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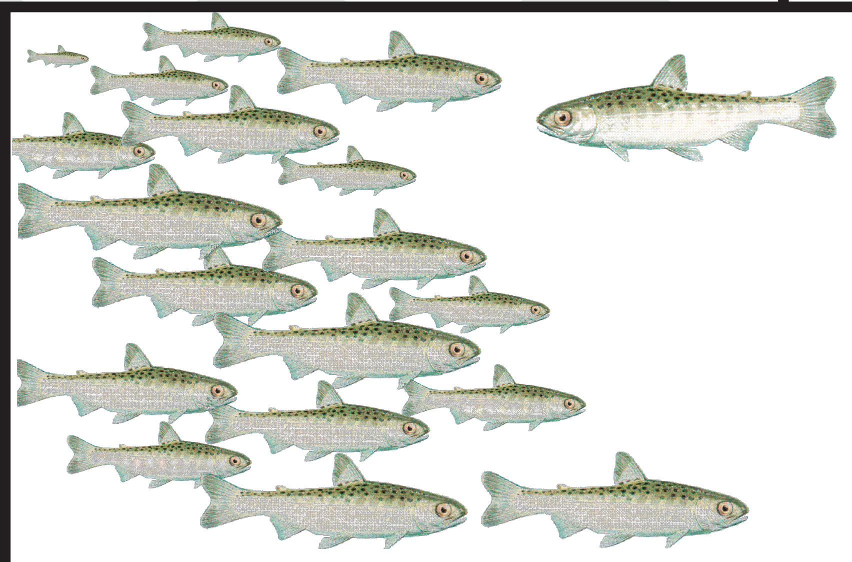
2006 Juvenile Salmonid Production Evaluation Report:

Green River, Dungeness River, and Cedar Creek



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Washington Department of
Fish and Wildlife
Fish Program

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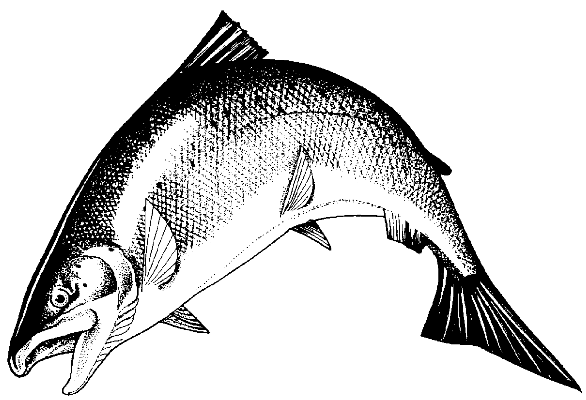
2006 Juvenile Salmonid Production Evaluation Report

Green River and Dungeness River Chinook Monitoring Evaluations and Cedar Creek Juvenile Salmon Production



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August 2008

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Green River

Measuring juvenile salmon production from large river systems like the Green River involves a tremendous amount of work. Key to developing these estimates are the long hours of trap operation provided by our dedicated scientific technicians: Bob Green, Josh Weinheimer and Paul Lorenz. Logistical support was provided by Wild Salmon Production/Evaluation Unit biologist Mike Ackley.

A number of other individuals and agencies contributed to this project. For providing access to the trap site, we thank the adjacent landowner Bill Mosby. We also thank Mike Wilson, manager of the Soos Creek Hatchery, for providing logistical support, office space and a secure staging site near the trap.

Dungeness River

WDFW scientific technicians Chris Burns, Fiona Taylor, Paul Lorenz, and Ken Gilliam worked the long hours of trap operation; their hard work and dedication was key to achieving our project goals. Wild Salmon Production Evaluation Unit biologist, Mike Ackley and scientific technician Brian Blazer provided logistical and technical support in all areas of the project.

In addition, we would like to thank the landowners of Dungeness Farms Inc., especially caretaker Matt Heins, who gave us unrestricted access to their property for trap placement and office trailer space, and provided power, water, phone, tools, and general support, and landowners Ray Gorynski and Nash Huber, who allowed us dike access to the trap site. We also thank Scott Chitwood and Rodger Mosley, employees of the Jamestown S'Klallam Tribe, for their contributions to this study, and Dan Witczak, manager of the Hurd Creek Hatchery, for providing logistical support and storage of our office trailer.

Cedar Creek

Skip Walch, Bao Le, Christina Luzier from the USFWS provided the CWT tagging machine and screw trap for this study. Julie Grobelny, and Scott Nelson worked the trap during the 2006 field season. Their fieldwork was exceptional, and allowed for project goals to be achieved. Additionally, field staff was responsible for data entry, which was accurate and timely. Jeff Grim (WDFW Science Division) analyzed the otoliths to determine the number of RSI origin coho salmon smolts collected. Steve VanderPloeg (WDFW Region 5 Fish Mgt.) created the site map. Cameron Sharpe (WDFW Science Division) assisted with coho data interpretation. Henry Cheng (WDFW Science Division) conducted the KS test on the large coho dataset. Bryce Glaser (WDFW, Region 5 Fish Mgt.) reviewed this report and his comments improved this manuscript.

Table of Contents

List of Tables vii

List of Figures ix

List of Figures ix

Executive Summary xi

Green River xi

Dungeness River xii

Cedar Creek xiii

1 Introduction 1-1

2 Green River 2-3

2.1 Methods 2-3
2.1.1 Trap Operations 2-3
2.1.2 Production Estimate 2-4

2.2 Results 2-7
2.2.1 Chinook 2-7
2.2.1.1 Catch 2-7
2.2.1.2 Size 2-8
2.2.1.3 Catch Expansion 2-10
2.2.1.4 Trap Efficiency 2-10
2.2.1.5 Production Estimate 2-11
2.2.2 Coho 2-13
2.2.2.1 Catch 2-13
2.2.2.2 Size 2-13
2.2.2.3 Catch Expansion 2-15
2.2.2.4 Trap Efficiency 2-15
2.2.2.5 Production Estimate 2-16
2.2.3 Steelhead 2-17
2.2.3.1 Catch 2-17
2.2.3.2 Size 2-17
2.2.3.3 Catch expansion 2-18
2.2.3.4 Trap Efficiency 2-18
2.2.3.5 Production estimate 2-18
2.2.4 Chum 2-18
2.2.4.1 Catch 2-18
2.2.4.2 Trap Efficiency 2-18
2.2.4.3 Production Estimate 2-19
2.2.5 Pink Salmon 2-19
2.2.5.1 Catch 2-19
2.2.5.2 Trap efficiency 2-19
2.2.5.3 Production estimate 2-19
2.2.5.4 Other Species 2-20

2.3 Discussion 2-21
2.3.1 Chinook 2-21
2.3.2 Coho 2-24
2.3.3 Pink Salmon 2-24
2.3.4 Recommendations 2-25
2.4 Appendices A & B 2-27
2.5 References 2-1
3 Dungeness River 3-3
3.1 Methods 3-3
3.1.1 Trap Operations 3-3
3.1.2 Chinook, Chum and Pink Salmon Production Estimate 3-4
3.1.3 Coho and Steelhead Smolt Production Estimate 3-6
3.2 Results 3-7
3.2.1 Chinook 0+ 3-7
3.2.1.1 Catch 3-7
3.2.1.2 Size 3-8
3.2.1.3 Catch Expansion 3-10
3.2.1.4 Trap Efficiency 3-11
3.2.1.5 Production Estimate 3-13
3.2.1.6 Hatchery Chinook Survival 3-14
3.2.1.7 Yearling Chinook 3-14
3.2.2 Coho 3-15
3.2.2.1 Catch 3-15
3.2.2.2 Size 3-16
3.2.2.3 Trap Efficiency 3-17
3.2.2.4 Production Estimate 3-17
3.2.3 Steelhead 3-18
3.2.3.1 Catch 3-18
3.2.3.2 Size 3-19
3.2.3.3 Trap Efficiency 3-19
3.2.3.4 Production Estimate 3-19
3.2.4 Chum 3-21
3.2.4.1 Catch 3-21
3.2.4.2 Size 3-21
3.2.4.3 Catch Expansion 3-21
3.2.4.4 Trap Efficiency 3-22
3.2.4.5 Production Estimate 3-22
3.2.5 Pink Salmon 3-23
3.2.5.1 Catch 3-23
3.2.5.2 Size 3-23
3.2.5.3 Catch Expansion 3-24
3.2.5.4 Trap Efficiency 3-24
3.2.5.5 Production Estimate 3-24
3.2.6 Other Species 3-25

3.3 Discussion ... 3-27
3.3.1 Chinook ... 3-27
3.3.1.1 Natural-Origin Chinook ... 3-27
3.3.1.2 Hatchery Chinook ... 3-28
3.3.2 Coho ... 3-28
3.3.3 Steelhead ... 3-29
3.3.4 Recommendations ... 3-29
3.4 Appendix C ... 3-31
3.5 References ... 3-51
4 Cedar Creek ... 4-1
4.1 Monitoring History ... 4-3
4.1.1 Study Site ... 4-3
4.2 Methods ... 4-5
4.2.1 Trap Operation ... 4-5
4.2.2 Juvenile Production Estimates ... 4-6
4.2.3 Contribution of Remote Site Incubator (RSI) to Coho Salmon Smolt Production ... 4-9
4.3 Results ... 4-11
4.3.1 Assumptions ... 4-11
4.3.2 Cutthroat Smolts ... 4-13
4.3.3 Steelhead Smolts ... 4-15
4.3.4 Coho Smolts ... 4-16
4.3.5 Other species and life stages ... 4-18
4.4 Discussion ... 4-19
4.4.1 Recommendations ... 4-20
4.5 References ... 4-21

List of Tables

Green River

Table 2 - 1. Hatchery releases that could have contributed to catches in the Green River screw trap in 2006[a]. 2-7

Table 2 - 2. Mean fork length (mm) standard deviation, and sample size of natural-origin Chinook 0+ measured, by statistical week, Green River 2006. 2-9

Table 2 - 3. Unmarked juvenile Chinook trap efficiency strata for the Green River screw trap, 2006. 2-11

Table 2 - 4. Ad-marked hatchery Chinook trap efficiency strata for the Green River screw trap, 2006. 2-11

Table 2 - 5. Summary of natural-origin and hatchery Chinook 0+ migration past the screw trap, Green River 2006. 2-12

Table 2 - 6. Mean fork length (mm) standard deviation, and sample size of natural-origin coho smolts measured, by statistical week, Green River 2006. 2-14

Table 2 - 7. Natural-origin coho estimated catch and migration, by efficiency strata, Green River screw trap, 2006. 2-16

Table 2 - 8. Chum fry estimated catch and migration, by efficiency strata, Green River screw trap, 2006. 2-19

Table 2 - 9. Egg to migrant survival rates correlated with flow, Green River, brood years 1999 - 2005. 2-22

Table 2 - 10. Fry and parr component and production estimates for naturally produced juvenile Chinook 0+, above the trap site, Green River, 2000-2006 2-23

Table 2 - 11. Catch and estimated production of pink fry captured in the Green River screw trap, 2000-2006. 2-24

Appendix A. Variance of total unmarked smolt numbers, , when the number of unmarked smolts, is estimated. by Kristen Ryding, WDFW Biometrician. 2-29

Appendix B 1. Daily actual and estimated catches and migration for natural-origin and hatchery Chinook 0+ migrants, Green River 2006. 2-31

Appendix B 2. Daily catch (including estimated missed catch) for coho, steelhead, chum, pink, and cutthroat, Green River 2006. 2-35

Dungeness River

Table 3 - 1. Hatchery releases upstream of the Dungeness River screw trap, 2006. 3-7

Table 3 - 2. Mean fork length (mm), standard deviation, range, and sample size of natural-origin Chinook 0+ measured by statistical week, Dungeness River 2006........... 3-9

Table 3 - 3. Chinook 0+ trap efficiency strata, Dungeness River screw trap 2006............... 3-12

Table 3 - 4. Summary of natural-origin and hatchery juvenile Chinook outmigration past the screw trap, Dungeness River 2006.. 3-13

Table 3 - 5. Estimation of natural-origin coho smolt production, Dungeness River 2006. .. 3-17

Table 3 - 6. Estimation of natural-origin steelhead smolt production, Dungeness River 2006. 3-20

Table 3 - 7. Mean fork lengths (mm), standard deviations, ranges, and sample sizes, of unmarked natural-origin chum fry, measured by statistical week, Dungeness River, 2006... 3-21

Table 3 - 8. Trap efficiency strata for chum, Dungeness River screw trap, 2006................. 3-22

Table 3 - 9. Trap efficiency strata for pink fry, Dungeness River screw trap, 2006............ 3-25

Table 3 - 10. Estimated survival from the release site to the trap for hatchery Chinook 0+, Dungeness River, 1996, 1997 and 2006. 3-28

Appendix C 1. Daily actual and estimated catches and migration for Chinook 0+ migrants, Dungeness River 2006. 3-33

Appendix C 2. Daily catches of Dungeness River coho and steelhead, and expanded catches of chum, pink, cutthroat, and bull trout/Dolly Varden, 2006................................ 3-39

Appendix C 3. Daily migration estimates for juvenile coho, steelhead, chum and pink salmon, Dungeness River 2006. 3-45

Cedar Creek

Table 4 - 1. Mean fork lengths (mm), standard deviations, ranges, and sample sizes, of natural-origin cutthroat measured by trapping interval, Cedar Creek, 2006. 4-13

Table 4 - 2. Catch and population estimates for sea-run cutthroat trout smolts emigrating past the Cedar Creek trap during 2006.. 4-14

Table 4 - 3. Mean fork lengths (mm), standard deviations, ranges, and sample sizes, of natural-origin Steelhead smolts measured by trapping interval, Cedar Creek, 2006. 4-15

Table 4 - 4 Catch and population estimates for steelhead smolts emigrating past the Cedar Creek trap during 2006. 4-16

Table 4 - 5. Coho mean fork lengths (mm), standard deviations, rangers, and sample sizes, measured by trapping interval, Cedar Creek 2006... 4-17

Table 4 - 6. Catch and population estimates for natural-origin coho salmon smolts emigrating past the Cedar Creek trap during 2006. 4-18

List of Figures

Green River

Figure 2 - 1. Map of the Green River screw trap location, relative to hatcheries and hydro projects, Middle Green River, 2006. 2-3

Figure 2 - 2. Range of Chinook 0+ fork lengths (mm) measured at the Green River screw trap, by week, in 2006. 2-9

Figure 2 - 3. Daily migration of unmarked Chinook 0+ in the Green River screw trap, relative to stream discharge at USGS gage# 1211300, January 24 through July 16, 2006. 2-13

Figure 2 - 4. Size of unmarked coho smolt fork lengths (mm) measured at the Green River screw trap, by week, in 2006. 2-14

Figure 2 - 5. Daily migration of natural-origin coho smolts in the Green River screw trap, relative to stream discharge at USGS gage# 1211300, January 24 through July 16, 2006. 2-16

Figure 2 - 6. Length frequency of unmarked steelhead smolt fork lengths (mm) measured at the Green River screw trap, 2006. 2-17

Figure 2 - 7. Natural-origin Chinook 0+ egg-to-migrant survival as a function of peak winter flow, migrations years 2001-2006, Green River. 2-22

Dungeness River

Figure 3 - 1. Map of the Dungeness River watershed with the location of the screw trap, Matriotti Creek and hatcheries. 3-3

Figure 3 - 2. Daily mean flow (USGS flow gauge #12048000, near Sequim) and trap position, Dungeness River 2006. 3-8

Figure 3 - 3. Weekly average, minimum, and maximum Chinook 0+ fork lengths (mm) measured at the Dungeness River screw trap, 2006. 3-10

Figure 3 - 4. Daily mean flow during the 2006 trapping season (February 1 - August 31) and 78-year average daily flow (1922-2006), Dungeness River near Sequim (USGS gage# 12048000). 3-13

Figure 3 - 5. Estimated daily migration of natural-origin Chinook 0+ , Dungeness River 2006. 3-14

Figure 3 - 6. Length frequency of natural-origin unmarked coho smolts, fork lengths (mm) measured at the Dungeness River screw trap, 2006. 3-16

Figure 3 - 7. Estimated daily coho smolt migration past the screw trap, based on proportion of catch, Dungeness River 2006. 3-18

Figure 3 - 8. Length frequency of unmarked steelhead smolt fork lengths (mm) measured at the Dungeness River screw trap, 2006. 3-19

Figure 3 - 9. Daily migration of natural-origin steelhead smolts in the Dungeness River screw trap relative to stream discharge measured at USGS Gage #12048000, 2006. 3-20

Figure 3 - 10. Estimated daily migration of chum fry past the Dungeness River screw trap, 2006. 3-23

Figure 3 - 11. Pink fry measured at the Dungeness River screw trap, 2006. 3-24

Figure 3 - 12. Estimated daily migration of pink salmon at the Dungeness River screw trap, 2006. 3-25

Cedar Creek

Figure 4 - 1. Lewis River subbasin with the Lewis River hatcheries and dam, Cedar Creek adult and juvenile trap site, smolt release site, acclimation ponds and remote site incubator sites. Map courtesy of Steve VanderPloeg, WDFW. 4-4

Figure 4 - 2. Thermally marked otolith. (Photo courtesy of Eric Volk, WDFW) 4-10

Figure 4 - 3. Comparison of first time captures and recaptures of natural-origin sea-run cutthroat trout, natural-origin steelhead, and natural-origin coho salmon smolts at the Cedar Creek trap in 2006. 4-12

Figure 4 - 4 . Weekly average, minimum, and maximum sea-run cutthroat trout smolt fork lengths measured at the Cedar Creek screw trap, 2006. 4-13

Figure 4 - 5. Weekly catch and population estimates for sea-run cutthroat trout smolts migrating past the Cedar Creek trap in 2006. 4-14

Figure 4 - 6. Weekly average, minimum, and maximum yearling steelhead fork lengths measured at the Cedar Creek screw trap, 2006. 4-15

Figure 4 - 7. Weekly catch and population estimates for steelhead smolts migrating past the Cedar Creek trap in 2006. 4-16

Figure 4 - 8. Weekly average, minimum, and maximum yearling natural-origin coho salmon fork lengths measured at the Cedar Creek screw trap, 2006. 4-17

Figure 4 - 9. Weekly catch and population estimates for natural-origin coho salmon smolts migrating past the Cedar Creek trap in 2006. 4-18

Executive Summary

Declining salmon populations in the 1980s and 1990s resulted in the listing of a number of Washington State salmon populations under the Endangered Species Act (ESA). Most of these listings occurred between 1997 and 1999, impacting fisheries and land management over the entire state. To better monitor the status of these listed species and their production trends, the Washington Department of Fish and Wildlife (WDFW) expanded its freshwater salmon production monitoring (smolt monitoring) program. The new sites established during this period included Cedar Creek in 1998 to monitor Lower Columbia River steelhead, the Green River in 2000 and the Dungeness River in 2005 to monitor Puget Sound Chinook. The SRFB has funded smolt monitoring on the Green River and Cedar Creek since 2002, and included the Dungeness River in 2006. This annual report describes the smolt monitoring activities that occurred on these three streams during the 2006 field season.

Green River

The Green River screw trap, located 55-km upstream of the mouth, was operated from January 24, through July 17, 2006. The focus of this project is to estimate the number of naturally-produced Puget Sound Chinook originating from this river system. Over this period, 3,528 naturally-produced sub-yearling Chinook were captured. As in previous years, the timing distribution of Chinook out-migrants were bimodal. In 2006, early fry migrants (January and mid-April) were outnumbered by later parr migrants (May through July), at 31% and 69%, respectively. The fork lengths measured on captured fry averaged 40-mm, while later parr migrants averaged between 74 and 94-mm.

In total, 102 marked Chinook groups were released upstream of the Green River trap to estimate the proportion of downstream migrants captured (trap efficiency). These groups were pooled into 18 strata, to increase confidence in the abundance estimates. Using these efficiency rates, an estimated 102,278 naturally-produced Chinook migrated during the trapping period. The 95% confidence interval for this estimate was 78,330 to 131,910 fry. Based on the number of parent brood spawners, the Green River Chinook egg-to-migrant survival was estimated at 1.47% for the 2005 brood.

A secondary objective for the Green River trapping project is to monitor and estimate natural production for the other salmonids migrating from the system. This was accomplished for coho and steelhead smolts, as well as chum and pink fry.

In total 1,422 unmarked coho smolts were capture, with an average fork length of 106.9-mm. Production of natural coho from above the trap was estimated at 31,460 smolts, ± 10,317 (95% CI).

Over the season 390 natural-origin steelhead smolts were captured, with an average fork length of 151.1-mm. Production of natural steelhead from above the trap was estimated at 16,748 smolts.

In addition 32,308 chum fry and 294.293 pink fry were captured. Production was estimated at 914,285 chum fry (± 258,852 , at 95% CI), and over 7-million pink fry.

Dungeness River

The Dungeness River screw trap was operated from February 2, through August 17, located just 0.5-RKm upstream from the mouth of the river. The focus of this project is to monitor annual production of Dungeness Chinook, which are part of the Puget Sound Chinook Evolutionarily Significant Unit (ESU). Over the trapping season, we captured a total of 6,533 naturally-produced 0+ Chinook migrants. As observed at other study sites, the timing distribution of Chinook out-migrants were bimodal, with an early migration as fry in February through mid-April, and the rest migrating as parr between May and August (57% fry, 43% parr). Chinook fork lengths averaged less than 40-mm for the fry component, and greater than 80-mm for smolts. The season average fork length was 57.9-mm.

A total of 85 groups of marked Chinook were released upstream of the trap to measure trap efficiency. These tests were separated into three groups based on trap position; these three groups were further arranged into 29 strata based on similar environmental conditions, to increase confidence in our estimates. Recapture rates averaged 9.86% for the combined groups and ranged from 1.3% to 27.9%. Over the season, 124,928 naturally-produced 0+ Chinook were estimated to migrate past the trap, with a 95% confidence interval of 95,362 to 154,494 Chinook.

In addition, this project also monitors natural-origin coho, chum and steelhead smolt production. A total of 1,964 coho smolts were captured; this included 170 of the 5,663 naturally-produced upper caudal (UC) fin-clipped coho released by the Jamestown S'Klallam Tribe from their weir on Matriotti Creek, a tributary to the Dungeness River. These marked fish were used to estimate the proportion of marked fish recaptured in the traps, assuming all of the marked Matriotti coho survived to pass the screw trap. Applying this efficiency to the catch results in a production estimate of 43,888 smolts, with a 95% confidence interval of 37,860 to 49,916 smolts.

A total of 425 naturally-produced steelhead smolts were captured over the season. As with the coho, the steelhead migrating from Matriotti Creek were UC-marked (497 total). Of these, only 29 were recaptured at the trap. This resulted in a recapture rate of 5.8%, which estimates natural steelhead production at 6,158 smolts ± 2,037 (95% CI).

In addition, 38 out of the 10,500 ad-marked hatchery steelhead released from the Dungeness Hatchery were captured The resulting low capture rate (0.36%) of hatchery fish indicates that heavy otter predation during rearing may have reduced the actual number released.

The chum migration was already underway when trapping began. A total of 28,457 chum fry were captured over the season, with an estimated missed catch of 4,285 fry. Weekly mean sizes ranged from 37.4-mm to 52.9-mm over the season, and averaged 40.1-mm.

A total of 12 marked chum fry groups were released upstream of the trap to measure trap efficiency from mid-March to early May. As with Chinook, these groups were combined into ten strata, resulted in a production estimate of 194,721 fry past the trap (± 31,354 , at 95% CI).

The pink fry migration was just starting when trapping began. For the season, an estimated 92,489 fry were captured, with an additional 19,000 fry estimated during periods when trapping was suspended. Weekly mean sizes ranged 32-mm to 43-mm, and averaged 34-mm over the season. A total of five mark-efficiency groups were released; two groups were combined to create four strata. Application of these rates to the expanded catch estimates a production of 696,642 fry ± 253,492 (95% CI).

Cedar Creek

The Cedar Creek screw trap was operated from February 20, through June 27, 2006. Located 4.0-Rkm upstream from its confluence with the North Fork Lewis River, this trap monitors the steelhead production from Cedar Creek. This stream's production makes up part of the listed Lower Columbia steelhead ESU. In addition to steelhead, coho and cutthroat productions are measured in the system. ESA-listed Lower Columbia Chinook are also present in Cedar Creek, but current funding is insufficient to monitor their production.

During the trapping period, a total of 787 steelhead trout pre-smolts and smolts were captured. Steelhead smolt fork lengths averaged 175.6-mm, with a declining trend in weekly mean sizes observed (186-mm to 163-mm) over the season. A total of 756 steelhead trout were marked by fin coloration using a Panjet inoculator and were released upstream of the trap to assess trap efficiency. Mark placement changed weekly, with 14 mark groups released. A total of 1,914 ± 196 (95% CI) steelhead trout were estimated to have migrated past the Cedar Creek trap using a pooled Peterson estimate.

In addition to steelhead, 43,008 ± 1,008 (95% CI) naturally-produced coho smolts, 7,584 ± 348 (95% CI) RSI-produced coho, and 5,720 ± 458 (95% CI) cutthroat trout were estimated to have migrated past the trap. The trap also captured a total of 1,339 Chinook fry, 101 cutthroat, 42 rainbow/steelhead, and 72 coho parr over the season.

1 Introduction

Declining salmon populations in the 1980s and 1990s resulted in the listing of a number of Washington State salmon populations under the Endangered Species Act (ESA), impacting fisheries and land management over the entire state. With the advent of these listings, the Washington Department of Fish and Wildlife (WDFW) expanded its freshwater salmon production monitoring (smolt monitoring) program to better measure the status and trends in listed populations, determine population structure, assess habitat and environmental impacts on production, and monitor the effects of recovery measures on these listed populations. New sites established during this period included Cedar Creek (1998) to monitor Lower Columbia River steelhead, Green River (2000) and Dungeness River (2005) to monitor Puget Sound Chinook. Funding from the legislature originally established monitoring on the Green River and Cedar Creek.

The legislature requested that the Washington Salmon Recovery Funding Board (SRFB) consider funding smolt monitoring in Spring 2002. The SRFB has subsequently funded smolt monitoring on the Green River and Cedar Creek beginning in 2001/2002. Monitoring on the Dungeness River began in 2005, and was funded through SRFB monies in 2006. This annual report describes the smolt monitoring activities that occurred on these three streams during the 2006 field season. It also presents production estimates for the listed species, as well as for a number of other populations rearing in these watersheds.

2 Green River

2006 Green River
Juvenile Salmonid Production Evaluation

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2.1 Methods

2.1.1 Trap Operations

A floating screw trap (Busack *et al.* 1991) was used on the Green River to capture downstream migrant salmonids. The trap was located at river kilometer (RKm) 55; approximately 975-m upstream of the Highway-18 bridge, on the left bank (Figure 2 - 1). This trap is fully described in Seiler *et al*. 2002.

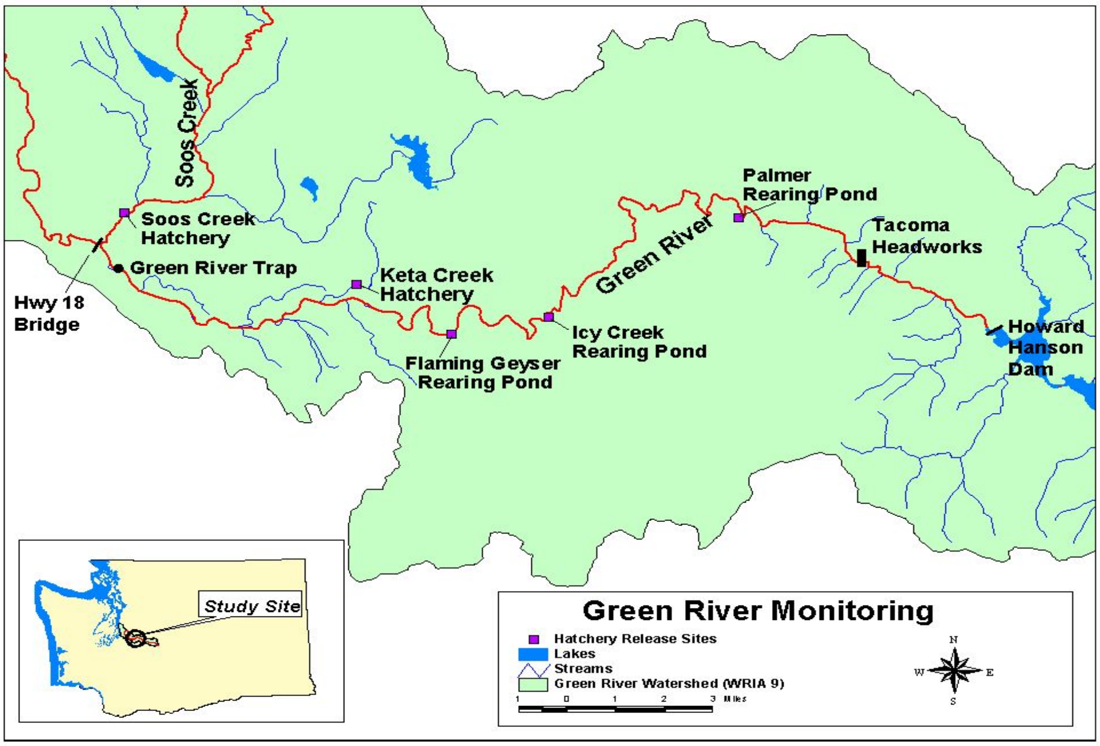

Figure 2 - 1. Map of the Green River screw trap location, relative to hatcheries and hydro projects, Middle Green River, 2006.

The Green River trap was installed and began operations on January 24. The trap was operated continuously through July 17, and except for periods when high flows, excessive debris, mechanical failure, or large numbers of hatchery precluded trapping. Trap operations were also suspended during daytime periods late in the trapping season, when catches were low and recreational use of the river was high. Fish were usually removed from the trap and counted at dawn and at dusk. The trap was also checked at other times, as needed, based on debris loads and catches. At the end of each trapping period, all fish captured were identified to species and enumerated. Fork length measurements were taken from a sample of the various naturally-produced salmonids captured. In addition, Chinook and coho smolts were checked for the presence of a coded-wire tag (CWT).

In order to estimate migration, groups of Chinook, coho and chum salmon were used to assess the capture efficiency of the trap. Fish used for trap efficiency testing were anesthetized with tricaine methanesulfonate (MS-222), and marked with either Bismarck-brown dye, or with a partial caudle fin-clip. Marked fish were allowed to recover in fresh water, transported 150m upstream of the trap and released. Capture rates were estimated by the proportion of marked fish recaptured in the trap.

2.1.2 Production Estimate

Production estimates were made using a stratified mark-recapture approach. The Petersen method, modified by Chapman (1951), was often used to estimate smolt abundance. Smolt abundance during time period *i* is estimated by;

Equation 2 - 1

$$\hat{U}_i = \frac{(u_i + 1)(M_i + 1)}{(m_i + 1)} - 1$$

where;

U_i = Migration of unmarked fish past the trap during time period *i*,
u_i = Catch of unmarked fish during time period *i*,
M_i = Marked fish released above the trap during time period *i*, and
m_i = Marked fish recaptured during time period *i*.

Seber (1982) provides an approximate unbiased estimate of the variance:

Equation 2 - 2

$$V(\hat{U}_i) = \frac{(M+1)(u+1)(M-m)(u-m)}{(m+1)^2(m+2)}$$

Total production over the entire smolt outmigration is estimated by;

Equation 2 - 3

$$\hat{N} = \sum_{i=1}^{n} \hat{U}_i$$

Similarly, the variance of *N* is estimated by the sum of the variances for U_i. The normal confidence interval about *N* is calculated using:

Equation 2 - 4

$$\hat{N}_{95\%ci} = \hat{N} \pm 1.96\sqrt{V(\hat{N})}$$

This approach assumes that marked fish and unmarked fish have the same probability of capture during each fishing period. Yet, recaptures of marked Chinook, coho, and chum salmon in the Green River occurred during a relatively short period (e.g. a few hours after release), whereas the unmarked catches they represent may occur over a longer period. If trapping is suspended during the period when only unmarked fish are passing the trap, the catch of unmarked fish must be estimated for the abundance estimator to be valid. In this case $\hat{u}_i$ is substituted for u_i in Equation 2 - 1. The variance, $V(\hat{U}_i)$, is now estimated using (see 2.4 Appendix A for derivation);

Equation 2 - 5

$$V(\hat{U}_i) = Var(\hat{u}_i)\left(\frac{(M_i+1)(M_i m_i + 3M_i + 2)}{(m_i+1)^2(m_i+2)}\right) + \left(\frac{(M_i+1)(M_i - m_i)\hat{u}_i(\hat{u}_i + m_i + 1)}{(m_i+1)^2(m_i+2)}\right)$$

To interpolate catch for periods when the trap was not fishing, diel differences in migration rates were evaluated. Salmonids often migrate at different rates between day and night periods (Seiler *et al.* 1981), therefore, fishing periods were stratified into daytime, nighttime, and combined periods. The stratification was simplified by performing the trap checks near daybreak and sunset periods. Catch during trapping intervals not fished were estimated by interpolating between catch rates from the previous and following fishing periods within the same diel stratum, and then expanding by the hours not fished. Catch rates were defined using:

Equation 2 - 6

$$\hat{R}_{fj} = \frac{C_{fj}}{T_{fj}}$$

where:

R_{fj} = *the catch rate during fishing period f in diel stratum j,*

C_{fj} = *catch during fishing period f in diel stratum j, and*

T_{fj} = *the duration of fishing period f in diel stratum j.*

The variance of the interpolated catch rate was estimated by:

Equation 2 - 7

$$V(\overline{R}_{fj}) = \frac{\sum(\hat{R}_{fj} - \overline{R}_{fj})^2}{n(n-1)}$$

Catch during the un-fished interval was then estimated by expanding the mean catch rate by the hours not fished (*T*). The estimated catch during the un-fished period was summed with the actual catch to estimate the total catch during each fishing period, $\hat{u}_i$. The catch variance was then estimated by:

Equation 2 - 8

$$V(\hat{C}) = V(\overline{R}_{fj})\hat{T}^2$$

2.2 Results

Estimating the production of natural-origin Chinook migrants was complicated by the large numbers of hatchery salmonids released into the river, mainly upstream of the trap. Table 2 - 1 provides a summary of hatchery releases that would have passed the screw trap in 2006. Except for Soos Creek, all of the release sites are located upstream of our trap site. Even though Soos Creek enters the Green River approximately 0.8-km downstream of our trap, a few individuals from these releases have contributed to our catches in previous years.

Table 2 - 1. Hatchery releases that could have contributed to catches in the Green River screw trap in 2006[a].

Species	Release Date(s)	Release Location	Brood Year	CWT Only	CWT Ad-mark	Ad-mark Only	Ad-mark RV	Unmarked
2005 Releases Above Howard Hanson Dam								
Coho		Howard Hanson Dam	2004					546,450
Chinook	3/10-3/25	Howard Hanson Dam	2004			570,181		
2006 Releases								
Chinook	3/16-5/3	Howard Hanson Dam	2005			467,875		24,625
	4/18-4/30	Icy Creek	2004		63,177	149,072		
	5/05-5/30	Soos Creek	2005	198,542	196,353	3,170,000		458
Coho	5/4-5/6	Keta Creek	2004	404	50,514	108,239		843
	4/08-4/15	Soos Creek	2004	45,000	44,838	309,000		
Steelhead	5/1	Soos Creek Winter	2004			32,000	24,800	
	5/1	Soos Creek Summer	2004			41,000		
	5/1-5/06	Palmer Winter	2004			174,270		
	5/1-5/16	Palmer Summer	2004			48,013		
	4/1	Icy Creek Winter	2004			4,176		
	4/1	Icy Creek Summer	2004			7,828		
	5/6	Flaming Gyser	2004			8,000		
Chum	3/22-5/31	Keta Creek	2005					1,770,000

[a] Soos Creek is the only release location downstream of the trap represented.

2.2.1 Chinook

2.2.1.1 **Catch**

Over the 173-day trapping interval, a total of 3,528 unmarked and 2,044 adipose fin-clipped (ad-marked) Chinook 0+ migrants were captured (2.4 Appendix A). Daily catches of unmarked Chinook 0+ averaged 3 fish/day through the first week of trapping. Catches remained low, and averaged 5 natural-origin recruits (NOR)/day through mid-February. Daily Chinook catches increased slowly, and the early portion of the migration, comprised mostly of newly emerged fry, peaked on March 18, with 67 fry captured. Daily catches gradually declined to zero April 26-27. From this point on, the migration increased quickly and peaked on May 28 and June 1, with daily catches of 366 and 338 migrants, respectively. This later-timed peak was largely comprised of zero-age parr that had reared for some weeks before migration. The unmarked Chinook parr catch declined steadily through the remainder of the trapping season, and averaged just 4 migrants per day by the end of the season.

Ad-marked Chinook 0+ entered catches on the first day of trapping, with 3 fry captured. No more fish were captured until March 23, with a total of 9 fry. Daily catches increased thereafter and peaked on May 7, with 175 ad-marked hatchery migrants captured. Catches remained steady through the month of May, averaging 34 ad-marked juvenile hatchery Chinook per day. Catches declined through June and July with only 1 hatchery Chinook captured during the final week of trapping.

In addition to the ad-marked hatchery fry captured, an unknown number of unmarked hatchery Chinook were also captured. To estimate the catch of the unmarked hatchery Chinook, we applied the ad-marked:unmarked ratio reported at release to the number of ad-marked Chinook captured at the trap. This approach estimates that 111 unmarked hatchery fish should have been captured. The first estimated unmarked hatchery was captured on March 23, one week after the reported release date of March 16.

Over the season, we also captured 154 Chinook 1+ migrants (147 ad-marked hatchery/CWT, and 7 unmarked). The peak hatchery Chinook 1+ catch occurred on April 18, the reported release date from the rearing facility at Icy Creek. Over the next two weeks, 133 hatchery fish were captured, 86% of the season total. The last hatchery Chinook 1+ was captured on the night of May 23.

2.2.1.2 Size

Unmarked Chinook 0+ averaged 45-mm or less through the first 11 weeks of trapping. Starting in the second week in April, and through the end of the trapping season, the unmarked Chinook fry lengths increased rapidly, averaging 2.7-mm per week; by the second week of July, unmarked parr averaged over 92-mm (Table 2 - 2, Figure 2 - 2). Migrants measuring less than 40-mm were observed through the month of April, after which, the minimum size increased to over 87-mm at the end of the trapping period. We speculated that 40-mm and smaller Chinook were newly emerged fry; we therefore believe that the increase in the minimum size was an indication that emergence was completed.

Table 2 - 2. Mean fork length (mm) standard deviation, and sample size of natural-origin Chinook 0+ measured, by statistical week, Green River 2006.

Statistical Week			Average	s.d.	Range		Number		Percent
No.	Begin	End			Min	Max	Sampled	Captured	Sampled
5	01/27/06	01/29/06	39.4	2.19	38	43	5	18	27.8
6	01/30/06	02/05/06	39.3	3.34	31	45	16	37	43.2
7	02/06/06	02/12/06	40.9	2.39	38	44	16	41	39.0
8	02/13/06	02/19/06	41.9	2.69	38	49	34	90	37.8
9	02/20/06	02/26/06	40.2	1.47	38	44	28	144	19.4
10	02/27/06	03/05/06	39.8	1.24	38	42	13	149	8.7
11	03/06/06	03/12/06	40.4	0.96	39	42	16	102	15.7
12	03/13/06	03/19/06	41.2	1.93	38	44	10	228	4.4
13	03/20/06	03/26/06	42.2	3.71	38	51	10	177	5.6
14	03/27/06	04/02/06	44.2	5.77	40	58	12	124	9.7
15	04/03/06	04/09/06	42.7	2.00	39	45	10	127	7.9
16	04/10/06	04/16/06	53.0	15.10	38	82	10	49	20.4
17	04/17/06	04/23/06	56.0	15.38	39	74	8	50	16.0
18	04/24/06	04/30/06	60.5	13.89	41	80	8	28	28.6
19	05/01/06	05/07/06	55.9	11.83	41	71	9	40	22.5
20	05/08/06	05/14/06	74.4	9.23	57	86	14	59	23.7
21	05/15/06	05/21/06	74.9	6.92	68	86	8	141	5.7
22	05/22/06	05/28/06	73.9	12.57	56	91	15	671	2.2
23	05/29/06	06/04/06	74.4	9.57	54	84	9	699	1.3
24	06/05/06	06/11/06	78.7	10.37	61	97	9	137	6.6
25	06/12/06	06/18/06	83.7	6.31	78	95	6	103	5.8
26	06/19/06	06/25/06	89.7	8.75	69	99	13	115	11.3
27	06/26/06	07/02/06	91.7	5.85	82	102	24	109	22.0
28	07/03/06	07/09/06	88.8	12.63	63	101	11	64	17.2
29	07/10/06	07/16/06	92.5	7.40	87	105	6	26	23.1
Season Total			57.7	21.22	31	105	320	3,528	9.1

Note: Unmarked hatchery Chinook may be present in sample from Stat Week 13 through the remainder of the season.

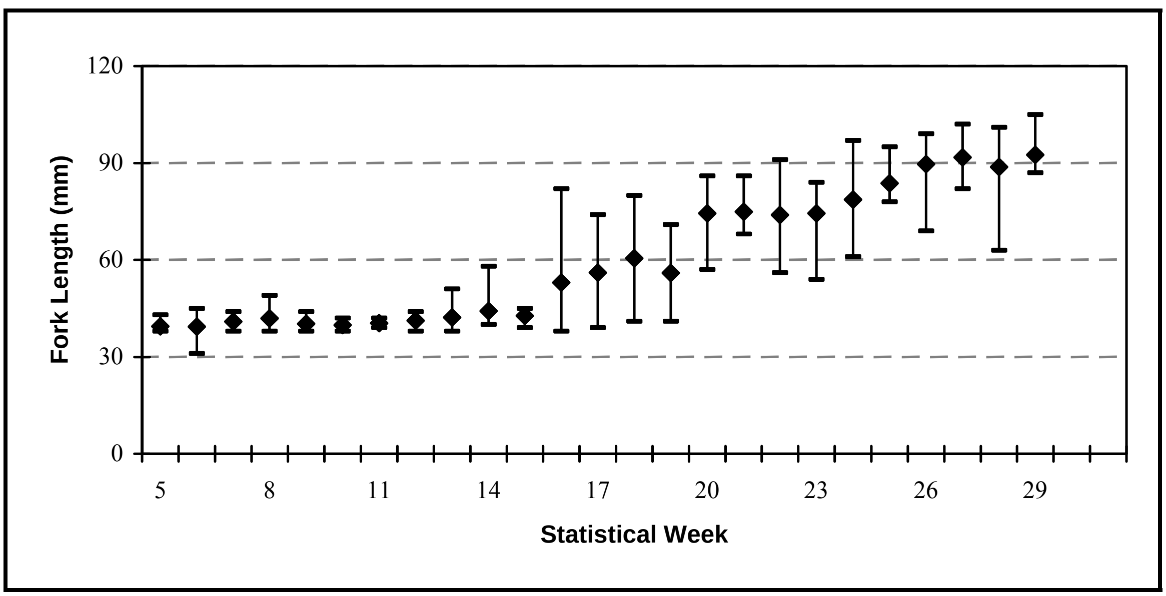

Figure 2 - 2. Range of Chinook 0+ fork lengths (mm) measured at the Green River screw trap, by week, in 2006.

2.2.1.3 Catch Expansion

The trap was operated 3,694.9 hours out of 4,169.5 possible hours in the 173-day trapping period, or 88.6% of the time. Trap operations were suspended twice during the season for high flows and heavy debris for a total of 40 hours. Linear interpolations estimated an additional 15 unmarked Chinook would have been captured had the trap been operated continuously. Trap operations were also suspended eight times, for a total of 6.6 hours, on the night of May 5 to avoid large numbers of migrating hatchery fish. We estimate an additional 71 (7 unmarked, 64 ad-marked) Chinook would have been captured during these outages. Beginning on June 12, and through the end of the season, trap operations were suspended during daylight hours when recreational use of the river was high and catches were low, for a total of 422 hours. By interpolating between the daylight periods sampled each week, an estimated 6 additional unmarked Chinook would have been captured during these 30 days.

Debris stopped the gear three times during the season, for a total of two hours. An estimated 3 additional Chinook would have been captured during these intervals. These intervals are minimized because the trap is equipped with a system that sends a signal to an alarm company when trap rotation is interrupted. The alarm company calls the field staff to alert them to the stoppage, and allows staff to repair the problem quickly, thereby precluding significant mortality or missed catch. An additional benefit is that this system allows us to know the exact time the stoppage occurred.

For the season, we estimated that an additional 28 unmarked Chinook would have been captured had we fished continuously. Addition of these estimated fish to our actual catch, estimated a total of 3,556 unmarked Chinook 0+ would have been captured had the trap operated continuously from January 24 to July 16. This represents a small increase (0.79%) over the actual catch of unmarked migrants. We also estimated 72 additional ad-marked hatchery Chinook 0+ (3.4%) over the actual catch.

Throughout the trapping season, no additional yearling Chinook were estimated for the periods of suspended trapping. A total of seven unmarked yearling Chinook were captured and that we presumed to be NORs.

2.2.1.4 Trap Efficiency

A total of 7,209 Chinook 0+ were marked and released in 102 groups 150-meters upstream of the trap. Because initial catches were low, from the start of the season through March 22, all but one of the efficiency group releases used hatchery fish from Soos Creek Hatchery (5,325 total Chinook fry). Tests performed after this period used both NORs and HORs captured in the trap. The number of fish released in each group ranged from 2 to 870 fry. Data from the 102 groups were pooled to form 18 strata. Given the small size of many of the release groups, this step increased the number of recaptures and our confidence in the abundance estimates. Recapture rates for these 18 strata averaged 4.0% for the season, and ranged from 1.80% to 10.70% (Table 2 - 3). Flows ranged from 10.6 to 67.1 cubic meters per second (cms) during the Chinook trap efficiency tests. No apparent relationship between flow and efficiency was found. Efficiency groups from the start of the season through May 10, were marked with Bismarck Brown dye, while efficiency groups released from May 11 through the end of the season were marked with a partial caudal fin-clip. Because of the low Chinook catches, we marked nearly all the unmarked Chinook captured for the season. The caudal mark was changed every few days to insure that marked fish were not holding above the trap before migrating downstream, and to facilitate stratification.

Table 2 - 3. Unmarked juvenile Chinook trap efficiency strata for the Green River screw trap, 2006.

Strata	# Tests Pooled	Dates		Numbers		Trap Efficiency
		Start	End	Released (M)	Recaptured (m)	
1	1	01/24/06	02/14/06	870	28	3.2%
2	1	02/15/06	02/16/06	385	23	6.0%
3	1	02/17/06	02/18/06	395	18	4.6%
4	1	02/19/06	02/21/06	300	17	5.7%
5	2	02/22/06	02/25/06	346	8	2.3%
6	2	02/26/06	03/02/06	399	13	3.3%
7	1	03/03/06	03/04/06	298	11	3.7%
8	2	03/05/06	03/09/06	600	11	1.8%
9	1	03/10/06	03/11/06	300	7	2.3%
10	1	03/12/06	03/14/06	300	12	4.0%
11	1	03/15/06	03/16/06	300	12	4.0%
12	1	03/17/06	03/18/06	300	20	6.7%
13	1	03/19/06	03/21/06	298	21	7.0%
14	1	03/22/06	03/25/06	280	12	4.9%
15	19	03/26/06	04/23/06	341	20	5.6%
16	14	04/24/06	05/21/06	234	25	10.7%
17	9	05/22/06	05/31/06	479	9	1.9%
18	43	06/01/06	07/16/06	784	28	3.6%
Total	**102**	**01/24/06**	**07/16/06**	**7,209**	**295**	**4.0%**

The test groups used to estimate the hatchery migration were the same as the ones used to estimate the NOR migration, however, only tests that corresponded with the hatchery outmigration were used. A total of 2,908 Chinook in 78 groups were pooled to form five strata. Recapture rates averaged 4.1% for the season and ranged from 2.9% to 6.6% for the ad-marked hatchery outmigrants (Table 2 - 4).

Table 2 - 4. Ad-marked hatchery Chinook trap efficiency strata for the Green River screw trap, 2006.

Strata	# Tests Pooled	Dates		Numbers		Trap Efficiency
		Start	End	Released (M)	Recaptured (m)	
1	1	01/24/06	03/21/06	870	28	3.2%
2	5	03/22/06	04/01/06	330	19	5.8%
3	14	04/02/06	05/05/06	331	22	6.6%
4	19	05/06/06	05/28/06	431	23	5.3%
5	39	05/29/06	07/16/06	946	27	2.9%
Total	**78**	**01/24/06**	**07/16/06**	**2,908**	**119**	**4.1%**

2.2.1.5 Production Estimate

In total, 105,120 unmarked Chinook 0+ migrants were estimated to have passed the screw trap between January 24 and July 16, with a coefficient of variation of 13.0%, and 95% confidence interval of 78,330 to 131,910 fry (Table 2 - 5, 2.4 Appendix B 1). This migration includes an estimated 2,392 unmarked hatchery Chinook that had been released above the trap. Because the unmarked hatchery fish were indistinguishable from the natural-origin Chinook in our catches, they were included in the data used to make the migration estimate. We later applied the proportion of unmarked hatchery fish in the total release (5.3%) to the total ad-marked hatchery catch to estimate the number of unmarked hatchery fish in the catch. The same hatchery efficiency rate was applied to the estimated unmarked catch to yield the unmarked hatchery migration estimate. Subtraction of the unmarked HORs from the estimated unmarked Chinook migration yields a production estimate of 102,728 natural-origin Chinook from above the trap (Table 2 - 5).

Table 2 - 5. Summary of natural-origin and hatchery Chinook 0+ migration past the screw trap, Green River 2006.

Type	Period	Catch Actual	Catch Est'd	Catch Total	Migration Estimate	CV	95% CI Low	95% CI High	Migration Variance
Unmarked	Total	3,528	28	3,556	105,120	13.00%	78,330	131,910	1.8682E+08
Early	1/24-4/23	1,336	15	1,351	32,435	8.33%	27,140	32,435	7.2993E+06
Late	4/24-7/16	2,192	13	2,205	72,685	18.43%	46,424	98,946	1.7952E+08
Estimated NOR				3,445	102,728				
Ad-marked HOR		2,044	72	2,116	43,513	11.23%	33,932	53,093	2.3893E+07
Unmarked HOR				111	2,392				

A large storm event on January 11-12, before the start of the trapping season, increased the river discharge to over 283 cms. The high flows were compounded by the fact that the flows increased extremely quickly, by as much as 113 cms in one day. These are the highest flows we have observed since trapping began in 2000. Trapping data from previous years of this study indicates that when flows increase to levels only half this high in January, a significant proportion of the hatched Chinook fry are transported downstream of the trapping location. With no trapping data prior to or during this event, it is impossible to estimate the number of Chinook that moved past the trap before January 24. Catches near the end of the season were very low, and therefore, no estimate of migration after the trapping season was made.

In addition to the NORs, we estimated 43,513 ad-marked hatchery Chinook 0+ migrated during the January 24 through July 16 trapping period (2.4 Appendix B 1).

A total of 7 unmarked and 147 ad-marked yearling Chinook were captured. All but 2 ad-marked HORs were captured after the reported release date from Icy Creek. Application of the 4.45% coho efficiency that was collected during the period when the majority of the yearling Chinook were captured, estimates 3,234 hatchery yearlings migrated past the trap. This estimate is far below the reported release of 212,249 Chinook 1+ from Icy Creek. The true number of Chinook released from the Icy Creek facility was unknown, but was likely substantially less than reported because of the heavy otter predation (Mike Wilson, pers comm).

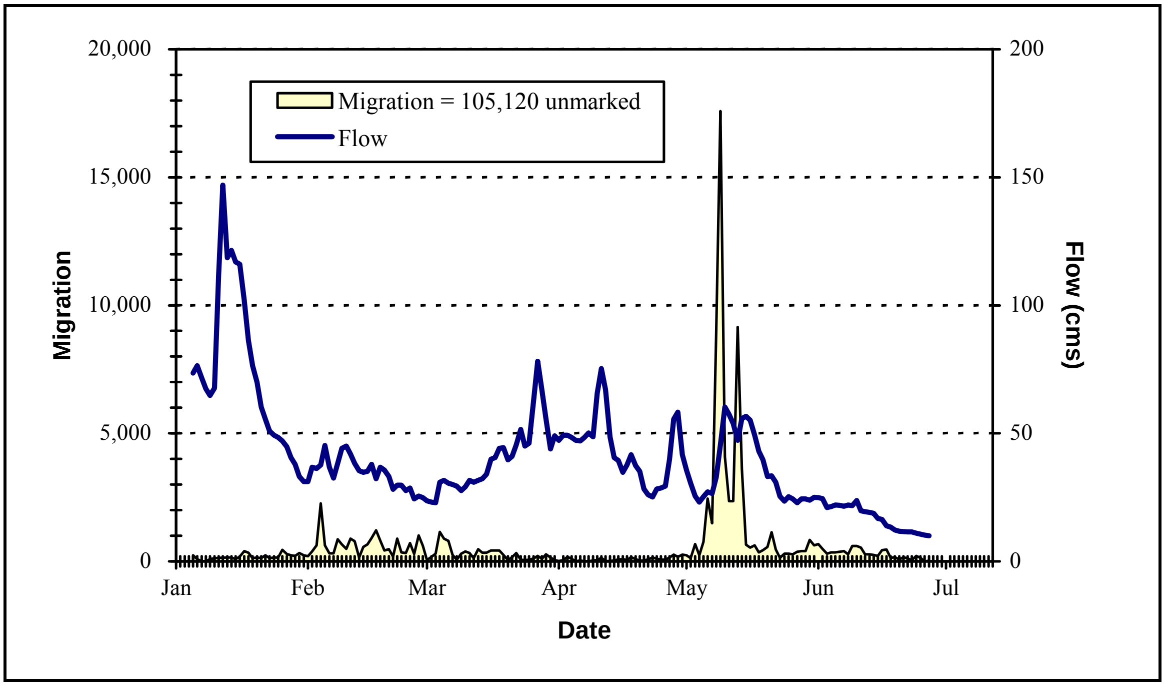

Figure 2 - 3. Daily migration of unmarked Chinook 0+ in the Green River screw trap, relative to stream discharge at USGS gage# 1211300, January 24 through July 16, 2006.

2.2.2 Coho

2.2.2.1 Catch

The first natural-origin unmarked coho pre-smolts/smolts were captured on the night of January 29. Catch rates were low, with only 149 individuals captured through April 15, an average catch of less than 3 fish per day. The only exception was a small increase February 10-11, when we captured 15 coho each night. Daily catches increased steadily through late April and early May; the unmarked NOR catch peaked May 16-17, with catches of 81 and 79 smolts, respectively. NOR catches quickly declined, and by the first week of June the average daily catch had dropped to 3 smolts per day. Over the season, we captured a total of 1,422 unmarked coho smolts.

Ad-marked hatchery coho yearlings appeared in the catch early in the season. The first yearling was captured on the night of February 5, well before any planned releases of hatchery fish. The capture of ad-marked hatchery smolts continued sporadically through the early part of the season, and by May 4, the start date for the Keta Creek Hatchery release, 31 ad-marked hatchery coho had already been captured. Unlike releases in previous years, virtually all coho released from Keta Creek Hatchery were ad-marked. Over the season, we captured a total of 1,529 ad-marked hatchery coho.

2.2.2.2 Size

Weekly average fork lengths for unmarked natural-origin coho ranged from between 93.5 to 126-mm over the trapping season (Table 2 - 6, Figure 2 - 4). Individual smolt sizes ranged from 74 to 190-mm, and averaged 106.9-mm over the season. In total, 122 natural-origin coho were measured, 8.6% of the total catch.

Table 2 - 6. Mean fork length (mm) standard deviation, and sample size of natural-origin coho smolts measured, by statistical week, Green River 2006.

Statistical Week			Average	s.d.	Range		Number		Percent
No.	Begin	End			Min	Max	Sampled	Captured	Sample
5	01/27/06	01/29/06	94.0	5.70	90	98	2	2	100.0
6	01/30/06	02/05/06	101.5	9.50	91	114	4	5	80.0
7	02/06/06	02/12/06	101.7	11.20	74	135	31	61	50.8
8	02/13/06	02/19/06	96.8	11.30	79	109	6	7	85.7
9	02/20/06	02/26/06	112.0	11.50	99	121	3	9	33.3
10	02/27/06	03/05/06	100.5	0.70	100	101	2	14	14.3
11	03/06/06	03/12/06	95.8	11.10	86	110	4	8	50.0
12	03/13/06	03/19/06	107.5	3.50	105	110	2	7	28.6
13	03/20/06	03/26/06	98.0	----	98	98	1	6	16.7
14	03/27/06	04/02/06	100.0	9.50	94	114	4	5	80.0
15	04/03/06	04/09/06	111.2	7.90	100	120	6	11	54.5
16	04/10/06	04/16/06	116.8	27.10	98	190	10	22	45.5
17	04/17/06	04/23/06	114.7	7.70	106	128	7	37	18.9
18	04/24/06	04/30/06	120.0	24.70	98	180	9	149	6.0
19	05/01/06	05/07/06	----	----	----	----	0	182	0.0
20	05/08/06	05/14/06	118.5	9.70	108	131	4	297	1.3
21	05/15/06	05/21/06	124.5	28.60	102	166	4	312	1.3
22	05/22/06	05/28/06	----	----	----	----	0	147	0.0
23	05/29/06	06/04/06	111.3	2.60	109	115	4	54	7.4
24	06/05/06	06/11/06	126.0	5.70	122	130	2	12	16.7
25	06/12/06	06/18/06	105.0	----	105	105	1	16	6.3
26	06/19/06	06/25/06	100.6	7.80	91	109	5	18	27.8
27	06/26/06	07/02/06	100.8	11.30	87	118	5	21	23.8
28	07/03/06	07/09/06	98.5	6.60	90	106	4	14	28.6
29	07/10/06	07/16/06	93.5	2.10	92	95	2	6	33.3
Season Total			106.9	15.70	74	190	122	1,422	8.6

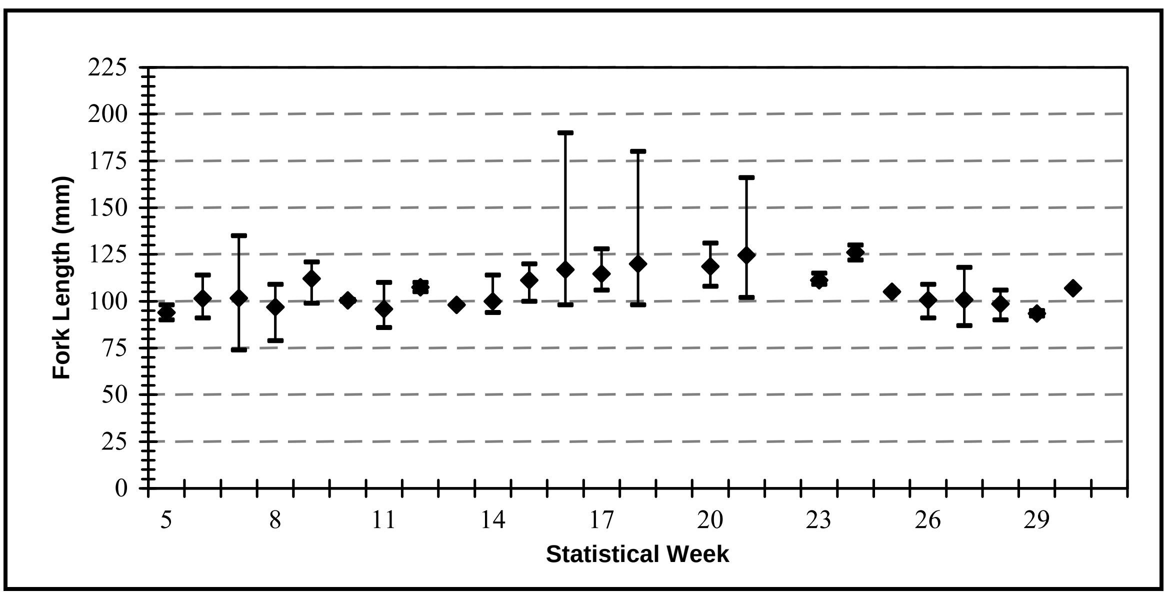

Figure 2 - 4. Size of unmarked coho smolt fork lengths (mm) measured at the Green River screw trap, by week, in 2006.

2.2.2.3 Catch Expansion

The trap was operated 3,694.9 hours out of the possible total 4,169.5 hours. We estimated through linear extrapolation that we would have captured an additional 133 natural-origin, and 1,970 hatchery coho smolts if we had fished continuously for seasonal totals of 1,555 and 3,499 natural-origin and hatchery coho, respectively (2.4 Appendix B 2). All of the estimated catch for the suspended operations, with the exception of 3 NORs, occurred on the night May 5. This was the first night following the volitional release of the Keta Creek Hatchery fish. High NOR catch rates before and after the period of suspended trapping resulted in an estimated total of 130 unmarked smolts missed during the 6.6 hours of suspended trapping on May 5, greater than any other single night's NOR catch. This might be attributed to a "pied piper effect," we hypothesize that migration rates may increase as NORs follow the mass of HORs migrating downstream. However, it is also possible that a portion of the unmarked catch on that night were comprised of unmarked hatchery fish, which would overestimate the NOR catch. Assuming that the hatchery fish had no effect on the natural-origin coho migration behavior, and using the catch rate prior to the hatchery release for the 6.6 hours of suspended trap operation, the number of missed NORs would be estimated at 17 smolts. We believe that the number is somewhere between these two estimates. With only 1,247 estimated unmarked hatchery fish released, combined with the inability to visually distinguish unmarked hatchery smolts and their natural-origin cohorts, we assumed that all the estimated unmarked fish were of natural-origin.

Throughout the trapping season, catch expansion for suspended trap operations resulted in an additional 1,971 ad-marked hatchery coho to the actual catch of 1,528 smolts, an increase of 56%. All of the estimated catch occurred on May 5, the first night following the Keta Hatchery release.

2.2.2.4 Trap Efficiency

A total of 993 natural-origin coho smolts in 58 groups (ranging from 1 to 81 smolts) were marked and released 150-meters upstream from the trap (Table 2 - 7). The 58 individual releases were combined into 11 strata. Given the small size of many of the release groups, this step increased the number of recaptures and our confidence in the abundance estimates. The season recapture rate averaged 5.8% and ranged from 1.9% to 21.4%. Flows ranged from 10.6 to 60.3 cms during the efficiency tests. No apparent relationship between flow and efficiency was found. We used a partial caudal fin-clip that was periodically changed to facilitate stratification. Because of the low coho abundance, we marked nearly all the natural-origin coho captured after May 3, the date of our first efficiency release group.

Table 2 - 7. Natural-origin coho estimated catch and migration, by efficiency strata, Green River screw trap, 2006.

Strata	# Tests Pooled	Dates Start	Dates End	Numbers Released (M)	Numbers Recaptured (m)	Trap Efficiency	Unmarked Catch (u)	Estimated Migration (U)
1	2	01/24/06	05/04/06	37	3	8.1%	594	5,652
2	4	05/06/06	05/09/06	140	4	2.9%	127	3,609
3	2	05/10/06	05/11/06	75	3	4.0%	97	1,861
4	1	05/12/06	05/12/06	50	3	6.0%	62	802
5	3	05/13/06	05/15/06	135	4	3.0%	151	4,133
6	1	05/16/06	05/16/06	62	4	6.5%	81	1,032
7	1	05/17/06	05/17/06	81	3	3.7%	79	1,639
8	1	05/18/06	05/18/06	76	3	3.9%	28	557
9	7	05/19/06	05/25/06	112	3	2.7%	105	2,994
10	1	05/26/06	05/26/06	14	3	21.4%	17	67
11	35	05/27/06	07/14/06	211	4	1.9%	214	9,115
TOTAL	**58**	**01/24/06**	**07/14/06**	**993**	**37**	**5.8%**	**1,555**	**31,460**

2.2.2.5 Production Estimate

Over the trapping season (January 24 through July 16), an estimated 31,460 natural-origin coho smolts migrated past the trap, with a coefficient of variation of 16.73% and 95% confidence interval of 21,143 and 41,777 (Figure 2 - 5). This estimate is for production originating from above the trap site; no estimate was made for production below the trap site.

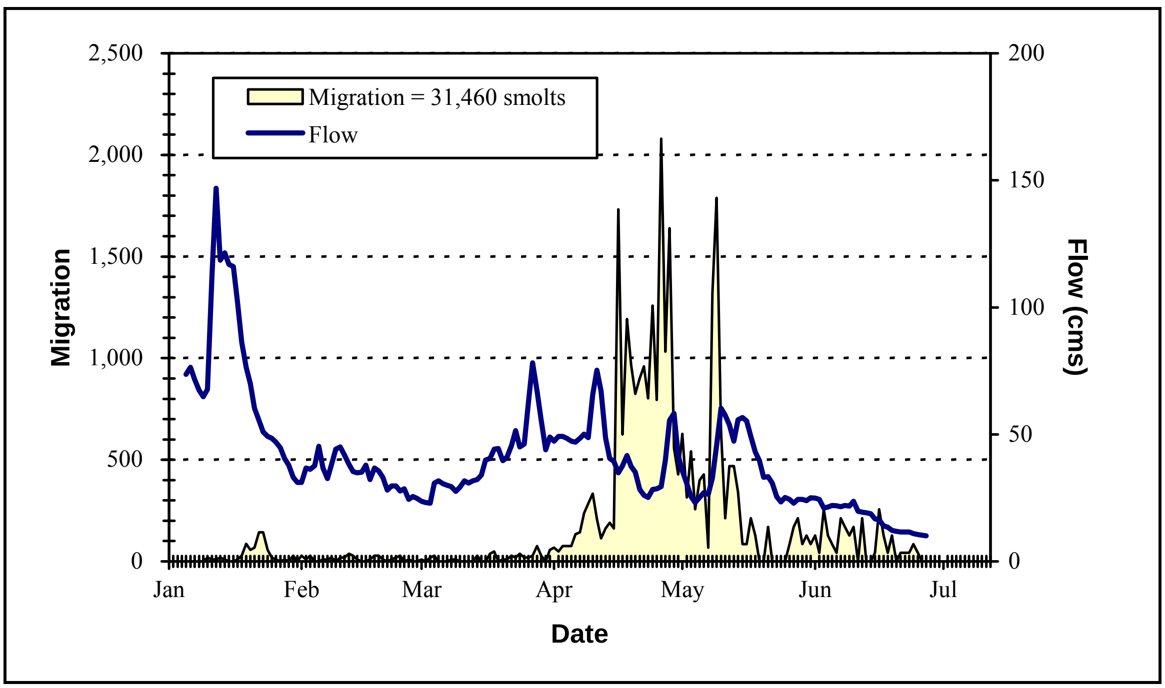

Figure 2 - 5. Daily migration of natural-origin coho smolts in the Green River screw trap, relative to stream discharge at USGS gage# 1211300, January 24 through July 16, 2006.

2.2.3 Steelhead

2.2.3.1 Catch

Over the trapping period, we caught 1,398 steelhead smolts (390 unmarked, 1,008 ad-marked). We captured 86 unmarked natural-origin steelhead smolts through February, 23% of the season total. Similar early-season migration patterns have been observed in previous years. Daily natural-origin smolt catches declined to nearly zero in late February, and remained low through mid-April. Daily unmarked smolt catches gradually increased through the remainder of April and the first half of May, and peaked on the nights of May 16 and May 28, with catches of 26 and 36 smolts, respectively. Daily catches quickly declined, and the last unmarked steelhead for the season was captured on the night of June 13.

During the month of May, 50 natural-origin steelhead (22 smolts captured in the trap and 28 smolts captured with hook and line) were retained to be surgically implanted with Vemco V7-2L acoustic tags. The tags were implanted in the smolts to track their migration from the river and through Puget Sound. Information from this collaborative project will be published by the US Army Corps of Engineers.

2.2.3.2 Size

Over the season, a total of 99 unmarked steelhead were measured (fork length), 25% of the total catch. Individuals ranged from 112 to 229-mm, and averaged 151.1-mm for the season (Figure 2 - 6).

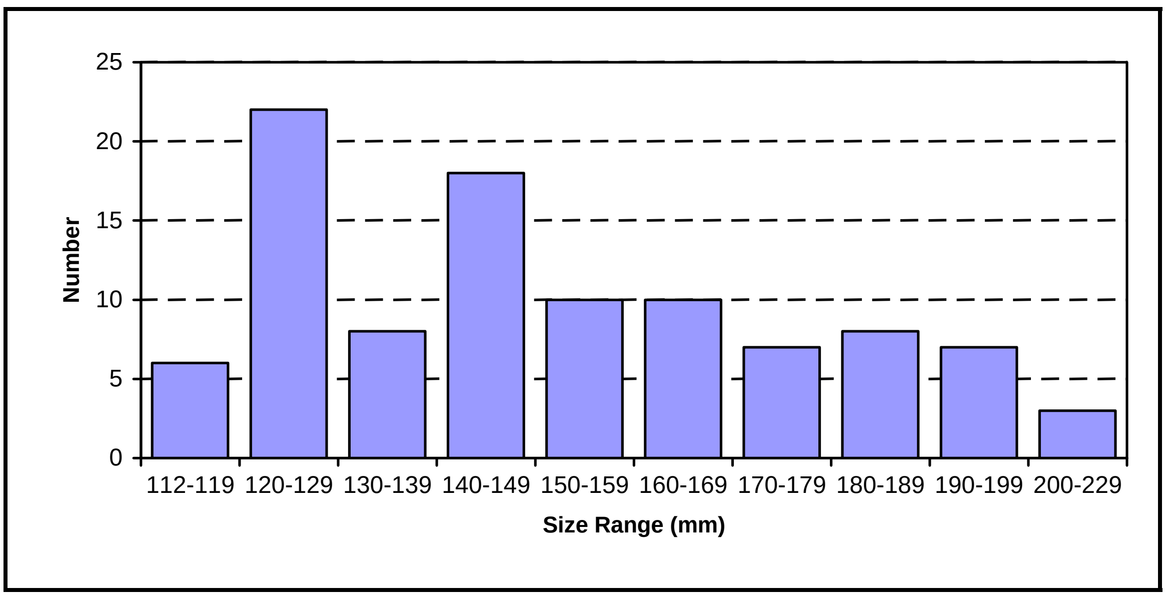

Figure 2 - 6. Length frequency of unmarked steelhead smolt fork lengths (mm) measured at the Green River screw trap, 2006.

2.2.3.3 Catch expansion

Through linear extrapolation, we estimated an additional 20 natural-origin and 91 hatchery steelhead smolts would have been captured had the trap fished continuously. With the exception of 3 unmarked natural-origin smolts, all the estimated missed catch of both natural-origin and hatchery smolts was for the 6.6 hours of suspended trap operation on the night of May 5. Total expanded catches were estimated at 410 natural-origin and 1,099 hatchery steelhead migrants (2.4 Appendix B 2)

2.2.3.4 Trap Efficiency

No trap efficiency tests were conducted using steelhead smolts. To estimate trap efficiency for steelhead, we applied a steelhead:coho capture rate ratio to each of the coho trap efficiency strata, an approach used in previous years of this study. In 2006, the steelhead:coho capture ratio of 60% was applied to each of the corresponding coho efficiency strata, resulting in steelhead efficiencies that ranged from 1.14% to 12.84%, and averaged 3.50% for the season. No variance estimates were made for these rates.

2.2.3.5 Production estimate

Application of the steelhead trap efficiency estimates to the expanded catch yielded a migration estimate of 16,748 natural-origin steelhead smolts and 36,735 hatchery smolts over the trapping season. Trapping operations encompassed the entire steelhead migration and therefore, no estimate of migration was made for the periods before and after the trapping interval. No variance or confidence intervals were developed for these estimates.

The hatchery migration estimate is just 5% of the reported number released. This is likely because hatchery smolts were thought to have suffered heavy losses due to otter predation prior to their release from the hatchery (Mike Wilson, pers comm.)

2.2.4 Chum

2.2.4.1 Catch

The chum catch was virtually nonexistent at the start of the season and remained low until the first week of March. Daily catches steadily increased through March and early-April, and peaked on the night of April 6, with 3,937 fry captured. Daily catches remained strong, averaging over 100 fry per day through April, before sharply declining in May. The last chum was captured on July 7. Over the season we captured a total of 32,308 chum fry.
Catch expansion
We estimated we would have captured an additional 272 chum fry had the trap operated continuously. The estimated missed catch represents less that 1% of the 32,580 fry estimated catch for the season.

2.2.4.2 Trap Efficiency

A total of 1,775 chum fry in 15 groups (from 23 to 298 fry per group) were marked with Bismarck Brown Dye and released 150-meters upstream of the trap (Table 2 - 8). Given the small size of many of the release groups, and to increase the number of recaptures and our confidence in the abundance estimates, 15 individual releases were combined into 6 strata. Recapture rates for these 6 strata averaged 4.10% for the season, and ranged from 2.5% to 6.39%. Flows ranged from 27.6 to 55.5 cms during the efficiency tests. There was no apparent relationship between flow and efficiency.

Table 2 - 8. Chum fry estimated catch and migration, by efficiency strata, Green River screw trap, 2006.

Strata	# Tests Pooled	Dates		Numbers		Trap Efficiency	Unmarked Catch (u)	Estimated Production (U)
		Start	End	Released (M)	Recaptured (m)			
1	1	01/24/06	03/24/06	298	9	3.02%	4,095	122,469
2	1	03/26/06	03/26/06	298	17	5.70%	285	4,750
3	1	03/28/06	03/28/06	158	10	6.33%	2,061	29,804
4	1	04/02/06	04/02/06	197	8	4.06%	11,268	247,917
5	2	04/10/06	04/12/06	133	4	3.01%	5,361	143,701
6	9	04/17/06	04/26/06	691	17	2.46%	9,510	365,644
TOTAL	**15**	**01/24/06**	**04/26/06**	**1,775**	**65**	**4.10%**	**32,580**	**914,285**

2.2.4.3 Production Estimate

Over the trapping season, we estimated 914,285 chum fry migrated past the trap, with a coefficient of variation of 14.44% and 95% confidence interval of 655,433 and 1,173,137. This estimate is for fry originating from above the trap site; no estimate was made for production below the trap site. This estimate includes hatchery chum fry released from Keta Creek; no separation of the catch was made between the natural-origin and hatchery fish because the fish released from Keta Creek were not marked.

2.2.5 Pink Salmon

2.2.5.1 Catch

We started catching pink fry the first day of trapping. Daily catches averaged 63 fry over the first week, then steadily increased through February and early March. The peak catch occurred on March 23, with 25,766 fry captured. Daily catches averaged 13,000 fry over the following two weeks, before quickly declining. By the first week of May, average catches had dropped to just 10 fry per day. The last pink was captured on June 6. Over the season, 294,293 fry were captured. We estimate that an additional 1,327 fry would have been captured had the traps operated continuously, for a total expanded catch of 295,620 pink fry.

2.2.5.2 Trap efficiency

No trap efficiency tests were conducted using pink fry. We elected to estimate abundance using the stratified chum salmon mark-recapture data to represent M_i and m_i in Equation 2 - 1. This approach was chosen because of the similarity in the size and migration timing of the pink and chum fry.

2.2.5.3 Production estimate

Over the season we estimated a total of 7,137,790 pink fry migrated past the trap, with a coefficient of variation of 15.96% and 95% confidence interval of 4,905,612 and 9,369,968. Some production migrated past the trap prior to trap installation, evident by the catch 57 pinks on the first night of fishing. No estimate was made for pink migration outside the trapping period or for production occurring below the trap site.

2.2.5.4 Other Species

We caught and enumerated a number of other age classes, as well as other fish species. Over the trapping period, we captured 130 coho fry, 133 steelhead parr, 6 cutthroat smolt, 2 parr, and 1 cutthroat adult. Non-salmonid species captured included sculpin (*Cottus* spp.), three-spine sticklebacks (*Gasterosteus aculeatus*), longnose dace (*Rhynichthys cataractae*), and lamprey ammocoetes.

2.3 Discussion

We developed estimates of migration past the trap for Green River natural-origin and hatchery Chinook 0+. A number of assumptions used to develop these estimates are discussed below. In addition, the estimates for natural-origin Chinook migrants are expanded to represent total basin production. For the first time in several years the hatchery coho released above the trap site were ad-marked before release, allowing us to estimate the number of unmarked natural-origin coho migrating from above our trap site. In-addition to the estimates made for the natural-origin Chinook and coho, we also estimated steelhead smolt and chum and pink fry migration past the trap.

2.3.1 Chinook

The Chinook production in 2006 was the lowest estimated in the seven years we have conducted this study on the Green River. The low production was a function of low parent spawner densities, poor egg-to-migrant survival and a negative interaction with the large return of pink salmon adults competing for in the same spawning areas.

In 2005, the female spawning escapement above the trap site, at RKm 55, was estimated at only 1,553 females/redds (includes Neuwaukum Creek), less than any previous escapement observed since the trapping project began in 2000. In addition to the low adult escapement, just before the start of the trapping season, river flows increased to levels higher than we have observed during any period over the previous six years of this study. On January 11-12, river flows at Auburn exceeded 283 cms. Flows of this magnitude would likely result in substantial bed movement, causing scour and deposition impacts to Chinook redds in the mainstem Green River. These impacts were likely more severe in the section of river upstream of RKm 76, the start of a large gorge where the river gradient increases. We have developed a strong relationship with peak winter flow (November through February) and egg-to-migrant survival (R^2 = 81%, Table 2 - 9, Figure 2 - 7). In 2005, 56% (787) of the 1,394 redds in the mainstem river, upstream of the trap site were observed within and above the gorge, in the higher-gradient section of the river. The combined effects of this high flow event and spawner distribution resulted in an egg-to-migrant survival of 1.47%, the lowest we have ever estimated in the Green River..

Egg-to-migrant survival is a measure of freshwater productivity for naturally-reared salmon. The estimated migration of 102,278 natural-origin Chinook 0+ migrants divided by the estimated egg deposition above the trap site of 6,988,500 eggs, results in an egg-to-migrant survival of 1.47%. The estimated egg deposition was derived by multiplying the 1,553 estimated number of Chinook redds above the trap site (Steve Foley pers. comm.) by an estimated Chinook fecundity of 4,500 eggs/female, assuming one redd per female.

In 2005, large numbers of pink salmon spawned in the section of river below the gorge, downstream of RKm 76. In these areas, WDFW biologists observed that Chinook appeared to be crowded out of the river margins by spawning pinks, and forced towards the deeper center of the river (thalweg), subjecting the redds to more intense flows and a greater likelihood of scour (Steve Foley, pers. comm.).

Table 2 - 9. Egg to migrant survival rates correlated with flow, Green River, brood years 1999 - 2005.

Brood Year	Trap Year	# Redds/ Females	Estimated			Peak Winter Flow (cms)
			Egg deposition	Migration	Survival	
1999	2000	1,625	7,312,500	535,708	7.33%	244.4
2000	2001	2,449	11,020,500	728,216	6.61%	62.9
2001	2002	2,711	12,199,500	412,460	3.38%	192.3
2002	2003	3,772	16,974,000	674,397	3.97%	231.6
2003	2004	3,124	14,058,000	270,877	1.93%	210.7
2004	2005	4,769	21,460,500	465,531	2.17%	238.4
2005	2006	1,553	6,988,500	102,728	1.47%	288.8

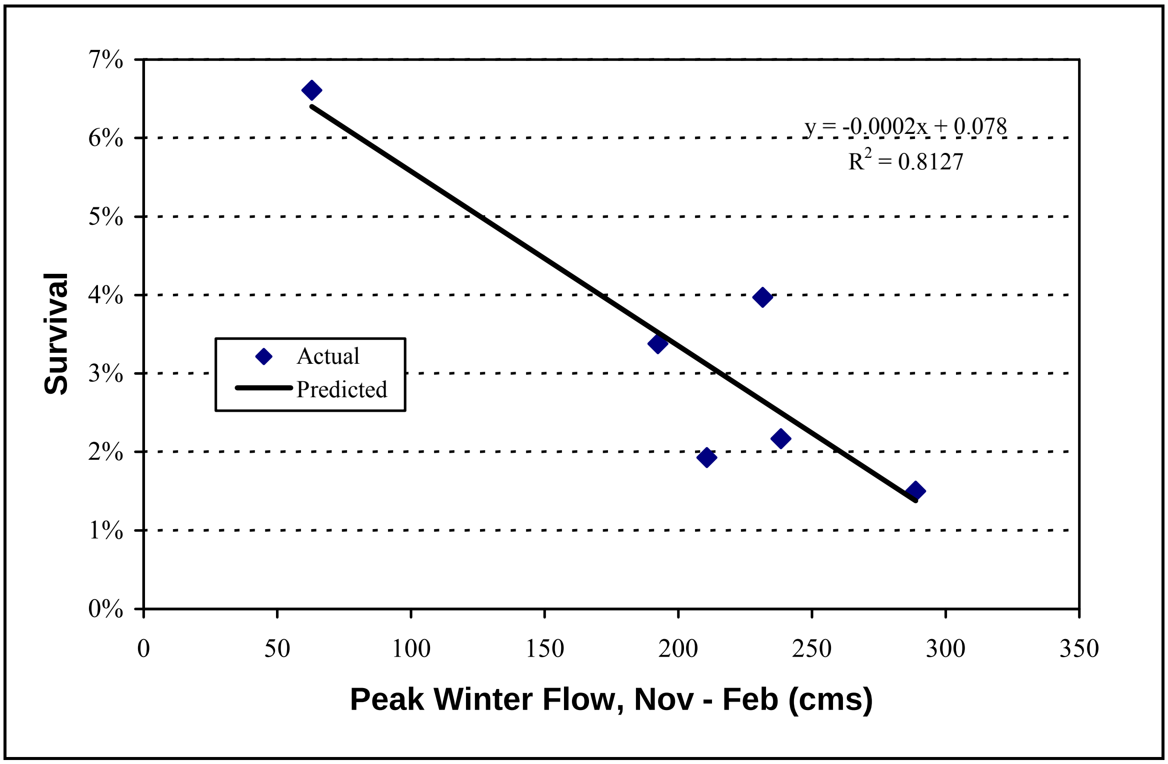

Figure 2 - 7. Natural-origin Chinook 0+ egg-to-migrant survival as a function of peak winter flow, migrations years 2001-2006, Green River.

The natural-origin Chinook 0+ production estimate made at the Green River trap site represents the production that occurred upstream of the trap. An additional 82 redds were estimated for the main river downstream of the trap. Assuming the same egg-to-migrant survival, we estimated production downstream of the trap at just 5,424 natural-origin Chinook 0+. In addition, a total of 598 female Chinook spawners were passed above the weir on Big Soos Creek; assuming they all spawned and had similar egg-to-migrant survival, we estimate 39,556, Chinook 0+ were produced from Soos Creek. This results in a total basin production estimate of 147,708 natural-origin Chinook 0+ migrants. The actual Soos Creek Chinook production may be higher because it has a lower gradient than the Green River, above the trap, and therefore the high flow effects were likely less severe.

The natural-origin Chinook 0+ migration for the Green River assumed a bi-modal timing distribution. The earliest component, composed of newly emerged Chinook fry, migrated past the trap from January 24 through April 23, and peaked in the second week of March. This was followed by a parr component that migrated from mid April through the end of the season, and peaked in late May/early June. The fry component in 2006 made up 31% of the production above the Green River trap. By comparison, the parr component was 69%, higher than any we have observed in the previous six years of this study (Table 2 - 10). The proportion of fry and parr migrants is influenced by such factors as flow and available rearing habitat. In 2006, the big storm on January 11-12 increased river discharge, which not only contributed to poor egg-to-migrant survival, but also likely moved any hatched fry downstream below the trap site. Consequently, the low Chinook fry densities remaining above the trap site following the high flow event, allowed the fry to rear prior to migrating as parr. Fry emerging after the high flow event in early January, were likely able to rear at a higher than usual rate due to the low densities.

Hatchery Chinook were released into tributaries above Howard Hansen Dam between March 16 and May 3. In total, 492,500 fry were released: 467,875 (95%) ad-marked and 24,625 unmarked. The unmarked fry did not contain CWTs, and were therefore indistinguishable from the natural-origin fry captured in the trap. We applied the proportion of ad-marked:unmarked fry at release to the estimated ad-marked catch (2,116 fry), estimated 111 unmarked hatchery fish captured. However, proportioning the estimated unmarked hatchery catch by day resulted in some days with more estimated unmarked hatchery fish than the total number of unmarked Chinook fry captured. Therefore, we estimated and removed the unmarked hatchery fish from the final unmarked Chinook migration estimate.

In total, 43,513 ad-marked hatchery Chinook 0+ were estimated to have migrated past the trap, with a CV of 11.23 and 95% confidence intervals of 33,932 and 53,093. Application of this estimate to the release of 467,875 ad-marked fry released estimates a survival rate past the trap of 9.3%. This is the largest estimated migration from above Howard Hansen Dam observed during this study. This is likely due to flows released to flush sediment from behind the dam, which allowed hatchery fry to migrate through the dam during their usual migration time, rather than wait for the reservoir to fill to utilize the surface passage facility.

Table 2 - 10. Fry and parr component and production estimates for naturally produced juvenile Chinook 0+, above the trap site, Green River, 2000-2006

Trap Year	Total Estimated Migration	Migration Interval	FRY			PARR		
			Migration Interval	Estimated Migration	% of Total	Migration Interval	Estimated Migration	% of Total
2000	535,708	1/1-7/13	1/1-4/15	366,013	68.30%	4/16-7/13	169,695	31.70%
2001	728,216	1/1-7/13	1/1-4/15	386,315	53.00%	4/16-7/13	341,901	47.00%
2002	412,460	2/7-7/11	2/7-5/1	358,313	87.00%	5/2-7/11	54,147	13.00%
2003	674,397	1/1-7/13	1/1-4/15	659,568	98.00%	4/16-7/13	14,829	2.00%
2004	270,877	1/1-7/14	1/1-4/15	171,181	63.00%	4/16-7/14	99,696	37.00%
2005	465,531	1/1-7/13	1/1-4/15	425585	91.42%	4/16-7/13	39,946	8.58%
2006	102,728	1/24-7/16	1/24-4/23	32195	31.34%	4/24-7/16	70,533	69.14%

2.3.2 Coho

This was the first year in several that we were able to estimate the natural-origin coho production migrating from the river above our trap site. This was possible because all hatchery coho released from the Keta Creek Hatchery, located above the trap site, were externally marked with an adipose fin-clip.

Trap calibration data estimated a capture efficiency rate of 5.8% over the season, higher than the rate estimated for Chinook 0+ (4.0%). Typically, smaller migrants are captured at a higher rate, because they are less able to avoid the trap (Seiler et al 2002). With this in mind, the production estimate for natural-origin coho smolts in 2006 may be underestimated. Because the steelhead estimate was based on a rate of 60% of the observed coho efficiency, the migration estimated for unmarked steelhead in 2006 may also be underestimated.

2.3.3 Pink Salmon

The pink salmon population in the Green River has substantially increased since the project's inception in 2000. During our first year of trapping, we captured just 1,200 fry. By Spring 2006, we captured close to 300,000 fry. Using our best available efficiency data, production estimates increased from under 20,000 fry in 2000, to over 7-million fry in 2006 (Table 2 - 11).

Table 2 - 11. Catch and estimated production of pink fry captured in the Green River screw trap, 2000-2006.

Trapping Year	Pink Fry Catch	Estimated Efficiency Species Used [a]	Estimated Efficiency Rate	Estimated Production
2000	1,200	Chum	6.6%	20,000
2002	16,392	Chinook	6.6%	250,000
2004	135,852	Chinook	5.1%	2,650,000
2006	295,620	Chum	4.1%	7,137,000

[a] Best available estimate

While the egg-to-migrant survival rate for Chinook was the lowest we have observed during this study, it appears that the pink egg-to-migrant survival rate was much higher. One possible explanation for the difference was spawner distribution. Virtually all the pink salmon spawned below RKm 76, where the high-gradient gorge begins, while 56% of the Chinook redds were observed upstream of the gorge. In addition, pink salmon spawned closer to the margins of the river, where flow velocities were slower, and the gravel was less likely to scour during high-flow events (Steve Foley pers comm).

2.3.4 Recommendations

1. Attempt to continue trap operation through hatchery releases, without adversely affecting the captured fish, to better understand HOR/NOR interactions as hatchery fish migrate through the system.
2. Install the trap by early January to intercept the start of the Chinook out-migration.
3. Continue to release as many calibration groups as possible through the entire season, with as many species as possible given the availability of each species.
4. Explore options to estimate natural-origin steelhead smolt production.
5. Electronically sample all coho smolts.

2.4 Appendices A & B

Appendix A. Variance of total unmarked smolt numbers, , when the number of unmarked smolts, is estimated. by Kristen Ryding, WDFW Biometrician.

The estimator for $\hat{U}_i$ is,

$$\hat{U}_i = \frac{\hat{u}_i\left(M_i+1\right)}{\left(m_i+1\right)}$$

the estimated variance of $\hat{U}_i$, $Var\left(U_i\right)$ is as follows,

$$Var\left(\hat{U}_i\right) = Var\left(\hat{u}_i\right)\left(\frac{\left(M_i+1\right)\left(M_i m_i+3M_i+2\right)}{\left(m_i+1\right)^2\left(m_i+2\right)}\right) + Var\left(\hat{U}_i \middle| E\left(\hat{u}\right)\right)$$

where

$$Var\left(\hat{U}_i \middle| E\left(\hat{u}\right)\right) = \frac{\left(M_i+1\right)\left(M_i-m_i\right)E\left(\hat{u}_i\right)\left(E\left(\hat{u}_i\right)+m_i+1\right)}{\left(m_i+1\right)^2\left(m_i+2\right)},$$

$E\left(\hat{u}_i\right)$ = the expected value of $\hat{u}_i$ either in terms of the estimator (equation for $\hat{u}_i$) or just substitute in the estimated value and, $Var\left(\hat{u}_i\right)$ depends on the sampling method used to estimate $\hat{u}_i$.

Derivation:

Ignoring the subscript i for simplicity, the derivation of the variance estimator is based on the following unconditional variance expression,

$$Var\left(\hat{U}\right) = Var\left(E\left(\hat{U}\middle|u\right)\right) + E\left(Var\left(\hat{U}\middle|u\right)\right).$$

The expected value and variance $\hat{U}$ given u is as before, respectively,

$$E\left(\hat{U}_i\middle|u\right) = \frac{u_i\left(M_i+1\right)}{\left(m_i+1\right)} \text{ and,}$$

$$Var\left(\hat{U}\middle|u\right) = \frac{u\left(u+m+1\right)\left(M+1\right)\left(M-m\right)}{\left(m+1\right)^2\left(m+2\right)}.$$

Substituting in $\hat{u}$ for u gives the following,

$$Var\left(\hat{U}\right) = Var\left(\frac{\hat{u}\left(M+1\right)}{\left(m+1\right)}\right) + E\left[\frac{\left(M+1\right)\left(M-m\right)\hat{u}\left(\hat{u}+m+1\right)}{\left(m+1\right)^2\left(m+2\right)}\right]$$

$$Var\left(\hat{U}\right) = \left(\frac{\left(M+1\right)}{\left(m+1\right)}\right)^2 Var\left(\hat{u}\right) + \frac{\left(M+1\right)\left(M-m\right)}{\left(m+1\right)^2\left(m+2\right)}\left[E\left(\hat{u}^2\right)+E\left(\hat{u}\right)\left(m+1\right)\right]$$

Note that,

$$E\left(\hat{u}^2\right) = Var\left(\hat{u}\right) + \left(E\hat{u}\right)^2$$

Substituting in this value for $E\left(\hat{u}^2\right)$,

$$Var\left(\hat{U}\right) = \left(\frac{(M+1)}{(m+1)}\right)^2 Var\left(\hat{u}\right) + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}\left[Var\left(\hat{u}\right) + \left(E\left(\hat{u}\right)\right)^2 + E\left(\hat{u}\right)(m+1)\right]$$

$$= \left(\frac{(M+1)}{(m+1)}\right)^2 Var\left(\hat{u}\right) + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}\left[Var\left(\hat{u}\right) + E\left(\hat{u}\right)\left[E\left(\hat{u}\right) + m + 1\right]\right]$$

$$Var\left(\hat{U}\right) = \left(\frac{(M+1)}{(m+1)}\right)^2 Var\left(\hat{u}\right) + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}Var\left(\hat{u}\right) + \frac{(M+1)(M-m)E\left(\hat{u}\right)\left[E\left(\hat{u}\right) + m + 1\right]}{(m+1)^2(m+2)}$$

$$Var\left(\hat{U}\right) = Var\left(\hat{u}\right)\left(\frac{(M+1)^2}{(m+1)^2} + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}\right) + \frac{(M+1)(M-m)E\left(\hat{u}\right)\left[E\left(\hat{u}\right) + m + 1\right]}{(m+1)^2(m+2)}$$

$$Var\left(\hat{U}\right) = Var\left(\hat{u}\right)\left(\frac{(M+1)^2}{(m+1)^2} + \frac{(M+1)(M-m)}{(m+1)^2(m+2)}\right) + Var\left(\hat{U}\middle|E\left(\hat{u}\right)\right)$$

$$Var\left(\hat{U}\right) = \frac{(M+1)}{(m+1)^2}Var\left(\hat{u}\right)\left(\frac{(M+1)(m+2)}{(m+2)} + \frac{(M-m)}{(m+2)}\right) + Var\left(\hat{U}\middle|E\left(\hat{u}\right)\right)$$

$$Var\left(\hat{U}\right) = \frac{(M+1)}{(m+1)^2}Var\left(\hat{u}\right)\left(\frac{Mm + 2M + m + 2 + M - m}{(m+2)}\right) + Var\left(\hat{U}\middle|E\left(\hat{u}\right)\right)$$

$$Var\left(\hat{U}\right) = Var\left(\hat{u}\right)\left(\frac{(M+1)(Mm + 3M + 2)}{(m+1)^2(m+2)}\right) + Var\left(\hat{U}\middle|E\left(\hat{u}\right)\right)$$

Appendix B 1. Daily actual and estimated catches and migration for natural-origin and hatchery Chinook 0+ migrants, Green River 2006.

Date	UNMARKED CHINOOK[a]				AD-MARKED HATCHERY			
	Catch			Migration	Catch			Migration
	Actual	Estimated	Total		Actual	Estimated	Total	
1/24/06	8		8	242	3		3	119
1/25/06	3		3	91				
1/26/06								
1/27/06								
1/28/06	3		3	91				
1/29/06	4		4	121				
1/30/06	3	1	4	121				
1/31/06	2	3	5	151				
2/1/06	5		5	151				
2/2/06	5		5	151				
2/3/06	3		3	91				
2/4/06	6		6	182				
2/5/06	13		13	394				
2/6/06	11		11	333				
2/7/06	4		4	121				
2/8/06	5		5	151				
2/9/06	4		4	121				
2/10/06	8		8	242				
2/11/06	4		4	121				
2/12/06	5		5	151				
2/13/06	5		5	151				
2/14/06	15		15	454				
2/15/06	17		17	282				
2/16/06	14		14	232				
2/17/06	10		10	216				
2/18/06	15		15	325				
2/19/06	14		14	239				
2/20/06	12		12	205				
2/21/06	23		23	392				
2/22/06	16		16	623				
2/23/06	58		58	2258				
2/24/06	16		16	623				
2/25/06	8		8	312				
2/26/06	11		11	317				
2/27/06	30		30	865				
2/28/06	23		23	663				
3/1/06	17		17	490				
3/2/06	31		31	893				
3/3/06	31		31	792				
3/4/06	6		6	153				
3/5/06	11		11	558				
3/6/06	13		13	659				
3/7/06	18		18	912				
3/8/06	24		24	1216				
3/9/06	16		16	811				
3/10/06	11		11	431				

[a] Season totals for the unmarked Chinook includes a estimated catch of 111 unmarked hatchery Chinook, with a migration estimate of 2,392 hatchery Chinook.

Table continued next page

Appendix B1. Daily actual and estimated catches and migration for natural-origin and hatchery Chinook 0+ migrants, Green River 2006.

Date	UNMARKED CHINOOK				AD-MARKED HATCHERY			
	Catch			Migration	Catch			Migration
	Actual	Estimated	Total		Actual	Estimated	Total	
3/11/06	12		12	471				
3/12/06	8		8	188				
3/13/06	38		38	894				
3/14/06	15		15	353				
3/15/06	14		14	331				
3/16/06	30		30	710				
3/17/06	20		20	290				
3/18/06	67	3	70	1014				
3/19/06	44		44	607				
3/20/06	4		4	55				
3/21/06	13		13	179				
3/22/06	14		14	305				
3/23/06	53		53	1153	9		9	152
3/24/06	41		41	892				
3/25/06	37		37	805	2		2	34
3/26/06	15		15	245	4		4	68
3/27/06	4		4	65	2		2	34
3/28/06	18		18	294	7		7	119
3/29/06	24		24	392	1		1	17
3/30/06	20		20	327				
3/31/06	8		8	131	3		3	51
4/1/06	29		29	473	12		12	203
4/2/06	21		21	343	22		22	318
4/3/06	21		21	343	9		9	130
4/4/06	26		26	424	12		12	173
4/5/06	26		26	424	7		7	101
4/6/06	26		26	424	12		12	173
4/7/06	15		15	245	5		5	72
4/8/06	3		3	49				
4/9/06	10		10	163	1		1	14
4/10/06	20		20	327	15		15	217
4/11/06	4		4	65	3		3	43
4/12/06	3		3	49	2		2	29
4/13/06	4		4	65	3		3	43
4/14/06		7	7	114	2	5	7	101
4/15/06	12	1	13	212	7	1	8	116
4/16/06	6		6	98	1		1	14
4/17/06	17		17	278	4		4	58
4/18/06	9		9	147	5		5	72
4/19/06	3		3	49	4		4	58
4/20/06	1		1	16	2		2	29
4/21/06	3		3	49	2		2	29
4/22/06	11		11	180	3		3	43
4/23/06	6		6	98	1		1	14
4/24/06					1		1	14
4/25/06	4		4	36	1		1	14

Table continued next page

Appendix B1. Daily actual and estimated catches and migration for natural-origin and hatchery Chinook 0+ migrants, Green River 2006.

Date	UNMARKED CHINOOK				AD-MARKED HATCHERY			
	Catch			Migration	Catch			Migration
	Actual	Estimated	Total		Actual	Estimated	Total	
4/26/06					3		3	43
4/27/06								
4/28/06	4		4	36	17		17	246
4/29/06	5		5	45	56		56	809
4/30/06	15		15	136	79		79	1142
5/1/06	1		1	9	51		51	737
5/2/06	2		2	18	20		20	289
5/3/06	4		4	36	156		156	2255
5/4/06	8		8	73	81		81	1171
5/5/06	2	7	9	82	20	64	84	1214
5/6/06	5		5	45	50		50	901
5/7/06	18		18	163	175		175	3153
5/8/06	9		9	82	150		150	2703
5/9/06	3		3	27	59		59	1063
5/10/06	4		4	36	20		20	360
5/11/06	8		8	73	15		15	270
5/12/06	16		16	145	38		38	685
5/13/06	11		11	100	21		21	378
5/14/06	8		8	73	19		19	342
5/15/06	7		7	63	18		18	324
5/16/06	16		16	145	27		27	487
5/17/06	29		29	263	36		36	649
5/18/06	20		20	181	19		19	342
5/19/06	29		29	263	21		21	378
5/20/06	26		26	236	10		10	180
5/21/06	14		14	127	5		5	90
5/22/06	14		14	673	10		10	180
5/23/06	5		5	240	5		5	90
5/24/06	16		16	769	11		11	198
5/25/06	51		51	2451	16		16	288
5/26/06	31		31	1490	11		11	198
5/27/06	188		188	9034	65		65	1171
5/28/06	366		366	17588	105		105	1892
5/29/06	85		85	4085	34		34	1152
5/30/06	49		49	2355	21		21	712
5/31/06	49		49	2355	20		20	678
6/1/06	338		338	9157	102		102	3457
6/2/06	134		134	3630	46		46	1559
6/3/06	24		24	650	9		9	305
6/4/06	20		20	542	12		12	407
6/5/06	23		23	623	13		13	441
6/6/06	13		13	352	12		12	407
6/7/06	16		16	433	8		8	271
6/8/06	21		21	569	20		20	678
6/9/06	42		42	1138	21		21	712
6/10/06	17		17	461	11		11	373

Table continued next page

Appendix B1. Daily actual and estimated catches and migration for natural-origin and hatchery Chinook 0+ migrants, Green River 2006.

Date	UNMARKED CHINOOK[a]				AD-MARKED HATCHERY			
	Catch			Migration	Catch			Migration
	Actual	Estimated	Total		Actual	Estimated	Total	
6/11/06	5			135	1			34
6/12/06	10	1		298	8			271
6/13/06	10	1		298	5			169
6/14/06	9	1		271	6			203
6/15/06	13	1		379	9			305
6/16/06	15			406	14			474
6/17/06	15			406	12	1		441
6/18/06	31			840	9	1		339
6/19/06	22	1		623	14			474
6/20/06	24	1		677	13			441
6/21/06	18			488	12			407
6/22/06	11			298	7			237
6/23/06	13			352	5			169
6/24/06	13			352	9			305
6/25/06	14			379	5			169
6/26/06	15			406	2			68
6/27/06	10			271	7			237
6/28/06	22			596	3			102
6/29/06	22			596	3			102
6/30/06	20			542	4			136
7/1/06	10			271	1			34
7/2/06	10			271	1			34
7/3/06	9			244	2			68
7/4/06	8			217				
7/5/06	16			433	4			136
7/6/06	17			461	1			34
7/7/06	5			135				
7/8/06	6			163				
7/9/06	3			81	1			34
7/10/06	6			163				
7/11/06	4			108				
7/12/06	2			54				
7/13/06	8			217				
7/14/06	5			135	1			34
7/15/06								
7/16/06	1			27				
Season Tot	**3,528**	**28**	**3,556**	**105,120**	**2,044**	**72**	**2,116**	**43,513**

[a] Season totals for the unmarked Chinook includes a estimated catch of 111 unmarked hatchery Chinook, with a migration estimate of 2,392 hatchery Chinook.

Appendix B 2. Daily catch (including estimated missed catch) for coho, steelhead, chum, pink, and cutthroat, Green River 2006.

Date	Times		COHO Smolts		Steelhead Smolts		CUTT Fry	Chum Fry	Pink Fry
	In	Out	NOR	HOR	NOR	HOR	NOR	NOR	NOR
01/24/06	19.20	0.00	0			0	0	0	57
01/25/06	24.13	0.00	0			0	0	0	58
01/26/06	24.00	0.00	0			1	1	1	68
01/27/06	24.00	0.00	0			0	1	1	37
01/28/06	24.00	0.00	0			0	0	1	61
01/29/06	23.83	0.00	2			3	0	0	81
01/30/06	14.67	9.33	1	0	0	2	0	0	79
01/31/06	15.08	8.92	1	0	0	4	0	0	112
02/01/06	24.00	0.00	2			2	0	0	46
02/02/06	24.00	0.00	1			2	0	0	38
02/03/06	24.00	0.00	0			2	0	0	46
02/04/06	24.00	0.00	0			1	0	0	70
02/05/06	23.83	0.00	1	1		4	0	0	71
02/06/06	24.17	0.00	3	1		7	0	0	50
02/07/06	24.00	0.00	9			5	0	0	23
02/08/06	24.00	0.00	6			6	0	0	56
02/09/06	24.00	0.00	7	1		4	0	0	61
02/10/06	24.00	0.00	15			6	0	1	54
02/11/06	24.00	0.00	15	1		4	0	0	35
02/12/06	24.00	0.00	6			3	0	0	30
02/13/06	24.00	0.00	2			5	0	0	39
02/14/06	24.00	0.00	1			4	0	0	88
02/15/06	24.00	0.00	0			4	0	0	100
02/16/06	24.00	0.00	1			4	0	0	139
02/17/06	24.00	0.00	0	2		2	0	0	75
02/18/06	24.00	0.00	3			1	0	0	56
02/19/06	24.00	0.00	0			1	0	0	55
02/20/06	24.00	0.00	3			0	0	0	49
02/21/06	24.00	0.00	1	1		0	0	0	118
02/22/06	24.00	0.00	3			0	0	0	107
02/23/06	24.00	0.00	0			4	0	5	225
02/24/06	23.75	0.00	0			5	0	0	59
02/25/06	23.92	0.00	1			0	0	4	66
02/26/06	23.67	0.17	1	0	0	1	0	0	153
02/27/06	24.00	0.00	2			0	0	11	232
02/28/06	24.83	0.00	0			1	0	5	215
03/01/06	23.17	0.00	2			2	0	12	231
03/02/06	24.00	0.00	2			1	0	29	358
03/03/06	24.00	0.00	4			0	0	24	630
03/04/06	24.00	0.00	3			2	0	14	525
03/05/06	24.00	0.00	1			1	0	4	303
03/06/06	24.00	0.00	0			3	0	30	399
03/07/06	24.00	0.00	0			0	0	45	1,236
03/08/06	23.50	0.00	1			4	0	24	433
03/09/06	24.00	0.00	3		1	1	0	26	316
03/10/06	24.00	0.00	3			3	0	31	248
03/11/06	24.00	0.00	1			0	0	21	989
03/12/06	24.00	0.00	0			2	0	18	624
03/13/06	24.00	0.00	1			1	0	31	503
03/14/06	24.00	0.00	2	1		0	0	24	655
03/15/06	24.00	0.00	3			1	0	114	1,258

Table continued next page

Appendix B2. Daily catch (including estimated missed catch) for coho, steelhead, chum, pink, and cutthroat, Green River 2006 (cont'd).

Date	Times		COHO Smolts		Steelhead Smolts		CUTT Fry	Chum Fry	Pink Fry
	In	Out	NOR	HOR	NOR	HOR	NOR	NOR	NOR
03/16/06	24.00	0.00	0			0	0	409	1,612
03/17/06	22.17	0.00	1			0	0	151	400
03/18/06	24.00	1.83	0	0	0	0	0	199	5,031
03/19/06	24.00	0.00	0			0	0	121	5,405
03/20/06	23.75	0.00	1	1		2	0	41	2,444
03/21/06	24.07	0.00	0			0	0	65	4,332
03/22/06	19.93	4.00	2	0	0	0	0	309	5,294
03/23/06	24.00	0.00	3			0	0	904	25,766
03/24/06	23.75	0.00	0			0	0	922	12,589
03/25/06	24.00	0.00	0			0	0	498	9,922
03/26/06	24.00	0.00	0			0	0	175	8,461
03/27/06	24.00	0.00	1			0	0	110	8,655
03/28/06	24.00	0.00	1			0	0	851	17,774
03/29/06	24.00	0.00	0			0	0	739	11,232
03/30/06	24.00	0.00	0			0	0	471	9,534
03/31/06	24.28	0.00	0			0	0	456	14,706
04/01/06	24.72	0.00	0			0	0	778	19,131
04/02/06	23.50	0.00	3	1		0	0	663	16,785
04/03/06	24.00	0.00	0			0	0	1,285	16,596
04/04/06	24.00	0.00	0			0	0	1,817	18,280
04/05/06	24.00	0.00	4			0	0	1,645	12,003
04/06/06	24.00	0.00	5	1		0	0	4,624	8,740
04/07/06	24.00	0.00	0			0	0	2,616	9,958
04/08/06	23.92	0.00	1			0	0	452	8,121
04/09/06	24.08	0.00	1			0	0	287	8,888
04/10/06	24.00	0.00	3	2		2	0	1,580	5,811
04/11/06	24.00	0.00	2	1		1	0	251	4,751
04/12/06	24.00	0.00	4			0	0	175	2,035
04/13/06	24.00	0.00	2			1	0	185	1,786
04/14/06	12.50	11.50	2	0	0	2	0	129	854
04/15/06	13.00	10.50	3	0	0	2	0	91	409
04/16/06	24.50	0.00	8			2	0	52	545
04/17/06	23.50	0.00	3			2	0	950	904
04/18/06	24.00	0.00	0	1		2	0	2,097	783
04/19/06	24.25	0.00	6			1	0	640	723
04/20/06	26.25	0.00	7			0	0	561	647
04/21/06	21.50	0.00	5			2	2	467	477
04/22/06	24.25	0.00	8			2	0	506	400
04/23/06	23.75	0.00	8			3	0	193	451
04/24/06	24.17	0.00	8	4		1	0	197	527
04/25/06	24.00	0.00	14	2		0	0	128	509
04/26/06	24.00	0.00	15			0	0	77	178
04/27/06	25.00	0.00	25	2		1	0	325	172
04/28/06	22.83	0.00	30	1		8	0	742	205
04/29/06	24.00	0.00	35	2		22	0	871	56
04/30/06	24.00	0.00	22	2		14	0	234	33

Table continued next page

Appendix B2. Daily catch (including estimated missed catch) for coho, steelhead, chum, pink, and cutthroat, Green River 2006 (cont'd).

Date	Times		COHO Smolts		Steelhead Smolts		CUTT Fry	Chum Fry	Pink Fry
	In	Out	NOR	HOR	NOR	HOR	NOR	NOR	NOR
05/01/06	24.00	0.00	12	1	47	8	0	101	10
05/02/06	24.00	0.00	17	2	191	5	0	32	11
05/03/06	24.00	0.00	20		235	4	0	31	1
05/04/06	24.00	0.00	17	84	99	3	0	17	7
05/05/06	17.17	6.58	182	2,723	146	22	0	162	35
05/06/06	24.00	0.00	22	201	43	5	0	16	4
05/07/06	24.00	0.00	42	192	84	2	0	44	4
05/08/06	24.00	0.00	34	59	49	4	0	36	0
05/09/06	24.00	0.00	29	25	27	2	0	15	0
05/10/06	24.00	0.00	47	42	7	0	0	12	0
05/11/06	24.00	0.00	50	4	9	1	0	7	2
05/12/06	24.00	0.00	62	42	11	2	0	18	5
05/13/06	24.00	0.00	46	11	6	0	0	22	0
05/14/06	24.00	0.00	29	10	8	3	0	10	0
05/15/06	24.00	0.00	76	17	10	7	1	19	1
05/16/06	23.83	0.00	81	17	23	26	0	22	4
05/17/06	23.92	0.00	79	6	12	19	0	98	0
05/18/06	24.00	0.00	28	5	15	7	0	56	0
05/19/06	24.00	0.00	15	3	2	5	0	6	0
05/20/06	24.00	0.00	22	7	6	7	0	21	0
05/21/06	24.00	0.00	11	1	1	0	0	7	0
05/22/06	24.00	0.00	19	1	1	2	0	25	0
05/23/06	24.00	0.00	9		1	0	0	9	0
05/24/06	24.00	0.00	14	1	1	5	0	20	0
05/25/06	24.00	0.00	15		3	4	0	37	0
05/26/06	24.00	0.00	17	2	1	2	0	8	0
05/27/06	23.92	0.00	31	7	4	6	0	38	1
05/28/06	23.92	0.00	42	3	28	36	0	40	0
05/29/06	24.17	0.00	15		12	12	1	3	0
05/30/06	23.83	0.00	5		2	5	0	6	0
05/31/06	24.00	0.00	11	1	3	1	0	7	0
06/01/06	24.17	0.00	11	1		7	0	39	1
06/02/06	23.83	0.00	8	1	4	10	0	42	0
06/03/06	24.00	0.00	2		1	2	0	9	0
06/04/06	24.17	0.00	2	1		2	0	1	1
06/05/06	24.00	0.00	5		2	1	0	2	1
06/06/06	24.00	0.00	3			1	0	1	0
06/07/06	24.00	0.00	0		1	0	0	1	0
06/08/06	24.00	0.00	0		1	2	0	4	0
06/09/06	24.00	0.00	4			0	0	3	0
06/10/06	23.83	0.00	0			0	0	2	0
06/11/06	24.17	0.00	0		1	0	0	1	0
06/12/06	8.75	15.25	0	0	0	0	0	1	0
06/13/06	8.75	15.25	0	0	0	1	0	2	0
06/14/06	10.33	15.25	2	0	0	0	0	2	0
06/15/06	8.75	13.67	4	0	0	0	0	1	0

Table continued next page

Appendix B2. Daily catch (including estimated missed catch) for coho, steelhead, chum, pink, and cutthroat, Green River 2006 (cont'd).

Date	Times		COHO Smolts		Steelhead Smolts		CUTT Fry	Chum Fry	Pink Fry
	In	Out	NOR	HOR	NOR	HOR	NOR	NOR	NOR
06/16/06	24.00	0.00	5			0	0	2	0
06/17/06	8.75	15.25	2	0	1	0	0	1	0
06/18/06	11.25	15.25	3	0	0	0	0	3	0
06/19/06	11.25	12.75	2	0	0	0	0	1	0
06/20/06	8.75	12.75	3	0	0	0	0	1	0
06/21/06	24.50	0.00	1			0	0	0	0
06/22/06	9.00	14.75	6	0	0	0	0	0	0
06/23/06	9.00	15.00	3	0	0	0	0	0	0
06/24/06	11.25	15.00	2	0	0	0	0	0	0
06/25/06	11.25	13.00	1	0	0	0	0	0	0
06/26/06	9.25	12.50	5	0	0	0	0	0	0
06/27/06	9.00	14.75	4	0	0	0	0	0	0
06/28/06	24.25	0.00	3			0	0	0	0
06/29/06	9.25	14.75	4	0	0	0	0	0	0
06/30/06	11.25	14.75	0	0	0	0	0	0	0
07/01/06	12.75	12.75	5	0	0	0	0	0	0
07/02/06	9.25	11.25	0	0	0	0	0	0	0
07/03/06	9.25	14.75	0	0	0	0	0	0	0
07/04/06	9.25	14.75	1	0	0	0	0	1	0
07/05/06	24.00	0.00	6			0	0	0	0
07/06/06	8.75	14.75	3	1	0	0	0	0	0
07/07/06	11.67	15.33	1	0	0	0	0	0	0
07/08/06	11.67	12.33	3	0	0	0	0	0	0
07/09/06	9.25	12.25	0	0	0	0	0	0	0
07/10/06	9.25	14.75	1	0	0	0	0	0	0
07/11/06	24.00	0.00	1			0	0	0	0
07/12/06	9.25	14.75	1	0	0	0	0	0	0
07/13/06	9.25	14.75	2	0	0	0	0	0	0
07/14/06	11.42	15.08	1	0	0	0	0	0	0
07/15/06	11.75	12.25	0	0	0	0	0	0	0
Season Total			1,555	3,499	1,099	410	6	32,580	295,620

2.5 References

Literature Cited: Green River

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3 Dungeness River

2006 Dungeness River
Juvenile Salmonid Production Evaluation

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3.1 Methods

3.1.1 Trap Operations

A floating five-foot diameter screw trap (Busack *et al.* 1991) was operated on the Dungeness River to capture downstream migrant salmonids. The trap was located at River Kilometer (RKm) 0.5, just above tidal influence (Figure 3 - 1). This trap is identical to that used on the Green River (Chapter 2.1.1).

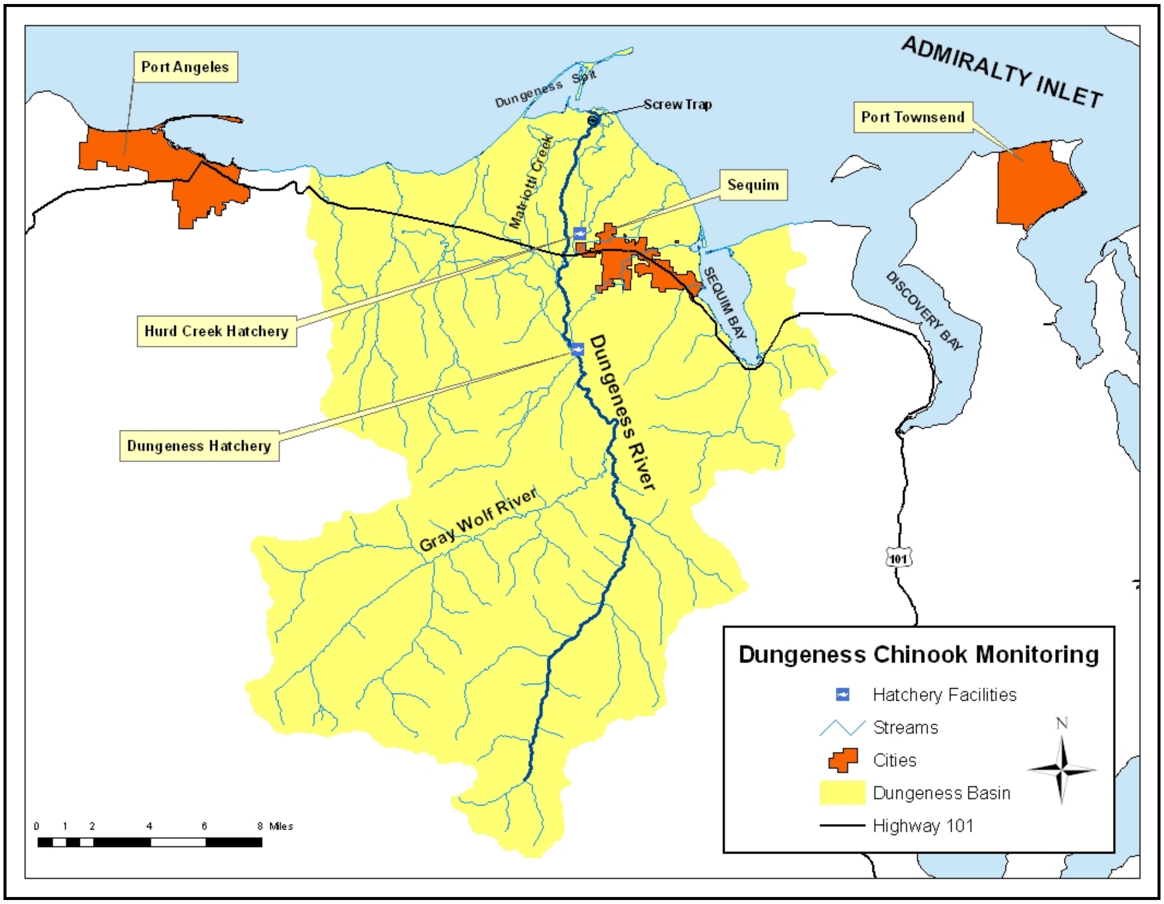

Figure 3 - 1. Map of the Dungeness River watershed with the location of the screw trap, Matriotti Creek and hatcheries.

The screw trap was operated continuously between February 2 and August 17, except for periods when high stream flows, heavy debris, mechanical failure, or large numbers of HORs released above the trap prevented its operation. Trapping was also suspended during daytime periods late in the trapping season, when catches were low and the potential for recreational use of the river was high. Fish were usually removed from the trap and counted at dawn and at dusk. In addition to these periods, the trap was checked, as needed, based on debris loads and capture rates. At the end of each trapping period, all fish captured in the trap were identified to species, checked for marks, CWTs, and enumerated. Fork length measurements were taken from a sample of the various natural-origin salmonids captured.

To estimate migration, groups of natural-origin Chinook, chum and pink migrants captured in the trap were marked with either a unique fin-clip or by staining with Bismarck Brown dye. The fish were marked in the morning and held in a perforated bucket placed in the trap live-box during the day. Each group of marked fish was released 150-meters upstream of the trap just before dark. Trap efficiency was estimated by the proportion of marked fish recaptured in the trap.

Coho and steelhead smolt trap efficiency was estimated by the proportion of marked fish released from a smolt fence-trap operated by the Jamestown S'Klallam Tribe on Matriotti Creek, which were subsequently captured in our screw trap. The Matriotti Creek trap was located just upstream from its confluence with the Dungeness River at rkm 3.1 (Figure 3 - 1). Coho and steelhead smolts captured in the Matriotti Creek trap were marked with a partial caudal fin-clip and released daily.

3.1.2 Chinook, Chum and Pink Salmon Production Estimate

Production estimates for these species were made using a stratified mark-recapture approach. The Petersen estimate, modified by Chapman (1951), is often used to estimate smolt abundance. Smolt abundance during time period *i* is estimated by;

Equation 3 - 1

$$\hat{U}_i = \frac{(u_i + 1)(M_i + 1)}{(m_i + 1)} - 1$$

where;

U_i = Migration of unmarked fish past the trap during time period *i*,
u_i = Catch of unmarked fish during time period *i*,
M_i = Marked fish released above the trap during time period *i*, and
m_i = Marked fish recaptured during time period *i*.

Seber (1982) provides and approximate unbiased estimate of the variance:

Equation 3 - 2

$$V(\hat{U}_i) = \frac{(M + 1)(u + 1)(M - m)(u - m)}{(m + 1)^2 (m + 2)}$$

Total production over the entire smolt outmigration is estimated by:

Equation 3 - 3

$$\hat{N} = \sum_{i=1}^{n} \hat{U}_i$$

Similarly, the variance of N is estimated by the sum of the variances for U_i. The normal confidence interval about N is calculated using:

Equation 3 - 4

$$\hat{N}_{95\%ci} = \hat{N} \pm 1.96\sqrt{V(\hat{N})}$$

This approach assumes that marked fish and unmarked fish have the same probability of capture during each fishing period. Yet, recaptures of marked Chinook, chum, and pink salmon occur during a relatively short period (e.g. a few hours after release), whereas the unmarked catches they represent may occur over a longer period. If trapping is suspended during the period when only unmarked fish are passing the trap, the catch of unmarked fish must be estimated for the abundance estimator to be valid. In this case $\hat{u}_i$ is substituted for u_i in Equation 2 - 1. The variance, $V(\hat{U}_i)$, is now estimated using (see 2.4 Appendix A for derivation);

Equation 3 - 5

$$V(\hat{U}_i) = Var(\hat{u}_i)\left(\frac{(M_i+1)(M_i m_i + 3M_i + 2)}{(m_i+1)^2(m_i+2)}\right) + \left(\frac{(M_i+1)(M_i - m_i)\hat{u}_i(\hat{u}_i + m_i + 1)}{(m_i+1)^2(m_i+2)}\right)$$

To interpolate catch for periods when the trap was not fishing, diel differences in migration rates were evaluated. Salmonids often migrate at different rates between day and night periods (Seiler *et al.* 1981), therefore, fishing periods were stratified into daytime, nighttime, and combined periods. The stratification was simplified by performing the trap checks near daybreak and twilight periods. Catch during trapping intervals not fished were estimated by interpolating between catch rates from the previous and following fishing periods within the same diel stratum, and then expanding by the hours not fished. Catch rates were defined using:

Equation 3 - 6

$$R_{fj} = \frac{C_{fj}}{T_{fj}}$$

where:

$$R_{fj} = \textit{the catch rate during fishing period } f \textit{ in diel stratum } j,$$
$$C_{fj} = \textit{catch during fishing period } f \textit{ in diel stratum } j, \textit{and}$$
$$T_{fj} = \textit{the duration of fishing period } f \textit{ in diel stratum } j.$$

The variance of the mean catch rate was estimated by:

Equation 3 - 7

$$V(\overline{R}_{fj}) = \frac{\sum(R_{fj} - \overline{R}_{fj})^2}{n(n-1)}$$

Catch during the un-fished interval was then estimated by expanding the mean catch rate by the hours not fished (T). The estimated catch during the un-fished period was summed with the actual catch to estimate the total catch during each fishing period, $\hat{u}_i$. The catch variance was then estimated by:

Equation 3 - 8

$$V\left(\hat{U}_i\right)=V\left(\overline{R}_{fj}\right)T^2$$

3.1.3 Coho and Steelhead Smolt Production Estimate

Coho and steelhead smolt production was estimated using a "total capture trap/partial capture trap" design (Volkhardt et al. 2007). This approach uses a simple pooled Peterson estimator (modified by Chapman 1951):

Equation 3 - 9

$$\hat{N}=\frac{(n+1)(M+1)}{(m+1)}-1$$

Where: $\hat{N}$ = total natural-origin coho smolt population estimate in the Dungeness River;

n = the number of natural-origin coho smolts captured in the partial-capture mainstem trap;

M = the number of natural-origin coho smolts that were upper caudal fin-marked and released at the total-capture tributary trap (Matriotti Creek); and

m = the number of marked fish recaptured in the partial-capture mainstem trap.

The variance of the coho and steelhead production estimate (Seber 1982) were found using:

Equation 3 - 10

$$Var\left(\hat{N}\right)=\frac{(M+1)(n+1)(M-m)(n-m)}{(m+1)^2(m+2)}$$

The normal confidence interval about *N* was calculated using Equation 2 - 4.

3.2 Results

Estimating the production of natural-origin Chinook migrants was complicated by the large numbers of hatchery salmonids planted into the river. Table 3 - 1 provides a summary of hatchery releases upstream of the screw trap in 2006.

Table 3 - 1. Hatchery releases upstream of the Dungeness River screw trap, 2006.

Species	Release Date(s)	Location	Brood Year	CWT Only	Ad-mark Only	Admk/ CWT
Chinook	June 3	Gray Wolf Ponds	2005	54,500		
	June 24	Gray Wolf Ponds	2005	54,000		
	April 5	Hurd Creek Hatchery	2004	48,931		
	April 5	Dungeness Hatchery	2004	37,000		
Coho	June 1	Dungeness Hatchery	2004		[a]500,000	
	Volitional[b]	Dungeness Hatchery	2004			[c]103
Steelhead	June 1	Dungeness Hatchery	2004		[a]10,500	

[a] Otter predation reduced the number of fish released by an unknown factor.
[b] May 9-25: this experimental group was part of a naturalized rearing project conducted by the University of Idaho.
[c] Otter predation reduced the original 10,000 tag group to a enumerated release of 103 smolts.

3.2.1 Chinook 0+

3.2.1.1 Catch

Over the 196-day season, we captured 6,533 unmarked natural-origin and 1,355 CWT hatchery Chinook 0+ migrants (3.4 Appendix C 1). Trap operation began on February 2, but the first Chinook fry was not captured until February 8, indicating that the Chinook out-migration had not yet started.

We fished the trap fished in several positions over the season to accommodate changing flows. From February 2 to February 15, the trap was operated in the same position it fished during the 2005 season, on the east bank of the river. By February 15, the river flows had dropped substantially and a total of 16 Chinook 0+ had been captured. We moved the trap across the river to the west bank, into the main channel of the river. The first night's catch in the new position totaled 6 Chinook fry, more than any previous single night's catch. The daily catch remained low throughout the entire month of February. Daily catches steadily increased in March, and peaked on March 23, with 440 natural-origin Chinook 0+ captured.

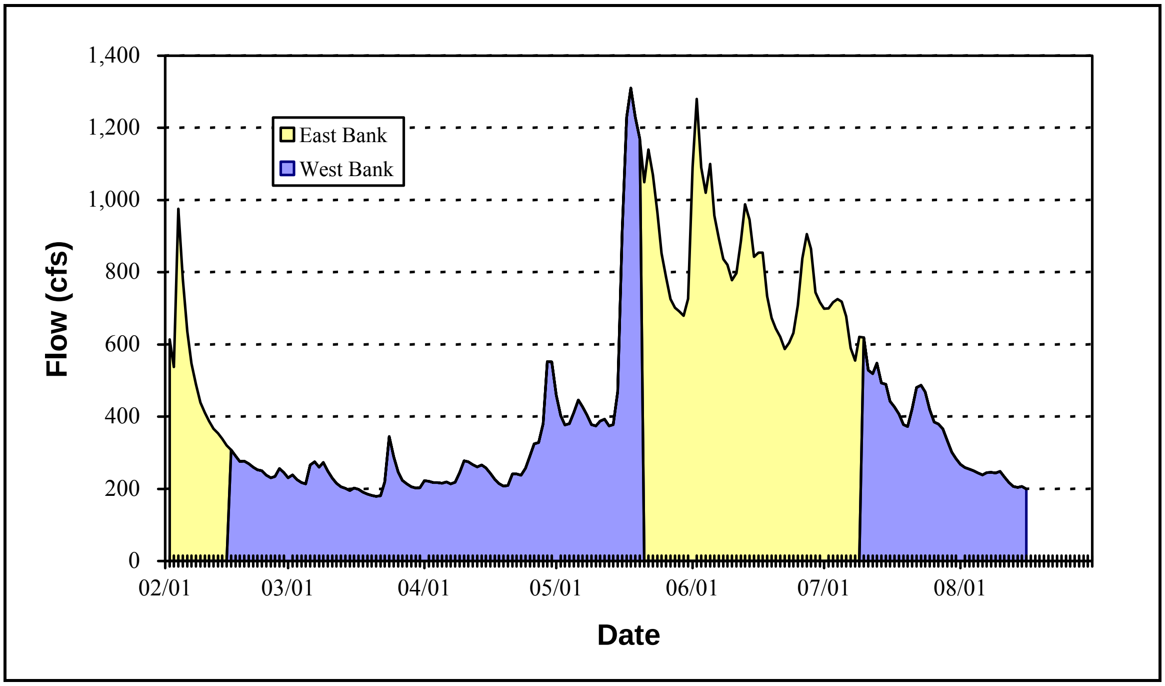

Figure 3 - 2. Daily mean flow (USGS flow gauge #12048000, near Sequim) and trap position, Dungeness River 2006.

The Chinook migration included two distinct peaks; newly emerged fry (early) and zero-age parr (later) migration trends; the later migration peak consisted of fish that had reared in the river and began their smoltification process before migrating. After the first peak on March 23, the daily catch quickly declined to zero on April 11. Catches remained low through the remainder of April and the first half of May, averaging fewer than 13 fish per day. The trap remained in the west bank fishing position until May 20, when increased flows from snow melt brought higher debris loads and limited employee access to the trap. The trap was moved back to the original east bank position and daily catches remained low and steady, averaging 23 fish per day. On July 9, as flows receded, the trap was moved back to the west bank position. Catches increased, averaging 86 Chinook/day for the following week, reflecting a higher trap efficiency at this position. From mid-July, the catch declined steadily and only 2 Chinook were captured on August 16, the last complete day of trap operation.

3.2.1.2 Size

We measured a total of 1,112 zero-age natural-origin Chinook over the migration. Measured sizes of captured Chinook did not increase until the first week of April. Fork lengths averaged 39-mm over the early portion of the migration. Size increased rapidly in late March and averaged 3-mm of growth per week through the rest of the trapping season. Over the final three weeks of the season the Chinook averaged 96-mm, with some individuals as large as 120-mm. (Table 3 - 2, Figure 3 - 3). Migrants measuring less than 40-mm were caught through mid-April, after which, the minimum size increased to over 80-mm by the end of the trapping season. Individuals smaller than 40-mm were assumed to be newly emerged fry; therefore, we believe that emergence was complete by the middle of April.

Table 3 - 2. Mean fork length (mm), standard deviation, range, and sample size of natural-origin Chinook 0+ measured by statistical week, Dungeness River 2006.

Statistical Week			Average	s.d.	Range		Number		Percent
No.	Begin	End			Min	Max	Sampled	Captured	Sample
6	02/02/06	02/05/06					0	0	0.0%
7	02/06/06	02/12/06	39.4	2.39	36	42	8	11	72.7%
8	02/13/06	02/19/06					0	13	0.0%
9	02/20/06	02/26/06	37.0	n/a	37		1	24	4.2%
10	02/27/06	03/05/06	38.5	0.93	37	40	11	198	5.6%
11	03/06/06	03/12/06	39.6	2.78	37	50	47	324	14.5%
12	03/13/06	03/19/06	40.6	3.81	33	56	106	1,002	10.6%
13	03/20/06	03/26/06	39.1	1.82	36	49	150	1,315	11.4%
14	03/27/06	04/02/06	40.8	3.99	37	65	106	494	21.5%
15	04/03/06	04/09/06	46.6	5.54	42	60	15	88	17.0%
16	04/10/06	04/16/06	43.9	9.60	33	79	36	67	53.7%
17	04/17/06	04/23/06	57.8	6.84	44	68	17	53	32.1%
18	04/24/06	04/30/06	55.8	6.69	44	70	57	113	50.4%
19	05/01/06	05/07/06	60.2	8.29	43	85	54	112	48.2%
20	05/08/06	05/14/06	65.4	9.44	50	87	33	63	52.4%
21	05/15/06	05/21/06	70.4	7.03	60	85	27	45	60.0%
22	05/22/06	05/28/06	62.0	6.67	50	82	36	107	33.6%
23	05/29/06	06/04/06	64.3	5.01	52	73	30	144	20.8%
24	06/05/06	06/11/06	68.8	8.07	54	89	59	173	34.1%
25	06/12/06	06/18/06	72.3	8.46	56	98	96	181	53.0%
26	06/19/06	06/25/06	75.0	7.71	59	96	80	133	60.2%
27	06/26/06	07/02/06	80.6	9.73	65	97	32	180	17.8%
28	07/03/06	07/09/06	81.3	7.50	70	85	4	62	6.5%
29	07/10/06	07/16/06	84.1	5.76	72	95	30	605	5.0%
30	07/17/06	07/23/06	84.7	6.75	70	100	32	405	7.9%
31	07/24/06	07/30/06	94.1	8.78	80	108	15	404	3.7%
32	07/31/06	08/06/06	90.3	6.38	80	105	17	148	11.5%
33	08/07/06	08/13/06	87.4	4.69	80	93	8	51	15.7%
34	08/14/06	08/20/06	108.0	9.75	95	120	5	18	27.8%
Season Total			**57.88**	**18.24**	**33**	**120**	**1,112**	**6,533**	**17.02%**

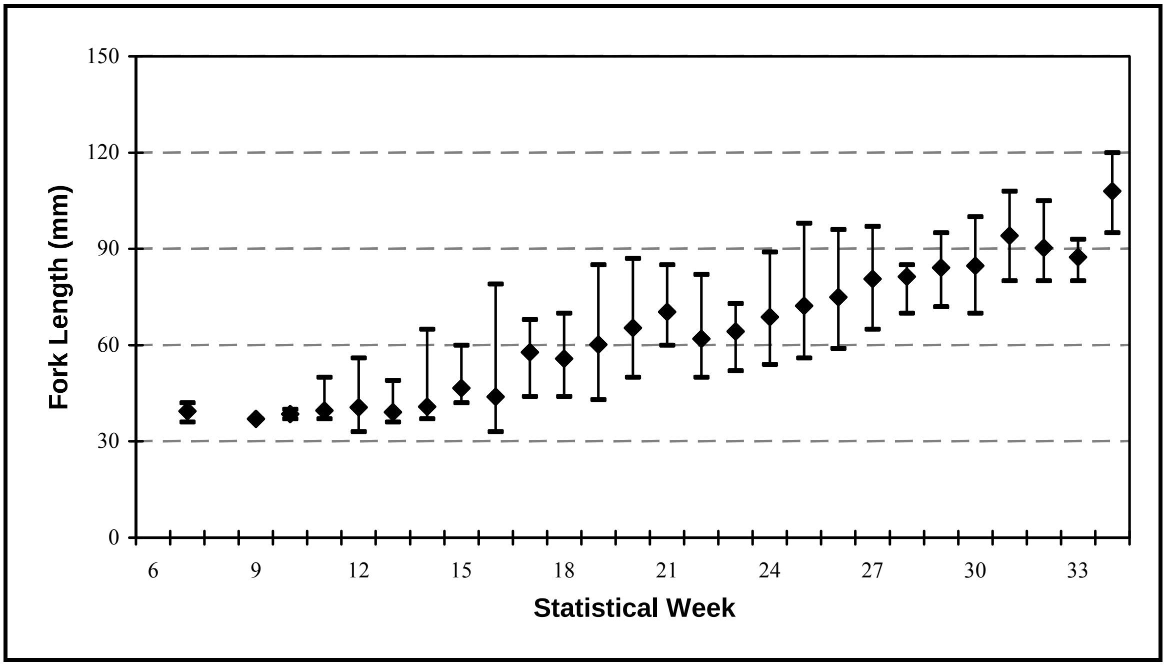

Figure 3 - 3. Weekly average, minimum, and maximum Chinook 0+ fork lengths (mm) measured at the Dungeness River screw trap, 2006.

3.2.1.3 Catch Expansion

The trap was operated 4,180 hours out of 4,697 possible hours in the 196-day trapping period, or 89.0% of the time. Over the course of the season trapping was suspended three times for a total of 1.5 hours for maintenance and trap movement; no additional Chinook were estimated to have been caught during this period. Trapping was also suspended to avoid large numbers of HORs for a total of 163.83 hours (78.67 hours daytime, and 85.16 hours nighttime). We estimated a catch of 207 natural-origin Chinook would have occurred during this period. The trap was removed from fishing or was stopped due to high water and heavy debris for a total of 176 hours (85.41 hours daytime, and 90.60 hours nighttime) on 14 different occasions, for which we estimated a missed catch of 146 NORs. With warming temperatures and limited manpower, late in the season we suspended trapping for 175.5 hours (114.18 hours daytime, and 61.32 hours nighttime) on 12 days, and estimated a missed catch of 62 natural-origin Chinook. In total, we estimated 415 additional natural-origin Chinook 0+ (6% increase over the actual catch) would have been captured had we been able to fish throughout the entire season. Addition of these fish estimates the total expanded catch of 6,948 natural-origin Chinook between February 2 and August 17 (3.4 Appendix C 1).

For the combined outage periods, we estimate an additional 18 hatchery Chinook fry would have been captured, with a total expanded catch of 1,373 HORs (3.4 Appendix C 1). Because of the low catches observed at the beginning and end of the trapping season, we assumed that the trapping season included the entire migration.

3.2.1.4 Trap Efficiency

A total of 3,946 Chinook 0+ migrants (2,992 NOR, 954 HOR) in 85 test-releases were marked and released approximately 150-yards upstream of the trap following the evening trap check at dusk. All of the fish that were marked and released were individuals that had been captured in the trap. Between June 6 and June 27, the test-releases were separated by origin, with 15 HOR, and 17 NOR efficiency groups released. Over this period, recapture rates for both the NOR and HOR releases averaged 4%. Because paired releases exhibited nearly identical catch rates, data from both the NOR and HOR test releases were pooled through the remainder of the season.

The trap efficiency tests were separated into three groups based on the different time periods and locations in which the trap fished (Table 3 - 3). Within each group, tests were pooled into fewer strata, where trapping conditions were similar, to increase recoveries and improve confidence in the estimates.

- **Group A – East Bank:** February 2, through February 15
  No calibration releases were made because of very low catches early in the season. Data from Strata 1 was applied to the February 2-15 catches.
- **Group 1 – West Bank:** February 16, through May 20
  Includes 15 calibration releases that were combined into seven strata. Trap efficiency rates for these strata ranged from 2.3% to 26.9%, and averaged 9.6%.
- **Group 2 – East Bank:** May 21 through July 9
  Includes 37 calibration releases were combined into six strata. Trap efficiency rates for these strata ranged from 1.30% to 17.60%, and averaged 8.32%.
- **Group 3 – West Bank:** July 10 through August 17.
  Includes 33 calibration releases that were combined into 16 strata. Trap efficiency rates for these strata ranged from 9.70% to 27.90%, and averaged 15.86%.

Flows ranged from 17.39 to 37.10 cubic meters per second (cms) during the Chinook trap efficiency tests. While flows affected trap positioning, there was no apparent relationship between flow and efficiency. This is probably due to the fact that flows in the Dungeness never reached the magnitude necessary to substantially alter the river cross-section at the trap site (Figure 3 - 4).

Table 3 - 3. Chinook 0+ trap efficiency strata, Dungeness River screw trap 2006.

Group	Trap Location	Strata	# Tests Pooled	Dates		Numbers		Trap Efficiency
				Release	Application	Release	Recaptured	
One	West Bank	1	2	3/11-3/15	2/2-3/15 [a]	164	5	3.00%
		2	2	3/16-3/21	3/16-3/21	85	5	5.90%
		3	1	3/22	3/22-3/23	70	8	11.40%
		4	2	3/24-3/27	3/24-3/28	220	5	2.30%
		5	1	3/31	3/29-4/7	101	4	4.00%
		6	5	4/14-5/8	4/8-5/8	51	7	13.70%
		7	2	5/9-5/11	5/9-5/20	26	7	26.90%
Two	East Bank	8	4	5/21-5/26	5/21-5/26	67	7	10.40%
		9	6	5/27-6/6	5/27-6/6	232	11	4.70%
		10	1	6/8	6/7-6/8	74	13	17.60%
		11	7	6/9-6/17	6/9-6/18	208	9	4.30%
		12	1	6/19	6/19	43	5	11.60%
		13	18	6/20-7/9	6/20-7/9	682	9	1.30%
Three	West Bank	14	2	7/10-7/11	7/10-7/11	108	15	13.90%
		15	1	7/12	7/12	120	18	15.00%
		16	1	7/13	7/13	114	25	21.90%
		17	1	7/14	7/14	104	21	20.20%
		18	1	7/15	7/15	136	38	27.90%
		19	1	7/16	7/16	107	19	17.80%
		20	1	7/17	7/17	64	12	18.80%
		21	1	7/18	7/18	88	12	13.60%
		22	1	7/19	7/19	93	15	16.10%
		23	1	7/20	7/20	97	12	12.40%
		24	2	7/21-7/22	7/21-7/22	134	13	9.70%
		25	1	7/23	7/23	70	11	15.70%
		26	2	7/24-7/25	7/24-7/25	64	8	12.50%
		27	4	7/26-7/29	7/26-7/29	236	29	12.30%
		28	1	7/30	7/30	92	14	15.20%
		29	12	7/31-8/15	7/31-8/17	296	32	10.80%
Season Totals			**85**			**3,946**	**389**	**9.86%**

[a] Trap operated in the East Bank position from February 2-15.

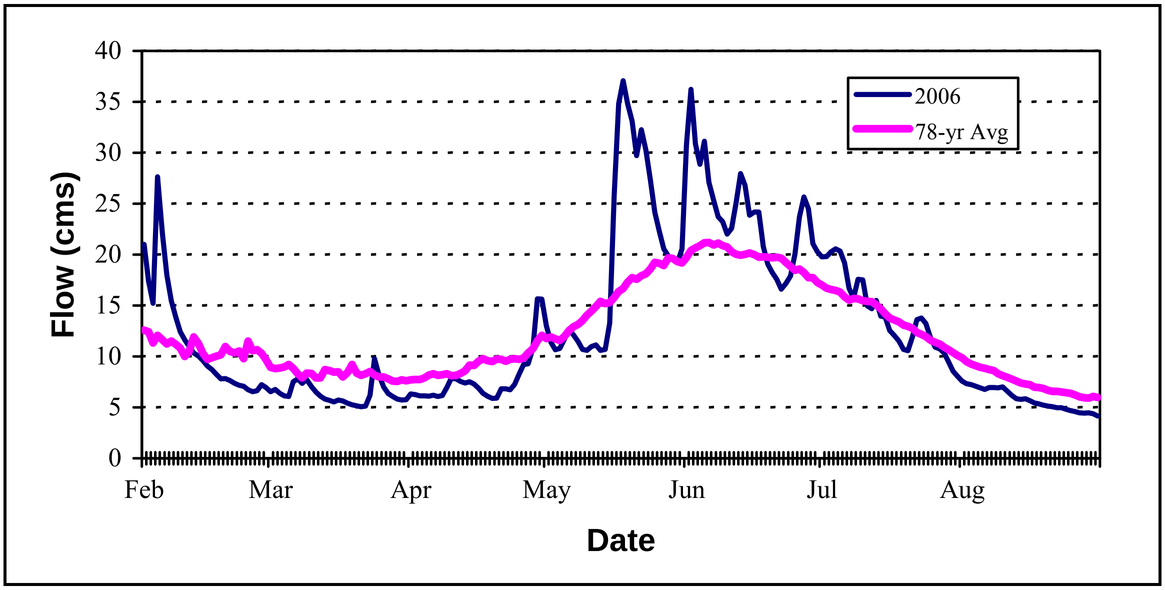

Figure 3 - 4. Daily mean flow during the 2006 trapping season (February 1 - August 31) and 78-year average daily flow (1922-2006), Dungeness River near Sequim (USGS gage# 12048000).

3.2.1.5 Production Estimate

Over the trapping season (February 2 through August 17), we estimated 124,928 natural-origin Chinook 0+ migrants passed the screw trap. This estimate has a coefficient of variation of 12.07% and 95% confidence intervals of 95,362 to 154,494 Chinook (Table 3 - 4). Because of low catches at the beginning and end of the trapping season, we assumed the entire migration period was trapped (Figure 3 - 5, 3.4 Appendix C 1). Using April 11 as a transition date between the fry and parr components of the Chinook 0+ migration, we estimate that 60% of the production migrated as fry and 40% migrated as parr.

Table 3 - 4. Summary of natural-origin and hatchery juvenile Chinook outmigration past the screw trap, Dungeness River 2006.

Origin	Interval	Catch			Migration	CV	95% CI	
		Actual	Est	Total	Estimate		Low	High
Wild	2/2-8/16	6,533	415	6948	124,928	12.07%	95,362	154,494
Hatchery	6/1-8/7	1,355	18	1,373	41,297	22.99%	22,684	59,909

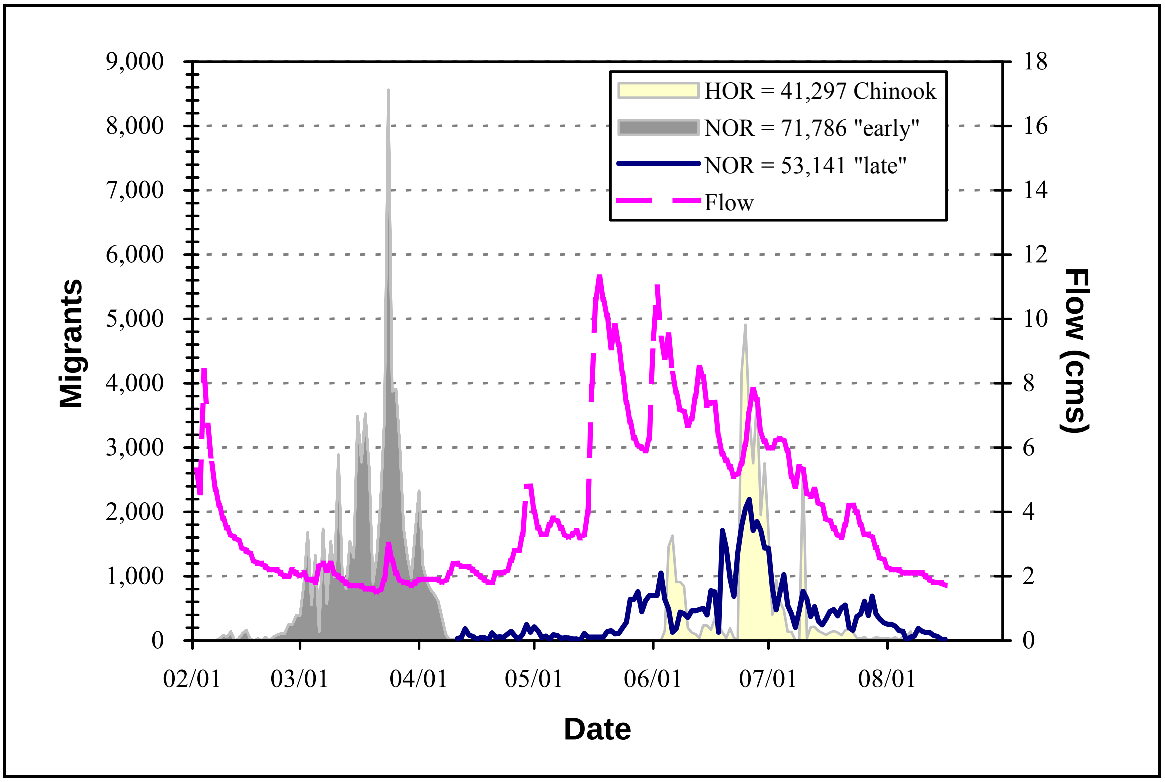

Figure 3 - 5. Estimated daily migration of natural-origin Chinook 0+ , Dungeness River 2006.

3.2.1.6 Hatchery Chinook Survival

A reported 108,500 CWT-only hatchery Chinook 0+ were released from the Grey Wolf acclimation ponds: 54,000 HORs on June 3, and 54,500 HORs on June 24. The fish appeared in the trap catches the day after their release, with peak catches on the second day following each release. Over the season we estimated 1,373 hatchery Chinook 0+ captured. Of these, 1,338 HORs were from the Grey Wolf pond releases, and 35 HORs (captured in early-March) were from a release of 223 fry we had picked up from the hatchery and used for trap calibration tests. Because the NOR and HOR efficiency rates were identical, we used the combined NOR/HOR efficiency data to estimate 41,297 hatchery Chinook 0+ migrated past the trap in 2006. Applying the estimated migration to the recorded release of 108,500 hatchery Chinook calculates survival to the trap at 38%.

3.2.1.7 Yearling Chinook

Over the season, we caught 758 yearling Chinook smolts. This catch consisted of 721 coded-wire tagged (CWT'd) HOR and 37 untagged fish. The first yearling Chinook was captured on February 25. A total of 4 untagged natural-origin smolts were captured prior to the hatchery yearling release. On April 5, a reported 85,931 CWT hatchery Chinook 1+ were released from the Dungeness and Hurd Creek Hatcheries.

In addition, we captured and measured 14 additional unmarked/non-CWT Chinook1+. These fish averaged a fork length size of 96 mm, much smaller than the hatchery yearlings (7.9 fish per pound). These 14 unmarked/non-CWT yearlings were therefore assumed of natural-origin. The remaining 19 unmarked/non-CWT Chinook 1+ could not be positively identified as either HOR or NOR.

We stopped fishing the trap once the hatchery fish reached it on the afternoon of April 5. Except for a few short fishing periods to collect samples for stomach content analysis, trap operations were suspended for the following 88 hours to avoid capturing thousands of these large, aggressive fish, and prevent over-crowding in the live box. We estimated that 99.7% of the hatchery fish migrated past the trap site within seven days. No estimate was made for the yearling Chinook migration past the trap because of the 88-hour outage during their peak migration period.

Gut content analysis was performed via gastric lavage on 168 hatchery Chinook yearlings captured at the trap. None of the Chinook sampled contained any fish. The Chinook were sampled as quickly as possible upon trap entry to preclude any in-trap predation.

3.2.2 Coho

3.2.2.1 Catch

The first NOR coho (8 natural-origin pre-smolts) were captured on February 2. Catches over the first week of trapping averaged 17 coho per day. Catches dropped to an average of 4 pre-smolt coho/day through the end of February. Pre-smolt catches remained low but steady, at 2 fish/day through March 31. A total of 270 natural-origin pre-smolts were captured before April 1; the yearling coho captured after this date were considered smolts.

Smolt catches remained low through mid-April, but increased with flow in late April/early May. Peak catches occurred on the night of May 15, with a one-night catch of 370 smolts. Trapping was suspended from the morning of May 16 through the afternoon of May 21, due to high flows and heavy debris. A total of 66 smolts were captured on May 22, the first full day of fishing following suspended trapping. Catches declined thereafter, and by the end of May, daily catches averaged 4 smolts. From June 15 through the end of the trapping season, we captured only 21 additional natural-origin coho smolts.

Over the season, we captured 1,964 natural-origin coho smolts (3.4 Appendix C 2). This catch included 170 UC-marked natural-origin smolts released from a trap operated the Jamestown S'Klallam Tribe on Matriotti Creek (RKm. 3.05). The Tribe used a partial upper caudal fin-clip (UC) from April 5 through June 26. The UC-marked coho first appeared in our catches on May 1.

Two groups of hatchery coho smolts were released from the Dungeness Hatchery: the larger production group of 500,000 ad-marked hatchery smolts released on June 1; the second group of 103 hatchery smolts was reared in a "Nature's Study" (naturalized rearing) pond and allowed to migrate volitionally. Over the season, a total of 482 ad-marked hatchery coho smolts were captured; of these, 89 ad-marked HORs were captured before June 1, the reported release date. The first ad-marked hatchery smolt was captured on February 11, and may have been a holdover from the previous year's release. The remaining 88 were captured between April 20 and the reported release date of June 1. These fish were likely hatchery escapees.

To avoid capturing large numbers of hatchery coho, and because of increasing flows, trap operation was suspended on the morning of June 1, for a total of 75.5 hours. A total of 166 ad-marked hatchery coho were captured on June 4, the first full day of trapping after operations resumed. Ad-marked HOR catches declined quickly, to an average of 4 coho/day by June 12. The last hatchery coho was captured on June 19. We believe virtually all the fish migrated past the trap site during the three day period the trap did not fish following the release, indicated by a season catch of just 482 fish. However, this hatchery group was also subject to heavy otter predation, and the actual number released from the hatchery is likely much lower than reported (Scott Williams, pers. comm.).

The second release group from the "Nature Study" pond originally consisted of 10,000 smolts, but was also subject to heavy otter predation. Only 103 smolts were counted migrating from the pond. None of these fish were captured in our trap.

3.2.2.2 Size

Over the season, we measured (fork length) a total of 115 unmarked natural-origin coho. Sizes ranged from 69 to 180 mm, and averaged 108.7-mm.

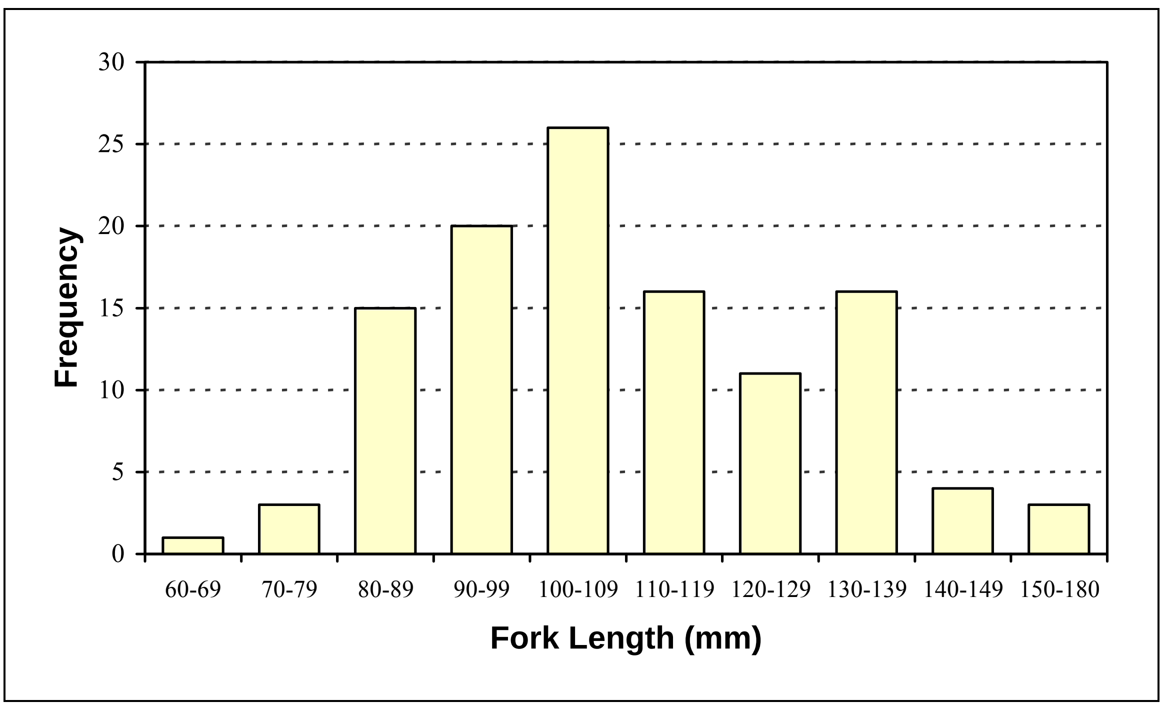

Figure 3 - 6. Length frequency of natural-origin unmarked coho smolts, fork lengths (mm) measured at the Dungeness River screw trap, 2006.

3.2.2.3 Trap Efficiency

In total, the Jamestown S'Klallam tribe marked and released 5,663 natural-origin coho smolts from their weir trap on Matriotti Creek; all were marked with a partial UC fin-clip. The weir remained operational and fish-tight over the entire trapping season. Over the season, 170 UC-marked smolts were captured in our screw trap. Applying the number of marked coho captured in the screw trap to the number released estimates that we recaptured 3.0% (170/5,663) of the marked coho smolts. This catch rate assumes that all the marked fish released from the weir survived and migrated past the trap during the trapping season. Because the trap was not fished continuously, this rate is not an estimate of instantaneous trap efficiency, but is based on the proportion of the Matriotti smolts captured.

3.2.2.4 Production Estimate

The smolts marked and released from the Matriotti Creek weir provided the basis for our smolt production estimate. A total of 43,888 natural-origin smolts were estimated to have migrated past the trap using the pooled Peterson Estimator (Chapman 1951) (3.4 Appendix C 3), with a coefficient of variation of 7.01% and a 95% confidence interval of 37,860 to 49,916 (Figure 3 - 7, Table 3 - 5).

Table 3 - 5. Estimation of natural-origin coho smolt production, Dungeness River 2006.

	Number	Formula
Total screw trap catches	1,964	
NOR pre-smolts	-270	
Unsampled catch	-370	
Wild coho captured (M_i)	**1,324**	
Marks recaptured (m_i)	170	$N = \frac{(n+1)(M+1)}{(m+1)} - 1$
Marks released (n)	5,663	
Total production (N)	**43,888**	
Variance (Var)	9.46E+06	$Var = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2(r+2)}$
Standard Deviation (sd)	3,076	
Coefficient of Var (CV)	7.01%	CV = sd/N
Confidence Interval (CI) +/-	6,028	CI = +/- 1.96(sd)
Estimated coho production		
Dungeness River	43,888	
Upper CI (95%)	49,916	
Lower CI (95%)	37,860	

Notes: Total mainstem catch includes Matriotti Creek smolts (170 total recaptured).
Pre-smolts and smolts not mark-sampled for the UC-mark were not included.

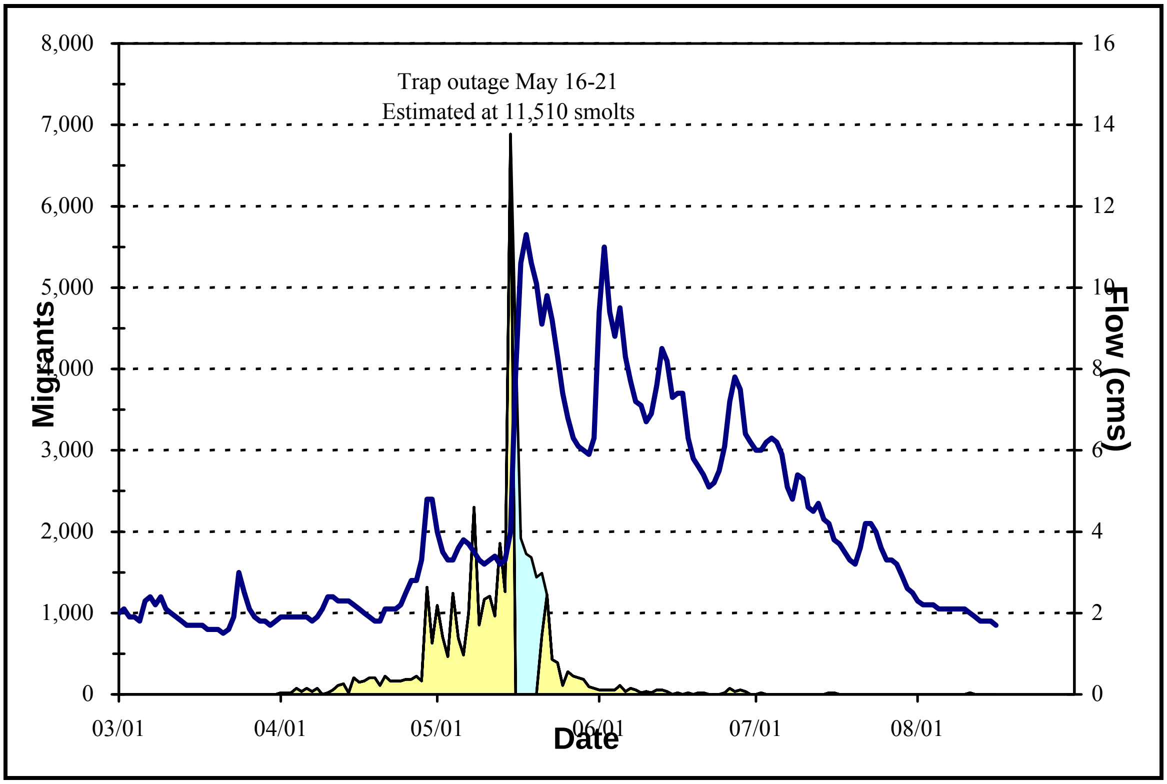

Figure 3 - 7. Estimated daily coho smolt migration past the screw trap, based on proportion of catch, Dungeness River 2006.

3.2.3 Steelhead

3.2.3.1 Catch

The first natural-origin steelhead smolt was captured on February 5. Catches varied between 0 and 5 steelhead smolts until the night of April 25, when 11 smolts were captured. Catches peaked on the nights of April 29 and May 15, at 30 and 57 smolts respectively. Daily catches remained steady through late-May before dropping off. The last natural-origin steelhead smolt was captured on the night of July 11. Over the season, a total of 425 natural-origin steelhead smolts (339 unmarked, 29 UC-marked, and 57 undetermined) were captured (3.4 Appendix C 2). As with the coho, virtually all the natural-origin steelhead captured in the Matriotti Creek Weir Trap were marked and released.

A total of 38 ad-marked hatchery steelhead smolts were captured. Four ad-marked hatchery smolts were captured prior to the reported release of 10,500 hatchery smolts from the Dungeness Hatchery on June 1; these may have been either escapees or holdovers from the previous year's release. The June 1 release date was a full month later than in previous years in an attempt to expedite their downstream migration and reduce negative interactions between NORs and HORs. The hatchery smolt outmigration occurred over a two-week period following release; the last was captured on June 13, with 66% captured by June 6. As with other species, the actual steelhead hatchery release is probably far fewer than reported due to heavy predation by otters (Scott Williams, pers comm.).

3.2.3.2 Size

Over the season, a total of 49 unmarked steelhead smolts were measured (fork length). Sizes ranged from 130-mm to 290-mm, and averaged 175.2-mm (Figure 3 - 8). We also measured 11 steelhead parr, which ranged in size from 73-mm to 115-mm, and averaged 89.7-mm over the season.

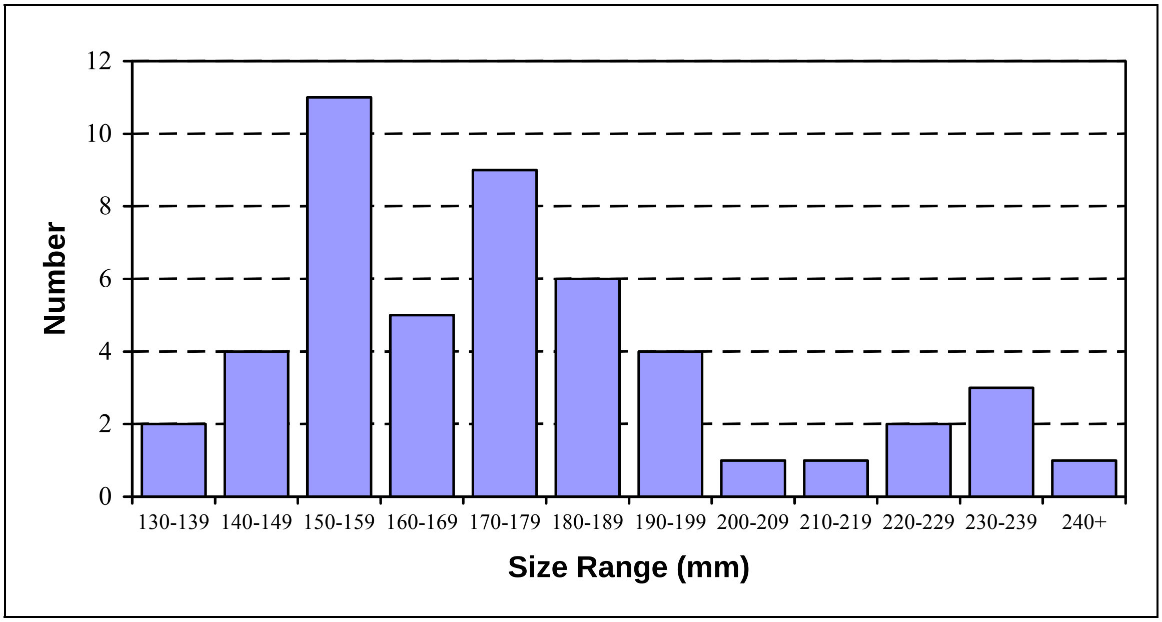

Figure 3 - 8. Length frequency of unmarked steelhead smolt fork lengths (mm) measured at the Dungeness River screw trap, 2006.

3.2.3.3 Trap Efficiency

In total, the Jamestown S'Klallam tribe marked and released 497 natural-origin steelhead smolts from their weir trap on Matriotti Creek. Over the season, 29 marked Matriotti smolts were captured in the screw trap. This catch rate assumes that all the marked fish released from the weir survived to migrate past the trap. Because the trap was not fished continuously, as with the coho, this rate is not an estimate of instantaneous trap efficiency. Instead, it is the proportion of the smolts captured.

3.2.3.4 Production Estimate

The UC-marked smolts released from the Matriotti Creek trap provided the basis for our steelhead smolt production estimate. While the total season catch of natural-origin steelhead was 425 smolts, 57 of these, captured on May 15, were not sampled for the UC-mark. We therefore excluded these smolts from the production estimate. Production was estimated from the 29 marked steelhead smolts found in the 368 smolts sampled. Relating this rate to the 497 smolts marked and released from the Matriotti Creek trap yields an estimated production of 6,125 smolts with a coefficient of variation of 16.96% and a 95% confidence interval of 4,089 to 8,162 (Table 3 - 6, Figure 3 - 9, 3.4 Appendix C 3).

Table 3 - 6. Estimation of natural-origin steelhead smolt production, Dungeness River 2006.

	Number	Formula
Total screw trap catches	425	
Unsampled catch	-57	
NOR steelhead captured (M_i)	**368**	
Marks recaptured (m_i)	29	$N = \frac{(n+1)(M+1)}{(m+1)} - 1$
Marks released (n)	497	
Total production (N)	**6,125**	
Variance (Var)	1.04E+06	$Var = \frac{(m+1)(c+1)(m-r)(c-r)}{(r+1)^2(r+2)}$
Standard Deviation (sd)	1,022	
Coefficient of Var (CV)	16.69%	CV = sd/N
Confidence Interval (CI) +/-	2,004	CI = +/- 1.96(sd)
Estimated steelhead production		
Dungeness River	6,125	
Upper CI (95%)	8,129	
Lower CI (95%)	4,122	

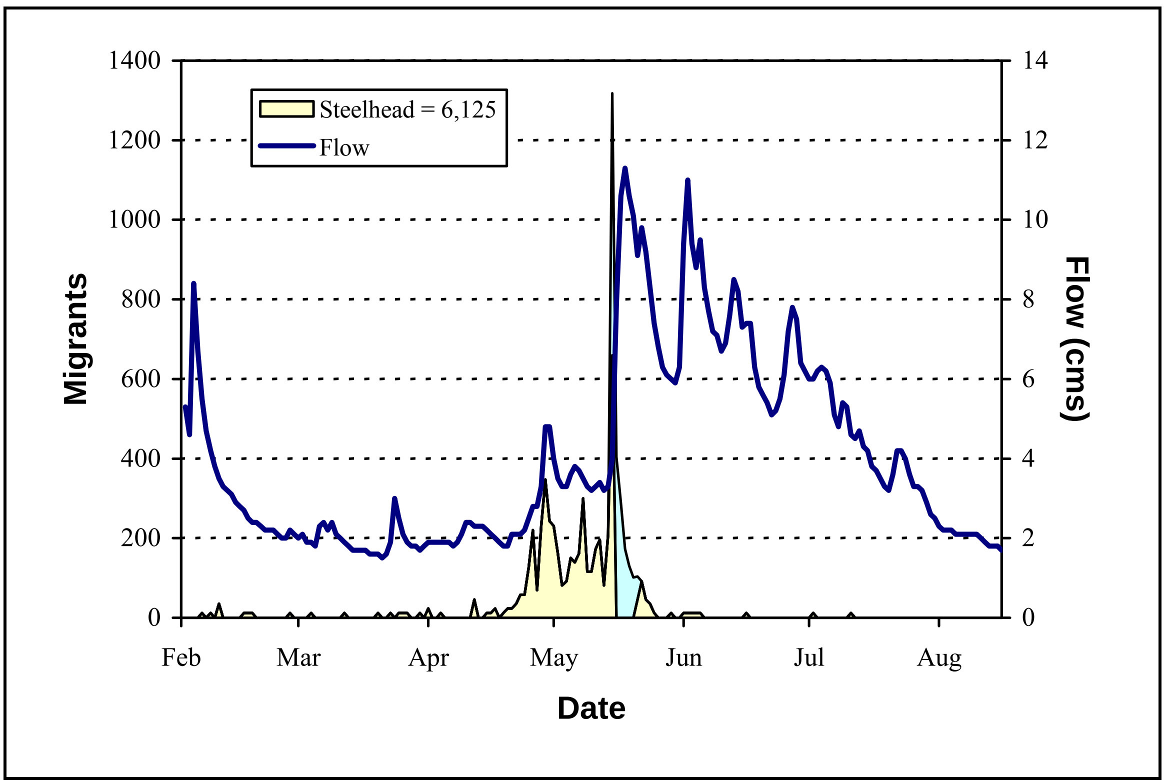

Figure 3 - 9. Daily migration of natural-origin steelhead smolts in the Dungeness River screw trap relative to stream discharge measured at USGS Gage #12048000, 2006.

3.2.4 Chum

3.2.4.1 Catch

A total of 28,457 chum fry were captured over the season. The chum migration was under way when trapping began, as indicated by a first-day catch of 31 fry. Daily catches averaged 25 chum/day for the first week, then quickly declined and remained low through the remainder of February. Catches increased steadily thereafter and peaked on April 10, at 2,573 fry. By early May, catches had declined to just a few fish per day. The last chum was captured on May 22 (3.4 Appendix C 2).

3.2.4.2 Size

Over the season, a total of 458 chum fry were measured (fork length), 1.61% of the total catch. Weekly mean sizes showed little variation until early April, when larger individuals began to enter the catch. Sizes ranged from 33-mm to 64-mm, and averaged 40.1-mm for the season (Table 3 - 7).

Table 3 - 7. Mean fork lengths (mm), standard deviations, ranges, and sample sizes, of unmarked natural-origin chum fry, measured by statistical week, Dungeness River, 2006.

Statistical Week			Average	s.d.	Range		Total	
Number	Begin	End			Min	Max	Sampled	Catch
6	02/02/06	02/05/06					0	113
7	02/06/06	02/12/06	37.4	1.86	33	39	11	81
8	02/13/06	02/19/06					0	3
9	02/20/06	02/26/06	39.3	1.53	38	41	3	9
10	02/27/06	03/05/06	37.8	1.20	36	40	9	149
11	03/06/06	03/12/06	39.9	1.58	37	43	30	109
12	03/13/06	03/19/06	39.1	2.66	33	50	85	1,687
13	03/20/06	03/26/06	39.2	3.44	33	49	64	3,273
14	03/27/06	04/02/06	37.8	1.28	34	41	81	6,572
15	04/03/06	04/09/06	43.7	8.14	38	53	3	1,197
16	04/10/06	04/16/06	40.1	2.46	34	50	124	9,100
17	04/17/06	04/23/06					0	3,911
18	04/24/06	04/30/06	43.3	2.70	38	48	19	2,081
19	05/01/06	05/07/06	50.9	3.14	44	56	20	118
20	05/08/06	05/14/06	52.9	6.58	43	64	9	40
21-34	05/15/07	08/15/07					0	14
Season Total			**40.1**	**4.15**	**33**	**64**	**458**	**28,457**

3.2.4.3 Catch Expansion

Over the season, trap operations were suspended for a total of 516.8 hours (see **Chapter 3.2.1.3**). During this period, we estimated an additional 4,285 chum fry would have been captured when the trap was not fishing, for a total estimated season catch of 32,742 fry (3.4 Appendix C 3). The estimated catch represents an increase of 13.1% over the actual catches.

3.2.4.4 Trap Efficiency

A total of 12 trap efficiency tests, using 1,052 chum out-migrants were conducted from mid-March to early May. Fry were marked with Bismarck-Brown dye, and released approximately 150-meters upstream of the trap. Calibration groups ranged from 4 to 145 fry. The proportion that was recovered in each group ranged from 0.0% to 26.5% and averaged 14.5%.

3.2.4.5 Production Estimate

The same stratified mark-recapture approach for estimating Chinook production was used for chum. The 12 test-releases were combined into ten strata (Table 3 - 8), with similar stream flow and catch rates. Pooling resulted in a few mark recoveries in all strata, increasing confidence in the resulting estimate. All calibration tests were conducted when the trap operated in the west bank position. Catches that occurred while the trap operated in other positions were few and efficiency estimates were not made. During the trapping period (February 2 through August 17), an estimated 194,721 chum fry migrated past the screw trap (3.4 Appendix C 3), with a coefficient of variation of 8.21% and 95% confidence intervals of 163,367 to 226,066 fry. No estimate for migration for before or after the trapping period was made.

Table 3 - 8. Trap efficiency strata for chum, Dungeness River screw trap, 2006

Eff	# Tests	Dates		Efficiency Test Data			Catch Data		
Strata	Pooled	Rel/Recap	Applied	Released	Recap	% Rcv'd	Est Catch	Migration	Var
1	1	3/15	2/2-3/15	37	3	8.11%	892	8,483	1.29E+07
2	1	3/16	3/16-3/18	145	10	6.90%	969	12,874	1.29E+07
3	1	3/21	3/19-3/21	116	11	9.48%	792	7,731	4.18E+06
4	1	3/22	3/22-3/26	108	17	15.74%	2,774	16,803	1.25E+07
5	1	3/31	3/27-4/6	98	18	18.37%	8,396	43,752	7.75E+07
6	1	4/14	4/7-4/15	137	28	20.44%	11,745	55,894	8.24E+07
7	1	4/16	4/16-4/19	144	15	10.42%	3,327	30,159	4.78E+07
8	1	4/23	4/20-4/24	98	26	26.53%	2,177	7,985	1.68E+06
9	1	4/25	4/25-4/28	140	20	14.29%	1,415	9,506	3.54E+06
10	3	5/2-5/11	4/29-8/16	29	4	13.79%	255	1,535	3.32E+05
Total	12			1,052	152	14.45%	32,742	194,721	2.56E+08

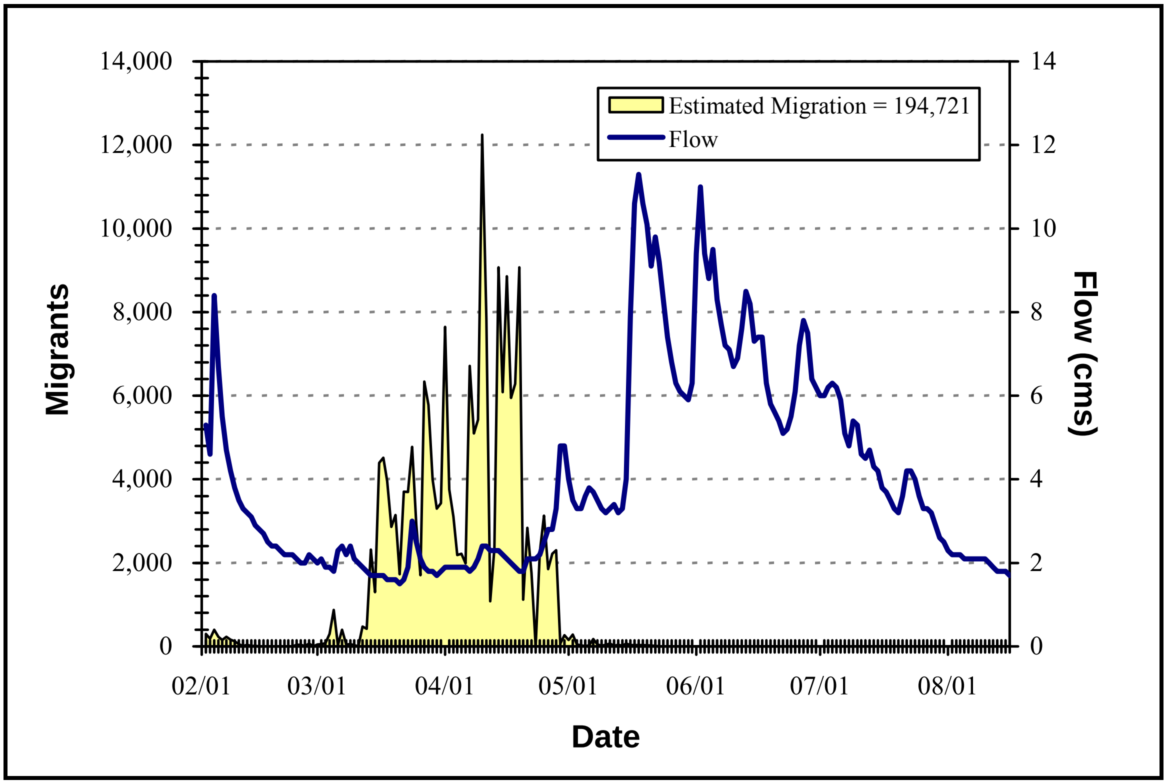

Figure 3 - 10. Estimated daily migration of chum fry past the Dungeness River screw trap, 2006.

3.2.5 Pink Salmon

3.2.5.1 Catch

Over the season 92,489 pink fry were captured. The pink migration was just starting when trapping began, as indicated by a first-day catch of 2 fry. Daily catches averaged 6 fish/day for the first week, then quickly declined to near zero, and remained low through the remainder of February. Thereafter, catches increased steadily and peaked in mid-April, with 5,952 fry captured on April 14. Between March 23 and this date, daily catches averaged close to 4,000 fry, and exceeded 5,000 fry on five separate days. Catches quickly declined to just 1 fish per day in early May. The last pink fry was captured on May 12 (3.4 Appendix C 2).

3.2.5.2 Size

Over the season, a total of 57 unmarked pink fry were measured (fork length), 0.06% of the total catch. Length samples were taken periodically over the entire migration. Sizes ranged from 32.0-mm to 43.0-mm, and averaged 34.0-mm (Figure 3 - 11). Because individuals showed little or no sign of growth over the trapping period, this likely indicates that the fry were migrating directly upon emergence from the gravel. The last pink fry measured on April 30, was 43-mm, much larger than the next largest individual (38-mm) measured on March 21.

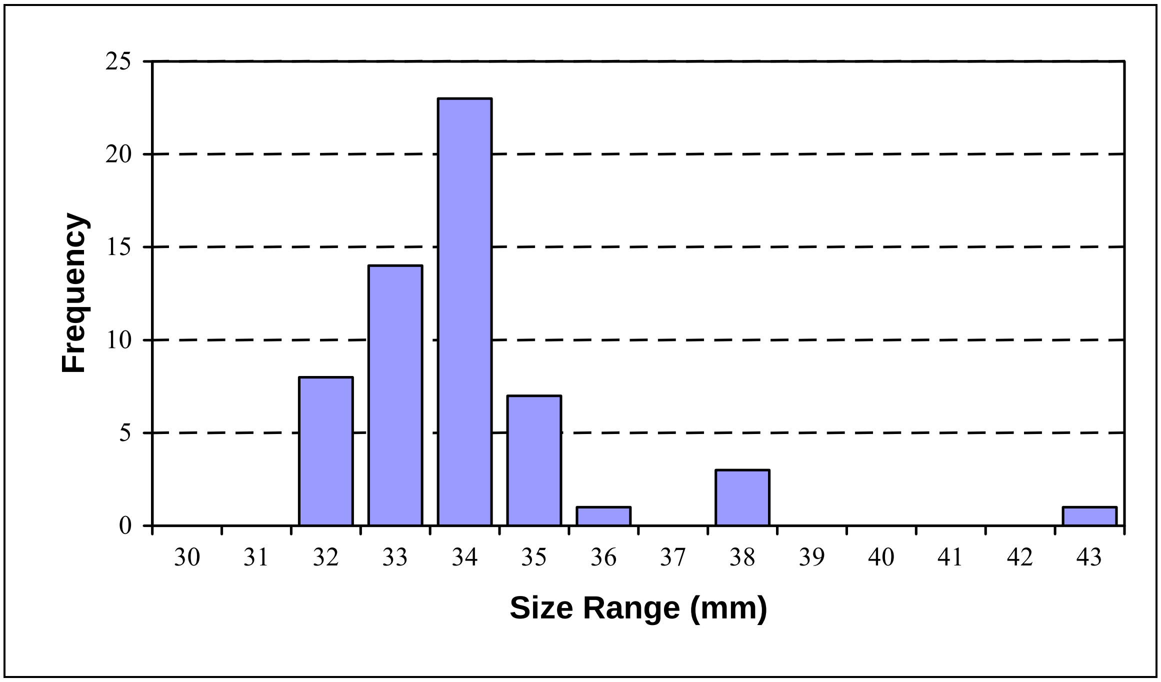

Figure 3 - 11. Pink fry measured at the Dungeness River screw trap, 2006.

3.2.5.3 Catch Expansion

Over the season, trap operations were suspended for a total of 516.8 hours (see **Chapter 3.2.1.3**). During this period, we estimated an additional 19,004 pink fry would have been captured when the trap was not fishing, for a total estimated season catch of 111,493 pink fry (3.4 Appendix C 3). The estimated catch represents an increase of 17% over the actual catches.

3.2.5.4 Trap Efficiency

A total of five trap efficiency groups, using 453 pink fry, were conducted over trapping season. Fry were marked with Bismarck-Brown dye, and released approximately 150-meters upstream of the trap. Individual release groups ranged from 8 to 213 fry. The proportion that was recovered in each stratum ranged from 8.6% to 25.0% and averaged 13% (Table 3 - 9).

3.2.5.5 Production Estimate

The same stratified mark-recapture approach for estimating Chinook production as was used for pinks. The five test-releases were combined into four strata (Table 3 - 9) to provide for adequate recoveries when flow condition and trap rates were similar. All tests and catches occurred while the trap was operated in the west bank position. During the trapping period (February 2 through August 17), an estimated 696,642 pink fry migrated past the screw trap (Figure 3 - 12, 3.4 Appendix C 3), with a coefficient of variation of 17.03% and 95% confidence intervals of 464,151 to 929,132 fry. No estimate for migration for before or after the trapping period was made.

Table 3 - 9. Trap efficiency strata for pink fry, Dungeness River screw trap, 2006.

Eff	# Tests	Dates		Efficiency Test Data			Catch Data		
Strata	Pooled	Rel/Recap	Applied	Released	Recap	% Rcv'd	Est Catch	Migration	Var
1	1	3/22	2/2-4/2	213	32	15.02%	46,759	303,231	2.29E+09
2	2	4/14-4/16	4/3-4/19	40	6	15.00%	57,220	335,151	1.16E+10
3	1	4/23	4/20-4/24	83	11	13.25%	5,999	41,999	1.17E+08
4	1	4/25	4/25-8/16	117	10	8.55%	1,515	16,262	2.01E+07
Season Total				453	59	13.02%	111,493	696,642	1.41E+10

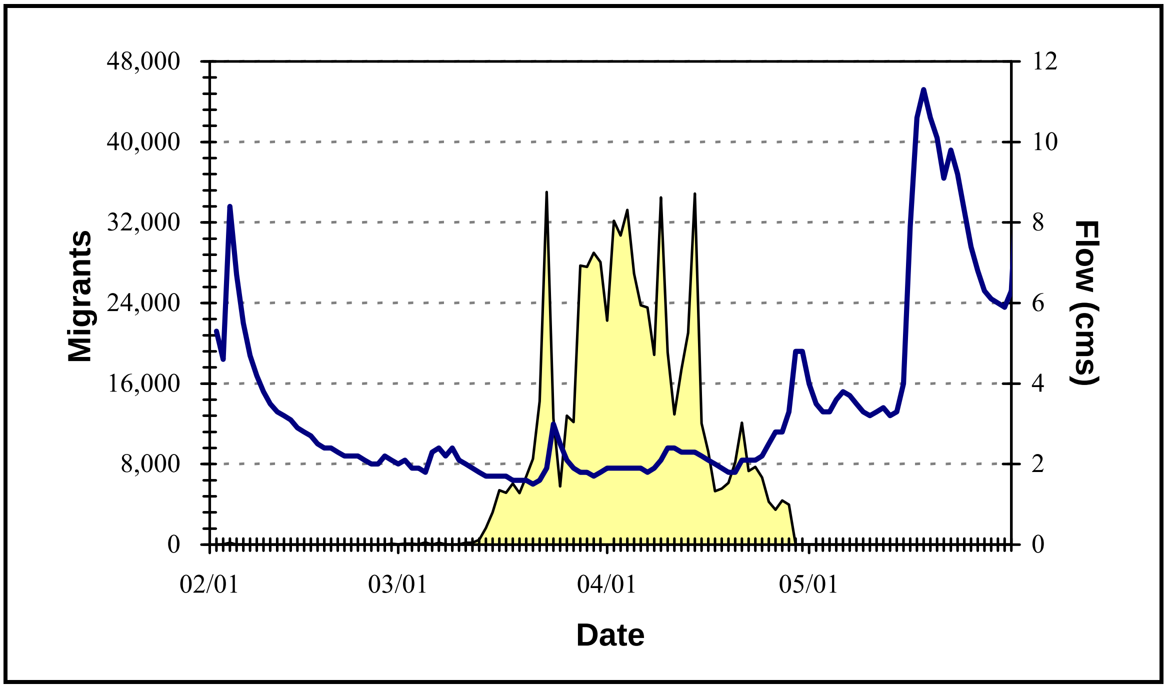

Figure 3 - 12. Estimated daily migration of pink salmon at the Dungeness River screw trap, 2006.

3.2.6 Other Species

A number of other fish species and other salmonid age classes were also captured and enumerated over the trapping period. A total of 7 coho fry, 12 cutthroat smolts, 1 steelhead adult, 11 Bull trout (10 smolt, and 1 adult, 3.4 Appendix C 2), and 55 unidentified trout fry were captured. We also captured 1,164 trout parr, of which 402 and 7 were positively identified as rainbow and cutthroat parr, respectively. Other species captured included unidentified species of sculpin (*Cottus spp*), three-spine sticklebacks (*Gasterosteus aculeatus*), lamprey ammocoetes (*Lampetra spp*), long-nose dace (*Rhinichthys cataractae*), starry flounders (*Platichthys stellatus*), and yellow perch (*Perca flavescens*)

3.3 Discussion

We developed estimates of migration past the trap for Dungeness River natural-origin Chinook 0+, coho smolts, steelhead smolts, chum, and pink fry. The assumptions used to develop these estimates follow.

3.3.1 Chinook

3.3.1.1 Natural-Origin Chinook

The accuracy of the natural-origin Chinook 0+ production estimate for the Dungeness River is partially dependent on the accuracy of the estimated catch during the periods trap operations were suspended. The trap was operated throughout the majority of the Chinook migration. Over the entired trapping season, we estimated a missed catch of 415 Chinook fry, an increase of only 6% over the actual catch.

The trap was installed and began fishing on February 2, before the Chinook migration had started. The trap was installed a month earlier than in 2005 in order to establish the true migration start date. This task was accomplished, as indicated by the fact that the first Chinook was not captured until six days after trapping began.

The accuracy of the production estimates also depends on the veracity of our estimated capture efficiency. We conducted 85 trap efficiency tests over the entire migration, using Chinook captured in our trap. During periods of low migration the numbers of fish in each efficiency test were quite small. We therefore created 29 strata by combining contiguous test groups. These strata were adjusted as necessary to ensure they reflected similar flow conditions, trap position and catch rates. Stratification was necessary to avoid errors associated with small sample sizes.

At the beginning of the season (February 2-15), the trap fished in the East Bank position. Catches during this period were so low no efficiency tests were possible. In order to estimate migration for this period, we applied the Strata 1 efficiency (3%). This rate is among the lowest of the efficiencies observed in the West Bank position, and, we believe, reasonably reflects capture rates for this period.

Egg-to-migrant survival is a measure of freshwater productivity for naturally-reared salmon. The estimated migration of 124,928 natural-origin Chinook 0+ divided by the estimated deposition of 1,983,344 eggs results in a survival rate of 6.3%. The estimated egg deposition was derived using a female escapement estimate (redd count) of 382 Chinook females made in 2005 (Randy Cooper, pers. comm.) and an average fecundity of 5,192 eggs/female (the average fecundity of the females collected from the Dungeness River for the Captive Brood Chinook Enhancement Project). The 6.3% survival rate estimated for the Dungeness Chinook is higher than the 3.6% survival we estimated for the 2004 brood. By comparison, over seven years of trapping at the Green River, we have observed only one egg-to-migrant survival rate that was higher (7.3% in 2000).

The natural-origin Chinook 0+ migration from the Dungeness River exhibited a bi-modal timing distribution. The earliest component, composed of newly-emerged Chinook fry, migrated past the trap from early February through mid April, and peaked on March 24. This was followed by the parr component, which migrated from mid April through early August, and peaked on June 27. Both the fry and parr migration peaks were later than those observed in 2005. We believe that this is more typical timing, as flows over the 2006 season were higher (the snow-pack was greater), which kept in-stream temperatures lower, thus slowing Chinook incubation and growth. In 2006, the fry component made up 60% of the total production, compared to a parr component of 40%. Proportions of fry and parr out-migrants are influenced by escapement levels (density effects), the magnitude of high flow events during incubation early in the season (when the smaller fry are susceptible to being washed downstream), and the availability of flow refugia (unpublished WDFW data). Flows were higher in 2006 (closer to normal) than in 2005, which increased the percentage of fish that migrated as newly-emerged fry.

3.3.1.2 Hatchery Chinook

During Summer 1996 and 1997, WDFW operated a screw trap on the Dungeness River to evaluate the migration survival rate of the released progeny of native captive brood spawners (Marlowe et al. 2001). The survival rates for the combined releases for those years (12.27% and 21.66% in 1996 and 1997, respectively) were significantly lower than the 40% survival estimated in 2006 (Table 3 - 10). The increased survival of the hatchery migrants was likely due in part of the higher river flows at the time of release; this would expedite the migration timing as well as provide more habitat and also increased cover to avoid predators.

Table 3 - 10. Estimated survival from the release site to the trap for hatchery Chinook 0+, Dungeness River, 1996, 1997 and 2006.

Year	Hatchery Group	Number Released	Estimated Migration	Estimated Survival	CV	95% $CI_{survival}$ Low	95% $CI_{survival}$ High
1996	Admk	4,018	1,267	31.54%	6.27%	37.66%	35.42%
	AdRV	1,115	203	18.21%	6.27%	15.97%	20.45%
	AdLV	7,880	127	1.61%	6.27%	1.41%	1.61%
	Total	**13,013**	**1,597**	**12.27%**	**5.07%**	**11.05%**	**13.49%**
1997	Admk	590,050	136,347	23.11%	3.46%	21.54%	24.68%
	AdCWT	415,452	87,768	21.13%	4.21%	19.39%	22.87%
	Blank wire	769,034	160,260	20.84%	3.08%	19.58%	22.10%
	Total	**1,774,536**	**384,375**	**21.66%**	**2.02%**	**20.80%**	**22.52%**
2006	**CWT only**	**108,500**	**41,297**	**38.06%**	**23.00%**		

3.3.2 Coho

The natural-origin coho production estimate was greatly simplified by the release of marked fish from the Matriotti Creek trap. The Matriotti trap remained fish tight and released marked coho over the entire migration in proportion to their migration timing. This eliminated the need to expand the screw trap catches for periods when trap operations were suspended. This was especially helpful during the 128-hour period the trap did not fish May 16-21, because of high flows, which coincides with the peak natural-origin smolt migration. With a coefficient of variation of only 7.03%, we feel confident that our estimated production of 44,000 coho accurately reflects the natural-origin smolt production in 2006. This is a conservative estimate, which only reflects the production migrating after April 1. Early in the trapping season, we captured 270 yearlings (205 fish in February, 65 fish in March), which were dark in appearance. These were deemed pre-smolts, and may not have been actively migrating, but just residing around the trap location and subject to multiple recaptures. If these coho were actually migrating, then our estimate is somewhat low.

3.3.3 Steelhead

In order to satisfy recommendations made after the 2005 trapping season, efforts were made to directly assess the natural-origin steelhead production migrating from the Dungeness River. The weir trap on Matriotti Creek, operated by the Jamestown S'Klallam Tribe caudal fin-marked the natural-origin steelhead smolts in addition to the coho smolts they had marked in 2005 and 2006. Application of the pooled Peterson population estimate (Chapman 1951) yielded a production of 6,125 natural-origin steelhead smolts.

3.3.4 Recommendations

Increase the accuracy of the production estimates made for the species that are captured, marked and released above the trap (Chinook, chum and pinks).

This will be accomplished in several ways. In 2006 the trap location was changed several times in response to river flow and catch rates. This complicated the analysis and ultimately decreased the quality of the estimates made. In 2007, we will attempt to operate the trap in the same location throughout the entire trapping season.

Efforts will be made to reduce the number of periods of suspended trapping due to high flow events and hatchery releases.

Increase the number of trap calibration test groups released for chum and (in even-numbered years) pinks.

Make an effort to evaluate size selectivity of the trap by measuring all fish recaptured from Matriotti Creek releases, and comparing them to the size at release from Matriotti.

3.4 Appendix C

Appendix C 1. Daily actual and estimated catches and migration for Chinook 0+ migrants, Dungeness River 2006.

Date	NOR Chinook				HOR Chinook			
	Catch			Migration	Catch			Migration
	Actual	Estimated	Total		Actual	Estimated	Total	
02/02/06								
02/03/06								
02/04/06								
02/05/06								
02/06/06								
02/07/06								
02/08/06	1		1	28				
02/09/06	3		3	83				
02/10/06	2		2	55				
02/11/06	5		5	138				
02/12/06								
02/13/06	1		1	28				
02/14/06	4		4	110				
02/15/06	6		6	165				
02/16/06	1		1	28				
02/17/06								
02/18/06	1		1	28				
02/19/06								
02/20/06	2		2	55				
02/21/06								
02/22/06	2		2	55				
02/23/06	3		3	83				
02/24/06	4		4	110				
02/25/06	4		4	110				
02/26/06	9		9	248				
02/27/06	9		9	248				
02/28/06	14		14	386	28		28	
03/01/06	14		14	386	6		6	
03/02/06	32		32	881				
03/03/06	61		61	1,680	1		1	
03/04/06	20		20	551				
03/05/06	48		48	1,322				
03/06/06	5		5	138				
03/07/06	63		63	1,735				
03/08/06	21		21	578				
03/09/06	56		56	1,542				
03/10/06	36		36	991				
03/11/06	105		105	2,891				
03/12/06	38		38	1,046				
03/13/06	29		29	799				
03/14/06	56		56	1,542				
03/15/06	47		47	1,294				
03/16/06	243		243	3,486				
03/17/06	193		193	2,769				
03/18/06	246		246	3,529				
03/19/06	188		188	2,697				
03/20/06	62		62	889				

Table continued next page

Appendix C1. Daily actual and estimated catches and migration for Chinook 0+ migrants, Dungeness River 2006. (cont'd).

Date	NOR Chinook				HOR Chinook			
	Catch			Migration	Catch			Migration
	Actual	Estimated	Total		Actual	Estimated	Total	
03/21/06	92		92	1,320				
03/22/06	278		278	2,196				
03/23/06	440		440	3,475				
03/24/06	232		232	8,560				
03/25/06	105		105	3,874				
03/26/06	106		106	3,911				
03/27/06	82		82	3,025				
03/28/06	47		47	1,734				
03/29/06	63		63	1,288				
03/30/06	48		48	981				
03/31/06	83		83	1,696				
04/01/06	114		114	2,330				
04/02/06	57		57	1,165				
04/03/06	45		45	920				
04/04/06	39		39	797				
04/05/06	2	33	35	715				
04/06/06		30	30	613				
04/07/06		17	17	347				
04/08/06	1	13	14	91				
04/09/06	1	2	3	20				
04/10/06	4		4	26				
04/11/06								
04/12/06	5		5	33				
04/13/06	7		7	46				
04/14/06	28		28	182				
04/15/06	13		13	85				
04/16/06	10		10	65				
04/17/06	3		3	20				
04/18/06	7		7	46				
04/19/06	7		7	46				
04/20/06	1		1	7				
04/21/06	18		18	117				
04/22/06	8		8	52				
04/23/06	9		9	59				
04/24/06	8		8	52				
04/25/06	15		15	98				
04/26/06	22		22	143				
04/27/06	11		11	72				
04/28/06	4		4	26				
04/29/06	15		15	98				
04/30/06	38		38	248				

Table continued next page

Appendix C1. Daily actual and estimated catches and migration for Chinook 0+ migrants, Dungeness River 2006 (cont'd).

Date	NOR Chinook				HOR Chinook			
	Catch			Migration	Catch			Migration
	Actual	Estimated	Total		Actual	Estimated	Total	
05/01/06	20		20	130				
05/02/06	33		33	215				
05/03/06	23		23	150				
05/04/06	7		7	46				
05/05/06	11		11	72				
05/06/06	4		4	26				
05/07/06	14		14	91				
05/08/06	12		12	78				
05/09/06	10		10	34				
05/10/06	13		13	44				
05/11/06	12		12	41				
05/12/06	7		7	24				
05/13/06	7		7	24				
05/14/06	2		2	7				
05/15/06	32		32	108				
05/16/06		16	16	54				
05/17/06		16	16	54				
05/18/06		16	16	54				
05/19/06		16	16	54				
05/20/06		16	16	54				
05/21/06	13	3	16	137				
05/22/06	18		18	154				
05/23/06	12		12	103				
05/24/06	13		13	111				
05/25/06	23		23	197				
05/26/06	33		33	283				
05/27/06	8	25	33	642				
05/28/06		33	33	642				
05/29/06	39		39	759				
05/30/06	23		23	448				
05/31/06	32		32	623				
06/01/06		36	36	701				
06/02/06		36	36	701				
06/03/06		36	36	701				
06/04/06	50	4	54	1,051	10		10	154
06/05/06	33		33	642	95		95	1,463
06/06/06	25		25	487	106		106	1,632
06/07/06	24		24	130	59		59	909
06/08/06	33	2	35	190	55	4	59	909
06/09/06	21		21	441	55		55	847
06/10/06	20		20	420	13		13	200
06/11/06	17		17	357	8		8	123
06/12/06	22		22	462	18		18	100
06/13/06	22		22	462	7		7	39
06/14/06	23		23	483	11		11	233
06/15/06	24		24	504	11		11	233

Table continued next page

Appendix C1. Daily actual and estimated catches and migration for Chinook 0+ migrants, Dungeness River 2006 (cont'd).

Date	NOR Chinook				HOR Chinook			
	Catch			Migration	Catch			Migration
	Actual	Estimated	Total		Actual	Estimated	Total	
06/16/06	19		19	399	8		8	169
06/17/06	35	2	37	776	16		16	339
06/18/06	36		36	755	11		11	233
06/19/06	17		17	131	6		6	127
06/20/06	25		25	1,712	2		2	42
06/21/06	21		21	1,438	9		9	191
06/22/06	14		14	959	5		5	42
06/23/06	10		10	685	1		1	8
06/24/06	20		20	1,370	62		62	4,169
06/25/06	26		26	1,781	73		73	4,909
06/26/06	30		30	2,055	52		52	3,497
06/27/06	32		32	2,192	41		41	2,757
06/28/06	25		25	1,712	56		56	3,766
06/29/06	27		27	1,849	29		29	1,950
06/30/06	24	1	25	1,712	41		41	2,757
07/01/06	21		21	1,438	25		25	1,681
07/02/06	21		21	1,438	6		6	403
07/03/06	12		12	822	14		14	941
07/04/06	7		7	479	9		9	605
07/05/06	11		11	753	7		7	471
07/06/06	15		15	1,027	2		2	134
07/07/06	8		8	548	2		2	134
07/08/06	6		6	411				
07/09/06	3		3	205				
07/10/06	68		68	465	40		40	2,690
07/11/06	112		112	767	14		14	41
07/12/06	101		101	649	25		25	207
07/13/06	84		84	375	33		33	216
07/14/06	110		110	529	33		33	149
07/15/06	86		86	305	24		24	118
07/16/06	44		44	242	25		25	90
07/17/06	67		67	339	22		22	123
07/18/06	65		65	451	29		29	149
07/19/06	81		81	481	17		17	122
07/20/06	50		50	383	14		14	87
07/21/06	52		52	506	20		20	157
07/22/06	57		57	554	19		19	188
07/23/06	33		33	200	13		13	129
07/24/06	22		22	161	6		6	40
07/25/06	51		51	373	4		4	31
07/26/06	52		52	412	7		7	55
07/27/06	77		77	610	1		1	8
07/28/06	49		49	388	3		3	25
07/29/06	87		87	690	6		6	50
07/30/06	66		66	414	5		5	42
07/31/06	37		37	334	4		4	30

Table continued next page

Appendix C1. Daily actual and estimated catches and migration for Chinook 0+ migrants, Dungeness River 2006 (cont'd).

Date	NOR Chinook				HOR Chinook			
	Catch			Migration	Catch			Migration
	Actual	Estimated	Total		Actual	Estimated	Total	
08/01/06	31		31	280	4		4	34
08/02/06	28		28	253	3		3	25
08/03/06	28		28	253	6		6	51
08/04/06	24	1	25	226	1		1	8
08/05/06		17	17	153		7	7	59
08/06/06		16	16	144		7	7	59
08/07/06					17		17	144
08/08/06	6		6	54				
08/09/06	8		8	72				
08/10/06	21		21	190				
08/11/06	16		16	144				
08/12/06		14	14	126				
08/13/06		14	14	126				
08/14/06	9		9	81				
08/15/06	7		7	63				
08/16/06	2		2	18				
Total	**6,533**	**415**	**6,948**	**124,928**	**1,355**	**18**	**1,373**	**41,297**

Appendix C 2. Daily catches of Dungeness River coho and steelhead, and expanded catches of chum, pink, cutthroat, and bull trout/Dolly Varden, 2006.

Date	Times		COHO Smolts	Steelhead Smolts	Chum Fry	Pink Fry	CUTT Smolt	Bull/Dolly	
	In	Out	NOR	NOR	NOR	NOR	NOR	Smolt NOR	Adult NOR
02/02/06	20.75	0.00	8	0	31	2	0		
02/03/06	19.92	0.92	15	0	19	5	0	0	0
02/04/06	25.57	1.37	16	0	42	28	0	0	0
02/05/06	23.82	0.00	31	0	24	1	0		
02/06/06	24.17	0.00	22	1	16	3	0		
02/07/06	24.50	0.00	17	0	24	1	0		
02/08/06	24.00	0.00	8	1	17	2	0		
02/09/06	23.50	0.00	2	0	13	0	0		
02/10/06	23.47	0.00	6	3	6	0	0		
02/11/06	23.80	0.00	5	0	1	0	0		
02/12/06	25.07	0.00	2	0	4	0	0		
02/13/06	23.67	0.00	3	0	1	1	0		
02/14/06	24.25	0.00	3	0	2	0	0		
02/15/06	22.75	0.00	6	0	0	0	0		
02/16/06	24.77	0.00	3	1	0	0	0		
02/17/06	23.50	0.00	4	1	0	0	0		
02/18/06	23.07	0.00	13	1	0	0	0		
02/19/06	24.83	0.00	5	0	0	0	0		1
02/20/06	25.00	0.00	4	0	0	0	0		
02/21/06	24.00	0.00	14	0	0	0	0		
02/22/06	23.83	0.00	5	0	0	0	0		
02/23/06	24.00	0.00	6	0	0	0	0		
02/24/06	20.00	1.13	2	0	4	0	0	0	0
02/25/06	25.75	0.00	1	0	4	0	0		
02/26/06	23.78	0.00	4	0	1	1	0		
02/27/06	25.00	0.00	0	1	7	1	0		
02/28/06	24.33	0.00	0	0	0	16	0		
03/01/06	24.00	0.00	8	0	5	6	0		
03/02/06	23.75	0.00	3	0	6	13	0		
03/03/06	24.25	0.00	2	0	8	15	0		
03/04/06	22.92	0.00	2	1	31	5	0		
03/05/06	24.08	0.00	3	0	92	35	0		
03/06/06	23.83	0.00	3	0	3	2	0		
03/07/06	24.08	0.00	2	0	42	31	0		
03/08/06	25.08	0.00	4	0	5	5	0		
03/09/06	23.25	0.00	1	0	6	2	0		
03/10/06	24.75	0.00	0	0	3	4	0		
03/11/06	24.00	0.00	0	0	0	31	0		
03/12/06	22.83	0.00	2	1	50	28	0		
03/13/06	23.50	0.00	0	0	44	72	0		
03/14/06	24.60	0.00	0	0	244	257	0		
03/15/06	25.32	0.00	0	0	137	494	0		

Table continued next page

Appendix C2. Daily catches of Dungeness River coho and steelhead, and expanded catches of chum, pink, cutthroat, and bull trout/Dolly Varden, 2006. (cont'd).

Date	Times In	Times Out	COHO Smolts NOR	Steelhead Smolts NOR	Chum Fry NOR	Pink Fry NOR	CUTT Smolt NOR	Bull/Dolly Smolt NOR	Bull/Dolly Adult NOR
03/16/06	24.25	0.00	0	0	331	833	0		
03/17/06	23.50	0.00	1	0	340	794	0		
03/18/06	24.00	0.00	2	0	298	935	0		
03/19/06	24.00	0.00	0	0	293	787	0		
03/20/06	23.65	0.00	3	1	322	1,042	0		
03/21/06	22.73	0.00	2	0	177	1,312	0		
03/22/06	24.73	0.00	2	0	611	2,196	0		
03/23/06	25.73	0.00	1	1	610	5,400	0		
03/24/06	23.65	0.00	6	0	789	1,937	0		
03/25/06	23.50	0.00	2	1	482	891	0		
03/26/06	23.50	0.00	1	1	282	1,973	0		
03/27/06	25.00	0.00	3	1	1,216	1,877	0		
03/28/06	23.00	0.00	4	0	1,109	4,276	0		
03/29/06	24.35	0.00	4	0	767	4,257	0		
03/30/06	24.32	0.00	2	1	633	4,472	0		
03/31/06	23.33	0.00	2	0	658	4,328	0		
04/01/06	26.00	0.00	1	2	1,468	3,429	0		
04/02/06	23.00	0.00	1	0	721	4,959	0		
04/03/06	23.50	0.00	1	0	596	5,243	0		
04/04/06	23.00	0.00	4	1	420	5,678	0		
04/05/06	15.00	12.25	0	0	426	4,596	0	0	0
04/06/06	10.25	11.00	2	0	382	4,058	0	0	0
04/07/06		24.00	0	0	1,410	4,020	0	0	0
04/08/06	0.50	21.50	2	0	1,071	3,220	0	0	0
04/09/06	4.42	19.58	0	0	1,141	5,887	0	0	0
04/10/06	24.00	0.00	1	0	2,573	3,259	0		
04/11/06	24.00	0.00	3	0	1,648	2,210	0		
04/12/06	24.00	0.00	6	4	226	2,969	0		
04/13/06	24.75	0.00	7	0	492	3,594	0		
04/14/06	25.25	0.00	1	0	1,906	5,952	0		
04/15/06	22.80	0.00	11	1	1,278	2,057	0		
04/16/06	24.07		8	1	977	1,572			
04/17/06	24.13	0.00	9	2	656	909	0		
04/18/06	22.50	0.00	11	0	693	948	0		
04/19/06	21.50	0.00	11	1	1,001	1,048	0		
04/20/06	28.50	0.00	6	2	305	1,167	0		
04/21/06	23.50	0.00	12	2	774	1,732	0		
04/22/06	23.50	0.00	9	3	480	1,043	0		
04/23/06	24.00	0.00	9	5	2	1,102	1		
04/24/06	24.25	0.00	9	5	616	955	0		
04/25/06	24.25	0.00	10	11	466	398	0		
04/26/06	25.00	0.00	10	19	276	323	0		
04/27/06	23.00	0.00	12	6	330	410	0		
04/28/06	23.50	0.50	8	19	343	370	0	0	0
04/29/06	23.17	0.00	71	30	11	1	0	1	
04/30/06	22.75	0.00	34	21	45	2	0		

Table continue next page

Appendix C2. Daily catches of Dungeness River coho and steelhead, and expanded catches of chum, pink, cutthroat, and bull trout/Dolly Varden, 2006. (cont'd).

Date	Times In	Times Out	COHO Smolts NOR	Steelhead Smolts NOR	Chum Fry NOR	Pink Fry NOR	CUTT Smolt NOR	Bull/Dolly Smolt NOR	Bull/Dolly Adult NOR
05/01/06	24.08	0.00	59	20	25	3	1		
05/02/06	24.00	0.00	38	14	47	2	0		
05/03/06	26.00	0.00	25	7	8	1	0		
05/04/06	23.00	0.00	67	8	4	1	0		
05/05/06	24.00	0.00	37	13	1	0	0		
05/06/06	24.50	0.00	26	12	4	0	0		
05/07/06	23.00	0.00	54	14	29	2	0		
05/08/06	24.67	0.00	124	26	8	0	0		
05/09/06	23.50	0.00	46	10	3	0	0		
05/10/06	24.50	0.00	63	10	6	0	0		
05/11/06	24.33	0.00	65	15	11	0	0		
05/12/06	23.50	0.00	52	17	3	2	0		
05/13/06	24.00	0.00	100	7	6	0	0		
05/14/06	24.00	0.00	68	18	3	0	0		
05/15/06	24.00	0.00	371	57	12	0	0		
05/16/06		24.00	0	0	5	0	0	0	0
05/17/06		24.00	0	0	5	0	0	0	0
05/18/06		24.00	0	0	5	0	0	0	0
05/19/06		24.00	0	0	5	0	0	0	0
05/20/06		24.00	0	0	5	0	0	0	0
05/21/06	15.25	8.00	29	3	2	0	1	0	0
05/22/06	25.25	0.00	66	8	2	0	0		
05/23/06	22.33	0.00	23	4	0	0	0		
05/24/06	24.75	0.00	21	3	0	0	0		
05/25/06	24.67	0.00	6	1	0	0	0		
05/26/06	22.67	0.00	15	0	0	0	1		
05/27/06	11.17	13.67	1	0	0	0	1	0	0
05/28/06		23.75	0	0	0	0	1	0	0
05/29/06	24.67	0.00	10	1	0	0	1		
05/30/06	23.27	0.00	5	0	0	0	0		
05/31/06	23.57	0.00	4	0	0	0	0		
06/01/06		24.00	0	0	0	0	0	0	0
06/02/06		24.00	0	0	0	0	0	0	0
06/03/06		24.00	0	0	0	0	0	0	0
06/04/06	21.92	3.50	3	1	0	0	0	0	0
06/05/06	24.75	0.00	6	1	0	0	0		
06/06/06	21.50	0.58	2	0	0	0	0	0	0
06/07/06	25.75	0.00	4	0	0	0	0		
06/08/06	21.33	1.00	3	0	0	0	0	0	0
06/09/06	25.92	0.00	1	0	0	0	0	1	
06/10/06	23.00	0.00	2	0	0	0	0		
06/11/06	24.67	0.00	1	0	0	0	0	1	
06/12/06	21.08	0.00	3	0	0	0	0	1	
06/13/06	25.75	0.00	3	0	0	0	0		
06/14/06	24.50	0.00	2	0	0	0	0		
06/15/06	22.92	0.00	0	0	0	0	0	1	

Note: On May 15, 370 coho and 57 steelhead were not mark-sampled for the UC-mark indicating release from Matriotti Creek. They were, however, included in the NOR catch count.

Table continued next page

Appendix C2. Daily catches of Dungeness River coho and steelhead, and expanded catches of chum, pink, cutthroat, and bull trout/Dolly Varden, 2006. (cont'd).

Date	Times In	Times Out	COHO Smolts NOR	Steelhead Smolts NOR	Chum Fry NOR	Pink Fry NOR	CUTT Smolt NOR	Bull/Dolly Smolt NOR	Bull/Dolly Adult NOR
06/16/06	24.08	0.00	1	1	0	0	0		
06/17/06	21.25	4.25	0	0	0	0	0	1	0
06/18/06	22.25	0.00	1	0	0	0	0		
06/19/06	25.50	0.00	0	0	0	0	0	1	
06/20/06	23.50	0.00	1	0	0	0	0		
06/21/06	25.25	0.00	1	0	0	0	0		
06/22/06	23.25	0.00	0	0	0	0	0		
06/23/06	22.25	0.00	0	0	0	0	0		
06/24/06	24.25	0.00	0	0	0	0	0		
06/25/06	23.83	0.00	1	0	0	0	0		
06/26/06	24.17	0.00	4	0	0	0	0		
06/27/06	24.67	0.00	2	0	0	0	0		
06/28/06	24.95	0.00	3	0	0	0	0		
06/29/06	23.63	0.00	2	0	0	0	0		
06/30/06	21.00	1.83	0	0	0	0	0	0	0
07/01/06	23.58	0.00	0	0	0	0	0		
07/02/06	25.33	0.00	1	1	0	0	0		
07/03/06	24.00	0.00	0	0	0	0	0		
07/04/06	22.75	0.00	0	0	0	0	0		
07/05/06	24.08	0.00	0	0	0	0	0		
07/06/06	24.08	0.00	0	0	0	0	0		
07/07/06	24.00	0.00	0	0	0	0	0		
07/08/06	23.83	0.00	0	0	0	0	0		
07/09/06	25.25	0.50	0	0	0	0	0	0	0
07/10/06	23.50	0.00	0	0	0	0	1	1	
07/11/06	22.08	0.00	0	1	0	0	0		
07/12/06	24.92	0.00	0	0	0	0	0		
07/13/06	23.92	0.00	0	0	0	0	1		
07/14/06	24.00	0.00	0	0	0	0	0		
07/15/06	24.17	0.00	1	0	0	0	1		
07/16/06	25.42	0.00	1	0	0	0	0		
07/17/06	24.00	0.00	0	0	0	0	1		
07/18/06	22.33	0.00	0	0	0	0	0		
07/19/06	24.25	0.00	0	0	0	0	0		
07/20/06	24.88	0.00	0	0	0	0	1		
07/21/06	23.62	0.00	0	0	0	0	0		
07/22/06	23.33	0.00	0	0	0	0	0		
07/23/06	26.08	0.00	0	0	0	0	2		
07/24/06	23.00	0.00	0	0	0	0	0		
07/25/06	23.00	0.00	0	0	0	0	0		
07/26/06	24.83	0.00	0	0	0	0	0		
07/27/06	23.08	0.00	0	0	0	0	0		
07/28/06	24.25	0.00	0	0	0	0	0		
07/29/06	23.83	0.00	0	0	0	0	0	1	
07/30/06	25.50	0.00	0	0	0	0	0		
07/31/06	24.00	0.00	0	0	0	0	0		

Table continued next page

Appendix C2. Daily catches of Dungeness River coho and steelhead, and expanded catches of chum, pink, cutthroat, and bull trout/Dolly Varden, 2006. (cont'd).

Date	Times In	Times Out	COHO Smolts NOR	Steelhead Smolts NOR	Chum Fry NOR	Pink Fry NOR	CUTT Smolt NOR	Bull/Dolly Smolt NOR	Bull/Dolly Adult NOR
08/01/06	22.58	0.00	0	0	0	0	0		
08/02/06	24.08	0.00	0	0	0	0	0		
08/03/06	13.75	10.00	0	0	0	0	0	0	0
08/04/06	13.67	10.42	0	0	0	0	0	0	0
08/05/06		25.50	0	0	0	0	0	0	0
08/06/06		24.00	0	0	0	0	0	0	0
08/07/06	13.58	8.67	0	0	0	0	0	0	0
08/08/06	16.92	10.33	0	0	0	0	0	0	0
08/09/06	22.00	0.00	0	0	0	0	0		
08/10/06	23.17	0.00	0	0	0	0	0		
08/11/06	15.00	10.33	1	0	0	0	0	0	0
08/12/06		24.00	0	0	0	0	0	0	0
08/13/06		24.00	0	0	0	0	0	0	0
08/14/06	14.42	8.58	0	0	0	0	0	1	0
08/15/06	14.17	9.67	0	0	0	0	0	0	0
08/16/06	13.92	10.00	0	0	0	0	0	0	0
Total	**4180.42**	**516.83**	**1,964**	**425**	**32,742**	**111,493**	**14**	**10**	**1**

Appendix C 3. Daily migration estimates for juvenile coho, steelhead, chum and pink salmon, Dungeness River 2006.

Date	NOR Coho Smolt	NOR Steelhead Smolts	NOR Pink Fry	NOR Chum Fry
02/02/06		0	13	295
02/03/06		0	32	181
02/04/06		0	182	399
02/05/06		0	6	228
02/06/06		12	19	152
02/07/06		0	6	228
02/08/06		12	13	162
02/09/06		0	0	124
02/10/06		35	0	57
02/11/06		0	0	10
02/12/06		0	0	38
02/13/06		0	6	10
02/14/06		0	0	19
02/15/06		0	0	0
02/16/06		12	0	0
02/17/06		12	0	0
02/18/06		12	0	0
02/19/06		0	0	0
02/20/06		0	0	0
02/21/06		0	0	0
02/22/06		0	0	0
02/23/06		0	0	0
02/24/06		0	0	38
02/25/06		0	0	38
02/26/06		0	6	10
02/27/06		12	6	67
02/28/06		0	104	0
03/01/06		0	39	48
03/02/06		0	84	57
03/03/06		0	97	76
03/04/06		12	32	295
03/05/06		0	227	875
03/06/06		0	13	29
03/07/06		0	201	399
03/08/06		0	32	48
03/09/06		0	13	57
03/10/06		0	26	29
03/11/06		0	201	0
03/12/06		12	182	475
03/13/06		0	467	418
03/14/06		0	1,667	2,320
03/15/06		0	3,204	1,303
03/16/06		0	5,402	4,397
03/17/06		0	5,149	4,517
03/18/06		0	6,063	3,959
03/19/06		0	5,104	2,860
03/20/06		12	6,757	3,143

Table continued next page

Appendix C3 Daily migration estimates for juvenile coho, steelhead, chum and pink salmon, Dungeness River 2006 (cont'd).

Date	NOR Coho Smolt	NOR Steelhead Smolts	NOR Pink Fry	NOR Chum Fry
03/21/06		0	8,508	1,728
03/22/06		0	14,241	3,701
03/23/06		12	35,019	3,695
03/24/06		0	12,561	4,779
03/25/06		12	5,778	2,920
03/26/06		12	12,795	1,708
03/27/06		12	12,172	6,337
03/28/06		0	27,730	5,779
03/29/06		0	27,606	3,997
03/30/06		12	29,001	3,299
03/31/06		0	28,067	3,429
04/01/06	19	23	22,237	7,650
04/02/06	19	0	32,159	3,757
04/03/06	19	0	30,709	3,106
04/04/06	74	12	33,257	2,189
04/05/06	37	0	26,920	2,220
04/06/06	74	0	23,769	1,991
04/07/06	37	0	23,546	6,710
04/08/06	74	0	18,860	5,097
04/09/06	0	0	34,481	5,430
04/10/06	19	0	19,089	12,245
04/11/06	56	0	12,944	7,843
04/12/06	111	46	17,390	1,076
04/13/06	130	0	21,051	2,341
04/14/06	19	0	34,862	9,071
04/15/06	204	12	12,048	6,082
04/16/06	149	12	9,208	8,856
04/17/06	167	23	5,324	5,947
04/18/06	204	0	5,553	6,282
04/19/06	204	12	6,138	9,074
04/20/06	111	23	8,170	1,119
04/21/06	223	23	12,126	2,839
04/22/06	167	35	7,302	1,761
04/23/06	167	58	7,715	7
04/24/06	167	58	6,686	2,259
04/25/06	186	127	4,272	3,131
04/26/06	186	220	3,467	1,854
04/27/06	223	69	4,401	2,217
04/28/06	167	231	3,971	2,304
04/29/06	1,318	347	11	66
04/30/06	631	243	21	271

Table continued next page

Appendix C3. Daily migration estimates for juvenile coho, steelhead, chum and pink salmon, Dungeness River 2006 (cont'd).

Date	NOR Coho Smolt	NOR Steelhead Smolts	NOR Pink Fry	NOR Chum Fry
05/01/06	1,095	231	32	150
05/02/06	705	162	21	283
05/03/06	464	81	11	48
05/04/06	1,244	92	11	24
05/05/06	687	150	0	6
05/06/06	483	139	0	24
05/07/06	1,003	162	21	175
05/08/06	2,302	300	0	48
05/09/06	854	116	0	18
05/10/06	1,170	116	0	36
05/11/06	1,207	173	0	66
05/12/06	965	196	21	18
05/13/06	1,857	81	0	36
05/14/06	1,262	208	0	18
05/15/06	6,888	659	0	72
05/16/06	2,302	231	0	30
05/17/06	2,302	231	0	30
05/18/06	2,302	231	0	30
05/19/06	2,302	231	0	30
05/20/06	2,302	231	0	30
05/21/06	724	46	0	12
05/22/06	1,225	92	0	12
05/23/06	427	46	0	0
05/24/06	390	35	0	0
05/25/06	111	12	0	0
05/26/06	278	0	0	0
05/27/06	223	0	0	0
05/28/06	204	0	0	0
05/29/06	186	12	0	0
05/30/06	93	0	0	0
05/31/06	74	0	0	0
06/01/06	56	12	0	0
06/02/06	56	12	0	0
06/03/06	56	12	0	0
06/04/06	56	12	0	0
06/05/06	111	12	0	0
06/06/06	37	0	0	0
06/07/06	74	0	0	0
06/08/06	56	0	0	0
06/09/06	19	0	0	0
06/10/06	37	0	0	0
06/11/06	19	0	0	0
06/12/06	56	0	0	0
06/13/06	56	0	0	0
06/14/06	37	0	0	0
06/15/06	0	0	0	0

Table continued next page

Appendix C3. Daily migration estimates for juvenile coho, steelhead, chum and pink salmon, Dungeness River 2006 (cont'd).

Date	NOR Coho Smolt	NOR Steelhead Smolts	NOR Pink Fry	NOR Chum Fry
06/16/06	19	12	0	0
06/17/06	0	0	0	0
06/18/06	19	0	0	0
06/19/06	0	0	0	0
06/20/06	19	0	0	0
06/21/06	19	0	0	0
06/22/06	0	0	0	0
06/23/06	0	0	0	0
06/24/06	0	0	0	0
06/25/06	19	0	0	0
06/26/06	74	0	0	0
06/27/06	37	0	0	0
06/28/06	56	0	0	0
06/29/06	37	0	0	0
06/30/06	0	0	0	0
07/01/06	0	0	0	0
07/02/06	19	12	0	0
07/03/06	0	0	0	0
07/04/06	0	0	0	0
07/05/06	0	0	0	0
07/06/06	0	0	0	0
07/07/06	0	0	0	0
07/08/06	0	0	0	0
07/09/06	0	0	0	0
07/10/06	0	0	0	0
07/11/06	0	12	0	0
07/12/06	0	0	0	0
07/13/06	0	0	0	0
07/14/06	0	0	0	0
07/15/06	19	0	0	0
07/16/06	19	0	0	0
07/17/06	0	0	0	0
07/18/06	0	0	0	0
07/19/06	0	0	0	0
07/20/06	0	0	0	0
07/21/06	0	0	0	0
07/22/06	0	0	0	0
07/23/06	0	0	0	0
07/24/06	0	0	0	0
07/25/06	0	0	0	0
07/26/06	0	0	0	0
07/27/06	0	0	0	0
07/28/06	0	0	0	0
07/29/06	0	0	0	0
07/30/06	0	0	0	0
07/31/06	0	0	0	0

Table continued next page

Appendix C3. Daily migration estimates for juvenile coho, steelhead, chum and pink salmon, Dungeness River 2006 (cont'd).

Date	NOR Coho Smolt	NOR Steelhead Smolts	NOR Pink Fry	NOR Chum Fry
08/01/06	0	0	0	0
08/02/06	0	0	0	0
08/03/06	0	0	0	0
08/04/06	0	0	0	0
08/05/06	0	0	0	0
08/06/06	0	0	0	0
08/07/06	0	0	0	0
08/08/06	0	0	0	0
08/09/06	0	0	0	0
08/10/06	0	0	0	0
08/11/06	19	0	0	0
08/12/06	0	0	0	0
08/13/06	0	0	0	0
08/14/06	0	0	0	0
08/15/06	0	0	0	0
08/16/06	0	0	0	0
Total	**43,888**	**6,125**	**696,642**	**194,721**

3.5 References

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4 Cedar Creek

2006 Cedar Creek
Juvenile Salmonid Production Evaluation

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4.1 Monitoring History

The Washington Department of Fish and Wildlife (WDFW) began adult steelhead monitoring in the Cedar Creek watershed during February 1998 after the installation of an adult trap in the Cedar Creek fishway (Rkm 4.0). This occurred after the National Marine Fisheries Service (NMFS) status review indicated populations of wild steelhead in the Lower Columbia River were at risk (Busby et al. 1996). The original intention was to monitor adult steelhead escapement and maintain the genetic diversity of wild steelhead in this basin by limiting the number of out of ESU hatchery steelhead spawning in the upper watershed. Later that year the adult monitoring program was expanded to include chinook salmon, coho salmon, and sea-run cutthroat trout. In March 1998, a rotary screw trap was installed to estimate steelhead, coho salmon, and sea-run cutthroat smolt production in this watershed. Smolt monitoring has continued through 2006 and has been funded in part by the Salmon Recovery Funding Board (SRFB). In 2006, sufficient funding was not available to begin juvenile trapping prior to the start of the fall chinook out-migration in late January; therefore, population estimates were not made for this species.

4.1.1 Study Site

Cedar Creek is a third order tributary to the Lewis River and is located in Clark County, WA (Figure 4 - 1). The mouth of Cedar Creek is located across from the Lewis River Salmon Hatchery at Rkm 26 on the Lewis River. The Cedar Creek basin, which drains approximately 88.6 kilometer, is a low gradient system with elevations ranging from 10 to 586 meters. The anadromous salmonid species identified in Cedar Creek include Chinook salmon, chum salmon, coho salmon, cutthroat trout, and steelhead. Hatchery smolt releases of steelhead, coho and spring chinook into the Lewis River strongly influence the escapement of these species in Cedar Creek. The Lewis Hatchery complex does not release fall chinook, so hatchery influence on fall Chinook escapement in Cedar Creek is strongly influenced by hatchery strays from outside the Lewis River basin. This has been measured by Coded Wire Tag (CWT) recovery. A natural falls exists at Rkm 4.0, which restricts adult salmon and steelhead passage at some flows. In the 1950's, a fish ladder was constructed by the Washington Department of Fisheries (WDF) to ensure salmon and steelhead passage at this location. This site is located below most of the coho salmon, steelhead, and sea-run cutthroat trout spawning habitat, the property is owned by WDFW, and the constricted river allows for acceptable trap efficiencies. These characteristics and properties make this site ideal for juvenile trapping.

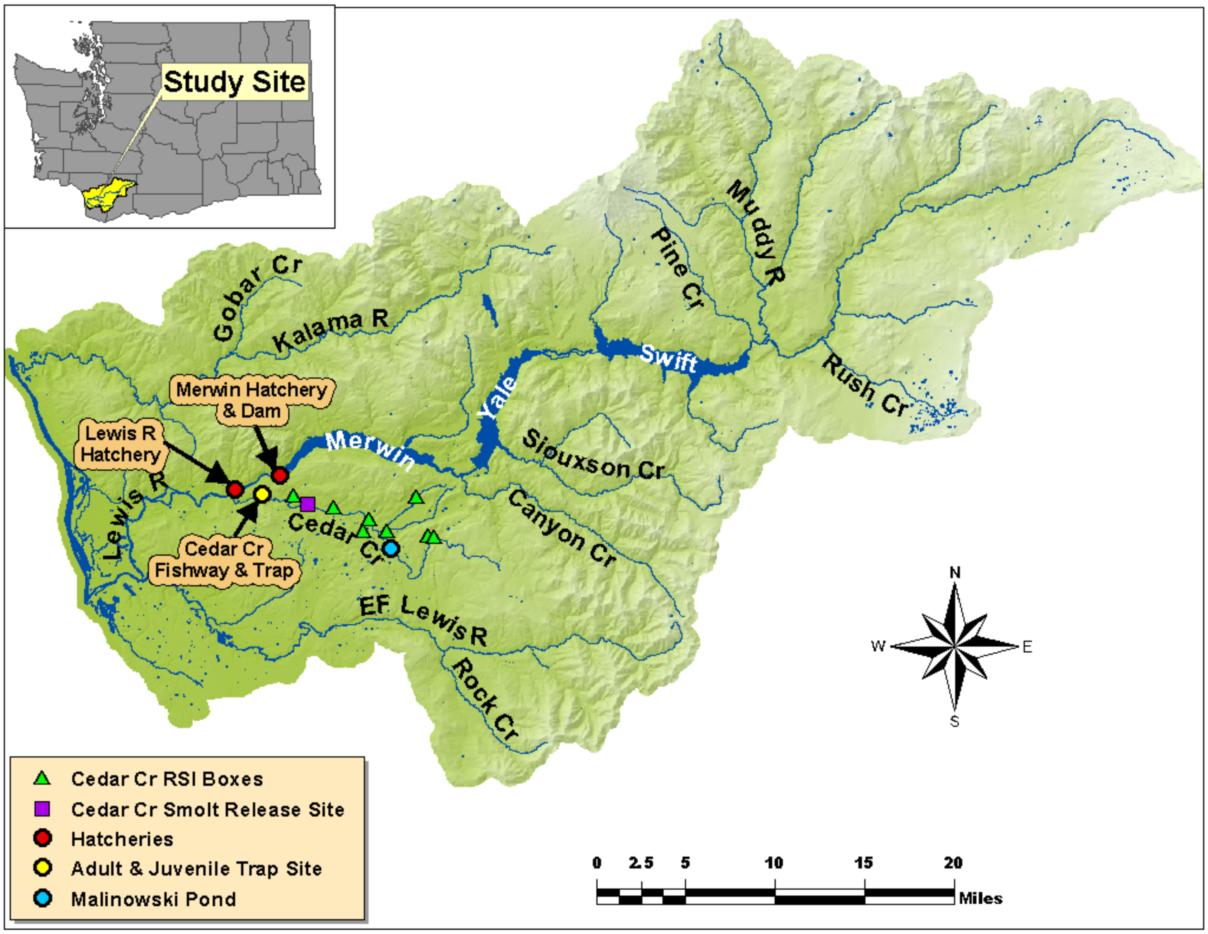

Figure 4 - 1. Lewis River subbasin with the Lewis River hatcheries and dam, Cedar Creek adult and juvenile trap site, smolt release site, acclimation ponds and remote site incubator sites. Map courtesy of Steve VanderPloeg, WDFW.

4.2 Methods

4.2.1 Trap Operation

On February 20, 2006 prior to the start of the smolt out-migration, a 1.5-meter rotary screw trap (EG Solutions, Eugene, OR) was installed just above the fish ladder at RKm 4.0. The trap was fished until the end of the smolt migration on June 27, 2006. The trap was located near the head of a pool, just below a narrow section of fast turbulent flowing water. The trap was positioned so that stream flow entered in a straight line. Water velocities at this site were generally greater than 1.5 meter/second producing cone revolutions of between 3 and 13.5 revolutions per minute (rpm). It is difficult to trap at this location over the range of flows experienced without moving the trap. Initially, the trap was installed in the middle of the pool. As flows decreased, the trap was moved upstream, first on March 28, and again on April 3 where it remained for the remainder of the season. The upstream sites are narrower and have higher water velocities. Trap efficiency is usually higher in these conditions, since the trap fishes a higher percentage of the streams cross sectional area when the stream width is narrower and trap avoidance is lower in faster more turbulent water.

The trap was fished 24 hours/day throughout the smolt out-migration period. A total of 10 days, during the season, were lost due to high flows and/or debris. A total of 8 of the missed days occurred before mid-March when smolt out migration is low. However, two days occurred in late April when smolt abundance is higher. Abundance estimates in these reports are likely biased low because it was difficult to develop correction factors for missed days given the marking schedule. The trap was checked daily in the morning; fish were removed from the live well and placed into a trough circulated with fresh stream water. Salmonid juveniles were sorted by species and life history stage. Salmonids were classified as fry, parr, pre-smolt, or smolt (Rawding et al. 1999). The criteria for parr included well-developed parr marks and heavy spotting across the dorsal surface. Pre-smolts were those fish that had faint parr marks, less prominent dorsal spotting, silvery appearance, and no dark caudal fin margin. Smolts consisted of those salmonids with deciduous scales, silver appearance, and a dark band on the outer margin of the caudal fin. Since smoltification is a process that salmon, steelhead, and cutthroat undergo along their downstream migration, and these salmonids are more than 140 Rkm from the ocean, it was more accurate to classify fish as pre-smolts and smolts. However, both groups were combined for the out migration analysis.

In all cases, captured juveniles were anesthetized with MS-222 (~ 40 mg/l) before handling, sampled as quickly as possible and were allowed to recover fully before being released into the river. The marked release occurred at the next available public access approximately 5.9 km above the trap site. Since steelhead and sea-run cutthroat abundance is low, all steelhead and sea-run cutthroat smolts and pre-smolts were marked and released upstream to increase the precision of the trap efficiency estimate. Wild coho salmon were more numerous, and up to 40 per day were released for trap efficiency tests with the remainder being released below the trap to continue their out migration. All marked fish were enumerated by species, and life stage, and fork lengths (mm) were taken. Stream temperatures and discharge were recorded by the Washington Department of Ecology (https://fortress.wa.gov/ecy/wrx/wrx/flows/station.asp?sta=27e100).

4.2.2 Juvenile Production Estimates

The number of juvenile out migrants was estimated by using a trap efficiency method of releasing marked fish upstream of the trap (Dempson and Stansbury 1991, Thedinga et al. 1994, Carlson et al. 1996, Plante et al. 1998). Captured juvenile salmonids were marked with Alcian Blue using a Panject Inoculator (Hart and Pitcher 1969, Thedinga and Johnson 1995). All coho were injected with 1½ length Coded Wire Tags (Northwest Marine Technology, Shaw Island, WA) and given a right or left ventral fin clip in accordance to the CWT code injected. The marking schedule rotated each week (interval) and used different fin combinations (left pectoral, right pectoral, anal) to distinguish between different mark intervals. Since the marking schedule was Sunday through Saturday, marks were recovered Monday through Sunday. Data was analyzed by interval, which consisted of a statistical week. Recapture intervals in this report were from Monday through Sunday. To achieve the desired level of precision all maiden steelhead and cutthroat were marked and released 5.9 km upstream while up to 40 maiden coho smolts per day were marked and released upstream to develop trap efficiency estimates.
Smolt abundance estimates in 1998 and 1999 were based on a temporal stratification design. Initial estimates used BOOTN software as presented in Thedinga et al. 1994 and further described in Murphy et al. (1996) to estimate smolt yield. This software uses Bailey (1951) estimate for trap efficiency (e) = (R+1)/(M+1), where M is the number of marked fish released upstream of the trap, and R is the number of marked fish recaptured. The number of migrants (N) = U/e, where U is the total unmarked catch, and e is the trap efficiency. Variance for each N was determined by a bootstrapping method (Efron and Tibshirani 1986) with 1,000 iterations from a Fortran program (Murphy et al. 1996). The 95% Confidence interval (95% CI) = 1.96 */√ where V is the variance determined from bootstrapping. From 2000 to 2003, population and trap efficiency estimates were calculated using Stratified Population Analysis Software (SPAS) developed by Arnason et al. (1996), which is based on the maximum likelihood estimator developed by Plante (1990). Trap efficiencies, population estimates, and standard error (SE) are estimated using standard likelihood methods using equations (1-3). SPAS computes a pooled Petersen (Chapman 1951), a Darroch Moment estimate, and a ML Darroch estimate for non-square arrays. The partially pooled ML Darroch estimate was used to estimate smolt yield during this period (Rawding et al. 2004).

The Chapman's modification to the Lincoln-Petersen estimate is often used to estimate smolt abundance. When stratified estimates are pooled this is referred to as the pooled Petersen and is:

$$N = \frac{(C+1)(M+1)}{(R+1)} - 1 \qquad (1)$$

where N is the population estimate, M is the total fish that are marked and released, C is the total of fish captured, and R is the number of marked fish that are recaptured. Seber (1982) provides and approximate unbiased estimate of the variance:

$$Var = \frac{(M+1)(C+1)(M-R)(C-R)}{(R+1)(R+1)(R+2)} \qquad (2)$$

and normal confidence intervals were calculated from the equation:

$$95\%\ CI = 1.96 * \sqrt{Var} \qquad (3)$$

Since trap efficiencies may change with flow or temperature (Seiler et al.1997, Schwartz and Dempson 1994, and Mantyniemi and Romakkaniemi 2002, Cheng and Gallinat 2004), the pooled Petersen estimate may not always be valid and in this case a stratified estimate is more appropriate (Darroch 1961, Seber 1982, Warren and Dempson 1995, Bannehaka et al. 1997, Miyakoshi and Kudo 1999). Out migration data was analyzed using the maximum likelihood estimator for stratified populations developed by Darroch (1961) as illustrated by Seber (1982). This is a standard analysis for salmonid smolt populations (Dempson and Stansbury 1991). Since 2004, the software used for this analysis has been a program called DARR (Darroch Analysis with Rank Reduction) developed by Bjorkstedt (2000). DARR 2.0 was used in this analysis and is an improved version of the original program Bjorkstedt (2005). In a temporally stratified study design fish are marked and released in s tagging strata, and tagged and untagged fish are recovered in t recovery strata. The number of smolts captured in recovery stratum j is u_j , m_i is the number of marked individuals released in tagging stratum i, and r_{ij} is the number of marked fish released in tagging stratum i that are recaptured in recovery stratum j. The probability that a fish tagged in the i^{th} period, will be captured in the j^{th} period, is the joint probability (π_{ij}) that an individual released in period i will resume migration and is susceptible to capture during period j (migration probability θ_{ij}) and is captured during period j (capture probability p_j). The joint probability is $\pi_{ij} = \theta_{ij}\, p_j$. Darroch (1961) provided a maximum likelihood estimator for obtaining n_j where $s = t$ and the rows of $\mathbf{R}$,$\{r_i\}$, are mutually independent and

$$r_i \sim \text{multinomial}\ (m_i, \pi_{ij})$$
$$u_j \sim \text{binomial}\ (n_j, p_j)$$

where $i = 1, 2, 3, \ldots s$, and $j = 1,2,3,\ldots t$.

Data are arranged in matrices as

$$\mathbf{u} = \begin{pmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{pmatrix}, \quad \mathbf{m} = \begin{pmatrix} m_1 \\ m_2 \\ m_3 \\ m_4 \end{pmatrix}, \quad \mathbf{R} = \begin{pmatrix} r_{11} & r_{12} & \ldots & r_{1\,t} \\ 0 & r_{22} & \ldots & r_{2\,t} \\ \ldots & \ldots & \ldots & \ldots \\ 0 & \ldots & 0 & r_{s\,t} \end{pmatrix}$$

The capture probability or the trap efficiency for each period is estimated as the proportion of marked fish that are recaptured from the matrices:

$$P = p\text{-}1 \qquad (4)$$

Counts of smolts are expanded to estimates of abundance

$$n = Du\ P \qquad (5)$$

where $\mathbf{p} = \mathbf{R}^{-1}\,\mathbf{m}$, $\mathbf{R}^{-1}$ is the inverse of the recapture matrix, n_j are the estimated number of smolts migrating past the trap in the j^{th} recovery period, $\mathbf{D_u}$ is a matrix with elements $\mathbf{u}$ arranged along the diagonal with zeros elsewhere, and **u** is the number of unmarked fish passing the trap during recovery stratum. The total abundance is estimated by summing the estimated number of unmarked individuals.

$$N = \Sigma\, nj \qquad (6)$$

The variance-covariance matrix for **n** is approximated by:

$$\text{cov (n)} \sim Dn\ \theta\text{-}1\ Du\ \ Dm\text{-}1\ (\theta')\text{-}1\ Dn + Dn\ (Dn - I) \qquad (7)$$

where D is the diagonal matrix, **I** is an identity matrix, elements of the vector **u** are calculated $u_i = \Sigma_j (\theta_{ij} / p_j) - 1$, and $\boldsymbol{\theta} = \mathbf{D_m^{-1}\ R\ D_p}$. The estimated variance is for the total population estimate is obtained by summing the elements of the variance-covariance matrix for the stratum estimates. Normal confidence limits were calculated from equation (3).

Initial data inputs to DARR consisted of a matrix of marks released, recaptures, and captures by week. DARR 2.0 applies a series of algorithms to aggregate data to yield an admissible estimate of abundance while preserving as much of the data structure as possible (Bjorkstedt 2005). To increase the precision of the smolt estimate, the partial pooling option in DARR was implemented. Guidance on appropriate methods of pooling mark and recovery strata are not always clear (Schwarz and Taylor 1998). Two diagnostic chi-square tests were used to determine if pooling adjacent strata was valid (Darroch 1961, Arnason et al. 1996, Schwarz and Taylor 1998). The equal proportions test determines if the ratio of marked to unmarked fish is constant across all strata and the complete mixing test determines if recovery probabilities are constant across all strata. If either test yields *P*-values greater than 0.05, strata can be pooled. Therefore, after the initial stratified estimate, a chi-square test was used to compare marked and unmarked smolts per release group to formally test pooling (Murphy et al. 1996). The first two weeks were tested for a significant difference (*P*-value <0.05). If not significant, then additional weeks were added until a significant difference was detected. This process was repeated beginning with the week that caused the *P*-value to drop below 0.05. Schwarz and Taylor (1998) indicated that recovery strata may be arbitrarily pooled without affecting the consistency of the Petersen estimate. Since the Darroch estimate is only valid when the number of tagged and recovery strata are equal, a DARR algorithm pools the recovery strata to match the tagging strata. The purpose of this pooling was to develop homogeneous periods for the population estimate and to increase the precision of the seasonal migration estimate. This the same pooling procedure used for the 1998-2005 smolt estimates.

Murphy et al. (1996) listed the standard assumptions of the Petersen method that apply in trap efficiency experiments: (1) The population is closed. (2) All fish have the same probability of capture in the first sample. (3) The second sample is either a simple random sample, or if the second sample is systematic, marked and unmarked fish mix randomly. (4) Marking does not affect likelihood of capture. (5) Fish do not lose their marks. (6) All recaptured marks are recognized. During the smolt-trapping season, steps were taken to reduce the possibility that these assumptions were violated. Assumption 1 is that of closure, which assumes that no fish leave or enter between sampling occasions. However, the Petersen estimate is still consistent if the loss rate of tagged and untagged smolts is the same (Arnason et al. 1996). Therefore, the closure assumption is considered be met in this study except for the 10 days between February 20 to April 24 when the trap was not fished due to high debris load and trap damage.

To the greatest extent possible, we conducted experiments to identify the bias caused by violations of other assumptions and develop correction factors. Assumptions 2 and 3 were addressed by estimating populations by species, origin, and life stage. The Kolmogorov-Smirnov (KS) test was used to test differences in capture rates of maiden and recaptured fish by length. Although Seber (1982) recommends a comparison of recaptured fish with those captured and not seen again, this is not possible with the batch mark we used for smolt trapping. For batch marked fish, we followed the recommendation of Thedinga et al. (1994) and compared recaptured fish with all marked fish. Assumptions 4 and 5 were addressed and estimated by holding marked fish to assess tag loss and handling mortality (Thedinga et al. 1994, Carlson et al. 1996, Rawding et al. 1999). When properly applied, the panjet mark is easily observed, and mark retention consistently exceeded the three-week period required for this study (Thedinga and Johnson 1995, Rawding and Cochran 2001).

4.2.3 Contribution of Remote Site Incubator (RSI) to Coho Salmon Smolt Production

WDFW and Fish First have implemented several habitat restoration projects in the Cedar Creek watershed. Fish First is a local grassroots fishing and conservation group working to increase juvenile salmon and steelhead productivity and capacity in Cedar Creek. Eggs were collected from adult non-adipose clipped coho salmon returning in the fall and winter of 2004 to the Lewis Hatchery complex. The eggs were incubated at Lewis River Hatchery and transferred to Washougal Hatchery for otolith marking. Manipulating water temperature between the eyed egg and yolk absorption stages creates thermal marks. Each time the water temperature is dropped by two to four degrees centigrade, a distinctive black band is deposited in the microstructure of the developing otolith. Exposure to chilled water for periods of 8 to 48 hours will create unique “bar” codes on the otolith that can be read (Figure 4 - 2). Each brood year has been assigned its own series, so it is possible to identify fish with unique life histories. Voucher samples were taken to determine mark quality and form. Otoliths collected from sampling coho salmon smolts were analyzed by WDFW, Science Division, Otolith Laboratory. Annually, a total of 420,000 thermally marked eggs for RSI are provided to Fish First.

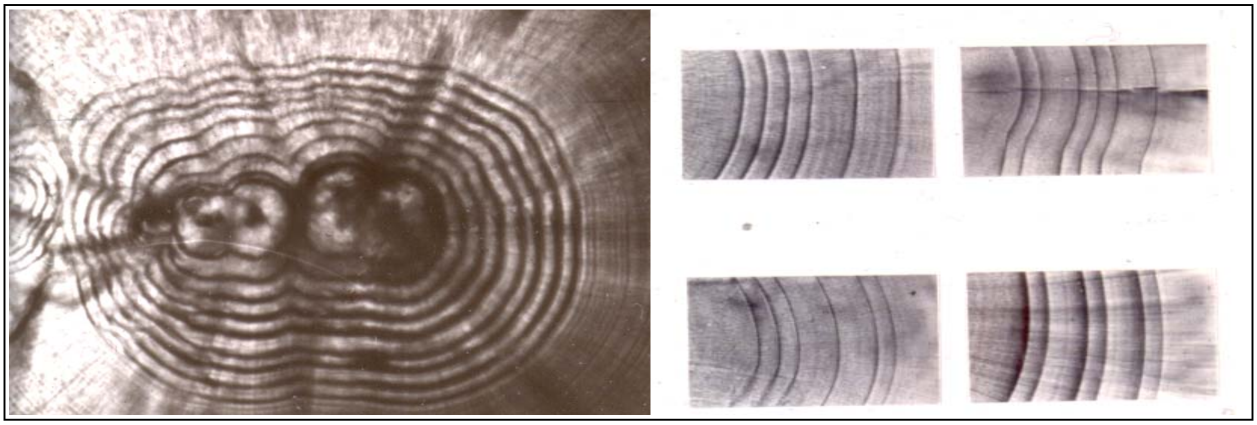

Figure 4 - 2. Thermally marked otolith. (Photo courtesy of Eric Volk, WDFW)

The origin of coho salmon smolts were classified as RSI or natural-origin. The proportion of coho salmon smolts in each category was estimated as:

$$p_k = \frac{n_k}{n_t} \tag{8}$$

Where n_k = the number of natural-origin or RSI otoliths from examined coho salmon smolts, and n_t = the number of analyzed otoliths. The variance of the proportion was estimates as:

$$V(p_k) = \frac{[p_k(1-p_k)]}{(n_t - 1)} \tag{9}$$

Abundance by origin was estimated as:

$$N * P(Var) = V(N)p_k^{\,2} + V(p_k)N^2 + V(N)V(p_k) \tag{10}$$

where N = coho smolt estimate from natural production and V(N) = the variance of the coho salmon smolt estimate from natural production.

4.3 Results

4.3.1 Assumptions

Assumptions 2 and 3 address equal probability of capture. In mark-recapture studies, population estimates are made for homogeneous groups because they are likely to have the same capture and recapture probabilities. In this study design, separate estimates were made for each species. Furthermore, estimates were only made for the pre-smolt/smolt life stage. Parr and fry are smaller than smolts and may not be actively migrating; therefore, parr and fry were identified and enumerated separately. In addition, trap efficiency and ultimately population estimates may be affected by fish size or length.

To examine possible size bias in capture probability, a Kolmogorov-Smirnov (KS) test was administered for each species. For sea-run cutthroat trout and steelhead, KS tests were not significant (P = 0.879 and 0.399, respectively) for size difference between recaptured and maiden capture fish (Figure 3). For coho, KS test results were significant (P <0.001), indicating a possible size bias in capture probability. Recaptured fish tended to be larger than maiden capture fish (Figure 4 - 3). While statistically significant, a comparison of weekly mean fork lengths for maiden captures and recaptures indicates the difference in means is 2.62 mm, suggesting the size difference may be biologically insignificant.

Assumptions 4, 5, and 6 address tag induced mortality, tag loss, and mark recognition. A secondary experiment was conducted to assess tag loss and handling mortality. From February 28 to June 20, a total of 155 coho salmon were marked, tagged, fin clipped, and held in a live box for a period of 24 hours after being trapped and marked. Panjet mark retention and survival were 100% indicating mark application was successful and tag (mark) loss and mortality assumptions were likely met. Coded-wire-tag (CWT) retention was greater than 99%.

We did not specifically assess if field staff properly identified marked or tagged fish. However, these experienced staff knew the importance of carefully sampling fish and the need to identify all tagged fish. The likelihood that staff did not correctly identify tags or marks in this study is believed to be low. Based on this information, no serious violation of the assumptions required for unbiased population estimates occurred and it is believed that the smolt population estimates for sea-run cutthroat trout, steelhead, and coho salmon are not significantly biased.

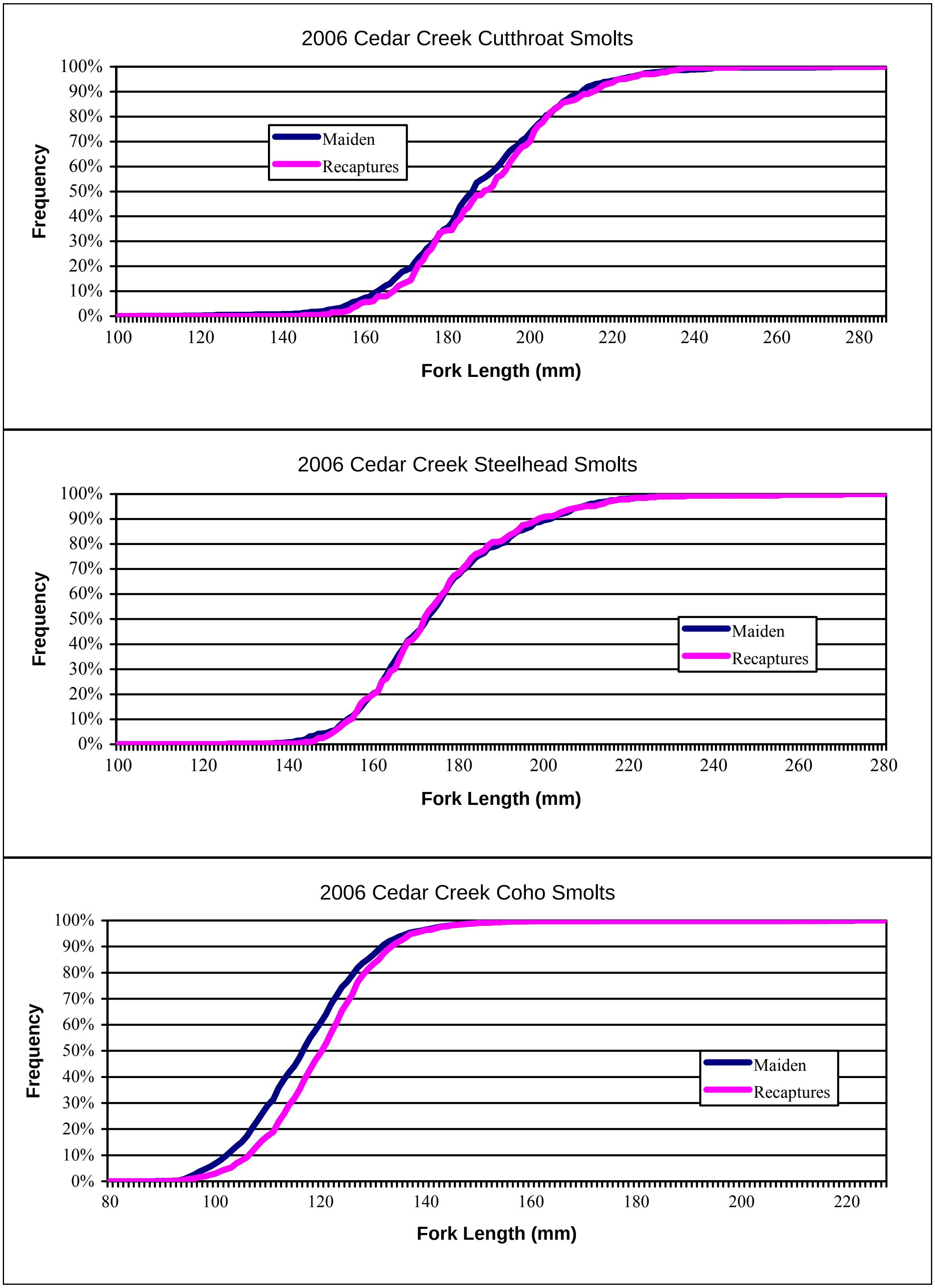

Figure 4 - 3. Comparison of first time captures and recaptures of natural-origin sea-run cutthroat trout, natural-origin steelhead, and natural-origin coho salmon smolts at the Cedar Creek trap in 2006.

4.3.2 Cutthroat Smolts

A total of 1,173 cutthroat trout classified as pre-smolts and smolts were captured during the trapping period. The mean fork length for wild sea-run cutthroat smolts was 188.4mm (SE=20.91) (Table 4 - 1). Over the season, the weekly mean size declined from 202 to 193mm between weeks 1 and 14 (Table 4 - 1 and Figure 4 - 4).

Table 4 - 1. Mean fork lengths (mm), standard deviations, ranges, and sample sizes, of natural-origin cutthroat measured by trapping interval, Cedar Creek, 2006.

Statistical Week			Average	s.d.	Range		Number		Percent
No.	Begin	End			Min	Max	Sampled	Captured	Sampled
9	02/20/06	02/26/06	202.4	28.92	138	284	31	75	41.3%
10	02/27/06	03/05/06	190.9	23.59	156	245	21	24	87.5%
11	03/06/06	03/12/06	189	27.86	116	245	20	20	100.0%
12	03/13/06	03/19/06	183.4	26.42	145	247	19	19	100.0%
13	03/20/06	03/25/06	195.3	21.1	155	244	21	24	87.5%
14	03/27/06	04/02/06	191	19.35	133	235	54	54	100.0%
15	04/03/06	04/09/06	192.6	21.93	134	257	75	75	100.0%
16	04/10/06	04/16/06	192.7	25.24	105	285	118	118	100.0%
17	04/17/06	04/22/06	197.3	18.84	143	245	67	68	98.5%
18	04/25/06	04/30/06	189.7	16.08	145	235	169	171	98.8%
19	05/01/06	05/07/06	186.6	18.06	121	234	219	223	98.2%
20	05/08/06	05/14/06	182.4	17.07	147	241	146	152	96.1%
21	05/15/06	05/21/06	179.3	15.54	147	227	71	72	98.6%
22	05/22/06	05/28/06	173.8	14.21	151	218	43	43	100.0%
23	05/29/06	06/04/06	176	15.86	145	214	30	30	100.0%
16	06/05/06	06/11/06	193.2	14.52	172	213	5	5	100.0%
Season Total			188.4	20.91	105	285	1,109	1,173	94.5%

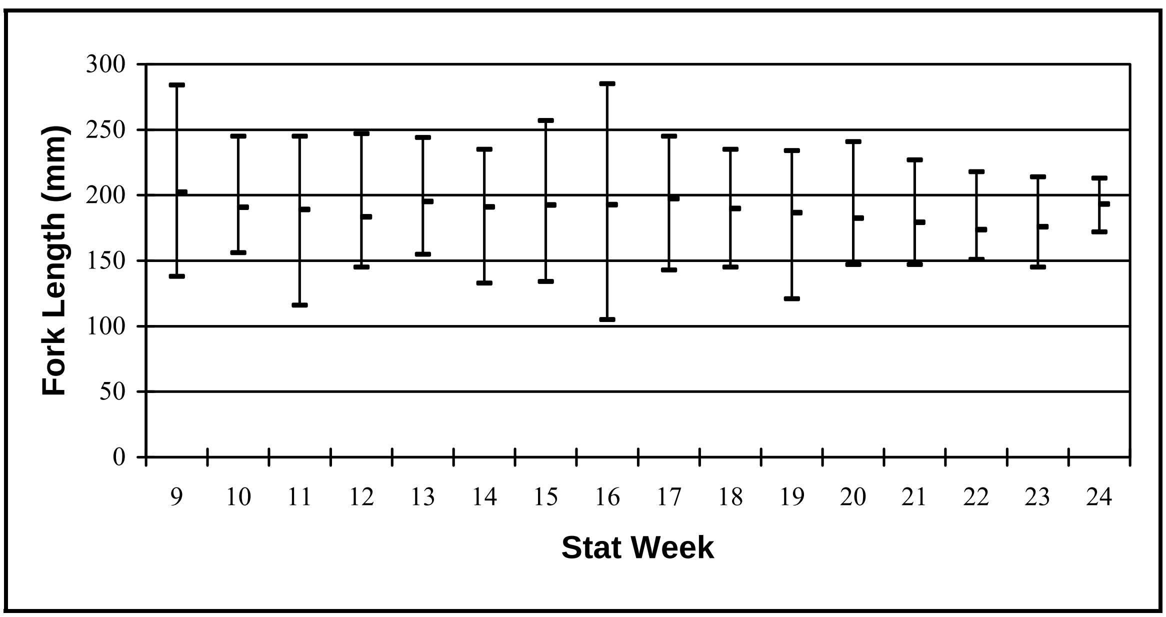

Figure 4 - 4 . Weekly average, minimum, and maximum sea-run cutthroat trout smolt fork lengths measured at the Cedar Creek screw trap, 2006.

A total of 1,109 cutthroat trout were marked for 16 different release groups. The Chi-Square diagnostic complete mixing and equal proportions tests for all groups pooled yielded *P*-values of less than 0.001. Since these *P*-values were less than 0.05, the pooled Petersen estimate was not considered valid. An admissible estimate of 5,777 (SE = 487) was obtained from DARR when release groups were reduced to eleven groups. The final stratum estimate based on partial pooling supported by chi square diagnostic tests resulted in 7 groups and an estimate of 5,720 with a 95% CI from 4,822 to 6,617 (Table 4 - 2). Trap efficiency for wild sea-run cutthroat smolts ranged from 5-13% between statistical weeks 9 and 13 and 13-39% from statistical weeks 14 to 22. The varying trap efficiencies were not unexpected. From statistical week 14 onward the trap was fished at a relatively consistent site at the head of the pool but prior to this, the trap was located further downstream where it was less efficient at capturing smolts due to lower water velocity and sampling a smaller cross-section of the creek. Weekly trap catches increased from statistical week 14 (April 3-9) to week 19 (May 1-7), and steadily declined through week 24 (June 6-11) (Figure 4 - 5). Based on population estimates from weekly trap efficiency, peak out-migration occurred during week 20 (May 8-14).

Table 4 - 2. Catch and population estimates for sea-run cutthroat trout smolts emigrating past the Cedar Creek trap during 2006.

Peterson Estimate	Period	Catch	Smolt Yield	SE	95% C.I.		CV
					Lower	Upper	
Pooled	1	1,173	4,908	246	4,662	5,154	5.02%
Initial Strata	11	1,173	5,777	487	4,822	6,731	8.43%
Final Strata	7	1,173	5,720	458	4,822	6,617	8.43%

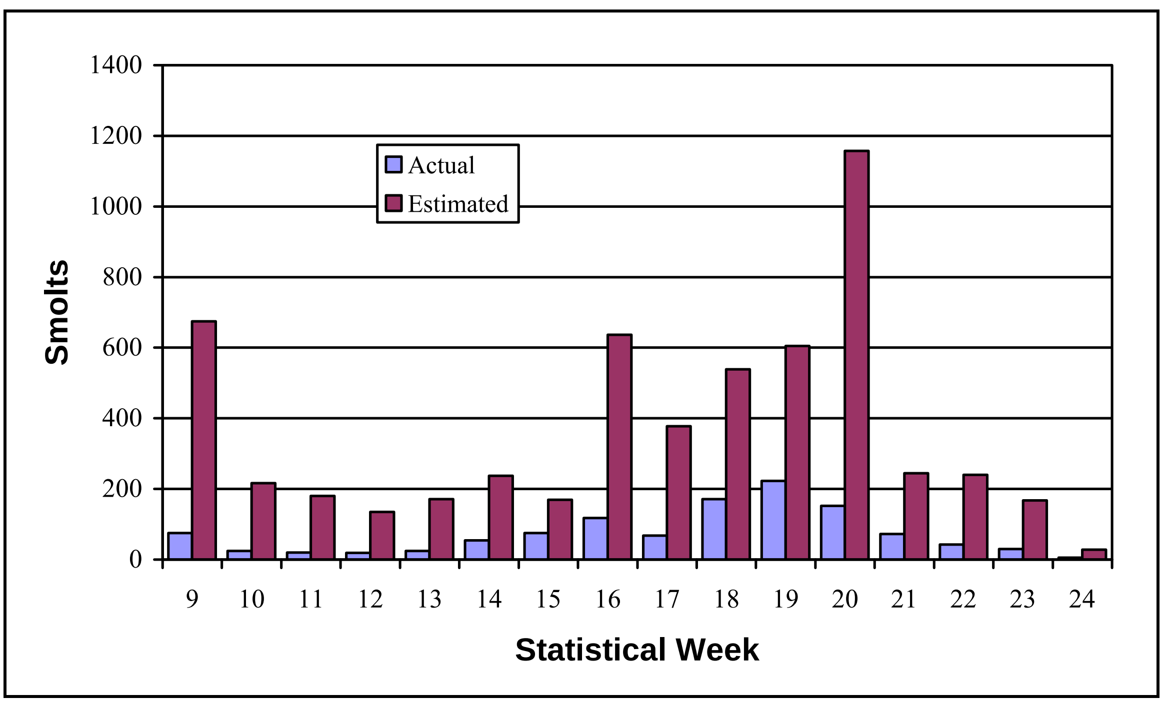

Figure 4 - 5. Weekly catch and population estimates for sea-run cutthroat trout smolts migrating past the Cedar Creek trap in 2006.

4.3.3 Steelhead Smolts

A total of 787 steelhead trout classified as pre-smolts and smolts were captured during the trapping period. The mean size for wild steelhead smolts was 175.6 mm (SE = 18.62). As with the sea-run cutthroat trout, the trend of the mean weekly fork lengths declined from 186 to 163 mm during the trapping period (Table 4 - 3 and Figure 4 - 6).

Table 4 - 3. Mean fork lengths (mm), standard deviations, ranges, and sample sizes, of natural-origin Steelhead smolts measured by trapping interval, Cedar Creek, 2006.

Statistical Week			Average	s.d.	Range		Number		Percent
No.	Begin	End			Min	Max	Sampled	Captured	Sampled
10	02/20/06	02/26/06	186.0	18.19	165	197	6	15	40.0%
11	02/27/06	03/05/06	0.0	0.00	0	0	0	0	0.0%
12	03/06/06	03/12/06	223.0	0.00	223	223	0	1	0.0%
13	03/13/06	03/19/06	191.2	23.91	163	218	4	5	80.0%
14	03/20/06	03/25/06	174.6	14.94	155	203	9	9	100.0%
15	03/27/06	04/02/06	191.5	20.28	157	249	31	32	96.9%
16	04/03/06	04/09/06	186.8	20.32	144	241	65	66	98.5%
17	04/10/06	04/16/06	182.7	20.51	147	233	75	75	100.0%
18	04/17/06	04/22/06	175.0	16.68	140	233	208	216	96.3%
19	04/25/06	04/30/06	171.7	16.49	142	241	191	197	97.0%
20	05/01/06	05/07/06	170.5	15.63	135	223	112	112	100.0%
21	05/08/06	05/14/06	165.8	12.74	141	193	41	44	93.2%
22	05/15/06	05/21/06	173.0	13.67	152	190	5	6	83.3%
23	05/22/06	05/28/06	163.7	17.41	134	184	9	9	100.0%
Season Total			**175.6**	**18.62**	**118**	**249**	1,109	1,173	94.5%

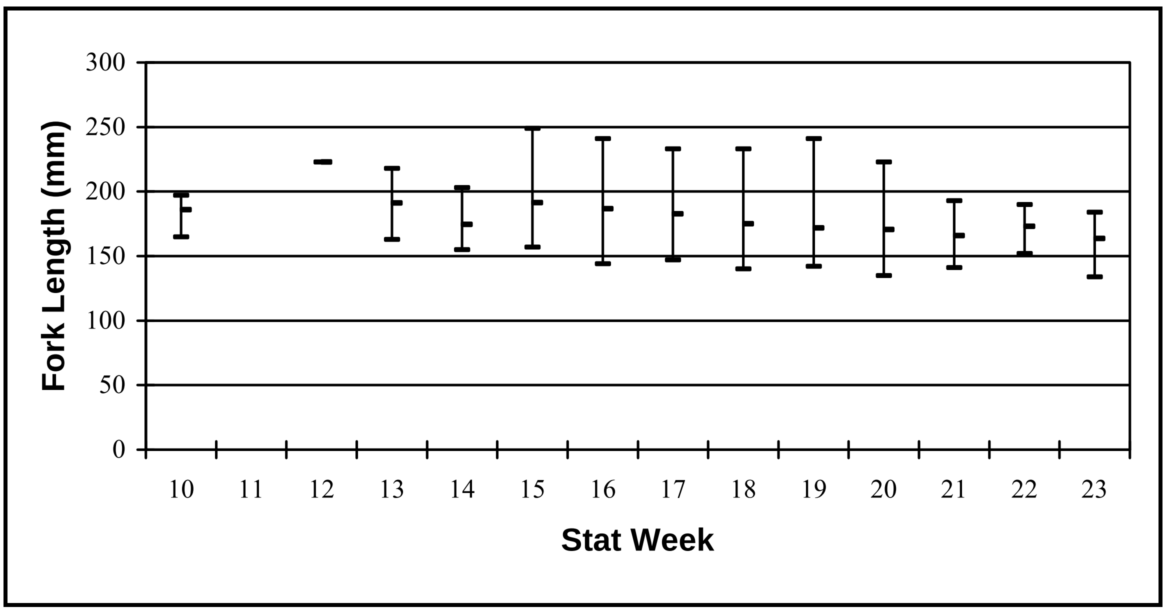

Figure 4 - 6. Weekly average, minimum, and maximum yearling steelhead fork lengths measured at the Cedar Creek screw trap, 2006.

A total of 756 steelhead trout were marked for 14 different release groups. For all groups pooled, the chi-square diagnostic for complete mixing and equal proportions tests yielded *P*-values less than 0.001 for each test. The initial estimate from DARR, reduced to eight periods, was 1,996 (SE=109). Chi-Square diagnostic tests indicated partial pooling for weeks 8-9, 10-11 and 13-14 was acceptable;

this yielded a final estimate of 1,914 (SE = 100). Weekly trap catches increased from week 10 to18, and steadily declined through week 23 (Figure 4 - 7). Based on population estimates from weekly trap efficiencies, peak steelhead emigration occurred during week 19 (May 1-7), which was 1 week earlier than the peak in sea-run cutthroat out-migration.

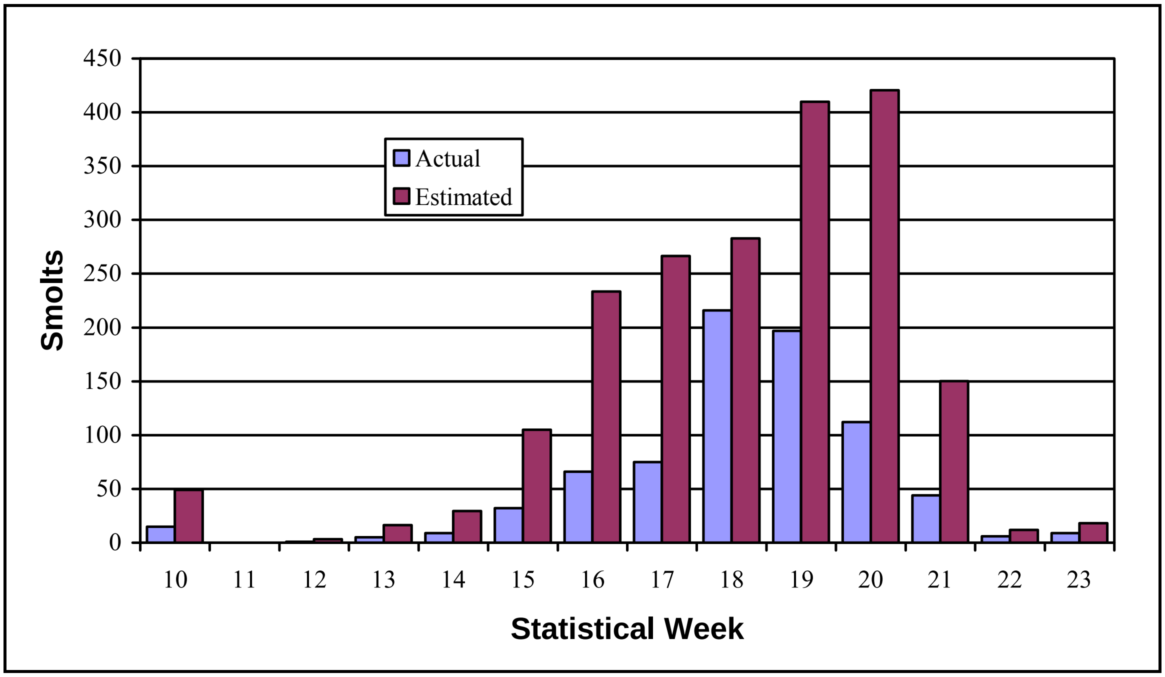

Figure 4 - 7. Weekly catch and population estimates for steelhead smolts migrating past the Cedar Creek trap in 2006.

Table 4 - 4 Catch and population estimates for steelhead smolts emigrating past the Cedar Creek trap during 2006.

Peterson Estimate	Period	Catch	Smolt Yield	SE	95% C.I.		CV
					Lower	Upper	
Pooled	1	756	1,802	91	1,711	1,893	5.04%
Initial Strata	8	756	1,996	109	1,896	2,105	5.46%
Final Strata	6	756	1,914	100	1,718	2,110	5.22%

4.3.4 Coho Smolts

Hatchery coho are from RSI production and wild is from natural in-river production, all smolts are included in the total. Both hatchery from RSI production and naturally produced coho salmon smolts were found in Cedar Creek. A supplementation program for coho salmon was initiated for Cedar Creek coho salmon to ensure fish could utilize habitat where restoration projects improved access and habitat. The hatchery coho smolt acclimation program was discontinued in 2004 but a Remote Site Incubator (RSI) program is ongoing. A total of 20,693 coho salmon classified as pre-smolts and smolts were captured during the trapping period. The mean fork length for coho salmon smolts was 115.5 mm (Table 4 - 5). Over the season, the mean weekly fork length of coho salmon ranged from 127mm to 101mm (Figure 4 - 8).

Table 4 - 5. Coho mean fork lengths (mm), standard deviations, rangers, and sample sizes, measured by trapping interval, Cedar Creek 2006.

Statistical Week			Average	s.d.	Range		Number		Percent
No.	Begin	End			Min	Max	Sampled	Captured	Sampled
9	02/20/06	02/26/06	107.1	8.84	93	142	144	750	19.2%
10	02/27/06	03/05/06	104.8	9.49	89	135	53	55	96.4%
11	03/06/06	03/12/06	110.1	11.75	92	153	63	83	75.9%
12	03/13/06	03/19/06	110.8	13.31	90	148	35	47	74.5%
13	03/20/06	03/25/06	117.1	12.52	94	143	36	43	83.7%
14	03/27/06	04/02/06	119.3	10.91	93	150	173	187	92.5%
15	04/03/06	04/09/06	123.5	10.97	98	174	230	374	61.5%
16	04/10/06	04/16/06	124.1	10.38	99	162	240	451	53.2%
17	04/17/06	04/22/06	127.6	18.13	97	230	280	1128	24.8%
18	04/25/06	04/30/06	123.2	9.67	81	156	280	2876	9.7%
19	05/01/06	05/07/06	119.7	10.32	99	217	280	4214	6.6%
20	05/08/06	05/14/06	116.4	8.77	99	152	240	3284	7.3%
21	05/15/06	05/21/06	113.2	10.01	91	199	280	3649	7.7%
22	05/22/06	05/28/06	111.9	10.63	86	152	280	2379	11.8%
23	05/29/06	06/04/06	108.7	10.57	92	157	234	582	40.2%
24	06/05/06	06/11/06	102.7	7.39	84	132	161	348	46.3%
25	06/12/06	06/18/06	101.4	8.53	91	155	120	243	49.4%
Season Total			**115.5**	**13.35**	**81**	**230**	**3,129**	**20,693**	15.1%

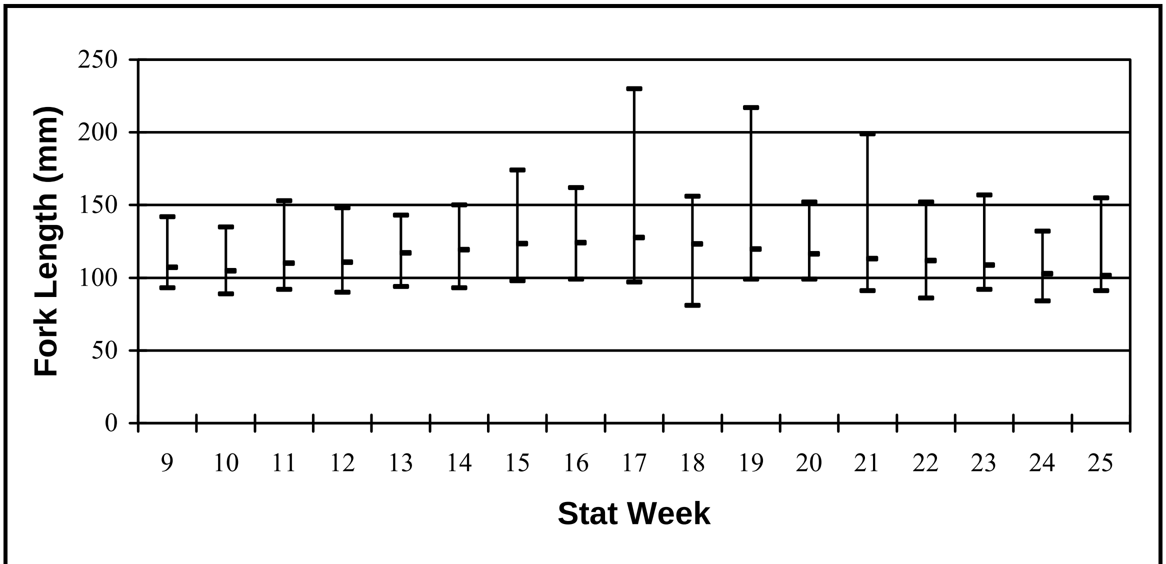

Figure 4 - 8. Weekly average, minimum, and maximum yearling natural-origin coho salmon fork lengths measured at the Cedar Creek screw trap, 2006.

A total of 3,129 coho salmon were marked for 17 different release groups. For all groups combined, the chi-square diagnostic complete mixing and equal proportions tests yielded *P*-values of less than 0.001 for both tests, which indicated the pooled Petersen estimate was not valid. An admissible coho salmon abundance estimate of 43,017 (SE =1131) was obtained from DARR with pooling into 13 groups. Chi-square diagnostic tests for partial pooling resulted in seven periods. The final seven-period estimate was 43,008 (SE = 1,008). The 95% CI for the final estimate ranged from 41,032 to 44,983 smolts (Table 4 - 6). Since trapping was initiated prior to the smolt out-migration no expansion of the estimate was required to obtain a total smolt out-migration estimate.

Coho salmon smolts were collected from February 28 through June 28. Using a systematic sampling rate of ~ 1:40. A total of 465 fish were sacrificed for otolith collection and analyzed. The results indicate that 383 (82.4%) were collected from adults that spawned in the river and 82 (17.6%) were collected from smolts originating from an RSI. The estimated natural production was 35,424 smolts with a 95% CI of 33,796 to 37,051 smolts. Production from RSIs totaled 7,584 smolts with a 95% CI from 7,236 to 7,932 smolts. Based on a total of 420,000 thermally marked eggs, the estimated egg to smolt survival was 1.8% with a 95% CI from 1.6% to 2.0%. Based on population estimates from weekly trap efficiencies, peak coho salmon emigration occurred during statistical week 20 (May 8-14), which is 1 week later than the steelhead out-migration and the same week as the cutthroat out-migration (Figure 4 - 9).

Table 4 - 6. Catch and population estimates for natural-origin coho salmon smolts emigrating past the Cedar Creek trap during 2006.

Peterson Estimate	Period	Catch	Smolt Yield	SE	95% C.I.		CV
					Lower	Upper	
Pooled	1	20,693	46,018	2,301	43,717	48,319	5.02%
Initial Strata	13	20,693	43,017	1,131	40,866	45,168	2.62%
Final Strata	7	20,693	43,008	1,008	41,032	44,983	2.34%

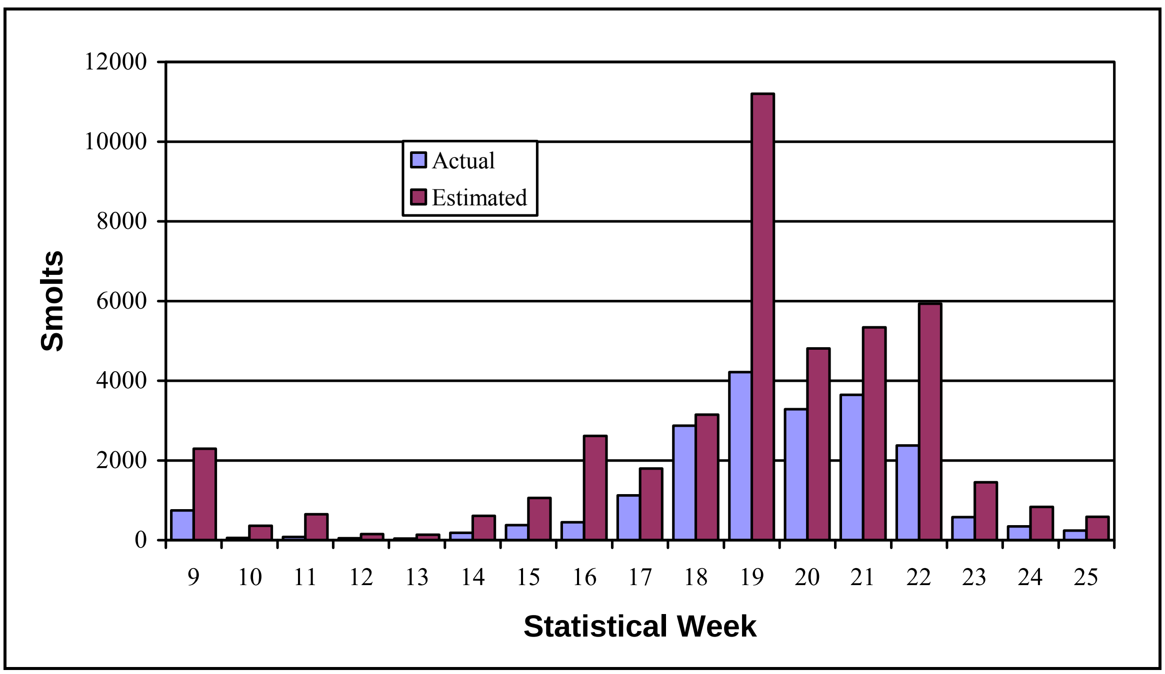

Figure 4 - 9. Weekly catch and population estimates for natural-origin coho salmon smolts migrating past the Cedar Creek trap in 2006.

4.3.5 Other species and life stages

A total of 1,343 Chinook fry/sub-yearlings were captured at the Cedar Creek trap during its operation period. An additional 99 cutthroat parr, 42 rainbow/steelhead parr, 301 coho salmon parr, 72 coho salmon fry, and 150 trout fry were trapped. Largemouth bass, bluegill, brown bullhead, crappie, sculpin, mountain whitefish, large scale sucker, three-spine stickleback, western brook lamprey, pacific lamprey, adult steelhead, adult cutthroat, and adult spring chinook were also identified by the sampling crew.

4.4 Discussion

Since the assumptions of the Petersen estimate were met for cutthroat and steelhead, population estimates are thought to be relatively unbiased for these species. For coho, KS test results indicate a significant difference between the size of maiden capture and recaptured coho salmon, which would violate assumptions 2 and 3 of the Petersen method regarding equal capture probability. The difference in means weekly size between maiden capture and recaptured coho was found to be < 3mm. Recaptured fish tended to be larger than maiden captures. It is unclear what may have led to this difference. Possibilities include an increased mortality rate on smaller fish (due to marking or predation), measurement error, and/or a delay in out migration after release above the trap, which would allow for growth to occur before recapture. While statistically significant, a size difference this small is likely biologically insignificant and population estimates for coho are still thought to be relatively unbiased.

During the ten trapping days missed from February 24 to April 23, an unknown number of fish passed the trap during these events. Since this was prior to significant migration, the number of fish passing during this time is likely small. No attempt was made to adjust the smolt estimates to account for the missing days.

In previous years, the estimated number of hatchery coho salmon smolts migrating past the trap was not significantly different from the number of hatchery coho salmon smolts released into Cedar Creek as long as the trap was operated throughout the entire migration period (Rawding et al. 2004, Rawding and Groesbeck 2005). However, the missed days in late April led to lower trap efficiencies for this weekly release group, which in part compensated for the missed days (Figure 9). However, it is unclear if this adjustment provided and unbiased estimate.

Robson and Reiger (1964) suggested that the precision of population estimates be scaled to the use of the estimate. For management, they recommended the 95% CI of the population estimate be less than 25% and for research they recommended 10% or less. This equates to a coefficient of variation (CV) of 12.7% and 5.1%, respectively. Since this monitoring project goes beyond management, project goals were for a CV of 5% or less for wild populations. For wild cutthroat, steelhead, and coho salmon smolts the CVs were 8.4%, 5.2%, and 2.3%, respectively. The precision of population estimates is directly tied to the number of recaptures, and for small populations like sea-run cutthroat and steelhead trout there are no easy solutions to increasing the level of precision other than marking all fish and choosing efficient sites to fish. In 2006, most cutthroat and steelhead smolts were marked and transported upstream. As long as abundance levels for cutthroat and steelhead smolts remain less than ~6,000 smolts, it will be difficult to achieve the precision goals for these species. However, it should be noted despite this difficulty, the CVs for cutthroat and steelhead were near the goal of 5%. Based on simulations (Dan Rawding - WDFW, unpublished), it was estimated that up to 40 coho salmon smolts per day should be used for trap efficiency tests. Catch above this level were injected with CWT, vent fin clipped and released below the trap. The CV for wild coho salmon was 2.3% and exceeded our precision target of a CV less than 5%.

A total of 19,389 wild coho salmon smolts were tagged with a CWT. This tagging serves two purposes, the first is to provide marks for a coho salmon smolt estimate obtained from adults (Seiler et al. 1997) and the second is to provide information about the ocean and Columbia River fisheries interception of wild Lower Columbia River coho salmon, which are listed for protection under the

Endangered Species Act (ESA). The ventral fin clip will enable the sampling crew to identify naturally produced CWT positive adults from Lewis Hatchery origin double index group fish that are not adipose clipped. Since, adult coho salmon typically return after two summers in the ocean, an independent smolt estimate from adult returns and harvest information will be available after the 2007 adult return.

4.4.1 Recommendations

1) This trapping operation covers a field season from early February to late June, which coincides with the migration of yearling coho salmon, steelhead, and sea-run cutthroat smolts. Fall chinook salmon are listed for protection under the ESA, and these fish also spawn in the watershed above the trap. Expanded funding should be provided to estimate the fall chinook out migration. This would necessitate initiating trapping by mid to late January.
2) An adult trap currently is operated by WDFW in a fish ladder adjacent to the juvenile trapping site. Currently, WDFW maintains a count of adult salmon, cutthroat, and steelhead. Also, a resistance board weir has been installed (fall 2006) to evaluate and calibrate the efficiency of the adult fish-way trap. With additional funding, precise adult population estimates could be calculated, using mark-recapture methods, thereby increasing the value of the juvenile dataset.
3) Population estimates are obtained from standard mark-recapture methods. Since temperature and flow are known to influence smolt migration (Seiler et al. 1997 and Rawding et al. 1999), flow and temperature data could be incorporated as co-variates to potentially develop estimates that are less biased and more precise
(Schwarz and Dempson 1994, Mantyniemi and Romakkaniemi 2002, Cheng and Gillinant 2004).

4.5 References

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