North Coast Restoration Project Effectiveness Monitoring
NF-2013-H-3
Draft Final Report

by
Fisheries and Oceans Canada
North Coast Resource Restoration Unit
for
Pacific Salmon Commission Northern Fund

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Cover photo courtesy of Mark Spoljaric, Haida Fisheries

Over the past 10-15 years in the BC North Coast Area, many restoration projects have been constructed; a partial list of 35 known projects is provided in Appendix 1. Millions of dollars have been spent on the construction of projects and comparatively few dollars have been invested in evaluating their effectiveness.

In Oct 2012, a report commissioned by the Pacific Salmon Commission Habitat and Restoration Technical Committee titled *Assessment of Salmon Habitat Status and Trends and Restoration Project Effectiveness* was released. This report identified that significant resources had been directed towards restoration efforts by various funding sources over the years, but that relatively little assessment of the benefits of these projects had been completed. It stressed the importance of effectiveness monitoring in order to guide future restoration efforts and techniques.

In April 2013, the Pacific Salmon Commission Northern Fund provided resources to DFO's North Coast Resource Restoration Unit to study a suite of restoration projects undertaken in the North Coast Area over the past ~10-25 years. The assessment work spans two fiscal years, the first of which included the following suite of studies:

- Restoration Project Assessment/Effectiveness Monitoring: Suggestions for Effective Study Design by Jan Heggeness
- An in-depth incubation study to document spawning success in the newly created Williams spawning channel in Lakelse, Year 1
- an overwintering study to examine the effectiveness of a fishway installed to provide access to wetland habitat upstream of Highway 37 North, and
- two small feasibility/study designs and proposals to conduct effectiveness monitoring at a variety of sites in 2014.

Year two involved the following studies:

- Completion of the in-depth incubation study and write-up to document spawning success in the newly created Williams spawning channel in Lakelse,
- Fishway Effectiveness Monitoring in Haida Gwaii
- Kalum Lake Spawning Channel Adult Enumeration (to be followed by downstream juvenile assessment in Spring 2015 if funded).

This draft includes reports for the two of the three projects in Year 2 and we are still waiting for the report for the work on the Kalum spawning channel enumeration. This draft will be updated with a copy of all the reports for both study years a summary of results and recommendations from each of the studies by the end of December 2014.

Appendices

Upper Williams Creek Spawning Channel and Scully Creek South: Sockeye Egg Incubation Study 2013-2014 by Neale Postma, Stantec – December 2014

Haida Gwaii Fishway Effectiveness Study by Mark Spoljaric, Haida Fisheries Program – October 2014

Haida Gwaii Fishway Effectiveness Study
Final Report

Prepared for:

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EXECUTIVE SUMMARY

Over the past 10-15 years in the BC North Coast Area, many salmon habitat restoration projects have been completed. These projects have typically been aimed at restoring degraded habitat. Recent investigations have shown that restoration measured designed to restore stream connectivity may be effective. On Haida Gwaii, a number of salmon bearing streams are impacted by road construction and have been traversed by bridge (larger streams), culverts or other fishway structures designed to restore stream connectivity and allow fish unimpeded movement up and downstream. We tested the effectiveness of 5 different fishways on the archipelago and found that none impeded juvenile fish passage upstream. We also looked for and found very little difference in abundance, size of salmonids and species richness of fish caught above and below the fishways on two selected streams. We then make recommendations to fine tune the study in the future which include continued sampling in order to determine how fish distribute through the system.

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INTRODUCTION

Over the past 10-15 years in the BC North Coast Area, many salmon habitat restoration projects have been completed. Millions of dollars have been spent on the construction of stream restoration measures but comparatively few dollars have been invested in evaluating their effectiveness.

Typically, restoration measures have been aimed at increasing in-stream complexity in streams that were degraded industrial land-use changes. Recent reviews of the effectiveness of these types of restoration measures have been rather negative. The results of a number of studies suggest that the effectiveness of stream restoration is negligible and that most restoration projects fail to achieve their objectives (Palmer *et al.* 2010, Bernhardt & Palmer 2011, Stranko *et al.* 2012).

The failure of habitat restoration projects to achieve objectives may be attributed to a number of factors. There is often limited information about pre- and post-restoration physical habitat, water quality, and biota (Roni *et al.* 2008). And, there is a paucity of long term studies (i.e. more than a decade post-construction) as the majority of evaluation studies are of limited scope and duration (Roni et al. 2008, Whiteway *et al*. 2010, White *et al*. 2011).

However, recent investigations have shown that restoration measured designed to restore stream connectivity in smaller streams fragmented by water blockages or flow diversions may be efficient (Rood *et al.* 2003, Catalano *et al.* 2007, Hall *et al.* 2011). In British Columbia, a number of salmon bearing streams are impacted by road construction and are subsequently traversed by bridge (larger streams), culverts or other structures designed to restore stream connectivity and allow fish unimpeded movement up and downstream.

On Haida Gwaii, several different types of structures have been installed to improve fish passage under highways and roads that cross over streams. Given that the streams are in relatively close proximity to each other presents a unique opportunity to assess the effectiveness of fishway structures on the archipelago. In the spring/summer/fall of 2014, the Haida Fisheries Program (HFP) will assist DFO in assessing the effectiveness of a number of these sites.

Objectives

Haida Fisheries believes that there are three objectives that are achievable with a relatively simple experimental design:

1. Do the selected Fishway structures facilitate the upstream movement of juvenile salmonid fry?

2. Are there differences in salmonid abundance above and below the selected fishways?
3. Is there a difference in species richness above and below selected fishways?

Null hypotheses:

1. Fishway structures do not impede juvenile salmonid movement upstream.
2. There are no differences in abundances above and below the selected fishways.
3. There is no difference in richness above and below selected fishways.

METHODS

Site selection

There were a number of creeks with fishways that are suitable for this study. Haida Fisheries selected streams with similar fishway structures and habitat characteristics. We selected two streams for our controlled experiment: Grouse Creek- a stream with a steep aluminum passage Fishway (Figure 1), wetland upstream (Figure 2) and good habitat downstream; Froese Creek- a stream with a concrete pool weir fishway with a “right angle” on the downstream side (Figure 3), good upstream and downstream habitat. We also selected three additional streams with concrete fishways and good upstream habitat to test fish passage and they are: Hannot Creek- concrete vertical slot fishway (Figure 4), Balance Rock Creek- concrete pool and weir fishway (Figure 5) and Charlie Hartie Creek- concrete step pool fishway (Figure 6).

Habitat Assessment

Haida Fisheries performed Level 1 habitat surveys (Johnston and Slaney, 1996) on our two experimental streams (Grouse and Froese Creeks). We recorded the standard Level 1 habitat survey data as well the habitat units as the stream dynamics changed as we moved upstream. The surveys were done to determine the appropriate area to set up treatment and control sites (see experimental design below).

Experimental design

Haida Fisheries designed a simple experiment to determine our objectives and test our hypotheses. First, we selected our treatment sites and isolated the area up and down stream of the fishway on both the experimental streams. On Grouse Creek we installed “Stop nets” (small beach seine’s) 20m above and 40m below the fishway structure (Figure 7). On Froese Creek Stop nets were installed 40m above and 20m below the fishway. On each stream, we ensured the isolated areas were “fish tight” by burying the nets lead lines (bottom of net) in the stream bed and extended each net up onto the stream bank. Nets were secured with rope and heavy duty twine. Second, we selected our control sites on both streams. To ensure that the habitat in our treatment and control sites was similar, we analyzed select habitat characteristics collected from the Level 1 survey data from within the treatment sites and chose similar habitat within a similar length for our control sites. Third, we captured fish in each of the isolated areas (both treatment and controls) using two passes with an electroshocker. Fish were identified, counted, anaesthetized (using a predetermined solution of TMS), measured (fork length (mm)), weighed (g) and marked with a caudal fin clip. In the treatment sites marked fish were released downstream of the fishway BUT still within the isolated area. In the control sites marked fish were released at the downstream end of the isolated area. Fourth, we set Gee traps above the fishway in the treatment sites and at the top end of the control sites but still within the isolated areas. Finally, Haida Fisheries returned to the experimental streams 24 hours later. We noted what was caught and released all fish (marked and un-marked) from the gee traps upstream of the isolated area in the treatment sites and downstream of the isolated area in the control sites. We then re-set the gee traps and check at 48, 72 and up to 96 hours later following the procedure outlined above.

Haida Fisheries also tested fish passage in three additional streams (Hannot, Balance Rock, and Charlie Hartie Creeks). In each stream, we captured fish using two passes with an electroshocker and then identified, counted, anaesthetized, measured, weighed and marked with a caudal fin clip. Processed fish were released at the downstream end of the fishway. We set Gee traps above the fishway and returned to the experimental streams 24, 48 and 72 hours later. Once recorded, all fish captured from the gee traps were released 75m upstream of the fishway.

The experiments and tests outlined above were initiated in May of 2014 and then replicated in August of the same year.

Analysis

All data were recorded in the field using Duksback waterproof notebooks. Once back at the office, the data were entered and summarized using Microsoft Excel. Statistics were performed using SPSS statistical software. Parametric data was analyzed using independent samples T-test's while non-parametric data was compared using Binomial tests (with a test proportion of 0.5).

RESULTS

Habitat assessment and control site selection

Grouse Creek

Haida Fisheries performed Level 1 habitat surveys on Grouse Creek. We surveyed a total of 580m of stream, which included the fishway and 20m of habitat before downstream end of the wetland. Back at the office we analyzed the data looking for areas of stream that had similar habitat characteristics (with the exception of the fishway in the treatment site). Our treatment site was 100m in length, had a predominantly gravel and sand substrate, medium/high spawning gravel quality, 1 pool, 2 riffles, 1 glide and 4 pieces of functional large woody debris (LWD). The top end of our control site was 3m downstream from the bottom end of the treatment site (Figure 8). The control was 90m in length and was statistically similar in habitat characteristics to our treatment site (Table 1; Figure 9).

Froese Creek

We surveyed a total of 330m of Froese Creek, which included the fishway and 140 of habitat upstream. Our treatment site was 30m in length, had a predominantly gravel and sand substrate, low/medium spawning gravel quality, 1 pool, 3 riffles, 4 glide and 3 pieces of functional large woody debris (LWD). The top end of our control site was 4m downstream from the bottom end of the treatment site (Figure 10). The control was 20m in length and was statistically similar in habitat characteristics to our treatment site (Table 2; Figure 11).

Fishway effectiveness

Controlled experiment

Haida Fisheries conducted a controlled experiment that tested the effectiveness of two fishway structures on the archipelago. Our experiment was replicated twice and we found variable but favourable results (see Table 3 for a summary of the results). In May on Froese Creek, we marked and released 14 coho (*Onchorhynchus kisutch*) and 17 Dolly Varden (*Slavelinus malma*) below the fishway and recaptured only one Dolly Varden above the fishway (6% of all DV marked and released below the fishway). At Grouse Creek, there were 40 coho and 20 Dolly Varden marked and released in the treatment site below the fishway but no recaptures. At the control site on Froese Creek, we recaptured one coho at the top end of the control site that represented 17% of the total number of marked coho released at the bottom of the site. Similarly, we recapture one coho at the Grouse Creek control site but that represented only 1% of the total number of marked coho released at the bottom of the site. In August on Froese Creek at the treatment site, we recaptured 7 coho (19% of marked CO) and 3 Dolly Varden (27% of marked DV). At the Grouse treatment site, 7 coho (16% of all marked CO) and 2 Dolly Varden (67% of marked DV) were recaptured above the fishway. At the Froese Creek control site, 6 coho (40% of marked CO) were recaptured at the top end of the site while neither of the two Dolly Varden marked was recaptured. There was only one coho recaptured (5% of marked CO) in the Grouse Creek control site and none of the 4 Dolly Varden marked were recaptured again in August.

Testing additional Fishways

Haida Fisheries also tested the effectiveness of three additional fishway structures on the archipelago (see Table 4 for a summary of the results). In May at Charlie Hartie Creek, one Dolly Varden (8% of marked DV) was recaptured above the fishway but none of the 5 coho that were marked and released below the fishway was recaptured. At Hannot Creek, none of the 12 coho or 5 Dolly Varden that were marked and released was recaptured. Similarly, none of the 27 coho or 9 dolly Varden marked at Balance rock Creek were recaptured. We had more success in August at all the streams. There were 8 coho (24% of marked CO) and 2 Dolly Varden (18% of marked DV) recaptured above the fishway at Charlie Hartie Creek. One Dolly Varden was recaptured (25% of marked DV) at Hannot Creek but none of the 15 coho marked was caught again. At Balance Rock Creek, 2 coho (2% of marked CO) were recaptured above the fishway but none of the 11 Dolly Varden was recaptured.

Salmonid abundance above and below fishway

Haida Fisheries tested for differences in salmonid abundance above and below the fishways on Grouse and Froese Creeks. Fish were collected in May and August of 2014 and the results are summarized in Table 5. In May, we found that there was significantly more Dolly Varden (DV) captured below the fishway (15 DV) than above (5 DV) on Grouse Creek ($p = 0.04$). There was no statistical difference in the number of coho (CO) captured above and below the fishway's on either creek and there was no statistical difference in the number of Dolly Varden caught on Froese Creek in May. In August, there were significantly more coho caught below (26 CO) than above (11 CO) the fishway ($p = 0.02$) of Froese Creek. There was no statistical difference in the number of Dolly Varden captured above and below the fishway's on either creek and there was no statistical difference in the number of coho caught on Grouse Creek in August.

We also tested for differences in size between fish captured above and below the fishway in our treatment sites. In May on Grouse Creek, on average coho captured above the fishway were significantly larger (average fork length (FL) = 69.7mm) than the coho caught below (average FL= 53.0mm) ($t=3.7$, $DF= 38$, $p< 0.001$). There was no statistical difference in the average size of Dolly Varden caught above ($n= 5$, average FL= 99.2mm) and below the fishway ($n= 15$, average FL= 100.5mm). In August on Grouse Creek, was no statistical difference in the average size of coho caught above (n=2 5, average FL= 65.0mm) and below the fishway ($n= 17$, average FL= 67.2mm) or in the average size of Dolly Varden caught above ($n= 1$, average FL= 95.0mm) and below ($n= 2$, average FL= 107.5mm), although the sample size for Dolly Varden is small. We did not find any statistical differences in average fork length above and below the fishway in either month on Froese Creek. In May, coho caught above (n=7, average FL= 71.1mm) and below (n= 7, average FL= 66.6mm); Dolly Varden caught above (n= 3, average FL= 102.3mm) and below the fishway (n= 4, average FL= 90.5mm). In August, coho caught above (n=11, average FL= 72.7mm) and below (n= 26, average FL= 68.0mm); Dolly Varden caught above (n= 4, average FL= 106.7mm) and below the fishway (n= 7, average FL= 101.1mm).

Species richness above and below fishway

Haida Fisheries looked for differences in species richness above and below the fishway's in our treatment sites on Grouse and Froese Creeks. There was no difference in species richness at either site. We found only coho and Dolly Varden in each system both above and below the fishway (revisit Table 5 for a summary). In Fact, coho and Dolly Varden were the only fish species found in all of the streams we looked at in this study.

DISCUSSION

The fishway effectiveness study was a success. Results show that all the fishway structures that we tested for juvenile fish passage facilitate the movement of juvenile salmonids upstream. All fish initially captured using electro-fishing techniques from both control and treatment sites in each locality were marked with a fin clip and then released at the downstream end of each site. Baited gee traps were placed at the upstream end of each site and allowed to fish for at least a 24 hour period. We recaptured marked salmonids above the respective fishways and the control sites at all the systems we looked at.

The treatment sites on both experimental streams produced favourable results. In May on Froese Creek, one of seven marked Dolly Varden was recaptured above the fishway in our isolated zone. The results on Froese Creek were replicated in August with greater success. We also recaptured a number of coho and Dolly Varden at Grouse Creek. This result was in contrast to what we found in May at Grouse Creek where we did not have any recaptures above the fishway. This is not to say that fish did not move upstream at Grouse Creek in the springtime but rather that we changed our sampling protocol and left the gee traps fishing for much longer to give the fish more time to move upstream if they chose to. In Grouse creek the number of coho recaptured increased with time. It is possible that in May juvenile salmonids did move upstream through the fishway but we did not recapture them because we didn't allow enough time for the fish to move through the structure.

We also tested to see if fish would move upstream at two control sites if we applied the same procedures that we used on the fish in the treatment sites. In May at each of our two control sites, we recaptured one coho fry over night. Although the initial mark groups differed significantly between streams (92 coho in Grouse Creek and 6 coho in Froese Creek) the fact that we recaptured marked fish indicates that these fish could disperse and move freely upstream in a relatively short period of time. Our results were replicated in August with greater success. Again as with the treatment sites, the longer the gee traps were left fishing the more recaptures. However, we should note that the fish movement that we were able to detect in the control sites happened in the first 48hours after the traps were set. We should also note that in most cases the majority of fish marked in our control sites were not recaptured. We do not know if they stayed near the release point at the bottom of the site or if they dispersed but did not go into our traps.

There was moderate success at the three additional streams we tested for juvenile passage through their fishway's. In May on Charlie Hartie Creek, one of thirteen marked Dolly Varden was recaptured above the fishway. There were no other recaptures at Balance Rock or Hannot Creeks this past spring. However, we were able to recapture marked fish in all three streams in August and the results from Charlie Hartie Creek were replicated with greater success. Although the number of recaptures was low the results demonstrate that juvenile fish can move upstream through the fishway on their respective streams. We should note that there is little downstream habitat below the fishway's at Hannot and Balance Rock Creeks. It is possible that marked fish released at the bottom of the fishway on these two systems were washed out into the brackish water immediately downstream of the release sites. It is also possible that marked fish swam upstream through the fishway and simply didn't enter the gee traps. Perhaps using the electroshocker in conjunction with the gee traps would be a more robust method to determine how marked fish disperse throughout the study sites.

Haida Fisheries tested for differences in salmonid abundance above and below the fishways on Grouse and Froese Creeks. Although our sample sizes were small we were able to determine that with a couple exceptions salmonid abundance was the same above and below the fishways on the experimental streams. We did find significantly more Dolly Varden in Grouse creek below the fishway in May. One possible explanation could be that larger Dolly Varden above the fishway out compete smaller fish and could force them downstream in search of new habitat, but we did not find any statistical difference in the size (fork length) of Dolly Varden above and below the fishway. An additional explanation is that we happened to sample a school that was making their way downstream in search of food. In August, there were significantly more coho caught below the fishway on Froese Creek. Again, there was no difference in size and it is possible that we sampled a school that was moving around the system in search of food.

We also looked for differences in size between fish found above and below the fishway in the experimental streams. There were significantly larger coho found upstream of the fishway on Grouse creek in May. There is a large wetland immediately upstream from the fishway and it is possible that there was more food available in the early spring to those coho residing there compared to the fish living downstream. We didn't find any other differences in size for either species throughout the course of our study.

Haida Fisheries also compared species richness at our sites. It would also appear that there are no differences in species richness above or below the fishways- we captured the same species of fish in each locality in control and treatment zones above and below fishways. The same results were found at the three additional streams. Similar species richness in the systems was expected however we were surprised that we only found two different species of fish. Perhaps we did not sample enough of the streams to get a comprehensive picture of what species of fish are present.

In conclusion, the results of this study demonstrate the effectiveness of the fishway structures on Haida Gwaii that we tested for juvenile fish passage. The results of the first round of sampling warrant further replication. We recommend following the same protocols that we used in August for future sampling (allow the gee traps to fish for up to 96 hours) which should allow enough time for marked fish to move upstream through the fishways if they so choose. We also suggest modifying the design to try and ascertain a better picture of fish distribution after being marked and released. This could involve further electrofishing in conjunction with gee trapping while making detailed notes on where in the section the fish were recaptured. One final recommendation would be to measure the recaptures to determine if there are any size limitations imposed by the fishways (i.e., are some fish too small to swim upstream through the structure).

REFERENCES

Bernhardt, E. S. & Palmer, M. A. (2011). Evaluating river restoration. *Ecological Applications* **21**(6): 1925-1925.

Bernhardt, E. S. & Palmer, M. A. (2011). River restoration: The fuzzy logic of repairing reaches to reverse catchment scale degradation. *Ecological Applications* **21**(6): 1926-1931.

Catalano, M. J., Bozek, M. A. & Pellett, T. D. (2007). Effects of dam removal on fish assemblage structure and spatial distributions in the baraboo river, wisconsin. *North American Journal of Fisheries Management* **27**(2): 519-530.

Hall, A. A., Rood, S. B. & Higgins, P. S. (2011). Resizing a river: A downscaled, seasonal flow regime promotes riparian restoration. *Restoration Ecology* **19**(3): 351-359.

Johnston, N. T., Slaney, P.A. (1996). "Fish Habitat Assessment Procedures." British Columbia Ministry of Environment, Lands and Parks, Watershed Restoration Program, Technical Circular No. 8.

Palmer, M. A., Menninger, H. L. & Bernhardt, E. (2010). River restoration, habitat heterogeneity and biodiversity: A failure of theory or practice? *Freshwater Biology* **55**: 205-222.

Roni, P., Hanson, K. & Beechie, T. (2008). Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques. *North American Journal of Fisheries Management* **28**(3): 856-890.

Rood, S. B., Gourley, C. R., Ammon, E. M., Heki, L. G., Klotz, J. R., Morrison, M. L., Mosley, D., Scoppettone, G. G., Swanson, S. & Wagner, P. L. (2003). Flows for floodplain forests: A successful riparian restoration. *Bioscience* **53**(7): 647-656.

Stranko, S. A., Hilderbrand, R. H. & Palmer, M. A. (2012). Comparing the fish and benthic macroinvertebrate diversity of restored urban streams to reference streams. *Restoration Ecology* **20**(6): 747-755.

White, S. L., Gowan, C., Fausch, K. D., Harris, J. G. & Saunders, W. C. (2011). Response of trout populations in five colorado streams two decades after habitat manipulation. *Canadian Journal of Fisheries and Aquatic Sciences* **68**(12): 2057-2063.

Whiteway, S. L., Biron, P. M., Zimmermann, A., Venter, O. & Grant, J. W. A. (2010). Do in-stream restoration structures enhance salmonid abundance? A meta-analysis. *Canadian Journal of Fisheries and Aquatic Sciences* **67**(5): 831-841.

Tables

Table 1. Comparison of habitat characteristics on Grouse Creek quantified through a Level 1 survey between the treatment and control site.

Habitat characteristic	Treatment	Control	Statistics
Length (m)	100	90	
Average bankfull width (m)	5.75	4.3	t= 0.31, df=5, p= 0.77
Number of pools	1	1	
Pool residual depth (m)	0.84	0.64	
Number of riffles	2	4	Binomial, p= 0.7
Number of glides	1	3	Binomial, p= 0.63
Dominant bed type	Gravel and sand	Gravel and sand	
Ave spawning gravel quality (1=Low, 2= med and 3= high)	2.5	1.5	t= 1.85, df=5, p= 0.12
Number of LWD 10-20cm	2	3	Binomial, p= 1.0
Number of LWD 20-50cm	2	4	Binomial, p= 0.69
Number of LWD >50cm	0	2	Binomial, p= 0.5
Total number of LWD	4	9	Binomial, p= 0.27

Table 2. Comparison of habitat characteristics on Froese Creek quantified through a Level 1 survey between the treatment and control site.

Habitat characteristic	Treatment	Control	Statistics
Length (m)	30	20	
Average bankfull width (m)	4.0	3.2	t= 1.35, df=3, p= 0.27
Number of pools	1	1	
Pool residual depth (m)	0.63	0.54	
Number of riffles	3	2	Binomial, p= 1.0
Number of glides	4	2	Binomial, p= 0.69
Dominant bed type	Sand/gravel	Sand	
Ave spawning gravel quality (1=Low, 2= med and 3= high)	1.3	1.5	t= 0.29, df=3, p= 0.79
Number of LWD 10-20cm	1	0	n/a
Number of LWD 20-50cm	0	1	n/a
Number of LWD >50cm	2	0	Binomial, p= 0.5
Total number of LWD	3	1	Binomial, p= 0.63

Table 3. Total numbers of fish captured, marked and recaptured on experimental streams. In control areas, all marked fish were released at the downstream end of the exclusion zone. In treatment areas, all marked fish were released below the fishway on the downstream end of the exclusion zone. CO= coho salmon; DV= Dolly Varden.

Creek	Date	Total marked-released at bottom of site	Total number caught above fishway (unmarked)	Recaptures- above fishway
Grouse Creek treatment	May 19, 2014	40 CO; 20 DV	8 Co; 1 DV	0
	Aug 12, 2014	42 CO; 3 DV	37 CO; 9 DV	0
	Aug 13, 2014		21 CO; 4 DV	1 CO; 2 DV
	Aug 14, 2014		10 CO; 3 DV	2 CO
	Aug 15, 2014		8 CO; 2 DV	4 CO
Grouse Creek control	May 19, 2014	92 CO; 10 DV	17 CO; 7DV	1 CO
	Aug 12, 2014	21 CO; 4 DV	29 CO	0
	Aug 13, 2014		76 CO; 1 DV	1 CO
	Aug 14, 2014		16 CO; 1 DV	0
	Aug 15, 2014		3 CO	0
Froese Creek treatment	May 19, 2014	14 CO; 7 DV	1 DV	1 DV
	Aug 13, 2014	37 CO; 11 DV	6 CO; 1 DV	3 CO
	Aug 14, 2014		6 CO; 2 DV	4 CO: 2 DV
	Aug 15, 2014		1 CO; 1DV	1 DV
Froese Creek control	May 19, 2014	6 CO; 4 DV	1 DV	1 CO
	Aug 13, 2014	15 CO; 2 DV	10 CO; 1 DV	6 CO
	Aug 14, 2014		1 CO	0
	Aug 15, 2014		0	0

Table 4. Total numbers of fish captured, marked and recaptured on selected streams. In control areas, all marked fish were released at the downstream end of the exclusion zone. In treatment areas, all marked fish were released below the fishway on the downstream end of the exclusion zone. CO= coho salmon; DV= Dolly Varden.

Creek	Date	Total marked-released below fishway	Total number caught above fishway (unmarked)	Recaptures- above fishway
Hannot Creek	May 19, 2014	12 CO; 5 DV	1 CO; 6 DV	0
	Aug 12, 2014	15 CO; 4 DV	1 CO; 1 DV	0
	Aug 13, 2014		25 CO; 1 DV	1 DV
	Aug 14, 2014		7 CO; 1 DV	0
	Aug 15, 2014		0	0
Balance Rock Creek	May 19, 2014	27 CO; 9 DV	3 CO; 4 DV	0
	Aug 13, 2014	101 CO; 17 DV	39 CO; 12 DV	0
	Aug 14, 2014		n/a	n/a
	Aug 15, 2014		30 CO; 4 DV	2 CO
Charlie Hartie Creek	May 19, 2014	5 CO; 13 DV	5 DV	1 DV
	Aug 13, 2014	33 CO; 11 DV	31 CO; 22 DV	6 CO; 2 DV
	Aug 14, 2014		n/a	n/a
	Aug 15, 2014		12 CO; 1 DV	2 CO

Table 5. Salmonid abundance above and below fishway's on selected streams. CO= coho salmon; DV= Dolly Varden.

Creek	Date	Total captured Treatment	Total captured above fishway	Total captured below fishway
Grouse Creek	May 19, 2014	40 CO; 20 DV	15 CO; 5 DV	25 CO; 15 DV
Grouse Creek	Aug 13, 2014	42 CO; 3 DV	25 CO; 1 DV	17 CO; 2 DV
Froese Creek	May 19, 2014	14 CO; 7 DV	7 CO; 3 DV	7 CO; 4 DV
Froese Creek	Aug 13, 2014	37 CO; 11 DV	11 CO; 4 DV	26 CO; 7 DV

FIGURES

Figure 1. Grouse Creek Steep aluminum passage.

Figure 2. Grouse Creek wetland.

Figure 3. Froese Creek concrete fishway (downstream).

Figure 4. Hannot Creek concrete fishway (downstream).

Figure 5. Balance Rock Creek concrete fishway (downstream).

Figure 6. Charlie Hartie Creek concrete fishway (downstream).

Figure 7. Installation of stop net on Froese Creek.

Figure 8. Grouse Creek treatment and control sites. Upstream net delineates the bottom of the treatment and the downstream net delineates the top of the control site.

Figure 9. Stream characteristics within the control site on Grouse Creek.

Figure 10. Froese Creek treatment and control sites. Upstream net delineates the bottom of the treatment and the downstream net delineates the top of the control site.

Figure 11. Froese Creek control site.

Upper Williams Creek Spawning Channel and Scully Creek South: Sockeye Egg Incubation Study 2013-2014

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Fisheries and Oceans Canada
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November 28, 2014

Sign-off Sheet

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Acknowledgements

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Executive Summary

Williams Creek (within the Skeena Watershed near Terrace, BC) historically supported up to 80 % of the Lakelse Lake Sockeye Salmon population which numbered in the tens of thousands up until the late 1960s (Powell 2013). Since then, numbers have declined to the hundreds and low thousands. This decline appears to be related to spawning habitat loss caused by logging-induced sedimentation. In response to this habitat loss, the Department of Fisheries and Oceans Canada (DFO) recently (completed in 2012) constructed a spawning channel on upper Williams Creek. To determine if this spawning channel is functional, DFO retained Stantec Consulting Ltd. to complete a Sockeye egg incubation study.

In this study, Sockeye eggs obtained from a hatchery were incubated and monitored in Upper Williams Creek spawning channel (aka Williams Channel) and, for comparison, in Scully Creek South. Scully Creek South is a nearby Lakelse Lake tributary that supports Sockeye Salmon and has undergone recent (since 2009) habitat restoration (beaver dam removals and off-channel rearing habitat installation).

The primary objectives of this study were to investigate:

- Egg-to-hatch and hatch-to-fry survival rates; and
- Water quality conditions, including:
    - o Hourly water temperature,
    - o Intergravel/Water Column Dissolved Oxygen, Temperature, pH, and Conductivity; and
    - o Water velocity and depth.

A total of ten incubation sites were selected: five in Williams Channel and five in Scully Creek South. At each incubation site, one hundred eyed eggs were loaded into the

lower half of a Jordan-Scotty instream incubation cassette. Five incubation cassettes were buried at each site, perpendicular to the flow. Jordan-Scotty incubation cassettes are designed to allow water/waste transmittal but prevent escape of alevins/fry. After an appropriate incubation period, the contents of each cassette were inspected to determine incubation survival.

A group of eyed eggs remained at the hatchery as a control to demonstrate that there were no fertilization or survival issues with the donor eggs used in the study. Survival rates of the control were monitored to the hatch and fry stages.

Water quality conditions were monitored during the entire study period from October 2013 to May 2014. Hourly intergravel and water column temperature was measured using Onset TidbiT™ temperature loggers. Loggers were positioned at the upstream and downstream ends of each study area. Dissolved oxygen (DO), pH, and conductivity were measured at each incubation site during cassette installation and hatch/fry inspections. Velocity and depth were measured at each incubation site a total of three times during the study period.

Williams Channel

The results of this study demonstrate that Williams Channel is able to support Sockeye Salmon egg incubation. Eyed egg-to-hatch survival averaged 94.7 % (n=1000) which was higher than the Snootli Creek Hatchery control group (85.3 %, n=5000). Eyed egg-to-fry survival averaged 60.7 % (n=1500) which was less than the hatchery control group (84.1 %, n=5000) and less than the expected survival (approximately 90 %, under ideal conditions) associated with the Scotty-Jordan instream incubators used in this study (Jordan 1988).

The incubation site showing the least eyed egg-to-fry survival was Site 5: 9.7%. Of the mortalities at Site 5, 98.0 % were alevins, which, based on DFO guideline ranges for Sockeye ATUs, hatched on approximately January 30, 2014. All instantaneous and logged water quality parameters monitored during the study were within BC guidelines for aquatic life. The intergravel water temperatures were above freezing (at 0^0C for two hours on January 31) for the incubation period and this compares favorably with depth and velocities measurements taken on the three dates. During all three sampling periods, there was flowing water over the incubation sites.

Spawning Coho salmon were noted during our first visit to site in October during the installation of the incubation cassettes, and were actively seeking out spawning locations. DFO habitat biologists (Lana Miller and James Powell) noted during a November flow discharge measurement on Williams Channel, that a couple of cassettes had been disrupted and were unburied. The cassettes were re-installed and there is the possibility that cassettes at Site 5 were disrupted at a later date by spawning Coho.

Based on the results of this study, it appears that the amount of flow (approximately 0.12 m^3/s) released into Williams Channel through the intake structure on Williams Creek was appropriate. follow-up study is recommended should the intake flow change from the release rate documented during our study period.

Scully Creek South

Mean survival rates across all incubation sites in Scully Creek South were considerably lower than those in the Snootli Creek Hatchery control group. In Williams Channel the mean survival was 58.5 % (n=985) for the eyed egg-to-hatch stage and 33.2 % (n=1500) for the eyed egg-to-fry stages. The mean survival for the Snootli Creek Hatchery control group (n=5000) was 85.4 % and 84.1 % respectively, for eyed egg-to-hatch and eyed egg-to-fry stages.

The incubation survival in Scully Creek South is consistent with the results of a previous incubation study done on Scully Creek in 2008-2009. The Guimond 2008-2009 study, identified low dissolved oxygen in Scully Creek South (Guimond 2009) as a factor of hatch mortalities. In this study, intergravel DO levels as low as 31.6 % at Site 3 were documented. Thus, the complete lack of survival at Site 3 was likely due to low DO.

As for the other sites, their overall poor incubation survival did not appear to be related to the water quality parameters monitored during this study as these parameters were within BC guidelines for aquatic life. Observed water velocities and depths recorded showed that water was present over the incubation sites. Freezing did not appear to be a likely cause, since water temperature did not drop to 0.0^0C until March 2, 2014 (and only remained below 1^0C for less than 24 hours), i.e. well after hatching would have occurred. And yet almost half (47.6 %) of all the mortalities at Scully Creek South were at the eyed egg stage.

However, DO demands for incubating eggs increase, as the eggs develop, with the greatest demand immediately before hatching (Quinn 2005). Despite our water quality monitoring results, the fact that eyed egg-to-hatch survival was low (i.e., < 50%) across 12 out of the 25 cassettes buried in total at the Scully Creek South incubation sites suggests that DO demands of the incubating eggs were not being met. Further investigation is needed to better understand the physiochemical factors influencing incubation survival in this system.

INTRODUCTION

Williams Creek historically supported up to 80 % of the Lakelse Lake Sockeye Salmon population which numbered in the tens of thousands up until the late 1960s. Since then, numbers have declined to the hundreds and low thousands (Powell 2013). This decline appears to be related to spawning habitat loss caused by logging-induced sedimentation. In response to this habitat loss, the Department of Fisheries and Oceans Canada (DFO) recently (completed in 2012) constructed a spawning channel on upper Williams Creek. To determine if this spawning channel is functional, DFO retained Stantec Consulting Ltd. to complete a Sockeye egg incubation study.

1.1 OBJECTIVES

The overall goal of this study was to determine if the Upper Williams Creek spawning channel is able to support Sockeye Salmon egg incubation. To make this determination, Sockeye eggs obtained from a hatchery were incubated in Upper Williams Creek spawning channel and, for comparison, in Scully Creek South. Scully Creek South is a nearby Lakelse Lake tributary that has undergone habitat restoration (beaver dam removals and off-channel rearing habitat installation).

The objectives of this study were to investigate:

- Egg-to-hatch and hatch-to-fry survival rates, and
- Water quality conditions, including:
  - Hourly water temperature,
  - Intergravel/Water Column Dissolved Oxygen, Temperature, pH, and Conductivity; and
  - Water velocity and depth.

Although other factors, such as substrate quality, and flow characteristics are known to influence incubation survival, these factors were outside the scope of this study and therefore not investigated in detail. Only basic substrate and flow data were collected.

1.2 BACKGROUND INFORMATION

1.2.1 Study Area

The study area consisted of two areas: the upper Williams Creek spawning channel and a section of Scully Creek South. Both systems are major tributaries to Lakelse Lake which ultimately flows into the Skeena River near the Terrace, BC (Figure 1).

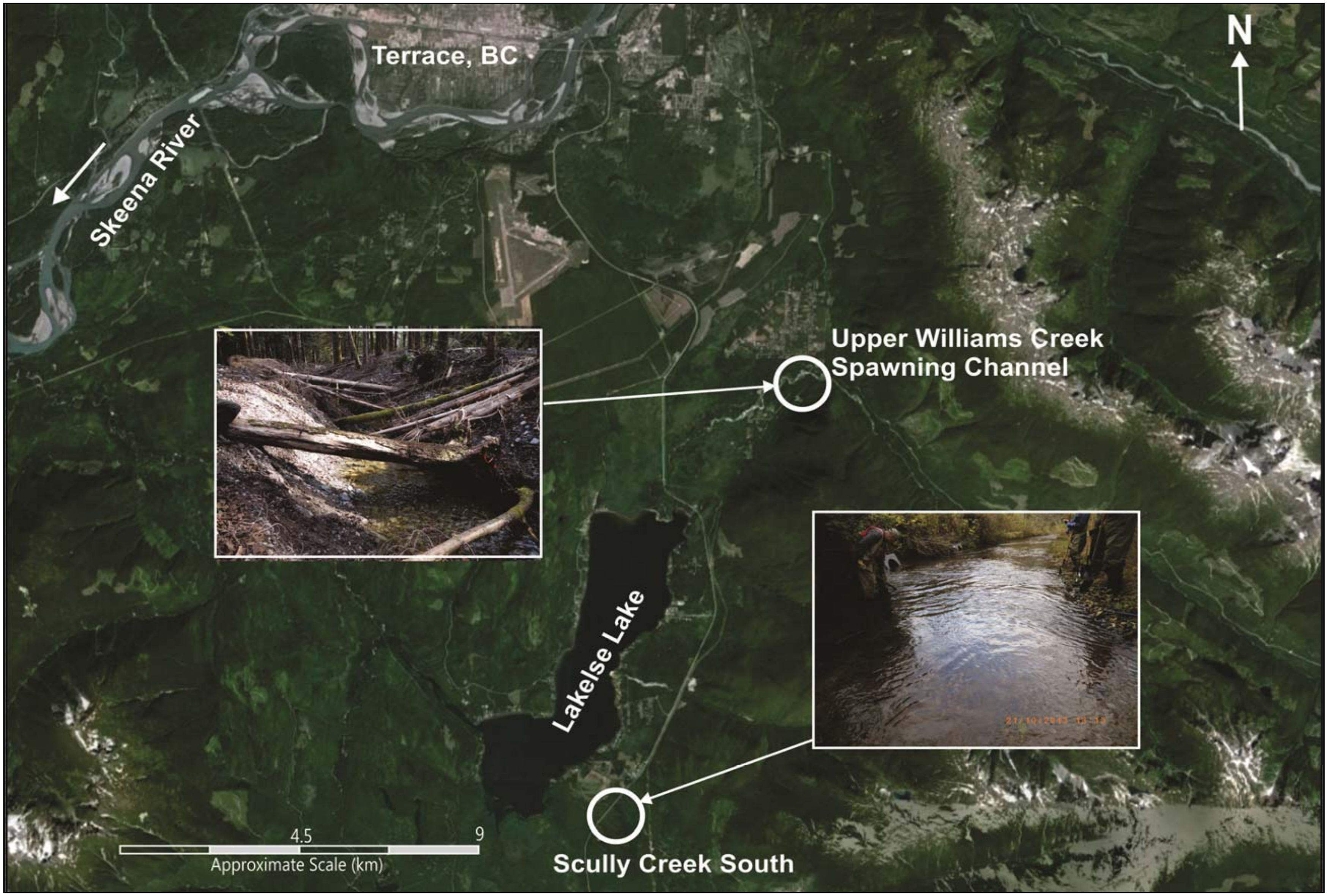

Figure 1 Overview of study area.

1.2.1.1 Upper Williams Creek Spawning Channel

The upper Williams Creek spawning channel (hereafter, referred to as Williams Channel) is a side channel of Williams Creek. Williams Creek flows into the northeast corner of Lakelse Lake, draining an area of approximately 207 km², most of which is steep mountainous terrain. Williams Creek is the largest tributary in the Lakelse Lake watershed, accounting for 62% of lake inflows (Powell 2013).

Williams Channel is approximately 700 m long, 2 to 3 m wide, and is located approximately 4 km upstream of Lakelse Lake, immediately southwest of the Williams Creek bridge on Old Lakelse Lake road. Williams Channel was constructed between 2009 and 2012 as part of the Lakelse Sockeye Recovery Program. Water in Williams Channel comes from a regulated streamside intake structure on Williams Creek (Powell 2013). Based on stream discharge measurements taken during the study period, the intake structure releases approximately 0.12 m^3/s into Williams Channel. Stream discharge measurements generated by DFO are shown in Appendix C. Gravels in the spawning channel are native to the site, which was historically part of the main Williams Creek spawning area (Powell 2013).

1.2.1.2 Scully Creek South

Scully Creek South is a natural, mostly groundwater fed channel of Scully Creek. Scully Creek flows into the southeast corner of Lakelse Lake, draining an area of approximately 29 km²; most of which is relatively flat due to its position on the Lakelse Lake floodplain. Scully Creek enters the lake through three main channels: north, middle, and south (Guimond 2009).

Scully Creek South extends approximately 2.5 km upstream of Lakelse Lake to the main channel of Scully Creek. The Scully Creek South study area was limited to a 200m section upstream of the Highway 37 bridge. Channel widths throughout this section are 4 to 5 m. Based on stream discharge measurements taken during the study period, mean stream discharge in this section was approximately 0.30 m3/s. Stream discharge measurements generated by DFO are shown in Appendix C. Recent (since 2009) habitat restoration activities in this section include the removal of old beaver structures and installation of large woody debris. Spawning Sockeye Salmon are known to use this section; the area was used as control site during a 2008-2009 Sockeye egg incubation study on Scully Creek (Guimond 2009).

1.2.2 Sockeye Salmon Life History

The life cycle of the Sockeye Salmon (*Oncorhynchus nerka*) includes freshwater and ocean phases. Typically, Sockeye eggs incubate in gravel beds in rivers or lakes for three to eight months, after which juvenile's rear in lake habitat for one to three years. This is followed by one to four years in the ocean before returning to freshwater to spawn and die (Burgner 1991).

1.2.2.1 Sockeye Egg-to-Fry Incubation

Factors influencing Sockeye egg survival and development during incubation are similar to that of other Pacific salmon species (Quinn 2005, Burgner 1991). Figure 2 summarizes the major factors influencing incubation survival.

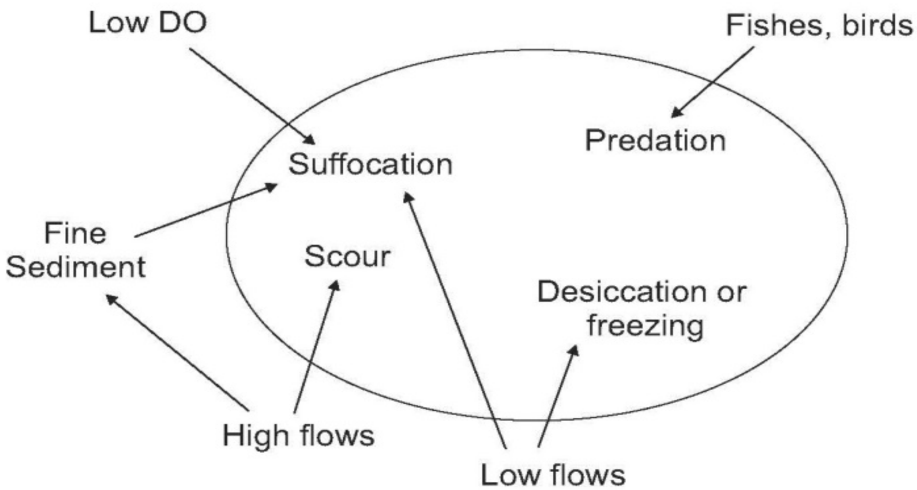

Figure 2 Factors influencing incubation survival. Factors inside the circle are direct causes of mortality; factors outside the circle influence those within the circle (adapted from Quinn, 2005).

Rates of egg incubation survival vary greatly depending on incubation conditions. Average egg-to-fry survival of Pacific salmon in natural spawning areas ranges from 1 to 19 % (Bradford 1994). In contrast, by carefully controlling incubation conditions, Pacific salmon hatcheries typically produce 75 to 95 % egg-to-fry survival (MacKinlay 2004). In between these two extremes are instream incubators (used in this study), which protect eggs from predators and silt suffocation. Under ideal conditions, instream incubators produce egg-to-fry survival rates of approximately 90 % (Jordan 1988).

2.0 METHODS

2.1 INCUBATION MONITORING

2.1.1 Incubation Site Selection

On October 21, 2013, a total of ten incubation sites were selected: five in Williams Channel and five in Scully Creek South. The table in Appendix 1 shows the UTM coordinates for each site. DFO personnel selected the incubation sites based on substrate, depth, and flow characteristics assessed in the field. The substrate size at all sites ranged from 5 to 70 mm, which is within the documented Sockeye spawning substrate range of 1 to 100 mm (Burgner 1991, Lorenz 1989). The depths at all sites ranged between 0.11 and 0.34 m (Table 1), some of which were less than the recommended Sockeye spawning range of 0.18 to 0.61 m (Anon. 2004). Although flow, i.e. velocity, was not measured during site selection, it was assessed and deemed to be within the documented Sockeye spawning range of 0.12 to 0.85 m/s (Anon. 2004). Note that velocity was measured at each site on three different occasions later during the study, see sections 3.1.5 and 3.2.5.

2.1.2 Installation of Incubation Cassettes

On October 22 and 23, 2013, eyed Sockeye Salmon eggs sourced from Williams Creek broodstock were installed at the ten incubation sites. The eggs had been fertilized and incubated to the eyed stage at the Snootli Creek Hatchery in Bella Coola. The eyed eggs were carefully transported in coolers to the incubation sites. At each incubation site, one hundred eyed eggs were loaded into the lower half of a Jordan-Scotty incubation cassette[1]. Jordan-Scotty incubation cassettes are designed to allow water/waste transmittal but prevent escape of alevins/fry (Photo 1, Appendix A).

Five incubation cassettes were buried at each site, perpendicular to the flow (Figure 3). If there was enough room, cassettes were buried side by side and if space was limited, the cassettes were staggered (Figure 3). Burial depths were approximately 0.25 m to allow for approximately 0.1 m of gravel over each cassette. These depths are consistent with egg burial depths of Sockeye Salmon documented in past studies, i.e. 0.05 to 0.28 m (Devries 1997). Mean gravel depths over cassettes and mean water depths over incubation sites were measured during installation, they are shown in Table 1. Each cassette was labeled with the stream name, site number, and cassette number written on flagging tape and attached with rope (Photo 2, Appendix B).

[1] Due to some egg loss during the transfer to trays, some incubation cassettes at Scully Creek South did not have 100 eyed eggs and this was taken into consideration for percent hatch and emergence survival.

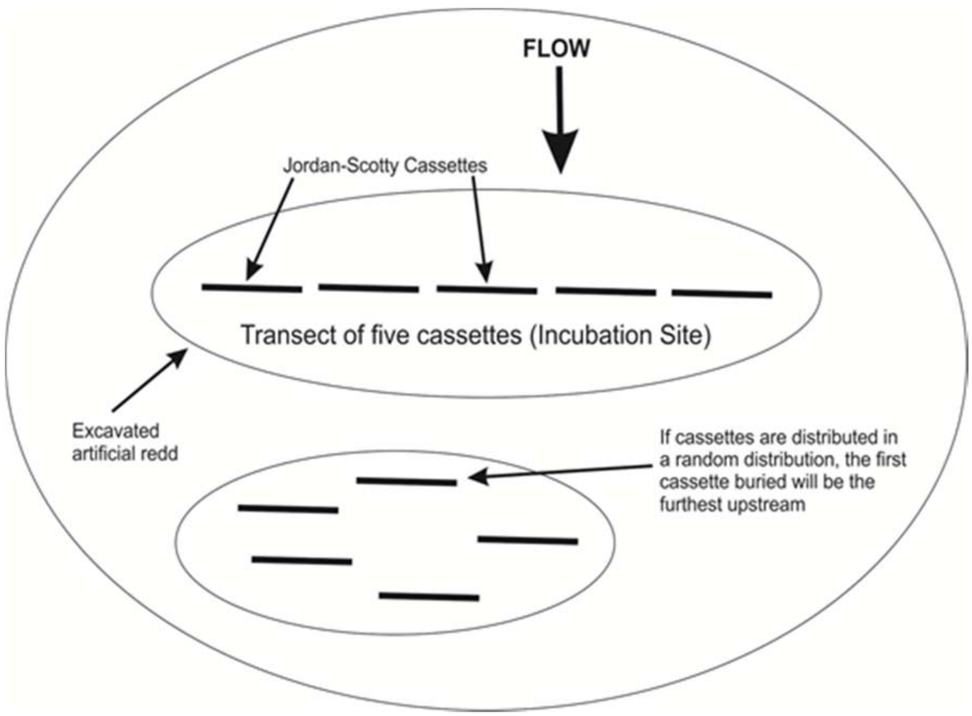

Figure 3 Schematic drawing showing installation options for Jordan-Scotty incubation cassettes within an incubation site.

Table 1 Mean gravel depths over cassettes and mean water depths over incubation sites during installation.

Area	Site #	Mean depth of gravel over cassettes (m)	Mean depth of water over incubation cassettes (m)
Williams Channel	1	0.10	0.34
Williams Channel	2	0.10	0.29
Williams Channel	3	0.08	0.25
Williams Channel	4	0.09	0.17
Williams Channel	5	0.09	0.14
Scully Creek South	1	0.12	0.14
Scully Creek South	2	0.09	0.18

Area	Site #	Mean depth of gravel over cassettes (m)	Mean depth of water over incubation cassettes (m)
Scully Creek South	3	0.10	0.21
Scully Creek South	4	0.10	0.15
Scully Creek South	5	0.12	0.11

A group of eyed eggs (5000, from 10 females/20 males) remained at the Snootli Creek Hatchery as a control to demonstrate that there were no fertilization or survival issues with the donor eggs used in the study. The control group of eyed eggs were handled using standard hatchery practices and were maintained separate from other groups at the hatchery. Survival rates were monitored to the hatch and fry stages.

2.1.3 Incubation Inspection Timing (ATUs)

Incubation inspection timing for the hatch and fry stages were based on estimated egg development inferred through Accumulated Thermal Units (ATUs). ATUs are calculated by summing daily mean temperature for the incubation period (Quinn 2005). For example, Sockeye typically hatch at approximately 650 ATUs, this could be, generally speaking, reached in 65 days at 10˚C or 130 days at 5˚C. Intergravel water temperatures were monitored in both systems throughout the study period to calculate ATUs.

2.1.4 Eyed Egg-to-Hatch Inspection

During eyed egg-to-hatch inspections, two incubation cassettes from each sample site were removed (downstream cassettes if possible to avoid potential sediment settling on remaining cassettes) and assessed. The contents from each cassette were emptied into a shallow wash basin and the number of eggs and alevins, live and dead, were enumerated (Photo 3, Appendix B). The remaining three cassettes at each incubation site were left in place for fry inspection. After enumeration, live eggs/alevins were deposited into the gravel near the site, by pouring the eggs/alevins into a 50 mm diameter pipe planted approximately 0.10 m into the stream bed. The area was then carefully covered with gravel.

2.1.5 Eyed Egg-to-Fry Inspection

During eyed egg-to-fry inspections, the remaining three incubation cassettes from each sample site were removed and assessed. The contents from each cassette were emptied into a shallow wash basin and the number of eggs, and alevins/fry, live and dead, were enumerated. (Photo 4, Appendix B). After enumeration, live fry were released near the site in areas of gentle flow near cover.

2.2 WATER QUALITY MONITORING

2.2.1 Intergravel and Water Column Water Quality

2.2.1.1 Hourly Temperature Data

Hourly water temperature was measured using Onset TidbiT™ temperature loggers (±0.2 °C) installed at the downstream and upstream ends (near Sites 1 and 5 respectively) of Williams Channel and Scully Creek South study areas for the duration of the study. Three loggers were installed in each stream: two near Site 1 (one intergravel, one water column) and one (intergravel) near Site 5. Intergravel loggers were buried 0.25 to 0.30 m (i.e. at the same depth as the incubation cassettes). Water column loggers were positioned on the stream bottom. The upstream (intergravel) loggers were used to calculate Accumulated Thermal Units (ATUs) which, in turn, were used to estimate egg development timing and associated inspections.

2.2.1.2 Dissolved Oxygen, Temperature, pH, and Conductivity

Dissolved oxygen, temperature, pH, and conductivity (intergravel and water column) were measured at each incubation site during cassette installation, hatch inspection, and fry inspection. Table 2 shows the water quality meters used to measure each water quality parameter. To measure the intergravel parameters, a Eureka Manta Water Quality Multi-probe was selected due to its non-consumptive DO operation, measuring instantaneous readings of DO, pH, temperature, and conductivity. The Manta multi-probe was buried at each of the incubation areas to a depth of 0.25 to 0.30 m, and kept buried at each site for 45 minutes. For each 45 minute period at least three measurements were taken (15 minute interval).

Table 2 Water quality meters used for intergravel and water column water quality monitoring.

Parameter	Water Quality Meter Used	
	Intergravel	Water Column
DO (%)	Eureka Manta Water Quality Multi-probe (optical DO sensor, ±0.2 mg/L ≤20 mg/L)	OxyGuard Handy Polaris meter (±1% of measured value)
Temp (ºC)	Eureka Manta Water Quality Multi-probe (±0.2 °C)	Hanna Combo meter (±0.5 °C)
pH	Eureka Manta Water Quality Multi-probe (±0.2 units)	Hanna Combo meter (±0.05 units)
Cond (µs/cm)	Eureka Manta Water Quality Multi-probe (±0.5%)	Hanna Combo meter (±2% reading)

2.2.2 Water Velocity and Depth

Water velocity (m/s) and depth were measured at each incubation site three times during the study period. Velocity/depth measurements were taken at the center, midpoint between the center and left bank, and midpoint between center and right bank, for a total of three measurements per site. Velocity was measured using a Swoffer Model 3000 flow meter set to a 20-second average. Measurements were taken at 60 % depth from the water surface. Depth was measure using the Swoffer rod, which is marked in 0.05 m increments.

2.3 DATA ANALYSIS

Data analysis included:

- Testing for differences in eyed egg-to-hatch and egg-to-fry survival between incubation sites and the hatchery control group (ANOVA).
- Testing for differences in eyed egg-to-hatch and egg-to-fry survival between Williams Channel and Scully Creek South (ANOVA).

3.0 RESULTS

3.1 WILLIAMS CHANNEL

3.1.1 Incubation Inspection Timing (ATUs)

Incubation inspection timing for hatch and fry stages were February 13, 2014 (645 ATUs) and May 23, 2014 (872 ATUs) respectively. Table 3 summarizes the ATU data collected during the incubation period and shows DFO's guideline ranges for Sockeye ATUs.

Table 3 Williams Channel ATU data and DFO guideline ranges for Sockeye ATUs by life stage.

Life Stage	Incubation Period	ATUs	DFO Guideline Ranges for Sockeye ATUs
Eyed	Fertilization to Installation (21Aug2013 to 23Oct2013)	438*	236-257
Hatch	Installation to Hatch Inspection (24Oct2013 to 13Feb2014)	645	614-694
Fry	Hatch Inspection to Fry Inspection (14Feb2014 to 23May2014)	872	943-1088

*Note that the fertilization to installation period took place at Snootli Creek Hatchery.

3.1.2 Eyed Egg-to-Hatch

Eyed egg-to-hatch results from two cassettes at each Williams Channel site are presented in Figure 4. Eyed egg-to-hatch survival (per cassette) ranged from 78.0 to 100.0 %. Mean eyed egg-to-hatch survival was highest at Site 1 (98.5 %), and lowest at Site 5 (88.5 %). There was no significant difference in eyed egg-to-hatch survival between Williams Channel incubation sites (ANOVA, $F_{4,5}=0.580$, $P>0.05$). Eyed egg-to-hatch survival averaged 94.7 % (n=1000) which was higher than the Snootli Creek Hatchery control group (85.3 %, n=5000). There was a significant difference in eyed egg-to-hatch survival between Williams Channel incubation sites and the control group (ANOVA, $F_{1,18}=5.23$, $P<0.05$).

Raw incubation data are shown in Appendix C.

Alevins removed from the cassettes had large egg sacs still attached, indicating that hatching had occurred recently. Thus showing their rate of development was consistent with the ATU data shown in Table 4.

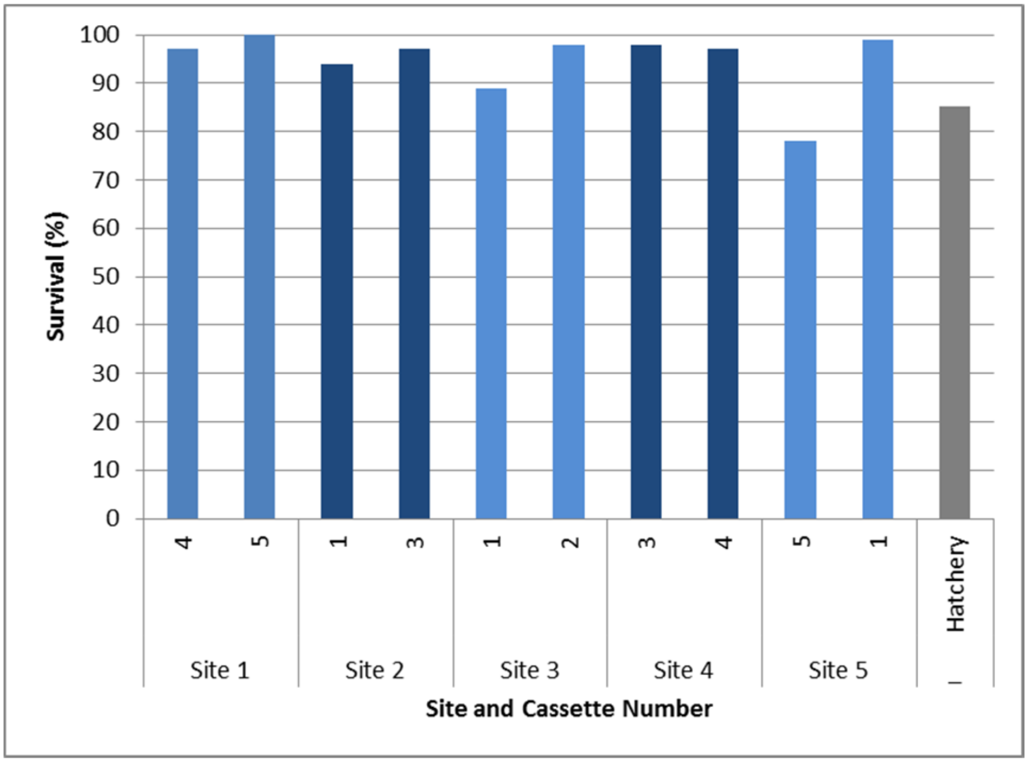

Figure 4 Eyed egg-to-hatch survival from Williams Channel and the control group at Snootli Creek Hatchery.

3.1.3 Eyed Egg-to-Fry Inspection

Eyed egg-to-fry inspection results from the final three cassettes at each Williams Channel site are presented in Figure 5. Eyed egg-to-fry survival (per cassette) ranged from 0.0 to 100.0 %. Mean eyed egg-to-fry survival was highest at Site 2 (96.0 %), and lowest at Site 5 (9.7 %, of which 98 % of the mortalities were alevins). There was a significant difference in eyed egg-to-fry survival between Williams Channel incubation sites (ANOVA, $F_{4, 10}=15.12$, $P<0.05$). Eyed egg-to-fry survival averaged 60.7 % (n=1500) which was considerably less than the hatchery control group (84.1 %, n=5000). There was a significant difference in eyed egg-to-fry survival between Williams Channel incubation sites and the control group (ANOVA, $F_{1, 28}=7.73$, $P<0.05$).

Raw incubation data are shown in Appendix C.

Fry removed from the cassettes had a small egg sacs still attached; indicating that fry development was not quite complete. Their incomplete development was expected since these cassettes were removed at 872 ATUs instead of the DFO guideline range of 943 to 1088 ATUs (shown in Table 3). Project scheduling did not allow for a later inspection date.

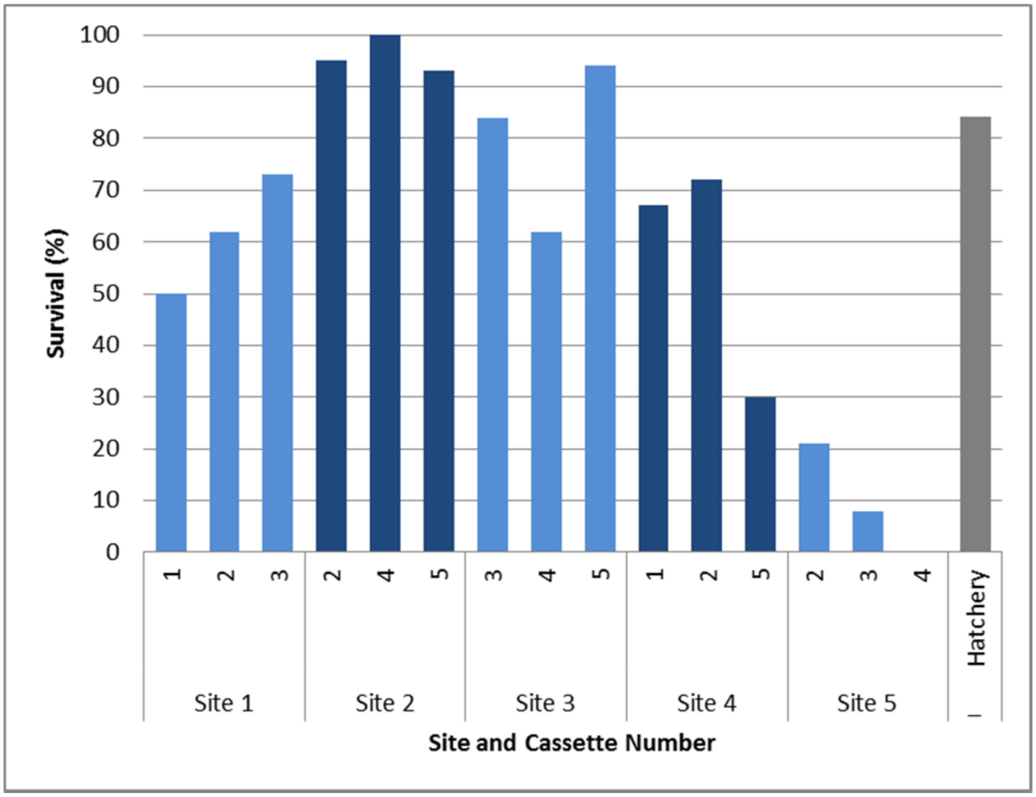

Figure 5 Eyed egg-to-fry survival from Williams Channel and the control group at Snootli Creek Hatchery.

3.1.4 Water Quality

3.1.4.1 Hourly Water Temperature

Hourly intergravel and water column water temperatures for Williams Channel during the study period, October 22, 2013 to May 22, 2014, are shown in Figure 6. Data were collected at the buried data logger near Site 5 for the entire study period, while the other two data loggers missed the period from January 08, 2014 to April 17, 2014 due to equipment malfunction.

The mean intergravel temperature over the entire study period for Williams Channel was 2.1˚C (STDEV ± 1.8), the instantaneous minimum temperature was 0.0 ˚C, and the instantaneous maximum temperature was 8.5 ˚C.

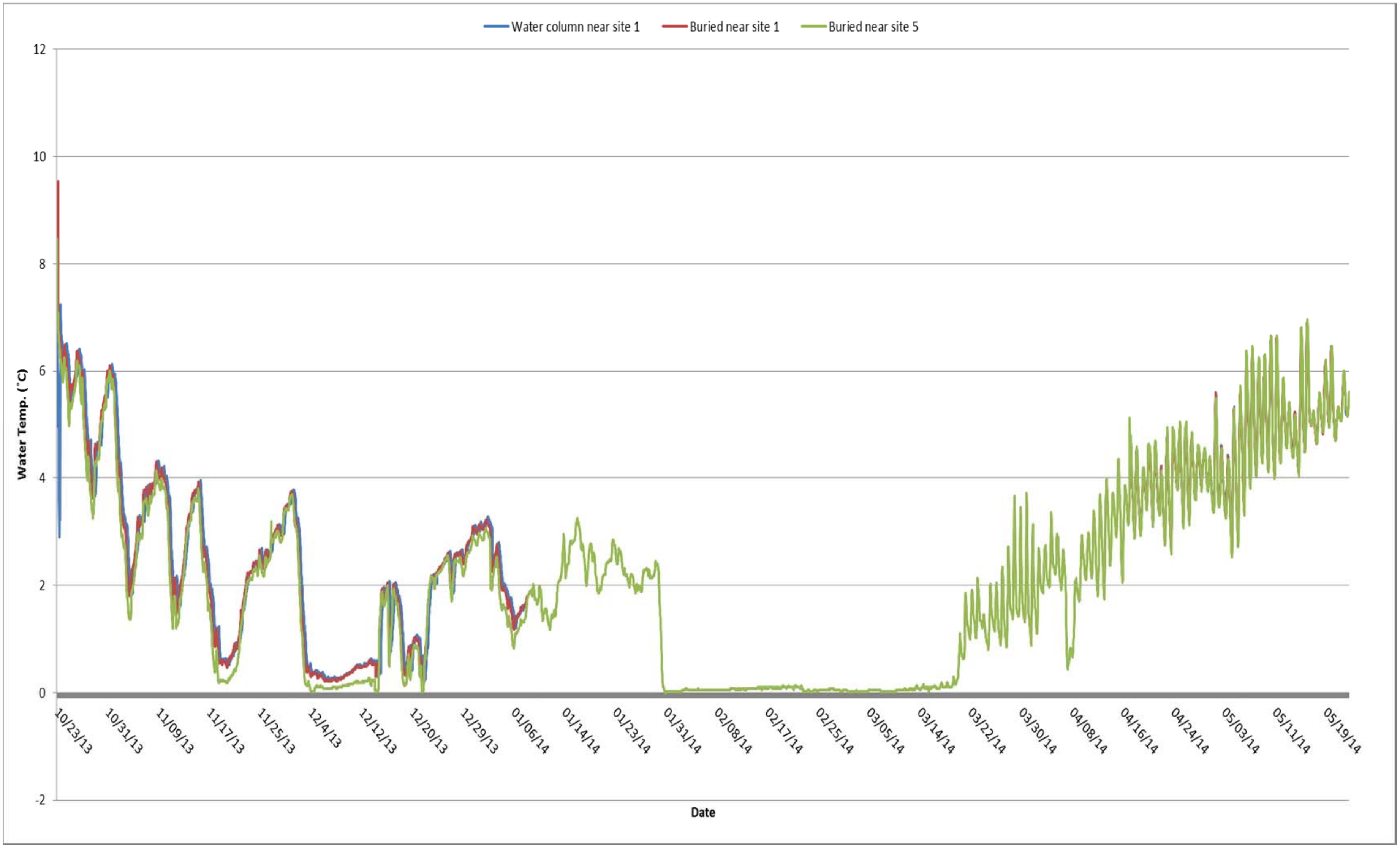

Figure 6 Williams Channel hourly temperature data from October 2013 to May 2014.

3.1.4.2 Water Column Dissolved Oxygen, Temperature, pH, and Conductivity

Water column dissolved oxygen, temperature, conductivity, and pH data were collected in Williams Channel three times during the study period. Data were collected on October 23, 2013, December 16, 2013, and May 23, 2014. Table 4 shows a comparison between water column data at Sites 1 to 5.

Table 4 Mean, standard deviation, and min/max, for Williams Channel water column dissolved oxygen (DO), temperature, pH, and conductivity.

Parameter		Site 1	Site 2	Site 3	Site 4	Site 5
DO (%)	Mean	93.7	94.3	95.7	96.0	96.7
	STDEV	6.1	5.7	5.1	5.6	6.5
	Min.	87.0	88.0	90.0	90.0	90.0
	Max.	99.0	99.0	100.0	101.0	103.0
Temp (^{0}C)	Mean	4.3	4.2	4.2	4.2	4.3
	STDEV	3.6	3.6	3.5	3.5	3.6
	Min.	0.3	0.2	0.2	0.2	0.2
	Max.	7.2	7.1	6.8	6.8	6.9
pH	Mean	7.5	7.4	7.6	7.5	7.6
	STDEV	0.1	0.3	0.1	0.2	0.3
	Min.	7.4	7.1	7.5	7.3	7.4
	Max.	7.6	7.7	7.6	7.8	7.9
Cond (µs/cm)	Mean	29.3	29.0	29.0	28.3	30.0
	STDEV	11.7	11.5	13.9	12.7	14.2
	Min.	16.0	16.0	13.0	14.0	14.0
	Max.	38.0	38.0	38.0	38.0	41.0

The BC guidelines for water column DO for embryo and alevin stages include an instantaneous minimum of 9 mg/L and a 30-day mean not lower than 11 mg/L. (RIC 1998). At 4˚C, 9 mg/L is equal to approximately 69% and 11mg/L is equal to approximately 84%, thus, as shown in the table above, all instantaneous (min) and mean measurements of DO were above the recommended guidelines. It is not certain if a 30-day mean limit not less than 11 mg/L was reached.

The BC guideline for water temperature for embryo survival is a maximum weekly average of 13 to 15 ˚C (RIC 1998). The mean intergravel[2] temperature over the entire study period for Williams Channel was 2.1˚C (STDEV ± 1.8), the instantaneous minimum temperature was 0.0 ˚C, and the instantaneous maximum temperature was 8.5 ˚C.

[2] As mentioned in Section 3.1.4.1, the water column data loggers the missed the period from January 08, 2014 to April 17, 2014 due to equipment malfunction.

The BC guideline for pH for aquatic life is 6.5-9.0(RIC 1998). As shown in the table above, all instantaneous (min and max) measurements of pH were within the recommended guideline.

There is no BC guideline for conductivity due to its natural variability.

3.1.4.3 Intergravel Dissolved Oxygen, Temperature, pH, and Conductivity

Intergravel dissolved oxygen, temperature, conductivity, and pH data were collected in Williams Channel three times during the study period. Data were collected on October 23, 2013, December 16, 2013, and May 23, 2014. Table 5 shows a comparison between intergravel data at Sites 1 to 5.

Table 5 Mean, standard deviation, and min/max for Williams Channel intergravel dissolved oxygen (DO), temperature, pH, and conductivity.

Parameter		Site 1	Site 2	Site 3	Site 4	Site 5
DO (%)	Mean	99.2	93.4	102.1	101.0	100.3
	STDEV	1.6	8.6	1.7	1.7	1.4
	Min.	97.3	79.7	101.0	99.5	98.5
	Max.	101.6	105.7	104.8	104.6	102.9
Temp (^{0}C)	Mean	3.7	3.7	3.6	4.6	4.7
	STDEV	1.5	1.1	1.5	2.2	2.4
	Min.	1.8	2.4	1.8	1.7	1.7
	Max.	5.1	5.2	5.3	6.8	7.1
pH	Mean	7.3	7.2	7.5	7.5	7.5
	STDEV	0.2	0.5	0.2	0.2	0.4
	Min.	7.0	6.7	7.3	7.2	6.9
	Max.	7.6	7.6	7.7	7.7	8.0
Cond (µs/cm)	Mean	39.4	44.2	39.1	31.8	39.9
	STDEV	7.9	7.4	10.5	5.6	13.1
	Min.	29.0	26.0	26.0	26.0	27.0
	Max.	48.0	50.5	51.7	37.0	60.4

The BC guidelines for intergravel DO for embryo and alevin stages include an instantaneous minimum of 6 mg/L and a 30-day mean not lower than 8 mg/L. (RIC 1998). At 4˚C, 6 mg/L is equal to approximately 46 % and 8 mg/L is equal to approximately 61 %, thus, as shown in the table above, all instantaneous (min) and mean measurements of DO were above the recommended guidelines. It is not certain if a 30-day mean limit not less than 11 mg/L was reached.

The BC guideline for water temperature for embryo survival is a maximum weekly average of 13 to 15 ˚C (RIC 1998). The mean intergravel[3] temperature over the entire study period for Williams Channel was 2.1˚C (STDEV ± 1.8), the instantaneous minimum temperature was 0.0 ˚C, and the instantaneous maximum temperature was 8.5 ˚C. All intergravel measurements of water temperature met the recommended guideline.

The BC guideline for pH for aquatic life is 6.5-9.0(RIC 1998). As shown in the table above, all instantaneous (min and max) measurements of pH were within the recommended guideline.

There is no BC guideline for conductivity due to its natural variability.

3.1.5 Water Velocity and Depth

Water velocity and depth data were collected in Williams Channel on December 16, 2013, February 13, 2014, and May 23, 2014. Table 6 shows the velocity ranges and depth ranges at Sites 1 to 5.

Table 6 Water velocity ranges and depth ranges at Williams Channel.

Date	Site 1		Site 2		Site 3		Site 4		Site 5	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
16-Dec-13	0.20-0.22	0.33-0.40	0.13-0.34	0.35-0.41	0.22-0.36	0.31-0.33	0.43-0.52	0.28-0.32	0.41-0.53	0.16-0.17
13-Feb-14	0.08-0.21	0.34-0.44	0.14-0.28	0.40-0.42	0.01-0.30	0.31-0.35	0.31-0.57	0.24-0.26	0.16-0.43	0.25-0.26
23-May-14	0.03-0.10	0.30-0.40	0.17-0.27	0.40-0.44	0.08-0.23	0.31-0.35	0.10-0.34	0.26-0.33	0.29-0.51	0.11-0.22

As mentioned previously, the intergravel water temperatures were above freezing for the incubation period and this compares favorably with depth and velocities measurements (Table 6) taken on the three dates. During all three sampling periods, there was flowing water over the incubation sites.

[3] As mentioned in Section 3.1.4.1, the water column data loggers the missed the period from January 08, 2014 to April 17, 2014 due to equipment malfunction.

3.2 SCULLY CREEK SOUTH

3.2.1 Incubation Inspection Timing (ATUs)

Incubation inspection timing for hatch and fry stages were December 16, 2014 (721 ATUs) and March 12, 2014 (969 ATUs) respectively. Table 7 summarizes the ATU data collected during the incubation period and shows DFO's guideline ranges for Sockeye ATUs.

Table 7 Scully Creek South ATU data and DFO guideline ranges for Sockeye ATUs by life stage.

Life Stage	Incubation Period	Mean Daily Temp. (˚C)	ATUs	DFO Guideline Ranges for Sockeye ATUs
Eyed	Fertilization to Installation (21Aug2013 to 22Oct2013)	6.96	431	236-257
Hatch	Installation to Hatch Inspection (23Oct2013 to 16Dec2013)	5.27	721	614-694
Fry	Hatch Inspection to Fry Inspection (17Dec2013 to 12Mar2014)	2.89	969	943-1088

Note that the fertilization to installation period took place at Snootli Creek Hatchery.

3.2.2 Eyed Egg-to-Hatch

Eyed egg-to-hatch results from two cassettes at each Scully Creek South site are presented in Figure 7. Eyed egg-to-hatch survival (per cassette) ranged from 0.0 to 91.0 %. Mean eyed egg-to-hatch survival was highest at Site 1 (89.5 %), and lowest at Site 3 (0.0 %). There was a significant difference in eyed egg-to-hatch survival between Scully Creek South incubation sites (ANOVA, $F_{4, 5}=6.95$, $P<0.05$). Eyed egg-to-hatch survival averaged 58.5% (n=985) which was lower than the Snootli Creek Hatchery control group (85.3%, n=5000). There was a significant difference in eyed egg-to-hatch survival between Scully Creek South incubation sites and the control group (ANOVA, $F_{1, 18}=5.23$, $P<0.05$).

Raw incubation data are shown in Appendix C.

Alevins removed from the cassettes had large egg sacs still attached, indicating that hatching had occurred recently. At all five sites, there were incubation cassettes which contained live eggs (n=7 out of 10 cassettes), as hatch had not occurred. The percentage of live eggs ranged from a high of 35% (cassette at Site 4) to 8% (cassette at Site 1). Comparing the ATUs calculated for the December 17 hatch timing visit: the rate of development was not consistent with the ATU data shown in Table 7.

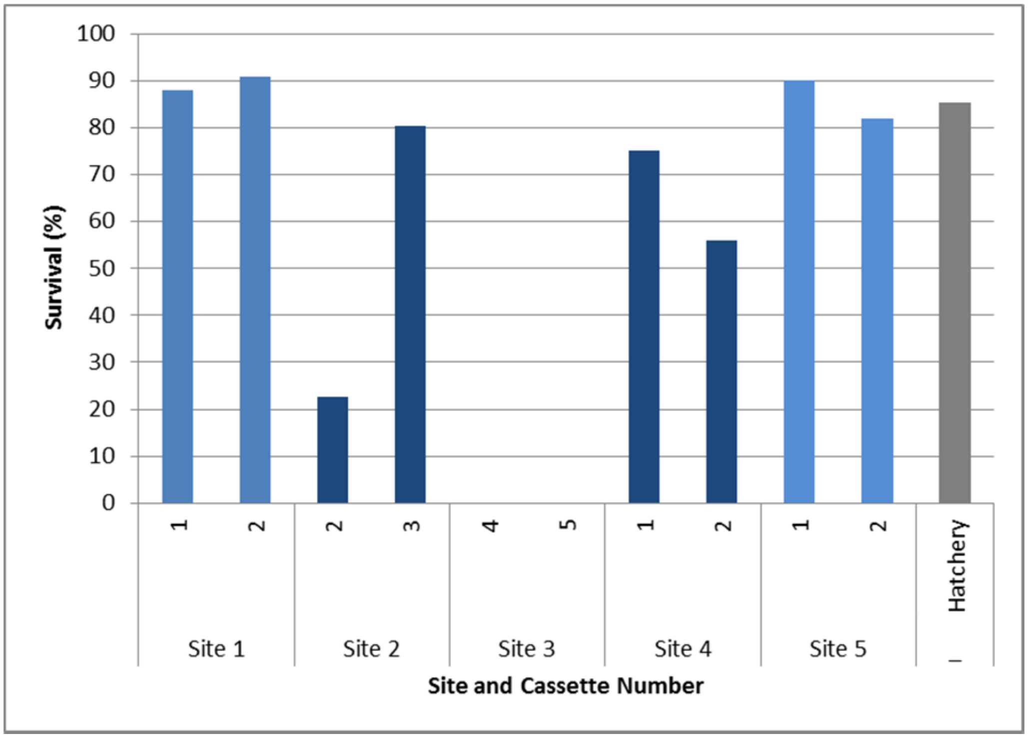

Figure 7 Eyed egg-to-hatch survival from Scully Creek South and control group at Snootli Creek hatchery.

3.2.3 Eyed Egg-to-Fry

Eyed egg-to-fry results from the final three cassettes at each Scully Creek South site are presented in Figure 8. Eyed egg-to-fry survival (per cassette) ranged from 0.0 to 90.0 %. Mean eyed egg-to-fry survival was highest at Site 1 (66.3 %), and lowest at Site 3 (0.0 %). Of the total mortalities, 94.0 % were eggs. There was a significant difference in eyed egg-to-fry survival between Scully Creek South incubation sites (ANOVA, $F_{4, 10}=7.38$, $P<0.05$). Eyed egg-to-fry survival averaged 33.2 % (n=1500) for the which was lower than the Snootli Creek Hatchery control group (84.1%, n=5000). There was a significant difference in eyed egg-to-fry survival between Scully Creek South incubation sites and the control group (ANOVA, $F_{1, 28}=49.72$, $P<0.05$).

Raw incubation data are shown in Appendix C.

Fry removed from the cassettes had a very small egg sacs still attached; indicating that fry development was not quite complete. Their incomplete development was not expected since these cassettes were removed at 969 ATUs which is within the DFO guideline range of 943 to 1088 ATUs (shown in Table 7).

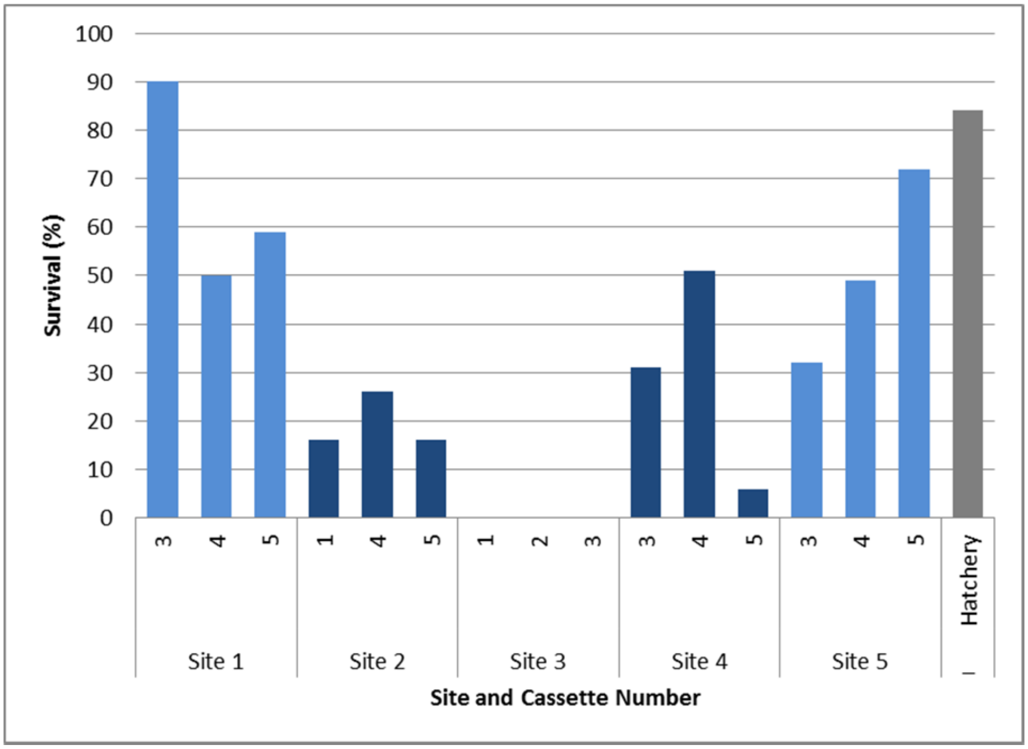

Figure 8 Mean eyed egg-to-fry survival from Scully Creek South incubation sites and Snootli Creek Hatchery.

3.2.4 Water Quality

3.2.4.1 Hourly Water Temperature

Hourly intergravel and water column water temperatures for Scully Creek South during the study period, October, 23 2013 to March 12, 2014, are shown in figure 9.

The mean intergravel temperature over the entire study period for Scully Creek South was 3.8˚C (STDEV ± 1.7), the instantaneous minimum temperature was 0.0 ˚C, and the instantaneous maximum temperature was 8.5 ˚C.

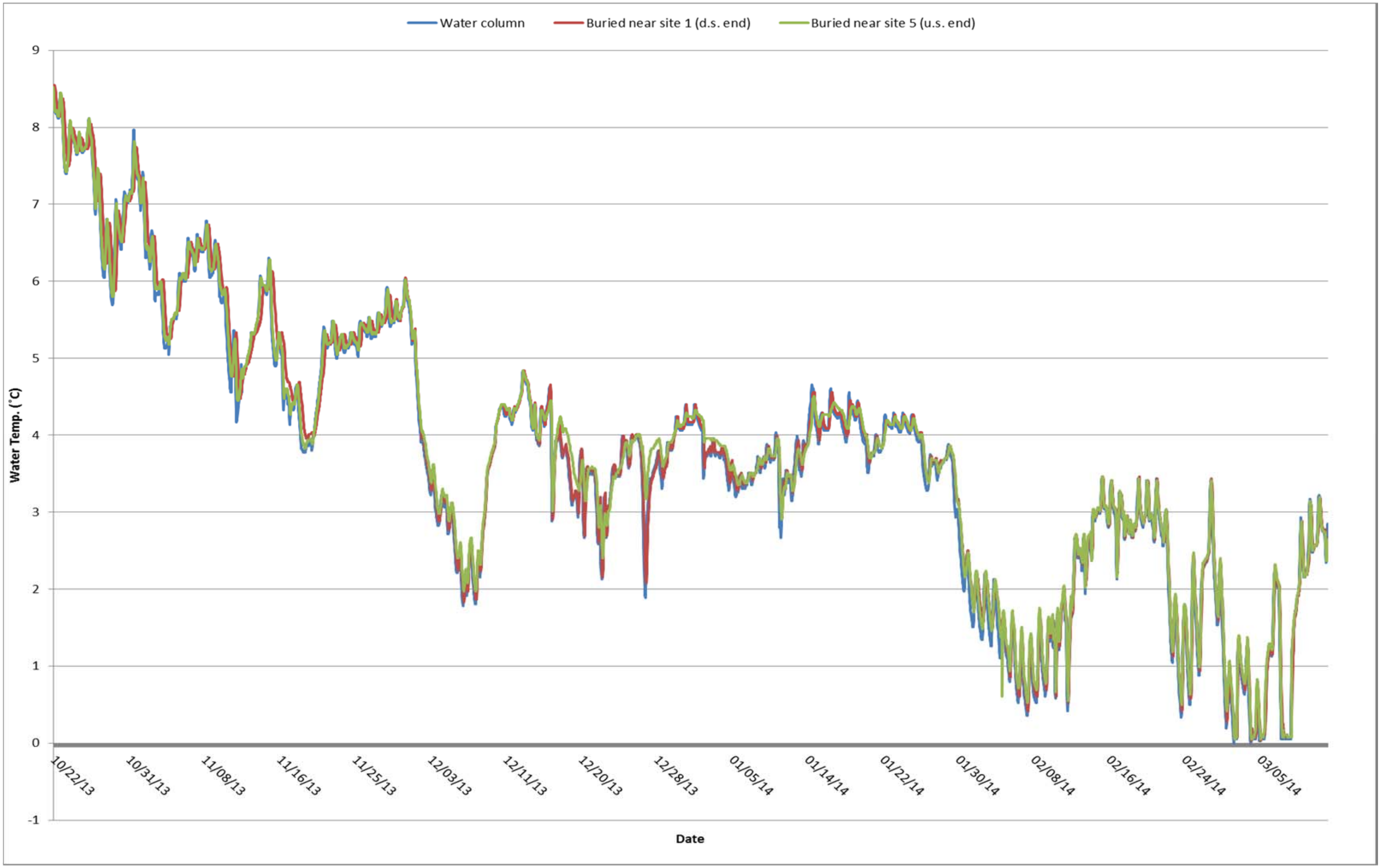

Figure 9 Scully Creek South hourly temperature data from October 2013 to March 2014.

3.2.4.1 Water Column Dissolved Oxygen, Temperature, pH, and Conductivity

Water column dissolved oxygen, temperature, conductivity, and pH data were collected on October 23, 2013, December 16, 2013, and March 12, 2014. Table 8 shows a comparison between water column data at Sites 1 to 5.

Table 8 Mean, standard deviation, and min/max for Scully Creek water column dissolved oxygen (DO), temperature, pH, and conductivity.

Parameter		Site 1	Site 2	Site 3	Site 4	Site 5
DO (%)	Mean	92.3	92.3	92.0	92.7	93.3
	STDEV	3.8	4.7	5.3	5.1	4.7
	Min.	88	87	86	87	88
	Max.	95	96	96	97	97
Temp (^{0}C)	Mean	5.0	5.0	5.0	5.0	4.8
	STDEV	3.2	3.3	3.3	3.2	3.4
	Min.	2.6	2.4	2.4	2.6	2.1
	Max.	8.6	8.7	8.7	8.7	8.6
pH	Mean	7.2	7.1	7.2	7.0	7.4
	STDEV	0.1	0.1	0.2	0.1	0.4
	Min.	7.1	6.9	7.1	6.9	7.1
	Max.	7.2	7.2	7.5	7.1	7.9
Cond (µs/cm)	Mean	49.0	41.3	46.3	47.3	39.3
	STDEV	12.5	3.2	8.1	9.7	5.5
	Min.	39.0	39.0	39.0	39.0	34.0
	Max.	63.0	45.0	55.0	58.0	45.0

The BC guidelines for water column DO for embryo and alevin stages include an instantaneous minimum of 9 mg/L and a 30-day mean not lower than 11 mg/L. (RIC 1998). At 4˚C, 9 mg/L is equal to approximately 69% and 11mg/L is equal to approximately 84%, thus, as shown in the table above, all instantaneous (min) and mean measurements of DO were above the recommended guidelines. It is not certain if a 30-day mean limit not less than 11 mg/L was reached.

The BC guideline for water temperature for embryo survival is a maximum weekly average of 13 to 15 ˚C (RIC 1998). The mean intergravel temperature over the entire study period for Scully Creek South was 3.8˚C (STDEV ± 1.7), the instantaneous minimum temperature was 0.0 ˚C, and the instantaneous maximum temperature was 8.5 ˚C.

The BC guideline for pH for aquatic life is 6.5-9.0(RIC 1998). As shown in the table above, all instantaneous (min and max) measurements of pH were within the recommended guideline.

There is no BC guideline for conductivity due to its natural variability.

3.2.4.2 Intergravel Dissolved Oxygen, Temperature, pH, and Conductivity

Intergravel dissolved oxygen, temperature, conductivity, and pH data were collected on October 23, 2013, December 16, 2013, and March 12, 2014. Table 9 shows a comparison between water column data at Sites 1 to 5.

Table 9 Mean, standard deviation, and min/max for Scully Creek South intergravel dissolved oxygen (DO), temperature, pH, and conductivity.

Parameter		Site 1	Site 2	Site 3	Site 4	Site 5
DO (%)	Mean	95.5	93.7	75.4	94.7	93.6
	STDEV	4.9	4.4	19.6	5.0	5.6
	Min.	88.9	88.1	31.6	87.2	85.7
	Max.	100.0	99.6	95.8	99.4	99.2
Temp (^{0}C)	Mean	4.8	4.5	4.5	4.4	4.2
	STDEV	2.4	2.0	2.0	2.0	2.0
	Min.	2.6	2.4	2.2	2.1	2.1
	Max.	8.0	7.1	7.0	6.9	6.8
pH	Mean	7.2	7.2	6.9	7.2	7.1
	STDEV	0.2	0.2	0.1	0.3	0.2
	Min.	7.0	6.9	6.7	6.9	6.9
	Max.	7.5	7.5	7.2	7.5	7.4
Cond (µs/cm)	Mean	57.8	54.9	40.0	51.7	54.2
	STDEV	4.3	2.9	8.2	5.9	2.2
	Min.	55.0	51.7	29.0	44.3	52.0
	Max.	69.6	59.0	52.1	59.0	57.0

Note highlighted value is outside the recommended range.

The BC guidelines for intergravel DO for embryo and alevin stages include an instantaneous minimum of 6 mg/L and a 30-day mean not lower than 8 mg/L. (RIC 1998). At 4˚C, 6 mg/L is equal to approximately 46 % and 8 mg/L is equal to approximately 61 %, thus, as shown in the table above, one instantaneous (min) measurement of DO (Site 3) was below the recommended guidelines. All other DO measurements were above the recommended guidelines.

The BC guideline for water temperature for embryo survival is a maximum weekly average of 13 to 15 ˚C (RIC 1998). The mean intergravel temperature over the entire study period for Scully Creek South was 3.8˚C (STDEV ± 1.7), the instantaneous minimum temperature was 0.0 ˚C, and the instantaneous maximum temperature was 8.5 ˚C.

The BC guideline for pH for aquatic life is 6.5-9.0(RIC 1998). As shown in the table above, all instantaneous (min and max) measurements of pH were within the recommended guideline.

There is no BC guideline for conductivity due to its natural variability.

3.2.5 Water Velocity and Depth

Water velocity and depth data were collected in Scully Creek South on December 17, 2013, February 20, 2014, and March 12, 2014. Table 10 shows the velocity ranges and depth ranges at Sites 1 to 5.

Table 10 Water velocity ranges and depth ranges at Scully Creek South.

Date	Site 1		Site 2		Site 3		Site 4		Site 5	
	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)	Velocity (m/s)	Depth (m)
17-Dec-13	0.58-1.12	0.13-0.14	0.30-0.50	0.25-0.30	0.37-0.53	0.24-0.27	0.20-0.31	0.22-0.26	0.45-0.76	0.12-0.18
20-Feb-14	0.00-0.31	0.02-0.06	0.26-0.35	0.19-0.21	0.27-0.36	0.13-0.18	0.09-0.14	0.19-0.26	0.17-0.56	0.06-0.09
12-Mar-14	0.61-0.88	0.04-0.15	0.34-0.38	0.26-0.28	0.20-0.43	0.22-0.27	0.16-0.27	0.17-0.29	0.29-0.68	0.14-0.15

Note highlighted values are outside the recommended range.

As mentioned previously, the intergravel water temperatures were above freezing for the incubation period and this compares favorably with depth and velocities measurements (Table 10) taken on the three dates. During all three sampling periods, there was flowing water over the incubation sites.

4.0 DISCUSSION

4.1 WILLIAMS CHANNEL

The results of this study demonstrate that Williams Channel is able to support Sockeye Salmon egg incubation. Eyed egg-to-hatch survival averaged 94.7 % (n=1000) which was higher than the Snootli Creek Hatchery control group (85.3 %, n=5000). Eyed egg-to-fry survival averaged 60.7 % (n=1500) which was less than the hatchery control group (84.1 %, n=5000) and less than the expected survival (approximately 90 %, under ideal conditions) associated with the Scotty-Jordan instream incubators used in this study (Jordan 1988).

The incubation site showing the least eyed egg-to-fry survival was Site 5: 9.7%. Of the mortalities at Site 5, 98.0 % were alevins, which, based on DFO guideline ranges for Sockeye ATUs (Table 4), hatched on approximately January 30, 2014. All instantaneous and logged water quality parameters monitored during the study were within BC guidelines for aquatic life (Section 3.1.4.1 and Tables 4 and 5). The intergravel water temperatures were above freezing (at 0^0C for two hours on January 31) for the incubation period and this compares favorably with depth and velocities measurements (Table 6) taken on the three dates. During all three sampling periods, there was flowing water over the incubation sites.

Spawning Coho salmon were noted during our first visit to site in October during the installation of the incubation cassettes, and were actively seeking out spawning locations. DFO habitat biologists (Lana Miller and James Powell) noted during a November flow discharge measurement on Williams Channel, that a couple of cassettes had been disrupted and were unburied. The cassettes were re-installed and there is the possibility that cassettes at Site 5 were disrupted at a later date by spawning Coho.

Based on the results of this study, it appears that the amount of flow (approximately 0.12 m^3/s) released into Williams Channel through the intake structure on Williams Creek was appropriate. A follow-up study is recommended should the intake flow change from the release rate documented during our study period.

4.2 SCULLY CREEK SOUTH

Mean survival rates across all incubation sites in Scully Creek South were considerably lower than those in the Snootli Creek Hatchery control group. In Williams Channel the mean survival was 58.5 % (n=985) for the eyed egg-to-hatch stage and 33.2 % (n=1500) for the eyed egg-to-fry stages. The mean survival for the Snootli Creek Hatchery control group (n=5000) was 85.4 % and 84.1 % respectively, for eyed egg-to-hatch and eyed egg-to-fry stages.

The incubation survival in Scully Creek South is consistent with the results of a previous incubation study done on Scully Creek in 2008-2009. The Guimond 2008-2009 study, identified low dissolved oxygen in Scully Creek South (Guimond 2009) as a factor of hatch mortalities. In this study, intergravel DO levels as low as 31.6 % at Site 3 (Table 9) were documented. Thus, the complete lack of survival at Site 3 was likely due to low DO.

As for the other sites, their overall poor incubation survival did not appear to be related to the water quality parameters monitored during this study as these parameters were within BC guidelines for aquatic life (Section 3.2.4.1 and Tables 9 and 10). Observed water velocities and depths recorded (Table 10) showed that water was present over the incubation sites. Freezing did not appear to be a likely cause, since water temperature did not drop to 0.0^{0}C until March 2, 2014 (and only remained below 1^{0}C for less than 24 hours), i.e. well after hatching would have occurred. And yet almost half (47.6 %) of all the mortalities at Scully Creek South were at the eyed egg stage.

However, DO demands for incubating eggs increase, as the eggs develop, with the greatest demand immediately before hatching (Quinn 2005). Despite our water quality monitoring results, the fact that eyed egg-to-hatch survival was low (i.e., < 50%) across 12 out of the 25 cassettes buried in total at the Scully Creek South incubation sites suggests that DO demands of the incubating eggs were not being met. Further investigation is needed to better understand the physiochemical factors influencing incubation survival in this system.

5.0 REFERENCES

Anon. 2004. Instream Flow Study Guidelines, Washington Dept. of Fish and Wildlife, Washington State Dept. of Ecology.

Burgner, R.L. 1991. Life History of Sockeye Salmon (Oncorhynchus nerka). In: Groot, C and L. Margolis (eds.). Pacific Salmon Life Histories. UBC Press. University of BritishColumbia, Vancouver. P. 3-117.

DeVries, P., 1997. Riverine salmonids egg burial depths: review of published data and implications for scour studies. *Can. J. Fish. Aquat. Sci.* 54: 1685-1698.

Fisheries and Oceans Canada. Habitat and Enhancement Branch. 2003. Habitat and Enhancement Facts and Figures. Third Edition.

Guimond, E. 2009. Scully Creek Sockeye Egg Incubation Assessment 2008-2009. Fisheries and Oceans Canada North Coast Resource Restoration Division.

Jordan, F.P. 1988. Description and Testing of a New Salmonid Egg Incubator. Canadian Technical report of fisheries and aquatic sciences; 1645.

Levy, D.A. and T.L. Slaney. 1993. A Review of Habitat Capacity for Salmon Spawning and Rearing. BC Resources Inventory Committee (RIC).

Lorenz, J.M. and J.H. Eiler. 1989. Spawning Habitat and Redd Characteristics of Sockeye Salmon in the Glacial Taku River, British Columbia and Alaska. *Transactions of American Fisheries Society* 118:495-502.

MacKinlay, D. 2004. The Status of Pacific Hatcheries in Canada. Fisheries and Oceans Canada.

Powell, J., S. Devcic, and L, Miller. 2013. Lakelse Sockeye Recovery Program Upper Williams Creek Spawning Channel Phase 3 Intake Install and Lower Channel Feasibility. Preparedfor the Pacific Salmon Commission. Vancouver, BC.

RIC (Resources Inventory Committee),1998. Guideline for Interpreting Water Quality Data. Prepared by BC Fisheries Information services Branch, Victoria, BC.

Quinn, T.P. 2005. The behavior and Ecology of Pacific Salmon and Trout. University of Washington Press.

Appendices

Appendix A INCUBATION SITE UTMS

Incubation site UTM coordinates.

Stream	Site #	Zone	Easting	Northing
Williams Channel	1	9U	533218	6032529
	2	9U	533329	6032612
	3	9U	533464	6032723
	4	9U	533528	6032802
	5	9U	533529	6032804
Scully Creek South	1	9U	529030	6022291
	2	9U	529034	6022272
	3	9U	529046	6022261
	4	9U	529083	6022262
	5	9U	529116	6022215

Appendix B SELECTED PHOTOS

Photo 1 Egg loading station at Scully Creek South – Jordan-Scotty incubation (yellow) with white egg loading trays.

Photo 2 Downstream view of Site 4 on Williams channel with orange flagging showing each incubation cassette's location.

Photo 3 Hatch stage at Williams Channel – note yolk sac on each alevin.

Photo 4 Fry stage at Scully Creek South.

Appendix C RAW INCUBATION SURVIVAL DATA

UPPER WILLIAMS CREEK SPAWNING CHANNEL AND SCULLY CREEK SOUTH: SOCKEYE EGG INCUBATION STUDY 2013-2014
APPENDIX C

Table 1 Eyed egg-to-hatch survival: Williams channel and Scully Creek South.

Area	Site Number	Cassette#	Number of Dead Eggs	Number of Live Eggs	Number of Dead Alevins	Number of Live Alevins	Percent Hatch	Percent Survival to Hatch Stage
Williams Channel	1	4	3	0	0	97	97	97
Williams Channel	1	5	0	0	0	100	100	100
Williams Channel	2	1	4	0	1	78	95	94
Williams Channel	2	3	1	0	2	97	99	97
Williams Channel	3	1	0	0	11	89	100	89
Williams Channel	3	2	0	0	2	98	100	98
Williams Channel	4	3	0	0	2	98	100	98
Williams Channel	4	4	1	0	2	97	99	97
Williams Channel	5	5	0	0	22	78	100	78
Williams Channel	5	1	0	0	1	99	100	99
Scully Creek South	1	1	0	12	0	88	88	88
Scully Creek South	1	2	0	8	1	90	92	91
Scully Creek South	2	2	29	25	21	22	44	23
Scully Creek South	2	3	0	21	1	78	81	80
Scully Creek South	3	4	100	0	0	0	0	0
Scully Creek South	3	5	100	0	0	0	0	0
Scully Creek South	4	1	5	16	4	75	79	75
Scully Creek South	4	2	7	35	2	56	58	56
Scully Creek South	5	1	4	0	6	90	96	90
Scully Creek South	5	2	3	11	4	82	86	82

Table 2 Eyed egg-to-fry survival: Williams channel and Scully Creek South.

Area	Site Number	Cassette Number	Number of Dead Eggs	Number of Dead Alevins	Number of Live Alevins	Percent Hatch	Percent Survival to Fry Stage
Williams Channel	1	1	50	0	50	50	50
Williams Channel	1	2	38	0	62	62	62
Williams Channel	1	3	20	7	73	80	73
Williams Channel	2	2	5	0	95	95	95
Williams Channel	2	4	0	0	100	100	100
Williams Channel	2	5	6	1	93	94	93
Williams Channel	3	3	5	11	84	95	84
Williams Channel	3	4	16	22	62	84	62
Williams Channel	3	5	0	6	94	100	94
Williams Channel	4	1	10	23	67	90	67
Williams Channel	4	2	8	20	72	92	72
Williams Channel	4	5	7	63	30	93	30
Williams Channel	5	2	6	73	21	94	21
Williams Channel	5	3	0	92	8	100	8
Williams Channel	5	4	0	100	0	100	0
Scully Creek South	1	3	10	0	90	90	90
Scully Creek South	1	4	50	0	50	50	50
Scully Creek South	1	5	40	1	59	60	59
Scully Creek South	2	1	76	8	16	24	16
Scully Creek South	2	4	69	5	26	31	26
Scully Creek South	2	5	84	0	16	16	16
Scully Creek South	3	1	100	0	0	0	0
Scully Creek South	3	2	100	0	0	0	0
Scully Creek South	3	3	100	0	0	0	0
Scully Creek South	4	3	52	17	31	48	31
Scully Creek South	4	4	42	7	51	58	51
Scully Creek South	4	5	80	14	6	20	6
Scully Creek South	5	3	62	6	32	38	32
Scully Creek South	5	4	51	0	49	49	49
Scully Creek South	5	5	26	2	72	74	72

Appendix D STREAM DISCHARGE DATA

Flows at Williams Creek

	Williams Creek				Williams Channel Upstream Site					Williams Channel at Weir					
	Area	Flow			Area	Flow			%	Area	Flow			%	%
Date	m^2	cms	lpm	cfs	m^3	cms	lpm	cfs	Mainstem	m^4	cms	lpm	cfs	Mainstem	US Site
27-Nov-13	4.45	1.69	101,400	60	0.34	0.12	7,500	4.4	7.3	1.25	0.09	5,600	3	5.5	75.0
16-Dec-13	7.66	5.24	314,700	185	0.42	0.14	8,600	5.1	2.7	1.30	0.10	5,800	3.4	1.8	66.5
13-Feb-14					0.58	0.12	7,500	4.4		1.37	0.08	5,100	3.0		68.4
12-Mar-14					0.36	0.12	7,000	4.1		1.39	0.10	5,900	3.5		85.3
23-May-14					0.38	0.10	6,300	3.6		1.11	0.09	5,300	3.1		84.3

Flows at Scully Creek

	Scully at Culvert				Scully Upstream Site			
	Area	Flow			Area	Flow		
Date	m^2	cms	lpm	cfs	m^3	cms	lpm	cfs
27-Nov-13	0.42	0.28	16,800	10	1.44	0.26	15,700	9
16-Dec-13	0.68	0.50	30,100	18				
13-Feb-14								
12-Mar-14	0.57	0.42	25,200	15	0.35	0.35	20,800	12
22-May-14	0.55	0.35	21,200	12	1.44	0.33	19,700	12

Williams Creek, below Old Lakesle Lake Road bridge

27-Nov-13

interval	0.25	m
stn start	0.3	m
stn end	12.75	m

Flow	cms	lpm	cfs
	1.689	101,400	59.62

Area	m^2
	4.450

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.25							
0.50		0.000	0.00			0.00	0.000
0.75							
1.00		0.043	0.00			0.00	0.000
1.25	0.17						
1.50		0.043	0.00			0.00	0.000
1.75	0.00						
2.00		0.028	0.09	0.06	0.11	0.09	0.002
2.25	0.11						
2.50		0.093	0.51	0.49	0.46	0.49	0.045
2.75	0.26						
3.00		0.205	0.59	0.51	0.61	0.57	0.117
3.25	0.56						
3.50		0.260	0.19	0.13	0.26	0.19	0.050
3.75	0.48						
4.00		0.208	0.70	0.80	0.76	0.75	0.156
4.25	0.35						
4.50		0.193	0.65	0.63	0.56	0.61	0.118
4.75	0.42						
5.00		0.270	0.59	0.64	0.63	0.62	0.167
5.25	0.66						
5.50		0.330	0.15	0.20	0.18	0.18	0.058
5.75	0.66						
6.00		0.353	0.53	0.47	0.47	0.49	0.173
6.25	0.75						
6.50		0.365	0.31	0.32	0.38	0.34	0.123
6.75	0.71						
7.00		0.340	0.40	0.36	0.38	0.38	0.129
7.25	0.65						
7.50		0.315	0.29	0.27	0.34	0.30	0.095
7.75	0.61						
8.00		0.258	0.37	0.36	0.42	0.38	0.099
8.25	0.42						
8.50		0.233	0.37	0.44	0.46	0.42	0.098
8.75	0.51						
9.00		0.238	0.43	0.30	0.35	0.36	0.086
9.25	0.44						
9.50		0.198	0.34	0.29	0.35	0.33	0.065
9.75	0.35						
10.00		0.155	0.34	0.29	0.28	0.30	0.047
10.25	0.27						
10.50		0.128	0.21	0.14	0.17	0.17	0.022
10.75	0.240						
11.00		0.078	0.35	0.35	0.31	0.34	0.026
11.25	0.070						
11.50		0.055	0.09			0.09	0.005
11.75	0.150						
12.00		0.053	0.14			0.14	0.007
12.25	0.060						
12.50		0.015	0.00			0.00	0.000
12.75	0.000						
end							0.000
							0.000
							0.000
							0.000

Williams Creek, above Old Lakesle Lake Road bridge

16-Dec-13

interval	0.5	m
stn start	2.0	m
stn end	22	m

Flow	cms	lpm	cfs
	5.244	314,700	185.19

Area	m^2
	7.655

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
2.00	0.17						
2.50		0.305	0.81	0.76	0.78	0.78	0.239
3.00	0.44						
3.50		0.375	0.83	0.90	0.81	0.85	0.318
4.00	0.31						
4.50		0.345	0.61	0.66	0.57	0.61	0.212
5.00	0.38						
5.50		0.250	0.59	0.70	0.77	0.69	0.172
6.00	0.12						
6.50		0.210	0.98	1.01	1.01	1.00	0.210
7.00	0.30						
7.50		0.340	0.64	0.65	0.59	0.63	0.213
8.00	0.38						
8.50		0.350	0.33	0.34	0.40	0.36	0.125
9.00	0.32						
9.50		0.355	0.63	0.60	0.67	0.63	0.225
10.00	0.39						
10.50		0.440	0.74	0.69	0.73	0.72	0.317
11.00	0.49						
11.50		0.475	0.68	0.65	0.58	0.64	0.302
12.00	0.46						
12.50		0.440	0.82	0.74	0.85	0.80	0.353
13.00	0.42						
13.50		0.415	0.99	1.05	1.07	1.04	0.430
14.00	0.41						
14.50		0.430	0.68	0.64	0.61	0.64	0.277
15.00	0.45						
15.50		0.465	0.95	0.84	0.90	0.90	0.417
16.00	0.48						
16.50		0.465	0.75	0.72	0.81	0.76	0.353
17.00	0.45						
17.50		0.495	0.84	0.91	0.81	0.85	0.422
18.00	0.54						
18.50		0.545	0.75	0.88	0.96	0.86	0.471
19.00	0.55						
19.50		0.485	0.43	0.26	0.39	0.36	0.175
20.00	0.42						
20.50		0.340	0.05	0.03	0.03	0.04	0.012
21.00	0.26						
21.50		0.130	0.01	0.02	0.02	0.02	0.002
22.00	0.00						
							0.000
							0.000
							0.000
							0.000
							0.000
							0.000
							0.000
							0.000
							0.000

Williams Creek Channel US site

27-Nov-13

interval	0.15	m
stn start	0.5	m
stn end	1.65	m

Flow	cms	lpm	cfs
	0.124	7,500	4.37

Area	m^2
	0.34

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.45	0.27						
0.60		0.083	0.47	0.46	0.44	0.46	0.038
0.75	0.28						
0.90		0.086	0.39	0.39	0.37	0.38	0.033
1.05	0.29						
1.20		0.087	0.40	0.37	0.38	0.38	0.033
1.35	0.29						
1.50		0.084	0.26	0.24	0.21	0.24	0.020
1.65	0.27						
end						0.00	0.000

UPPER WILLIAMS CREEK SPAWNING CHANNEL AND SCULLY CREEK SOUTH: SOCKEYE EGG INCUBATION STUDY 2013-2014
APPENDIX D

Williams Channel , Upstream

16-Dec-13

interval	0.15	m
stn start	0.45	m
stn end	1.71	m

Flow	cms	lpm	cfs
	0.143	8,600	5.05

Area	m^2
	0.421

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.45	0.34						
0.60		0.092	0.32	0.32	0.30	0.31	0.03
0.75	0.27						
0.90		0.093	0.36	0.35	0.36	0.36	0.03
1.05	0.35						
1.20		0.111	0.45	0.41	0.43	0.43	0.05
1.35	0.39						
1.50		0.114	0.31	0.30	0.23	0.28	0.03
1.65	0.37						
1.71		0.011	0.12	0.17	0.16	0.15	0.00
1.71							

Williams Channel , Upstream

13-Feb-14

interval	0.15	m
stn start	0.20	m
stn end	2.00	m

Flow	cms	lpm	cfs
	0.124	7,500	4.38

Area	m^2
	0.581

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.20	0.23						
0.35		0.080	0.17	0.21	0.20	0.19	0.02
0.50	0.30						
0.65		0.102	0.12	0.13	0.11	0.12	0.01
0.80	0.38						
0.95		0.110	0.17	0.13	0.19	0.16	0.02
1.10	0.35						
1.25		0.111	0.26	0.26	0.27	0.26	0.03
1.40	0.39						
1.55		0.119	0.37	0.35	0.38	0.37	0.04
1.70	0.40						
1.85		0.060	0.12	0.09	0.09	0.10	0.01
2.00	0.00						

UPPER WILLIAMS CREEK SPAWNING CHANNEL AND SCULLY CREEK SOUTH: SOCKEYE EGG INCUBATION STUDY 2013-2014
APPENDIX D

Williams Channel , Upstream

12-Mar-14

interval	0.15	m
stn start	0.00	m
stn end	0.90	m

Flow	cms	lpm	cfs
	0.115	7,000	4.06

Area	m^2
	0.365

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.00	0.35						
0.15		0.114	0.45	0.22		0.34	0.04
0.30	0.41						
0.45		0.128	0.22	0.31		0.27	0.03
0.60	0.44						
0.75		0.123	0.31	0.39		0.35	0.04
0.90	0.38						

UPPER WILLIAMS CREEK SPAWNING CHANNEL AND SCULLY CREEK SOUTH: SOCKEYE EGG INCUBATION STUDY 2013-2014
APPENDIX D

Williams Channel , Upstream

23-May-14

interval	0.10	m
stn start	0.05	m
stn end	1.10	m

Flow	cms	lpm	cfs
	0.103	6,300	3.65

Area	m^2
	0.381

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.05	0.14						
0.15		0.052	0.12	0.39		0.26	0.01
0.25	0.38						
0.35		0.081	0.39	0.29		0.34	0.03
0.45	0.43						
0.55		0.083	0.29	0.11		0.20	0.02
0.65	0.40						
0.75		0.078	0.11	0.23		0.17	0.01
0.85	0.38						
0.95		0.071	0.23	0.52		0.38	0.03
1.05	0.33						
1.10		0.016	0.52	0.24		0.38	0.01
1.10	0.31						

Williams Creek Channel at the Weir

27-Nov-13

interval	0.1	m
stn start	0.0	m
stn end	4.5	m

Flow	cms	lpm	cfs
	0.093	5,600	3.28

Area	m^2
	1.25

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.00	0.22						
0.10		0.040	0.00			0.00	0.000
0.20	0.26						
0.30		0.054	0.00			0.00	0.000
0.40	0.28						
0.50		0.057	0.00			0.00	0.000
0.60	0.29						
0.70		0.058	0.04	0.06	0.04	0.05	0.003
0.80	0.29						
0.90		0.058	0.06	0.06	0.05	0.06	0.003
1.00	0.29						
1.10		0.058	0.07	0.06	0.08	0.07	0.004
1.20	0.29						
1.30		0.058	0.12	0.13	0.12	0.12	0.007
1.40	0.29						
1.50		0.058	0.14	0.09	0.12	0.12	0.007
1.60	0.29						
1.70		0.058	0.11	0.12	0.15	0.13	0.007
1.80	0.29						
1.90		0.058	0.15	0.12	0.16	0.14	0.008
2.00	0.29						
2.10		0.058	0.14	0.13	0.09	0.12	0.007
2.20	0.29						
2.30		0.058	0.12	0.10	0.11	0.11	0.006
2.40	0.29						
2.50		0.058	0.12	0.12	0.10	0.11	0.007
2.60	0.29						
2.70		0.058	0.11	0.07	0.08	0.09	0.005
2.80	0.29						
2.90		0.058	0.09	0.10	0.10	0.10	0.006
3.00	0.29						
3.10		0.058	0.07	0.08	0.07	0.07	0.004
3.20	0.29						
3.30		0.058	0.09	0.08	0.09	0.09	0.005
3.40	0.29						
3.50		0.058	0.08	0.07	0.07	0.07	0.004

UPPER WILLIAMS CREEK SPAWNING CHANNEL AND SCULLY CREEK SOUTH: SOCKEYE EGG INCUBATION STUDY 2013-2014
APPENDIX D

3.60	0.29						
3.70		0.058	0.07	0.06	0.07	0.07	0.004
3.80	0.29						
3.90		0.058	0.06	0.06	0.07	0.06	0.004
4.00	0.29						
4.10		0.058	0.03	0.01	0.02	0.02	0.001
4.20	0.290						
4.30		0.058	0.01	0.01	0.00	0.01	0.000
4.40	0.290						
4.50						0.00	0.000
end							
						0.00	0.000
						0.00	0.000
						0.00	0.000
						0.00	0.000
						0.00	0.000
						0.00	0.000

Williams Channel , at the ds weir

16-Dec-13

Flow	cms	lpm	cfs
	0.095	5,800	3.36

interval	0.25	m
stn start	0.0	m
stn end	4.5	m

Area	m^2
	1.303

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.00	0.25						
0.25		0.135	0.00				
0.50	0.29						
0.75		0.146	0.02	0.04	0.04	0.03	0.005
1.00	0.30						
1.25		0.149	0.13	0.13	0.11	0.12	0.018
1.50	0.30						
1.75		0.148	0.17	0.16	0.15	0.16	0.024
2.00	0.29						
2.25		0.145	0.13	0.11	0.10	0.11	0.016
2.50	0.29						
2.75		0.145	0.07	0.08	0.07	0.07	0.011
3.00	0.29						
3.25		0.145	0.07	0.10	0.07	0.08	0.012
3.50	0.29						
3.75		0.145	0.06	0.07	0.04	0.06	0.008
4.00	0.29						
4.25		0.145	0.01	0.01		0.01	0.001
4.50	0.29						

Williams Channel , at the ds weir

13-Feb-14

interval	0.25	m
stn start	0.50	m
stn end	5.00	m

Flow	cms	lpm	cfs
	0.085	5,100	3.00

Area	m^2
	1.370

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.50	0.29						
0.75		0.148	0.00				
1.00	0.30						
1.25		0.153	0.02	0.03	0.02	0.02	0.004
1.50	0.31						
1.75		0.155	0.09	0.08	0.13	0.10	0.016
2.00	0.31						
2.25		0.155	0.12	0.13	0.11	0.12	0.019
2.50	0.31						
2.75		0.153	0.12	0.10	0.10	0.11	0.016
3.00	0.30						
3.25		0.150	0.08	0.09	0.09	0.09	0.013
3.50	0.30						
3.75		0.150	0.11	0.10	0.10	0.10	0.016
4.00	0.30						
4.25		0.153	0.01	0.02	0.02	0.02	0.003
4.50	0.31						
4.75		0.155	0.00	0.00			
5.00	0.31						

Williams Channel , at the ds weir

12-Mar-14

interval	0.15	m
stn start	0.10	m
stn end	4.30	m

Flow	cms	lpm	cfs
	0.098	5,900	3.46

Area	m^2
	1.391

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.10	0.26						
0.25		0.090	0.00				
0.40	0.34						
0.55		0.101	0.00				
0.70	0.33						
0.85		0.101	0.00	0.03		0.02	0.002
1.00	0.34						
1.15		0.102	0.03	0.08		0.06	0.006
1.30	0.34						
1.45		0.102	0.08	0.13		0.11	0.011
1.60	0.34						
1.75		0.102	0.13	0.11		0.12	0.012
1.90	0.34						
2.05		0.101	0.11	0.15		0.13	0.013
2.20	0.33						
2.35		0.099	0.15	0.09		0.12	0.012
2.50	0.33						
2.65		0.099	0.09	0.11		0.10	0.010
2.80	0.33						
2.95		0.099	0.11	0.09		0.10	0.010
3.10	0.33						
3.25		0.099	0.09	0.08		0.09	0.008
3.40	0.33						
3.55		0.099	0.08	0.01		0.05	0.004
3.70	0.33						
3.85		0.099	0.01	0.07		0.04	0.004
4.00	0.33						
4.15		0.099	0.07	0.06		0.07	0.006
4.30	0.33						

Williams Channel , at the ds weir

23-May-14

interval	0.10	m
stn start	0.20	m
stn end	4.30	m

Flow	cms	lpm	cfs
	0.087	5,300	3.08

Area	m^2
	1.108

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.20	0.24						
0.30		0.048	0.00				
0.40	0.24						
0.50		0.052	0.00				
0.60	0.28						
0.70		0.056	0.00	0.00			
0.80	0.28						
0.90		0.056	0.00	0.02		0.01	0.001
1.00	0.28						
1.10		0.056	0.02	0.06		0.04	0.002
1.20	0.28						
1.30		0.056	0.06	0.09		0.08	0.004
1.40	0.28						
1.50		0.057	0.09	0.09		0.09	0.005
1.60	0.29						
1.70		0.058	0.09	0.10		0.10	0.006
1.80	0.29						
1.90		0.058	0.10	0.11		0.11	0.006
2.00	0.29						
2.10		0.058	0.11	0.15		0.13	0.008
2.20	0.29						
2.30		0.058	0.15	0.13		0.14	0.008
2.40	0.29						
2.50		0.056	0.13	0.13		0.13	0.007
2.60	0.27						
2.70		0.054	0.13	0.12		0.13	0.007
2.80	0.27						
2.90		0.054	0.12	0.10		0.11	0.006
3.00	0.27						
3.10		0.054	0.10	0.08		0.09	0.005
3.20	0.27						
3.30		0.055	0.08	0.10		0.09	0.005
3.40	0.28						
3.50		0.055	0.10	0.10		0.10	0.006
3.60	0.27						
3.70		0.055	0.10	0.09		0.10	0.005

3.80	0.28						
3.90		0.056	0.10	0.08		0.09	0.005
4.00	0.28						
4.10		0.056	0.08	0.00		0.04	0.002
4.20	0.28	0.000					
4.30			0.00				

Scully Creek Culvert

29-Nov-13

interval	0.1	m
stn start	0.1	m
stn end	4.3	m

Flow	cms	lpm	cfs
	0.280	16,800	9.88

Area	m^2
	0.42

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.10	0.12						
0.20		0.025	0.12	0.10	0.17	0.13	0.003
0.30	0.13						
0.40		0.029	0.77	0.80	0.81	0.79	0.023
0.50	0.16						
0.60		0.035	1.00	0.94	0.92	0.95	0.033
0.70	0.19						
0.80		0.033	0.86	0.95	0.81	0.87	0.029
0.90	0.14						
1.00		0.031	0.98	0.99	1.00	0.99	0.031
1.10	0.17						
1.20		0.032	0.86	0.86	0.52	0.75	0.024
1.30	0.15						
1.40		0.028	0.88	0.81	0.81	0.83	0.023
1.50	0.13						
1.60		0.025	0.78	0.80	0.78	0.79	0.020
1.70	0.12						
1.80		0.026	0.83	0.79	0.85	0.82	0.021
1.90	0.14						
2.00		0.026	0.56	0.51	0.55	0.54	0.014
2.10	0.12						
2.20		0.021	0.50	0.47	0.48	0.48	0.010
2.30	0.09						
2.40		0.016	0.76	0.78	0.73	0.76	0.012
2.50	0.07						
2.60		0.014	0.59	0.59	0.60	0.59	0.008
2.70	0.07						
2.80		0.014	0.55	0.50	0.49	0.51	0.007
2.90	0.07						
3.00		0.014	0.59	0.64	0.64	0.62	0.009
3.10	0.07						
3.20		0.012	0.29	0.32	0.32	0.31	0.004
3.30	0.05						
3.40		0.006	0.29	0.32	0.32	0.31	0.002
3.50	0.01						
3.60		0.007	0.28	0.29	0.26	0.28	0.002
3.70	0.06						
3.80		0.011	0.32	0.33	0.33	0.33	0.004
3.90	0.05						

4.00		0.008	0.10	0.08	0.06	0.08	0.001
4.10	0.03						
4.20		0.003	0.00			0.00	0.000
4.30	0.000						
end							

Scully Culvert

17-Dec-13

interval	0.25	m
stn start	0.0	m
stn end	4.1	m

Flow	cms	lpm	cfs
	0.501	30,100	17.71

Area	m^2
	0.675

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.10	0.14						
0.35		0.090	0.12	0.10	0.19	0.14	0.012
0.60	0.22						
0.85		0.113	0.99	0.98	0.97	0.98	0.110
1.10	0.23						
1.35		0.113	0.92	0.91	0.92	0.92	0.103
1.60	0.22						
1.85		0.103	0.78	0.76	0.79	0.78	0.080
2.10	0.19						
2.35		0.080	0.90	0.91	0.89	0.90	0.072
2.60	0.13						
2.85		0.068	0.98	1.07	1.14	1.06	0.072
3.10	0.14						
3.35		0.060	0.50	0.51	0.51	0.51	0.030
3.60	0.10						
3.85		0.050	0.46	0.42	0.44	0.44	0.022
4.10	0.10						

Scully Culvert

12-Mar-14

interval	0.1	m
stn start	0.0	m
stn end	4.2	m

Flow	cms	lpm	cfs
	0.420	25,200	14.82

Area	m^2
	0.568

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.00	0.00						
0.10		0.010	0.40	0.25		0.33	0.003
0.20	0.10						
0.30		0.023	0.25	0.90		0.58	0.013
0.40	0.13						
0.50		0.026	0.90	0.87		0.89	0.023
0.60	0.13						
0.70		0.033	0.87	0.90		0.89	0.029
0.80	0.20						
0.90		0.039	0.90	0.87		0.89	0.035
1.00	0.19						
1.10		0.038	0.87	0.90		0.89	0.034
1.20	0.19						
1.30		0.043	0.90	0.76		0.83	0.036
1.40	0.24						
1.50		0.045	0.76	0.63		0.70	0.031
1.60	0.21						
1.70		0.040	0.63	0.70		0.67	0.027
1.80	0.19						
1.90		0.038	0.70	0.84		0.77	0.029
2.00	0.19						
2.10		0.034	0.84	0.94		0.89	0.030
2.20	0.15						
2.30		0.029	0.94	0.84		0.89	0.026
2.40	0.14						
2.50		0.026	0.84	1.11		0.98	0.025
2.60	0.12						
2.70		0.023	1.11	1.04		1.08	0.025
2.80	0.11						
2.90		0.023	1.04	0.76		0.90	0.021
3.00	0.12						
3.10		0.021	0.76	0.48		0.62	0.013
3.20	0.09						
3.30		0.018	0.48	0.35		0.42	0.007
3.40	0.09						
3.50		0.017	0.35	0.28		0.32	0.005
3.60	0.08						
3.70		0.015	0.28	0.24		0.26	0.004
3.80	0.07						

3.90		0.014	0.24	0.14		0.19	0.003
4.00	0.07	0.000					
4.10		0.013	0.14	0.00		0.07	0.001
4.20	0.060						

Scully Culvert

22-May-14

interval	0.1	m
stn start	0.0	m
stn end	4.2	m

Flow	cms	lpm	cfs
	0.353	21,200	12.47

Area	m^2
	0.552

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.00	0.00						
0.10		0.010	0.00	0.02		0.01	0.000
0.20	0.10						
0.30		0.022	0.02	0.52		0.27	0.006
0.40	0.12						
0.50		0.030	0.52	0.68		0.60	0.018
0.60	0.18						
0.70		0.035	0.68	0.73		0.70	0.025
0.80	0.17						
0.90		0.036	0.73	0.87		0.80	0.029
1.00	0.19						
1.10		0.039	0.87	0.87		0.87	0.034
1.20	0.20						
1.30		0.038	0.87	0.69		0.78	0.030
1.40	0.18						
1.50		0.037	0.69	0.65		0.67	0.025
1.60	0.19						
1.70		0.037	0.65	0.58		0.61	0.023
1.80	0.18						
1.90		0.036	0.58	0.83		0.71	0.025
2.00	0.18						
2.10		0.033	0.83	0.80		0.82	0.027
2.20	0.15						
2.30		0.030	0.80	0.81		0.80	0.024
2.40	0.15						
2.50		0.031	0.81	0.73		0.77	0.024
2.60	0.16						
2.70		0.031	0.73	0.70		0.71	0.022
2.80	0.15						
2.90		0.026	0.70	0.61		0.65	0.017
3.00	0.11						
3.10		0.020	0.61	0.32		0.47	0.009
3.20	0.09						
3.30		0.016	0.32	0.34		0.33	0.005
3.40	0.07						
3.50		0.014	0.34	0.28		0.31	0.004
3.60	0.07						
3.70		0.013	0.28	0.25		0.27	0.003
3.80	0.06						

3.90		0.011	0.25	0.21		0.23	0.003
4.00	0.05						
4.10		0.007	0.21	0.00		0.10	0.001
4.20	0.020						

Scully Creek Site 5

29-Nov-13

interval	0.1	m
stn start	0.0	m
stn end	4.5	m

Flow	cms	lpm	cfs
	0.262	15,700	9.24

Area	m^2
	1.44

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.00	0.00						
0.10		0.015	0.00			0.00	0.000
0.20	0.15						
0.30		0.032	0.00			0.00	0.000
0.40	0.17						
0.50		0.038	0.00			0.00	0.000
0.60	0.21						
0.70		0.045	0.09	0.08	0.09	0.09	0.004
0.80	0.24						
0.90		0.049	0.07	0.08	0.06	0.07	0.003
1.00	0.25						
1.10		0.057	0.06	0.09	0.11	0.09	0.005
1.20	0.32						
1.30		0.066	0.11	0.11	0.12	0.11	0.007
1.40	0.34						
1.50		0.064	0.15	0.18	0.20	0.18	0.011
1.60	0.30						
1.70		0.063	0.22	0.17	0.18	0.19	0.012
1.80	0.33						
1.90		0.067	0.21	0.21	0.19	0.20	0.014
2.00	0.34						
2.10		0.071	0.24	0.20	0.23	0.22	0.016
2.20	0.37						
2.30		0.078	0.25	0.27	0.28	0.27	0.021
2.40	0.41						
2.50		0.083	0.35	0.31	0.33	0.33	0.027
2.60	0.42						
2.70		0.082	0.37	0.37	0.39	0.38	0.031
2.80	0.40						
2.90		0.084	0.37	0.35	0.39	0.37	0.031
3.00	0.44						
3.10		0.088	0.27	0.35	0.37	0.33	0.029
3.20	0.44						
3.30		0.089	0.25	0.24	0.32	0.27	0.024
3.40	0.45						
3.50		0.085	0.12	0.17	0.15	0.15	0.012
3.60	0.40						

3.70		0.076	0.12	0.10	0.04	0.09	0.007
3.80	0.36						
3.90		0.070	0.09	0.09	0.11	0.10	0.007
4.00	0.34						
4.10		0.069	0.00			0.00	0.000
4.20	0.350						
4.30		0.069	0.00			0.00	0.000
4.40	0.340						
4.50			0.00			0.00	0.000
end	0.260						

Scully Site 5

12-Mar-14

interval	0.1	m
stn start	0.0	m
stn end	4.2	m

Flow	cms	lpm	cfs
	0.347	20,800	12.24

Area	m^2
	0.347

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.00	0.00						
0.10		0.007	0.00	0.00		0.00	0.000
0.20	0.07						
0.30		0.016	0.00	0.00		0.00	0.000
0.40	0.09						
0.50		0.014	0.00	0.00		0.00	0.000
0.60	0.05						
0.70		0.014	0.00	0.05		0.03	0.000
0.80	0.09						
0.90		0.032	0.05	0.14		0.10	0.003
1.00	0.23						
1.10		0.052	0.14	0.32		0.23	0.012
1.20	0.29						
1.30		0.067	0.32	0.24		0.28	0.019
1.40	0.38						
1.50		0.082	0.24	0.21		0.23	0.018
1.60	0.44						
1.70		0.098	0.21	0.39		0.30	0.029
1.80	0.54						
1.90		0.114	0.39	0.53		0.46	0.052
2.00	0.60						
2.10		0.121	0.53	0.45		0.49	0.059
2.20	0.61						
2.30		0.119	0.45	0.30		0.38	0.045
2.40	0.58						
2.50		0.113	0.30	0.23		0.27	0.030
2.60	0.55						
2.70		0.106	0.23	0.28		0.26	0.027
2.80	0.51						
2.90		0.099	0.28	0.19		0.24	0.023
3.00	0.48						
3.10		0.092	0.19	0.13		0.16	0.015
3.20	0.44						
3.30		0.084	0.13	0.08		0.11	0.009
3.40	0.40						
3.50		0.077	0.08	0.02		0.05	0.004
3.60	0.37						

3.70		0.061	0.02	0.00		0.01	0.001
3.80	0.24						
3.90		0.041	0.00	0.00		0.00	0.000
4.00	0.17	0.000					
4.10		0.031	0.00	0.00		0.00	0.000
4.20	0.140						

Scully Creek Site 5

22-May-14

interval	0.1	m
stn start	0.0	m
stn end	4.4	m

Flow	cms	lpm	cfs
	0.328	19,700	11.58

Area	m^2
	1.441

STN	DEPTH	AREA	m/s				FLOW
	m	m^2	1	2	3	AVE	m^3/s
0.00	0.00						
0.10		0.008	0.000			0.00	0.000
0.20	0.08						
0.30		0.019	0.000			0.00	0.000
0.40	0.11						
0.50		0.023	0.000			0.00	0.000
0.60	0.12						
0.70		0.019	0.000	0.041		0.02	0.000
0.80	0.07						
0.90		0.026	0.041	0.055		0.05	0.001
1.00	0.19						
1.10		0.043	0.055	0.121		0.09	0.004
1.20	0.24						
1.30		0.051	0.121	0.135		0.13	0.007
1.40	0.27						
1.50		0.067	0.135	0.109		0.12	0.008
1.60	0.40						
1.70		0.090	0.109	0.262		0.19	0.017
1.80	0.50						
1.90		0.106	0.262	0.418		0.34	0.036
2.00	0.56						
2.10		0.116	0.418	0.516		0.47	0.054
2.20	0.60						
2.30		0.120	0.516	0.491		0.50	0.060
2.40	0.60						
2.50		0.117	0.491	0.289		0.39	0.046
2.60	0.57						
2.70		0.110	0.289	0.242		0.27	0.029
2.80	0.53						
2.90		0.101	0.242	0.244		0.24	0.025
3.00	0.48						
3.10		0.090	0.244	0.148		0.20	0.018
3.20	0.42						
3.30		0.082	0.148	0.144		0.15	0.012
3.40	0.40						
3.50		0.080	0.144	..057		0.14	0.012
3.60	0.40						

3.70		0.068	0.000			0.00	0.000
3.80	0.28						
3.90		0.053	0.000			0.00	0.000
4.00	0.25						
4.10		0.036	0.000			0.00	0.000
4.20	0.110						
4.30		0.016	0.000			0.00	0.000
4.40	0.050						