

**Assessment of Incubation Survival of Summer-Run Chinook  
Salmon in the Puntledge River Headpond and at the Bull Island  
Restoration Sites**

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## **1.0 Executive Summary**

Since the early 1900s, hydroelectric development, logging and other industrial and urban development have impacted the Puntledge River. Hydro development in the watershed has contributed to a significant decline in summer-run chinook salmon. The loss of valuable spawning habitat through a number of impacts in the headpond reach lead to hatchery practices (up until 2001) which involved taking every returning adult for hatchery broodstock and preventing access to the historic habitat above the diversion dam. Although the habitat in the headpond is severely impacted, the potential for natural production may still be there.

A study to 1) determine whether spawning habitat in the headpond reach could support a spawning population of summer run chinook and 2) monitor incubation success in the recently rehabilitated spawning habitat at the Bull Island secondary channel, commenced in the fall of 2002 at the Puntledge River.

The results of the incubation component of the study in the headpond reach at Supply Creek found that egg to fry survival was variable across the channel (mean survival: 57%, range: 16% – 92%), but the parameters measured were inconclusive in determining what caused the variability. Information on stream velocity, water depth, intragravel dissolved oxygen concentrations and substrate quality were the parameters required to determine the spawning habitat preferences for summer run chinook. We were unable to obtain detailed information on intragravel dissolved oxygen and substrate quality.

The results of the incubation component of the study demonstrate that there is potential for natural production in the Supply Creek area. Water velocity and depth are adequate for supporting a spawning population. In its present state, substrate quality and intragravel dissolved oxygen concentrations are likely inadequate for high incubation success. Rehabilitation of spawning substrate would likely increase the egg to fry survival in this area. The high incubation success observed at the Bull Island spawning platforms demonstrates the value of introducing high quality spawning substrate as a means of enhancing spawning populations of summer run chinook. The Bull Island project should be used as a template for potential rehabilitation in the head pond reach.

## **2.0 Introduction**

In 1993 a survey of the headpond and falls reaches of the Puntledge River was undertaken to assess the feasibility of enhancing existing chinook spawning habitat that had been impacted by hydroelectric development in the watershed (Benneyfield and McLaren 1994). Two locations in the headpond reach and five sites in the falls reach were identified as good candidates for rehabilitating spawning habitat. Supply Creek in the headpond and the Bull Island Secondary Channel in the falls reach were two of the sites identified in the study. A deficiency of suitable spawning habitat has been identified as one of the main limiting factors to summer chinook production. If the long-term vision for the Puntledge River is the restoration of fisheries habitats within the system that will sustain natural production, then the spawning habitat above and below the diversion dam must be evaluated and restored.

Efforts are underway in the Puntledge watershed to address the loss of summer Chinook spawning habitat. In the fall of 2001, surplus summer-run chinook broodstock from the Puntledge River Hatchery were allowed above the diversion dam for the first time in 36 years. A study was undertaken to look at incubation success at the Supply Creek confluence that same year. Results from the 2001 incubation study were encouraging (survival to swim-up ranged from 11% to 81%) and lead to a more detailed incubation study in 2002 at Supply Creek (DFO 2001 Unpublished data).

In the summer of 2002 phase one of the Bull Island secondary channel rehabilitation project was completed. The project was designed to increase the quantity and quality of spawning habitat in the falls reach. Details of the project are summarized in Norgan 2002. Bull Island was included as part of the Supply Creek incubation study to determine incubation success in the recently rehabilitated chinook spawning habitat. Results from the Supply Creek and Bull Island incubation studies will provide useful information in determining habitat criteria for successful summer-run chinook spawning and incubation in the headpond reach of the Puntledge River.

## **2.1 Objectives**

The objectives of the 2002/03 incubation study were to:

- assess incubation success in the Headpond reach and the Bull Island secondary channel
- produce a matrix comparing egg-to-fry survival to habitat variables – depth, velocity and substrate composition; and,
- determine the habitat criteria for successful summer-run chinook spawning and incubation in the Headpond reach of the Puntledge River.

## **3.0 Study Area**

### **3.1 Supply Creek**

This site is located at the confluence of Supply Creek and the Puntledge River in the “Headpond” reach, approximately 2.6 km downstream of the BC Hydro impoundment dam at the mouth of Comox Lake, and 1.1 km upstream of the diversion dam (Figure 1 and Plate 1). Historically, this area supported a significant proportion of spawning summer

chinook salmon and is presently one of two areas in this reach where spawning activity has been observed since adults have been allowed above the diversion dam. Gravel recruitment from Supply Creek has accumulated in a large submerged gravel bar along the left bank of the mainstem river, and persists today.

### **3.2 Bull Island Secondary Channel**

Bull Island is located 300 m upstream of the Comox logging bridge in the falls reach (Figure 1 and 2; Plates 2a and 2b). Flow from the river splits into the secondary channel at a small upstream islet, then drops over a bedrock incline and down through a 20 m wide channel containing sections of boulder, accumulation of logs and wood debris and finer gravel and cobble beds. The channel is approximately 640 m in length. Two sites in this secondary channel were selected to monitor incubation success, one upstream and one downstream of a large logjam.

## **4.0 Methods**

### **4.1 Water Quality**

#### **4.1.1 Temperature**

Water temperature was monitored throughout the incubation period using an Onset Tidbit<sup>®</sup> temperature logger located at the inlet to the upper hatchery site. The data was periodically downloaded in order to calculate the Accumulated Thermal Units (ATU - daily mean temperature times the number of days) to estimate the rate of development.

#### **4.1.2 Surface and Intragravel Dissolved Oxygen**

Intragravel oxygen samples were collected at some of the representative sites with a 30 cm long metal syringe. Intragravel water samples extracted were expelled into a 500 ml plastic container where dissolved oxygen, % saturation and water temperatures were taken with a YSI 55 Dissolved Oxygen meter.

### **4.2 Discharge**

#### **4.2.1 Supply Creek**

On 5 of the 8 visits, discharge in the headpond was measured using a Swiffer current meter and a 1.4 m top-setting wading rod (a 2 m top-setting rod was used on the March 26 survey). When depths were greater than 1 m, measurements were taken from an inflatable zodiac. Velocities were taken at 2 m intervals along a transect perpendicular to the channel, from left bank to right bank, and for the most part, were located over the incubation cassettes.

#### **4.2.2 Bull Island**

Discharge was measured on 8 dates at Bull Island Site 2 (upstream of the logjam) using a Swiffer current meter with a 1.4 m top setting wading rod. Velocities were taken at 1.0 m intervals along a transect perpendicular to the channel, from the left bank to the right

bank. On one occasion (November 14, 2002) velocities were measured over each of the incubation cassettes planted at Sites 1 and 2.

#### **4.2.3 Water Levels**

Solinst water level data loggers were installed at Supply Creek and Bull Island Site 2 on January 8, 2003.

Staff gauges were installed at Bull Island and Supply Creek on January 8 and February 7 respectively. The Bull Island staff gauge is attached to a log on the left bank of the secondary channel at the upstream end of the spawning platform Site 2. The Supply Creek staff gauge is attached to a stump on the left bank next to the water level logger (Figure 1).

On February 7 a spirit level survey was done at each of the two study sites to connect the water level loggers and staff gauges to vertical control stations with assumed datum's. For Supply Creek the water level logger and the staff gauge were connected to Stations 1 and 928. The approximate elevations for the two stations are based on elevations presented in Bengeyfield and McLaren 1994.

Water level readings were adjusted using the following equations:

- $129.70 \text{ m (depth probe elevation)} + \text{logger reading} = \text{assumed water level msl}$  and
- $129.61 \text{ m (0 on the staff gauge)} + \text{staff gauge reading} = \text{assumed water level msl}$ .

The accuracy of the level logger can be checked by comparing the water level reading to Stations 1 or 928 using a spirit level or by comparing the reading to the staff gauge water level. Table 1 provides elevation information for the Supply Creek water level recording site.

**Table 1. Elevations of water level monitoring equipment at Supply Creek, Puntledge River, 2003.**

<b>Location</b>	<b>Elevation (estimated) msl in meters</b>
Solinst logger depth probe elevation	129.7
0 on the staff gauge	129.61
Station 1	131.0
Station 928	131.64

For Bull Island the water level logger and the staff gauge were connected to Station 1563. The approximate elevation for the station is assumed. This station was established on December 5, 2002 by DFO.

Water level readings were adjusted using the following equations:

- $96.07 \text{ m (depth probe elevation)} + \text{logger reading} = \text{assumed water level msl}$  and
- $96.16 \text{ m (0 on the staff gauge)} + \text{staff gauge reading} = \text{assumed water level msl}$ .

The accuracy of the level logger can be checked by comparing the water level reading to Station 1563 using a spirit level or by comparing the reading to the staff gauge water level. Table 2 provides elevation information for the Bull Island water level recording site.

**Table 2. Elevations of water level monitoring equipment at Bull Island, Puntledge River, 2003.**

Location	Elevation (estimated) msl in meters
Solinst logger depth probe elevation	96.07
0 on the staff gauge	96.161
Station 1563	96.88

### **4.3 Substrate Composition**

#### **4.3.1 Supply Creek**

Substrate composition is based on visual estimates collected by D. Burt and Associates in the summer of 2002. The estimates were made along the flow and incubation transect line at 2 m intervals. Discharge was too high to collect substrate samples at the time the incubation cassettes were retrieved.

#### **4.3.2 Bull Island**

Screened gravel was placed at three rehabilitation sites in the Bull Island secondary channel during the summer of the 2002. Substrate composition for the Bull Island incubation sites was 15% small gravel, 50% large gravel and 35% small gravel (Norgan 2002).

### **4.4 Incubation Success**

#### **4.4.1 Supply Creek**

On October 21, 2002, summer-run chinook eggs and milt (Puntledge stock) were stripped from 6 females and 6 males at the lower Puntledge Hatchery Facility. For each female chinook, an average egg weight was calculated and approximately 2500 eggs were placed in a 10 litre bucket. The eggs from the 6 females were combined in the one bucket yielding approximately 15,000 eggs. These eggs were then divided into four 4 litre buckets, two containing 2500 eggs in each to transport to the study site and the other two containing 5000 eggs each to remain at Puntledge hatchery as a control group. Milt from six male summer chinook was taken and stored in separate whirl-pak bags. Two bags for each male were kept, one for the study and one for the control groups. The eggs and milt were kept cool on ice and transported to the study site at Supply Creek in the headpond reach.

Once at the site, the eggs from one bucket were fertilized with 3 of the males (labeled male A, B and C) by pouring the milt from the 3 whirl-pak bags into the bucket. After allowing a minute to complete fertilization, the eggs were water hardened and loaded into Jordan-Scotty incubation cassettes. As each incubator was filled (200 eggs per cassette) it was assembled and passed to divers who buried them in the gravel. The depth of the

holes excavated for placement of the incubators was approximately 0.3 m. The procedure was repeated with the second bucket of eggs, being fertilized with the remaining 3 males labeled D, E, and F. Certified DFO divers buried a total of 21 cassettes in the gravel. Cassettes were located at approximately 2 metre intervals along a transect, perpendicular to the channel, in water depths ranging from 0.2 - 2 m. Each cassette was secured by a 50 cm length of ¼ inch polypropylene rope to a 40 cm length of rebar, painted fluorescent orange, and situated upstream of the cassette. The control group of eggs at Puntledge Hatchery were fertilized as above, one bucket of 5000 eggs with males A, B, and C and the other with males D, E, and F. Each group was placed in a Heath tray and survival to swim-up was monitored.

On November 21, 2002, cassette 2 was removed to determine stage of development. The cassette was returned to the original site. On January 16, 2003, 8 cassettes from sites along the transect representing a range of habitat conditions were removed and survival was determined. The cassettes were not returned to their original sites so the remaining live alevins were buried in the gravel at the confluence of Supply Creek.

On March 26, 2003 the remaining cassettes were removed and percent survival to swim-up stage was calculated.

#### **4.4.2 Bull Island Sites 1 and 2**

On November 14, 2002, approximately 4000 eyed chinook eggs were obtained from the Puntledge River hatchery. The eggs were from a batch of 281,779 eggs. Survival data for this batch of eggs was used as the control. The eggs were placed in a 4 litre bucket for transport to the study site. The eyed chinook eggs were loaded into 9 Jordan-Scotty Incubators at Site 1 and into 8 incubators at Site 2 (Figure 2). As each incubator was filled (200 eggs per cassette) it was assembled and buried in the gravel. The depth of the holes excavated for placement of the incubators was approximately 0.3 m. Each cassette was secured by a 50 cm length of ¼ inch polypropylene rope to a 40 cm length of rebar, painted fluorescent orange, and situated upstream of the cassette.

On January 16, 4 cassettes were removed from Site 1 and 4 cassettes from Site 2 to determine stage of development and survival. The cassettes were not returned to their original sites so the remaining live alevins were released from the cassettes into a hole dug in the channel and covered with gravel. On February 21, 2003 the remaining cassettes were removed and percent survival to swim-up stage was calculated.

Hydraulic sampling of Site 2 was completed on February 21, 2003 to collect additional information on egg to fry survival of natural redds.

## **5.0 Results**

### **5.1 Water Temperature**

Mean daily water temperatures provided information on accumulated thermal units (ATU's) for predicting stages of development. Data collected with the Tidbit temperature loggers was summarized and data was input into a WinSIRP Excel spreadsheet to determine the time when 50% of the chinook eggs would hatch and the approximate time

of emergence. The model predicted that the time to the eyed stage of development was November 11. The time to 50 % hatch was Dec. 12, 2002 and the time of emergence would be approximately Feb. 27, 2003. On November 21 survey, 100% of the eggs were eyed. By January 8 all of the developing embryos were at the alevin stage. The eggs at Bull Island were >90% buttoned up by February 21, 2003.

Water temperature data is presented in Figure 3.

## **5.2 Surface and Intragravel Dissolved Oxygen**

### **5.2.1 Supply Creek**

Surface and intragravel flow was sampled to determine dissolved oxygen levels at the incubation site. Samples were limited to sampling shallow water habitat along the left side of the channel. Water velocities were too high to get divers in to take representative samples at the individual incubation sites. Results of dissolved oxygen sampling are presented in Appendix 1 and summarized in Table 3.

Table 3. Mean surface and intragravel dissolved oxygen measurements at Supply Creek and Bull Island, 2002 - 2003.

<b>Location</b>	<b>Mean surface DO (mg/l)</b>	<b>Range</b>	<b>Mean Intragravel DO (mg/l)</b>	<b>Range</b>
Supply Creek	12.09	11.5 – 12.4	10.21	8.6 – 11.98
Bull Island Site 1	11.72	11.4 – 12.4	10.51	9.36 – 11.98
Bull Island Site 2	11.9	11.3 – 12.93	10.83	9.56 – 12.18

The data suggests that the intragravel concentrations of dissolved oxygen were within acceptable limits for buried embryo and alevin stages, which were above the water quality criteria instantaneous minimum of 6.0 mg/l. Unfortunately no dissolved oxygen levels were measured at representative sites across the channel. The sampling technique for determining intragravel dissolved oxygen may not be providing an accurate estimate or our sampling effort was not sufficient to detect areas with DO's below the minimum criteria. It is likely sampling effort was too limited to determine if intragravel flow/dissolved oxygen levels were too low in some areas across the channel to support developing embryos. Given that velocities and water depths at individual cassettes were generally above the spawning habitat criteria for chinook salmon one can speculate that intragravel flow has been limited by accumulations of sediment in the interstitial spaces of the spawning substrate (Table 6). There have been no spawning chinook in this area for 36 years and therefore no gravel has been turned over in that period of time, which has led to loss of or reduced intragravel flows in some areas, which may explain some of the variability in incubation success.

## **5.2.2 Bull Island**

Surface and intragravel flow was sampled to determine dissolved oxygen levels at incubation Sites 1 and 2. Results of dissolved oxygen sampling are presented in Appendix 2 and summarized in Table 3.

The data suggests that the intragravel concentrations of dissolved oxygen were within acceptable limits for buried embryo and alevin stages. Since this habitat was recently restored with screened gravel, it is not surprising that we obtained high intragravel dissolved oxygen levels.

## **5.3 Discharge**

### **5.3.1 Supply Creek**

Discharge ranged from 9.28 m<sup>3</sup>/s to 46.5 m<sup>3</sup>/s during the 2002 – 2003 monitoring period (Table 4). Water velocity measured over individual cassettes is presented in Table 6.

### **5.3.2 Bull Island**

Discharge ranged from 1.33 m<sup>3</sup>/s to 3.88 m<sup>3</sup>/s during the 2002 – 2003 monitoring period (Table 4). Water velocities measured over individual cassettes are presented in Appendix 2.

### **5.3.3 Water Level Monitoring**

Water levels monitored during the winter of 2003 for Supply Creek and the Bull Island study sites are presented in Figures 4 and 5.

Over time the data collected will be used to develop a stage/discharge-rating curve.

## **5.4 Substrate Composition**

Substrate composition is based on visual estimates of surface composition. The results are presented in Table 6. Superficial observations of spawning substrate are generally of low value since surface composition does not necessarily represent what the substrate composition is beneath the surface. Gravel quality data collected at Carnation Creek demonstrates that there are significant differences in substrate composition between the surface, middle and bottom layers of a frozen core sample (Scrivener and Brownlee, 1982). The bottom layer has the highest composition of finer material and the top layer having the lowest percentage of fine material (<9.55 mm).

Superficial estimates of fines by D. Burt and Associates ranged from 10 – 25% (Table 6). The spawning substrate in this area has not been cleaned through spawning activity for 36 years due to the deliberate exclusion of spawning chinook from this area. The absence of significant spawning populations in this reach has likely lead to accumulations of fine sediments in the gravel, particularly below the surface and therefore cursory observations may be underestimating the composition of fines.

## **5.5 Incubation Success**

### **5.5.1 Supply Creek**

During the November 21 site visit, cassette 2 was removed to assess the stage of development (Plates 3 and 4). The survival to eyed stage for this cassette was 92%. The same cassette was removed on January 8, 2003 to assess survival and stage of development hatch. Survival to the alevin stage for cassette 2 was 65% (Table 5).

On January 16, 8 cassettes were removed to determine survival post hatch (Plate 5). Cassettes were removed from sites with varying depths, velocities and substrate composition. Survival ranged from 44% to 93% (Table 5). There did not appear to be any one specific area along the transect line that experienced higher survival than other locations. For example in the deeper section along the right bank, two cassettes (17 and 19) spaced 4 meters apart had similar water depths, flows and substrate composition but had very different survivals (C-17 = 46% and C-19 = 80%).

High water levels delayed the removal of the remaining cassettes until March 26. Again survival to fry stage along the transect line was variable, ranging from 16% to 92% (Tables 5 and 6). Plates 6 and 7 are examples of cassettes removed from the channel on March 26, 2003.

### **5.5.2 Bull Island**

On January 16, 2003, 4 cassettes were removed from incubation Sites 1 and 2 to assess the stage of development and survival. Plates 8 and 9 are examples of cassettes removed on January 16, 2003. Survival to the alevin stage was 98% (range; 97.5% - 99.5%) for Site 1 and 98% (range: 97.5% - 99.0.%) for Site 2. The remaining cassettes were removed on February 21, 2003. Survival to the fry stage was high at both sites. Survival at Site 1 was 98% (range: 96.0% - 98.5%) and at Site 2 was 98% (range: 97% - 100%)(Table 7).

Hydraulic sampling methodology was used to assess survival in natural redds on February 21, 2003. Mean survival for the three chinook redds was 77% (range: 63.6% - 98.8%). The survival in the coho redds was 100% (Table 8).

## **6.0 Discussion**

The primary objective of this study was to determine the habitat criteria for successful summer-run chinook spawning and incubation in the headpond reach of the Puntledge River. Information gained would be used to develop prescriptions for enhancing existing habitat in this area.

Incubation success was assessed at Supply Creek in the headpond reach and at rehabilitated spawning habitat in the Bull Island secondary channel (Figures 1 and 2). The results from the Supply Creek study were inconclusive in that the sample data was too limited (not enough data or replicates) to explain the high variability in egg to fry survival at the 20 incubation sites across the channel (Table 6). Detailed information on intragravel dissolved oxygen concentrations and substrate compositions were not

collected. The site selected for the study was difficult to assess for intragravel dissolved oxygen concentrations and substrate composition. Divers were required to plant the incubators at the beginning of the study and were to collect information on intragravel dissolved oxygen and substrate quality at the incubation sites. High water velocities prohibited the use of divers to sample intragravel dissolved oxygen and substrate composition.

The superficial estimates of substrate composition collected by D. Burt and Associates would not be representative of the composition beneath the surface. Surface appearance of gravels is an inadequate and often misleading indicator of gravel quality for salmonid reproduction. The method does not describe gravel quality at the 20 to 30 cm depth where spawning salmonids usually deposit their eggs (Everest et al 1981). Research has shown that streambed gravels with similar surface properties and appearance can have very different properties a few centimetres below the surface (Everest et al 1981). Accumulations of finer particles in the substrate below the surface are probably significantly higher than those observed for estimates of surface composition (Table 6). Since the substrate in this area has not been cleaned by a large spawning population for 36 years, it is likely that fines composition with increasing depth below the substrate surface is sufficiently high to reduce intragravel flows, resulting in lower concentrations of dissolved oxygen.

The survival data from individual incubators planted across the channel indicates that oxygen delivery to the incubation cassettes was inadequate at a number of the sites for normal development of the embryos. This is probably the result of varying degrees of silt content in the interstitial spaces of the gravel at each of the incubation sites. Accumulations of fine material in the top layer of substrate at Supply Creek would have affected the exchange rates of surface and intragravel flow resulting in low dissolved oxygen concentrations at some of the incubation sites. Studies at Carnation Creek found that accumulations of sand and pea gravel in the top layer of the bed deposited post logging appears to have filled in the spaces between the gravel and reduced the intragravel velocity of interstitial water. Exchange rates between surface and intragravel water also appears to have been reduced, resulting in lower concentrations of subsurface dissolved oxygen (Scrivner and Brownlee 1980). Healey (1991) states that egg mortality is associated with low dissolved oxygen and poor percolation of water through spawning gravel, with increasing mortality below percolation rates of 0.034 cm/s.

Data collected on water velocities and depth were adequate for determining if they meet the criteria for summer chinook spawning. The velocities were within the range of 0.32 – 1.09 m/sec and above the minimum depth of 0.3 m stated in the literature (Koning and Keely 1997)(Table 6). Healey (1991) stated “Provided the condition of good subgravel flow is met, chinook apparently will spawn in water that is shallow or deep, slow or fast, and where the gravel is coarse or fine”.

Although the data is inconclusive in that the parameters measured do not explain the variability in egg to fry survival, the data does demonstrate that incubation success in this area is sufficiently high to support incubating eggs (9 of the 21 cassettes had greater than 60% egg to fry survival). Given that the water depths and velocities meet the criteria for spawning summer chinook, enhancement of spawning substrate would probably increase

incubation success significantly. Prescription development for enhancing spawning substrate in the headpond reach should be considered.

The high egg to fry survival at Bull Island was not unexpected (Table 7). The substrate at the two sites in Bull Island was comprised of screened gravel placed in the channel in the summer of 2002. The high egg to fry survivals indicates good intragravel flow and oxygen concentrations. Data collected on intragravel dissolved oxygen at the two sites further supports the conclusion that there exists good intragravel flow to support developing embryos. Oxygen levels were well above the water quality criteria instantaneous minimum of 6.0 mg/l. Intragravel dissolved oxygen concentrations did not drop below 9.0 mg/l at the two study sites. Water velocities and depths measured over individual cassettes are within the spawning criteria for summer chinook (Appendix 2). The velocities were within the range of 0.32 – 1.09 m/sec and above the minimum depth of 0.3 m (Appendix 2). This site should be used as a template for rehabilitation works in the headpond reach.

## **7.0 Recommendations**

1. Develop prescriptions to rehabilitate spawning substrate in the headpond reach of the Puntledge River.
2. Recommend that the riparian area in the head pond be protected from future logging.
3. Begin dialogue with the landowner of the upper Supply Creek watershed to provide adequate buffers along all watercourses during logging operations.
4. Continue to collect data on intragravel dissolved oxygen, water depth, water velocity, water temperature and substrate quality. Sampling of substrate should use a technique that provides vertical stratification of the substrate.
5. Continue to monitor flows, water depths, and intragravel dissolved oxygen and incubation success at the Bull Island spawning platforms.

## **8.0 Acknowledgements**

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## **9.0 References**

Bengeyfield, W. and W. A. McLaren. 1994. Puntledge River Gravel Placement Feasibility Study. Unpubl. Rep. To BC Hydro, Vancouver, B.C., by Global Fisheries Consultants Ltd. and McLaren Hydrotechnical Engineering.

DFO. 2001. Unpublished egg to fry survival data collected at Supply Creek, 2001. Fisheries and Oceans Canada, Nanaimo, B.C.

Everest, F.H., F.B. Lotspeich and W. R. Meehan. 1981. New Perspectives on Sampling, Analysis and Interpretation of Spawning Gravel Quality. In: N. B. Armantrout (ed.) Acquisition and Utilization of Aquatic Habitat Inventory Information, p. 325 – 333. Western Division, American Fisheries Society, Portland, Oregon.

Guimond, E. 2002. Analysis of Fisheries Impacts Related to Hydroelectric Development in the Puntledge River Watershed. Draft Report. Fisheries and Oceans Canada, Oceans and Community Stewardship, Nanaimo, B.C. 30 p. + app.

Healey, M. C. 1991. Life History of Chinook Salmon (*Oncorhynchus tshawytscha*), p. 312 – 393. In; C. Groot and L. Margolis (ed.) Pacific Salmon Life History. UBC Press, Vancouver, B.C.

Norgan R. 2002. Puntledge River - Bull Island Back Channel Gravel Placement (Phase 1). Unpublished report to BC Hydro, Vancouver, B.C. by Fisheries and Oceans Canada, Nanaimo, B.C.

Scrivener, J.C. and M. J. Brownlee. 1982. An analysis of Carnation Creek gravel quality data, 1973 – 1981. In G.F. Hartman (ed.) Proceedings of the Carnation Creek Workshop: A ten year review, p. 154 – 176. Pacific Biological Station, Nanaimo, B.C.