Reintroduction of Lower Columbia River Chum Salmon into Duncan Creek
2007 Annual Report

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Forward

The National Marine Fisheries Service (NMFS) listed Lower Columbia River (LCR) chum salmon as threatened under the Endangered Species Act (ESA) in March, 1999 (64 FR 14508, March 25, 1999). The listing was in response to the reduction in abundance from historical levels of more than one-half million returning adults to fewer than 10,000 present-day spawners (Johnson et al. 1997). Harvest, habitat degradation, changes in flow regimes, riverbed movement and heavy siltation have been largely responsible for this decline (Johnson et al. 1997). The timing of seasonal changes in river flow and water temperatures is perhaps the most critical factor in structuring the freshwater life history of this species (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.

Prior to 1997, only two chum salmon populations were recognized as genetically distinct in the Columbia River, although spawning had been documented in many Lower Columbia River tributaries. The first population was in the Grays River (Rkm 34), a tributary of the Columbia River, and the second was a group of spawners utilizing the mainstem Columbia River just below Bonneville Dam (Rkm 235) adjacent to Ives Island and in Hardy and Hamilton creeks (Johnson *et al.* 1997). Using additional DNA samples, Small *et al.* (2006) grouped chum salmon spawning in the mainstem Columbia River and the Washington State tributaries into three groups: the Coastal, the Cascade and the Gorge. The Coastal group comprises those spawning in the Grays River, Skamokawa Creek and the broodstock used at the Sea Resources facility on the Chinook River. The Cascade group comprises those spawning in the Cowlitz (both summer and fall stocks), Kalama, Lewis, and East Fork Lewis rivers, with most supporting unique populations. The Gorge group comprises those spawning in the mainstem Columbia River from the I-205 Bridge up to Bonneville Dam and those spawning in Hamilton and Hardy creeks.

Response to the federal ESA listing has been primarily through direct-recovery actions: reducing harvest, hatchery supplementation using local broodstock for populations at catastrophic risk, habitat restoration (including construction of spawning channels) and flow agreements to protect spawning and rearing areas. Both state and federal agencies have built controlled spawning areas. In 1998, the Washington Department of Fish and Wildlife (WDFW) began a chum salmon supplementation program using native stock on the Grays River. This program was expanded during 1999 – 2001 to include reintroduction into the Chinook River using eggs from the Grays River Supplementation Program. These eggs are incubated at the Grays River Hatchery, reared to release size at the Sea Resources Hatchery on the Chinook River, and the fry are released at the mouth of the Chinook River.

Native steelhead, chum, and coho salmon are present in Duncan Creek, and are recognized as subpopulations of the Lower Gorge population (Myers et al. 2003), and are focal species in the Lower Columbia Fish Recovery Board (LCFRB) plan. Steelhead, chum and coho salmon that spawn in Duncan Creek are listed as Threatened under the ESA. Duncan Creek is classified by the LCFRB plan as a watershed for intensive monitoring (LCFRB 2004). This project was identified in the 2004 Federal Columbia River Power System (FCRPS) revised Biological Opinion (revised BiOp) to increase survival of chum salmon, “BPA will continue to fund the program to re-introduce Columbia River chum salmon into Duncan Creek as long as NOAA Fisheries determines it to be an essential and effective contribution to reducing the risk of extinction for this ESU.” (USACE *et al.* 2004, page 85-86). The Governors Forum on Monitoring and Salmon Recovery and Watershed Health recommends one major population from each ESU have adult and juvenile monitoring (Rcukelshaus and Koenings 2006). Duncan Creek chum salmon are identified in this plan to be intensively monitored. This project is

consistent with the Columbia Basin System Planning Salmon and Steelhead Production Plan for chum salmon in the lower Columbia Subbasin (WDF et al. 1990). Planners recommended that a combination of natural and hatchery production would be the most likely way to produce the most rapid sustainable improvement in chum runs. Specifically, it was assumed that improving habitat conditions would promote efficient natural production, and that the most rapid way to rebuild the run would be to combine releases of an appropriate stock into the improved habitat (WDF et al. 1990).

WDFW's recovery strategy for LCR chum salmon, as outlined in the WDFW Grays River and Washougal Hatchery Genetic Management Plans (HGMP), is as follows. First, determine if remnant populations of chum salmon exist in LCR tributaries. Second, if such populations exist, develop stock-specific recovery plans involving habitat restoration that include the creation of spawning refugias, supplementation where necessary, and a habitat and fish monitoring and evaluation plan. If chum salmon have been extirpated from previously utilized streams, develop reintroduction plans that utilize appropriate genetic donor stock(s) of LCR chum salmon, and integrate habitat improvement and fry-to-adult survival evaluations.

The Duncan Creek Project was developed using the recovery strategy implemented for LCR chum salmon. Biologists with WDFW and the Pacific States Marine Fisheries Commission (PSMFC) identified Duncan Creek as an ideal upriver location below Bonneville Dam for chum salmon reintroduction. It has several attributes that make it a viable location for a reintroduction project: chum salmon were historically present, the creek is low gradient, has numerous springs/seeps, has a low potential for future development and is located close to a donor population of Lower Gorge (LG) chum salmon.

The Duncan Creek Project has two goals: 1) reintroduction of chum salmon into Duncan Creek by providing off-channel high-quality spawning and incubation areas, and 2) to simultaneously evaluate natural recolonization and supplementation strategies. The tasks associated with reestablishing a naturally self-sustaining population include: 1) removing mud, sand and organics present in four of the creek branches, and replacing them with gravels expected to provide maximum egg-to-fry survival rates at a depth of at least two feet (completed in 2001); 2) armoring the sides of these channels to reduce importation of sediment by fish spawning on the margins (ongoing); 3) planting native vegetation adjacent to the channels to stabilize the banks, trap silt and provide shade (ongoing); 4) annual sampling of gravel in the spawning channels to detect changes in gravel composition and sedimentation levels (ongoing). Schroder (2000) developed the tasks associated with the second goal of the recovery strategy for LCR chum salmon, and they are detailed in the Monitoring and Evaluation Plan for the Duncan Creek Chum Salmon Reintroduction Program (Duncan M&E). Four criteria are used to evaluate the success of this program: 1) the egg-to-fry survival rates in the renovated channels, 2) the survival of the eggs and fry used in the artificial rearing program in Duncan Creek, 3) the survival and spawning-ground distribution of adult chum salmon produced from the spawning channels and the artificial rearing program, and 4) 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 Reintroduction Efforts

Currently, two methods of reintroduction are being simultaneously evaluated at Duncan Creek. Recolonization is occurring by introducing adult chum salmon from the LG population into Duncan Creek and allowing them to naturally reproduce. The other supplementation strategy requires adults to be collected and artificially spawned, incubated, reared, and fed-fry released at the mouth of Duncan Creek.

Part I: Adult Returns to Duncan Creek and Mainstem Seining

Introduction

Capturing returning adults from project releases, and developing accurate population estimates are critical to evaluating the success of the different reintroduction strategies used at Duncan Creek. Three types of information are needed to produce survival estimates and to make assessments about where adult chum salmon from the Duncan Creek Project spawn (Schroder 2000). First, accurate project-origin fry numbers, from both hatchery releases and those naturally produced in the spawning channels. Second, all project fry produced must be marked for identification as adults. Finally, adults returning to local spawning areas need to be sampled for these marks and accurate estimates of the spawning population must be made at all locations where adults are sampled for marks. In addition to providing data needed to evaluate the success of reintroduction strategies, adult trapping at Duncan Creek may provide an additional source of broodstock.

Operating an adult trap at the Duncan Creek Dam has been problematic. The Duncan M&E recommended an adult “V” weir trap and live box be used at the Duncan Creek Dam to enumerate adult chum salmon that enter Duncan Creek (Schroder 2000). The dam structure provides the only structure/solid ground near the creek mouth where a trap could be placed. The dam at Duncan Creek consists of two main parts: a lake level control/fish passage side (sluiceway), and a spillway side. Figure 1 is a picture of the dam taken in October of 2002 as the lake was being lowered to allow for fish passage. In the upper right side of the picture, the spillway side of the dam can be seen. The left side of the dam is a concrete sluiceway with two vertical weir gates. These gates are closed to maintain the lake during the summer, then held in the raised position during the fall, winter and early spring to provide fish passage. This sluiceway provided the best location to place the adult trap.

Analysis of historic Columbia River water levels, measured on the south bank 0.9 miles downstream from the Bonneville Dam powerhouse approximately 50 feet upstream from Tanner Creek (Rm144.5) (USGS Tanner Creek Gauge <http://waterdata.usgs.gov/or/nwis/uv?14128870>) during trapping months (October through December 1981-2002), showed river levels resulting in over 8 feet of water depth in the dam sluiceway. A value of approximately 11.2 at this gauge results in a Columbia River water level equal to the bottom of the concrete sill at the sluiceway, and allows for adult passage when combined with the outflow from Duncan Creek. Tanner Creek staff gauge levels of 11.5 and above are necessary for the Columbia River to inundate the floor of the sluiceway. Because of the relatively short trapping

season and the importance of having the trap operational over the whole season, a trap was needed that could operate under a great range of water depths. WDFW biologists, working in cooperation with KPFF Engineering, designed a trap that would function similarly to the fish brails used at hatcheries.

Figure 1. Duncan Creek Dam structure from the downstream side (Columbia River) during lake lowering, 2002.

A severe storm in early November, 2006, with near record levels of precipitation, resulted in both high amounts of water and debris that had to pass through the adult trap at the dam. The trap was not able to withstand the pressure created by the debris load on the upstream weir and it was torn from its mounting bolts. When the trap was pushed down the sluiceway it removed the downstream cross-weirs. More details on this event are provided in the **Results** section. To compensate for losing the adult trap, walking surveys were done to enumerate and recover salmonid carcasses in Duncan Creek.

Seining was identified by Schroder (2000) as the method that would be used to collect broodstock from mainstem spawning areas. Adults were to be captured as they staged and spawned in shallow water (< 10' deep). During the fall of 2001 and 2002, tangle nets were used (200' x 12' x 2" "floating" type) to capture adults. Tangle nets catch adults by their maxillary bones and teeth, which, while effective, fish removal is very labor intensive and may be selective for more mature adults and males. During the fall of 2003, we evaluated beach seines (200' x 12' with ¼ inch mesh "sinking" type) as an alternative method to capture adults. The beach seine did not appear to be selective and allowed for faster processing of adults out of the nets. Tangle nets required all adults to be removed and placed into a second holding net before any could be processed. Using the beach seine eliminated this step since the

adults could be left crowded up in the beach seine without fear of additional injury or mortality, thus increasing efficiency in the field. Switching to a sinking style net also allowed deeper water to be fished. After minimal testing, the beach seine proved preferable and use of the tangle net was discontinued in 2003.

In addition to supplying broodstock for supplementation, mainstem seining provides the opportunity to estimate spawning area populations via mark/recapture. Area-Under-the-Curve (AUC) is the primary method used by PSMFC and Oregon Department of Fish and Wildlife (ODFW) to estimate mainstem and tributary Columbia River chum escapement, but they have also used mark-recapture of carcasses and peak counts to estimate populations for the Ives Island group (van der Naald et al. 2002, 2003, 2004 and 2005). WDFW has expressed concern about the observer efficiency and residence time assumptions needed to develop accurate and precise AUC or peak count expansion population estimates for mainstem Columbia River spawning sites (Rawding and Hillson 2003). Rawding and Hillson (2003) compared mark-recapture methods in 2002 with AUC and peak count expansion and found that peak count and AUC estimates were biased low due to an overestimate of residence time and an underestimate of observer efficiency (Figure 2). Since this project requires accurate and precise estimates to evaluate reintroduction strategies and potential straying of project-origin chum salmon, this project has marked and released adults seined for broodstock but not used, to make independent population estimates using the Jolly-Seber and Petersen models for mainstem spawning locations.

Figure 2. Comparison of chum salmon population estimates derived from five different methods for I-205 area (vertical bars indicate 95% CI), 2003.

Minimum represents minimum number of unique adults from seining and tagging (# tagged plus untagged carcass recoveries), **JS Carc Tagging** represents a Jolly-Seber model carcass tagging experiment done by BPA Project #199900301, **JS Seine** represents seining and re-seining efforts and **Petersen** represents a live mark and dead recovery pooled Petersen estimate.

Methods

Returns to Duncan Creek: Adult Trapping and Walking Surveys

The details of design, construction, installation and modifications made for the adult trap at Duncan Creek has been well documented in previous annual reports (Hillson 2003) and will not be repeated here. The only changes in the trap from prior years were the removal of one board from each of the cross-weirs to reduce the water levels in the sluiceway, and the last cross-weir was moved closer to the lip of the sluiceway. Both of these changes were recommendations from the 2006 annual report.

Adult salmonids in the trap were captured either by hand or by using an adult dip net. Unmarked adults were placed into an anesthetic bath (MS-222) until calm enough for sampling. Biological data collected from adults included: species, sex, marks/clips, presence/absence of coded wire tag (CWT) and fork length. In addition, scale and DNA samples were collected from chum salmon adults. Each adult was marked with two uniquely numbered Floy anchor-dart tags (Floy Tag & Manufacturing, Inc., Seattle, WA.) prior to release. Adults were allowed to recover from the anesthetic in the trap prior to release. All chum salmon were taken to the spawning channels and released above the monitoring weirs. All other salmonids were released into Duncan Creek at the railroad bridge (RM 0.79). A staff gauge was attached to the trap box for monitoring water depth across the trap's floor.

After the adult trap was destroyed and river levels dropped, walking surveys were done in the spawning channels from the monitoring weirs down to their confluence with the creek and in the creek, from approximately 50 yards upstream of that confluence down as far as lake levels and mud would permit. These surveys occurred almost daily during periods of high fish abundance (through early December) and then to two or three times per week until the end of the season. In addition, Duncan Creek was surveyed weekly from the railroad bridge down to the dam, river levels and mud permitting. During these surveys, adults and redds were enumerated and carcasses sampled for biological data, otoliths and DNA samples were collected from carcasses when possible.

To increase the number of naturally produced chum salmon fry available for strontium marking the following spring, and the likelihood of recovering the adult carcasses, chum salmon seen during walking surveys were captured and placed above the monitoring weirs using either a small stick-seine or a dip-net. To ensure that at least one rate of egg-to-fry survival would be comparable to prior years, all adults collected from Duncan Creek were placed above the north monitoring weir. The channels above the south monitoring weir were reserved for adults collected from mainstem areas that met broodstock criteria (criteria detailed in the following section).

Mainstem Seining

Normalized broodstock collection curves were created using 2002-05 abundance data from Columbia River mainstem spawning sites (Figure 3) for hatchery broodstock, and tributary spawning locations for direct adult supplementation broodstock (Figure 4). Weekly collection goals were then calculated based

on the season's cumulative goal for broodstock. If weekly goals were not met, additional adults could be collected during the following weeks to meet the cumulative collection total.

Figure 3. Normalized arrival timing for Ives Island area chum salmon, 2002-05, used for a hatchery broodstock collection curve.

Figure 4. Normalized arrival timing of Hamilton and Hardy creeks adult chum salmon, 2002 – 05, used for direct adult supplementation broodstock collection.

As in past years, the collection goal for both supplementation programs was a minimum of 35 pairs as recommended by Schroder (2000) to maintain genetic diversity. Additionally, broodstock collection goals are set for each channel based on desired spawner density. The 2006 spawner density goals were 25% (40 pairs) and 40% (36 pairs), north and middle channels respectively.

The same criteria have been in place since 2002 for selecting adults to be used in either supplementation program. For inclusion in the hatchery program, females needed to be in good condition, show no signs of redd digging activity (e.g. wear on the lower caudle fin) and, when checked for ripeness, have a soft belly indicating a loose egg mass. Since the intention was to spawn all fish the day following collection, fully green females were intentionally excluded during hatchery broodstock selection. For inclusion in the direct-adult supplementation program, females needed to be in good condition, show no signs of redd digging activity and have a firm belly indicating a complete egg mass. Males needed to be at least in fair condition and produce milt when checked for ripeness to be used in either program.

The strict criteria for inclusion in either program for females, combined with declining returns of chum salmon to spawning areas near Bonneville Dam (nearly 30% each year 2002-2005) have prevented the project from reaching broodstock collection goals in most years. In response, the criteria for females were changed for both programs. Beginning in 2006, females that showed signs of digging but were estimated to still have >75% of their eggs could be retained for hatchery broodstock. However, preference was given to females that met the original collection criteria to fill daily collection goals. To increase the number of direct supplementation adults placed into the spawning channels, ripe and partially spawned (>75% eggs still present) females could be placed above one of the two monitoring weirs. Only green females were placed above the other monitoring weir. This allowed for one accurate,

unbiased estimate of egg-to-fry survival. The criteria for males to be included in either program were not changed.

Personnel from WDFW and PSMFC collected adults from several known spawning locations using beach seines. A sinking style 200 foot x 12 foot beach seine with ¼ inch mesh was used exclusively for adult capture in 2006. Adults were captured as they staged and spawned in shallow water (< 18' deep). Mainstem seining locations include the Ives, Horsetail, Multnomah, St Cloud and I-205 (Woods and River Shore) areas. While Small *et al.* (2004) grouped chum salmon spawning in the mainstem Columbia River from the I-205 Bridge up to Bonneville Dam and those spawning in Hamilton and Hardy creeks into one group, the I-205 area was found to be genetically distinct from those spawning near Bonneville Dam. Consequentially, no supplementation broodstock are collected from the I-205 area. Seining in this area is done exclusively for population estimates.

Seines were set on foot or by boat, depending on flow conditions and water depths. Start and stop points for each area were designated in 2003 and have remained consistent to the extent that flow and river levels allow.

Adults selected for inclusion into a supplementation program were marked with uniquely numbered Ketchum wing band tags (National Band and Tag Company, Newport KY.) applied to the left opercle so that at spawning/recovery the date, time and location of capture could be identified. After tagging, the adults were placed into a fish tube made of three foot sections of 10" diameter PVC pipe, perforated with several one and a half inch holes, and equipped with removable end pieces. These tubes were used to hold adults in the field while processing the remaining adults caught in a seine set. The same holding tubes were used to keep adults separate during transport. A 400-gallon tanker truck equipped with an oxygen supply was used exclusively during the 2006 season to transport fish collected during seining activities.

Results

Returns to Duncan Creek: Adult Trapping and Walking Surveys

Trap installation took one day and was completed on November 2, 2006. The following day, as recommended in last year's annual report, one board was removed from each cross-weir to reduce water depth in the sluiceway and lake level, and the bottom cross-weir was moved closer to the lip of the sluiceway. Full-time trapping began the afternoon of November 3, 2006. Unfortunately, a severe storm brought heavy precipitation to the region soon after the trap was installed (Figure 5). This storm resulted in not only a dramatic increase in creek discharge that had to pass through the trap but also large amounts gravel and large woody debris coming out of the headwaters area of Duncan Creek. Despite setting the control gates at a level that should have prevented floating woody debris from entering the sluiceway, enough debris made it under the gates to remove the adult trap and cross weirs, destroying them in the process. This occurred sometime during the night of November 5, 2006; local residents reported hearing loud noises around 2 AM but did not investigate.

In the two days the trap was functional, 28 coho salmon were captured (Table 1). After sampling and tagging, all 28 adults were transported to the railroad bridge on Duncan Creek and released.

Figure 5. Comparison of average daily discharge (cfs), November 1-15, 2006 and average daily discharge November 1-15 1999-2005, USGS gauge 14222500 East Fork Lewis River, near Heisson, WA.

Table 1. Daily trapping totals at Duncan Creek Dam, fall 2006.

Date	Chum	Coho		Chinook	Steelhead	
	Unmarked	Ad-clipped	Unmarked	Unmarked	Ad-clipped	Unmarked
Nov 4		12	5			
Nov 5		8	3			
Total	0	20	8	0	0	0

To compensate for the lack of an adult trap, walking surveys were conducted to count/recover adult salmonids that volunteered to Duncan Creek. Estimating the number of adult chum salmon that volunteered to Duncan Creek using survey live counts was explored but not used due to complications in using the AUC methodology when fish are removed from the survey area. Carcass recovery rates of adults placed in the spawning channels, fall 2002 through fall 2005, ranged from 98-100%, averaging 99.1%. Given this high recovery rate of carcasses, the number of adults captured in Duncan Creek and the channels below the monitoring weirs, 33 adults (14 males and 19 females), and the number of carcasses recovered below the monitoring weirs and in the creek itself, 9 adults (five males and four females), were combined to estimate the 2006 adult return to Duncan Creek, 42 adults total (19 males and 23 females).

Mainstem Seining

To maximize the likelihood of capturing females that will meet the criteria for inclusion in a supplementation program, each site was seined twice a week once chum presence was expected. To accomplish this, two seining crews were used, one to work in the Bonneville Dam area and another for the I-205 area. Daily seining totals of salmonids, by area, are detailed in Table 2. This table contains only maiden (first capture) data for chum salmon. Other species are not tagged prior to release so it is possible for other salmonid species to be double counted in this table. The storm that destroyed the adult trap at Duncan Creek also impacted mainstem seining. Unusually high river levels prevented us from seining each of the four locations in the Ives area or making “normal” sets in the other seining areas until flow and river levels returned to a more normal condition. High river levels prevented seining on November 9, 2006, at the Horsetail, Multnomah, St Cloud and I-205 areas. It wasn’t until after November 16, 2006, that we were able to set all locations normally again. Inclement weather prevented seining December 7-8, 2006, at Ives, Horsetail, Multnomah and St Cloud. A second substantial storm, this one in the Upper Columbia River Basin, resulted in increased flows and river levels disrupting seining again in mid-December (Figure 6). High river levels prevented seining on December 15, 2006, at the Horsetail, Multnomah and St Cloud areas and again December 28-29, 2006, at Ives, Horsetail, Multnomah and St Cloud areas.

Eighty-seven adults captured during mainstem seining activities were retained for use in supplementation programs. Totals retained by method were 57 (28 males and 29 females) and 30 (15 males and 15 females), hatchery and direct-adult supplementation, respectively (Table 3 and 4).

Table 2. Adult seining data (maiden captures only for chum salmon), fall 2006.

Date	Location	Chum	Chinook	Coho	Steelhead	
					Marked	Un-marked
11/1	I-205 (Woods)	0				1
11/2	Ives Area	3	2	68		
11/3	Horsetail, Multnomah and St. Cloud	0		2		
11/7	Ives Area*	1	2			
11/7	I-205 (Woods and River Shore)	0				
11/13	Ives Area*	3	3			
11/14	Horsetail, Multnomah and St. Cloud*	0				
11/14	I-205 (Woods and River Shore)*	0				
11/15	Ives Area*	0	0			
11/16	Ives Area	20	43	3		
11/16	I-205 (Woods and River Shore)	19				
11/17	Horsetail, Multnomah and St. Cloud*	11		1	1	
11/20	Ives Area	36	74	4		
11/20	I-205 (Woods and River Shore)	34				
11/21	Horsetail, Multnomah and St. Cloud	39				
11/22	Ives Area	11	42			
11/24	I-205 (Woods and River Shore)	109				
11/27	Ives Area	27				
11/27	I-205 (Woods and River Shore)	91				
11/28	Horsetail, Multnomah and St. Cloud	87				
11/29	Ives Area	11				
11/30	I-205 (Woods and River Shore)	123				
12/1	Horsetail, Multnomah and St. Cloud	111				
12/4	Ives Area	124				
12/4	I-205 (Woods and River Shore)	78				
12/5	Horsetail, Multnomah and St. Cloud	41				
12/7	I-205 (Woods and River Shore)	102				1
12/11	Ives Area	54				
12/11	I-205 (Woods and River Shore)	50				
12/12	Horsetail, Multnomah and St. Cloud	17				
12/14	Ives Area	19				
12/14	I-205 (Woods and River Shore)	30				
12/18	Ives Area	9				
12/18	I-205 (Woods and River Shore)	4				
12/19	Horsetail, Multnomah and St. Cloud*	4				
12/21	Ives Area*	0				
12/21	I-205 (Woods and River Shore)	3				
12/22	Horsetail, Multnomah and St. Cloud*	1				
12/26	Ives Area*	0				
12/28	I-205 (Woods and River Shore)	0				

* Denotes a day when seining deviated from normal sets due to high flows or river levels.

Figure 6. Comparison of average daily river level (ft), Nov. 1 – Dec. 31, 2006 and average daily river level Nov. 1 – Dec 31, 2002-2005, USGS gauge 14128870 Columbia River below Bonneville Dam, OR.

Table 3. Date of capture and origin of adults taken to Washougal Hatchery, fall 2006.

Date	Location	Total number adult chum salmon seined	# Taken to Washougal Hatchery	
			Male	Female
11/20	Ives Area	36	2	2
11/21	Multnomah Area	27	3	4
11/21	St. Cloud Area	16	4	3
11/28	Multnomah Area	60		8
11/28	St. Cloud Area	24	8	
12/4	Ives Area	124	3	3
12/5	Multnomah Area	24	2	3
12/5	St. Cloud Area	9	1	
12/11	Ives Area	54	3	4
12/12	Multnomah Area	5		1
12/12	St. Cloud Area	12	2	1
Total		391	28	29

Table 4. Date of capture and origin of adults taken to Duncan Creek, fall 2006.

Date	Location	Total number adult chum salmon seined	# Taken to Duncan Creek	
			Male	Female
11/16	Ives Area	20	2	1
11/20	Ives Area	36	5	5
11/22	Ives Area	11	1	1
11/27	Ives Area	27	1	1
11/28	Multnomah Area	60		2
11/28	St. Cloud Area	24	2	
11/29	Ives Area	11	1	1
12/1	Multnomah Area	69	2	3
12/4	Ives Area	124	1	1
Total		414	15	15

Discussion

Returns to Duncan Creek: Adult Trapping and Walking Surveys

The loss of the adult trap to high water and debris was unfortunate, and regrettably, preventable. The creek conditions resulting from the storm, particularly the amount of debris produced, were underestimated. Despite placing the water-control gates at an elevation that should have caught debris and kept it upstream of the trap, enough debris passed under the gates to occlude the upstream weir. Once blocked, head pressure built until the mounting bolts failed. The thought at the time was that by restricting the amount of water that could pass the dam, the lake would reform and eventually reach the level where water/debris would exit over the lowered spillway. Looking back now at the flow produced by the storm, it is highly unlikely that any chum salmon would have attempted to enter Duncan Creek during the storm or soon after it ended. The best course of action probably would have been to shut the trap down by closing the water control gates completely and letting the lake re-fill, and then dealing with the reformed lake and debris once outflow decreased to normal levels.

Rawding and Hillson (in prep) estimate the LG chum salmon spawning population (Ives Island, Horsetail, Multnomah and St. Cloud groups, excluding tributary spawners) for the fall of 2006 was 955, yielding an observed stray rate into Duncan Creek of 4.4% (42/955), the highest rate seen in project history. This compares to rates of 1.26%, 0.17%, 0.90% and 0.20% seen in 2005, 2004, 2003 and 2002 respectively (Hillson 2006). Decoding of otoliths recovered from adults recovered in Duncan Creek, detailed in **Part V: Adult Returns** of this report, will further define the 2006 stray rate since project-origin adults are not strays. However, since natural-origin fry originating from the spawning channels were not marked until 2004, age-4 and age-5 adults produced from the spawning channels (2002 and 2003 outmigrants) cannot be identified.

Having an adult trap at the mouth of Duncan Creek is very important to the project. The trap not only allows for a census count of returning chum salmon adults, but provides a location for collection of direct-adult supplementation broodstock. Given its importance, funds were requested to replace the trap and the cross-weirs. In August of 2006, funds were approved and the trap and cross-weirs should be in place before the fall 2007 adult return. The new trap will function in the same manner as the original trap

but will have the capability of being installed and removed without a boom-truck and construction crew. This will not only allow project personnel to install and remove the trap annually after initial installation, thus reducing out-year budgets, but will also allow prompt removal if environmental conditions threaten the trap in future years.

Mainstem Seining

High water levels did impact mainstem seining by forcing changes in set locations, start and stopping points during the season. While this may bias direct comparisons to numbers captured during seining in past years, the method was still effective at capturing broodstock and allowed population estimates to be calculated via a mark/recapture methodology.

Annual impacts, numbers and values of percent handled and removed for supplementation programs, are detailed in Table 5. Number unique and percent handled were calculated by adding the number of maiden adults caught in a location on a day when broodstock collection for that specific supplementation method could have occurred, percents were derived by dividing that total by the population estimate. Numbers handled and percentages cannot be added together for total impacts since broodstock collection for both methods can and does occur on the same day. The numbers handled are not the same because broodstock collection for the hatchery only occurs on two of the four weekly seining days. Numbers removed can be added to estimate the impact of broodstock collection. While a statistical analysis was not done, all 2006 values fall within or very near values of past years. The overall impact, percent removed for broodstock to support both supplementation programs from areas where broodstock were removed for 2006 was estimated to be 4.5% (87/1,929), very close to the 2005 value of 4.4% (59/1,340). This reinforces the fact that success in collecting/meeting broodstock goals is highly dependant on retuning adult numbers. It is surprising that relaxing the criteria for females to be used in the hatchery program did not result in a larger increase in the 2006 impact. It is encouraging to see that 2006 population estimates increased in all but one location when compared to 2005 values. This halts a decreasing trend in area and overall population size that has persisted since 2003.

Table 5. Population estimates (95% CI), numbers handled (%) and number removed (%) for supplementation programs by seining area and brood year, 2002-2006.

Location, Year	Population Estimate (95% CI)	Number unique (% Handled)		Number Removed (%)		
		Channels	Hatchery	Channels	Hatchery	Combined
Ives Area ¹						
2002	3,179 (+/- 293)	Unknown ²	Unknown ²	50 (1.6%)	171 (5.4%)	221 (7.0%)
2003	1,901 (+/- 283)	225 (11.8%)	185 (10.0%)	15 (0.8%)	29 (1.6%)	44 (2.3%)
2004	1,408 (+/- 276)	407 (39.1%)	None	27 (2.6%)	None	27 (2.6%)
2005	1,018 (+/- 212)	339 (33.3%)	229 (22.4%)	28 (2.8%)	6 (0.6%)	34 (3.3%)
2006	1,380 (+/- 542)	315 (22.8%)	254 (18.4%)	21 (1.5%)	17 (1.2%)	38 (2.8%)
Horsetail						
2002	Not seined	Not seined	Not seined	Not seined	Not seined	Not seined
2003	Not seined	Not seined	Not seined	Not seined	Not seined	Not seined
2004	102 (+/- 27)	59 (57.8%)	None	1 (1.0%)	None	1 (1.0%)
2005	19 (+/- 0) ³	13 (68.4%)	None	1 (5.3%)	None	1 (5.3%)
2006	63 (+/- 30)	22 (34.9%)	12 (19.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
Multnomah						
2002	1,267 (+/- 421)	None	None	None	None	0 (0.0%)
2003	1,024 (+/- 59)	380 (37.1%)	377 (36.8%)	18 (1.8%)	26 (2.5%)	44 (4.3%)
2004	652 (+/- 68)	388 (59.5%)	None	29 (4.4%)	None	29 (4.4%)
2005	211 (+/- 33)	100 (47.4%)	61 (28.9%)	9 (4.3%)	13 (6.2%)	22 (10.4%)
2006	313 (+/- 52)	187 (59.7%)	117 (37.3%)	7 (2.2%)	21 (6.7%)	28 (8.9%)
St. Cloud						
2002	Not seined	Not seined	Not seined	Not seined	Not seined	Not seined
2003	180 (+/- 25)	115 (63.9%)	101 (56.1%)	21 (11.7%)	23 (12.8%)	44 (24.4%)
2004	109 (+/- 20)	79 (72.5%)	None	11 (10.1%)	None	11 (10.1%)
2005	92 (+/-48)	31 (33.7%)	18 (19.6%)	1 (1.1%)	1 (1.1%)	2 (2.2%)
2006	173 (+/- 68)	102 (59.0%)	60 (34.7%)	2 (1.2%)	19 (11.0%)	21 (12.1%)
I-205 Area						
2002	3,468 (+/- 352)	Unknown ²	Unknown ²	15 (0.4%)	0 (0.0%)	15 (0.4%)
2003	2,844 (+/-159)	None	None	None	None	None
2004	2,102 (+/- 290)	None	None	None	None	None
2005	1,009 (+/- 54)	None	None	None	None	None
2006	862 (+/-32)	None	None	None	None	None

¹ Estimate includes some, if not all, adults destined for tributaries (Hamilton and Hardy creeks).

² Actual number and percent handled unknown because adults were released without tags (unable to calculate number maiden captures).

³ There were no recaptures of tagged adults at this location; population estimate reported here is minimum number maiden fish at location.

Part II: 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 LG population, and to provide a source of chum salmon for reintroduction

into Duncan Creek and other potential spawning sites. This is accomplished both by collecting sufficient numbers of broodstock to maintain genetic diversity, and by collecting those adults over the entire run period. The HGMP for Washougal Hatchery chum salmon calls for at least 35 pairs to be spawned using factorial crosses to maintain genetic diversity. Historical run-timing records were consulted to calculate the number needed weekly to maintain natural run timing. As in prior years, broodstock were collected from known nearby spawning areas of the LG population. Methods used to spawn, incubate, and track various biological parameters from adult collection through fry emergence and ponding are detailed in Schroder (2000). These methods are similar to those presented in the Summer Chum Salmon Conservation Initiative (WDFW and Point no Point Treaty Tribes 2000). Measurements of phenotypic traits collected from females used in the supplementation program provided the necessary data to produce predictive regression formulas of fecundity for estimating the egg-to-fry survival rates of naturally spawning females in the channels.

Methods

Holding, Spawning and Rearing

Upon arrival at the hatchery, fish were kept in the holding/transport tubes and placed on the bottom of an adult holding pond. Fish were re-checked at the hatchery for spawning readiness based on the observed state of ripeness at time of capture. Once the number of ripe females was determined, the number of males needed to perform the factorial cross was calculated. Males were checked for ripeness, and the first available ripe males were used for spawning.

Protocols outlined by Schroder (2000) were followed to spawn, incubate and track various biological parameters from adult collection through fry emergence and ponding. These methods are similar to those presented in the Summer Chum Salmon Conservation Initiative (WDFW and PNPTT, 2000).

In summary, ripe females and males were killed with a sharp blow to the head, and a gill arch was cut to bleed the females. Each fish was labeled by stapling a square of water-proof paper with it's assigned number to the opercle. Fish were numbered consecutively (F-1, F-2, F-3, M-1, M-2, M-3, etc) throughout the spawning season. Before any eggs were removed, each female's weight, fork and mid-eye-to-hypural (MEtH) 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 appeared to have partially spawned were also noted. Each female was wiped down to remove contaminants and water prior to egg collection. Eggs were extracted using a spawning knife and collected in a dry plastic bucket. Milt was collected only after all females in the cross had been spawned. Males were also wiped down prior to spawning and milt was expressed into a clean, dry container. 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 initial estimate of fecundity was calculated. Biological sampling of each fish included scale, pathogen, DNA and GSI samples. Five unfertilized 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 were mixed, water added, and backup milt applied, the eggs were allowed to sit for two minutes. Individual lots were then recombined, if needed, and placed into a Heath incubation tray. Eggs were exposed to an iodophor Betadine (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 reached the eyed stage (~ 400 ° C Temperature Units (TUs)), they were shocked, and 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 eyed eggs. These estimates were then used to calculate the mean and standard deviation. This mean number of eyed eggs, plus the number of non-viable eggs removed, provided a more accurate estimate of fecundity. Folded Vexar, which prevents yolk sac deformations and maximizes yolk material utilization rates, was placed in each Heath tray before returning the eggs to the trays after shocking and picking.

Fish liberated from a recovery program must be marked for identification upon recovery (Schroder et al. 1995), and for comparisons to be made between different treatment groups. All fish released under this hatchery program were thermally marked. Thermal marks are created by manipulating temperatures during the stages between eyed and yolk absorption (Volk et al. 1999). Each time the water temperature is dropped by 2-4° C, a distinctive black band is deposited in the microstructure of a developing otolith (Figure 7). Exposure to chilled water for periods of 8 to 48 hours will essentially create readable bar codes on the otoliths. The bar codes were determined and a schedule established for chilled water applications by personnel in the WDFW Otolith Lab. Hatchery personnel applied the treatments, and voucher samples were taken to determine mark quality and form.

Figure 7. Photomicrographs showing the general appearance of thermally marked salmonid otoliths, from Schroder (2000).

At ~ 800 ° C TU five to ten fry from each Heath tray were visually inspected 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 from the tray:

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

When the average of these individual K_D values was ~ 1.9 , the fry were ready to be ponded. K_D values were calculated again using five fry from each tray when they were ponded. Mortalities and abnormalities were enumerated and recorded for each female when the fry were ponded. These mortality numbers combined with those removed at the eyed stage were used to calculate egg-to-fry survival rates.

For chum salmon recovery projects at WDFW hatcheries, it is recommended that fed fry be reared to 1 - 1.5 grams or 50 - 55 mm in fork length before release. Such fry will likely realize significant survival advantages without suffering any loss in their osmo-regulatory capacity (Steve Schroder, WDFW, personal communication). This size standard will be followed until data specific to a release location or stock indicates an alternative size may have an increased survival potential (Ames et al. 2000).

The fry were divided into rearing vessels and held at accepted rearing densities and flow index values. Fry were fed a semi-moist diet with no fines, as mash diets are known to produce gill abrasions in chum salmon fry. Once the fish were actively feeding, they received a daily ration of 3% of their body weight, throughout the day with feeding occurring at least once every hour. In addition to hand feeding, mechanical auto-feeders were used in 2007. Weekly weight measurements were taken to adjust the ration level. Feed size increased as the fish grew, but pellet size never exceeded one-fortieth of fork length of the reared fish. Mortalities were recorded and removed daily. Rearing vessels were cleaned at least once per week. Several environmental parameters were measured and recorded during the rearing period, with flow rates and DO levels measured and recorded weekly. Water temperatures were recorded twice daily (in the morning and after the last feeding) with a hand-held thermometer. Daily rainfall and ambient air temperatures were also recorded daily.

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 0.01g on the day of release. These data were used to produce mean weights, lengths, condition (K) values, coefficient of variation statistics for each measured parameter, and frequency distributions for lengths and weights.

Results

Spawning

The spawning protocol detailed by Schroder (2000) was followed when possible, and spawning occurred four times between November 22 and December 13, 2006 (Table 6). The exception to following spawning protocols occurred on November 28, when snow and ice surrounded the hatchery facility making unsafe driving conditions for the tanker truck. A decision was made to spawn any suitable females collected that day, with equal number of males, on the riverbank and then transport the eggs and milt to the hatchery using a four-wheel drive vehicle. Once at the hatchery, the milt and eggs were mixed using a factorial cross. Total egg mass and sub-sample egg weights were not done to speed up the process, it had already been an hour since spawning, so eggs were divided into factorial lots by eye. Once the eggs had been fertilized, standard spawning protocols were again followed. All adults were spawned within two days of capture. Males were selected for spawning based on the number of ripe females and on a first captured-first used, basis. Table 7 details information on capture location and date and spawning date as well as biological data collected from males used for spawning. An estimated 63,132 green eggs were collected during the spawning season. One female escaped while being removed from a holding tube on December 12. Once free, the female mixed in with adult chinook and coho that were being held in the adult pond. This female was not recovered until the following week when

hatchery personnel sorted the entire adult holding pond. Since the female had not spawned yet she was transported to the Duncan Creek spawning channels and placed with males that were still alive in the north spawning channel.

The age composition (determined via scale analysis) of females taken to Washougal Hatchery was dominated by age-4 fish, 92.9 % versus 7.1 % for age-3; no spawned females were identified as age-5 (Figure 8). Similarly, the male age composition was dominated by age-4 fish, 92.6 % versus 3.7 % for age-3 and 3.7 % for age-5 (Figure 8).

Age-3 females fork lengths ranged from 65 cm to 69 cm, averaging 67.0 cm, age-4 females ranged from 64 cm to 78 cm, averaging 71.3 cm (Figure 9). The single age-3 male had a fork length of 71 cm, age-4 male fork lengths ranged from 69 cm to 86 cm, averaging 76.7 cm, the single age-5 male's fork length was 85.5 cm (Figure 9).

Table 6. Summary of data collected from female chum salmon spawned, 2006.

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 (cm)	MEtH length (mm)	Age	Green egg mass weight (g)	Mean green egg weight (g)	Estimated fecundity
F-1	Ives	11/20/06	11/20/06	M-1, M-2, M-3, M-4	Good	-----	70.0	550	NA		0.326	2,518
F-2	Ives	11/20/06	11/22/06	M-2, M-1, M-3, M-4	Good	4991.0	75.5	610	4	636.0	0.295	2,381
F-3	Ives	11/21/06	11/22/06	M-3, M-1, M-2, M-4	Good	3996.5	71.5	585	4	660.0	0.292	2,731
F-4	Multnomah	11/21/06	11/22/06	M-4, M-1, M-2, M-3	Good	3250.0	66.0	525	4	594.0	0.293	2,844
F-5	Multnomah	11/21/06	11/22/06	M-5, M-6, M-7, M-8	Good	3456.5	66.5	540	4	642.0	0.244	2,909
F-6	St Cloud	11/21/06	11/22/06	M-6, M-5, M-7, M-8	Good	5256.5	76.0	620	4	780.0	0.293	2,886
F-7	St Cloud	11/21/06	11/22/06	M-7, M-5, M-6, M-8	Good	4377.5	73.0	590	4	772.0	0.277	2,922
F-8	St Cloud	11/21/06	11/22/06	M-8 M-5, M-6, M-7	Good	3859.5	72.0	57.5	4	564.0	0.272	2,147
F-9	Multnomah	11/21/06	11/22/06	M-9, M-10, M-11, M-12	Good	3251.0	67.0	550	4	512.0	0.286	1,899
F-10	Multnomah	11/28/06	11/28/06	M-10, M-9, M-11, M-12	Good	-----	69.0	-----	4	-----	-----	2,016
F-11	Multnomah	11/28/06	11/28/06	M-11, M-9, M-10, M-12	Good	-----	77.0	-----	4	-----	-----	1,731
F-12	Multnomah	11/28/06	11/28/06	M-12, M-9, M-10, M-11	Good	-----	65.0	-----	3	-----	-----	2,007
F-13	Multnomah	11/28/06	11/28/06	M-13, M-14, M-15, M-16	Good	-----	71.0	-----	4	-----	-----	2,415
F-14	Multnomah	11/28/06	11/28/06	M-14, M-13, M-15, M-16	Good	-----	72.0	-----	4	-----	-----	1,630
F-15	Multnomah	11/28/06	11/28/06	M-15, M-13, M-14, M-16	Good	-----	70.0	-----	4	-----	-----	2,007
F-16	Multnomah	11/28/06	11/28/06	M-16, M-13, M-14, M-15	Good	-----	70.0	-----	4	-----	-----	2,519
F-17	Multnomah	11/28/06	11/28/06	M-17, M-18, M-19, M-20	Good	-----	64.0	-----	4	-----	-----	1,666
F-18	Multnomah	12/5/06	12/6/06	M-18, M-17, M-19, M-20	Good	4379.0	71.0	570	4	556.0	0.225	2,783
F-19	Multnomah	12/5/06	12/6/06	M-19, M-17, M-18, M-20	Good	4169.5	70.0	570	4	688.0	0.298	2,142
F-20	Ives	12/4/06	12/6/06	M-20, M-17, M-18, M-19	Good	4650.0	72.0	600	4	818.0	0.281	2,327
F-21	Ives	12/4/06	12/6/06	M-21, M-22, M-23	Good	4732.5	71.5	580	4	850.0	0.358	1,783
F-22	Ives	12/4/06	12/6/06	M-22, M-21, M-23	Good	4603.0	72.0	580	4	882.0	0.309	2,274
F-23	Ives	12/4/06	12/6/06	M-22, M-21, M-23	Good	4073.5	69.0	560	3	734.0	0.271	2,151
F-24	Multnomah	12/5/06	12/6/06	M-23, M-21, M-22	Good	4580.5	71.0	590	4	724.0	0.301	1,955
F-25	Ives	12/11/06	12/13/06	M-24, M-25, M-26	Good	3729.5	67.0	540	4	650.0	0.283	2,293
F-26	Ives	12/11/06	12/13/06	M-25, M-24, M-26	Good	4502.5	72.0	570	4	870.0	0.329	1,999
F-27	Multnomah	12/12/06	12/13/06	M-26, M-24, M-25	Good	6221.5	78.0	620	4	926.0	0.285	1,955
F-28	Multnomah	12/12/06	12/13/06	M-27, M-28	Good	5081.0	78.0	610	4	856.0	0.331	2,242

Table 7. Summary of data collected from male chum salmon spawned, 2006.

Male #	Location of capture	Date of capture	Date of spawning	Condition at spawning	Fork length (mm)	MEtH (mm)	Whole body weight (g)	Age	Used as primary male with female #
M-1	St Cloud	11/21/06	11/22/06	Good	72.5	56.0	4117.0	4	F-1
M-2	St Cloud	11/21/06	11/22/06	Good	74.0	57.0	4366.0	4	F-2
M-3	St Cloud	11/21/06	11/22/06	Good	79.0	60.5	6002.5	4	F-3
M-4	Ives	11/20/06	11/22/06	Good	79.0	61.0	6027.0	4	F-4
M-5	Multnomah	11/21/06	11/22/06	Good	85.5	65.5	7619.5	5	F-5
M-6	Multnomah	11/21/06	11/22/06	Good	73.5	57.5	4820.5	4	F-6
M-7	Multnomah	11/21/06	11/22/06	Good	74.0	57.0	4682.5	4	F-7
M-8	St Cloud	11/21/06	11/22/06	Good	80.5	61.0	6240.0	4	F-8
M-9	Ives	11/20/06	11/22/06	Good	75.0	57.5	-----	NA	F-9
M-10	St Cloud	11/28/06	11/28/06	Excellent	86.0	65.0	-----	4	F-10
M-11	St Cloud	11/28/06	11/28/06	Excellent	79.0	60.5	-----	4	F-11
M-12	St Cloud	11/28/06	11/28/06	Good	78.0	60.0	-----	4	F-12
M-13	St Cloud	11/28/06	11/28/06	Good	81.0	61.0	-----	4	F-13
M-14	St Cloud	11/28/06	11/28/06	Good	77.0	60.5	-----	4	F-14
M-15	St Cloud	11/28/06	11/28/06	Poor	79.0	61.0	-----	4	F-15
M-16	St Cloud	11/28/06	11/28/06	Good	79.0	61.5	-----	4	F-16
M-17	St Cloud	11/28/06	11/28/06	Good	74.0	57.5	-----	4	F-17
M-18	Ives	12/4/06	12/6/06	Good	78.5	61.0	6342.0	4	F-18
M-19	Multnomah	12/5/06	12/6/06	Good	73.0	57.0	4483.5	4	F-19
M-20	Ives	12/4/06	12/6/06	Fair	76.0	59.0	4710.0	4	F-20
M-21	Ives	12/4/06	12/6/06	Fair	79.0	60.0	5111.5	4	F-21
M-22	St Cloud	12/5/06	12/6/06	Fair	78.0	60.0	5241.0	4	F-22,F-23
M-23	Multnomah	12/5/06	12/6/06	Good	76.0	60.0	5096.0	4	
M-24	St Cloud	12/12/06	12/13/06	Good	70.0	54.0	3530.0	3	F-25
M-25	St Cloud	12/12/06	12/13/06	Good	75.0	57.0	4403.5	4	F-26
M-26	Ives	12/11/06	12/13/06	Good	75.0	58.0	5072.0	4	F-27
M-27	Ives	12/11/06	12/13/06	Fair	74.0	57.0	4608.5	4	F-28
M-28	Ives	12/11/06	12/13/06	Good	69.0	-----	-----	4	-----

Figure 8. Age composition of adult chum salmon spawned at Washougal Hatchery, 2006.

Figure 9. Fork lengths (mm) of male (top) and female (bottom) chum salmon spawned at Washougal Hatchery, grouped by age and 10 mm increments, 2006.

Incubation

All green eggs were disinfected in the Heath trays with a 60-minute treatment of PVP before being moved into the incubation stacks. Flow through the Heath stacks was 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 the eggs hatched (minimum of five days) to prevent fungus

(*Saprolegnia sp.*) growth in the trays. The eggs were shocked by pouring them into a bucket half full of water and then back into their trays. A total of 4,924 non-viable eggs were recovered after shocking (Table 8). The number of non-viable eggs per female removed after shocking ranged from 40 to 639 and averaged 179.

Table 8. 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, 2007.

Female	Non-viable eggs	Eyed egg weight (g)	Mean live eyed egg estimate	95% C.I.		+/-	CV	Fecundity (based on sampling*)	Survival green to eyed
				High	Low				
F-1	74	760	2,439	2,838	2,040	398.79	13.22	2,518	96.86%
F-2	55	700	2,321	2,371	2,271	50.07	1.74	2,381	97.48%
F-3	61	774	2,665	2,715	2,615	49.87	1.51	2,731	97.58%
F-4	158	654	2,681	2,740	2,622	58.64	1.77	2,844	94.27%
F-5	102	700	2,802	2,891	2,713	88.52	2.55	2,909	96.32%
F-6	85	872	2,796	2,918	2,674	121.71	3.52	2,886	96.88%
F-7	53	846	2,864	2,950	2,778	85.84	2.42	2,922	98.02%
F-8	40	632	2,102	2,175	2,029	73.05	2.81	2,147	97.90%
F-9	58	556	1,836	1,956	1,716	119.63	5.27	1,899	96.68%
F-10	60	854	1,956	2,036	1,876	80.00	3.31	2,016	97.02%
F-11	67	970	1,664	1,707	1,621	42.51	2.07	1,731	96.13%
F-12	195	650	1,812	1,933	1,691	121.23	5.41	2,007	90.28%
F-13	70	626	2,345	2,380	2,310	35.01	1.21	2,415	97.10%
F-14	68	682	1,562	1,590	1,534	28.01	1.45	1,630	95.83%
F-15	305	830	1,702	1,800	1,604	97.91	4.65	2,007	84.80%
F-16	578	594	1,941	1,970	1,912	29.44	1.23	2,519	77.05%
F-17	111	956	1,555	1,774	1,336	219.50	11.41	1,666	93.34%
F-18	279	580	2,499	2,593	2,405	94.20	3.05	2,783	89.80%
F-19	213	720	1,924	1,936	1,912	12.32	0.52	2,142	89.82%
F-20	386	826	1,936	2,118	1,754	181.76	7.59	2,327	83.20%
F-21	144	906	1,634	1,660	1,608	26.41	1.31	1,783	91.64%
F-22	447	870	1,822	1,835	1,809	12.51	0.55	2,274	80.12%
F-23	87	842	2,059	2,112	2,006	52.50	2.06	2,151	95.72%
F-24	46	820	1,904	1,969	1,839	65.00	2.76	1,955	97.39%
F-25	639	522	1,649	1,748	1,550	98.52	4.83	2,293	71.91%
F-26	90	984	1,904	1,963	1,845	59.04	2.51	1,999	95.25%
F-27	226	926	1,724	1,771	1,677	46.75	2.19	1,955	88.18%
F-28	227	928	2,010	2,040	1,980	29.94	1.20	2,242	89.65%

* 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 first thermal marks were applied to the otoliths prior to hatching. Five thermal events were applied to produce the pre-hatch mark of: | | | | (narrow – narrow – narrow – narrow). A post-hatching thermal mark of : | | | (narrow – narrow – wide) was also applied. Visualize these " | " as circles to get a good representation of the mark (Figure 10).

Figure 10. Photomicrograph showing the thermal mark created in 2007.

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 8. Mean fecundity estimates for females with reproductive effort values (total egg mass weight/total body weight) >16% only, ranged from 1,783 to 2,922, averaging 2,385. Survival rates from green to eyed egg stage ranged from 71.91% to 98.02%, averaging 92.01% (Table 8).

The eggs began to hatch after they had accumulated approximately 600 TU °C. A total of 1,270 dead alevins, non-viable eggs and fry with obvious deformities were removed from the trays prior to ponding, resulting in an average eyed-egg-to-ponding survival rate of 97.99%. Loss, by female, from the eyed egg stage to ponding is detailed in Table 9. Individual fork lengths and weights were taken on 25 fry from each tray just prior to ponding. K_D values of fry from each tray at ponding are presented in Table 9.

Table 9. Loss by female from the eyed egg stage to ponding and sampling data at ponding, spring 2007.

Female #	Loss at shocking	Loss at ponding	Survival eyed-egg to ponding	Average values at ponding		K _D value
				Weight (g)	Fork length (mm)	
F-1	74	24	99.0%	10.5	37.3	1.98
F-2	55	27	98.8%	10.3	37.5	1.99
F-3	61	186	93.0%	8.2	34.5	1.98
F-4	158	36	98.7%	9.1	34.9	2.00
F-5	102	38	98.6%	9.0	35.9	1.98
F-6	85	5	99.8%	11.0	38.9	1.93
F-7	53	20	99.3%	10.4	37.6	1.99
F-8	40	17	99.2%	10.7	38.2	1.95
F-9	58	14	99.2%	11.5	38.3	1.96
F-10	60	6	99.7%	12.3	36.7	2.00
F-11	67	21	98.7%	11.5	36.7	2.00
F-12	195	10	99.4%	11.0	37.5	1.98
F-13	70	14	99.4%	11.1	36.9	1.93
F-14	68	18	98.8%	12.5	39.3	1.99
F-15	305	11	99.4%	13.7	38.8	1.96
F-16	578	6	99.7%	9.2	37.4	1.92
F-17	111	8	99.5%	9.7	36.4	1.98
F-18	279	12	99.5%	8.6	36.3	1.91
F-19	213	2	99.9%	10.1	38.5	1.87
F-20	386	11	99.4%	10.4	38.8	1.92
F-21	144	9	99.4%	14.4	40.7	1.97
F-22	447	460	74.8%	10.0	38.2	1.93
F-23	87	90	95.6%	9.4	37.2	1.94
F-24	46	61	96.8%	10.4	37.4	2.00
F-25	639	2	99.9%	13.8	39.4	2.00
F-26	90	15	99.2%	12.8	38.8	2.01
F-27	226	140	91.9%	12.7	39.7	1.96
F-28	227	7	99.7%	11.6	38.1	2.03

Rearing

A total of 56,838 fry were ponded into two rearing troughs. The flow rate was initially set at 25 gpm and adjusted by hatchery personnel as the fry grew to maintain the flow index within an acceptable range. A pump failure occurred over the weekend of April 22-23 forcing hatchery personnel to remove the fry from the troughs and place them in one of the full sized concrete raceways. Feeding small numbers of fish in a large rearing vessel can be problematic. Fortunately, the fry were large enough at this time, and there were sufficient numbers, to not have growth rates affected by being in a larger rearing vessel.

Mortalities were removed and enumerated daily. A total of 2,448 mortalities were removed between ponding and release, resulting in a survival rate of 95.7% from ponding to release. The majority of the mortality (68%) occurred in a one-week period after the fry had been moved to the concrete raceway and experienced outbreaks of *ichthyophthirius* and *saprolegnia*. This diagnosis was made by a WDFW pathologist who was called to the hatchery when daily mortality rates began increasing the week after they had been moved. Additions of formalin to the raceway, as recommended by the pathologist, at concentrations of 1:10,000 and then 1:8,000 twice with salt blocks were done to bring the daily mortality rate down.

Release

A total of 54,390 fry were released at dusk on May 15 into Duncan Creek just below the railroad bridge (RM 0.79). The overall survival rate from green egg stage to release was 86.15%. Results of the sampling done the day of release are reported in Table 10. The fry were dip netted from the raceway and placed into a 400-gallon tanker truck for transport to the release site. The truck was placed as close to the creek possible and a flex hose was attached to the tank to transfer the fry. The fish were monitored for 15-20 minutes for any immediate mortality. No direct mortalities were observed at release.

Table 10. Average size (g), fork lengths (mm) and K_D values on release day, 2007.

Raceway #	# Released	Release Date	Average FL (STD)	Average Wt. (STD)	Average K _D (STD)
1	54,390	5/15	56.6 (4.02)	1.45 (0.29)	1.99 (0.05)

Discussion

The goal for hatchery broodstock collection was to maintain genetic diversity and timing by having representative collections. The curve displayed in Figure 4 was the collection curve developed from 2002-05 data, assuming stream residence time to be six days and a collection goal of 35 females. Analysis of the 2006 return data showed adults returning to mainstem spawning areas near Bonneville Dam later than in recent years; mean arrival date was seven days later than the 2002-05 mean. An increase in returns to mainstem Columbia River spawning sites in 2006 combined with relaxing the criteria for females resulted in 57 adult chum salmon being collected for artificial propagation at Washougal Hatchery. A comparison of cumulative broodstock collection versus collection curves using the 2002-06 and 2006 actual arrival timing, adjusted to 57 adults, shows that broodstock collection in 2006 was very similar to actual arrival timing (Figure 11). As in the 2003 and 2005 seasons, similar numbers of adults were collected for hatchery broodstock from the three main spawning areas near Duncan Creek: The Ives, Multnomah and St Cloud spawning areas. This is acceptable from a genetic standpoint; multidimensional scaling of microsatellite DNA analyses presented in Small et al (2006) and Small (2004) grouped adults from the Ives, Multnomah and St Cloud spawning areas. Broodstock were not collected from the I-205 spawning area in 2006, spawners from these areas grouped away from the adults collected from these upstream spawning areas in the same multidimensional scaling of microsatellite DNA analyses (Small et al 2006 and Small 2004). Population data collected in 2006 will be used to refine the broodstock collection curve for 2007.

Figure 11. Comparison of 2002-06 mean and 2006 Columbia River mainstem chum salmon spawner arrival curves and cumulative hatchery broodstock collection.

A summary of 2006-07 hatchery activities and comparative values for prior years is presented in Table 11. A total of 4,924 dead/non-viable eggs were removed after shocking. A total of 1,270 mortalities/monstrosities were recovered between the eyed egg stage and ponding, resulting in a mortality rate of 2.2%. This compares to rates of 3.0%, 4.8%, 1.8% and 12.6% in 2005-06, 2003-04, 2002-03 and 2001-02, respectively. A total of 2,448 mortalities were recovered between ponding and release, yielding a survival rate of 95.7% from ponding to release.

Table 11. Numbers of females spawned, estimated egg take and percent survival between milestone stages for chum salmon spawned at Washougal Hatchery, 2001-07.

Year	# of females spawned	Estimated # of eggs taken	% Survival				Number fry released
			Green to eyed egg stage	Eyed egg to ponding	Ponding to release	Green egg to release	
2001-02	23	65,922	91.3	87.3	98.1	78.2	45,046
2002-03	93	244,156	92.5	98.2	98.1	89.2	217,436
2003-04	35	87,486	93.7	95.2	97.4	86.9	75,952
2004-05	----	-----	---	---	---	---	-----
2005-06	9	24,830	90.1	97.0	92.5	80.9	19,817
2006-07	28	63,132	92.0	97.8	95.7	86.2	54,390
Overall	188	476,633	92.4	96.3	97.4	86.6	412,641

Note: No hatchery program during the 2004-05 season

Despite problems, the Washougal Hatchery operations for chum salmon were successful in 2006-07. While the goal of collecting 30-50 females for the formulation of the predictive formulas needed for fecundity estimates of channel spawning females was not met, green-egg-to-release survival was close to 90%, and fry were above recommended size, average weight and fork length, at release. As in prior years, the fry from the hatchery were not ready for release until May. Ideally, these fry would be ready for release at the same time as those naturally produced in the channels are outmigrating, which occurs in April. Automatic feeders were used in 2006 and 2007 in an effort to speed up growth and have the fry ready for release earlier. These feeders do appear to have an impact; fry reached release size and weight criteria earlier but still not early enough to match natural run-timing. If the intent is to continue using Washougal Hatchery facilities to rear artificially-spawned juveniles, and matching the natural migration timing is important, a heated water system may be necessary to duplicate temperatures that naturally-produced fry experience in the channels.

In an effort to increase imprinting to Duncan Creek, the release location of hatchery-reared fry was changed. In past years fry were released at the mouth of the creek. Releasing the fry at the creek mouth was done for three reasons. The first being logistical, there was easy access for getting the planting truck to the waters edge. The second was concern over low water levels in Duncan Creek and the spawning channels at the time when the fry were ready for release. Lastly, by agreement with the landowners association, the dam's knife gates can be closed at the end of May to allow for lake re-formation and there was concern that under low water levels fry may not exit the system and thus be trapped until mid- to late June when water levels were high enough to allow passage over the dam's spill lip. However in 2007, the fry were ready mid-May, there was sufficient water still flowing in Duncan Creek to alleviate concerns about fry not being able to migrate to the Columbia River in a timely manner, and a scour hole created during winter storm runoff events, had formed just below the railroad bridge providing a suitable release location that could be accessed by the planting truck.

Potential problems identified in Hillson (2003) relating to incubation and rearing space limitations at Washougal Hatchery still exist. One of those problems, identified in 2003, lack of water pressure to rearing troughs when placed outside of raceways, likely resulted in the substantial loss this season during rearing due to outbreaks of *ichthyophthirius* and *saprolegnia* after the fry had to be moved from rearing troughs to a concrete raceway when a pump failed. The fry had to be moved because when the pump failed it was not possible to provide enough water to the rearing troughs outside the raceway. Savings in project budgets from FY 04-06 had been identified for use in FY 07 to construct a new rearing area at Washougal Hatchery to solve the water pressure issue as well as expand the number of rearing troughs. However, budget reductions in FY07 resulted in these funds used instead to cover within-year project budget shortfalls.

Part III: Monitoring the Physical Attributes of Spawning Channels

Introduction

Historically, Duncan Creek was an important spawning area for chum salmon. After the construction of an earthen dam in the lower portion of Duncan Creek to form a small lake for recreation in 1961, chum

salmon abundance in the creek declined. In 1999, chum salmon were listed under the ESA and recovery efforts increased. Spawning channels have been used successfully to both establish and to reestablish chum salmon populations (Bonnell 1991; Cowan 1991). Preliminary investigations by WDFW, PSMFC, and KPFF Engineering indicated that a spawning channel in Duncan Creek could be successful if passage conditions at the lake outlet were modified and lake levels managed to allow migration. The original chum salmon spawning area in Duncan Springs was rehabilitated in October 2000, and a spawning channel was constructed at this site in October 2001, by KPFF Engineering. See Appendix A of Hillson (2002) for details of the channel's engineering and construction.

Continued monitoring of the spawning channels physical attributes is an important component of the reintroduction program. Monitoring the environmental conditions will identify potential factors responsible for survival/mortality rates. Salmonid research demonstrates 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 mortality causes during the incubation period (see Wickett 1954; Wickett 1958; Alderdice et al. 1958; McNeil 1962; Cooper 1965; McNeil 1966; Lotspeich and Everest 1981; Witzel and MacCrimmon 1981; Alexander and Hansen 1986; Kondolf et al. 1991; Marten 1992; Geist and Dauble 1998; Argent and Flebbe 1999; Baxter and McPhail 1999). Temperatures of less than 36 °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 the composition of spawning gravels, specifically the proportion of materials $\leq 3.3\text{mm}$, 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). Lotspeich and Everest (1981) 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 12).

Table 12. Composition of gravel to be placed in the Duncan Creek spawning channels (Schroder 2000).

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 on incubation survival include: redd superimposition, scouring and gravel fill as a result of dynamic river flows, high or low water temperatures during critical incubation times, sedimentation or high levels of sand and silt in the spawning gravels, low seepage velocity and/or low dissolved oxygen (DO) levels in the interstitial spaces, dewatering of eggs or alevins, and the presence of intra-gravel predators. Of these factors, gravel composition, water temperature, low seepage velocity (vertical hydraulic gradients (VHG)) and low DO levels in the interstitial spaces are of primary concern in the Duncan Creek channels. Monitoring these environmental conditions will provide information needed to characterize conditions in the channels

between fertilization and emergence. The other environmental factors identified, while important, are not of great concern since this spawning area is in a spring channel and protected from extreme environmental variation. Factors such as redd superimposition and egg retention due to overcrowding can be controlled by maintaining densities of females at levels that ensure at least two square meters of spawning area per female, and placing the fish into the channels over a two-or three-day period (Schroder 1973); this should not be a factor until adult abundance in the channel approaches capacity.

Gravel sampling in the channels can determine changes in gravel composition, with emphasis on material less than 3.3 mm in diameter, such as sands and fines. If gravel monitoring indicates the Fredle Index is decreasing over time, or the percentage of fines less than 0.85mm is increasing, gravel-cleaning efforts may be implemented. Gravel samples were collected from the spawning channels and analyzed in 2002, 2003, 2004 and 2005. In 2006, Columbia River water levels rose and flooded the spawning channels preventing gravel sampling activities at the end of fry trapping. Gravel sampling was planned to take place prior to introducing adults into the spawning channels in the fall of 2006. However, funding levels were reduced in Fiscal Year (FY) 07 and no gravel sampling occurred.

Methods

Water temperatures were continuously monitored using 18 Onset® temperature data loggers, 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. Six of these units were attached to sections of ¾ inch rebar driven into the gravel substrate to anchor the data logger. Two were placed into each channel, one at the top and the other just above the weir or confluence, at mid-water depth. The remaining 12 were attached to lengths of eighth inch stainless cable and buried 12 inches in the channel substrate, four per channel, evenly spaced down the channel's length to the weir or confluence. The other end of the cable was attached to ¾ inch rebar driven into the bank as anchors. Data loggers were placed prior to introducing adults to the channels each fall and recovered after fry trapping ended in the spring.

Mini-piezometers were placed at the top and then every 50' down the length of each channel to the weir or confluence to monitor DO levels, vertical hydraulic gradients (VHG) and water temperatures in the hyporheic zone. The mini-piezometers were placed at approximately mid-channel and driven 12" into the substrate so that intra-gravel water could be sampled at the same depth as eggs were expected to be deposited. Mini-piezometers were placed prior to introducing adults and once adults are placed into the channels, measurements of DO and temperature (three readings at each mini-piezometer to calculate a mean value) were recorded every two weeks until fry emigration was complete. Mid-water temperature and DO values were also recorded outside the first and last piezometer in each channel when values inside the piezometers were recorded. Schroder (2000) recommends VHG values be determined three times over the course of the season; once at the end of spawning, again at the end of December when typical winter flows are occurring and, finally, at the end of the fry emigration in the spring. Because the end of spawning normally occurs around the end of December, these two sampling times normally are combined. VHG values are determined using the following formula:

$$VHG = \Delta h/L$$

Where Δh is the measured difference in water elevation between the inside of the piezometer and the outside stream water surface. Calculated as $h_s - h_1$, where h_s is the distance from the top of the piezometer

to the stream surface and h_1 is the distance from the top of the piezometer to the water surface inside the piezometer. In the formula, L equals the distance below the streambed to the top of the first row of piezometer holes (Barnard and McBain 1994; Dahm and Valett 1998). Positive VHG values indicate upwelling occurrence and negative values indicate areas of down-welling (Freeze and Cherry 1979). Beginning in 2004, Kolor Kut water finding paste (Kolor Kut Products Company LTD, Houston Texas) has been used to measure water levels in the mini-piezometers. The paste changes color from a light brown to bright red when exposed to water. Measurements were taken by coating approximately two inches of the bottom of a very small diameter steel rod with the paste. A pair of vice-grips was used to hold the steel rod. They were clamped on, leaving approximately the length needed to submerge the rod end by an inch. This rod was lowered beside, or into, the mini-piezometer until the coated end made good contact with the water surface and the vice-grips jaw tips were in contact with the top of the mini-piezometer. A small stilling well was used when water current made readings difficult.

Water velocity was measured using a digital current meter just prior to introducing adults, again immediately after all adults in a channel had perished, and then monthly until fry emigration ceased. Velocities were measured just upstream of the two weirs and the south channel's confluence; three readings were taken at each location to calculate a mean.

Water depths were measured at staff gauges on the upstream side of each monitoring weir and in the two stilling wells. Levels were recorded daily during the fall spawning season, sporadically during early winter, then daily once fry trapping began through the end of the season. Changes in staff gauge readings due to activities like installing and removing weir grates and installing fry traps were recorded so that readings could be normalized over the season. The upper well is located next to the top of the south channel; the lower well is located next to the confluence of the south and middle channels. The wells are not the same depth, but they do provide a good index of ground water table activity. Readings were made using a 10 foot section of 1½ inch wooden dowel marked in 1 cm increments from the bottom to the top. Heavy seine twine was loosely attached through holes drilled at the top and bottom. A ½ inch float was threaded onto the twine, free to move up or down. The dowel was placed into the stilling well, held vertical at a specific spot, and the float moved to mark the water surface. The twine was then tightened to hold the float in place against the dowel while it was removed from the well. Depth was then measured where the float touched the marked scale.

Results

Both sub-surface and mid-water temperature data loggers were in place by November 16, 2006. Temperature loggers were recovered on May 8, 2007. Daily average water temperatures were calculated for each data logger and these results are reported in **Appendix A** Table 1. Additional values of sub-surface, mid-water temperature and DO levels are available from the bi-monthly sampling at the mini-piezometers (Table 13 and 14). Piezometers were assigned numbers, increasing sequentially from the top of the channel to confluence for the south channel, and to the weirs for the other two channels. Values reported as top and bottom in Tables 13 and 14 are those recorded outside the first and last piezometer in each channel.

Measurements to calculate VHG were recorded on December 27, 2006, and May 7, 2007. In addition to these formal measurements, a visual check for VHG was made and recorded at each mini-piezometer when DO and temperature values were taken on several sampling days. These results, both measured and

visual, are reported in Table 15 (a comment of “up” indicates up-welling, “---” indicates no difference, and “down” indicates down-welling for visual checks).

Water velocities were measured using a digital current meter once adults were in the channels, and then monthly until fry trapping ceased. Measurements were taken in front of each weir and, on several occasions, at the confluence of the south channel with the middle channel (Table 16). When present, grates and fry traps were thoroughly cleaned and any head created was allowed to recede before measurements were recorded.

Staff gauges were placed on the upstream side of both weirs on November 21, 2002. No attempt was made to set the two gauges to read equal heights in relation to each other. Survey measurements were taken on January 9, 2003, to determine the difference in height of the staff gauges. Corresponding heights of the two gauges differed by an estimated 0.88 feet, with the north weir being lower. This is due to elevation differences in the two channels. Staff gauges were placed so that recorded measurements allowed comparison of water depth at the weir slots. These gauges are not removed between seasons to allow for direct comparisons between years. Staff gauge heights were recorded daily when adult chum salmon were present, sporadically during the incubation period, and then daily again once fry trapping began (Table 17). When grates or fry traps were in place at the weirs, they were thoroughly cleaned and any head created allowed to recede before measurements were recorded. Unless noted, the values reported in Table 17 were corrected for the differences in water heights due to grates, fry traps and sand bag placement for fry trapping, and represent what these values would likely be without these obstructions.

Water depth measurements taken in the two stilling wells are reported in Table 18. These values are presented graphically along with the stage of the East Fork Lewis River (USGS East Fork Lewis River near Heisson Gauge <http://waterdata.usgs.gov/wa/nwis/uv?14222500>) in Figure 12.

Table 13. Mean water temperature values from mini-piezometer sampling, 2006-07.

South channel		Mini-piezometer #								
Date	Top	1	2	3	4	5	6	7	8	Bottom
11/15/2006	9.5	9.80	9.80	9.50	9.80	9.50	9.60	9.40	9.20	9.3
11/29/2006	9.3	9.50	9.50	9.60	9.30	9.30	9.30	9.20	9.30	9.1
12/13/2006	9.5	9.60	9.50	9.60	9.30	9.30	9.20	9.10	9.30	9.1
12/27/2006	9.1	9.00	8.80	8.80	8.70	8.70	8.60	8.50	8.40	8.5
01/16/2007	9.0	8.20	8.20	8.30	8.50	8.50	8.50	8.40	8.60	8.4
01/30/2007	8.0	8.00	7.90	8.00	7.90	7.80	7.80	7.90	7.90	7.8
02/16/2007	8.3	8.60	8.60	8.70	8.60	8.40	8.40	8.50	8.50	8.4
03/02/2007	8.4	8.60	8.50	8.60	8.60	8.60	8.80	8.80	8.80	8.8
03/19/2007	8.5	8.50	8.50	8.90	8.70	8.70	8.80	8.80	8.70	8.6
04/05/2007	8.5	8.60	8.60	8.30	8.50	8.40	8.50	8.50	8.50	8.6
04/16/2007	9.8	9.10	8.80	9.00	8.80	8.90	9.00	9.10	9.10	9.2
05/02/2007	9.0	8.60	8.50	8.50	8.60	8.80	8.80	8.80	8.80	8.7

Middle channel		Mini-piezometer #				
Date	Top	1	2	3	4	Bottom
11/15/2006	9.0	9.50	9.40	9.30	9.40	9.0
11/29/2006	9.0	9.30	9.20	9.20	9.10	8.9
12/13/2006	9.0	8.80	8.80	8.80	8.80	8.8
12/27/2006	8.0	8.50	7.90	8.30	8.50	8.5
01/16/2007	8.0	8.60	8.40	8.40	8.10	8.3
01/30/2007	7.9	8.30	7.90	8.00	7.90	8.0
02/16/2007	8.4	8.70	8.60	8.60	8.80	8.5
03/02/2007	8.8	9.10	9.20	9.40	9.60	9.4
03/19/2007	8.6	9.00	9.10	9.00	9.00	9.0
04/05/2007	8.6	9.00	8.80	8.80	8.80	8.9
04/16/2007	9.4	9.70	9.70	9.70	9.20	9.5
05/02/2007	9.0	9.00	9.20	9.10	9.20	9.0

North channel		Mini-piezometer #				
Date	Top	1	2	3	4	Bottom
11/15/2006	8.80	8.80	8.80	8.60	8.60	8.30
11/29/2006	8.80	8.50	8.20	8.20	8.00	8.10
12/13/2006	8.80	8.60	8.30	8.20	7.90	8.00
12/27/2006	7.50	7.60	7.70	7.80	7.50	7.60
01/16/2007	7.90	7.70	7.90	7.80	7.70	7.80
01/30/2007	8.00	7.90	7.90	7.90	7.80	8.00
02/16/2007	7.90	8.00	7.90	8.30	8.10	8.10
03/02/2007	8.80	8.60	too deep	8.80	8.80	8.70
03/19/2007	8.00	8.20	8.30	8.40	8.30	8.00
04/05/2007	8.30	8.00	8.10	8.20	8.00	8.10
04/16/2007	8.90	8.90	9.00	9.30	9.30	9.30
05/02/2007	8.80	8.70	8.90	8.90	9.10	9.00

Table 14. Mean DO values from mini-piezometer sampling, 2006-07

South channel		Mini-piezometer #								
Date	Top	1	2	3	4	5	6	7	8	Bottom
11/15/2006	9.00	9.80	9.80	10.30	9.50	9.80	10.50	10.30	10.20	10.50
11/29/2006	9.50	9.00	9.00	9.50	9.20	9.50	10.80	9.50	9.50	10.00
12/13/2006	9.00	9.00	9.00	9.40	8.70	7.30	10.40	7.90	8.20	10.10
12/27/2006	10.10	8.30	10.60	11.30	9.20	6.80	10.30	8.10	0.30	10.30
01/16/2007	10.10	11.80	11.20	11.30	8.90	6.50	10.20	8.50	0.30	10.20
01/30/2007	10.50	12.50	11.60	11.90	7.40	10.40	10.40	8.00	0.20	11.40
02/16/2007	10.90	8.20	11.30	12.00	11.60	8.30	11.00	10.80	10.50	11.30
03/02/2007	11.20	13.00	16.20	18.60	14.00	14.10	14.30	14.00	14.20	12.20
03/19/2007	11.00	11.10	17.10	16.10	14.20	14.50	14.50	13.70	14.00	11.90
04/05/2007	11.10	12.30	11.00	13.00	11.70	10.40	13.30	11.80	11.50	11.90
04/16/2007	9.80	13.80	14.90	13.50	11.60	11.40	14.50	12.90	13.20	12.50
05/02/2007	10.50	14.60	15.40	15.30	14.40	11.30	16.40	15.90	15.90	13.40
Middle channel		Mini-piezometer #								
Date	Top	1	2	3	4	Bottom				
11/15/2006	10.30	12.50	12.10	12.20	11.80	10.30				
11/29/2006	10.00	13.00	11.00	11.00	10.90	10.10				
12/13/2006	9.90	12.60	10.30	10.10	10.60	10.20				
12/27/2006	9.60	12.10	11.90	7.20	2.80	10.10				
01/16/2007	10.10	14.50	11.80	6.90	3.50	10.20				
01/30/2007	10.70	19.40	13.10	5.20	1.90	11.40				
02/16/2007	11.20	17.00	10.10	7.60	8.30	11.50				
03/02/2007	11.20	15.60	13.00	13.20	14.30	12.00				
03/19/2007	11.50	18.40	13.80	11.90	14.70	11.50				
04/05/2007	11.00	12.80	12.60	8.40	12.50	12.10				
04/16/2007	11.40	12.20	12.30	11.80	14.60	12.30				
05/02/2007	12.80	15.30	13.90	14.00	16.90	14.40				
North channel		Mini-piezometer #								
Date	Top	1	2	3	4	Bottom				
11/15/2006	9.50	10.00	10.10	9.50	10.00	10.25				
11/29/2006	9.20	9.50	9.60	8.80	9.50	10.60				
12/13/2006	9.00	1.00	1.40	8.00	10.80	10.80				
12/27/2006	10.40	2.50	9.60	0.20	6.00	10.90				
01/16/2007	10.50	1.80	9.80	1.50	8.50	12.50				
01/30/2007	10.70	0.20	10.90	0.10	7.40	12.20				
02/16/2007	11.40	8.80	8.70	7.80	10.10	12.10				
03/02/2007	12.70	26.70	too deep	16.50	16.60	12.70				
03/19/2007	11.30	23.60	13.90	11.30	16.90	12.10				
04/05/2007	11.20	2.70	6.00	1.70	3.80	12.30				
04/16/2007	11.10	13.80	9.10	15.20	14.20	12.60				
05/02/2007	12.40	23.30	16.00	17.70	15.60	13.60				

Table 15. Results of VHG sampling, both measured and visual, 2006-07

South channel		Mini-piezometer #						
Date	1	2	3	4	5	6	7	8
11/15/2006	Up	WTF	WTF	Down	---	Up	WTF	---
11/29/2006	Up	WTF	---	Down	---	Up	WTF	---
12/13/2006	Up	---	---	Down	---	Up	WTF	---
12/27/2006	0.24	0.00	0.03	0.09	-0.06	0.00	0.00	0.02
01/16/2007	Up	WTF	WTF	---	---	Up	---	Up
01/30/2007	Up	---	---	---	---	---	---	---
02/16/2007	Up	---	---	---	---	---	---	---
03/02/2007	Up	WTF	Up	WTF	---	---	---	---
03/19/2007	Up	WTF	Up	WTF	---	Up	---	---
04/05/2007	Up	---	Up	Up	WTF	Up	WTF	Up
04/16/2007	Up	WTF	Up	---	---	---	WTF	Up
05/02/2007	0.08	0.01	0.00	0.00	-0.03	0.00	0.00	0.02

WTF= water too fast to estimate VHG visually

Middle channel		Mini-piezometer #		
Date	1	2	3	4
11/15/2006	Up	Up	---	Up
11/29/2006	Up	Up	---	Up
12/13/2006	Up	Up	---	Up
12/27/2006	0.09	0.89	0.25	0.01
01/16/2007	Up	Up	---	Up
01/30/2007	Up	Up	---	---
02/16/2007	---	Up	---	---
03/02/2007	---	Up	---	---
03/19/2007	Up	Up	---	---
04/05/2007	Up	Up	---	---
04/16/2007	Up	Up	Up	Up
05/02/2007	0.06	1.07	0.00	0.00

North channel		Mini-piezometer #		
Date	1	2	3	4
11/15/2006	Up	---	Up	Up
11/29/2006	Up	---	Up	Up
12/13/2006	Up	---	Up	Up
12/27/2006	0.00	0.48	0.02	0.39
01/16/2007	Up	Up	Up	---
01/30/2007	---	---	---	---
02/16/2007	---	Up	Up	---
03/02/2007	Up	Up	Up	---
03/19/2007	Up	Up	Up	---
04/05/2007	Up	---	---	---
04/16/2007	---	Up	Up	---
05/02/2007	0.00	0.04	0.07	0.00

Table 16. Water velocity measurements (fps) at the two weirs in the Duncan spawning channels.

Date	South weir	North weir	South channel confluence
11/29/2006	0.553	0.892	1.006
12/27/2006	0.448	0.851	1.020
01/30/2007	0.506	0.482	1.128
03/02/2007	0.274	0.180	0.525
04/05/2007	0.412	0.143	0.555

Table 17. Staff gauge heights (feet) recorded at the two weirs, 2006-07.

Date	South	North	Date	South	North	Date	South	North	Date	South	North
11/4/06	0.65	0.95	1/9/07	1.06	0.61	3/21/07	0.90	0.85	4/27/07	0.80	0.82
11/5/06	0.78	1.09	1/18/07	0.94	0.59	3/22/07	0.90	0.86	4/28/07	0.80	0.82
11/6/06	0.87	0.89	1/22/07	0.90	0.59	3/23/07	0.90	0.85	4/29/07	0.90	0.88
11/7/06	2.38	2.18	1/25/07	0.89	0.59	3/24/07	0.90	0.86	4/30/07	0.80	0.83
11/8/06	1.78	1.48	1/29/07	0.88	0.57	3/25/07	1.29	1.04	5/1/07	0.84	0.85
11/9/06	2.43	4.33	2/2/07	0.84	0.57	3/26/07	0.95	0.87	5/2/07	0.80	0.82
11/10/06	1.00	0.78	2/6/07	0.83	0.57	3/27/07	1.27	0.95	5/3/07	0.80	0.82
11/11/06	0.95	0.65	2/9/07	0.83	0.57	3/28/07	0.93	0.86	5/4/07	0.80	0.82
11/12/06	1.48	1.38	2/15/07	0.88	0.14	3/29/07	0.91	0.86	5/5/07	0.80	0.82
11/14/06	1.03	0.93	2/16/07	0.53	0.64	3/30/07	0.90	0.85	5/6/07	0.82	0.84
11/15/06	0.95	0.75	2/21/07	1.10	0.86	3/31/07	0.90	0.86	5/7/07	0.80	0.82
11/16/06	1.06	0.87	2/22/07	1.01	0.84	4/1/07	1.06	0.94	5/8/07	0.80	0.83
11/17/06	0.93	0.82	2/23/07	0.97	0.83	4/2/07	1.05	0.86			
11/18/06	0.83	1.08	2/24/07	0.95	0.83	4/3/07	1.08	0.93			
11/19/06	0.95	0.68	2/25/07	0.94	0.92	4/4/07	0.86	0.85			
11/20/06	0.87	0.67	2/26/07	0.95	0.83	4/5/07	0.86	0.85			
11/22/06	0.88	0.99	2/27/07	1.00	0.82	4/6/07	0.85	0.85			
11/24/06	1.00	0.98	2/28/07	0.90	0.84	4/7/07	0.85	0.85			
11/25/06	0.90	0.88	3/1/07	0.89	0.83	4/8/07	1.03	0.91			
11/26/06	1.01	0.88	3/2/07	0.91	0.84	4/9/07	0.91	0.85			
11/27/06	0.91	0.87	3/3/07	0.90	0.83	4/10/07	1.03	0.89			
11/28/06	0.90	0.67	3/4/07	0.91	0.91	4/11/07	0.85	0.85			
11/29/06	0.89	0.66	3/5/07	0.91	0.84	4/12/07	0.85	0.84			
11/30/06	0.90	0.67	3/7/07	0.89	0.83	4/13/07	0.85	0.84			
12/1/06	0.83	0.65	3/8/07	0.91	0.83	4/14/07	0.85	0.85			
12/2/06	0.88	0.66	3/9/07	0.90	0.84	4/15/07	1.06	0.88			
12/3/06	0.85	0.75	3/10/07	0.90	0.84	4/16/07	0.88	0.84			
12/4/06	0.87	0.66	3/11/07	1.01	0.93	4/17/07	0.99	0.89			
12/5/06	0.83	0.64	3/12/07	1.09	0.87	4/18/07	0.85	0.85			
12/6/06	0.97	0.67	3/13/07	0.91	0.91	4/19/07	0.85	0.85			
12/7/06	0.82	0.67	3/14/07	0.95	0.85	4/20/07	0.85	0.84			
12/8/06	0.88	0.76	3/15/07	0.93	0.85	4/21/07	0.85	0.84			
12/9/06	0.83	0.76	3/16/07	0.93	0.86	4/22/07	0.99	0.89			
12/11/06	0.90	0.70	3/17/07	0.91	0.85	4/23/07	0.93	0.84			
12/12/06	1.04	0.95	3/18/07	1.04	1.00	4/24/06	0.92	0.87			
12/14/06	1.41	0.95	3/19/07	1.04	0.91	4/25/06	0.80	0.84			
12/27/06	0.99	0.61	3/20/07	1.01	0.98	4/26/06	0.80	0.84			

Table 18. Water depth (cm) measurements recorded in stilling wells, 2006-07.

Date	Upper	Lower	Date	Upper	Lower	Date	Upper	Lower	Date	Upper	Lower
11/04/06	46.0	165.0	12/12/06	146.0	186.0	03/15/07	144.0	176.0	04/18/07	137.0	169.0
11/05/06	77.5	185.0	12/14/06	163.5	178.0	03/16/07	144.0	176.0	04/19/07	137.0	169.0
11/06/06	146.0	171.0	12/15/06	156.0	178.0	03/17/07	142.0	175.0	04/20/07	136.0	169.0
11/07/06	167.0	264.0	12/27/06	158.5	178.0	03/18/07	141.0	176.0	04/21/07	135.0	169.0
11/08/06	161.0	207.0	01/18/07	150.0	174.0	03/19/07	141.0	177.0	04/22/07	136.0	172.0
11/10/06	151.0	190.0	01/22/07	145.0	173.0	03/20/07	141.0	179.0	04/23/07	134.0	170.0
11/11/06	147.0	177.5	01/25/07	145.0	173.0	03/21/07	141.0	175.0	04/24/07	134.0	171.0
11/12/06	144.5	179.0	01/29/07	142.0	172.0	03/22/07	141.0	175.0	04/25/07	132.0	167.0
11/13/06	149.0	209.0	02/02/07	138.0	171.0	03/23/07	140.5	175.0	04/26/07	132.0	167.0
11/14/06	148.0	192.0	02/06/07	136.0	171.0	03/24/07	140.0	175.0	04/27/07	131.0	167.0
11/15/06	145.0	193.0	02/09/07	136.0	171.0	03/25/07	148.0	183.0	04/28/07	130.0	167.0
11/16/06	144.0	193.0	02/15/07	150.0	175.0	03/26/07	148.0	181.0	04/29/07	129.0	175.0
11/17/06	139.5	188.5	02/21/07	155.0	182.0	03/27/07	147.0	178.0	04/30/07	128.0	170.0
11/18/06	137.0	200.0	02/22/07	151.0	179.0	03/28/07	143.0	171.0	05/01/07	127.0	169.0
11/19/06	137.5	180.0	02/23/07	147.5	177.0	03/29/07	141.0	171.0	05/02/07	128.0	167.0
11/20/06	138.0	181.0	02/24/07	146.0	176.0	03/30/07	141.0	170.0	05/03/07	127.0	167.0
11/22/06	135.0	213.0	02/25/07	148.0	179.0	03/31/07	141.0	170.0	05/04/07	126.0	167.0
11/24/06	148.0	177.5	02/26/07	147.0	176.0	04/01/07	147.0	176.0	05/05/07	124.0	167.0
11/25/06	148.0	175.5	02/27/07	145.0	176.0	04/02/07	147.0	175.5	05/06/07	124.0	169.0
11/26/06	145.0	178.0	02/28/07	143.0	176.0	04/03/07	139.0	177.0	05/07/07	123.0	167.0
11/27/06	148.0	175.0	03/01/07	143.0	175.0	04/04/07	138.0	169.0	05/08/07	120.0	167.0
11/28/06	140.5	186.0	03/02/07	142.0	175.5	04/05/07	136.0	169.0			
11/29/06	138.0	199.0	03/03/07	143.0	176.0	04/06/07	136.0	169.0			
11/30/06	138.0	196.0	03/04/07	137.0	178.0	04/07/07	136.0	169.0			
12/01/06	176.5	177.0	03/05/07	142.5	175.0	04/08/07	136.0	175.0			
12/02/06	135.5	180.0	03/06/07	147.0	181.0	04/09/07	136.0	174.0			
12/03/06	133.5	170.5	03/07/07	142.0	174.5	04/10/07	137.0	181.0			
12/04/06	133.5	172.5	03/08/07	143.0	175.0	04/11/07	136.0	168.5			
12/05/06	131.5	177.0	03/09/07	142.0	175.0	04/12/07	136.0	169.0			
12/06/06	136.0	191.0	03/10/07	142.0	175.0	04/13/07	137.0	169.0			
12/07/06	136.0	191.0	03/11/07	143.0	179.0	04/14/07	137.0	169.0			
12/08/06	130.5	174.5	03/12/07	152.0	181.0	04/15/07	135.0	175.0			
12/09/06	131.0	170.0	03/13/07	148.0	179.0	04/16/07	135.0	173.5			
12/11/06	135.0	181.5	03/14/07	146.0	177.0	04/17/07	137.0	179.0

Figure 12. Stilling well water depths and stage of the East Fork Lewis River, 2006-07.

Discussion

Installation of environmental monitoring equipment was delayed in 2006 due to a severe winter storm in early November (Figure 6). However, all equipment was in place before adults were released into the channels. Log barriers placed in the fall of 2003 to protect the spawning channels from high water events in Duncan Creek performed as intended and no events, such as overland flows, occurred during the fall/winter/spring of 2006-07 that would have introduced “fines” to the channels or changed the Fredle Index values calculated from samples collected during the 2004-05 season. The egg-to-fry survival rates for 2006-07, reported later in this document, also suggest that gravel conditions in the channels remain very favorable to spawning and incubation.

Daily average temperatures recorded by data loggers placed in the spawning gravel of the middle and north (November 16, 2006 through May 8, 2007) channels (the two channels used by adults) ranged from 7.3 to 10.4 °C, well above the 2.2 °C minimum that can negatively impact spawning and incubation (Schroder 1973; Koski 1975). The average sub-surface water temperature for the middle channel during the 2006-07 season was 8.8 °C. This value falls in the range of values calculated for the 2003-04 (8.8 °C), 2004-05 (9.4 °C) and 2005-06 (9.0 °C) seasons. The average sub-surface water temperature for the north channel during the 2006-07 season was 8.2 °C, which falls between the values calculated for the 2003-04 (8.1 °C) and 2004-05 (8.5 °C) seasons.

While better than measurements recorded in prior years, the 2006-07 water velocity measurements taken at the two collection weirs are still consistently lower than recommended by Schroder (2000). No clear pattern has developed for water velocities, except that the north channel has had consistently higher values than the middle channel for all years sampled.

Continued monitoring of the hyporheic zone, including temperature, gravel composition, hydraulic gradients, and DO levels will continue to ensure that the incubation environment in the Duncan Creek channels is suitable for this ESA-listed species.

Part IV: Natural Spawning and Juvenile Production Monitoring

Introduction

Recolonization by adults straying from the LG population, and the capture and release of LG population adults into the channels are the two primary means of reinitiating natural spawning in the Duncan Creek spawning channels. Adult chum salmon returning to Duncan Creek can either be placed above the weirs in the spawning channels to reproduce naturally, or transported to Washougal Hatchery for use in the hatchery supplementation portion of the program. The reproductive success of adults placed in the spawning channels 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 are constructed and maintained correctly, and female densities remain at less than one female per two 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 for 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 salmon 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. Schroder (2000) recommends artificially spawning 30-50 females to develop regression formulas to predict fecundity. Multiple years of data must be collected on artificially-crossed females of the LG population to develop these fecundity relationships and to 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 is measured by sampling the females less than 24 hours after death and counting potentially viable eggs.

Success of adults spawning in the channels can also be measured by estimating the number of returning adults from natural reproduction occurring in the Duncan Creek spawning channels, the fry-to-adult survival rate called for in the LCR chum salmon recovery strategy. This requires that all fry be trapped when migrating out of the spawning channels and marked for identification as adults. Lastly, adult chum salmon returning to spawn from Bonneville Dam downstream to the I-205 Bridge must be sampled for Duncan Creek Project marks, and an estimate of adult abundance in the different spawning locations made. Juveniles trapped in 2002 and 2003 were not marked with strontium (Sr) due to lack of required permits. These permits have since been received and all chum fry from the spawning channels have been marked by immersion in a strontium bath since spring of 2004 (2003 brood year). Strontium marking is carried out under an Investigational New Animal Drug (INAD) permit (# 010536 D-0005), issued by the Federal Food and Drug Administration Center for Veterinary Medicine.

Methods

Weekly spawning-ground surveys of Duncan Creek and the channels below the weirs were conducted by PSMFC personnel. All adult chum observed, dead or alive, were enumerated and biological samples were collected from carcasses. Biological sampling included: taking tissue samples for genetic analysis, scales for aging, lengths (fork (mm) and mid-eye-to-hypural (MEtH) (mm)), gender and the number of eggs retained in females. Carcass recovery location and tag number(s), if present, were also recorded. WDFW and PSMFC personnel conducted daily surveys of the spawning channels above the monitoring weirs to collect these data on post-spawn mortalities.

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 explained the greatest amount of variation, were used. Regardless of the formula, 95% confidence intervals were calculated and three values (expected, upper and lower 95% CI) were developed for each female. The sum of these individual female values were used to create an expected, upper and lower 95% CI of PED for each channel.

Data to calculate values of AED for individual females were collected during daily surveys above the weirs. Egg size was measured by randomly collecting up to ten eggs from any female found with viable retained eggs. These eggs were placed in water, refrigerated for 24 hours, blotted dry and individually weighed to the nearest milligram. Egg size has been shown to vary little within a female; modal coefficient of variation for Grays River females equaled 2.5% (Steve Schroder, pers. comm.). A sample of one or two eggs can be used to determine egg size (Schroder 2000). After sampling, the carcass was removed from the channel and placed into the riparian zone of Duncan Creek to constrain pathogens and maintain DO levels in the channels.

Enumeration of out-migrating fry was done with downstream migrant traps at the two monitoring weirs, put into place during channel construction. When operated properly, the weirs should be 100% efficient in capturing juveniles, providing an actual outmigration count rather than an estimate. One weir is below two channels, the south and middle, the other is below the north channel (Figure 13). Fence-panel weir fry traps were used to capture the migrating fry in 2007 (Blankenship and Tible 1980). These were the same traps used in 2003-06. The fence panels were modified in 2004 with an additional piece of fine mesh vexar added to the bottom edge of every panel (Hillson 2004). When installing the fry traps, trenches were dug in the gravel to set the fence-panel weirs. Then, with the added strip of vexar lying along the bottom, the trench was filled with gravel. This effectively formed a barrier preventing fry from swimming through the gravel or under the bottom of the fence panels.

Figure 13. Diagram of Duncan Creek and the renovated spawning channels.

Traps were checked daily by either WDFW or PSMFC personnel. All trapped fish were enumerated, marked and released daily; mortalities and their location (on fence panels or in live box) were recorded. Strontium marking was accomplished via a six-hour immersion in a marking bath with a concentration of 2000 ppm strontium chloride hexahydrate (Schroder et al 1995). Because of concerns about on-site disposal and storage of marking water, a recirculating marking bath was designed in 2004. Hillson (2004) detailed the construction and operation of this system. To accomplish dusk/nighttime releases, fry were removed from the live boxes and placed into the marking bath so that the end of the six-hour marking period coincided with dusk/nighttime, and they could be immediately released. Direct mortality associated with strontium marking or sampling was evaluated. Every Tuesday, up to 200 fry from that day's collection were divided into treatment and control groups and held for 48 hours to assess delayed mortality. Every Thursday, five fry from the treatment group were taken to Washougal Hatchery to be grown out and then sacrificed for voucher samples.

Up to thirty randomly-chosen fry from each channel were weighed (0.01 g) and measured (fork length) every Monday, Wednesday and Friday. These data were used to calculate K_D values (Bams 1970) for individual fish.

Results

All adults placed in the channels above the monitoring weirs were tagged (a numbered opercule tag if collected from a mainstem area and double Floy tags if captured below the weirs in Duncan Creek) and given an opercule punch. In addition, those brought from mainstem spawning areas had their fork lengths recorded prior to release. The channels above the south monitoring weir received 30 adults (15 males and 15 females) and the channel above the north monitoring weir received 34 adults (14 males and 20 females) (Table 19). As stated in **Section I**, only females that met the strict original criteria for inclusion as broodstock were put above one of the two monitoring weirs, this was the south monitoring weir in 2006. Any other females collected from mainstem areas along with all volunteers to Duncan Creek were placed above the north monitoring weir, including the one brought to the channels that escaped at the hatchery. No adults escaped from above the weirs in 2006. However, nine additional carcasses (five males and four females) were sampled below the monitoring weirs.

Biological data collected during spawning-ground surveys above and below the weirs is summarized in Table 20. Three scales were taken from each fish for age determination. Age-4 fish dominated the age structure of males: 12% age-3, 88% age-4 (Figure 14). Age-4 fish also dominated the age structure of females: 3% age-3, 94% age-4 and 3% age-5 (Figure 14). A comparison of average fork and mid-eye-to-hypural lengths by age and sex can be found in Table 21. Age-3 male fork lengths ranged from 71 cm to 76.5 cm, averaging 74.3 cm, age-4 males ranged from 67 cm to 84 cm, averaging 76.0 cm (Figure 15). The single age-3 female had a fork length of 68 cm, age-4 females ranged from 63 cm to 77 cm, averaging 69.5 cm and the single age-5 female had a fork length of 70 cm (Figure 15). The number of retained viable eggs for females sampled above the monitoring weirs ranged from zero to 2,213 and averaged 97.8 (n=33).

Table 19. Date of capture and origin of adult chum salmon used for supplementation in the Duncan Creek spawning channels, fall 2006.

Date	Location	Number adult chum salmon seined (includes fresh and recaptured adults)	Duncan Creek Channels			
			Above south weir		Above north weir	
			Male	Female	Male	Female
11/16	Ives Area	20	2	1		
11/20	Ives Area	36	5	5		
11/22	Ives Area	11	1	1		
11/25	Duncan Creek	3			2	1
11/26	Duncan Creek					1
11/27	Ives Area	27	1	1		
11/28	Multnomah Area	60		2		
11/28	St. Cloud Area	24	2			
11/29	Ives Area	11	1	1		
11/29	Duncan Creek					1
11/30	Duncan Creek				2	1
12/1	Duncan Creek				2	2
12/1	Multnomah Area	69	2	3		
12/2	Duncan Creek					1
12/4	Duncan Creek					2
12/4	Ives Area	124	1	1		
12/5	Duncan Creek				1	1
12/7	Duncan Creek					2
12/8	Duncan Creek					1
12/11	Ives Area	54				1
12/12	Duncan Creek				7	6
Total			15	15	14	20

Table 20. Biological data from adults placed in spawning channels and found below monitoring weirs, fall 2006.

Date released	Date sampled	Sex	Channel N=North M= Middle	Age	Fork length (cm)	Mid-eye-to-hypural (cm)	# of eggs retained	Comments
16-Nov	26-Nov	M	M	4	84.0	64.0		
16-Nov	26-Nov	M	M	4	83.5	63.0		
16-Nov	03-Dec	F	M	4	70.0	55.5	3	
20-Nov	28-Nov	M	M	4	72.0	56.0		
20-Nov	03-Dec	M	M	4	78.0	58.0		
20-Nov	03-Dec	M	M	4	77.0	60.0		
20-Nov	05-Dec	F	M	4	74.0	58.0	6	
20-Nov	07-Dec	F	M	4	66.0	54.0		
20-Nov	07-Dec	F	M	4	67.0	54.5		
20-Nov	07-Dec	F	M	4	68.0	55.0	5	
20-Nov	07-Dec	M	M	4	79.0	59.0		
20-Nov	07-Dec	M	M	4	81.0	61.5		
20-Nov	11-Dec	F	M	4	74.0	58.5		
22-Nov	03-Dec	M	M	3	76.5	57.0		
22-Nov	----	F	M	4	69.0	55.5	2	
27-Nov	11-Dec	F	M	4	63.0	51.0		
27-Nov	11-Dec	M	M	4	73.0	55.0		
28-Nov	09-Dec	F	M	4	69.0	53.0		
28-Nov	09-Dec	M	M	4	77.0	58.5		
28-Nov	11-Dec	F	M	4	71.0	56.0	274	
28-Nov	18-Dec	M	M	4	79.0	60.0		
29-Nov	07-Dec	M	M	4	72.0	55.0		
29-Nov	18-Dec	F	M	4	72.0	59.0		
01-Dec	18-Dec	F	M	4	74.0	57.0		
01-Dec	18-Dec	F	M	4	71.0	57.0		
01-Dec	18-Dec	F	M	4	69.0	56.0	125	
01-Dec	18-Dec	M	M	4	74.0	57.0		
01-Dec	----	M	M	4	76.5	58.0		
04-Dec	18-Dec	F	M	4	67.0	54.0	500	
04-Dec	28-Dec	M	M	3	73.0	57.0		
19-Dec	03-Jan	F	M	4	77.0	62.5	2213	From Hatchery, pre-spawn mort
25-Nov	03-Dec	M	N	4	75.0	58.0		captured from Duncan Creek
25-Nov	07-Dec	M	N	4	77.0	59.5		captured from Duncan Creek
25-Nov	18-Dec	F	N	4	71.0	57.0		captured from Duncan Creek
26-Nov	07-Dec	F	N	4	68.0	54.5	2	captured from Duncan Creek
29-Nov	18-Dec	F	N	4	67.0	54.5		captured from Duncan Creek
30-Nov	11-Dec	F	N	4	71.0	55.5	3	captured from Duncan Creek
30-Nov	18-Dec	M	N	3	71.0	54.1		captured from Duncan Creek
30-Nov	18-Dec	M	N	4	70.0	53.5		captured from Duncan Creek
01-Dec	07-Dec	F	N	4	75.0	58.0		captured from Duncan Creek
01-Dec	11-Dec	M	N	4	77.0	58.0		captured from Duncan Creek
01-Dec	18-Dec	M	N	4	74.0	57.5		captured from Duncan Creek
01-Dec	----	F	N	4	72.0	57.5	33	captured from Duncan Creek
02-Dec	18-Dec	F	N	4	64.0	54.0		captured from Duncan Creek
04-Dec	18-Dec	F	N	----	68.0	55.5		captured from Duncan Creek
04-Dec	18-Dec	F	N	4	75.0	60.0		captured from Duncan Creek
05-Dec	18-Dec	M	N	4	72.0	55.5		captured from Duncan Creek
05-Dec	----	F	N	4	68.0	52.5	12	captured from Duncan Creek
07-Dec	18-Dec	F	N	4	68.0	54.5		captured from Duncan Creek
07-Dec	18-Dec	F	N	4	65.0	54.0		captured from Duncan Creek
08-Dec	11-Dec	F	N	4	68.0	53.0	7	captured from Duncan Creek
12-Dec	18-Dec	F	N	4	70.0	55.5		captured from Duncan Creek
12-Dec	18-Dec	M	N	4	72.0	54.0		captured from Duncan Creek
12-Dec	18-Dec	M	N	4	74.0	57.0		captured from Duncan Creek

Table 20. Continued

Date released	Date sampled	Sex	Channel	Age	Fork length (cm)	Mid-eye-to-hypural (cm)	# of eggs retained	Comments
12-Dec	18-Dec	M	N	4	71.0	54.5		captured from Duncan Creek
12-Dec	18-Dec	M	N	4	72.0	56.0		captured from Duncan Creek
12-Dec	18-Dec	M	N	4	71.0	53.0		captured from Duncan Creek
12-Dec	18-Dec	M	N	4	76.0	57.0		captured from Duncan Creek
12-Dec	28-Dec	F	N	4	64.0	51.0		captured from Duncan Creek
12-Dec	28-Dec	F	N	4	71.0	56.0	6	captured from Duncan Creek
12-Dec	28-Dec	F	N	4	70.0	58.0	30	captured from Duncan Creek
12-Dec	28-Dec	F	N	4	64.0	53.0	5	captured from Duncan Creek
12-Dec	28-Dec	M	N	4	67.0	53.5		captured from Duncan Creek
12-Dec	----	F	N					captured from Duncan Creek
----	28-Nov	M		4	80.5	60.0		dead below S weir
----	03-Dec	M		4	83.0	62.0		dead below conf.
----	03-Dec	M		4	81.5	61.0		dead below conf.
----	03-Dec	M		4	80.0	60.0		dead below N weir
----	03-Dec	M		3	76.5	58.5		dead below S weir
----	11-Dec	F		3	68.0	55.0	1	dead below conf.
----	11-Dec	F		4	69.0	55.0		dead below conf.
----	11-Dec	F		4	68.0	57.0		dead below conf.
----	09-Jan	F		5	70.0	56.5		dead below S wier

Figure 14. Age composition of adult chum salmon sampled above and below monitoring weirs, Duncan Creek fall 2006.

Table 21. Average fork length (cm) and mid-eye-to-hypural lengths (cm) by sex and age of adults placed into spawning channels and sampled below monitoring weirs, fall 2006.

Sex	Age	N=	Avg. fork length (cm)	Avg. mid-eye-to-hypural (cm)
Male	3	4	74.3	56.7
	4	30	76.0	57.8
	5	0	----	----
	Combined	34	75.8	57.5
Female	3	1	68.0	55.0
	4	35	69.3	55.6
	5	1	70.0	56.5
	Combined	37	69.3	55.6

Figure 15. Fork lengths (mm) of male (top) and female (bottom) chum salmon placed in the Duncan Creek spawning channels, grouped by age and 10 mm increments, fall 2006.

Data from females spawned at Washougal Hatchery in 2006 were used to create predictive regression formulas to estimate PED of females who spawned naturally in the channels in 2006. Individual reproductive values (total egg mass weight (g) / body weight (g)) were calculated for all females spawned at the hatchery. Females with reproductive values less than 16% have likely lost eggs or already spawned at least once in the river before capture (Steve Schroder, pers. comm.) and were not included in the regression analysis.

The best relationships, highest R-squared value, were used to calculate female PED values. Since all the females placed above the south monitoring weir were age-4, only two equations were needed: age-4 Log10 MEtH length ($R^2 = 0.097$) and age-4 Log10 MEtH length and mean green egg size ($R^2 = 0.495$). Expected individual PED values were then summed to create a total channel PED. Confidence intervals (95%) were then calculated for each individual PED value. A standard error (SE) value for total channel PED was derived by taking the square root of the summed variance values of the individual PED's 95% confidence interval values. Each channel's SE was multiplied by 1.96 to generate 95% confidence intervals for total channel PED values. Values of expected total channel PED along with upper and lower 95% confidence intervals are presented in Table 22. For comparison, average fecundity by age was also used to estimate PED. Because the channel above the north monitoring weir received all chum salmon that were captured in Duncan Creek, regardless of ripeness/spawning state, any estimates of PED values for these females would be mostly speculative and thus not calculated. A statistical method to do this in future years will be presented in the discussion section.

The number of retained eggs was known for all females that spawned above the weirs (Table 20). This allowed AED values (expected, upper and lower 95% CI) to be calculated for each channel (Table 23).

Table 22. PED values (expected, lower and upper 95% CI) for the Duncan Creek spawning channels by method, fall 2006.

Predictive fecundity regression formulas			
Channel	Expected	Lower 95% CI	Upper 95% CI
South	36,963	34,283	39,644
North	Not estimated	Not estimated	Not estimated
Using mean fecundity by age group			
Channel	Expected	Lower 95% CI	Upper 95% CI
South	35,771	32,965	38,578
North	Not estimated	Not estimated	Not estimated

Table 23. AED values (expected, lower and upper 95% CI) for the Duncan Creek spawning channels by method, fall 2006.

Predictive fecundity regression formulas			
Channel	Expected	Lower 95% CI	Upper 95% CI
South	36,048	33,368	38,729
North	Not estimated	Not estimated	Not estimated
Using mean fecundity by age group			
Channel	Expected	Lower 95% CI	Upper 95% CI
South	34,856	32,050	37,663
North	Not estimated	Not estimated	Not estimated

Intra-gravel temperatures, recorded bi-monthly from inside piezometers, were used to estimate daily temperature units (TUs) of the first eggs deposited in the channels, and thus estimate emergence. Historical data from the spawning channels suggest that 1550 to 1600 °F (860 to 890 °C) TUs are needed before any fry will be seen in the traps. To ensure that none were missed, fry trapping began at both weirs on February 21, five days before any fry were projected to reach 1500 °F TUs.

The number of fry captured in a monitoring weir fry trap is used in conjunction with the combined AED value for females that spawned above the weir to calculate expected, upper and lower 95% CI for egg-to-fry survival rates. Juvenile trapping operations began on February 21 and ended May 8, 2007. A total of 29,707 chum salmon fry (20,402 and 9,371 south and north weir traps respectively) were recovered from the two fry traps (Table 24). Daily trapping totals and cumulative percent passage at each weir are displayed in Figures 16 and 17. Other salmonids trapped/seined included 420 age-0 coho, 96 age-1 coho, 7 trout *sp.* fry and 29 yearling+ trout *sp.* (**Appendix B** Table 1). Daily trapping totals are reported in **Appendix B** Table 1. On May 7 and 8, the channels were seined and an additional 68 fry (2 above the south and 66 above the north) were recovered above the weirs. Seining was triggered by total collection numbers below 20 for over a week.

A total of 50 mortalities were recovered at the two traps (30 and 20 from the south and north weir traps respectively) resulting in a trapping-related mortality rate of 0.17% (**Appendix B** Table 1). The trap at the south weir had daily mortality rates for chum salmon fry ranging from 0.0 to 50% (one out of two fry collected that day) with an overall season rate of 0.15%. The trap at the north weir had daily rates ranging from 0.0 to 20% (one out of five fry collected that day) with an overall season rate of 0.21%.

Table 24. Number of chum salmon fry trapped and seined from the Duncan Creek spawning channels, spring 2007.

	Chum salmon fry		
	Alive	Dead	Total (mortality)
South weir trap	20,372	30	20,402 (0.15%)
North weir trap	9,285	20	9,305 (0.21%)
Trapping total	29,657	50	29,707 (0.17%)
Seining	68	0	68 (0.00%)
Combined	29,725	50	29,775 (0.17%)

Figure 16. Daily collection totals of chum salmon fry at the south weir in the Duncan Creek spawning channels, spring 2007.

Figure 17. Daily collection totals of chum salmon fry at the north weir in the Duncan Creek spawning channels, spring 2007.

Individual weight and length data were collected on a maximum of 30 out-migrating fry from each trap at least three times per week (normally on Monday, Wednesday and Friday) throughout the season. Results of this sampling are presented in Table 25.

Table 25. Daily average weights, fork lengths and K_D values with 95% CI of chum salmon fry at the two traps, 2007.

South weir trap						North weir trap					
Date	Average weight (g)	Mean FL (mm)	n=	K_D	+/-	Date	Average weight (g)	Mean FL (mm)	n=	K_D	+/-
28-Feb	0.36	37.0	1	1.92	---	28-Feb			0		
2-Mar	0.35	36.0	2	1.95	0.23	2-Mar			0		
5-Mar	0.34	36.9	20	1.90	0.04	5-Mar			0		
7-Mar	0.33	36.7	30	1.89	0.04	7-Mar			0		
9-Mar	0.33	36.9	30	1.88	0.03	9-Mar			0		
12-Mar	0.37	37.9	30	1.89	0.03	12-Mar	0.41	38.0	1	1.95	---
14-Mar	0.41	39.8	30	1.86	0.04	14-Mar	0.43	41.0	1	1.84	---
16-Mar	0.40	39.4	30	1.86	0.05	16-Mar	0.38	38.3	3	1.88	0.05
19-Mar	0.41	39.9	30	1.86	0.04	19-Mar	0.41	39.5	15	1.88	0.05
21-Mar	0.40	39.6	30	1.86	0.02	21-Mar	0.40	39.5	30	1.86	0.03
23-Mar	0.41	39.9	30	1.87	0.03	23-Mar	0.39	39.5	30	1.86	0.03
26-Mar	0.41	40.7	30	1.83	0.03	26-Mar	0.41	40.6	30	1.83	0.03
28-Mar	0.40	39.4	30	1.86	0.04	28-Mar	0.42	40.4	30	1.85	0.04
30-Mar	0.40	39.8	30	1.86	0.03	30-Mar	0.40	40.3	30	1.84	0.02
2-Apr	0.40	39.5	30	1.86	0.05	2-Apr	0.42	40.4	30	1.85	0.03
4-Apr	0.39	39.1	30	1.87	0.03	4-Apr	0.41	40.0	30	1.86	0.03
6-Apr	0.39	39.0	30	1.87	0.02	6-Apr	0.44	40.8	30	1.86	0.03
9-Apr	0.43	40.2	30	1.88	0.04	9-Apr	0.45	40.9	30	1.88	0.03
11-Apr	0.46	40.8	9	1.89	0.06	11-Apr	0.45	40.8	30	1.88	0.04
13-Apr			0			13-Apr	0.43	40.4	30	1.87	0.05
16-Apr			0			16-Apr	0.51	42.1	30	1.89	0.06
18-Apr			0			18-Apr	0.43	40.7	30	1.86	0.05
20-Apr	0.82	48.0	1	1.95	---	20-Apr	0.47	41.3	30	1.87	0.05
25-Apr			0			25-Apr	0.49	41.3	6	1.90	0.06
27-Apr	1.02	49.0	1	2.05	---	27-Apr	0.43	42.1	8	1.75	0.10
03-May	1.84	60.0	1	2.04	---	03-May	0.47	43.8	4	1.77	0.02
04-May	1.76	59.0	4	2.04	0.01	04-May	0.82	47.2	30	1.97	0.05

A total of 29,725 fry were placed into the strontium marking bath. Of these, zero died during the six-hour holding period resulting in a marking mortality rate of 0.0%. A total of 1,068 fry (534 and 534 in the control and test groups respectively) were used in the 48 hour delayed mortality evaluation. No mortalities were recovered during the holding period. Five fry from each week's test group, 25 total for the season, were taken to Washougal Hatchery to be grown out and then sacrificed for voucher samples. Strontium-marked voucher fry were grown out so that additional calcium carbonate would be present on the otolith outside of the strontium-marked area. Each group of five voucher fry was reared separately. Removal of voucher fry and mortalities resulted in 29,700 strontium-marked fry being released.

Table 26 details the egg-to-fry survival rates calculated using the AED estimates (expected, lower and upper 95% CI) from the predictive formulas, and mean fecundity rates. The number of fry used in these rates is the number trapped plus seined.

Table 26. Egg-to-fry survival rates (expected, lower and upper 95% CI) for the Duncan Creek spawning channels above monitoring weirs by method, 2007.

Predictive fecundity regression formulas			
Channel	Expected	Lower 95% CI	Upper 95% CI
South	56.6%	52.7%	61.1%
North	Not estimated	Not estimated	Not estimated
Using mean fecundity by age group			
Channel	Expected	Lower 95% CI	Upper 95% CI
South	58.5%	54.2%	63.7%
North	Not estimated	Not estimated	Not estimated

Discussion

The recruitment rate of adult chum salmon (both strays and project origin) into Duncan Creek for 2006 was estimated to be 4.4%, this compares to rates of 1.26%, 0.17%, 0.9%, 0.2% and 0.33-1.0% for 2005, 2004, 2003, 2002 and 2001, respectively. At these low rates, combined with low overall adult returns to this area, it would take many generations for the Duncan Creek spawning channel to reach maximum capacity. Therefore, supplementation with evaluation should continue to ensure the rapid reestablishment of a spawning population in Duncan Creek.

Maintaining natural run timing when collecting broodstock is very important. Actual 2006 tributary spawner run timing, the 2002-06 average tributary spawner run timing and the cumulative count of adults added to the spawning channels in 2006 are presented in Figure 18. While not tested statistically, it appears that broodstock collection for the spawning channels in 2006 closely followed the 2006 natural run timing.

Figure 18. Comparison of 2006 tributary spawner run timing, 2002-06 average tributary spawner run timing and the cumulative number of broodstock collected for the spawning channels in 2006.

The egg-to-fry survival rate for the south channel, using expected values of AED, was 57%. This rate falls within the upper range recorded to date for the spawning channels (Table 27). The estimated egg-to-fry survival rate for the south channel in 2006-07 is close to the expected rate based on the most recent physical habitat sampling (2004-05 Fredle index and percent fines), indicating rates could be 60% to 80% (Chapman 1988). The overall egg-to-fry survival rate for channels supplemented with only green females, 2002-2007 seasons, is 44%.

Table 27. Numbers of adults released, fry totals at each weir and estimated egg-to-fry survival rates at the Duncan Creek spawning channels, 2001-2007.

Season	# Adults released above weir		Fry totals at weir		Egg-to-fry survival rate (%)	
	South (M/F)	North (M/F)	South	North	South	North
2001-02	27 (16/11)	16 (8/8)	1,100 ¹	7,383 ¹	11-17 ²	34-56 ²
2002-03	19 (10/9)	46 (23/23)	9,399	16,079	44 ³	35 ³
2003-04	16 (8/8)	38 (19/19)	15,539	29,911	64	58
2004-05	57 (29/28)	12 (6/6)	19,419	8,395	23	42
2005-06	6 (3/3)	40 (21/19)	4,532 ⁴	26,446 ⁴	51 ⁴	56 ⁴
2006-07	30 (15/15)	34 (14/19)	20,402	9,305 ⁵	57	---
Total	155 (81/74)	185 (91/94)	70,391	97,519	40	49 ⁶

¹ Actual counts only, see Hillson (2002) for details.

² See Hillson (2002) for explanation of range in rates.

³ Channels experienced extremes in low and high water levels, see Hillson (2003) for details.

⁴ These values are minimums, Columbia River flows backwatered the channels, fry trapping was not 100%

⁵ No egg-to-fry survival rate for this channel, no criteria for females placed into this channel other than presence in Duncan Creek.

⁶ Rate only includes data from years when only green females were placed into this channel

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 (Schroder 2000). K_D values can be used to ascertain intra-gravel conditions. Poor intra-gravel conditions may result in premature fry emergence which would be reflected in higher than expected K_D values. Mean K_D values recorded for fry trapped at the weirs for both traps was 1.87 (95% CI +/- 0.04), indicating good conditions in the channels.

Changing to a fence-weir panel fry trap and oversized live boxes in 2003 from the fyke nets and small live boxes used in 2002 reduced the overall trapping-related mortality to 0.79%, down from 10.4% in 2002. The majority of mortalities recovered in 2003 were a result of impingement on the fence-weir panels around the sandbags placed to prevent fry from escaping under the panels. Modifications were made to the fence-weir panels in 2004 negating the need for sandbags, and overall trapping-related mortality was reduced further to only 0.19%. The fry trapping-related mortality rate in 2007 was only 0.17%, the same as 2006, matching the lowest rate in project history.

Analysis of otoliths recovered from 2005 voucher fry, using Laser Ablation Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS), for detectable changes in Sr levels showed that a clear and recognizable mark was present (Hillson 2005). Changes in the strontium marking protocol were made in 2005 in response to concerns that the 2004 strontium marks might not be visible using back-scattered scanning electron imaging. These changes were: 1) increasing the strontium salt concentration in the marking bath to 2000ppm, and 2) increasing the time fry are held in the bath to six hours. Strontium-marked voucher fry from the 2007 season have not been examined. However, the same marking protocol developed in 2005 was used in 2007, and the mark is expected to have the same clarity.

Otolith Lab personnel will evaluate the voucher otoliths using back-scattered scanning electron imaging as soon as access to a scanning electron microscope becomes available (Eric Volk, WDFW Otolith Lab, per. comm.). If the marks are not visible using back-scattered scanning electron imaging, adult recoveries in 2006 through 2011 could only be identified analytically using LA-ICP-MS as naturally-produced project origin adults.

Part V: Adult Returns

Introduction

Measuring the survival and documenting spawning ground distribution of adult chum salmon produced from the two supplementation strategies is one of the four tasks outlined by Schroder (2000) to evaluate the success of this reintroduction program. To determine an adult survival value for each strategy, four things are needed. The first is accurate values for the number of fry annually produced from each strategy. The second is that the fry need to be permanently marked so that when recovered as adults they can be assigned to a strategy. The third is that chum salmon spawning in the Columbia River and its tributaries, from the I-205 Bridge to Bonneville Dam, need to be sampled to identify project-origin adults. Finally, accurate and precise spawning population estimates are needed for areas where sampling for project-origin adults occurred.

Methods for calculating population estimates of spawning chum salmon in the Columbia River and its tributaries were compared by Rawding and Hillson (2003). Because of issues raised in that paper, specifically the validity of key assumptions in the Area-Under-the-Curve (AUC) method, this project chose to conduct adult tagging in conjunction with broodstock seining to generate population estimates via mark/recapture beginning in fall 2002. Details of methods, analysis and the evolution of this marking program are beyond the scope of this report and can be found in Rawding and Hillson (2003 and in prep). Unless noted, population estimates given in this report are the result of mark/recapture tagging programs. Specifically, the estimates for spawners in Hardy and Hamilton creeks, Hamilton Spring Channel and the Ives area were generated via carcass tagging; estimates for the Horsetail, Multnomah, St Cloud and I-205 areas were generated via live tagging.

Columbia River chum salmon mature and return to spawn at ages three, four, or five. Therefore, recovery data will need to be pooled and reported by brood year (BY) and supplementation strategy. Adults from both supplementation strategies could have been present in the fall of 2006. These would be BY 2001 adults returning as age-5 spawners, BY 2002 adults returning as age-4 spawners and BY 2003 adults returning as age-3 spawners. Strontium marking of fry resulting from adult supplementation into the spawning channels began in 2004 (BY 2003) providing the first opportunity to identify project-origin natural spawner adults.

Methods

The methods to accurately determine the number of fry produced from each supplementation strategy and to mark these fry have been detailed in this and prior annual reports for this project. Identification of project-origin adults was done by examination (decoding) of otoliths for thermal and Sr marks (Volk et al 1999 and Brenkman et al 2007). All project hatchery-origin fry have been thermally marked; Sr marking has been done annually since spring 2004. When a chum salmon carcass was sampled (recovery location, sex, fork length and scales removed for aging), if possible one or both otoliths were also recovered and placed in a uniquely numbered sampling vial containing 200 proof Ethyl Alcohol USP. In areas where carcass tagging was done to estimate spawner populations (Ives area, Hardy and Hamilton creeks, and Hamilton Spring Channel) the carcass was returned to moving water after being sampled and tagged. In areas where carcass tagging was not conducted to estimate the spawning population (Duncan Creek,

Horsetail, Goodbear/Archer Creek, Multnomah, St Cloud and the I-205 areas) the tail of the fish was removed to prevent duplicate counting.

As mentioned above, details of methods and analysis for population estimates can be found in Rawding and Hillson (2003 and in prep). Carcass tagging in the Ives area was conducted under the Evaluation of Fall Chinook and Chum Salmon Spawning Below Bonneville, The Dalles, Johns Day, and McNary Dams Project (BPA project # 1999-003-01). Carcass tagging in Hardy Creek and the Hamilton Spring Channel was conducted under the Evaluate Factors Limiting Columbia River Gorge Chum Salmon Populations Project (BPA project # 2000-012-00). Data from those projects carcass-tagging programs were provided to personnel of this project for population estimate analysis and inclusion in this report.

The percent of project-origin spawners for each area is calculated by dividing the number of project-origin otoliths by the total number of decoded otoliths for each area. Results of otolith decoding from adults removed for broodstock were added back to the area of collection. The percent of project-origin adults recovered in each area was then applied to the population estimate to generate the estimated number of project-origin adults in that area and project-origin contribution rates for the areas were calculated. Numbers of project-origin adults in each area were then summed to a total return number by strategy. These totals and the number of marked fry released will be used to generate an estimate of fry-to-adult survival rates once all age classes have returned for a given BY.

Results

Of the 456 otoliths collected, the otolith lab was able to decode 444. The number of otoliths decoded and the number of hatchery-origin recoveries by sampling location is presented in Table 28. The results of parsing each area's spawning population by the percentage of thermally marked otoliths identified by location and origin are presented in Table 29. Percent contribution rates of hatchery-origin adults are reported in Table 30. Results of the analysis using LA-ICP-MS to determine project origin natural production is presented in Table 31. There was a very small sample size, n=14, of the 444 possible, for this analysis in 2006 since only age-3 (2003 brood year) strontium marked adults would be present and age-3 adults compromised less than 8% of the overall 2006 return.

Table 28. Numbers of otoliths decoded, number of hatchery-origin adults identified through otolith decoding by brood year, fall 2006.

Location	Number Otoliths decoded	# Duncan Creek Project		
		2001 BY	2002 BY	2003 BY
Hamilton Creek	81	0	0	0
Hamilton Spring Channel	29	0	0	0
Hardy Creek	12	0	0	0
Ives Area	161	0	0	0
Duncan Creek	41	0	0	0
Horsetail Area	10	0	0	0
Multnomah Area	38	0	0	0
Goodbear/Archer Creeks	2	0	0	0
St Cloud Area	25	0	0	0
I-205 Area	45	0	0	0

Table 29. Results of parsing population estimates based on otolith sampling to determine the number of hatchery-origin adults at a spawning location, fall 2006.

Location	Population Estimate (95% CI)	Duncan Creek Project		
		2001 BY	2002 BY	2003 BY
Hamilton Creek	246 (69-423)	0	0	0
Hamilton Spring Channel	236 (230-243)	0	0	0
Hardy Creek	104 (94-113)	0	0	0
Ives Area	348 (245-451)	0	0	0
Duncan Creek	42 (*)	0	0	0
Horsetail Area	63 (33-93)	0	0	0
Multnomah Area	313 (365-261)	0	0	0
Goodbear/Archer Creeks	3(*)	0	0	0
St Cloud Area	173 (105-241)	0	0	0
I-205 Area	862 (830-893)	0	0	0
Total		0	0	0

* No CI are available, population estimate reported is the number of unique individuals sampled in that area.

Table 30. Percent contribution rates for hatchery-origin adults, fall 2006.

Location	Duncan Creek Project		
	2001 BY	2002 BY	2003 BY
Hamilton Creek	0	0	0
Hamilton Spring Channel	0	0	0
Hardy Creek	0	0	0
Ives Area	0	0	0
Duncan Creek	0	0	0
Horsetail Area	0	0	0
Multnomah Area	0	0	0
Goodbear/Archer Creeks	0	0	0
St Cloud Area	0	0	0
I-205 Area	0	0	0

Table 31. Numbers of otoliths decoded for Strontium mark, number of natural production project-origin adults identified through otolith decoding by brood year, fall 2006.

Location	Number Otoliths decoded	# Duncan Creek Project
		2003 BY
Hamilton Creek	3	0
Hamilton Spring Channel	0	0
Hardy Creek	2	0
Ives Area	4	0
Duncan Creek	3	0
Horsetail Area	0	0
Multnomah Area	0	0
Goodbear/Archer Creeks	0	0
St Cloud Area	1	0
I-205 Area	1	0

Discussion

This was the third year for returning project-origin adults and the first year that naturally spawning project-origin adults could be identified via strontium marks. The recovery rate for otoliths from tributary spawners was 25.96%, the recovery rate for mainstem spawners was 15.86%, yielding a combined otolith recovery rate of 18.58% in 2006. These rates are lower than what we were able to achieve in 2005: 54.73% for tributaries, 16.25% for mainstem and a combined rate of 23.09%. Recovery rates for otoliths at all but the Multnomah spawning area and Duncan Creek trap were lower in 2006 when compared to 2005. Effort levels did not change between years but flows were higher in 2006 than 2005 during our sampling time and this is likely the reason for the decrease in recoveries.

Given that progeny from three hatchery brood years, 2001-2003, would be returning in 2006 it is perplexing that no hatchery project-origin adults were found. The overall contribution rate of project hatchery-origin adults to the chum salmon spawning population between Bonneville Dam and the I-205 Bridge was estimated to be 3.54% in 2005 (Hillson 2006). It is possible that project origin adults returned in 2006 but the sampling effort was not intense enough to recover/detect them. It is also possible that river/estuary conditions become unfavorable between the time when natural-origin fry outmigrated in mid-March through early-April and mid-May when the hatchery fry were released.

In addition, on the first pass of otolith decoding 78 of the 444 otoliths examined were thought to have had thermal marks indicating hatchery origin. However, when the voucher otoliths were decoded the marks did not match and the otolith lab designated these marks as “mimic” patterns, four mimic patterns were identified. The otolith lab was asked to decode additional voucher samples, initially only five of the twenty-five voucher samples collected from each mark group were decoded, to see if these patterns could be found in the other voucher samples but no matching patterns were found. This amount of mimic marks is highly unlikely and very unexpected. The quality/clarity of the marks had otolith lab personnel convinced that they were artificially placed on the otoliths. Producing a clear thermal mark on the otolith requires the ambient temperature to change at least two degrees C in under thirty minutes and only one mark/bar will be produced in a 24 hour period. One plausible explanation for the creation of these mimic marks was that rapid large fluctuations in tailwater elevation could influence warm-water upwelling in the egg pocket of a redd resulting in a quick change of ambient temperature. This could certainly happen at the mainstem spawning areas, with the Ives area the most likely location. However, these mimic patterns were found in every area sampled except the Horsetail spawning area and appear to be predominately on the Washington State side of the river (Table 32).

Table 32. Distribution of Thermal Mimic Patterns, fall 2006.

Location	Population Estimate (95% CI)	# Decoded otoliths	# With Mimic Pattern	% Of Population
Hamilton Creek	246 (69-423)	81	15	18.5%
Hamilton Spring Channel	236 (230-243)	29	3	10.3%
Hardy Creek	104 (94-113)	12	1	8.3%
Ives Area	348 (245-451)	161	34	21.1%
Duncan Creek	42 (*)	41	7	17.1%
Horsetail Area	63 (33-93)	10	0	0.0%
Multnomah Area	313 (365-261)	38	1	2.6%
Goodbear/Archer Creeks	3(*)	2	2	100.0%
St Cloud Area	173 (105-241)	25	7	28.0%
I-205 Area	862 (830-893)	45	8	17.8%
Total		444	78	15.6%

* No CI are available, population estimate reported is the number of unique individuals sampled in that area.

Expanding the mimic marks by recovery rates results in 372 (15.6%) of the adult return in 2006 having these mimic marks. Age was known from scale analysis for 77 of the 78 adults with mimic marks and all but three adults were age-4 (two were age-3 and one was age-5). This is only the second year when large numbers of otoliths have been decoded from these areas; it remains to be seen if large numbers of mimic marks is a frequent occurrence. If future returns have similar numbers of these mimic marks present it may be necessary to add a secondary external mark (adipose clip) on hatchery project-origin fry to distinguish them. Thermal marks would still be needed to identify BY, and prevent mimic marks from confounding future analysis.

The lack of natural production project-origin adults being detected in 2006 while disappointing, was not unexpected due to only one BY of strontium marked fish returning, as age-3 adults, in combination with the low percent of age-3 adults in the 2006 return. In 2007, with two BY's of strontium marked adults returning and having age-4 marked adults present, which will greatly increase our sample size, we should expect to recover strontium-marked adults.

Since it is very uncommon for chum salmon to return as age-6 adults, the 2006 return marks the end of the 2001 hatchery BY brood cycle and a fry-to-adult survival rate can be estimated. A total of 45,046 hatchery fry were released in 2002, 67 adults were estimated to have returned from this release (all in 2005 as age-4 adults) resulting in a fry-to-adult survival rate of 0.15%. However, if adults from this BY returned exhibiting a typical age distribution, i.e. some as age-3, most as age-4 and a few as age-5 and age-6, but we did not detect them due to sampling issues the fry-to-adult survival rate would increase. The 2002-2006 chum salmon average spawner age structure was 24% as age-3, 69% as age-4, 7% as age-5, and >0.1% as age-6 (n= 3,451) for mainstem and tributary spawning areas near Bonneville Dam. Adding in the expected numbers of age-3 and age-5 adults to the 67 age-4 adults yields approximately 100 total adults would have returned from the 2002 hatchery fed-fry release, increasing the fry-to-adult survival to 0.22%.

Summary

The Duncan Creek Chum Salmon Project was successful in 2005-06, providing knowledge and experience that will improve program execution in future years. All broodstock collection was done using beach seines, likely decreasing the stress on adults handled while increasing capture efficiency. We were able to adapt to the loss of the adult trap at the start of the season and still achieve our goal of capturing and recovering the majority, if not all, of the chum salmon that volunteered to Duncan Creek. Changes to the broodstock collection criteria allowed for the inclusion of a higher percentage of females seined. This in turn allowed us to meet the minimum collection goal for females at the spawning channels and nearly meet the goal for artificially-spawned females, despite only a small increase in overall adult return size and a challenging seining season due to unusually high river levels. The lack of recovered hatchery project-origin adults in the 2006 return was disappointing and still unexplained. Certain infrastructure weaknesses exposed in past seasons still exist and one of those negatively impacted the project (pump failure at hatchery) in 2006. An egg-to-fry survival rate of 57% is in the upper range of historical channel performance indicating that the spawning channels are still providing favorable spawning and incubation conditions.

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Appendix A

Summary table reporting average daily temperatures in the Duncan Creek spawning channels (Table 1).

Appendix A. Table 1. Daily average water temperatures, Duncan Creek spawning channels, November 16, 2006 to May 7, 2007.

Date	South channel					Middle channel					North channel							
	Mid					Mid					Mid					Mid		
	Water	Sub-surface			water	water	Sub-surface			water	water	Sub-surface			water			
	Top	#1	#2	#3	#4	bottom	top	#1	#2	#3	#4	bottom	top	#1	#2	#3	#4	bottom
11/16	9.9			9.8	9.7	9.8	9.8	9.7	9.8	9.8	9.8	9.4	10.4		9.7	9.8	10.3	9.9
11/17	9.8			9.7	9.5	9.6	9.8	9.6	9.7	9.7	9.7	9.2	10.3		9.6	9.7	10.3	9.7
11/18	9.8			9.7	9.4	9.6	9.8	9.6	9.7	9.6	9.6	9.2	10.2		9.5	9.6	10.2	9.6
11/19	9.8			9.7	9.5	9.6	9.8	9.6	9.7	9.7	9.6	9.3	10.0		9.5	9.5	10.2	9.5
11/20	10.0			9.9	9.7	9.8	9.7	9.6	9.8	9.8	9.8	9.4	10.0		9.3	9.4	10.1	9.5
11/21	9.9			9.8	9.7	9.7	9.7	9.6	9.8	9.7	9.8	9.3	9.8		9.1	9.3	9.9	9.4
11/22	9.9			9.8	9.6	9.6	9.6	9.6	9.7	9.6	9.7	9.2	9.8		9.1	9.2	9.9	9.3
11/23	9.9			9.8	9.6	9.7	9.6	9.6	9.7	9.6	9.7	9.2	9.7		9.2	9.2	9.9	9.3
11/24	9.8			9.9	9.7	9.8	9.6	9.6	9.7	9.7	9.8	9.3	9.7		9.1	9.1	9.9	9.3
11/25	9.8			9.9	9.7	9.8	9.6	9.6	9.7	9.6	9.8	9.2	9.6		9.1	9.1	9.7	9.2
11/26	9.8			9.8	9.5	9.5	9.6	9.6	9.5	9.5	9.6	9.0	9.4		8.9	9.1	9.6	9.0
11/27	9.8			9.7	9.5	9.5	9.6	9.5	9.5	9.5	9.5	9.0	9.4		8.9	9.1	9.5	9.0
11/28	9.7			9.6	9.4	9.4	9.6	9.5	9.4	9.3	9.4	8.9	9.3		8.9	9.0	9.4	8.8
11/29	9.6			9.4	9.0	9.1	9.5	9.5	9.1	9.0	9.1	8.6	9.1		8.7	9.0	9.3	8.6
11/30	9.7			9.5	9.3	9.3	9.5	9.5	9.3	9.3	9.4	8.9	9.1		8.6	8.8	9.1	8.6
12/1	9.8			9.7	9.5	9.5	9.5	9.3	9.5	9.5	9.6	9.1	9.1		8.4	8.6	9.1	8.6
12/2	9.6			9.4	9.1	9.2	9.5	9.3	9.1	9.0	9.1	8.6	9.0		8.4	8.7	9.0	8.3
12/3	9.5			9.2	8.8	8.9	9.4	9.3	8.9	8.9	8.9	8.5	8.9		8.2	8.8	8.9	8.2
12/4	9.6			9.5	9.2	9.2	9.4	9.3	9.1	9.2	9.3	8.8	8.9		8.5	8.5	8.9	8.4
12/5	9.7			9.6	9.3	9.3	9.3	9.3	9.3	9.2	9.3	8.9	8.9		8.5	8.3	8.9	8.3
12/6	9.6			9.3	9.0	9.1	9.3	9.3	9.1	9.0	9.0	8.6	8.9		8.4	8.5	8.8	8.2
12/7	9.6			9.3	9.0	9.1	9.3	9.3	9.0	9.0	9.0	8.6	8.9		8.3	8.7	8.8	8.2
12/8	9.5			9.2	8.9	9.0	9.3	9.3	9.0	8.9	8.9	8.5	8.8		8.2	8.7	8.8	8.1
12/9	9.6			9.3	9.0	9.1	9.3	9.3	9.0	9.0	9.1	8.6	8.8		8.4	8.5	8.8	8.2
12/10	9.7			9.5	9.1	9.3	9.3	9.3	9.2	9.2	9.3	8.8	8.8		8.3	8.3	8.8	8.2
12/11	9.7			9.6	9.3	9.4	9.3	9.3	9.2	9.2	9.4	8.9	8.8		8.0	8.0	8.8	8.2
12/12	9.6			9.7	9.4	9.5	9.3	9.2	9.3	9.3	9.6	8.9	8.7		8.0	8.0	8.8	8.1
12/13	9.4			9.6	9.4	9.5	9.2	9.2	9.2	9.2	9.6	8.9	8.5		8.1	8.0	8.6	8.1
12/14	9.4			9.4	9.2	9.3	9.1	9.1	9.1	9.0	9.4	8.7	8.3		8.2	8.0	8.4	8.1
12/15	9.3			9.4	9.1	9.3	9.0	9.0	8.9	8.8	9.3	8.4	8.0		7.7	7.8	8.2	7.9
12/16	9.1			9.1	8.7	9.0	8.9	8.8	8.8	8.6	9.0	8.2	7.9		7.7	7.9	8.0	7.8
12/17	8.9			8.9	8.6	8.8	8.8	8.8	8.7	8.5	8.8	8.1	7.8		7.5	7.9	7.9	7.6
12/18	8.7			8.8	8.5	8.6	8.8	8.8	8.6	8.5	8.7	8.1	7.8		7.8	8.0	7.9	7.7
12/19	8.6			8.7	8.4	8.5	8.8	8.8	8.3	8.5	8.6	8.1	7.8		7.9	8.0	7.9	7.7
12/20	8.5			8.6	8.4	8.4	8.8	8.8	8.4	8.4	8.5	8.0	7.8		7.8	8.1	7.9	7.6
12/21	8.6			8.7	8.6	8.6	8.8	8.8	8.5	8.7	8.6	8.3	7.8		8.0	8.0	7.9	7.7
12/22	8.7			8.7	8.6	8.6	8.8	8.8	8.5	8.7	8.7	8.3	7.8		8.0	7.8	7.9	7.7
12/23	8.6			8.7	8.6	8.6	8.8	8.8	8.5	8.6	8.7	8.3	7.8		7.9	7.8	7.9	7.6
12/24	8.6			8.7	8.6	8.5	8.8	8.8	8.5	8.5	8.6	8.2	7.7		8.0	7.8	7.8	7.6
12/25	8.7			8.8	8.6	8.6	8.8	8.8	8.6	8.7	8.7	8.3	7.7		7.7	7.7	7.7	7.6
12/26	8.7			8.7	8.6	8.6	8.8	8.8	8.5	8.5	8.7	8.2	7.5		7.9	7.7	7.7	7.6
12/27	8.6			8.7	8.6	8.6	8.7	8.8	8.5	8.6	8.7	8.2	7.4		7.9	7.6	7.6	7.5
12/28	8.5			8.5	8.4	8.4	8.7	8.7	8.3	8.4	8.5	8.0	7.4		7.7	7.6	7.5	7.4
12/29	8.4			8.5	8.3	8.4	8.7	8.7	8.3	8.3	8.4	7.9	7.3		7.7	7.8	7.4	7.4
12/30	8.3			8.4	8.2	8.3	8.7	8.7	8.2	8.3	8.3	7.9	7.3		7.6	7.7	7.3	7.4
12/31	8.3			8.4	8.2	8.3	8.7	8.7	8.3	8.3	8.3	7.9	7.3		7.7	7.8	7.3	7.4
1/1	8.3			8.4	8.3	8.3	8.7	8.7	8.4	8.5	8.4	8.0	7.3		7.7	7.8	7.4	7.5
1/2	8.5			8.6	8.6	8.6	8.7	8.8	8.6	8.7	8.7	8.3	7.4		7.4	7.7	7.5	7.6
1/3	9.2			9.2	8.9	9.0	9.1	9.1	8.9	9.0	9.1	8.6	8.4		8.2	8.3	8.5	8.1
1/4	8.3			8.5	8.4	8.4	8.7	8.8	8.4	8.5	8.5	8.2	7.4		8.0	7.7	7.6	7.5
1/5	8.3			8.4	8.4	8.4	8.7	8.8	8.5	8.6	8.5	8.2	7.4		8.0	7.7	7.6	7.5
1/6	8.3			8.4	8.4	8.4	8.7	8.8	8.5	8.6	8.5	8.2	7.5		8.0	7.7	7.6	7.5

Appendix A. Table 1. Continued

Date	South channel						Middle channel						North channel					
	Mid Water Top	Sub-surface				Mid water bottom	Mid water top	Sub-surface				Mid water bottom	Mid water top	Sub-surface				Mid water bottom
		#1	#2	#3	#4			#1	#2	#3	#4			#1	#2	#3	#4	
1/7	8.3			8.4	8.4	8.4	8.7	8.7	8.6	8.7	8.5	8.3	7.4		8.1	7.7	7.5	7.5
1/8	8.1			8.4	8.4	8.4	8.7	8.7	8.6	8.7	8.5	8.3	7.4		8.0	7.7	7.5	7.5
1/9	8.1			8.4	8.4	8.3	8.7	8.7	8.5	8.6	8.4	8.3	7.4		8.0	7.7	7.5	7.5
1/10	8.0			8.1	8.1	8.0	8.7	8.7	8.4	8.5	8.2	8.1	7.3		8.0	7.8	7.4	7.4
1/11	7.9			8.0	8.0	7.9	8.6	8.7	8.2	8.3	8.0	7.9	7.4		7.8	7.8	7.4	7.4
1/12	7.8			7.9	7.9	7.8	8.6	8.7	7.8	8.3	7.9	7.8	7.4		7.7	7.8	7.5	7.4
1/13	7.8			7.9	7.9	7.9	8.7	8.7	7.8	8.4	8.0	8.0	7.6		7.7	7.8	7.5	7.5
1/14	7.8			7.8	7.8	7.7	8.7	8.8	7.8	8.2	7.8	7.7	7.5		7.6	7.9	7.6	7.5
1/15	7.8			7.8	7.7	7.7	8.7	8.8	7.8	8.1	7.8	7.6	7.6		7.6	7.9	7.7	7.5
1/16	7.8			7.9	7.8	7.7	8.7	8.8	7.6	8.3	7.9	7.8	7.7		7.8	8.0	7.7	7.5
1/17	7.9			8.1	8.1	8.0	8.8	8.8	8.1	8.6	8.2	8.1	7.9		8.1	8.0	7.8	7.7
1/18	7.9			8.1	8.2	8.1	8.8	8.8	8.2	8.5	8.2	8.1	7.9		8.1	8.0	7.9	7.7
1/19	8.0			8.2	8.2	8.1	8.8	8.8	8.2	8.6	8.2	8.1	7.9		8.1	8.0	8.0	7.7
1/20	8.0			8.3	8.3	8.1	8.8	8.8	8.4	8.6	8.3	8.2	7.9		8.2	7.9	8.0	7.7
1/21	8.0			8.2	8.3	8.2	8.8	8.8	8.4	8.6	8.4	8.3	8.0		8.3	7.9	8.1	7.7
1/22	8.1			8.3	8.3	8.2	8.8	8.8	8.5	8.6	8.4	8.3	8.0		8.3	7.9	8.1	7.7
1/23	8.0			8.2	8.3	8.2	8.9	8.8	8.4	8.6	8.4	8.2	8.0		8.2	7.8	8.1	7.7
1/24	8.0			8.2	8.2	8.1	8.9	8.8	8.4	8.6	8.3	8.1	8.0		8.1	7.9	8.1	7.7
1/25	8.0			8.2	8.2	8.1	8.9	8.9	8.3	8.6	8.3	8.2	8.0		8.2	7.9	8.1	7.6
1/26	7.9			8.2	8.1	8.0	8.9	8.9	8.2	8.5	8.2	8.0	8.0		8.0	8.0	8.1	7.7
1/27	7.9			8.1	8.0	8.0	8.9	8.9	8.2	8.4	8.1	8.0	7.9		8.0	8.1	8.0	7.6
1/28	7.9			8.0	7.9	7.9	8.9	8.9	8.1	8.3	8.1	7.9	7.9		8.0	8.1	7.9	7.6
1/29	7.9			8.0	8.0	8.0	8.9	9.0	8.1	8.4	8.1	8.0	7.9		8.1	8.1	8.0	7.6
1/30	7.9			8.0	7.9	7.9	9.0	8.8	8.1	8.4	8.1	7.9	7.9		8.0	8.1	8.0	7.6
1/31	7.9			8.0	8.0	8.0	9.0	9.0	8.1	8.4	8.1	8.0	7.9		8.0	8.2	8.0	7.6
2/1	8.0			8.1	8.1	8.0	9.0	8.9	8.0	8.5	8.1	8.1	8.0		8.1	8.1	8.1	7.6
2/2	8.0			8.1	8.1	8.0	9.0	9.0	8.1	8.5	8.2	8.1	7.9		8.2	8.0	8.1	7.6
2/3	8.0			8.3	8.3	8.2	9.0	8.9	8.3	8.6	8.4	8.3	8.0		8.3	7.8	8.1	7.7
2/4	8.1			8.4	8.4	8.3	9.0	9.0	8.5	8.7	8.5	8.4	8.1		8.3	7.8	8.2	7.7
2/5	8.1			8.3	8.3	8.2	9.0	9.0	8.5	8.6	8.4	8.3	8.1		8.2	7.9	8.1	7.7
2/6	8.1			8.3	8.3	8.2	9.0	8.9	8.5	8.6	8.4	8.3	8.1		8.2	7.9	8.1	7.8
2/7	8.1			8.3	8.2	8.2	9.0	9.0	8.4	8.6	8.4	8.2	8.1		8.2	8.1	8.2	7.8
2/8	8.1			8.3	8.4	8.3	9.0	9.0	8.6	8.7	8.5	8.4	8.1		8.3	8.1	8.2	7.9
2/9	8.1			8.4	8.5	8.3	9.0	8.9	8.6	8.7	8.6	8.4	8.1		8.3	8.0	8.2	7.9
2/10	8.1			8.3	8.3	8.3	9.0	9.0	8.5	8.7	8.4	8.3	8.1		8.2	8.0	8.2	7.9
2/11	8.1			8.4	8.4	8.4	9.0	9.0	8.6	8.7	8.5	8.4	8.1		8.3	8.1	8.2	7.9
2/12	8.1			8.4	8.5	8.3	9.0	8.9	8.7	8.7	8.5	8.4	8.1		8.3	8.1	8.2	7.9
2/13	8.1			8.3	8.4	8.3	9.0	8.9	8.6	8.7	8.5	8.4	8.1		8.3	8.0	8.2	7.9
2/14	8.0			8.4	8.4	8.3	9.0	9.0	8.6	8.7	8.5	8.4	8.1		8.3	8.0	8.2	8.0
2/15	7.9			8.2	8.3	8.1	9.0	8.9	8.7	8.8	8.3	8.4	8.1		8.4	8.0	8.2	8.0
2/16	7.8			8.1	8.2	8.1	8.9	8.8	8.5	8.6	8.2	8.3	7.9		8.3	8.0	8.0	7.8
2/17	8.0			8.2	8.4	8.2	8.8	8.7	8.6	8.7	8.4	8.4	7.7		8.4	8.0	7.9	7.8
2/18	7.8			8.1	8.2	8.1	8.7	8.7	8.6	8.6	8.3	8.3	7.6		8.3	8.0	7.7	7.7
2/19	7.8			8.1	8.2	8.1	8.7	8.7	8.5	8.6	8.2	8.3	7.5		8.2	7.9	7.7	7.7
2/20	7.5			7.9	8.0	7.9	8.7	8.7	8.4	8.5	8.0	8.2	7.5		7.9	8.0	7.7	7.7
2/21	7.6			7.9	8.0	7.9	8.6	8.6	8.4	8.5	8.1	8.1	7.6		7.7	8.1	7.7	7.8
2/22	7.6			7.9	8.0	7.9	8.6	8.5	8.4	8.5	8.1	8.1	7.5		7.6	8.1	7.7	7.7
2/23	7.6			8.0	8.1	8.0	8.7	8.5	8.4	8.5	8.1	8.1	7.6		7.6	8.1	7.7	7.7
2/24	7.6			7.8	7.9	7.8	8.7	8.6	8.3	8.3	8.0	7.9	7.5		7.5	8.0	7.7	7.6
2/25	7.6			7.9	8.0	7.9	8.7	8.7	8.4	8.4	8.1	8.1	7.6		7.6	8.0	7.7	7.7
2/26	7.6			7.9	8.0	7.9	8.7	8.7	8.4	8.5	8.1	8.1	7.6		7.5	8.0	7.7	7.7
2/27	7.6			7.9	7.9	7.9	8.7	8.7	8.3	8.4	8.0	8.0	7.5		7.5	7.9	7.7	7.6

Appendix A. Table 1. Continued

Date	South channel					Middle channel					North channel						
	Mid water top	Sub-surface			Mid water bottom	Mid water top	Sub-surface			Mid water bottom	Mid water top	Sub-surface			Mid water bottom		
	#1	#2	#3	#4		#1	#2	#3	#4		#1	#2	#3	#4			
2/28	7.6		7.9	8.0	7.9	8.7	8.7	8.3	8.4	8.1	8.0	7.6		7.4	7.9	7.7	7.5
3/1	7.7		8.0	8.1	8.0	8.7	8.7	8.3	8.4	8.1	8.1	7.6		7.4	7.9	7.7	7.6
3/2	7.6		7.9	8.0	7.9	8.7	8.7	8.3	8.4	8.1	8.0	7.6		7.5	7.9	7.7	7.6
3/3	7.7		8.1	8.2	8.1	8.7	8.7	8.4	8.6	8.3	8.2	7.8		7.5	8.0	7.8	7.8
3/4	7.8		8.0	8.2	8.0	8.7	8.7	8.5	8.6	8.3	8.2	7.7		7.8	8.1	7.8	7.8
3/5	7.8		8.2	8.3	8.1	8.7	8.7	8.6	8.6	8.3	8.3	7.8		7.4	8.2	7.9	7.8
3/6	7.8		8.2	8.3	8.2	8.8	8.7	8.5	8.7	8.4	8.3	7.9		7.6	8.2	7.9	7.8
3/7	7.8		8.1	8.2	8.2	8.8	8.8	8.6	8.6	8.4	8.3	7.7		7.3	8.1	7.8	7.7
3/8	7.8		8.2	8.2	8.2	8.8	8.8	8.6	8.6	8.4	8.3	7.7		7.3	8.0	7.9	7.7
3/9	7.8		8.2	8.3	8.2	8.8	8.8	8.6	8.7	8.4	8.3	7.7		7.4	8.1	7.8	7.7
3/10	7.9		8.2	8.4	8.3	8.8	8.8	8.7	8.8	8.4	8.4	7.7		7.4	8.1	7.8	7.7
3/11	7.9		8.3	8.5	8.4	8.8	8.8	8.7	8.8	8.5	8.5	7.8		7.3	8.2	7.8	7.8
3/12	7.9		8.2	8.3	8.2	8.8	8.8	8.7	8.8	8.4	8.4	7.7		7.3	8.1	7.8	7.7
3/13	7.8		8.1	8.3	8.1	8.8	8.8	8.6	8.8	8.4	8.4	7.7		7.4	8.2	7.8	7.8
3/14	7.8		8.1	8.2	8.1	8.7	8.7	8.6	8.7	8.3	8.3	7.6		7.5	8.2	7.8	7.7
3/15	7.8		8.1	8.3	8.1	8.7	8.7	8.7	8.7	8.4	8.4	7.6		7.7	8.3	7.8	7.8
3/16	7.9		8.2	8.4	8.2	8.7	8.7	8.7	8.7	8.5	8.4	7.6		7.7	8.3	7.8	7.8
3/17	7.9		8.3	8.5	8.3	8.8	8.8	8.7	8.8	8.6	8.5	7.7		7.7	8.4	7.8	7.9
3/18	7.9		8.3	8.4	8.3	8.8	8.8	8.7	8.8	8.6	8.5	7.7		7.6	8.3	7.9	7.9
3/19	8.0		8.2	8.4	8.3	8.8	8.8	8.7	8.8	8.5	8.4	7.8		7.7	8.4	7.9	7.9
3/20	7.9		8.1	8.3	8.1	8.8	8.8	8.7	8.7	8.4	8.3	7.8		7.8	8.4	7.9	8.0
3/21	7.9		8.2	8.4	8.2	8.8	8.8	8.7	8.8	8.5	8.5	7.9		8.0	8.6	8.1	8.2
3/22	7.9		8.3	8.4	8.3	8.8	8.8	8.8	8.9	8.6	8.5	7.9		8.0	8.6	8.2	8.2
3/23	8.0		8.3	8.4	8.3	8.8	8.8	8.8	8.8	8.6	8.5	8.0		8.0	8.6	8.1	8.2
3/24	7.9		8.3	8.4	8.3	8.8	8.8	8.8	8.8	8.6	8.4	8.1		7.9	8.5	8.1	8.2
3/25	7.9		8.2	8.4	8.2	8.8	8.8	8.8	8.9	8.5	8.5	8.1		8.1	8.6	8.3	8.3
3/26	7.8		8.1	8.2	8.1	8.8	8.8	8.7	8.9	8.3	8.4	8.1		8.2	8.7	8.3	8.2
3/27	7.8		8.1	8.3	8.1	8.7	8.8	8.7	8.9	8.4	8.4	8.1		8.1	8.6	8.2	8.2
3/28	7.9		8.2	8.4	8.2	8.8	8.8	8.8	8.9	8.5	8.5	8.2		8.2	8.7	8.3	8.3
3/29	8.0		8.3	8.4	8.3	8.8	8.8	8.8	8.9	8.6	8.5	8.2		8.4	8.8	8.3	8.5
3/30	8.0		8.3	8.5	8.3	8.8	8.8	8.9	9.0	8.7	8.6	8.2		8.2	8.8	8.3	8.4
3/31	8.0		8.3	8.4	8.3	8.8	8.8	8.8	8.9	8.5	8.5	8.2		8.1	8.7	8.2	8.3
4/1	8.0		8.3	8.5	8.3	8.9	8.8	8.8	8.9	8.7	8.6	8.3		8.3	8.8	8.4	8.5
4/2	8.0		8.2	8.4	8.2	8.9	8.8	8.8	8.9	8.5	8.5	8.2		8.2	8.7	8.3	8.3
4/3	8.0		8.2	8.4	8.2	8.9	8.8	8.8	8.9	8.5	8.5	8.3		8.4	8.8	8.3	8.4
4/4	8.1		8.4	8.6	8.4	8.9	8.8	8.9	9.0	8.7	8.6	8.3		8.5	8.8	8.3	8.5
4/5	8.1		8.5	8.6	8.5	8.9	8.8	9.0	9.0	8.8	8.8	8.4		8.7	8.9	8.4	8.7
4/6	8.1		8.6	8.7	8.5	8.9	8.8	9.0	9.1	8.9	8.8	8.4		8.7	9.0	8.4	8.7
4/7	8.1		8.5	8.5	8.4	8.9	8.9	8.9	9.0	8.7	8.6	8.3		8.3	8.8	8.4	8.5
4/8	8.1		8.5	8.6	8.5	9.0	9.0	9.0	9.0	8.9	8.7	8.4		8.4	8.9	8.4	8.6
4/9	8.1		8.4	8.4	8.3	9.0	9.0	8.9	8.9	8.6	8.6	8.4		8.4	8.8	8.4	8.5
4/10	8.1		8.4	8.5	8.3	9.0	9.0	8.9	9.0	8.7	8.6	8.4		8.5	8.9	8.5	8.6
4/11	8.0		8.3	8.3	8.2	9.0	9.0	8.8	8.9	8.5	8.5	8.4		8.4	8.8	8.4	8.5
4/12	8.0		8.3	8.4	8.3	9.0	9.0	8.9	8.9	8.6	8.5	8.5		8.4	8.8	8.4	8.5
4/13	8.1		8.4	8.5	8.4	9.0	9.0	8.9	9.1	8.8	8.7	8.5		8.5	8.9	8.5	8.6
4/14	8.1		8.5	8.6	8.4	9.0	9.0	9.0	9.1	8.9	8.7	8.5		8.5	8.9	8.5	8.6
4/15	8.2		8.5	8.6	8.5	9.0	9.0	9.0	9.1	8.9	8.7	8.5		8.5	9.0	8.6	8.7
4/16	8.3		8.3	8.4	8.3	9.0	9.0	8.9	8.9	8.6	8.5	8.4		8.4	8.9	8.6	8.6
4/17	8.2		8.4	8.5	8.4	9.0	9.0	8.9	9.0	8.7	8.6	8.4		8.5	8.9	8.6	8.6
4/18	8.3		8.3	8.5	8.3	9.0	9.0	8.9	9.0	8.7	8.7	8.5		8.5	8.9	8.7	8.6
4/19	8.2		8.4	8.7	8.5	9.0	9.0	9.0	9.1	8.9	8.8	8.6		8.6	9.1	8.7	8.8
4/20	8.2		8.4	8.6	8.4	9.0	9.0	9.0	9.0	8.9	8.8	8.5		8.6	9.2	8.6	8.8

Appendix A Table 1. Continued

Date	South channel						Middle channel						North channel					
	Mid water top	Sub-surface				Mid water bottom	Mid water top	Sub-surface				Mid water bottom	Mid water top	Sub-surface				Mid water bottom
		#1	#2	#3	#4			#1	#2	#3	#4			#1	#2	#3	#4	
4/21	8.1			8.3	8.5	8.3	9.0	9.0	8.9	8.9	8.6	8.6	8.5		8.5	8.9	8.5	8.6
4/22	8.1			8.4	8.6	8.4	9.0	9.0	9.0	9.0	8.8	8.7	8.5		8.5	9.0	8.6	8.7
4/23	8.1			8.5	8.8	8.5	9.0	9.0	9.1	9.1	9.0	8.8	8.6		8.7	9.1	8.6	8.7
4/24	8.1			8.4	8.6	8.4	9.0	9.0	9.0	9.0	8.8	8.6	8.5		8.5	9.0	8.6	8.6
4/25	8.1			8.5	8.7	8.5	9.0	9.0	9.0	9.0	8.9	8.7	8.5		8.6	9.0	8.7	8.7
4/26	8.1			8.5	8.9	8.6	9.0	9.0	9.1	9.1	9.0	8.8	8.6		8.7	9.1	8.8	8.8
4/27	8.1			8.6	9.0	8.7	9.0	9.0	9.1	9.1	9.2	8.9	8.6		8.7	9.2	8.8	8.9
4/28	8.1			8.6	9.0	8.7	9.0	9.0	9.2	9.0	9.1	8.9	8.6		8.8	9.2	8.8	8.9
4/29	8.1			8.5	8.9	8.7	9.0	9.0	9.2	9.0	9.0	8.9	8.7		8.7	9.2	8.9	8.9
4/30	8.1			8.6	8.8	8.6	9.0	9.0	9.2	9.1	9.0	8.8	8.6		8.7	9.2	8.9	8.8
5/1	8.1			8.5	8.8	8.6	9.0	9.0	9.1	9.1	8.9	8.8	8.6		8.6	9.1	8.8	8.8
5/2	8.0			8.5	8.8	8.5	9.0	9.0	9.2	9.0	9.0	8.7	8.6		8.7	9.1	8.8	8.8
5/3	8.0			8.5	8.8	8.5	9.0	9.0	9.1	9.0	8.9	8.7	8.6		8.7	9.1	8.8	8.9
5/4	8.0			8.5	8.8	8.5	9.0	9.0	9.1	9.0	8.9	8.8	8.6		8.7	9.1	8.8	8.9
5/5	8.0			8.5	8.9	8.6	9.0	9.0	9.1	9.1	9.0	8.8	8.7		8.7	9.2	9.0	9.0
5/6	8.0			8.5	8.8	8.6	9.0	9.0	9.1	9.1	9.0	8.8	8.7		8.7	9.2	8.9	8.9
5/7	8.2			8.8	9.3	15.6	15.7	9.0	9.4	9.2	9.4	15.6	15.8		8.9	9.3	8.8	8.9

Appendix B

Summary tables reporting daily collection of salmonids and daily percent mortality for age 0+ chum at the two weirs in Duncan Creek (Table 1), and daily totals of strontium-marked fry placed into the marking bath, mortality in the marking bath, number of strontium-marked fry released daily and results of the 48 hour delayed-mortality study (Table 2), 2007.

Appendix B. Table 1. Daily collection numbers of salmonids and daily percent mortality for age 0+ chum salmon at the two weirs in the Duncan Creek spawning channels, 2007.

Date	South weir							North weir						
	Chum				Coho		Other	Chum				Coho		Other
	Age 0+				Age 0+	Age 1+		Age 0+				Age 0+	Age 1+	
	Live	Dead	Total	% Mort	Total	Total		Live	Dead	Total	% Mort	Total	Total	
21-Feb	0	0	0		85			0	0	0				
22-Feb	0	0	0		16			0	0	0				
23-Feb	0	0	0		12	1		0	0	0				
24-Feb	0	0	0		4	5		0	0	0				
25-Feb	0	0	0		3	3		0	0	0				
26-Feb	0	0	0					0	0	0				
27-Feb	0	0	0		1	1		0	0	0				
28-Feb	1	0	1	0.0%		1		0	0	0				
01-Mar	0	0	0		1			0	0	0				
02-Mar	2	0	2	0.0%	1			0	0	0				
03-Mar	2	0	2	0.0%	1			0	0	0				
04-Mar	5	0	5	0.0%	1			0	0	0				
05-Mar	20	0	20	0.0%		1		0	0	0				
06-Mar	129	0	129	0.0%				0	0	0				
07-Mar	129	0	129	0.0%			1 Sm. STHD/RB	0	0	0				
08-Mar	454	0	454	0.0%		1		0	0	0				
09-Mar	317	0	317	0.0%			1 Clip Juv. STHD	0	0	0				
10-Mar	508	0	508	0.0%	17	1		0	0	0				
11-Mar	502	0	502	0.0%	2			0	0	0				
12-Mar	387	0	387	0.0%		1		1	0	1	0.0%			
13-Mar	537	0	537	0.0%		1		4	0	4	0.0%			
14-Mar	479	0	479	0.0%				1	0	1	0.0%			
15-Mar	499	1	500	0.2%		1		0	0	0				
16-Mar	635	0	635	0.0%		1		3	0	3	0.0%			
17-Mar	917	1	918	0.1%				3	0	3	0.0%			
18-Mar	1120	3	1123	0.3%				3	0	3	0.0%			
19-Mar	966	2	968	0.2%		1		15	0	15	0.0%			
20-Mar	1082	0	1082	0.0%		1		171	0	171	0.0%			
21-Mar	1172	0	1172	0.0%				210	0	210	0.0%			
22-Mar	1381	0	1381	0.0%	1			104	0	104	0.0%			
23-Mar	1227	4	1231	0.3%	2			57	0	57	0.0%			
24-Mar	1048	2	1050	0.2%	2	1		147	0	147	0.0%			
25-Mar	1171	3	1174	0.3%	4	1		220	2	222	0.9%			
26-Mar	1048	1	1049	0.1%				252	0	252	0.0%			

Appendix B. Table 1. Continued

Date	South weir							North weir						
	Chum				Coho			Chum				Coho		
	Age 0+				Age 0+		Age 1+	Age 0+				Age 0+		Age 1+
	Live	Dead	Total	% Mort	Total	Total		Live	Dead	Total	% Mort	Total	Total	
27-Mar	937	0	937	0.0%	2		N. Pikeminnow Juv	467	0	467	0.0%			
28-Mar	542	1	543	0.2%				320	3	323	0.9%			
29-Mar	627	0	627	0.0%			1 Sm. STHD/RB	491	1	492	0.2%			
30-Mar	439	1	440	0.2%				727	0	727	0.0%			
31-Mar	325	3	328	0.9%				880	1	881	0.1%			
01-Apr	521	2	523	0.4%				371	0	371	0.0%			
02-Apr	175	0	175	0.0%				338	0	338	0.0%			
03-Apr	192	1	193	0.5%				244	2	246	0.8%		3	
04-Apr	151	2	153	1.3%			1 Sm. Juv. STHD	265	0	265	0.0%			
05-Apr	233	0	233	0.0%				533	0	533	0.0%			
06-Apr	174	0	174	0.0%		1		239	1	240	0.4%			
07-Apr	82	0	82	0.0%			2 Sm. Juv. STHD	302	0	302	0.0%			
08-Apr	98	1	99	1.0%				818	1	819	0.1%			
09-Apr	34	0	34	0.0%		1	2 Sm. Juv. STHD	409	1	410	0.2%			
10-Apr	55	1	56	1.8%	1	1	2 cutthroat, 1 Amneocete	469	1	470	0.2%			
11-Apr	9	0	9	0.0%				218	0	218	0.0%			
12-Apr	21	0	21	0.0%		1		173	0	173	0.0%			
13-Apr	0	0	0			2		176	0	176	0.0%			
14-Apr	3	0	3	0.0%		2	3 cutthroat trout	21	1	22	4.5%			
15-Apr	5	0	5	0.0%	1	2		123	1	124	0.8%			
16-Apr	0	0	0			3	1 Sm. STHD/RB	68	0	68	0.0%			
17-Apr	0	0	0		1			27	1	28	3.6%			
18-Apr	0	0	0			1		39	0	39	0.0%			
19-Apr	1	0	1	0.0%		1	1 Sm. STHD/RB	59	0	59	0.0%			
20-Apr	1	0	1	0.0%		4		64	1	65	1.5%			
21-Apr	0	0	0		5	3	1 Sm. STHD/RB, 1 cutthroat	29	0	29	0.0%			
22-Apr	0	0	0		1	4		15	1	16	6.3%			
23-Apr	2	0	2	0.0%	2	4	1 Sm. STHD/RB1 Sm clip STHD	41	0	41	0.0%			
24-Apr	1	1	2	50.0%	3	1		16	0	16	0.0%			
25-Apr	0	0	0			2	1 Amneocete	6	0	6	0.0%			
26-Apr	0	0	0		1	1	1 Sm. STHD/RB	9	0	9	0.0%			
27-Apr	1	0	1	0.0%		1	1 Sm. STHD/RB	8	0	8	0.0%			
28-Apr	0	0	0		1	2	1 Sm. STHD/RB	0	0	0				
29-Apr	0	0	0			3		8	0	8	0.0%			

Appendix B. Table 1. Continued

Date	South weir							North weir						
	Chum			% Mort	Coho		Other	Chum			% Mort	Coho		Other
	Age 0+		Age 0+		Age 1+	Age 0+		Age 0+	Age 1+					
	Live	Dead	Total		Total	Live		Dead	Total	Total		Total		
30-Apr	0	0	0		5	1	1 Sm. STHD/RB, 1 cutthroat	4	0	4	0.0%			
01-May	0	0	0		2	2		5	0	5	0.0%			
02-May	0	0	0		5	1	5 Sm. STHD/RB, 1 cutthroat	3	0	3	0.0%			
03-May	1	0	1	0.0%	8	3		11	0	11	0.0%			
04-May	4	0	4	0.0%	10	1		88	1	89	1.1%			
05-May	0	0	0		5	2		2	0	2	0.0%			
06-May	0	0	0		7	4		4	0	4	0.0%			
07-May	0	0	0					4	1	5	20.0%			
08-May	0	0	0		3	7		0	0	0				
Seining														
07-May	1	0	1	0.0%	247	9		60	0	60	0.0%			
08-May	1	0	1	0.0%	42	1		6	0	6	0.0%			
Total	20,374	30	20,404	0.15%	420	93		9,351	20	9,371	0.21%		3	

Appendix B. Table 2. Daily totals for strontium marking of age-0+ chum salmon at the Duncan Creek spawning channels, 2007.

Appendix B: Table B1. Daily totals for strontium marking of age-0 channel catfish at the Diamond Green spawning channel, 2007.										
Date	Daily collection (minus morts)	Strontium marking bath			Delayed mortality test				# Voucher fry removed from test group	Daily # released
		#	#	#	# Held in each group		# Mortalities recovered			
		Added	Morts	Removed	Test	Control	Test	Control		
2/21	0	0	0	0						0
2/22	0	0	0	0						0
2/23	0	0	0	0						0
2/24	0	0	0	0						0
2/25	0	0	0	0						0
2/26	0	0	0	0						0
2/27	0	0	0	0						0
2/28	1	1	0	1						1
3/1	0	0	0	0						0
3/2	2	2	0	2						2
3/3	2	2	0	2						2
3/4	5	5	0	5						5
3/5	20	20	0	20						20
3/6	129	129	0	129						129
3/7	129	129	0	129						129
3/8	454	454	0	454						454
3/9	317	317	0	317						317
3/10	508	508	0	508						508
3/11	502	502	0	502						502
3/12	388	288	0	288	100	100				188
3/13	541	541	0	541			0	0		541
3/14	480	580	0	580			0	0	5	675
3/15	499	499	0	499						499
3/16	638	638	0	638						638
3/17	920	920	0	920						920
3/18	1,123	1,123	0	1,123						1,123
3/19	981	881	0	881	100	100				781
3/20	1,253	1,253	0	1,253			0	0		1,253
3/21	1,382	1,482	0	1,482			0	0	5	1,577
3/22	1,485	1,485	0	1,485						1,485
3/23	1,284	1,284	0	1,284						1,284
3/24	1,195	1,195	0	1,195						1,195
3/25	1,391	1,391	0	1,391						1,391
3/26	1,300	1,200	0	1,200	100	100				1,100
3/27	1,404	1,504	0	1,504			0	0		1,599

Appendix B. Table 2. Continued.

Appendix B: Table 2: Continued.

Date	Daily collection (minus morts)	Strontium marking bath			Delayed mortality test				# Voucher fry removed from test group	Daily # released
		# Added	# Morts	# Removed	# Held in each group		# Morts recovered			
					Test	Control	Test	Control		
3/28	862	962	0	962			0	0	5	1,062
3/29	1,118	1,118	0	1,118						1,118
3/30	1,166	1,166	0	1,166						1,166
3/31	1,205	1,205	0	1,205						1,205
4/1	892	892	0	892						892
4/2	513	413	0	413	100	100				313
4/3	436	436	0	436			0	0		436
4/4	416	516	0	516			0	0	5	611
4/5	766	766	0	766						766
4/6	413	413	0	413						413
4/7	384	384	0	384						384
4/8	916	916	0	916						916
4/9	443	343	0	343	100	100				243
4/10	524	524	0	524			0	0		524
4/11	227	327	0	327			0	0	5	422
4/12	194	194	0	194						194
4/13	176	176	0	176						176
4/14	24	24	0	24						24
4/15	128	128	0	128						128
4/16	68	34	0	34	34	34				0
4/17	27	27	0	27			0	0		27
4/18	39	73	0	73			0	0	0	107
4/19	60	60	0	60						60
4/20	65	65	0	65						65
4/21	29	29	0	29						29
4/22	15	15	0	15						15
4/23	43	43	0	43						43
4/24	17	17	0	17						17
4/25	6	6	0	6						6
4/26	9	9	0	9						9
4/27	9	9	0	9						9
4/28	0	0	0	0						0
4/29	8	8	0	8						8
4/30	4	4	0	4						4
5/1	5	5	0	5						5

Appendix B. Table 2. Continued.

Appendix B: Table 2: Continued.

Date	Daily collection (minus morts)	Strontium marking bath			Delayed mortality test				# Voucher fry removed from test group	Daily # released
		#	#	#	# Held in each group		# Morts recovered			
		Added	Morts	Removed	Test	Control	Test	Control		
5/2	3	3	0	3						3
5/3	12	12	0	12						12
5/4	92	92	0	92						92
5/5	2	2	0	2						2
5/6	4	4	0	4						4
5/7	65	65	0	65						65
5/8	7	7	0	7						7
Total	29,725	29,725	0	29,725	534	534	0	0	25	29,700