser River at Hope and the Herrling Island Side Channel measured at three hydrometric stations, 15 September 2009 to 22 April 2010.

Run Size

In years with larger run sizes, as experienced for Pink Salmon in 2009, the total number of stranded fish and mortalities caused by stranding increased. For example, more than 200 Pink and 16 Chum Salmon were observed stranded in 2009, compared to a previous high of 29 fish stranded in 2005. When abundance is high, fish will use more of the river bed area for spawning and utilize marginal areas at a higher rate than when abundance is low.

SITE SPECIFIC PARAMETERS AFFECTING CHUM STRANDING, STRANDING MORTALITY AND REDD DEWATERING

Over the five years of field studies on the effects of WAH GS outages on Chum and Pink Salmon spawning in the Herrling Island Side Channel, a total of seven sites were monitored (Figure 14). These sites differed in their probability for fish stranding and related effects. In general, shallow sites with low gradient in marginal areas were the most prone to dewatering; while deeper sites with higher gradient bottoms and steeper sides would not become dewatered during WAH GS outages.

Examples of sites prone to dewatering include “the fingers” in Site 1 (Figure 15) and sites with similar characteristics to Site 4 or Site 7 (Figure 16).

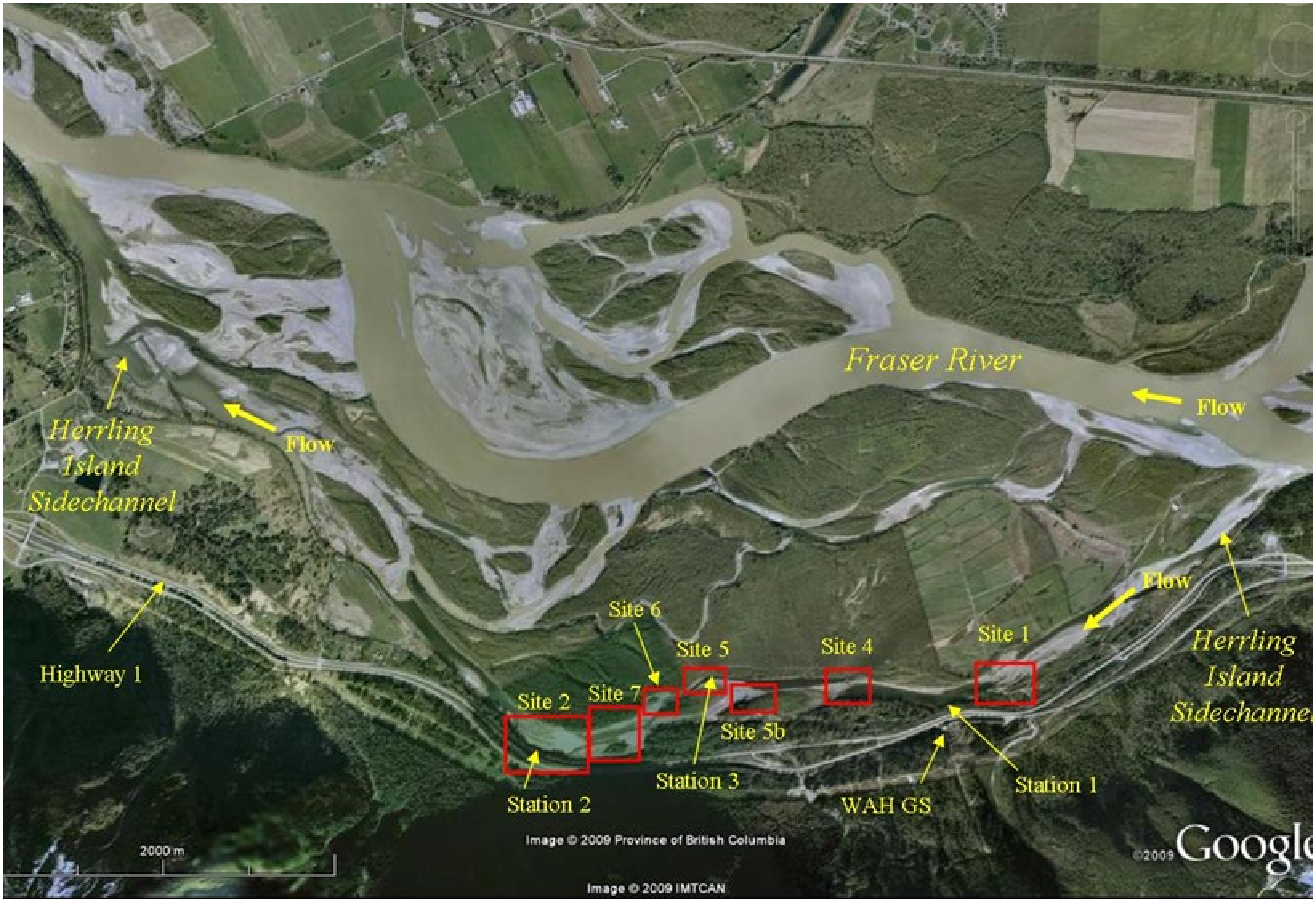


Figure 14 Aerial photograph of the Herrling Island Side Channel showing the WAH GS, three hydrometric stations, and index sites used to monitor Pink and Chum Salmon spawning activity in 2009 (Source: Smith 2010).

Figure 15 Aerial photography (top) and on the ground photographs (bottom) of Site 1 with the characteristic “fingers” prone to dewatering (bottom right) during WAH GS outages.

Figure 16 Photographs of dewatered redds taken at Site 7 (left) and Site 4 (right) during WAH GS outages.

EXCLUSION FENCING

One way to prevent fish from spawning in sites that are prone to dewatering (aside from eliminating WAH GS outages), especially if the sites do not have high flows (as in the example of “the fingers” in Figure 15), is the installation of exclusion fences.

From 2010 to 2014 Living Resources Environmental (2010, 2011, 2012, 2013) constructed, maintained and monitored the success of exclusion fences in the Herrling Island Side Channel and the continuation of this work is planned for the future. The results of these studies showed that exclusion fencing is successful in preventing spawning in marginal areas when:

- The Herrling Island Side Channel is not being temporarily inundated by flows from the Fraser River main stem (which breach the exclusion fencing);
- The fencing is built structurally sound enough to withstand WAH GS discharges;
- The fencing is not breached by predators such as bears; and
- The fencing structures are regularly monitored and maintained.

Under these conditions, exclusion fencing can prevent Pink and Chum Salmon spawners from entering spawning areas that dewater during WAH GS outages (see right panel of Figure 17). It is likely that most of the Chum Salmon shown in this picture would have spawned upstream of the fencing had it not been installed. Chum Salmon redd distribution in an area prone to dewatering, compared across years with and without the use of exclusion fencing, supports the notion that exclusion fencing was able to prevent spawning in those areas (Figure 18).

Figure 17 Exclusion fencing installed on the Herrling Island Side Channel in its initial (right panel) and more advanced progression (left panel) (Source: Living Resources 2013).

Figure 18 Chum Salmon redd distribution in the upstream end of Section 1 of the Herrling Island Side Channel, also called "the fingers" without (top panel) and with exclusion fencing installed (bottom panel) (Sources: top panel, Smith 2008; bottom panel, Living Resources 2012).

All exclusion fencing installed from 2010 to 2013 by Living Resources was of a temporary nature. However, the double-fence design shown in the left panel of Figure 17 appeared to be more effective in excluding salmon, while not being breached.

For a more reliable solution that could withstand breaching from temporary Fraser River mainstem flows and predators, sturdy aluminum fence panels could be built and installed annually on a removable substructure. Such a design would be more costly to build, and would still need to be monitored and maintained throughout its deployment. The potential loss of sturdier panels during high water should also be taken into account when considering this option.

Long-term funding for annual deployment, monitoring and maintenance of exclusion fencing would likely reduce the number of adult and juvenile salmon strandings, stranding-caused mortalities and redd dewatering. However, the use of exclusion fencing would likely never entirely prevent any of these occurrences from happening and the current exclusion fencing would likely be unsuitable to prevent juvenile stranding.

SPAWNING AREA CHANNEL RECONFIGURATION AND WHITE STURGEON SPAWNING

This section was written under the guidance of, and with information provided by, Erin Stoddard, Ecosystem Biologist and White Sturgeon Specialist, BC Ministry of Forest, Lands and Resource Operations.

As part of the attempt to exclude spawning Chum and Pink Salmon from marginal areas of the Herrling Island Side Channel to avoid the dewatering of their redds during WAH GS outages, it was suggested that the channel morphology be modified. The suggested modification would make the marginal areas steeper and less suited for salmon spawning; and thus WAH GS outages would not lead to fish, redd or egg strandings. However, in addition to providing salmon spawning habitat, the Herrling Island Side Channel is also an area of essential importance to White Sturgeon spawning in the Lower Fraser River.

Information on the location of White Sturgeon spawning areas and abundance of mature size (>160 cm) White Sturgeon in the Herrling Island Side Channel during their spawning period was collected for management and protection of the species during several studies over the last decade. In 2013, high resolution, side-scanning sonar was used to detect and enumerate White Sturgeon in turbid waters during their high water spawning period in several side channels (Figure 19) (English 2013). From 17 June to 10 July 2013, four side-scanning surveys were completed in 9 different side channels and other potential spawning habitats. The largest number of White Sturgeon (>160 cm) were found to be in the Herrling Island Side Channel (Table 2). Within the Herrling Island Side Channel, large White Sturgeon (>160 cm) were observed holding upstream and downstream of the WAH GS outlet (Figure 20).

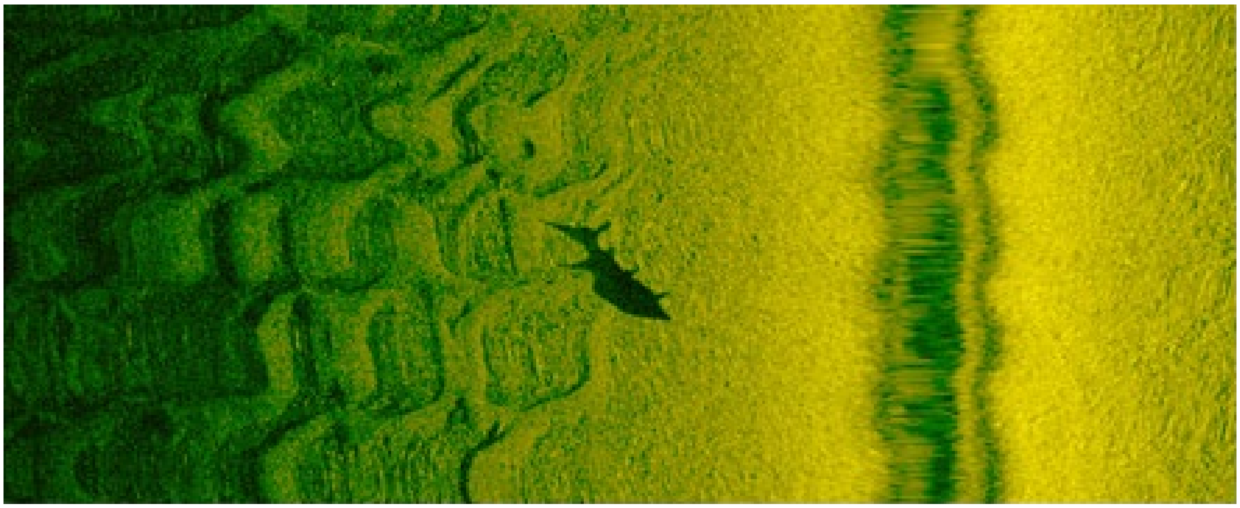


Figure 19 A single 2.56 m White Sturgeon over sandy bottom, Herrling Island Side Channel, 3 June 2013 (Source: English 2013).

Table 2 Summary of the number of White Sturgeon detected by date and location in the Lower Fraser River in 2013 (Source: English 2013).

	Herrling	Jesperson	Seabird	Minto	Powerline	Agassiz	Log Dump	Ruby Creek	Tranmer	Total
06/03/2013	43	2								45
06/04/2013	63									63
06/17/2013		3		20						23
06/18/2013	61								2	63
06/19/2013			36		7		17	10		70
06/24/2013		15		23						38
06/25/2013	55					4			8	67
06/26/2013			31		22		9	14		76
07/01/2013		9		27						36
07/02/2013	42					22			4	68
07/03/2013			9		10		4	17		40
07/08/2013		3		11						14
07/09/2013	21					4			7	32
07/10/2013			10		7		1	9		27
Total	285	32	86	81	46	30	31	50	21	635

Figure 20 Distribution of large (>160 cm) White Sturgeon (white circles) throughout the Herrling Island Side Channel on June 4, 2013 (top panel) and June 25, 2013 (bottom panel).

In addition to the observation of large White Sturgeon throughout the side channel, earlier studies caught freshly laid White Sturgeon eggs on egg mats deployed throughout the Herrling Island Side Channel. Specifically, egg mats located upstream and downstream of the WAH GS outlet between Site #1 and Site #2 on Figure 21 had the highest numbers of White Sturgeon eggs deposited on them (Triton 2013).

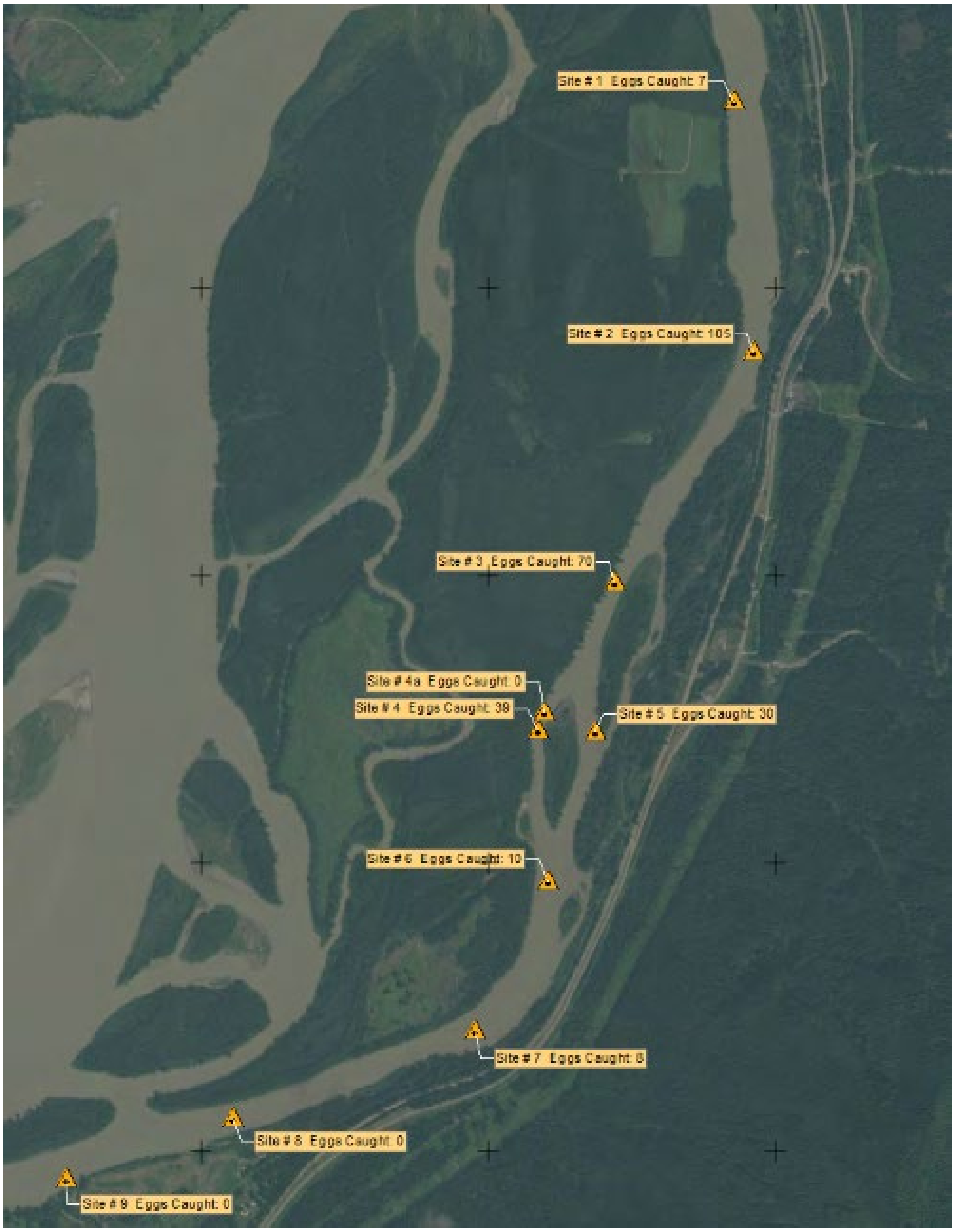


Figure 21 Sampling sites where egg mats were located in the Herrling Island Side Channel and the number of White Sturgeon eggs caught at each site in 2013 (Source: Triton 2013).

Based on the 2013 egg mat results, White Sturgeon eggs were also found deposited in the thalweg, as well as the more marginal areas, of the Herrling Island Side Channel (Triton 2013).

The degree of attention that is paid to the status of White Sturgeon in the Lower Fraser River is reflected in the progression of its listings as a species of concern. In 2003, White Sturgeon were nationally re-assessed as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), given that three of the six identified populations where at imminent threat of extinction due to lack of recruitment for a generation or more. The species was previously designated as Special Concern (in 1990). In 2006, four of the six populations were subsequently legally listed as Endangered under the federal Species at Risk Act (SARA). The lower and mid-Fraser River White Sturgeon populations were not legally listed for social and economic reasons, and a catch and release sport fishery was retained for both (downstream of the Cottonwood River confluence). Ongoing fisheries and recovery management activities including monitoring and research were identified as critical to ensure conservation and management objectives could be met.

It should be noted that COSEWIC re-classified and reviewed White Sturgeon as four Designatable Units (DU) in 2012 including the Upper Fraser (Nechako, Upper Fraser populations and Middle Fraser populations), Lower Fraser (below Hell's Gate), Kootenay and Columbia; these new status assessments await consideration under SARA. The Lower Fraser DU is designated as Threatened (principally based on restricted range rather than abundance) while the Middle Fraser (as part of the Upper Fraser DU) is now designated as Endangered. Despite the combining of some populations by COSEWIC, the Province of BC continues to manage White Sturgeon at the population level.

Current status reports indicate that there may be recruitment issues with the lower Fraser River White Sturgeon population (Nelson et al. 2014). As a consequence, recovery managers and stakeholders have undertaken numerous projects, including spawning and juvenile habitat indexing and assessments to better understand recruitment and the recovery potential of the population.

Based on all of these studies, including the ones cited in this report, the Herrling Island Side Channel is the most significant spawning site for White Sturgeon known for the lower Fraser River population. Only one other site near Seabird Island has been recently (2014) confirmed as a Lower Fraser White Sturgeon spawning site (E. Stoddard, BC Ministry of Forest, Lands and Resource Operations, personal communication).

Any physical modification of the channel morphology of the Herrling Island Side Channel would have far-reaching consequences for the lower Fraser River White Sturgeon population and is therefore not recommended. It would also not likely be supported or approved by the regulatory agencies.

CONCLUSIONS AND RECOMMENDATIONS

The WAH GS typically operates to meet local peak electricity load. This results in daily fluctuations in flows in the Herrling Island Side Channel between September and April, a period when the Fraser River does not typically effect side channel flows except through groundwater contributions (BC Hydro 2005). Based on these operational constraints and the resulting planned outages of the WAH GS, marginal areas of the Herrling Island Side Channel were regularly dewatered throughout the Pink and Chum Salmon spawning periods from 2005 to 2013. This measure was taken in an unsuccessful attempt to dissuade salmon from using these marginal areas for spawning, egg incubation and initial juvenile development in the gravel. Both salmon species used marginal areas for the aforementioned activities when WAH GS was operating and adult as well as juvenile fish were stranded and killed as a result during WAH GS shut downs. The frequency of dewatering caused mortality for all developmental stages in the gravel are unknown since these stages occupy the gravel at depths that may retain water even during WAH GS shut downs. More monitoring work in winter and spring and specifically during long-term freezing conditions would need to be carried out to quantify dewatering and freezing losses in the gravel.

Ladell and McCubbing (2013), described a so called “Block Loading Flow Regime” to improve spawning and decrease dewatering of Chum Salmon redds in the Stave River below Ruskin Dam. In this example, a minimum discharge through Ruskin Dam ensures that almost all of the suitable spawning habitat remains inundated while discharges above this minimum discharge remain non-prescribed. A similar minimum discharge that ensures inundation of most of the spawning habitat in the Herrling Island Side Channel can be suggested based on water stage levels in relation to discharge for this location and a “Block Loading Flow Regime” could be tried.

Aside from operational changes temporary exclusion fences have been shown to prevent adult salmon from entering marginal areas for spawning if they are properly constructed and maintained. The design including the erection of two side by side and parallel fences appears to be the better design to prevent breaches caused by high water or bears. An even sturdier fence design, following exploratory pilot deployment, using fabricated aluminum fence panels anchored to the ground may prove to be even more effective but will still need to be regularly maintained throughout the spawning period.

As an alternative measure to prevent adult salmon from spawning in marginal areas, the reduction of areas that are dewatered during low flows through re-contouring of the Herrling Island Side Channel was suggested. This measure is not recommended as it could easily interfere with the importance of the side channel as the only proven White Sturgeon spawning habitat in the Lower Fraser River and should therefore be dismissed.

A WAH GS discharge regime such as a "Block Loading Flow Regime" (Ladell and McCubbing 2013) that would not lead to sequential flooding and dewatering of marginal areas in the Herrling Island Side Channel would ensure that neither Pink nor Chum Salmon adults, eggs and juveniles stages in the gravel would be stranded and killed. If this kind of discharge regime cannot be established while generating electricity at WAH GS, the annual deployment of exclusion fencing combined with more monitoring on the effects of dewatering of redds in late winter and spring should be carried out.

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