# Re-Introduction of Lower Columbia River Chum Salmon into Duncan Creek

**Annual Report**
**2001-2002**

DOE/BP-00007373-1

October 2002

This Document should be cited as follows:

*Hillson, Todd, ''Re-Introduction of Lower Columbia River Chum Salmon into Duncan Creek'', Project No. 2001-05300, 63 electronic pages, (BPA Report DOE/BP-00007373-1)*

Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97208

This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

# Re-Introduction of Lower Columbia River Chum Salmon into Duncan Creek
Annual Report for 2002

Todd D. Hillson
Washington Department of Fish and Wildlife

Contract # 200105300
For The Bonneville Power Administration
Portland, Oregon

# Index

# List of Tables

# List of Figures

# Forward

The National Marine Fisheries Service (NMFS) listed Lower Columbia River chum as threatened under the auspices of the Endangered Species Act (ESA) in March of 1999 (64 FR 14508, March 25, 1999). The listing was in response to reduction in abundance from historical levels of more than half a million returning adults to fewer than 10,000 spawners present day (Johnson *et al.* 1997). Harvest, loss of habitat, changes in flow regimes, riverbed movement and heavy siltation have been largely responsible for the decline in this species in the Columbia River. The timing of seasonal changes in river flow and water temperatures is perhaps the most critical factor in structuring the freshwater life history of chum salmon (Johnson *et al.* 1997). This is especially true of the population located directly below Bonneville Dam where hydropower operations can block access to spawning sites, dewater redds, strand fry, cause scour or fill of redds and increase sedimentation of spawning gravels.

Currently only two main populations are recognized as genetically distinct in the Columbia River, although spawning has been documented in most lower Columbia River tributaries (Johnson *et al.*, 1997; Keller 2001). The first is located in the Grays River (RKm 34) (Grays population), a tributary of the Columbia, and the second is a grouping of spawners that utilize the Columbia River just below Bonneville Dam (RKm 235) adjacent to Ives Island and in Hardy and Hamilton creeks (Bonneville population). A possible third population of mainstem spawners, found in the fall of 1999, were located spawning above the I-205 bridge (approximately RKm 182), the Woods Landing/Rivershore population.

Response to the federal ESA listing has been primarily through direct recovery actions. Both state and federal agencies have built controlled spawning areas. Just prior to listing in 1998, the Washington Department of Fish and Wildlife began a chum supplementation program using native stock on the Grays River. This program was expanded in 1999 to include reintroduction into the Chinook River using eggs from the Grays River supplementation program. These eggs are incubated at the Sea Resources Hatchery on the Chinook River and the fry are released at the mouth of the river.

The recovery strategy for Lower Columbia River chum as outlined in the Hatchery Genetic Management Plan (HGMP) for the Grays River project has four main tasks. First, determine if remnant populations of Lower Columbia River chum salmon exist in Lower Columbia River tributaries. Second, if such populations exist, develop stock-specific recovery plans that would involve habitat restoration including the creation of spawning refugias, supplementation if necessary and a habitat and fish monitoring and evaluation plan. If chum have been extirpated from previously utilized streams, develop re-introduction plans that utilize appropriate genetic donor stock(s) of Lower Columbia River chum salmon and integrate habitat improvement and fry-to-adult survival evaluations. Third, reduce the extinction risk to Grays River chum salmon population by randomly capturing adults in the basin for use in a supplementation program and reintroduction of Lower Columbia River chum salmon into the Chinook River basin.

The Duncan Creek project was developed in response to task #2 of the recovery strategy for Lower Columbia River chum. Biologists with the Washington Department of Fish and Wildlife (WDFW) and Pacific States Marine Fisheries Commission (PSMFC) identified Duncan Creek as an ideal upriver location below Bonneville Dam for chum re-introduction. It has several attributes that make it a viable location for a chum re-introduction project: historically chum were present, the creek is low gradient, has numerous springs/seeps, has a low potential for future development and is located very close to a donor population of Lower Columbia River chum.

The Duncan Creek project has two goals: 1) re-introduction of chum into Duncan Creek by providing off channel high quality spawning and incubation areas and 2) to simultaneously evaluate natural re-colonization and a supplementation strategy where adults are collected and spawned artificially at a hatchery. The eggs from these artificial crossings are then either incubated at Duncan Creek or incubated and the fry reared at the hatchery to be released back into Duncan Creek. Tasks associated with the first goal include: 1) removing mud, sand and organics present in four of the creek branches and replace with gravels expected to provide maximum egg-to-fry survival rates to a depth of at least two feet; 2) armoring the sides of these channels to reduce importation of sediment by fish spawning on the margins; 3) planting native vegetation adjacent to these channels to stabilize the banks, trap silt and provide shade; 4) annual sampling of gravel in the spawning channels to detect changes in gravel composition and sedimentation levels. Tasks associated with the second goal of the recovery strategy for Lower Columbia River chum are detailed in The Monitoring and Evaluation Plan for the Duncan Creek Chum Salmon Reintroduction Program (Duncan M&E). Four main questions are used to evaluate the success of this program. These are: 1) what egg-to-fry survival rates are being achieved in the renovated channels, 2) what is the survival of the eggs and fry used in the artificial rearing program that will take place in Duncan Creek, 3) what is the survival and spawning ground distribution of adult chum salmon produced from the spawning channels and from the artificial rearing program, and 4) what is the straying rate of non-program chum salmon into Duncan Creek. The monitoring portion of the Duncan M&E includes documenting and monitoring the physical attributes of the channels. These physical attributes include, but are not limited to gravel composition, sedimentation load, dissolved oxygen (DO) levels, vertical hydraulic gradients and water temperatures in the hyporheic zone and flow.

# Evaluation and Monitoring of Re-Introduction Efforts

Two methods of re-introduction, natural re-colonization and supplementation are being simultaneously evaluated. Natural re-colonization would occur via straying of adults from below Bonneville. The supplementation strategy required adults to be collected and artificially spawned and had two options for incubation and rearing. Remote Site Incubators (RSI) to incubate eggs at Duncan Creek, while not ruled out for use in future years, were not used in 2001. All eggs from the artificial crossings at Washougal Hatchery were incubated and the fry reared to release size at the hatchery.

## Part I: Duncan Creek Chum Salmon Hatchery Program

### Introduction

The goal of the Duncan Creek chum salmon hatchery program at Washougal Hatchery is to preserve genetic diversity within the Bonneville population and provide a source of chum salmon for reintroduction in Duncan Creek and other Gorge area tributaries. This is accomplished by collecting sufficient numbers of broodstock to maintain genetic diversity and collecting those adults over the entire run period. Mating enough individuals to maintain an effective population size of greater than 35 is reported in the Duncan M&E as the minimum needed to maintain genetic diversity. Historical run timing records would be consulted to calculate the number needed weekly to maintain natural run timing. Eventually, all fish needed for this program should be available by operating an adult trap at the mouth of Duncan Creek. Fish used in 2001 were collected from known nearby spawning areas of the Bonneville population. Methods used to spawn, incubate and track various biological parameters from adult collection through fry emergence and ponding are detailed in Appendix 1 of the Duncan M&E. These methods are similar to those presented in the Summer Chum Conservation Initiative (WDFW and Point no Point Treaty Tribes 2000). Measurements of phenotypic traits collected on females used in the supplementation program will also provide the data needed to produce the predictive regression formulas of fecundity for estimating the egg-to-fry survival rates of females that spawned naturally in the channels.

### Methods

### Adult Collection

PSMFC personnel collected adults from several known spawning locations around and in Duncan Creek using beach seines and tangle nets. Adults selected for the supplementation program at Washougal Hatchery were placed into a fish tube. The fish tubes were three feet long sections of 10" diameter PVC pipe, perforated with several one and a half inch holes, and equipped with removable end pieces. The sex of the fish, date, time and location of capture was recorded with a pencil on each tube. A 400-gallon tank mounted on the back of a flatbed truck was used to transport the fish, which remained in the tubes during transport.

**Holding, Spawning and Rearing**

Upon arrival at the hatchery the fish were placed, still in the fish tube, into an adult holding pond. The tubes were suspended in the water column on ropes. Fish were checked for spawning readiness based on the observed state of ripeness at time of capture. Once the number of ripe females had been determined the number of males needed to perform the factorial cross would be calculated. Males were checked for ripeness and used on a first into hatchery basis.

Methods used to spawn, incubate and track various biological parameters from adult collection through fry emergence and ponding were detailed in Appendix 1 of the Duncan M&E. These methods are similar to those presented in the Summer Chum Conservation Initiative (WDFW and PNPTT, 2000). A brief summary of these methods is presented below.

Ripe females were killed with a sharp blow to the head and a gill arch was cut to bleed the female. Males were also killed with a sharp blow, but not bled. Each fish was labeled by stapling a square of Rite-in-the-Rain paper with its assigned number to the opercle. Fish were numbered consecutively (F-1, F-2, F-3, M-1, M-2, M-3, etc) through the spawning season. Before any eggs were removed from the female, its weight, fork and mid-eye-to-hypural lengths were recorded. A conditional assessment (ranging from excellent to poor) based on fin condition, scale loss and fungal infection was recorded for each adult. Females that may have already spawned (spent) or were thought to have partially spawned were also noted. Each female was wiped down to remove contaminants and water prior to eggs being collected. Eggs were extracted via a spawning knife and collected in a dry plastic bucket. Milt was collected only after all females to be used in the cross had been spawned. Males were also wiped down prior to spawning and milt was expressed into a clean dry container. All gametes were stored in coolers with ice between sampling until fertilization occurred. Total egg mass weight (weight of green eggs minus ovarian fluid, 0.1 g accuracy) and mean green egg weight (0.01 g accuracy) were recorded for each female. Using these two values, an estimate of fecundity can be calculated. Biological sampling of each fish included; scale samples, pathogen samples, DNA samples and GSI samples. Additionally, five eggs were collected from each female to be water hardened and individually weighed to the nearest mg.

Factorial crosses were used whenever numbers of ripe males and females allowed. Each female's eggs were divided into the number of lots needed by weight. Milt was divided equally using a graduated syringe. No backup males were needed when performing factorial crosses since the males can backup each other. If a one-to-one cross occurred, another male would be needed as the backup. After the gametes had been mixed, water added and backup milt applied, the eggs were allowed to sit for two minutes. After this time, individual lots were recombined if needed and placed into a Heath incubation tray. Folded Vexar, which prevents yolk sac deformations from occurring and maximizes yolk material utilization rates, was placed in each Heath tray. Eggs were then exposed to a PVP solution for 60 minutes in the Heath tray before being moved into incubation racks. Each Heath tray was labeled with the females' number and spawn date.

After the eggs had reached the eyed stage (around 680 Temperature Units (TU)) and been shocked, non-viable eggs were removed and enumerated by hand. A total weight of eyed eggs was recorded and five sub-samples were weighed and hand counted to calculate estimates of total number of eyed eggs. These estimates were then used to calculate a mean number of eyed eggs with 95% confidence intervals. This mean number of eyed eggs plus the number of non-viable eggs removed provided a more accurate estimate of fecundity.

Fish liberated from a recovery program need to be marked so that they can be identified upon recovery. Marking also allows comparisons to be made between different treatment groups. Fish released under this program were all thermally marked. Thermal marks are created by manipulating temperatures during the stages between eyed and yolk absorption. Each time the water temperature is dropped by 2-4$^{o}$ C a distinctive black band is deposited in the microstructure of a developing otolith (Figure 1). Exposure to chilled water for periods of 8 to 48 hours will essentially create bar codes on the otoliths that can be read. The bar codes will be determined and a schedule for chilled water applications by personnel in the WDFW's Otolith Lab. Hatchery personnel were responsible for applying the treatments. Voucher samples were taken to determine mark quality and form.

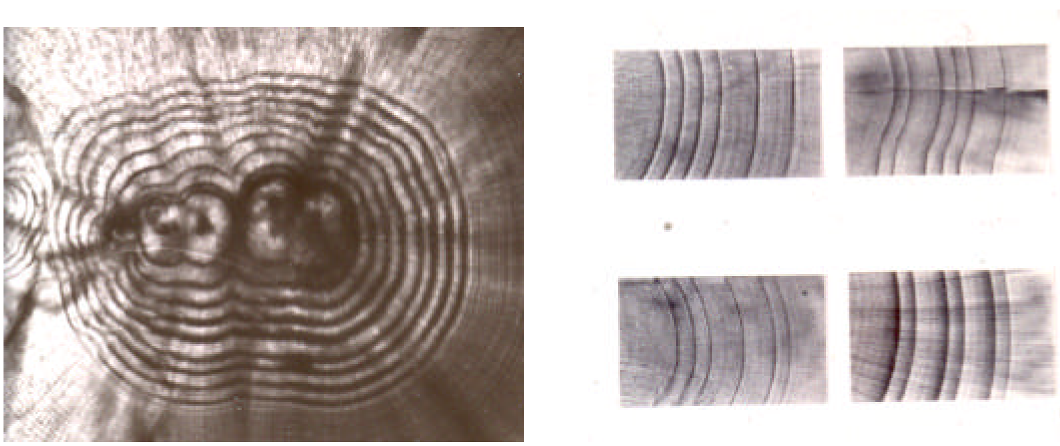


Figure 1. Photomicrographs that show the general appearance of thermally marked salmonid otoliths.

Mortalities and abnormalities were enumerated and recorded for each female when the fish were ponded. These mortality numbers, combined with those removed at the eyed stage, were used to calculate egg-to-fry survival rates for each female. At around 1,500 TU a visual inspection was made of five to ten fry from each Heath tray to ascertain the width of yolk still visible on each fry. When only a small slit was observed, $K_D$ values (Bams 1970) were calculated on 10 to 20 individuals.

$$K_D = (10\sqrt[3]{\text{Wt in mg}}) / \text{Fork Length in mm}$$

When the average of these individual $K_D$ values was around 1.9 the fry were ready to be ponded. $K_D$ values will be calculated again using 20 to 40 fry from each tray when they are ponded.

All chum salmon recovery projects at Washington hatcheries released fed fry at 1 to 1.5 grams or 50 to 55 mm in fork length. It is believed that such fry will realize significant survival advantages and not suffer any loss in their osmo-regulatory capacity. This size standard will be followed until data specific to a release location or stock indicates that an alternative size may have an increased survival potential.

The fry were divided into rearing vessels and held at accepted rearing densities and flow index values. Fry were to be fed a semi-moist diet with no fines, mash diets have shown to produce gill abrasions in chum fry. Once the fish are actively feeding, a daily ration of 3% of body weight was fed. This ration was spread out over the day, feeding every hour. Weekly weight measurements were taken to adjust the ration level. Feed size should increase as the fish grow, but pellet size will never exceed one-fortieth of fork length. Mortalities were enumerated and removed daily. Rearing vessels were cleaned at least once per week. Several environmental parameters were measured and recorded during the rearing period. Flow rates, DO levels and Total Settleable Solids (TSS) were measured and recorded weekly. Water temperatures were recorded twice daily, morning and after the last feeding with a hand held thermometer and continuously with a Tidbit recorder. Daily rainfall and ambient air temperature were also recorded daily.

Fry were released at night on an outgoing tide. Feeding ceased two or three days prior to release, and fifty random fish from each rearing vessel were measured, fork length to the nearest mm, and individually weighed to the nearest 0.01 g. This data was used to produce mean weights, lengths, K values, coefficient of variation statistics for each of these parameters and frequency distributions for lengths and weights.

## Results

### Broodstock Collection and Holding

A total of 51 adults (27 males and 24 females) were taken to Washougal Hatchery for spawning (Table 1). Once placed into the PVC holding tubes after collection, they were transported to the hatchery in a 400-gallon truck bed mounted tank. At the hatchery they were placed in an asphalt lined holding pond, suspended in the pond via ropes tied to the PVC tubes. Four adults died while being held, one female and three males.

Table 1. Date of Capture and Origin of Adults used at Washougal Hatchery, 2001.

| Date | Location | Number Adult Chum Seined | | # Taken to Washougal Hatchery Male | Female |
|---|---|---|---|---|---|
| 11/13/2001 | Hamilton Slough | 18 | | 2 | 1 |
| 11/13/2001 | Duncan Creek | 3 | | | 1 |
| 11/15/2001 | Duncan Creek | 1 | | 1 | |
| 11/16/2001 | Duncan Creek | 4 | | 1 | 1 |
| 11/20/2001 | Hamilton Slough | 45 | (# estimated) | 4 | 2 |
| 11/21/2001 | Hamilton Slough | 46 | | 8 | 6 |
| 11/29/2001 | Above Hamilton Creek/Ives Island Bay | 30 | (# estimated) | 2 | 3 |
| 11/30/2001 | Ives Island | 6 | | 3 | 3 |
| 12/03/2001 | Hamilton Slough | 1 | | | 1 |
| 12/05/2001 | Above Hamilton creek | 10 | | 5 | 5 |
| 12/11/2001 | St. Cloud area | 60-70 | (# estimated) | 1 | 1 |
| | Total | | | 27 | 24 |

**Spawning**

The spawning protocol outlined in the Duncan M&E Appendix 1 was followed with the following exceptions: 1) Mid-Eye-To-Hypural lengths were not recorded and 2) the first and last females spawned were not part of a factorial cross and no backup male was used (Table 2). Spawning occurred seven times between November 19 and December 12 (Table 2). The number of females spawned on a given day ranged from one on first and last spawn, to six females on November 29. Green females were not brought to the hatchery. Most females were spawned within a few days of their capture, the number of days between the two events ranged from zero (two fish) to nine days, averaging three days. Males were selected for spawning based on the number of ripe females and a first into hatchery, first used basis. Table 3, contains information, capture location/date and spawning date as well as biological data collected on male chum used for spawning. Most males were also spawned within a few days of their capture, the number of days between the two events ranged from zero (one fish) to eight days, averaging four days.

The age composition of females used at the Washougal hatchery was almost evenly split between age-3 and age-4 fish, 47.8% and 52.2% respectively (Figure 2). Age-3 fish, comprising 78.3% of the fish whose age could be determined, dominated the age structure of the males used (Figure 2).

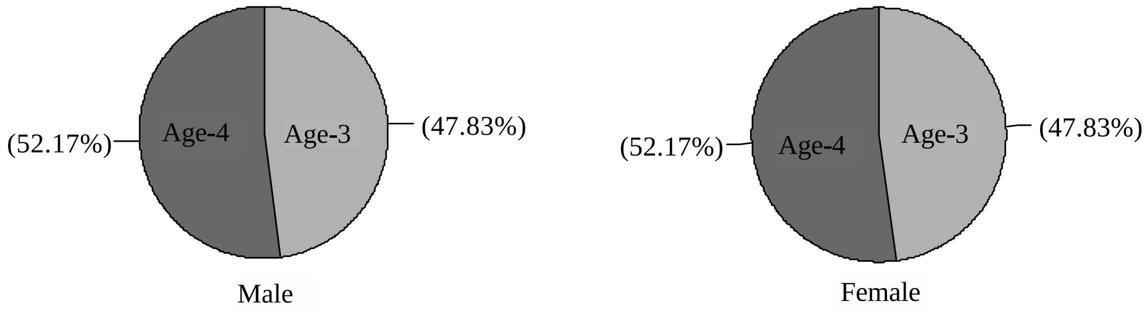



Figure 2. Age Composition of Adult Chum Spawned at Washougal Hatchery, 2001.

Fork lengths for age-3 females ranged from 635 mm to 700 mm, averaging 679.6 mm, and age-4 females ranged from 680 mm to 731 mm, averaging 703.4 mm (Figure 3). Fork lengths for age-3 males ranged from 630 mm to 840 mm, averaging 729.7 mm, and age-4 males ranged from 630 mm to 870 mm, averaging 775.3 mm (Figure 4). Whole body weight for age-3 females ranged from 2,890.0 g to 4,239.5 g, averaging 3,721.1 g, and age-4 female whole body weight ranged from 3,426.0 g to 4,804.5 g, averaging 4,001.7 g.

Reproductive values were calculated for all females spawned (Table 2). Estimated fecundity (excluding females with K values = 16%), at the green egg stage for age-3 females ranged from 2,890 to 3,460, averaging 3,211, age-4 females ranged from 2,234 to 3,529, averaging 2,930. An estimated total of 65,922 green eggs were taken over the spawning season.

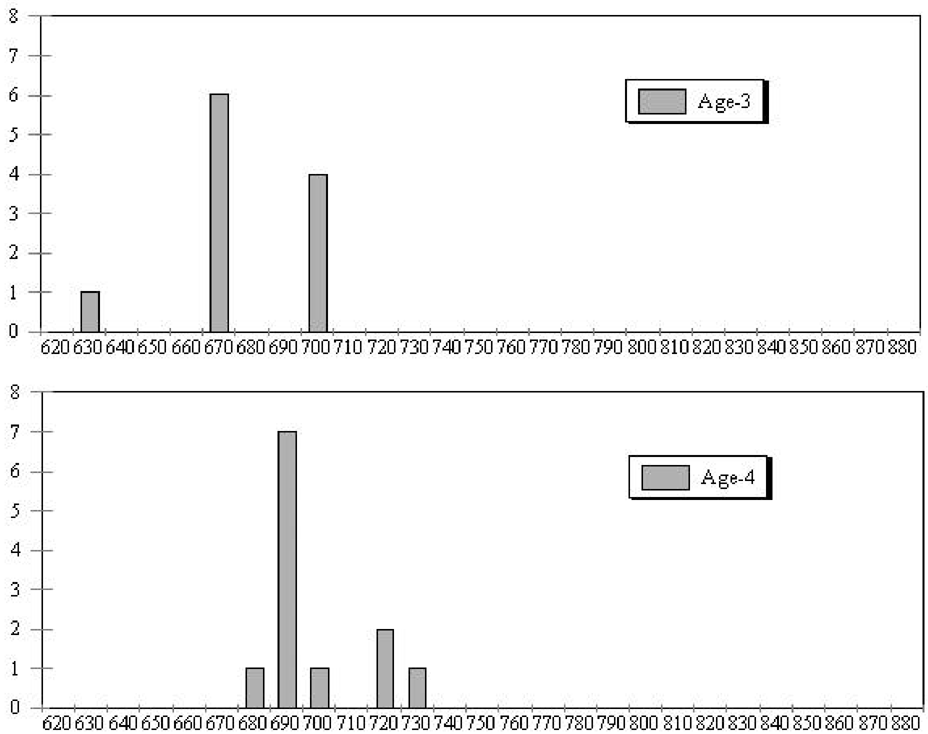



Figure 3. Fork Lengths, grouped by age and 10 mm increments, of Female Chum Spawned at Washougal Hatchery, 2001.

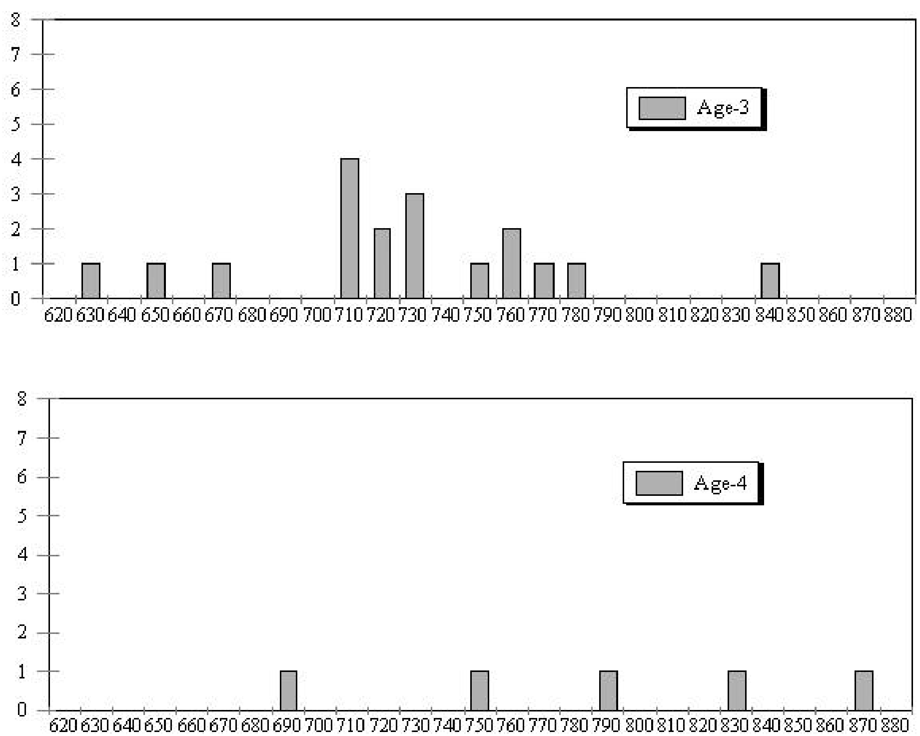



Figure 4. Fork Lengths, grouped by age and 10 mm increments, of Male Chum Spawned at Washougal Hatchery, 2001.

Table 2. Location and Date of Capture, Date of Spawning, Factorial Crosses, Condition, Weight, Fork Length (mm), Age, Green Egg Mass Weight, Mean Green Egg Weight and Estimated Fecundity of Female Chum Spawned at Washougal Hatchery, 2001.

| Female # | Location of capture | Date of capture | Date of Spawning | Factorial Spawning, Primary Male listed first | Condition of Fish at Spawning | Whole Body Weight (g) | Fork Length (mm) | Age | Green Egg Mass Weight (g) | Mean Green Egg Weight (g) | Estimated Fecundity |
|---|---|---|---|---|---|---|---|---|---|---|---|
| F-1 | Duncan Creek | 11/13/01 | 11/15/01 | M-1 | Fair | 2,890.0 | 635 | 3 | 412.7 | 0.1688 | 2,444 |
| F-2 | Duncan Creek | 11/16/01 | 11/19/01 | M-2, M-3 | Good | 3,880.0 | 698 | 4 | 352.9 | 0.2698 | 1,308 |
| F-3 | Ives Island | 11/13/01 | 11/19/01 | M-3, M-2 | Fair | 4,804.5 | 731 | 4 | 739.1 | 0.2918 | 2,533 |
| F-4 | Ives Island | 11/21/01 | 11/26/01 | M-4, M-5, M-6 | Good | 4,056.5 | 698 | 4 | 600.8 | 0.2650 | 2,267 |
| F-5 | Ives Island | 11/21/01 | 11/26/01 | M-5, M-4, M-6 | Good | 4,239.5 | 700 | 3 | 804.7 | 0.2550 | 3,156 |
| F-6 | Ives Island | 11/21/01 | 11/26/01 | M-6, M-5 | Good | 4,060.0 | 698 | 4 | 803.2 | 0.2752 | 2,919 |
| F-7 | Ives Island | 11/21/01 | 11/26/01 | M-7, M-6 | Good | 3,650.0 | 701 | 4 | 739.1 | 0.2700 | 2,737 |
| F-8 | Ives Island | 11/29/01 | 11/29/01 | M-8, M-10 | Excellent | 3,668.0 | 675 | 3 | 726.4 | 0.2394 | 3,034 |
| F-9 | Ives Island | 11/21/01 | 11/29/01 | M-9, M-8 | Excellent | 3,983.5 | 700 | 3 | 833.7 | 0.2461 | 3,388 |
| F-10 | Ives Island | 11/20/01 | 11/29/01 | M-10, M-8 | Poor | 3,614.0 | 670 | 3 | 680.6 | 0.2355 | 2,890 |
| F-11 | Ives Island | 11/21/01 | 11/29/01 | M-11, M-12, M-14, M-13 | Fair | 3,971.5 | 700 | 3 | 746.1 | 0.2250 | 3,316 |
| F-12 | Ives Island | 11/29/01 | 11/29/01 | M-12, M-11, M-14, M-13 | Excellent | 3,959.0 | 678 | 3 | 702.9 | 0.2147 | 3,275 |
| F-13 | Ives Island | 11/29/01 | 11/29/01 | M-14, M-11, M-13 | Excellent | 3,652.5 | 678 | 3 | 747.6 | 0.2161 | 3,460 |
| F-14 | Ives Island | 11/30/01 | 12/04/01 | M-16, M-15 | Excellent | 3,735.5 | 700 | 3 | 745.1 | 0.2437 | 3,058 |
| F-15 | Ives Island | 11/30/01 | 12/04/01 | M-15, M-16 | Excellent | 3,669.5 | 670 | 3 | 730.7 | 0.2157 | 3,387 |
| F-16 | Mouth of Hamilton Creek | 12/03/01 | 12/04/01 | M-17, M-18 | Excellent | 4,614.0 | 726 | 4 | 928.8 | 0.2706 | 3,432 |
| F-17 | Ives Island | 11/30/01 | 12/04/01 | M-18, M-17 | Excellent | 3,549.5 | 670 | 3 | 717.4 | 0.2283 | 3,143 |
| F-18 | Above Mouth of Hamilton | 12/05/01 | 12/06/01 | M-19, M-20, M-21 | Good | 3,995.0 | 695 | 4 | 706.7 | 0.2631 | 2,686 |
| F-19 | Above Mouth of Hamilton | 12/05/01 | 12/06/01 | M-20, M-19, M-21 | Good | 3,980.5 | 692 | 4 | 863.0 | 0.2445 | 3,529 |
| F-20 | Ives Island | 12/05/01 | 12/06/01 | M-21, M-19, M-20 | Good | 3,617.5 | 698 | 4 | 785.6 | 0.2653 | 2,961 |
| F-21 | Above Mouth of Hamilton | 12/05/01 | 12/06/01 | M-22, M-23 | Good* | 4,142.5 | 726 | 4 | 483.8 | 0.2653 | 1,824 |
| F-22 | Ives Island | 12/05/01 | 12/06/01 | M-23, M-22 | Good* | 3,426.0 | 680 | 4 | 613.7 | 0.2747 | 2,234 |
| F-23 | Saint Cloud | 12/11/01 | 12/12/01 | M-24 | Poor | 3,794.0 | 698 | 4 | 796.1 | 0.2705 | 2,943 |

* These fish were described as partially spawned out at the time of spawning.

Table 3. Location and Date of Capture, Date of Spawning, Factorial Crosses, Condition, Weight, Fork Length (mm) and Age of Male Chum Spawned at Washougal Hatchery, 2001.

| Male # | Location of Capture | Date of Capture | Date of Spawning | Condition at Spawning | Fork Length (mm) | Whole Body Weight (g) | Age | Used as Primary Male with Female # |
|---|---|---|---|---|---|---|---|---|
| M-1 | Duncan Creek | 11/13/01 | 11/15/01 | Good | 650 | 3,220.5 | 3 | F-1 |
| M-2 | Duncan Creek | 11/13/01 | 11/19/01 | Fair | 777 | 4,932.0 | 3 | F-2 |
| M-3 | Duncan Creek | 11/16/01 | 11/19/01 | Good | 765 | 4,934.5 | 3 | F-3 |
| M-4 | Ives Island | 11/20/01 | 11/26/01 | Good | 710 | 4,620.0 | 3 | F-4 |
| M-5 | Ives Island | 11/20/01 | 11/26/01 | Good | 760 | 5,113.5 | 3 | F-5 |
| M-6 | Ives Island | 11/20/01 | 11/26/01 | Good | 716 | 4,430.0 | 3 | F-6 |
| M-7 | Ives Island | 11/20/01 | 11/26/01 | Good | 870 | 7,656.5 | 4 | F-7 |
| M-8 | Ives Island | 11/21/01 | 11/29/01 | Poor | 709 | 3,812.5 | Unreadable | F-8 |
| M-9 | Ives Island | 11/21/01 | 11/29/01 | Excellent | 678 | 3,572.5 | 3 | F-9 |
| M-10 | Ives Island | 11/21/01 | 11/29/01 | Poor | 690 | 3,732.0 | 4 | F-10 |
| M-11 | Ives Island | 11/21/01 | 11/29/01 | Fair | 840 | 5,800.0 | 3 | F-11 |
| M-12 | Ives Island | 11/21/01 | 11/29/01 | Poor | 630 | 2,511.5 | 3 | F-12 |
| M-13 | Ives Island | 11/29/01 | 11/29/01 | Excellent | 711 | 4,647.0 | 3 | |
| M-14 | Ives Island | 11/29/01 | 12/04/01 | Excellent | 710 | 4,000.5 | 3 | F-13 |
| M-15 | Ives Island | 11/30/01 | 12/04/01 | Excellent | 723 | 4,618.5 | 3 | F-14 |
| M-16 | Ives Island | 11/30/01 | 12/04/01 | Good | 830 | 6,871.0 | 4 | F-15 |
| M-17 | Ives Island | 11/30/01 | 12/04/01 | Excellent | 733 | 5,725.0 | 3 | F-16 |
| M-18 | Mouth of Hamilton Creek | 12/03/01 | 12/06/01 | Fair | 720 | 4,107.0 | 3 | F-17 |
| M-19 | Mouth of Hamilton Creek | 12/05/01 | 12/06/01 | Good | 798 | 5,875.5 | 4 | F-18 |
| M-20 | Mouth of Hamilton Creek | 12/05/01 | 12/06/01 | Good | 739 | 4,496.0 | 3 | F-19 |
| M-21 | Mouth of Hamilton Creek | 12/05/01 | 12/06/01 | Good | 730 | 4,904.0 | 3 | F-20 |
| M-22 | Ives Island | 12/05/01 | 12/06/01 | Good | 755 | 4,883.0 | 3 | F-21 |
| M-23 | Ives Island | 12/05/01 | 12/06/01 | Good | 755 | 4,510.5 | 4 | F-22 |
| M-24 | Saint Cloud | 12/11/01 | 12/12/01 | Fair | 787 | 5,776.5 | 3 | F-23 |

## Incubation

All green eggs were disinfected in the Heath trays with a 60-minute treatment of iodophor Betadine before being moved into the incubation stacks. Flow through the Heath stacks were set at four gallons per minute and monitored by hatchery personnel. Daily formalin treatments, 15 min per day at 470 ml per minute were applied from day two until just before (minimum of five days) the eggs hatched to prevent fungus (*Saprolegnia sp*.) growth in the trays. At around 680 TU the eggs were shocked in their trays by manual agitation. After waiting 24 hours, the eggs were then hand picked to remove any mortalities and unfertilized eggs. It was discovered at this time that all the eggs from female #23 were non-viable. This female was reported to be in poor condition when brought to the hatchery. However, a reproductive value (total egg mass weight / body weight) of 20.98% indicates that she had not spawned yet. Only one male was used, no backup male was available, to fertilize her eggs. Because no comment was made that her eggs appeared to be water hardened at spawning, or problems with that tray of eggs prior to shocking, a non-fertile male was most likely the cause of the loss. An estimated total of 4,913 non-viable eggs were recovered after shocking (Table 4). This number decreases to 1,970 with the removal of those from female #23. From this point on in the report, unless specified, all rates and totals reported will not include data from female #23. The number of non-viable eggs per female removed after shocking ranged from 15 to 294, averaging 90.

The first thermal marks were applied to the otoliths prior to hatching. Four thermal events were applied to produce the pre-hatch mark of: ¦ ¦ ¦   ¦ . A post-hatching thermal mark, ¦ ¦   ¦ ¦   ¦ ¦ , was also applied. With one day of ambient temperatures being applied between treatments to produce the narrow spacing and three days between to produce the wide spacing. Visualize these "¦ " as circles to get a good representation of the mark.

Fecundity estimates calculated after shocking and picking based on five samples of viable eyed eggs, including 95% C.I. and the CV of the mean are reported in Table 4. Mean fecundity estimates ranged from 1,302 to 3,077, averaging 2,575. Survival rates from green to eyed egg stage ranged from 88.88% to 99.28%, averaging 97.19% (Table 4).

Table 4. Number of Non-Viable Eggs at Shocking, Mean Live Eyed Egg Estimates, 95% C.I. and C.V., Fecundity and % Survival Rates from Green to Eyed Egg Stage, 2002.

| Female | Non-Viable Eggs | Eyed Egg Weight | Mean Live Eyed Egg Estimate | Total eggs | 95% C.I. | | +/- | CV | Fecundity (base on sampling*) | Survival Green to Eyed |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | High | Low | | | | |
| F-1 | 218 | 456.0 | 2,244 | 2,467 | 2,285.38 | 2,202.62 | 41.38 | 1.49 | 2,467 | 90.96% |
| F-2 | 57 | 378.6 | 1,240 | 1,302 | 1,249.02 | 1,230.98 | 9.02 | 0.59 | 1,302 | 95.24% |
| F-3 | 39 | 823.0 | 2,511 | 2,555 | 2,537.63 | 2,484.37 | 26.63 | 0.86 | 2,555 | 98.28% |
| F-4 | 89 | 528.1 | 1,736 | 1,830 | 1,769.06 | 1,702.94 | 33.06 | 1.54 | 1,830 | 94.86% |
| F-5 | 140 | 737.7 | 2,629 | 2,774 | 2,725.76 | 2,532.24 | 96.76 | 2.98 | 2,774 | 94.77% |
| F-6 | 192 | 724.4 | 2,318 | 2,515 | 2,333.64 | 2,302.36 | 15.64 | 0.55 | 2,515 | 92.17% |
| F-7 | 183 | 672.5 | 2,151 | 2,339 | 2,236.64 | 2,065.36 | 85.64 | 3.22 | 2,339 | 91.96% |
| F-8 | 19 | 683.4 | 2,569 | 2,593 | 2,608.44 | 2,529.56 | 39.44 | 1.24 | 2,593 | 99.07% |
| F-9 | 110 | 780.5 | 2,849 | 2,964 | 2,867.41 | 2,830.59 | 18.41 | 0.52 | 2,964 | 96.12% |
| F-10 | 120 | 620.2 | 2,309 | 2,434 | 2,350.52 | 2,267.48 | 41.52 | 1.45 | 2,434 | 94.86% |
| F-11 | 52 | 715.5 | 2,784 | 2,841 | 2,809.72 | 2,758.28 | 25.72 | 0.75 | 2,841 | 97.99% |
| F-12 | 15 | 668.9 | 2,730 | 2,750 | 2,776.86 | 2,683.14 | 46.86 | 1.39 | 2,750 | 99.27% |
| F-13 | 47 | 706.7 | 2,853 | 2,905 | 2,909.53 | 2,796.47 | 56.53 | 1.60 | 2,905 | 98.21% |
| F-14 | 16 | 704.6 | 2,884 | 2,905 | 2,911.47 | 2,856.53 | 27.47 | 0.77 | 2,905 | 99.28% |
| F-15 | 172 | 664.9 | 2,435 | 2,612 | 2,445.90 | 2,424.10 | 10.90 | 0.36 | 2,612 | 93.22% |
| F-16 | 42 | 897.2 | 2,992 | 3,039 | 3,022.42 | 2,961.58 | 30.42 | 0.82 | 3,039 | 98.45% |
| F-17 | 294 | 598.0 | 2,389 | 2,688 | 2,412.37 | 2,365.63 | 23.37 | 0.79 | 2,688 | 88.88% |
| F-18 | 41 | 664.4 | 2,198 | 2,244 | 2,219.06 | 2,176.94 | 21.06 | 0.77 | 2,244 | 97.95% |
| F-19 | 38 | 834.3 | 3,034 | 3,077 | 3,051.39 | 3,016.61 | 17.39 | 0.46 | 3,077 | 98.60% |
| F-20 | 21 | 773.7 | 2,579 | 2,605 | 2,588.13 | 2,569.87 | 9.13 | 0.27 | 2,605 | 99.00% |
| F-21 | 40 | 480.9 | 1,581 | 1,626 | 1,645.64 | 1,516.36 | 64.64 | 3.31 | 1,626 | 97.23% |
| F-22 | 25 | 471.7 | 1,583 | 1,613 | 1,595.03 | 1,570.97 | 12.03 | 0.61 | 1,613 | 98.14% |

* Fecundity calculated using mean number of live eyed eggs + dead eggs removed + five eggs removed at spawning for calculating water hardened green egg weight.

The eggs began to hatch around 950 TU. The daily formalin treatments had stopped due to hatching, and an outbreak of *Saprolegnia sp.* resulted in several thousand mortalities. After the initial increase in loss, a WDFW fish pathologist was called in to examine the alevins and determine the cause of mortality. *Saprolegnia sp.* was found on the head and gills of live fish and covering the entire body of the older mortalities, no internal bacteria were found. The pathologist recommended a treatment of hydrogen peroxide at 11 ml per min for 30 minutes daily. This treatment was applied for ten days and resulted in a dramatic decrease in mortality. A total of 5,994 dead alevins, mostly due to *Saprolegnia sp.*, were recovered from the trays. An additional 131 non-viable eggs and 539 monstrosities were also removed from the trays between hatching and ponding. These activities resulted in a loss totaling 6,664 (12.6%) from picked eyed eggs to ponding. Table 5. provides a breakout of loss by female from the green egg stage to ponding.

$K_D$ values of each tray at ponding are recorded in Table 6. Individual fork lengths and weights were taken on five fry from each tray just prior to ponding. Fork lengths ranged from 31 mm to 39 mm, and averaged 35.8 mm. Individual weight ranged from 0.214 g to 0.420 g, averaging 0.346 g.

Table 5. Breakdown of Loss by Female from the Green Egg Stage to Ponding, 2002.

| Female # | Loss at shocking | # Non-Viable Eggs at Hatching | # Alevin Mortalities | Monstrosities Removed | Total | % Loss |
|---|---|---|---|---|---|---|
| F-1 | 218 | 1 | 116 | 8 | 343 | 14% |
| F-2 | 57 | 1 | 357 | 23 | 438 | 34% |
| F-3 | 39 | 0 | 454 | 14 | 507 | 20% |
| F-4 | 89 | 3 | 307 | 4 | 403 | 22% |
| F-5 | 140 | 15 | 153 | 6 | 314 | 11% |
| F-6 | 192 | 32 | 16 | 9 | 249 | 10% |
| F-7 | 183 | 21 | 363 | 18 | 585 | 25% |
| F-8 | 19 | 4 | 296 | 9 | 328 | 13% |
| F-9 | 110 | 1 | 216 | 8 | 335 | 11% |
| F-10 | 120 | 13 | 138 | 24 | 295 | 12% |
| F-11 | 52 | 2 | 466 | 12 | 532 | 19% |
| F-12 | 15 | 2 | 240 | 7 | 264 | 10% |
| F-13 | 47 | 6 | 124 | 64 | 241 | 8% |
| F-14 | 16 | 1 | 67 | 32 | 116 | 4% |
| F-15 | 172 | 0 | 124 | 8 | 304 | 12% |
| F-16 | 42 | 2 | 180 | 10 | 234 | 8% |
| F-17 | 294 | 11 | 91 | 44 | 440 | 16% |
| F-18 | 41 | 11 | 569 | 69 | 690 | 31% |
| F-19 | 38 | 3 | 826 | 50 | 917 | 30% |
| F-20 | 21 | 0 | 554 | 44 | 619 | 24% |
| F-21 | 40 | 2 | 130 | 14 | 186 | 11% |
| F-22 | 25 | 0 | 207 | 62 | 294 | 18% |
| F-23 | 2,943 | --- | --- | --- | 2,943 | 100% |

Table 6. Average Weights, Fork Lengths, Date Ponded and KD Values at Ponding by Female, 2002.

| Female # | # Fry Sampled | Average Weight (g) | Average Fork Length (mm) | Date Ponded | $K_D$ Value |
|---|---|---|---|---|---|
| F-1 | 36 | 0.19 | 32.0 | 3/11/02 | 1.80 |
| F-2 | 30 | 0.38 | 36.0 | 3/22/02 | 1.99 |
| F-3 | 21 | 0.40 | 37.0 | 3/22/02 | 2.00 |
| F-4 | 24 | 0.33 | 36.0 | 4/01/02 | 1.92 |
| F-5 | 31 | 0.37 | 35.6 | 4/01/02 | 2.01 |
| F-6 | 27 | 0.59 | 38.0 | 4/01/02 | 2.03 |
| F-7 | 32 | 0.42 | 38.0 | 4/01/02 | 1.96 |
| F-8 | 28 | 0.40 | 37.6 | 4/05/02 | 1.96 |
| F-9 | 33 | 0.33 | 35.0 | 4/05/02 | 1.97 |
| F-10 | 31 | 0.32 | 36.0 | 4/05/02 | 1.87 |
| F-11 | 32 | 0.31 | 34.7 | 4/05/02 | 1.94 |
| F-12 | 36 | 0.28 | 34.0 | 4/05/02 | 1.92 |
| F-13 | 38 | 0.28 | 34.0 | 4/05/02 | 1.92 |
| F-14 | 45 | 0.31 | 34.0 | 4/05/02 | 1.99 |
| F-15 | 30 | 0.36 | 36.0 | 4/05/02 | 1.99 |
| F-16 | 30 | 0.37 | 37.0 | 4/10/02 | 1.95 |
| F-17 | 30 | 0.31 | 35.4 | 4/10/02 | 1.90 |
| F-18 | 30 | 0.38 | 37.6 | 4/18/02 | 1.93 |
| F-19 | 25 | 0.36 | 36.0 | 4/18/02 | 1.95 |
| F-20 | 24 | 0.38 | 37.0 | 4/18/02 | 1.94 |
| F-21 | 28 | 0.39 | 37.4 | 4/18/02 | 1.95 |
| F-22 | 26 | 0.41 | 37.4 | 4/18/02 | 1.98 |

**Rearing**

A total of 45,934 fry were ponded in four rearing troughs. Trough #1 had a volume of approximately 87 cubic feet (653 gallons) of rearing space and received 5,021 fry (females 1-3). Trough #2 had a volume of approximately 90 cubic feet (672 gallons) of rearing space and received 12,771 fry (females 4-9). Trough #3 had a volume of approximately 76.5 cubic feet (572 gallons) of rearing space and received 14,665 fry (females 10-15). Trough #4 had a volume of approximately 82 cubic feet (613 gallons) of rearing space and received 13,477 fry (females 16-22). Flow rates were initially set at 25 gpm and adjusted by hatchery personnel as the fry grew to maintain the flow index in an acceptable range.

Weekly sampling, three weight samples of 25 fry for each trough, was conducted to calculate daily feed amounts and to gauge when the fry would be ready for release. The fry were fed at a rate of 3% body weight per day. Feeding occurred eight times a day, approximately 1/8$^{th}$ of the daily ration every hour. A total of 65 pounds of Moore Clark brand #0 crumb starter feed was used over the 67-day rearing period. Weekly sampling results are provided in Table 7.

Mortalities were removed and enumerated daily. A total of 888 mortalities were removed from the four troughs between ponding and release, resulting in a survival rate of 98.1%.

Total settleable solid samples taken from the inflow were generally very low to undetectable on the Imhoff cones. Dissolved oxygen levels in the troughs ranged from 11.2 to 13.0, averaging 12.0, during the rearing period. Water temperatures over the rearing period averaged 47 $^{0}$F and 43 $^{0}$F, afternoon and morning respectively.

Table 7. Results of Weekly Fry Sampling, 2002.

| Sample | Trough #1 Average | | Trough #2 Average | | Trough #3 Average | | Trough #4 Average | |
|---|---|---|---|---|---|---|---|---|
| Date | Size (g) | # Fish/lb | Size (g) | # Fish/lb | Size (g) | # Fish/lb | Size (g) | # Fish/lb |
| 18-Mar-02 | 0.272 | 1,668 | | | | | | |
| 25-Mar-02 | 0.344 | 1,319 | | | | | | |
| 1-Apr-02 | 0.484 | 937 | 0.320 | 1,417 | | | | |
| 8-Apr-02 | 0.514 | 882 | 0.363 | 1,250 | 0.333 | 1,362 | | |
| 15-Apr-02 | 0.665 | 682 | 0.544 | 834 | 0.363 | 1,250 | 0.423 | 1,072 |
| 22-Apr-02 | 0.786 | 577 | 0.635 | 714 | 0.454 | 999 | 0.454 | 999 |
| 29-Apr-02 | 0.847 | 536 | 0.907 | 500 | 0.514 | 882 | 0.635 | 714 |
| 6-May-02 | 1.150 | 394 | 1.210 | 375 | 0.786 | 577 | 0.816 | 556 |
| 13-May-02 | | | | | 1.090 | 416 | 1.090 | 416 |

**Release**

A total of 45,046 fry were liberated at night from the Skamania Landing's boat ramp, located on the Columbia River just yards downstream from the mouth of Duncan Creek. The overall survival rate from green egg stage to release was 82.5%, dropping to 78.2% with the addition of female #23. Fish were released on two different nights, troughs #1 and #2 were released on May 8, and troughs #3 and #4 were released on May 16. Results of the sampling done the day of release are reported in Table 8. The fry were dip netted from the troughs and placed into a 400-gallon tanker truck for transport to the release site.

The truck was backed down the ramp and a flex hose attached to the tank to get the fry into the water. The fish were monitored for 15-20 minutes for any immediate mortality and to see that the fry moved off into deeper water. No mortalities were observed at release.

Table 8. Average Size (g) and Fork Lengths (mm) by Trough on Release Day, 2002.

| Release | Trough #1 Average | | Trough #2 Average | | Trough #3 Average | | Trough #4 Average | |
|---|---|---|---|---|---|---|---|---|
| Date | Size (g) | Fork L. (mm) | Size (g) | Fork L. (mm) | Size (g) | Fork L. (mm) | Size (g) | Fork L. (mm) |
| 8-May-02 | 1.581 | 53.3 | 1.488 | 52.7 | | | | |
| 16-May-02 | | | | | 1.29 | 51.0 | 1.52 | 53.0 |

**Discussion**

Fifty-one adult chum were collected for artificial propagation at Washougal Hatchery. A total of 23 females were spawned yielding an estimated 65,922 green eggs taken. The survival rate from green to eyed egg stage was only 82.9%. This low rate is a result of the total loss of one female's egg production and an overestimation in the calculation for the number of green eggs per female at spawning. When formulating the predictive regression formulas it was discovered that the fecundity estimate at the eyed egg stage was on average 87% of the fecundity estimate (live and dead eggs combined) recorded at the green egg stage. This difference should not be more than two or three percent. This error is most likely due to incomplete draining of ovarian fluid before weighing the green egg mass. A total of 6,664 mortalities were recovered between the eyed egg stage and ponding, mostly due to an outbreak of *Saprolegnia sp.*, resulting in a mortality rate of 12.6%. A total of 888 mortalities were recovered between ponding and release, a survival rate of 98.1% from ponding to release. Two nighttime releases totaling 45,046 chum fry were made near the mouth of Duncan Creek in May of 2002. This results in an overall estimated survival rate from green egg to release (using eyed egg fecundity estimates) of 78.2%.

Other than the outbreak of *Saprolegnia sp.*, activities at Washougal Hatchery went fairly well. As mentioned before, no plan for collecting adults over the whole spawning season was in place during the fall of 2001. All of the females were spawned at the hatchery before a single adult was placed into the renovated Duncan Creek channels. Once fish began being placed in the channels no additional adults were brought to the hatchery. This may be the reason for the difference in age structures for fish placed into the channels verses those spawned at the hatchery. The sampling and data collection needs to be more precise and complete in 2002-03 so that the accuracy of the predictive fecundity formulas can be increased. Folded pieces of Vexar were placed into the Heath trays with the green eggs, possibly resulting in mortalities. It is not necessary to place these in until after the eggs have been shocked and picked to gain the benefits the Vexar provides. Early placement may have resulted in dead areas of water movement during the green egg stage resulting in egg suffocation and/or caused abrasions on the eggs when the trays were agitated to shock the eggs. The Vexar may have also hidden non-viable eggs or pieces of egg material during the picking process. This organic material would have provided the *Saprolegnia sp.* with a place to start and proliferate in the Heath trays. While it did not appear to cause any problems in 2002, Moore Clark brand crumb #0 starter diet is a dry diet. The Duncan M&E plan recommends using a semi-moist feed and one should be found to use in 2003. Even given the advantage of being spawned earlier, the fry from the hatchery were not ready for release until May. The goal is to have these fry ready for release at the same time as fry naturally produced in the channels are outmigrating. If the intent is to continue using the Washougal Hatchery facilities to rear the artificially spawned juveniles, a heated water system may be necessary to match the water temperatures that the naturally produced fry experience in the channels.

## Part II: Monitoring of the Physical Attributes of the Spawning Channels

### Introduction

Historically Duncan Creek was an important spawning area for chum salmon. After the construction of a pond in the lower portion of Duncan Creek in 1961, chum salmon in the creek declined. In 1999 chum salmon were listed under the Endangered Species Act and efforts increased to rebuild chum salmon populations. Spawning channels have been used successfully to establish and re-establish chum salmon populations (Bonnell 1984; Cowan 1984). After preliminary investigation by WDFW, PSMFC, and KPFF engineering it was determined that a spawning channel in the Duncan Springs area could be successful for chum salmon if passage conditions at the pond outlet could be modified and the pond levels managed to assist in chum salmon migration. The original chum salmon spawning site in Duncan Springs was rehabilitated in October 2000 and a chum salmon spawning channel was constructed at this site in October 2002 by KPFF engineering (Appendix A).

Continued monitoring of the physical attributes of the spawning channels is an important component of the re-introduction program. Monitoring of the environmental conditions will identify factors responsible for survival/mortality rates. Salmonid research has shown that extremely high mortality rates, up to 99%, can occur between fertilization and emergence ( Wickett 1952; Hunter 1948; Neave and Foster 1955). Several studies have attempted to identify causes of mortality during the period of incubation (see Wickett 1954; Wickett 1958; Alderdice *et al*. 1958; McNeil 1962; Cooper 1965; McNeil 1966, 1983; Loptspeich and Everest 1981; Alexander and Hansen 1986; Kondolf *et al*. 1991; Marten 1992; Geist and Dauble 1998; Argent and Flebbe 1999; Baxter and McPhail 1999). Low temperatures, less than 36 $^{o}$F during the spawning period, can delay spawning and increase egg retention rates (Schroder 1973; Koski 1975). Relatively low or high temperatures prior to blastopore closure have also been shown to cause high mortality rates in salmonid embryos (Brannon 1987; Tang et al. 1987; McNeil and Bailey 1975). Several researchers have linked embryonic salmonid survival to composition of the spawning gravels, specifically the proportion of materials = 3.3mm, fines and sand. Materials of this size can reduce permeability of the gravel, thus reducing oxygen exchange and intra-gravel flows (McNeil and Ahnell 1964; Koski 1966, 1975; Tagart 1976, 1984; Witzel and MacCrimmon 1983). Sowden and Power (1985) proposed that the geometric mean of the spawning substrate particle ($D_g$) be divided by its associated standard deviation ($S_g$) to produce the "fredle index" ($f_i$). Chapman (1988) plotted fredle index values against egg-to-fry survival rates from four independent studies and found that survival rates increased as the fredle value rose from one to four. The gravel "recipe" placed in the Duncan Creek spawning channels was expected to yield a fredle index value of 5.2 (Table 9).

Table 9. Composition of Gravel to be Placed in the Duncan Creek Spawning Channel.

| Diameter of Gravel | Expected Volume (%) |
|---|---|
| 4 –6 inch rock | 2 |
| 2.5 – 4 inch rock | 13 |
| 1 - 2.5 inch rock | 35 |
| 0.75 –1 inch rock | 35 |
| 0.375 – 0.75 inch rock | 10 |
| No. 4 – 0.375 inch rock | 5 |
| No. 10 – No. 4 material | 0 |

Environmental factors often cited as having the greatest influence for incubation survival include: redd superimposition, scouring and gravel fill as a result of dynamic river flows, high or low water temperatures during critical times of incubation, sedimentation or the incidence of high levels of sand and silt in the spawning gravels, low seepage velocity and/or low dissolved oxygen levels in the interstitial spaces, dewatering of eggs or alevins, and the presence of intra-gravel predators. Of the factors identified above, gravel composition, water temperature, low seepage velocity (vertical hydraulic gradients) and/or low DO levels in the interstitial spaces are of primary concern in the Duncan Creek channels. Monitoring these environmental conditions will provide the information needed to characterize the conditions in the channels occurring between fertilization and emergence. The other environmental factors identified, while important, should not be of great concern since this spawning area is in a spring channel and protected from extreme environmental variation. Factors like redd superimposition and egg retention due to overcrowding can be controlled by maintaining densities of females at levels that ensure each female has at least three square meters of spawning area and placing the fish into the channels over a two or three day period (Schroder 1973) but this should not be a factor until adult abundance in the channel approaches capacity.

Annual sampling of the gravel in the channels will document changes in the gravel composition with emphasis on sands and fines, material less than 3.3 mm in diameter. If annual gravel monitoring documents the fredle index decreasing over time or percentage of fines less than 0.85mm increasing, this could trigger gravel cleaning efforts. Piezometers will be used to monitor and document water temperatures, seepage velocities (vertical hydraulic gradients) and DO levels present in the hyporheic zone.

Gravel sampling was scheduled to be done prior to the introduction of fish into the channels. However, due to limited resources it was not done until the summer of 2002, after the first year of use. Lake levels remained high and gravel sampling was limited to the upper two-thirds of one channel. Flooding the channels was intentionally done to limit re-colonization of non-indigenous plant species, specifically reed canary grass (*Phalaris arundinacea)*.

**Methods**

The protocol for selecting and analyzing gravel samples outlined in the Duncan M&E was followed. A total of twenty gravel core samples were scheduled to be collected from the area above the weirs in each channel, 60 samples total. Two channels located above the south weir were sampled independently (Figure 5). The south channel would be sampled to its confluence with the middle channel. The middle channel would be sampled to the weir. Sampling locations were determined by measuring center channel length to the weirs, south channel measured to confluence with middle. The channels were then divided into four equal sections, and these sections were divided into ten equal plots. A random number generator was used to select five plots in each section to be sampled (four sections, with five sampled plots each, resulting in 20 samples per channel). Section and plot boundaries were marked with survey flags inserted into the gravel. All samples were taken in the center of the channel on the plots downstream boundary.

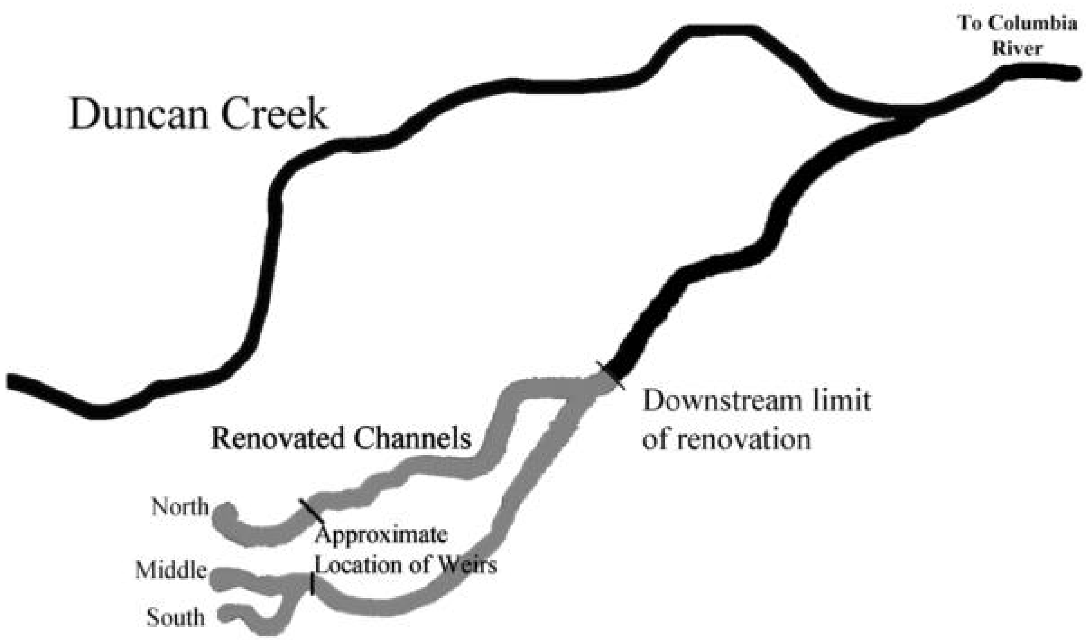



Figure 5. Diagram of Duncan Creek and the New Renovated Channels.

A McNeil Sampler (McNeil and Ahnell 1964) was used to collect standardized core samples. The sampler was inserted into the substrate to a depth of approximately six inches. All material inside the sampling cylinder, six inches deep by four inches in diameter, would be removed by hand and placed in the larger cylinder. Fines suspended in the water column by excavation activities were collected by slowly inserting a plunger/gasket to the bottom of the sampling cylinder. This plunger has a one-way-flapper valve to allow the plunger to be inserted without driving the water and suspended materials inside the sampler out into the surrounding gravel. Once the plunger was at the bottom of the sampling cylinder it was pulled up approximately ½" to form a seal with the gasket. Then the sampler, gravel and water retained inside, would be lifted from the streambed and placed over a five-gallon plastic pail. The contents of the sampler were then released into the pail by allowing the plunger to fall through. Gravel still remaining in the large cylinder of the sampler would be poured into the pail; additional water would be used if needed to rinse all materials from the sampler. When the water depth in the channel was = 12", additional pails were needed to hold the complete sample. Figure 6 is a composite of four pictures taken during the gravel sampling. Arranged clockwise from the upper left these are pictures of: 1) removing the gravel from inside the samplers core, 2) the sampler being placed on a collection bucket, 3) looking down into the sampler (this one has gravel and water inside) after the plunger has been released and 4) pouring the remainder of the sample into the collection bucket.

Figure 6. Taking a Gravel Sample With a McNeil Sampler.

Samples were dried and processed through a series of nine Tyler sieves (76.1 mm, 50.0 mm, 52.0 mm, 12.5 mm, 9.51 mm, 6.35 mm, 4.76 mm, 2.36 mm and 1.70 mm) using a Tyler sieve shaker. The weight of materials retained on each sieve and the solid bottom pan were recorded. These weights were then converted to weight fractions (%) of the sample. Values for $D_g$ were calculated for each sample from the sieve data by the method of moments, according to Shirazi et al. (1981):

$$D_g = d_1^{w1} \text{ x } d_2^{w2} \text{ x } \ldots \text{ x } d_n^{wn} \quad (1)$$

Where $d_1 \ldots d_n$ = sieve size (mm) $1 \ldots n$; and $w_1 \ldots w_n$ = percent of sample weight retained on sieve $1 \ldots n$.

Values for $S_g$ were calculated using the "non-biased" or "n-1" method:

$$S_g = \sqrt{(n\sum x^2 - (\sum x^2))/n(n-1)} \qquad (2)$$

A fredle index was then calculated based on these samples (Sowden and Power 1985):

$$f_i = D_g / S_g \qquad (3)$$

Gravel particles of mean diameter > 50 mm were excluded from the fredle index calculation for reasons of weight bias (Sowden and Power 1985). Rood (1998) provided a formula for calculating the precision (I) at which a particular fraction of the gravel was collected:

$$I = DF/F^* \qquad (4)$$

Where, F* is the mean percentage of a particular fraction and DF is the confidence interval around that mean percentage. Applying this formula to the data collected allowed precision estimates to be calculated for particular gravel fractions and determine if 20 samples per channel was enough to provide the desired precision rate (I = 10%).

Water temperatures were monitored using eight Onset® Optic StowAway® data loggers. These data loggers were set to record the temperature every two hours. The data loggers were placed into a section of two-inch diameter perforated PVC pipe six to eight inches long. These units were then attached to sections of ¾" rebar that could be driven into the gravel substrate to anchor the data logger. The Duncan M&E calls for placing these units at mid-water depth, with one at the top and bottom of each channel. For the 2001-02 season, the data loggers were all located on or in the channel's gravel bottom. One data logger was placed at the top of each channel and buried 5-6" in the gravel. The remaining loggers were placed on the gravel, spread out down the channels: one mid-way between the top and the weir of each channel, another placed at each weir and the final ones placed at the bottom of each channel just upstream of the two channel's confluence (Figure 5).

**Results**

Gravel sampling was conducted on July 19, 2002. Elevated lake levels prevented sampling in all but the upper 2/3 of the south channel. All 3 channels were measured in preparation for a full-scale gravel-sampling program. The channel's were measured from the top of the their respective seeps to the weirs for the middle and north, and to it's confluence with the middle for the south at the approximate middle of the channels width. The lengths, in feet, were 365, 212 and 180, south, middle and north channel respectively. A summary of the 13 gravel samples is reported in Table 10. The results are presented in percentage of total sample to make comparisons between samples easy since all the samples had different total weights. Fredle index values ranged from 5.9 to 14.1 for the 13 samples, with a mean of 8.8. The percentage of fines less than 3.3 mm averaged 10% and those less than 1.7 mm averages 8%.

Table 10. Results of Gravel Sampling, 13 Samples from the South Channel.

| Sample | Percent of Total Sample at each Particle Size Interval (mm) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ID # | >76.1 | >50.0 | >25.0 | >12.5 | >9.51 | >6.35 | >4.76 | >2.36 | >1.70 | <1.69 | $f_i$ |
| S-1-1 | 0.00% | 5.26% | 69.41% | 20.28% | 1.46% | 3.38% | 0.00% | 0.00% | 0.00% | 0.21% | 6.0 |
| S-1-2 | 0.00% | 7.63% | 57.49% | 26.46% | 2.77% | 4.68% | 0.62% | 0.02% | 0.00% | 0.33% | 8.1 |
| S-1-4 | 0.00% | 20.55% | 56.15% | 17.57% | 1.31% | 0.93% | 0.24% | 0.33% | 0.23% | 2.69% | 5.9 |
| S-1-5 | 18.73% | 10.62% | 39.06% | 24.47% | 3.00% | 2.93% | 0.63% | 0.11% | 0.03% | 0.42% | 9.9 |
| S-1-8 | 0.00% | 0.00% | 64.17% | 30.12% | 3.61% | 1.88% | 0.11% | 0.00% | 0.00% | 0.10% | 7.9 |
| S-2-1 | 22.59% | 11.32% | 25.24% | 20.06% | 5.74% | 6.81% | 2.66% | 3.52% | 0.89% | 1.17% | 14.1 |
| S-2-3 | 0.00% | 4.66% | 31.44% | 17.06% | 3.37% | 4.65% | 1.78% | 2.69% | 1.35% | 33.00% | 8.2 |
| S-2-4 | 0.00% | 12.35% | 41.83% | 17.59% | 2.55% | 2.88% | 1.00% | 1.54% | 1.06% | 19.20% | 6.9 |
| S-2-7 | 0.00% | 15.38% | 43.53% | 18.29% | 2.25% | 3.16% | 0.81% | 0.38% | 0.52% | 15.68% | 6.9 |
| S-2-8 | 0.00% | 15.30% | 38.08% | 20.74% | 4.14% | 4.81% | 1.78% | 2.69% | 1.32% | 11.13% | 9.1 |
| S-3-2 | 0.00% | 0.00% | 47.99% | 27.97% | 4.06% | 4.43% | 1.28% | 1.32% | 0.78% | 12.16% | 8.9 |
| S-3-3 | 0.00% | 18.95% | 25.57% | 27.16% | 5.52% | 6.42% | 2.13% | 1.94% | 1.11% | 11.20% | 13.0 |
| S-3-5 | 0.00% | 0.00% | 55.76% | 29.82% | 4.89% | 6.58% | 1.21% | 0.07% | 0.01% | 1.66% | 9.4 |
| Mean | 3.18% | 9.39% | 45.82% | 22.89% | 3.44% | 4.12% | 1.10% | 1.12% | 0.56% | 8.38% | 8.8 |
| Precision | 29.9% | 10.1% | 2.1% | 4.2% | 27.7% | 23.1% | 86.6% | 84.5% | 169.1% | 11.3% | --- |

The gravel recipe placed in the Duncan Creek spawning channels was expected to yield a fredle index value of 5.2. However, the mean of the fredle index values for the samples taken in 2002 was estimated to be 8.8.

Temperature data loggers were in place and recording temperatures beginning at 5 p.m. on December 11, 2001, and most were maintained until May 28, 2002. The logger at the south channel weir had to be removed on February 19 because it interfered with fry trapping operations. Data from December 11 to January 4 for the temperature logger located above the south channel weir is missing and un-recoverable. Data from February 1 to February 19 for the temperature logger located above the confluence of the two main channels in the south channel is also missing and un-recoverable. Data after March 5 for the two temperature loggers placed just above the confluence of the two main channels is not available at this time. These two loggers became un-retrievable when the lake level was increased (backfilled) by high water in the Columbia River. No data can be found for the two loggers placed above the weir of the north channel. It is presumed that they are still in place and are currently un-recoverable due to water depth and turbidity. These four temperature loggers will be recovered in early October when the lake level is lowered. Weekly average daily, maximum and minimum temperatures, for the six loggers with data available are reported in Table 11.

Table 11. Weekly Average Daily, Maximum and Minimum Temperatures ($^{o}$F), December 12, 2001 to May 28, 2002.

| | Temperature Data Logger Location | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sub-Surface of South Channel | | | Above Weir in South Channel | | | At weir of South Channel | | | Above Confluence, in South Channel | | | At weir of North Channel | | | Above Confluence, in North Channel | | |
| Week | Avg. | Max. | Min. | Avg. | Max. | Min. | Avg. | Max. | Min. | Avg. | Max. | Min. | Avg. | Max. | Min. | Avg. | Max. | Min. |
| 12/12 - 16 | 45.63 | 46.63 | 44.74 | --- | --- | --- | 47.26 | 47.89 | 46.67 | 47.16 | 47.71 | 46.77 | 44.64 | 45.08 | 44.08 | 44.18 | 44.53 | 43.70 |
| 12/17 - 23 | 46.50 | 46.65 | 46.29 | --- | --- | --- | 47.12 | 47.49 | 46.89 | 46.99 | 47.50 | 46.68 | 44.92 | 45.11 | 44.68 | 44.18 | 44.68 | 44.01 |
| 12/24 - 30 | 46.94 | 46.97 | 46.89 | --- | --- | --- | 46.25 | 46.65 | 45.86 | 45.51 | 46.16 | 44.91 | 45.18 | 45.43 | 44.99 | 44.09 | 44.60 | 43.56 |
| 12/31 - 1/6 | 47.16 | 47.25 | 47.01 | 47.06 | 47.30 | 46.74 | 46.91 | 47.25 | 46.66 | 46.41 | 46.83 | 46.01 | 45.92 | 46.10 | 45.78 | 44.80 | 45.05 | 44.53 |
| 1/7 - 13 | 47.35 | 47.40 | 47.28 | 47.28 | 47.46 | 47.18 | 47.30 | 47.56 | 47.09 | 47.13 | 47.50 | 46.83 | 45.64 | 45.85 | 45.45 | 44.75 | 45.12 | 44.60 |
| 1/14 - 20 | 47.40 | 47.52 | 47.25 | 46.98 | 47.11 | 46.87 | 47.15 | 47.41 | 47.01 | 46.90 | 47.20 | 46.60 | 45.89 | 46.06 | 45.82 | 44.89 | 45.20 | 44.75 |
| 1/21 - 27 | 46.49 | 46.97 | 46.06 | 46.82 | 47.03 | 46.67 | 46.81 | 47.21 | 46.46 | 46.64 | 47.05 | 46.31 | 45.08 | 45.58 | 44.55 | 44.24 | 44.83 | 43.78 |
| 1/28 - 2/3 | 47.05 | 47.13 | 46.93 | 46.60 | 46.87 | 46.47 | 46.92 | 47.25 | 46.73 | 46.60 | 46.98 | 46.19 | 45.37 | 45.63 | 45.27 | 44.46 | 44.90 | 44.16 |
| 2/4 - 10 | 47.02 | 47.13 | 46.98 | 46.67 | 46.95 | 46.47 | 47.01 | 47.41 | 46.73 | --- | --- | --- | 45.97 | 46.21 | 45.74 | 44.90 | 45.50 | 44.38 |
| 2/11 - 17 | 47.16 | 47.40 | 47.01 | 46.79 | 47.30 | 46.55 | 47.11 | 47.92 | 46.69 | --- | --- | --- | 46.38 | 46.93 | 46.06 | 45.42 | 46.54 | 44.83 |
| 2/18 - 24 | 47.62 | 47.72 | 47.45 | 47.07 | 47.34 | 46.95 | 47.50 | 48.00 | 47.17 | 47.33 | 48.02 | 46.71 | 46.83 | 47.33 | 46.41 | 45.94 | 46.54 | 45.35 |
| 2/25 - 3/3 | 47.80 | 47.80 | 47.76 | 46.76 | 47.46 | 46.43 | --- | --- | --- | 46.76 | 48.90 | 45.64 | 46.21 | 47.41 | 45.58 | 45.39 | 47.35 | 44.38 |
| 3/4 - 10 | 47.44 | 47.60 | 47.29 | 46.67 | 47.15 | 46.36 | --- | --- | --- | 47.17 | 48.53 | 46.45 | 46.88 | 47.33 | 46.57 | 45.88 | 47.13 | 45.31 |
| 3/11 - 17 | 47.10 | 47.52 | 46.86 | 46.78 | 47.35 | 46.51 | --- | --- | --- | --- | --- | --- | 45.73 | 46.46 | 44.86 | --- | --- | --- |
| 3/18 - 24 | 47.72 | 47.80 | 47.56 | 46.67 | 47.18 | 46.39 | --- | --- | --- | --- | --- | --- | 46.01 | 46.61 | 45.58 | --- | --- | --- |
| 3/25 - 31 | 47.79 | 47.80 | 47.64 | 47.10 | 48.17 | 46.59 | --- | --- | --- | --- | --- | --- | 46.91 | 47.96 | 46.41 | --- | --- | --- |
| 4/1 – 7 | 47.79 | 47.84 | 47.72 | 47.31 | 48.65 | 46.51 | --- | --- | --- | --- | --- | --- | 47.29 | 48.32 | 46.69 | --- | --- | --- |
| 4/8 - 14 | 47.76 | 47.84 | 47.56 | 47.22 | 47.82 | 46.83 | --- | --- | --- | --- | --- | --- | 47.08 | 47.76 | 46.62 | --- | --- | --- |
| 4/15 - 21 | 47.66 | 47.72 | 47.60 | 47.14 | 47.62 | 46.82 | --- | --- | --- | --- | --- | --- | 45.98 | 46.93 | 45.30 | --- | --- | --- |
| 4/22 - 28 | 47.82 | 48.00 | 47.76 | 47.34 | 48.73 | 46.55 | --- | --- | --- | --- | --- | --- | 47.41 | 48.83 | 46.69 | --- | --- | --- |
| 4/29 - 5/5 | 47.81 | 47.96 | 47.72 | 47.82 | 49.52 | 46.83 | --- | --- | --- | --- | --- | --- | 47.80 | 49.19 | 47.09 | --- | --- | --- |
| 5/6 - 12 | 47.86 | 48.11 | 47.72 | 47.84 | 49.16 | 46.91 | --- | --- | --- | --- | --- | --- | 48.09 | 49.71 | 47.22 | --- | --- | --- |
| 5/13 - 19 | 47.77 | 48.23 | 47.52 | 47.93 | 48.72 | 47.51 | --- | --- | --- | --- | --- | --- | 48.30 | 49.71 | 47.52 | --- | --- | --- |
| 5/20 - 26 | 47.90 | 48.46 | 47.54 | 48.19 | 49.36 | 47.63 | --- | --- | --- | --- | --- | --- | 48.45 | 49.95 | 47.72 | --- | --- | --- |
| 5/27 -28 | 47.85 | 48.07 | 47.66 | 48.81 | 49.66 | 48.13 | --- | --- | --- | --- | --- | --- | 48.34 | 48.93 | 47.97 | --- | --- | --- |

**Discussion**

Comparison of the results of the gravel sampling to the channel recipe showed that large sized gravel component ( 4”- 6”) was missing in our sampling. It appears that the proportion of 2.5 – 4 inch (63.5 – 102 mm) gravel was similar. The proportion of 1 – 2.5 inch (25 – 64 mm) gravel appears to be slightly greater than the recipe. The percentage of gravel in the 0.75 –1 inch (19 – 25 mm) and 0.375 – 0.75 inch (9.5 – 19 mm) range is lower than recommended. The percentage of gravel in the 0.375 – 0.0067 inch range (9.5 –1.7 mm) was similar to the recipe. While some of the individual samples had high percentages of fines (material < 1.69 mm) the overall mean of that proportion was 8.38%. The mean fredle index value (8.8) from our sampling was slightly higher than the expected (5.2) fredle index value from the gravel recipe. Slight differences in gravel composition may be due to the limited sampling and not a reflection of the channels on a whole. The results of the precision estimates calculations support this with only two of the ten proportions sampled having I values of less than 10%.

Tagart (1984) graphed the relationship between percent fines (fraction < 0.850 mm) and estimated survival (egg deposition to emergence) for coho. Plotting the percent fines from the 13 gravel samples against the relationship shows that estimated survival in the south channel should be greater than 60%. Chapman (1988) graphed survival to emergence in relation to the fredle index for coho (Koski 1966) chinook and steelhead (Tappel and Bjornn 1983) and sockeye (Coopers 1965). Based on these studies, the mean fredle index value for the south channel (8.8) would yield survival rates ranging from approximately 60% for sockeye to 80% chinook salmon.

It was unfortunate that only a small section of one channel was accessible for gravel sampling. The whole channel system above the weirs will be sampled in June of 2003 after that season’s chum fry out-migration has been completed. This sampling will undoubtedly yield a better picture of gravel composition in the channels and any decisions on cleaning and/or maintenance should be delayed until it is completed.

Any type of analysis on the temperature data collected during the 2001-02 season would be very difficult. Due to unfamiliarity with the temperature data logging software ,no electronic copies of the data were kept for the majority of the season. The loggers were downloaded, printouts and graphs of the data were created but not saved in a way that when the same logger was downloaded again it didn’t over-write the previous data saved for that logger. As a result, the majority of the data had to be re-entered by hand into a spreadsheet and only daily averages, maximums and minimums were entered. Data from two of the eight temperature loggers was unavailable at report writing time (loggers not retrieved before water levels increased, prevented retrieval) for any of the season. Data from two other loggers was only available for half of the season for the same reason mentioned above. Given this, a detailed analysis and discussion of water temperatures in the channels will not be attempted this year. A full water temperature monitoring program and analysis will be conducted over the 2002-03 season and reported in the 2003 annual report. Preliminary analysis of minimum temperature data indicates that temperatures exceeded 42 degrees and were well above the 36 degree minimum that can negatively impact spawning and incubation (Schroder 1973; Koski 1975).

Based on our temperature and gravel composition monitoring, the spawning channel was constructed in a manner that should maximize the incubation success of chum salmon spawning naturally in Duncan

Creek. Continued monitoring of the hyporheic zone including temperature, gravel composition, hydraulic gradients, and dissolved oxygen levels should continue to ensure incubation survival for this ESA-listed species is maximized. Re-establishment of a Duncan Creek spawning population will help reduce risks to Lower Columbia River Chum Salmon.

## Part III: Natural Spawning

### Introduction

Re-colonization via adults straying from the Bonneville population or the capture and release of Bonneville population adults into the channel were the two primary means of initiating natural spawning in the Duncan Creek spawning channel. Adult chum captured in Duncan Creek could either be placed above the weirs in the spawning channels to reproduce naturally or transported to the Washougal Hatchery to be used in a hatchery supplementation program. Success of adults placed in the spawning channels, a measure of the incubation characteristics of each channel, is estimated by evaluating egg-to-fry survival rates. To evaluate egg-to-fry survival rates in naturally spawning fish, two estimates of egg deposition are needed: Potential Egg Deposition (PED) and Actual Egg Deposition (AED), and the total number of fry captured at each channel's weir. As detailed in the Duncan M&E, egg-to-fry survival rates should exceed 40% if the channels were constructed and maintained correctly and female densities remain at less than one female per three square meters.

PED relies on relationships between phenotypic traits such as length or body weight to estimate the fecundity of an individual female. Body size/fecundity relationships have been developed by researchers on several salmonid species (see Pritchard 1937; Rounsefell 1957; Allen 1958; Donaldson and Menasveta 1961; Gray 1965; Smolei 1966; Kato 1978; Gall and Gross 1978; Schroder 1981). These researchers showed that 10 to 70% of the variation in fecundity could be explained with female size (length or weight). Schroder (unpublished data) was able to explain 95% of the variation in fecundity of artificially spawned Grays River chum in 1998 and 1999 by using multiple regression analyses of log body weight, egg weight and transformed reproductive effort (total egg mass weight/total body weight). While egg weight and length data can be collected from live fish, reproductive effort requires that the fish be spawned artificially. Removal of the reproductive effort value reduced the amount of variance that could be explained. Replacing reproductive effort with a K value (weight/length cubed) in the regression models resulted in formulas that could explain 67 to 94% of the variation associated with fecundity. The Duncan M&E recommends artificially spawning 30-50 females to develop regression formulas that can be used to predict fecundity. Multiple years of data will need to be collected on artificially crossed females of the Bonneville population to develop these fecundity relationships and measure yearly variation. AED equals PED minus any potentially viable (not deformed or still firmly attached to the ovarian membrane) eggs retained by the female at death. This can be simply measured by sampling the females soon (< 24 hours) after death and counting the number of potentially viable eggs. Due to budgetary constraints, biological sampling of females in the channels during 2001-02 was limited. Sampling was done on a weekly basis instead of daily and no egg size values were recorded.

Success of adults spawning in the channels can also be measured by estimating the number of returning adults from these matings, the fry-to-adult survival rate called for in the Lower Columbia River chum recovery strategy. This would require that all fry be trapped when migrating out of the spawning channels and these fry be marked for identification as adults. Lastly, adult chum of the Bonneville population would need to be sampled and a determination of adult abundance in the different spawning locations made. Unfortunately, juveniles trapped in 2002 were not marked with strontium (Sr) as recommended in the Duncan M&E. Lack of permits needed to apply and dispose of the strontium were the reasons for not using this marking method in 2002. This prevents any estimates of egg-to or fry-to-adult survival rates of those chum salmon naturally produced in the spawning channels in 2001.

## Methods

PSMFC personnel again collected adults from known local chum spawning areas using beach seines and tangle nets for this activity. Adults selected to be placed above the weirs were placed into a fish tube. The fish tubes used were three feet long sections of 10" diameter PVC pipe, perforated with several one and a half-inch holes, and equipped with removable end pieces. If the fish needed to be transported a 400-gallon truck-mounted tank was used. A numbered jaw tag was to be applied on all adults moved into the spawning channels above the weirs. Spawning ground surveys of Duncan Creek and the channels below the weirs were conducted by PSMFC personnel beginning November 1, 2001, and ending on January 4, 2002. All adult chum observed, dead or alive, were enumerated and biological samples were collected on all post-spawn mortalities. Biological sampling included: taking tissue samples for genetic analysis, scales for aging the fish, lengths (fork (mm) and mid-eye-to-hypural (mm)) and the number of retained eggs on females. The sex, location and tag number, if present, were also recorded. Additional surveys were conducted above the weirs to collect this data on post-spawn mortalities of adults placed there.

Estimation of the PED for each female placed in the spawning channels would ideally be calculated by multiple regression formulas using body weight, egg size and K. If egg size was unknown for an individual female because all of her eggs were deposited, formulas using body weight and K or just body weight, whichever explains the greatest amount of variation, would be used. Regardless of the formula used, 95% confidence intervals were calculated and three values (expected, maximum and minimum) were developed for each female. These individual values were summed creating an expected, maximum and minimum PED for each channel.

Data to calculate values of AED for individual females were collected during weekly spawning ground surveys. Under a fully-funded monitoring program when retained eggs were found, egg size would be measured by randomly collecting ten eggs. These eggs would be placed in water, refrigerated for 24 hours, blotted dry and individually weighed to the nearest milligram. Because egg size has been shown to vary little within a female, (modal coefficient of variation for Grays River females equaled 2.5%) even a sample of one or two eggs can be used to determine egg size (Duncan M&E). After sampling, the carcass was removed from the channel and placed into Duncan Creek or the Columbia River. This was done to constrain pathogens and to maintain DO levels in the channels.

Enumeration of out-migrating fry was done by trapping at two weirs, put into place during the construction of the channels. When operated properly we expect that the weirs will be 100% efficient in capturing juveniles, and the outmigration will be a count not an estimate. One weir is below two channels, the south and middle, the other is below the north channel (Figure 2). Two differently designed traps were used to capture the migrating fry in 2002. The trap located at the south weir consisted of a flume, catch box and a live box (Figure 7). A large mesh screen separated the catch box and live box to exclude larger fish (age 1+ coho smolts and resident trout) from the live box where the chum fry would be held. The trap located at the north weir consisted of a nylon mesh net acting as a flume to deliver fish into a live box (Figure 8). Sand bags were used at both weirs to create a pool for the live boxes.

PSMFC personnel were scheduled to check both traps daily. Assessing fry condition at emergence was also detailed in the Duncan M&E. Thirty randomly chosen fry from each channel were to be weighed (0.01 g) and measured (fork length) every Monday, Wednesday and Friday. These values were to be used to calculate a $K_D$ value (Bams 1970) for each individual fish.

Figure 7. Fry trap operated at the South weir.

Figure 8. Fry trap operated at the North weir.

**Results**

Duncan Creek was seined six times between November 13 and December 20, 2001 (Table 12). At least one adult chum was found in Duncan Creek each time it was seined. A total of 11 adult chum were seined from Duncan Creek. A total of 27 chum were observed (25 live and two dead) during four spawning ground surveys conducted below the weirs of the channels and in Duncan Creek between November 20, 2001 and January 4, 2002. Five surveys were conducted in the spawning channels above and below the weirs between December 14, 2001 and January 4, 2002. Because no adult trap was operated at the mouth of Duncan Creek during the 2001 adult migration period, the exact number of adult chum and other salmonids that volitionally entered Duncan Creek is unknown. Combining the seining and survey efforts results in a possible total (live fish observed during surveys may have also been seined) of 40-43 adult chum that voluntarily entered Duncan Creek. Construction work in the channels was ongoing during early seining efforts. Muddy water due to construction made seining difficult and may have discouraged and or delayed adult chum from entering Duncan Creek during this time period. Although a final estimate of the Bonneville chum population is not available, it is believed to be between one and three thousand, yielding an observed stray rate (27/(1-3000) of 1/3 to 1 percent.

Forty-four adults were released above the weirs into the Duncan Creek spawning channels. Table 13 details the locations were adult chum placed into the spawning channels were collected. Adults were placed into the channels from December 6 to 20 and December 7 to 14, south and north channels respectively. All adults placed above the weirs in the channels, except for six males (three on Dec 6 and three on Dec 17), were marked with a numbered steel jaw tag. The south channel received 28 adults (16 male, 11 females and one unknown) and the north channel received 16 adults (eight male and eight female). Eight adults (three male and five females) escaped from above the south weir, one of the females was re-captured two days after escaping and placed back above the weir. Of the remaining four female escapees, all but one was found dead (spawned out) below the weirs in the channels during spawning ground surveys. The final disposition of three escaped males is unknown.

Biological data collected during spawning ground surveys above the weirs is summarized in Table 14. Three scales were taken from each fish when sampled for age determination. Age-3 fish dominated the age structure of those placed above the weirs, 91.6% of the male and 78.9% of the females (Figure 9). The four untagged females sampled below the weirs were also age-3 fish. A comparison of average fork and mid-eye-to-hypural lengths by age and sex can be found in Table 15. Fork lengths for age-3 females ranged from 620 mm to 750 mm, averaging 675 mm, and age-4 females ranged from 680 mm to 760 mm, averaging 720 mm (Figure 10). Fork lengths for age-3 males ranged from 660 mm to 800 mm, averaging 733 mm, and age-4 males ranged from 710 mm to 770 mm, averaging 747 mm (Figure 11). The number of retained viable eggs ranged from zero to 675, averaging 86.2 (n=11). The number of retained viable eggs was not recorded for five of the 16 females sampled. No data were collected on egg size of females found with retained eggs.

Table 12. Adult Seining Data, 2001.

| Date | Location | # Salmonids Caught: Chum | Chinook | Coho | Whitefish |
|---|---|---|---|---|---|
| 11/07/2001 | Ives Island | | | 1 | |
| 11/13/2001 | Hamilton Slough | 18 | 25 | 7 | |
| 11/13/2001 | Duncan Creek | 3 | | | |
| 11/14/2001 | Ives Bay | 1 | | | |
| 11/15/2001 | Duncan Creek | 1 | | | |
| 11/16/2001 | Duncan Creek | 4 | | | |
| 11/20/2001 | Hamilton Slough | 45 | 20 | 7 | |
| 11/21/2001 | Hamilton Slough | 46 | 18 | 5 | 1 |
| 11/27/2001 | Wood's Landing | 125-150 | | | |
| 11/29/2001 | Above Hamilton Creek/Ives Island bay | 30 | | | |
| 11/30/2001 | Ives Island | 6 | | | |
| 12/03/2001 | Hamilton Slough | 1 | | | |
| 12/05/2001 | Above Hamilton Creek | 10 | | | |
| 12/06/2001 | Duncan Creek | 3 | | | |
| 12/07/2001 | Ives Island above Hamilton Creek | 3 | | | |
| 12/07/2001 | Duncan Creek | 1 | | | |
| 12/11/2001 | St. Cloud area (Goodbear/Archer) | 60-70 | | | |
| 12/12/2001 | St. Cloud area (Goodbear/Archer) | 50 | | | |
| 12/14/2001 | St. Cloud area (Goodbear/Archer) | 27 | | | |
| 12/17/2001 | St. Cloud area (Goodbear/Archer) | 17 | | | |
| 12/18/2001 | St. Cloud area (Goodbear/Archer) | Unknown number caught, all fish released due to snow | | | |
| 12/19/2001 | St. Cloud area (Goodbear/Archer) | 40-50 | | | |
| 12/20/2001 | St. Cloud area (Goodbear/Archer) | 10 | | | |
| 12/20/2001 | Duncan Creek | 2 | | | |

Table 13. Date of Capture and Origin of Adult Chum Moved to Duncan Creek Channels, 2001.

| | | | | Duncan Creek Channels | | | |
|---|---|---|---|---|---|---|---|
| | | | | Above South Weir | | Above North Weir | |
| Date | Location | Number Adult Chum Seined | | Male | Female | Male | Female |
| 12/06/2001 | Duncan Creek | 3 | | 3 | | | |
| 12/07/2001 | Ives Island above Hamilton Creek | 3 | | | | 1 | 2 |
| 12/07/2001 | Duncan Creek | 1 | | 1 | | | |
| 12/11/2001 | St. Cloud area (Goodbear/Archer) | 60-70 | (# estimated) | | | 1 | 1 |
| 12/12/2001 | St. Cloud area (Goodbear/Archer) | 50 | | | | 4 | 5 |
| 12/14/2001 | St. Cloud area (Goodbear/Archer) | 27 | | | | 2 | |
| 12/17/2001 | St. Cloud area (Goodbear/Archer) | 17 | | 3 | 5 | | |
| 12/19/2001 | St. Cloud area (Goodbear/Archer) | 40-50 | (# estimated) | 8 | 3 | | |
| 12/20/2001 | St. Cloud area (Goodbear/Archer) | 10 | | 1 | 1 | | |
| 12/20/2001 | Duncan Creek | 2 | | | 2 | | |
| | Total | | | 16 | 11 | 8 | 8 |

Table 14. Biological Data of Adults Placed in Spawning Channels, 2001-02.

| Date Sampled | Sex | North or South Channel | Age | Fork Length (cm) | Mid-Eye-to-Hypural (cm) | Jaw Tag # | # of eggs retained in carcass | Comments |
|---|---|---|---|---|---|---|---|---|
| 12/14/01 | M | South | 3 | 75 | 56 | ---- | ---- | |
| 12/14/01 | M | South | 3 | 66 | 50 | ---- | ---- | |
| 12/14/01 | M | North | 3 | 72 | 54 | ---- | ---- | |
| 12/14/01 | M | North | 3 | 76 | 55 | 8903 | ---- | |
| 12/14/01 | M | North | 4 | 71 | 55 | ---- | ---- | |
| 12/20/01 | M | North | 3 | 72 | 54 | 8901 | ---- | |
| 12/20/01 | F | North | 3 | 75 | 58 | 8999 | 1 | |
| 12/20/01 | F | North | 4 | 76 | 59 | ---- | 675 | |
| 12/20/01 | M | North | 3 | 75 | 56 | ---- | ---- | |
| 12/20/01 | F | North | 3 | 70 | 54 | 11901 | 2 | |
| 12/26/02 | M | South | 3 | 68 | 51 | 8914 | ---- | |
| 12/26/02 | M | South | 3 | 75 | 56 | 9817 | ---- | |
| 12/26/02 | M | South | 3 | 70 | 54 | 8915 | ---- | |
| 12/26/02 | M | South | 3 | 75 | 55 | 8916 | ---- | |
| 12/26/02 | M | South | 3 | 74 | 55 | 8918 | ---- | |
| 12/26/02 | M | South | 3 | 73 | 53 | ---- | ---- | |
| 12/26/02 | F | South | 3 | 68 | 52 | 11918 | Not recorded | |
| 12/26/02 | M | North | 3 | 70 | 53 | 8908 | ---- | |
| 12/26/02 | M | North | 3 | 69 | 51 | 8905 | ---- | |
| 12/26/02 | M | North | 4 | 77 | 57 | 9000 | ---- | |
| 12/26/02 | F | North | 3 | 67 | 52 | 11910 | 11 | fish was partially eaten |
| 12/26/02 | F | North | 4 | 71 | 53 | 11904 | Not recorded | fish was partially eaten |
| 12/26/02 | F | North | 4 | 72 | 55 | 11908 | 6 | |
| 12/26/02 | F | Escapee | 4 | 68 | 54 | 8907 | Not recorded | escaped from South channel, spawned below weir |
| 12/26/02 | F | Escapee | 3 | 67 | 51 | 11913 | Not recorded | escaped from South channel, spawned below weir |
| 12/31/01 | F | South | 4 | 73 | 56 | 11820 | 90 | |
| 12/31/01 | F | South | 3 | 65 | 19 | 11917 | 4 | |
| 12/31/01 | F | South | 3 | 65 | 51 | 11916 | 159 | |
| 12/31/01 | M | South | 4 | 76 | 56 | 8912 | ---- | |
| 12/31/01 | M | South | 3 | 77 | 57 | 8911 | ---- | |
| 12/31/01 | M | South | 3 | 76 | 55 | 8913 | ---- | |
| 12/31/01 | M | South | 3 | 73 | 53 | 8920 | ---- | |
| 12/31/01 | M | North | 3 | 77 | 58 | 8904 | ---- | |
| 12/31/01 | M | North | 3 | 82 | 60 | 11912 | ---- | |
| 12/31/01 | M | North | 3 | 72 | 56 | 8902 | ---- | |
| 12/31/01 | F | North | 3 | 68 | 53 | 11909 | 0 | |
| 12/31/01 | F | North | 3 | 62 | 49 | 11907 | 0 | |
| 12/31/01 | F | Escapee | 3 | 70 | 55 | 8906 | 0 | escaped from South channel, spawned below weir |
| 1/4/02 | F | Escapee | 3 | 66 | Not recorded | 8910 | Not recorded | escaped from South channel, spawned below weir |

Table 15. Average Fork Length (cm) and Mid-Eye-to-Hypural Lengths (cm) by Sex and Age of Adults Placed Above Spawning Channel Weirs, 2001.

| Sex | Age | N= | Avg. Fork Length (cm) | Avg. Mid-Eye-to-Hypural (cm) |
|---|---|---|---|---|
| Male | 3 | 23 | 73.3 | 54.6 |
| | 4 | 3 | 74.7 | 55.3 |
| | Combined | 26 | 73.4 | 54.7 |
| Female | 3 | 11 | 65.7 | 52.4* |
| | 4 | 5 | 71.0 | 54.5 |
| | Combined | 16 | 68.9 | 53.4** |

* N=10, one female sampled did not have mid-eye-to-hypural length recorded.
** N=15, one female sampled did not have mid-eye-to-hypural length recorded.

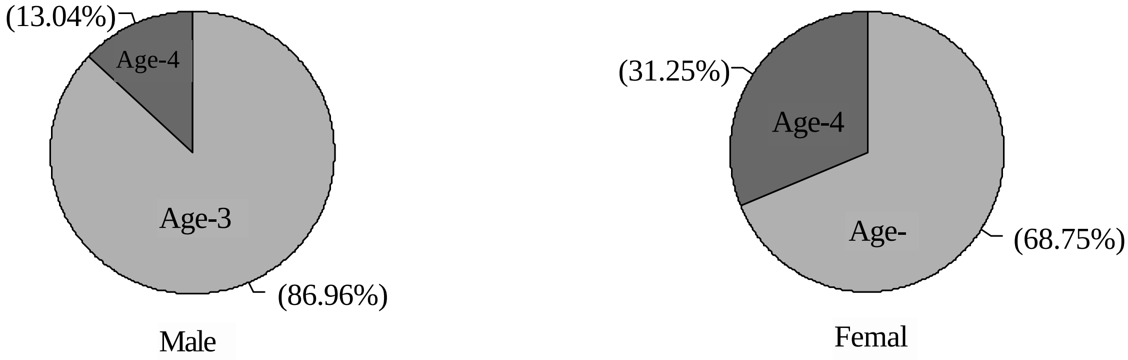



Figure 9. Age Composition of Adult Chum Sampled in the Duncan Creek Spawning Channels, 2001.

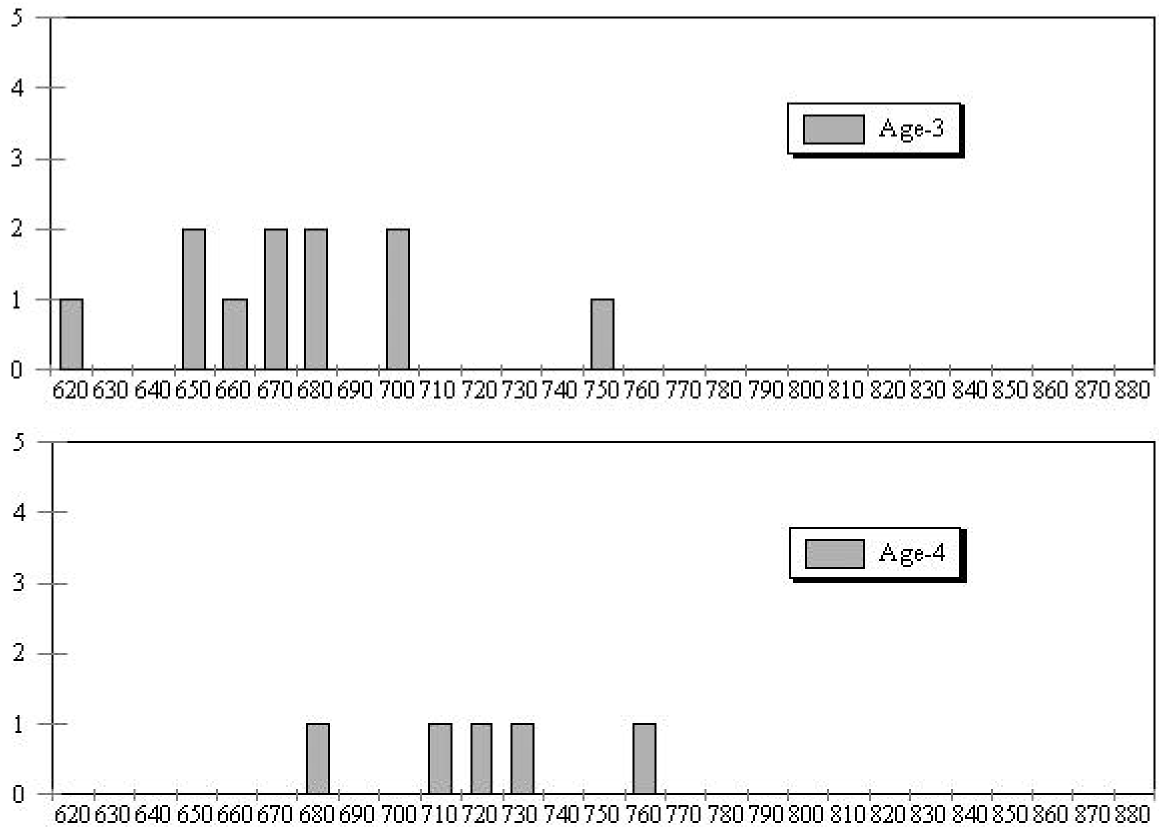



Figure 10. Fork Lengths, grouped by age and 10 mm increments, of Female Chum Sampled in the Duncan Creek Spawning Channels, 2001.

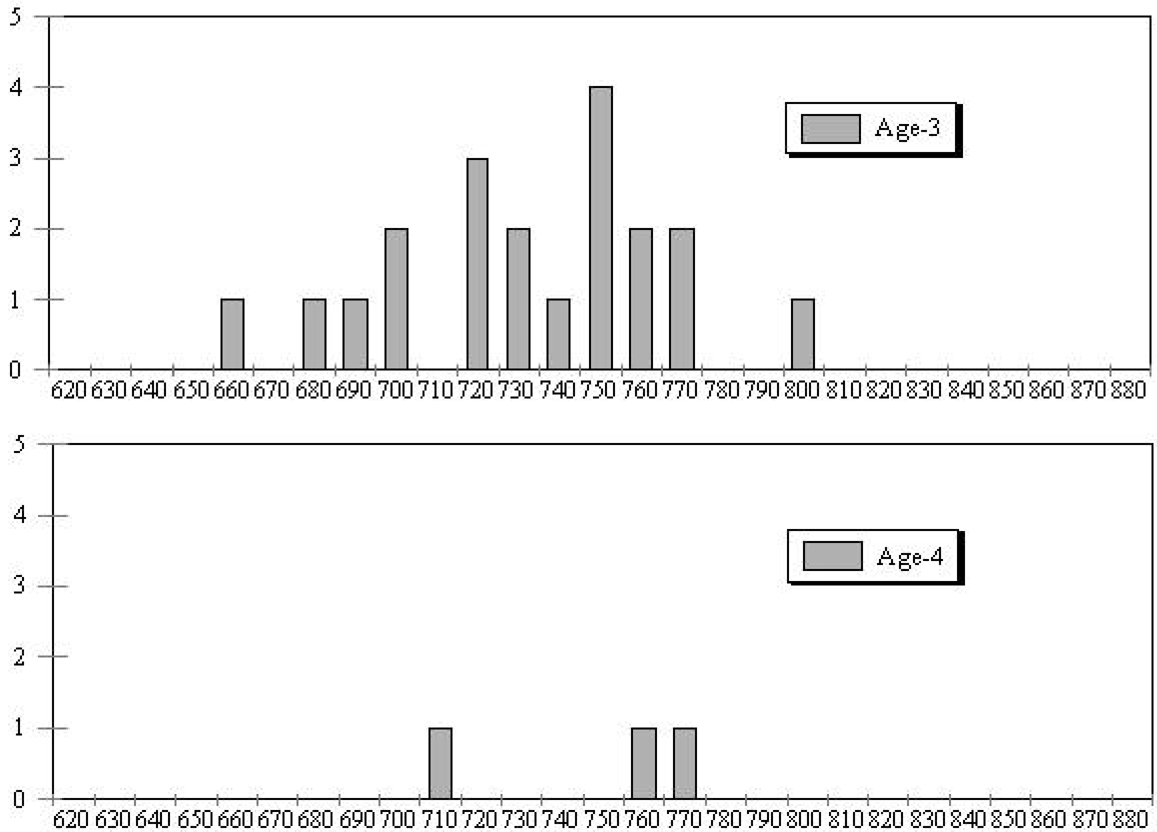


Figure 11. Fork Lengths, grouped by age and 10 mm increments, of Male Chum Sampled in the Duncan Creek Spawning Channels, 2001.

Females spawned at the Washougal Hatchery were used to create predictive regression formulas to estimate PED of females who spawned naturally in the channels. Individual reproductive values (total egg mass weight (g) / body weight (g)) were calculated for all females spawned at the hatchery (Table 16). Females with reproductive values less than 16% have most likely lost eggs or have already spawned at least once in the river before capture (Steve Schroder, pers. comm.) and were not included in the regression analysis. Another female (#23) was excluded because all her eggs were found to be non-viable when shocked. This resulted in only 17 sets of data to use in the regression analysis.

Ideally, values of fork length, weight, mid-eye-to-hypural length, egg size and age would have been collected on all females that spawned in the channels. However, limited sampling resulted in data sets of fork length, mid-eye-to-hypural length and age for those females. No mid-eye-to-hypural lengths were recorded for females spawned at the hatchery, which left fork length and age as the only values that could be used to predict PED.

Using only fork length in the regression resulted in a non-significant relationship ($R^2 = 0.10$, ANOVA $P > 0.05$). A regression analysis by age group, using Log10 fork length yielded better results. Fork lengths, grouped by age were able to explain 54% (ANOVA $P = 0.05$) of the variation in fecundity of age 3 and 45% (ANOVA $P = 0.1$) of the variation in age 4 females. Multiple regression using Log10 fork length and age was able to explain 45% (ANOVA $P = 0.05$) of the variation of both age groups. Lastly, mean fecundity by age was also calculated. Confidence intervals (95%) were calculated for all significant regressions, and the mean fecundities by age to yield expected, maximum and minimum PED values for each female that spawned in the channels. These values were summed to create the expected, maximum and minimum PED of each channel (Table 17). A multiple regression analysis using Log10 fork length, average green egg size and age was able to explain 72% (ANOVA $P = 0.001$) of the variation in fecundity.

Table 16. K Values for Females Spawned at Washougal Hatchery, 2001.

| Female # | Whole Body Weight (g) | Total Green Egg Weight (g) | K Value |
|---|---|---|---|
| F-1 | 2,890.0 | 412.7 | 14.28% |
| F-2 | 3,880.0 | 352.9 | 9.10% |
| F-3 | 4,804.5 | 739.1 | 15.38% |
| F-4 | 4,056.5 | 600.8 | 14.81% |
| F-5 | 4,239.5 | 804.7 | 18.98% |
| F-6 | 4,060.0 | 803.2 | 19.78% |
| F-7 | 3,650.0 | 739.1 | 20.25% |
| F-8 | 3,668.0 | 726.4 | 19.80% |
| F-9 | 3,983.5 | 833.7 | 20.93% |
| F-10 | 3,614.0 | 680.6 | 18.83% |
| F-11 | 3,971.5 | 746.1 | 18.79% |
| F-12 | 3,959.0 | 702.9 | 17.75% |
| F-13 | 3,652.5 | 747.6 | 20.47% |
| F-14 | 3,735.5 | 745.1 | 19.95% |
| F-15 | 3,669.5 | 730.7 | 19.91% |
| F-16 | 4,614.0 | 928.8 | 20.13% |
| F-17 | 3,549.5 | 717.4 | 20.21% |
| F-18 | 3,995.0 | 706.7 | 17.69% |
| F-19 | 3,980.5 | 863.0 | 21.68% |
| F-20 | 3,617.5 | 785.6 | 21.72% |
| F-21 | 4,142.5 | 483.8 | 11.68% |
| F-22 | 3,426.0 | 613.7 | 17.91% |

Table 17. PED Values (expected, maximum and minimum) for the Duncan Creek Channels by Method, 2002.

| Channel | Expected | Maximum | Minimum |
|---|---|---|---|
| Multiple Regression Using Log10 Fork Length and Age | | | |
| South | 10,079 | 12,349 | 7,809 |
| North | 22,453 | 26,339 | 18,567 |
| Total | 32,532 | 38,688 | 26,376 |
| Regression Using Log10 Fork Length by Age Group | | | |
| South | 10,835 | 12,003 | 9,667 |
| North | 23,384 | 30,531 | 16,237 |
| Total | 34,219 | 42,534 | 25,904 |
| Using Mean Fecundity by Age Group | | | |
| South | 10,730 | 11,552 | 9,908 |
| North | 21,204 | 23,193 | 19,215 |
| Total | 31,934 | 34,745 | 29,123 |

The number of retained eggs is known for 10 of the 12 females that spawned in the channels above the weirs (Table 14). These values were converted to percent retained eggs using the individual expected fecundity values derived from the predictive regression formula using Log10 fork length and age. The mean of these percentages (0.20%) was used as the retention rate for the two females with no values reported. The mean value was used to give each sample value equal weight. This allowed for AED values (expected, maximum and minimum) to be calculated for each channel (Table 18).

Table 18. AED Values (expected, maximum and minimum) for the Duncan Creek Channels by Method, 2002.

| Channel | Expected | Maximum | Minimum |
|---|---|---|---|
| Multiple Regression Using Log10 Fork Length and Age | | | |
| South | 9,821 | 12,030 | 7,611 |
| North | 21,753 | 25,537 | 17,969 |
| Total | 31,574 | 37,567 | 25,580 |
| Regression Using Log10 Fork Length by Age Group | | | |
| South | 10,577 | 11,729 | 9,424 |
| North | 22,685 | 29,705 | 15,665 |
| Total | 33,262 | 41,434 | 25,089 |
| Using Mean Fecundity by Age Group | | | |
| South | 10,472 | 11,260 | 9,684 |
| North | 20,503 | 22,461 | 18,546 |
| Total | 30,975 | 33,721 | 28,229 |

Due to lack of manpower and debris (primarily algae) the traps were not operated through the full migration period. Trapping totals were used with AED values to calculate expected, maximum and minimum egg-to-fry survival rates for the two channels. Two fry traps were operated between March 18 and May 23, 2002, one at each weir. The trap at the south weir began trapping immediately, the trap at the north weir was not operational until March 21. Both traps were plagued by debris (algae, leaves, sticks, canary reed grass and moss) blockages. On several days it was noted that the water levels may have, or did, reach heights that were over the top of the traps due to debris blockages. During the middle of the trapping season (April 18 to 22) high flows in the Columbia River backed the lake up into the channels all the way to the weirs. The traps were removed and then re-installed when water levels dropped to levels that allowed trapping. Trapping ended even though chum fry were still present in the daily catches because of high water levels in the Columbia River backing up the lake again. A total of 8,483 (1,100 and 7,383 south and north weir traps respectively) chum fry were recovered between the two traps (Table 19). While the totals differed by several orders of magnitude, daily collection numbers at the two weirs mirrored each other for most of the season (Figures 12 and 13). Daily trapping totals are reported in Appendix B. On April 14 the zipper on the trap at the north weir broke due to high flows and debris, resulting in 3,000 (estimated) chum fry escaping from the trap. Because it is unknown exactly how may fry were lost in this incident, the estimate (3,000 fry) will not be added to the totals reported in this section. On the day the traps were removed, the channels were seined and an additional 119 fry (12 above the south and 107 above the north) were enumerated above the weirs. There were no releases of marked fish above the traps to estimate trapping efficiency. Given events outlined above, the total of chum fry reported in Table 19 should be taken as a minimum number produced in the channels. In addition to chum fry, several coho (age 0+ and 1+) and one cutthroat trout were trapped at the weirs (Table 20).

Observed mortalities were thought to be primarily a result of high water velocities in the live boxes resulting in fry getting fatigued and then impinging on the screens. The trap at the south weir had daily mortality rates for chum fry ranging from 0 to 100% with an overall season rate of 33.6%. The trap at the north weir had lower daily rates, ranging from 0 to 33.3% with an overall season rate of 6.4% for chum fry. Age 0+ coho faired better at the south weir with a season mortality rate of 7.6% and a mortality rate (6.8%) similar to chum at the north weir.

Table 19. Number of Chum Fry Trapped and Seined from the Duncan Creek Channels, 2002.

| | Chum Fry | | |
|---|---|---|---|
| | Alive | Dead | Total |
| South Weir Trap | 726 | 374 | 1,100 |
| North Weir Trap | 6,911 | 472 | 7,383 |
| Trapping Total | 7,637 | 846 | 8,483 |
| Seining | 119 | 0 | 119 |
| Combined | 7,756 | 846 | 8,602 |

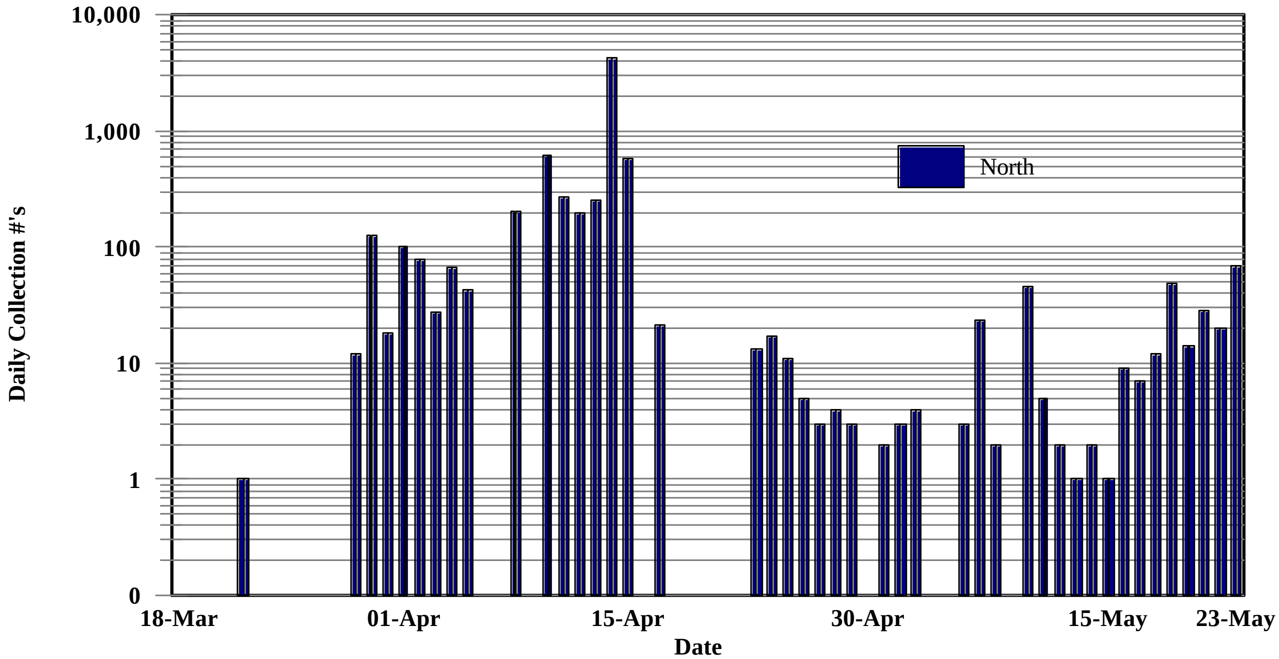



Figure 12. Daily Collection Totals of Chum Fry at the North Weir in the Duncan Creek Spawning Channels, 2002.

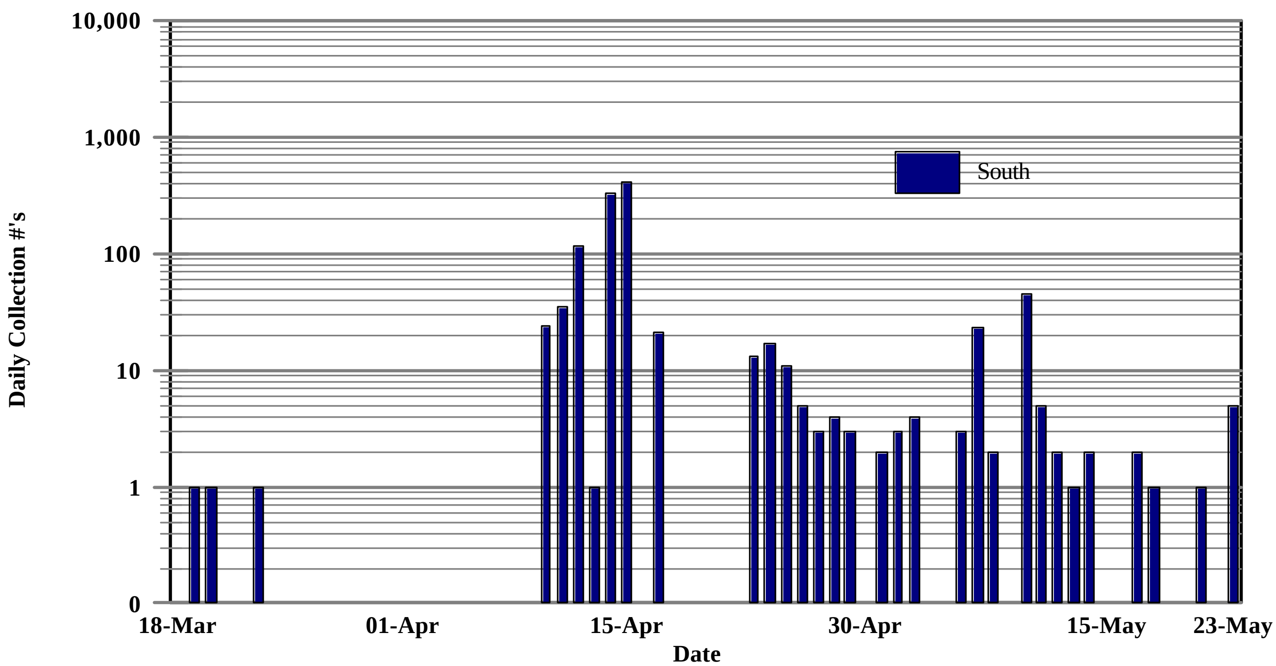



Figure 13. Daily Collection Totals of Chum Fry at the South Weir in the Duncan Creek Spawning Channels, 2002.

Table 20. Number of Other Salmonids Trapped from the Duncan Creek Spawning Channels, 2002.

| | Coho | | | |
|---|---|---|---|---|
| | Age 0+ | Age 1+ | Total | Cutthroat |
| South Weir Trap | 358 | 36 | 394 | 1 (280mm) |
| North Weir Trap | 43 | 0 | 43 | 0 |
| Seining | 80 | 0 | 80 | 0 |
| Combined | 481 | 36 | 517 | 1 |

Weights and lengths of out-migrating fry were taken sporadically through the season. Average weight and fork length data is presented in Table 21. Few individual weights were recorded, only group average weights, so there are very few individual $K_D$ values to report. Instead, most of what is reported in Table 21 are daily $K_D$ values using average weigh and fork length.

Table 21. Daily Average Weights, Fork lengths and $K_D$ Values of Chum Fry at the Two Traps, 2002.

| South Weir Trap | | | | | North Weir Trap | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Date | Avg. wt (g) | Mean FL (mm) | n= | $K_D$ | Date | Avg. wt (g) | Mean FL (mm) | n= | $K_D$ |
| 03/20/02 | 0.30 | 39.00 | 1 | 1.72 | 04/22/02 | ----- | 36.00 | 1 | ----- |
| 04/11/02 | 0.57 | 38.94 | 16 | 2.13 | 04/30/02 | 0.52 | 39.45 | 40 | 2.04 |
| 04/13/02 | 0.40 | 41.00 | 1 | 1.80 | 03/31/02 | ----- | 38.72 | 18 | ----- |
| 04/14/02 | 0.86 | 41.21 | 33 | 2.31 | 04/02/02 | 0.55 | 39.20 | 30 | 2.09 |
| 04/15/02 | 0.90 | 40.40 | 25 | 2.39 | 04/04/02 | 0.92 | 39.67 | 50 | 2.46 |
| 04/23/02 | 0.88 | 41.00 | 6 | 2.34 | 04/05/02 | 0.58 | 39.49 | 37 | 2.12 |
| 04/24/02 | 0.80 | 40.09 | 11 | 2.32 | 04/08/02 | 0.48 | 40.10 | 42 | 1.95 |
| 04/26/02 | 0.43 | 39.00 | 5 | 1.93 | 04/10/02 | 0.72 | 41.10 | 39 | 2.18 |
| 04/27/02 | 0.87 | 39.67 | 3 | 2.40 | 04/11/02 | 0.50 | 39.00 | 10 | 2.04 |
| 04/28/02 | 0.55 | 42.00 | 4 | 1.95 | 04/13/02 | 0.59 | 40.41 | 32 | 2.08 |
| 04/29/02 | 0.67 | 42.00 | 3 | 2.08 | 04/14/02 | 0.80 | 42.68 | 25 | 2.18 |
| 05/01/02 | 0.80 | 40.00 | 2 | 2.32 | 04/15/02 | 0.63 | 38.41 | 32 | 2.23 |
| 05/02/02 | 0.37 | 37.67 | 3 | 1.90 | 04/23/02 | 0.56 | 38.90 | 52 | 2.12 |
| 05/03/02 | 0.63 | 41.50 | 4 | 2.07 | 04/24/02 | 0.57 | 39.44 | 39 | 2.10 |
| 05/06/02 | 0.67 | 44.67 | 3 | 1.96 | 04/25/02 | 0.67 | 39.10 | 31 | 2.24 |
| 05/07/02 | 0.97 | 46.91 | 23 | 2.11 | 04/26/02 | 0.53 | 38.41 | 29 | 2.10 |
| 05/08/02 | 0.60 | 44.00 | 2 | 1.92 | 04/27/02 | 0.55 | 40.91 | 11 | 2.01 |
| 05/10/02 | 0.98 | 49.29 | 45 | 2.02 | 04/28/02 | 0.68 | 39.67 | 9 | 2.21 |
| 05/11/02 | 0.94 | 45.20 | 5 | 2.17 | 04/29/02 | ----- | 40.00 | 2 | ----- |
| 05/12/02 | 0.95 | 48.00 | 2 | 2.05 | 04/30/02 | ----- | 39.33 | 3 | ----- |
| 05/13/02 | 1.00 | 51.00 | 1 | 1.96 | 05/01/02 | 0.80 | 42.00 | 1 | 2.21 |
| 05/14/02 | 0.90 | 46.50 | 2 | 2.08 | 05/02/02 | ----- | 38.00 | 2 | ----- |
| 05/17/02 | 1.30 | 53.00 | 2 | 2.06 | 05/04/02 | 0.59 | 42.65 | 17 | 1.96 |
| 05/18/02 | 0.90 | 49.00 | 1 | 1.97 | 05/05/02 | ---- | 42.67 | 3 | ----- |
| 05/21/02 | 1.40 | 54.00 | 1 | 2.07 | 05/06/02 | 0.76 | 43.87 | 15 | 2.08 |
| 05/23/02 | 1.64 | 57.20 | 5 | 2.06 | 05/07/02 | 0.57 | 41.67 | 6 | 1.99 |
| | | | | | 05/08/02 | 0.60 | 44.00 | 2 | 1.92 |
| | | | | | 05/10/02 | 0.83 | 46.91 | 11 | 2.00 |
| | | | | | 05/12/02 | 1.02 | 48.08 | 13 | 2.09 |
| | | | | | 05/13/02 | ----- | 50.00 | 1 | ----- |
| | | | | | 05/14/02 | 0.60 | 42.00 | 1 | 2.01 |
| | | | | | 05/15/02 | 1.10 | 51.00 | 1 | 2.02 |
| | | | | | 05/16/02 | 1.25 | 50.11 | 9 | 2.15 |
| | | | | | 05/17/02 | 1.40 | 49.14 | 7 | 2.27 |
| | | | | | 05/18/02 | 1.27 | 52.42 | 12 | 2.07 |
| | | | | | 05/19/02 | 1.34 | 52.81 | 42 | 2.09 |
| | | | | | 05/20/02 | 1.24 | 52.00 | 14 | 2.06 |
| | | | | | 05/21/02 | 1.32 | 51.61 | 28 | 2.13 |
| | | | | | 05/22/02 | 1.37 | 53.85 | 20 | 2.06 |
| | | | | | 05/23/02 | 1.31 | 53.48 | 69 | 2.04 |

Table 22 details the egg-to-fry survival rates calculated using the three AED estimates (expected, maximum and minimum) from the three prediction formulas. The number of fry used in these rates is the actual number of fry trapped, no expansion estimates were done. It was hoped that the gaps in daily fry numbers could be filled with estimates using data from two other chum fry trapping operations (Hamilton and Hardy creeks operated by the U.S. Fish and Wildlife Service) in the area. However, daily trapping numbers were not available at the time of this report writing. Keeping this in mind, the rates reported should be considered a minimum. By including in the estimated 3,000 fry that were lost from the north weir on April 14, the north channels rate increases by 13 to 14 percentage points. The combined rate would increases by 9 to 10 percentage points.

Table 22. Egg-to-Fry Survival Rates (expected, maximum and minimum) for the Duncan Creek Cannels by Method, 2002.

| | Multiple Regression Using Log10 Fork Length and Age | | |
|---|---|---|---|
| Channel | Expected | Maximum | Minimum |
| South | 11.20% | 9.14% | 14.45% |
| North | 33.94% | 28.91% | 41.09% |
| Combined | 26.87% | 22.58% | 33.16% |
| | **Regression Using Log10 Fork Length by Age Group** | | |
| Channel | Expected | Maximum | Minimum |
| South | 10.40% | 9.38% | 11.67% |
| North | 32.55% | 24.85% | 47.13% |
| Combined | 25.50% | 20.47% | 33.81% |
| | **Using Mean Fecundity by Age Group** | | |
| Channel | Expected | Maximum | Minimum |
| South | 10.50% | 9.77% | 11.36% |
| North | 36.01% | 32.87% | 39.81% |
| Combined | 27.39% | 25.16% | 30.05% |

## Discussion

Typical $K_D$ values in chum salmon fry range from 1.8 to 2.0, the higher the number the more yolk the fry still has present, values of = 1.7 indicate emaciated fry. $K_D$ values can be used to ascertain intra-gravel conditions. Poor intra-gravel conditions may result in pre-mature emergence of the fry which would be reflected in higher than expected $K_D$ values. Again, lack of funding for a full biological sampling program resulted in this data being collected sporadically through the 2002 outmigration. On only two occasions, March 20 and April 14, were $K_D$ values recorded for fry trapped at the weirs equal to or below 1.8.

The stray rates for 2001 into Duncan Creek were estimated to be near 1% of the Bonneville population. At this rate it would take many generations for the Duncan Creek spawning channel to meet carrying capacity. Therefore, supplementation and its evaluation should continue for the rapid re-establishment of a spawning population in Duncan Creek.

The mean expected egg-to-fry survival rate was calculated at 34% for the north channel. The expected survival based on the physical habitat sampling was 60% to 80%. However, on April 14 it was estimated that 3,000 fry escaped prior to being counted due to equipment failure. If this estimate is correct, over 10,000 migrants left the north channel yielding an egg to fry survival of 46%. Two days after this peak count, the trap was pulled for four days. Over the course of four days from the peak count to pulling the trap, with the assumed lost catch of 3,000 added, 69% of the total chum outmigrants passed the trap. If this rate of outmigration continued during the four days the trap was pulled, we estimate over 12,000 outmigrants should have passed the trap. This yields an egg-to-fry survival rate of almost 56% to the north weir. Estimating passage at the south weir during the four day period that the trap was pulled yields an additional 650 outmigrants. This increases the egg-to-fry survival rate above the south weir to 17%.

The estimates of 46% to 56% egg-to-fry survival above the north weir are close to the predicted salmonid egg-to-fry survival based on fines from Tagert (1984) and the fredle index from Chapman (1988). If the missed estimate is correct and the expansion for missed days is correct, it appears that least one of the spawning channels is yielding egg-to-fry survival rates near the upper end of those observed for salmon and the physical characteristics of the channel are optimum for chum salmon egg-to-fry survival. The lower than expected rate at the south weir cannot be explained at this time based on the physical monitoring that was done in 2001-02.

Every effort needs to be made in 2003 to keep the fry traps operational throughout the whole outmigration season. Releases of marked fry above the weirs should be made in 2003 to estimate trap efficiency over the course of the outmigration to provide a more accurate total number of outmigrating fry. Complete sampling of females that spawned in the channels and those spawned at Washougal Hatchery would have also resulted in a better prediction formula for PED values and more accurate egg-to-fry survival rates.

Construction of the channels was still in progress at the start of the spawning season. Turbid water as a result of this may have prevented some adults from entering Duncan Creek. This also prevented placing adults collected over the entire spawning season into the channels. This will not be the case in 2002 and a plan will be in place to collect adults for seeding the channels and the supplementation program with adults representing the whole spawning period. A trap or weir should be installed at the mouth of Duncan Creek to facilitate collection of adults used in this program. This would also provide a more accurate picture of migration timing and accurate numbers of adult chum and other salmonids that may volitionally enter Duncan Creek. This structure would also give us the opportunity to exclude other salmonid adults from entering Duncan Creek to prevent predation on chum fry in the channels when they emerge. The steps needed to mark the trapped outmigrating fry with strontium need to be completed prior to the 2003 outmigration. Uniquely marking the fry produced in the channels will allow estimates of straying rates, both into Duncan Creek by adults produced in other areas and of Duncan Creek origin adults to other areas. Marking would also allow for an estimate of egg or fry to adult survival rates to be made.

## Summary

Overall, the Duncan Creek chum project was a success in 2001. A historical spawning/rearing location was re-opened and fry were documented outmigrating from this area. The evaluation and monitoring portions of the Duncan Creek chum project were under-funded and under-staffed. Cost for construction of the spawning channels and broodstock collection efforts ran into the money needed for evaluation and monitoring. As a result, we had to make assumptions for the data analysis from 2001-02. However, it did provide us with insight into how the evaluation and monitoring program worked and what needs to be changed for the 2002-03 season.

# Acknowledgements

I want to thank Ken Keller, Steve West, Brian Gale, Brian McNamara and the personnel at Washougal Hatchery for conducting the field work and activities related to the supplementation program. The U. S. Forest Service, Wind River Station, for the use of their gravel sampling equipment. Dan Rawding and Joe Hymer for providing program oversight and comments on this manuscript. Steve Schroder developed the framework for this project and wrote the draft Duncan Creek monitoring and evaluation plan. Andy Jansky and all the personnel at KPPF Engineering for their work on the spawning channels.

# Literature Cited

Alderdice, D.F., W.P. Wickett, and J.R. Brett. 1958. Some effects of temporary exposure to low dissolved oxygen levels on pacific salmon eggs. Journal. Fish. Res. Bd. Can. 15(2):229-250.

Alexander, G.R., and E.A. Hansen. 1986. Sand bed load in a brook trout (*Salvlinus frontinalis*) stream. North Am. J. Fish. Management 6(1): 9-23.

Allen, G.H. 1958. Notes on the fecundity of silver salmon (*Oncorhynchus kisutch*). Progr. Fish-Culturist 20(4): 163-169.

Argent, D.G., and P.A. Flebbe. 1999. Fine sediment effects on brook trout eggs in laboratory streams. Fisheries Research (Amsterdam) 39(3): 253-262.

Bams, R.A. 1970. Evaluation of a revised hatchery method tested on pink and chum salmon fry. J. Fish. Res. Bd. Can. 27: 1429-1452.

Baxter, J.S., and J.D. McPhail. 1999. The influence of redd site selection, groundwater upwelling and over-winter incubation temperatures on survival of bull trout (*Salvelinus confluentus*) from egg to alevin. Can. J. Zool. 77: 1233-1239.

Bonnell, R.G. 1991. Construction, Operation, and Evaluation of Groundwater-Fed Side Channels for Chum Salmon in British Columbia**.** *In* J. Colt and R. J. White [ed.]. Fisheries Bioengineering Symposium*.* American Fisheries Society Publication, 556pages.

Brannon, E.L. 1987. Mechanisms stabilizing salmonid fry emergemce timming, p. 120-124. *In* H.D. Smith, L. Margolis and C.C. Wood [ed.] Sockeye salmon (*Oncorhynchus nerka*) population biology and future management. Can. Spec. Publ. Fish. Aquat. Sci. 96.

Chapman, D.W. 1988. Critical review of variables used to define effects of fines in redds of large salmonids. Trans. Am. Fish. Soc. 117(1): 1-21.

Cooper, A.C. 1965. The effect of transported stream sediments on survival of sockeye and pink salmon eggs and alevin. International Pacific Salmon Fisheries Commission Bull. 18.

Cowen L. 1991. Physical Characteristics and Intragravel Survival of Chum Salmon in Developed and Natural Groundwater Channels in Washington. *In* J. Colt and R. J. White [ed.]. Fisheries Bioengineering Symposium*.* American Fisheries Society Publication, 556pages.

Donaldson, L.R., and D. Menasveta. 1961. Selective breeding of chinook salmon. Trans. Am. Fish. Soc. 90(2): 160-164

Gall, G.A.E., and S.J. Gross. 1978. A genetics analysis of the performance of three rainbow trout broodstocks. Aquaculture 15: 113-127.

Geist, D.R., and D.D. Dauble. 1998. Redd site selection and spawning habitat use by fall chinook salmon: the importance of geomorphic features in large rivers. Environmental Management 22: 655-669.
Gray, P.L. 1965. Fecundity of the chinook salmon (*Oncorhynchus tshawytscha*) related to size, age, and egg diameter. M.S. Thesis, Univ. Washington, Seattle. 65 pp.

Hunter, J.G. 1948. Natural propagation of salmon in the central coastal area of British Columbia. Fish. Res. Bd. Can. Progr. Rep. of the Pacific Coast Stations, No. 77, p. 105-106.

Johnson, O.W., W.S. Grant, R.G. Kope, K. Neely, F.W. Waknitz, and R.S. Waples. 1997. Status review of chum salmon from Washington, Oregon, and California. U.S. Dept. Commer., NOAA Tech. Memo. NMFS-NWFSC-32, 280 p.

Kato, T. 1978. Relation of growth to maturity of age and egg characteristics in kokanee salmon (*Oncorhynchus nerka*). Bull. Freshwater Fish. Res. Lab. Tokyo 28(1): 61-75.

Keller, Ken. 2002. 2001 Columbia River Chum Return. Washington Department of Fish and Wildlife, Columbia River Progress Report #2002-9. Olympia.

Kondolf, G.M., G.F. Cada, M.J. Sale, and T. Felando. 1991 Distribution and stability of potential spawning gravels in steep boulder-bed streams of the eastern Sierra Nevada. Trans. AM. Fish. Soc. 120(2): 177-186

Koski, K.V. 1966. The survival of coho salmon (*Oncorhynchus kisutch*) from egg deposition to emergence in three Oregon streams. M.S. Thesis, Oregon Sate Univ. Corvallis. 84 pp.

Koski, K.V. 1975. The survival and fitness of two stocks of chum salmon (*Oncorhynchus keta*) from egg deposition to emergence in a controlled–stream environment at Big Beef Creek. Ph.D. Thesis, Univ. Washington, Seattle, 212 pp.

Lotspeich, F.B., and F.H. Everest. 1981 A new method for reporting and interpreting textual composition of spawning gravel. U.S. Forest Service Research Note PNW-139.

Marten, P.S., 1992. Effects of temperature variation on the incubation and development of brook trout eggs. Progressive Fish-Culturist 54(1): 1-6.

McNeil, W.J. 1962. Variations in dissolved oxygen content of intragravel water in four spawning streams of Southeastern Alaska. U.S. Fish Wild. Service Spec. Sci. Rep. Fish. No. 402.

McNeil, W.J., and W.H. Ahnell. 1964. Success of pink salmon spawning relative to size of spawning bed materials. U.S. Fish Wild. Service Spec. Sci. Rep. Fish. No. 469.

McNeil, W.J. 1966. Effects of the spawning bed environment on reproduction of pink and chum salmon. U.S. Fish and Wildlife Service Fishery Bull. 65: 495-523.

McNeil, W.J., and J.E. Bailey. 1975. Salmon ranchers manual. Northwest Fish Center. Auke Bay Fish. Lab. Processed Rep. 95 pp.

Pritchard, A.L. 1937. Variation in the time of run, sex proportions, size and egg content of adult pink salmon (*Oncorhynchus gorbuscha*) at McClinton Creek, Masset Imlet, B.C. J. Biol. Board Can. 3(5): 403-416.

Rood, K. 1998. Nechako River substrate quality and composition. Nechako Fisheries Conservation Program Technical Report No. M89-7. 29pp and one Appendix.

Rounsefell, G.A. 1957. Fecundity of North American Salmonidae. U.S. Fish and Wildlife Serv. Fish. Bull. 57(122): 451-468

Schroder, S.L. 1973. Effects of density on the spawning success of chum salmon (*Oncorhynchus keta*) in an artificial spawning channel. M.S. Thesis, Univ. Washington, Seattle, 78pp.

Schroder, S.L. 1981. The role of sexual selection in determining overall mating patterns and mate choice in chum salmon. Ph.D. Thesis, Univ. Washington, Seattle, 274pp.

Shirazi, M. A., W. K. Seim, and D. H. Lewis. 1981. Characterization of spawning gravel and stream system evaluation. Pages 227-278 *in* Proceedings from the conference on salmon spawning gravel: a renewable resource in the Pacific Northwest. Washington State University, Washington Water Research Center Report 39, Pullman.

Smolei, A.I. 1966. Fecundity of sevan trouts. Vop.Ikhtiol. 6(1): 77-83. [Biol. Abstr. No.11481, Vol. 49, 1968]

Sowden, T.K., and G. Power. 1985 Predictions of rainbow trout embryo survival in relation to groundwater seepage and particle size of spawning substrates. Trans. Am. Fish. Soc. 114: 804-812

Tang, J., M.D. Manson, and E.L. Brannon. 1987. Effects of temperature extremes on the mortality and development rates of coho salmon embryos and alevins. The progressive Fish-Culturist 49: 167-174.

Tagart, J.V. 1976 The survival from egg deposition to emergence of coho salmon in the Clearwater River, Jefferson County, Washington. Masters Thesis. University of Washington, Seattle.

Tagart, J.V. 1984 Coho salmon survival from egg deposition to emergence. Pages 173-182 *in* J. M. Walton and D. B. Houston, editors. Proceedings of the Olympic wild fish conference. Peninsula College, Fisheries Technology Program, Port Angeles, Washington.

Washington Department of Fish and Wildlife, and Point No Point Treaty Tribes. 2000. Summer Chum Conservation Initiatives: An implementation plan to recover summer chum salmon in the Hood Canal and Strait of Juan de Fuca region. Available on the Web at: http://www.wa.gov/wdfw/fish/chum/chum/htm

Wickett, W.P. 1952. Production of chum and pink salmon in a controlled stream. Fisheries Research Board of Canada, Progress Reports of the Pacific Coast Stations, No. 93, p.7-9.

Wickett, W.P. 1954. The oxygen supply to salmon eggs in spawning beds. Journal Fish. Res. Bd. Can. 11(4):933-953.

Wickett, W.P. 1958. Review of certain environmental factors affecting the production of pink and chum salmon. Journal Fish. Res. Bd. Can. 15(5):1103-1126.

Witzel, L.D., and H.R. MacCrimmon. 1981. Role of gravel substrate on ova survival and alevin emergence of rainbow trout, *Salmo gairdneri*. Can J. Zool. 59: 629-636.

Witzel, L.D., and H.R. MacCrimmon. 1983. Embryo survival and alevin emergence of brook charr, *Salvlinus frontinalis,* and brown trout, *Salmo trutta*, relative to redd gravel composition. Can J. Zool. 61: 1783-1792.

# Appendix A

Report By KPFF Consulting Engineers on the Engineering and Construction of the Protected Spawning and Rearing Area at Duncan Creek

# Introduction

This phase of the project, funded by a BPA grant and administered by Pacific States Marine Fishery Commission, focuses on creation of Chum Spawning Channels on Duncan Creek.

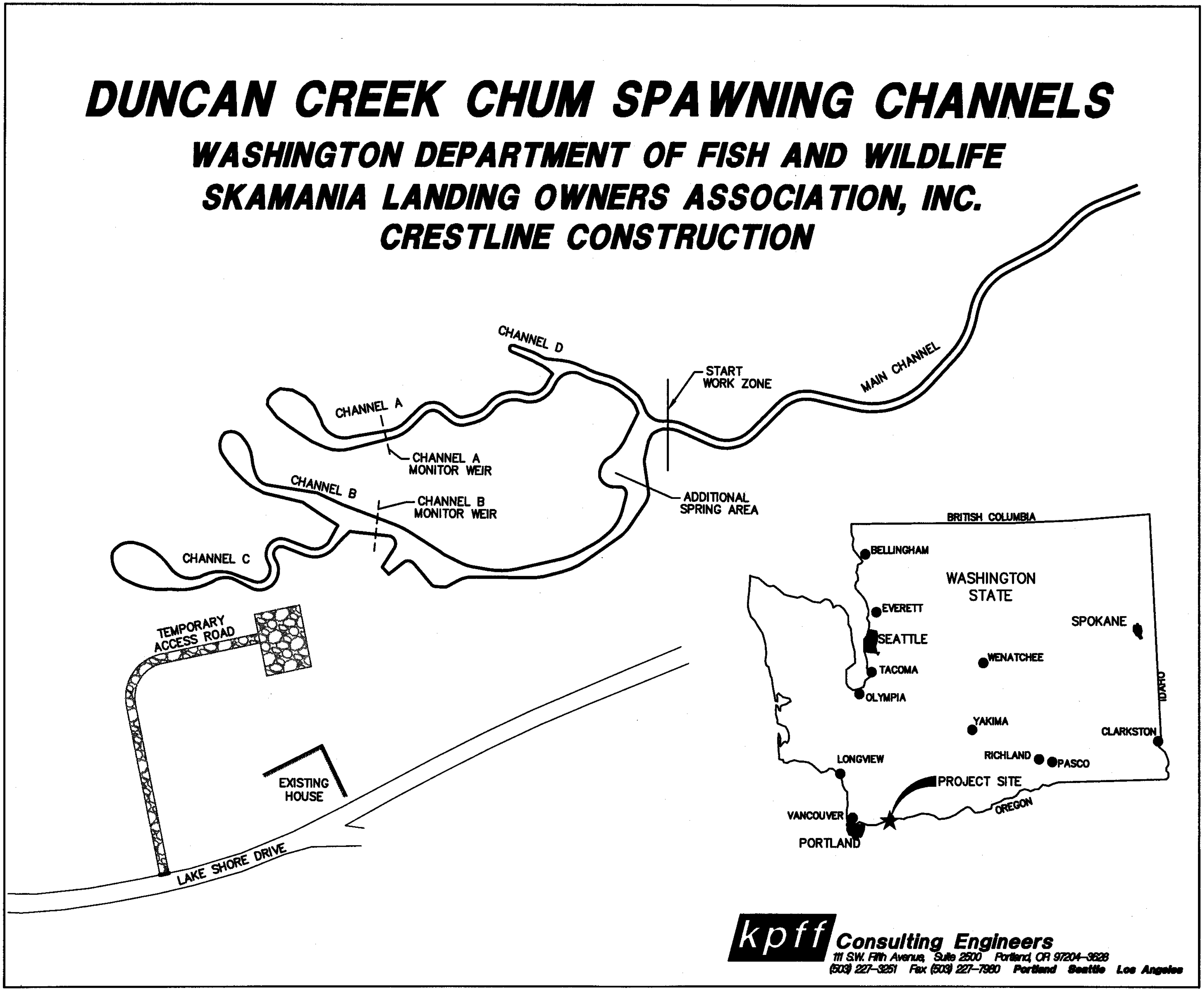
Chum historically used these channels until the Dam was construction in 1963. The combination of restricted access and significant sedimentation caused the ideal spawning habitat to be degraded.

The completion of the Fish Passage Phase of the project in 2001 now provides access to the springs from the main stem Columbia River. The next step was to restore the hospitable nature of the creek for spawning.

This phase of work includes removal of sediment, invasive Canary Reed Grass control, and replacement of clean spawning rock in the channel bottom *(See Figures 1 and 2)*. Capture and monitoring weirs are included to allow Fish and Wildlife to track the success of the project in the future. Three large Chum production areas have been created, consisting of spawning ponds along channels A, B, and C.


Figure 1: Before *(Grass Choked Springs)*

Figure 2: After *(Cleared Grass, New River Rock)*

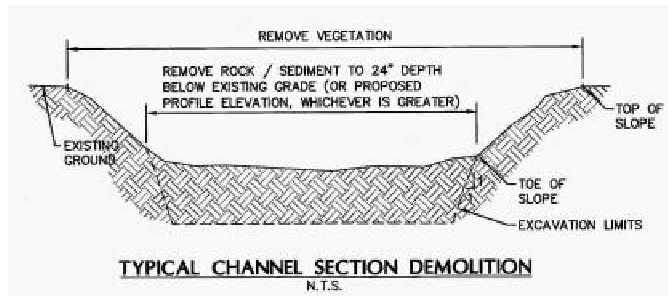

DUNCAN CREEK CHUM SPAWNING CHANNELS
WASHINGTON DEPARTMENT OF FISH AND WILDLIFE
SKAMANIA LANDING OWNERS ASSOCIATION, INC.
CRESTLINE CONSTRUCTION
CHANNEL D
START WORK ZONE
MAIN CHANNEL
CHANNEL A
CHANNEL A MONITOR WEIR
CHANNEL B
CHANNEL B MONITOR WEIR
ADDITIONAL SPRING AREA
CHANNEL C
TEMPORARY ACCESS ROAD
EXISTING HOUSE
LAKE SHORE DRIVE
BRITISH COLUMBIA
BELLINGHAM
WASHINGTON STATE
EVERETT
SPOKANE
SEATTLE
WENATCHEE
TACOMA
OLYMPIA
IDAHO
YAKIMA
CLARKSTON
LONGVIEW
RICHLAND
PASCO
PROJECT SITE
OREGON
VANCOUVER
PORTLAND
kpff Consulting Engineers
111 S.W. Fifth Avenue, Suite 2500 Portland, OR 97204-3628
(503) 227-3251 Fax (503) 227-7980 Portland Seattle Los Angeles

***Work Summary***

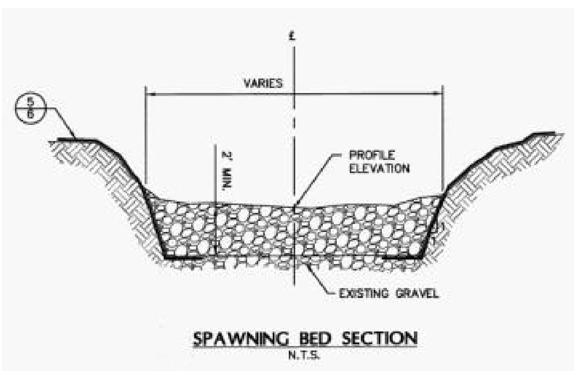
The work initiated with establishing erosion control measures to minimize impacts to the site due to construction. These measures included sediment control fencing around soil stockpile areas, hay bales downstream of work zones and silt control fencing in the stream to control downstream sediment transport. Once protected, work tasks including clearing of the channels, creating the spawning ponds, establishing a weir system for monitoring, bank planting and revegetation.

Spawning Ponds and Channels

Deep pool areas (bowls) were created at the end of channels A, B, and C with water depth and materials suitable for spawning. The bowls were cleared of sediment down to existing native rock *(See Figure 3: Typical Channel Section Demolition)*, then restocked with at least two feet of fresh spawning rock *(See Figure 4: Spawning Bed Section)*.




TYPICAL CHANNEL SECTION DEMOLITION
N.T.S.




SPAWNING BED SECTION
N.T.S.

Spawning Pond A was cleared to a 35-foot width from the junction to the end of channel A. Initially 5 feet of sediment was excavated to reach the native rock. Later the channel was further excavated to establish a deep enough pool – 2 feet of water, another 6 to 8 inches to approximately 2 feet below subgrade.

Pond B was cleared from the channel B junction to the upstream end approximately 15-feet wide. Utilizing cross channel rock weirs, a 6-inch minimum pool depth was established with excellent flow conditions. Special attention was given to the placement of rocks to facilitate a more natural looking stream with small riffles and pools.

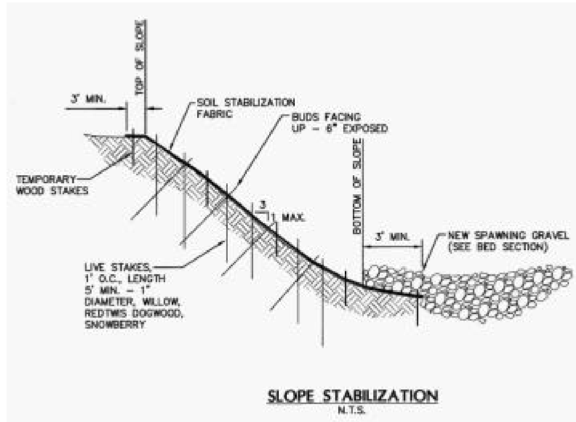
At the upstream end of channel C spring water was encountered during excavation for Pond C. This area proved more sensitive to Duncan Creek flows and flow rates decreased as creek flows dropped. When the spawning rock was placed in the pond, most of the water flowed below the surface, through the rocks. To increase pond depth a small "V" was formed at the base of the channel to concentrate the flow, and a small cross weir was placed in the bottom of the channel to create a small backwater.

Channel Restoration

The streambeds for channels A, B, and C were repaired to establish quality passageways to the spawning ponds. Sediments were cleared from the channels and rock placed to achieve target flow and pond depths. Some deeper areas were created between riffles allowing resting places. Large rocks from the site were placed in the channel to increase diversity and seed the natural adjustment of the streambed. Existing onsite root wads and woody debris were also placed back in the stream. Two additional spring areas in the lower zone were also cleared, one named channel D, and one at the confluence of Channels A and B. Reasonable flow rates were established in those areas as well, and sources appeared to be independent of other springs.

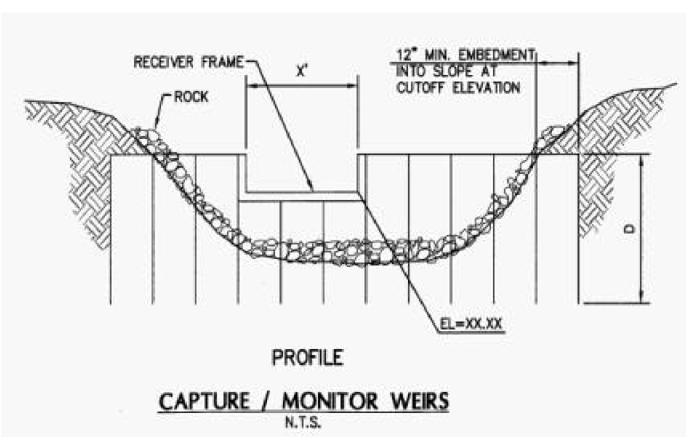
Bank Planting and Re-vegetation

After restoring the channels and spawning ponds, the areas surrounding them were stabilized and vegetated. Jute stabilization fabric was placed on all open cut soil slopes and secured. Plantings were placed through the fabric. Stabilization of the banks and revegetation with preferred native plantings will minimize reoccurrence of bank erosion into the stream *(See Figure 5: Slope Stabilization)*. The vegetation will also provide necessary shade for safe fish passage through the stream by lowering water temperatures. On the site 150 cedar trees, 150 gooseberry plantings, and 3000 other plantings were placed, including Pacific Willow, Red Osier Dogwood, Sitka Willow, and Columbia River Willow. Small swales were also created in areas with a high potential for erosion to divert sediment-filled water away from the reconstructed streams. The cedar trees experienced limited success without having watering, however some have survived. The willows have performed more adequately.




Capture and Monitoring Weirs

In order to evaluate success of the project, two weirs were installed to facilitate capturing and monitoring. The weirs were designed to meet the necessary widths and thicknesses of the frames required by WDF+W capture nets. The structures were placed at the upper end of channel A and below the confluence of channels B and C. Channel A weir was placed closer to the bowl area than the original designed location due to channel geometry and stream gradient. This placement will keep the weir above lake levels and allow a variable depth pool. The final location of the Channel B weir is per plan and below the confluence of B and C. This location provided a 2 to 3-foot deep large pool at the intersection.




The weirs are constructed of sheet pile with a receiver frame made of a 2-inch steel "C" channel, welded underwater, in place *(See Figure 6: Capture/Monitor Weirs)*. This design avoids in-water concrete placement, stream diversions and potential water seal failures. A two-part epoxy was used to seal any small pinholes in the weir system. A 12-inch wide grip-strut catwalk was planned for access and maintenance, but later agreed to be unnecessary and visually intrusive.

**Summary**

During the construction process adaptations were required due to the large number of unknowns when dealing with a natural site. In order to achieve the desired pond depths, stream flow rate and depth, and other goals to make it a hospitable spawning environment minor modifications were made onsite. The decision making process focused on minimizing current and future environmental impacts, creating a self-sustaining habitat, constructability issues and ease of maintenance. WDF+W was consulted throughout the process to find the best solutions. Some example modifications are adding cross weirs composed of natural materials, shaping the streambed to consolidate flow, designing capture weirs to minimize impacts, putting native materials such as root wads and large rocks back into the stream to help create diversity.

Quantities & Costs

Over the course of the project the following quantity of materials were installed:

| | |
|---|---|
| Straw Bales……………………………………….. | 149 bales |
| Jute Mating……………………………………….. | 34,875 sq ft |
| Silt Fence………………………..……………… | 1180 lf |
| Streambed Gravel……………………….…..… | 2203.80 tns |
| Bank Run Sand…………………….…….….... | 134.49 tns |
| Pit Run………………………………..……… | 1055.85 |
| 1½-0 Crushed Rock……………………………… | 103.32 tns |
| Trees ……………………………………..….… | 300 ea |
| Plantings (Willows & Dogwoods)……….….… | 3000 ea |

The total engineering and construction costs for the project were:

| | |
|---|---|
| Pay Estimate #1 Construction Work……..……… | $173,964.27 |
| Washington State Sales Tax………………. | $12,177.50 |
| Pay Estimate #2 Construction Work……..…….... | $7,851.85 |
| Washington State Sales Tax.…………….... | $549.62 |
| Pay Estimate #3 Construction Work……….…..... | $4,460.43 |
| Washington State Sales Tax….……………. | $312.23 |

Subtotal Construction………………….....$199,315.90

| | |
|---|---|
| Engineering Design……………………………….. | $67,746.00 |
| **Total Design & Construction…………..………..** | **$267,061.90** |

# Appendix B

Daily Collection Numbers of Salmonids and Daily Percent Mortality for Age 0+ Chum at the Two Weirs in Duncan Creek, 2002

Table 1. Daily Collection Numbers of Salmonids and Daily Percent Mortality for Age 0+ Chum at the Two Weirs in Duncan Creek, 2002.

| | South Weir | | | | | | | | | | North Weir | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chum | | | | Coho | | | | | | Chum | | | | Coho | | | | | |
| | Age 0+ | | | | Age 0+ | | | Age 1+ | | | Age 0+ | | | | Age 0+ | | | Age 1+ | | |
| Date | Live | Dead | Total | % Mort. | Live | Dead | Total | Live | Dead | Total | Live | Dead | Total | % Mort. | Live | Dead | Total | Live | Dead | Total |
| 19-Mar | 1 | 0 | 1 | 0.00% | 10 | 0 | 10 | 1 | 0 | 1 | 0 | 0 | 0 | | 0 | 0 | 0 | | | 0 |
| 20-Mar | 0 | 1 | 1 | 100.00% | 30 | 11 | 41 | 6 | 0 | 6 | | | 0 | | | | 0 | | | 0 |
| 21-Mar | 0 | 0 | 0 | | 0 | 10 | 10 | 1 | 3 | 4 | | | 0 | | | | 0 | | | 0 |
| 22-Mar | 0 | 0 | 0 | | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 23-Mar | 1 | 0 | 1 | 0.00% | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 24-Mar | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 25-Mar | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 26-Mar | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 27-Mar | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 28-Mar | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 29-Mar | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 0 | 12 | 0.00% | 2 | 0 | 2 | 0 | 0 | 0 |
| 30-Mar | 0 | 0 | 0 | | 2 | 1 | 3 | 0 | 0 | 0 | 124 | 0 | 124 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 31-Mar | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 18 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-Apr | 0 | 0 | 0 | | 3 | 0 | 3 | 0 | 0 | 0 | 100 | 0 | 100 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 2-Apr | 0 | 0 | 0 | | 0 | 0 | 0 | 1 | 0 | 1 | 77 | 2 | 79 | 2.53% | 0 | 0 | 0 | 0 | 0 | 0 |
| 3-Apr | 0 | 0 | 0 | | 0 | 0 | 0 | 3 | 0 | 3 | 27 | 0 | 27 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 4-Apr | 0 | 0 | 0 | | 0 | 0 | 0 | 3 | 2 | 5 | 67 | 0 | 67 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 5-Apr | 0 | 0 | 0 | | 1 | 0 | 1 | 0 | 0 | 0 | 41 | 2 | 43 | 4.65% | 0 | 0 | 0 | 0 | 0 | 0 |
| 6-Apr | | | | | | | | | | | Traps were not checked | | | | | | | | | |
| 7-Apr | | | | | | | | | | | | | | | | | | | | |
| 8-Apr | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 202 | 2 | 204 | 0.98% | 0 | 0 | 0 | 0 | 0 | 0 |
| 9-Apr | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 10-Apr | 24 | 0 | 24 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 588 | 25 | 613 | 4.08% | 1 | 0 | 1 | 0 | 0 | 0 |
| 11-Apr | 26 | 9 | 35 | 25.71% | 5 | 0 | 5 | 0 | 0 | 0 | 229 | 38 | 267 | 14.23% | 0 | 0 | 0 | 0 | 0 | 0 |
| 12-Apr | 97 | 18 | 115 | 15.65% | 4 | 3 | 7 | 1 | 0 | 1 | 190 | 7 | 197 | 3.55% | 0 | 0 | 0 | 0 | 0 | 0 |
| 13-Apr | 0 | 1 | 1 | 100.00% | 0 | 0 | 0 | 0 | 0 | 0 | 228 | 22 | 250 | 8.80% | 0 | 0 | 0 | 0 | 0 | 0 |
| 14-Apr | 191 | 136 | 327 | 41.59% | 27 | 11 | 38 | 3 | 2 | 5 | 4,055 | 180 | 4235 | 4.25% | 16 | 0 | 16 | 0 | 0 | 0 |
| 15-Apr | 237 | 180 | 417 | 43.17% | 245 | 0 | 245 | 2 | 5 | 7 | 385 | 192 | 577 | 33.28% | 20 | 3 | 23 | 0 | 0 | 0 |

Table 1. Continued

| | South Weir | | | | | | | | | | North Weir | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chum | | | | Coho | | | | | | Chum | | | | Coho | | | | | |
| | Age 0+ | | | | Age 0+ | | | Age 1+ | | | Age 0+ | | | | Age 0+ | | | Age 1+ | | |
| Date | Live | Dead | Total | % Mort. | Live | Dead | Total | Live | Dead | Total | Live | Dead | Total | % Mort. | Live | Dead | Total | Live | Dead | Total |
| 16-Apr | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 17-Apr | 13 | 8 | 21 | 38.10% | 0 | 0 | 0 | 0 | 0 | 0 | 13 | 8 | 21 | 38.10% | 0 | 0 | 0 | 0 | 0 | 0 |
| 18-Apr | | | | | | | | | | | | | | | | | | | | |
| 19-Apr | | | | | | | | | | Traps were not in operation due to high water | | | | | | | | | | |
| 20-Apr | | | | | | | | | | | | | | | | | | | | |
| 21-Apr | | | | | | | | | | | | | | | | | | | | |
| 22-Apr | 0 | 0 | 0 | | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | | 1 | 0 | 1 | 1 | 0 | 1 |
| 23-Apr | 6 | 7 | 13 | 53.85% | 0 | 0 | 0 | 0 | 0 | 0 | 6 | 7 | 13 | 53.85% | 0 | 0 | 0 | 0 | 0 | 0 |
| 24-Apr | 11 | 6 | 17 | 35.29% | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 6 | 17 | 35.29% | 0 | 0 | 0 | 0 | 0 | 0 |
| 25-Apr | 3 | 8 | 11 | 72.73% | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 8 | 11 | 72.73% | 0 | 0 | 0 | 0 | 0 | 0 |
| 26-Apr | 5 | 0 | 5 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 5 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 27-Apr | 3 | 0 | 3 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 28-Apr | 4 | 0 | 4 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 4 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 29-Apr | 3 | 0 | 3 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 30-Apr | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 1-May | 2 | 0 | 2 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 2-May | 3 | 0 | 3 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 3-May | 4 | 0 | 4 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 4 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 4-May | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 |
| 5-May | 0 | 0 | 0 | | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | 1 | 0 | 1 | 0 | 0 | 0 |
| 6-May | 3 | 0 | 3 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 7-May | 23 | 0 | 23 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 23 | 0 | 23 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 8-May | 2 | 0 | 2 | 0.00% | 2 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 2 | 0.00% | 2 | 0 | 2 | 0 | 0 | 0 |
| 9-May | | | | | | | | | | | Traps were not checked | | | | | | | | | |
| 10-May | 45 | 0 | 45 | 0.00% | 6 | 0 | 6 | 0 | 0 | 0 | 45 | 0 | 45 | 0.00% | 6 | 0 | 6 | 0 | 0 | 0 |
| 11-May | 5 | 0 | 5 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 5 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 12-May | 2 | 0 | 2 | 0.00% | 4 | 0 | 4 | 0 | 0 | 0 | 2 | 0 | 2 | 0.00% | 4 | 0 | 4 | 0 | 0 | 0 |
| 13-May | 1 | 0 | 1 | 0.00% | 3 | 0 | 3 | 0 | 0 | 0 | 1 | 0 | 1 | 0.00% | 3 | 0 | 3 | 0 | 0 | 0 |
| 14-May | 2 | 0 | 2 | 0.00% | 1 | 0 | 1 | 0 | 0 | 0 | 2 | 0 | 2 | 0.00% | 1 | 0 | 1 | 0 | 0 | 0 |

Table 1. Continued

| | South Weir | | | | | | | | | | North Weir | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Chum | | | | Coho | | | | | | Chum | | | | Coho | | | | | |
| | Age 0+ | | | | Age 0+ | | | Age 1+ | | | Age 0+ | | | | Age 0+ | | | Age 1+ | | |
| Date | Live | Dead | Total | % Mort. | Live | Dead | Total | Live | Dead | Total | Live | Dead | Total | % Mort. | Live | Dead | Total | Live | Dead | Total |
| 15-May | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 16-May | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 9 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 17-May | 2 | 0 | 2 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 7 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 18-May | 1 | 0 | 1 | 0.00% | 1 | 0 | 1 | 0 | 0 | 0 | 12 | 0 | 12 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 19-May | 0 | 0 | 0 | | 4 | 0 | 4 | 0 | 0 | 0 | 48 | 1 | 49 | 2.04% | 0 | 0 | 0 | 0 | 0 | 0 |
| 20-May | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 14 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 21-May | 1 | 0 | 1 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 | 28 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 22-May | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 20 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 23-May | 5 | 0 | 5 | 0.00% | 7 | 0 | 7 | 0 | 0 | 0 | 69 | 0 | 69 | 0.00% | 1 | 0 | 1 | 0 | 0 | 0 |
| 15-May | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 16-May | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 0 | 9 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 17-May | 2 | 0 | 2 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0 | 7 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 18-May | 1 | 0 | 1 | 0.00% | 1 | 0 | 1 | 0 | 0 | 0 | 12 | 0 | 12 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 19-May | 0 | 0 | 0 | | 4 | 0 | 4 | 0 | 0 | 0 | 48 | 1 | 49 | 2.04% | 0 | 0 | 0 | 0 | 0 | 0 |
| 20-May | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 0 | 14 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 21-May | 1 | 0 | 1 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 | 28 | 0 | 28 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 22-May | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | 20 | 0.00% | 0 | 0 | 0 | 0 | 0 | 0 |
| 23-May | 5 | 0 | 5 | 0.00% | 7 | 0 | 7 | 0 | 0 | 0 | 69 | 0 | 69 | 0.00% | 1 | 0 | 1 | 0 | 0 | 0 |
| Seining | | | | | | | | | | | | | | | | | | | | |
| 23-May | 12 | 0 | 12 | | 79 | 0 | 79 | 0 | 0 | 0 | 107 | 0 | 107 | | 1 | 0 | 1 | 0 | 0 | 0 |
| Totals | 738 | 374 | 1,112 | 33.63% | 437 | 36 | 473 | 23 | 13 | 36 | 6,799 | 500 | 7,299 | 6.85% | 59 | 3 | 62 | 1 | 0 | 1 |