# MONITORING AND EVALUATION OF THE CHELAN COUNTY PUD HATCHERY PROGRAMS

## 2007 Annual Report

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# PREFACE

This annual report is the result of coordinated field efforts conducted by Washington Department of Fish and Wildlife (WDFW), the Confederated Tribes and Bands of the Yakama Nation (Yakama Nation), Chelan County Public Utility District (Chelan PUD), and BioAnalysts, Inc. An extensive amount of work was conducted in 2006 and 2007 to collect the data needed to monitor the effects of the Chelan County PUD Hatchery Programs. This work was directed and coordinated by the Habitat Conservation Plan (HCP) Hatchery Committee, consisting of the following members: David Carie, U.S. Fish and Wildlife Service (USFWS); Jerry Marco, Confederated Tribes of the Colville Reservation (Colville Tribes); Kristine Petersen, National Marine Fisheries Service (NMFS); Shaun Seaman, Chelan County PUD; Tom Scribner, the Yakama Nation; and Kirk Truscott, WDFW.

The approach to monitoring the hatchery programs was guided by the "*Conceptual Approach to Monitoring and Evaluating the Chelan County Public Utility District Programs*" written by Andrew Murdoch and Chuck Peven. Technical aspects of the monitoring and evaluation program were developed by the Hatchery Evaluation Technical Team (HETT), which consists of the following scientists: Matt Cooper, USFWS; Steve Hays, Chelan PUD; Tracy Hillman, BioAnalysts; Tom Kahler, Douglas PUD; Rick Klinge, Douglas PUD; Russell Langshaw, Grant PUD; Ben Lenz, Grant PUD; Andrew Murdoch, WDFW; Keely Murdoch, Yakama Nation; Kristine Petersen, NMFS; Chuck Peven, Chelan PUD; and Ali Wick, Anchor Environmental. The HETT developed an "*Analytical Framework for Monitoring and Evaluating PUD Hatchery Programs*" (Hays et al. 2006), which directs the analyses of hypotheses developed under the conceptual approach. Most of the analyses outlined in the Analytical Framework paper will be conducted after the fifth year of monitoring.

Most of the work reported in this paper was funded by Chelan PUD. Bonneville Power Administration purchased the Passive Integrated Transponder (PIT) tags that were used to mark juvenile Chinook and steelhead. This is the second annual report written under the direction of the HCP.

*"I often say that when you can measure something and express it in numbers, you know something about it. When you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind. It may be the beginning of knowledge, but you have scarcely in your thoughts advanced to the stage of science, whatever it may be."*

*Lord Kelvin*

# SECTION 1: INTRODUCTION

Chelan PUD implements hatchery programs as part of two Habitat Conservation Plan (HCP) agreements related to the operation of Rocky Reach and Rock Island dams. The HCPs define the goal of achieving no net impact to spring Chinook, summer/fall Chinook, sockeye salmon, steelhead, and coho salmon affected by the operation of these dams. The two HCPs identify general program objectives as "*contributing to the rebuilding and recovery of naturally reproducing populations in their native habitats, while maintaining genetic and ecologic integrity, and supporting harvest*." The fish resource management agencies initially developed the following general goal statements for each hatchery program, which were adopted by the Hatchery Committee:

*(1) Support the recovery of ESA listed species by increasing the abundance of natural adult population, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity.*

Includes the Wenatchee spring Chinook, Wenatchee summer steelhead, and Methow spring Chinook programs.

*(2) Increase the abundance of the natural adult population of unlisted plan species, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity. In addition, provide harvest opportunities in years when spawning escapement is sufficient to support harvest.*

Includes the Wenatchee sockeye, Wenatchee summer/fall Chinook, Methow summer/fall Chinook, Okanogan summer/fall Chinook, and Okanogan sockeye programs.

*(3) Provide salmon for harvest and increase harvest opportunities, while segregating returning adults from natural tributary spawning populations.*

Includes the Turtle Rock summer/fall Chinook program.

Thus, there are two different types of artificial propagation strategies that address the different goals of the program: supplementation and harvest augmentation. The supplementation programs primarily focus on increasing the natural production of fish in tributaries. A fundamental assumption of this strategy is that hatchery fish returning to the spawning grounds are "reproductively similar" to naturally produced fish. The second program type, harvest augmentation, focuses on increasing harvest opportunities. This is accomplished by releasing hatchery fish directly into the Columbia River with the intent that returning adults remain segregated from the naturally spawning populations in tributaries.

Monitoring is needed to determine if the programs are performing properly. The HCP Hatchery Committee adopted a monitoring and evaluation (M&E) approach that will guide the assessment of the hatchery programs. The approach, developed by Murdoch and Peven (2005), identified the following objectives:

(1) Determine if supplementation programs have increased the number of naturally spawning and naturally produced adults of the target population relative to a non-supplemented population (i.e., reference stream) and the changes in the natural replacement rate (NRR) of the supplemented population is similar to that of the non-supplemented population.

(2) Determine if the run timing, spawn timing, and spawning distribution of both the natural and hatchery components of the target population are similar.

(3) Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program. Additionally, determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.

(4) Determine if the hatchery adult-to-adult survival (i.e., hatchery replacement rate or HRR) is greater than the natural adult-to-adult survival (i.e., natural replacement rate or NRR) and equal to or greater than the program specific HRR expected value based on survival rates listed in the BAMP (1998).

(5) Determine if the stray rate of hatchery fish is below the acceptable levels to maintain genetic variation between stocks.

(6) Determine if hatchery fish were released at the programmed size and number.

(7) Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity (i.e., number of juveniles per redd) of supplemented streams when compared to non-supplemented streams.

(8) Determine if harvest opportunities have been provided using hatchery returning adults where appropriate (e.g., Turtle Rock program).

Two additional objectives that were not explicit in the goals specified above but were included in the M&E approach because they relate to goals and concerns of all artificial production programs include:

(9) Determine whether bacterial kidney disease (BKD) management actions lower the prevalence of disease in hatchery fish and subsequently in the naturally spawning population. In addition, when feasible, assess the transfer of *Renibacterium salmoninarum* (Rs) infection at various life stages from hatchery fish to naturally produced fish.

(10) Determine if the release of hatchery fish impact non-target taxa of concern (NTTOC) within acceptable limits.

Attending each objective is one or more testable hypotheses (see Murdoch and Peven 2005). Each hypothesis will be tested statistically following the routines identified in Hays et al. (2006). Most of these analytical routines will be conducted at the end of five-year monitoring blocks, as outlined in the M&E plan (Murdoch and Peven 2005; Hays et al. 2006).

Throughout each five-year monitoring period, annual reports will be generated that describe the M&E data collected during a specific year. This is the second annual report developed under the direction of the M&E guidance approach (Murdoch and Peven 2005). The purpose of this report is to describe monitoring activities conducted in 2007. Activities included broodstock collection, collection of life-history information, within hatchery spawning and rearing activities, juvenile monitoring within streams, and redd and carcass surveys. Data from reference areas are not included in this annual report, because the process of selecting reference areas is still occurring. To the extent currently possible, we have included information collected before 2007.

This report is divided into several sections, each representing a different species (i.e., steelhead, sockeye salmon, spring Chinook, and summer Chinook). For all species we provide broodstock information; hatchery rearing history, release data, and survival estimates; juvenile migration and productivity estimates; redd counts, distribution, and spawn timing; spawning escapements; and life-history characteristics. For salmon species, we also provide information on carcasses.

Finally, we end each section by addressing compliance issues with ESA/HCP mandates. For each Chelan PUD Hatchery Program, WDFW and the PUD are authorized annual take of ESA-listed spring Chinook and steelhead through Section 10 of the Endangered Species Act (ESA), including:

1. ESA Section 10(a)(1)(A) Permit No. 1395, which authorizes the annual take of adult and juvenile endangered upper Columbia River (UCR) spring Chinook and threatened UCR steelhead associated with implementing artificial propagation programs for the enhancement of UCR steelhead. The authorization includes takes associated with adult broodstock collection, hatchery operations, juvenile fish releases, monitoring and evaluation activities, and management of adult returns related to UCR steelhead artificial propagation programs in the UCR region (NMFS 2003a).
2. ESA Section 10(a)(1)(A) Permit No. 1196, which authorizes the annual take of adult and juvenile endangered UCR spring Chinook and threatened UCR steelhead associated with implementing artificial propagation programs for the enhancement of UCR spring Chinook. The authorization includes takes associated with adult broodstock collection, hatchery operations, juvenile fish releases, and monitoring and evaluation activities supporting UCR spring Chinook artificial propagation programs in the UCR region (NMFS 2004).
3. ESA Section 10(a)(1)(A) Permit No. 1347, which authorizes the annual incidental take of adult and juvenile endangered UCR spring Chinook and threatened UCR steelhead through actions associated with implementing artificial propagation programs for the enhancement of non-listed anadromous fish populations in the UCR. The authorization includes incidental takes associated with adult broodstock collection, hatchery operations, juvenile fish releases, and monitoring and evaluation activities associated with non-listed summer Chinook, fall Chinook, and sockeye salmon artificial propagation programs in the UCR region (NMFS 2003b).

# SECTION 2: SUMMARY OF METHODS

Sampling in 2007 followed the methods and protocols described in Murdoch and Peven (2005) and Peven (2006). In this section we only briefly review the methods and protocols. More detailed information can be found in Murdoch and Peven (2005) and Peven (2006).

## 2.1 Broodstock Sampling

Methods for collecting broodstock during 2007 are described in Appendix A in WDFW (2007). Methods for sampling broodstock are described in Appendices A and B in Murdoch and Peven (2006). Generally, 2007 broodstock were collected over the migration period (to the extent allowed in ESA-permit provisions) in proportion to their temporal occurrence at collection sites, with in-season adjustments dictated by 2007 run timing and trapping success relative to achieving weekly and annual collection objectives. Pre-season weekly collection objectives are shown in Table 2.1 and assumptions associated with broodstock trapping are provided in Table 2.2.

**Table 2.1.** Weekly collection objectives for steelhead, sockeye, and Chinook in 2007.

| Collection week beginning day | Chiwawa Spring Chinook[a] | | Wild Wenatchee Summer Chinook | Wild ME/OK Summer Chinook | Wenatchee Steelhead | | Wild Wenatchee Sockeye[b] | |
|---|---|---|---|---|---|---|---|---|
| | Hatchery | Wild | | | Hatchery | Wild | Male | Female |
| 20 May | 1 | | | | | | | |
| 27 May | 5 | 2 | | | | | | |
| 3 June | 11 | 5 | | | | | | |
| 10 June | 17 | 5 | | | | | | |
| 17 Jun | 19 | 6 | | | | | | |
| 24 Jun | 22 | 6 | | | | | | |
| 1 Jul | 27 | 7 | 126 | 87 | 1 | 1 | | |
| 8 Jul | 14 | 5 | 98 | 83 | 1 | 1 | | |
| 15 Jul | 4 | 2 | 82 | 83 | 1 | 1 | 20 | 20 |
| 22 Jul | 3 | 1 | 63 | 73 | 1 | 1 | 41 | 41 |
| 29 Jul | 0 | 1 | 44 | 59 | 1 | 1 | 25 | 25 |
| 5 Aug | | | 29 | 44 | 4 | 4 | 20 | 20 |
| 12 Aug | | | 21 | 40 | 7 | 7 | 16 | 16 |
| 19 Aug | | | 16 | 26 | 8 | 8 | 8 | 8 |
| 26 Aug | | | 13 | 24 | 7 | 7 | | |
| 2 Sep | | | | 23 | 6 | 6 | | |
| 9 Sep | | | | 14 | 6 | 6 | | |
| 16 Sep | | | | | 8 | 8 | | |
| 23 Sep | | | | | 9 | 9 | | |
| 30 Sep | | | | | 17 | 17 | | |
| 7 Oct | | | | | 15 | 15 | | |
| 14 Oct | | | | | 8 | 8 | | |
| 21 Oct | | | | | 4 | 4 | | |
| 28 Oct | | | | | | | | |

| Collection week beginning day | Chiwawa Spring Chinook[a] | | Wild Wenatchee Summer Chinook | Wild ME/OK Summer Chinook | Wenatchee Steelhead | | Wild Wenatchee Sockeye[b] | |
|---|---|---|---|---|---|---|---|---|
| | Hatchery | Wild | | | Hatchery | Wild | Male | Female |
| **Total** | **123** | **40** | **492** | **556** | **104** | **104** | **130** | **130** |

[a] Collection quota based on 30 April 2007 run-escapement abundance and migration timing estimate.
[b] Collection targeted equal numbers of males and females.

**Table 2.2.** Biological and trapping assumptions associated with collecting broodstock for the Chelan PUD Hatchery Programs.

| Assumptions | Wenatchee Steelhead | Wenatchee Sockeye | Chiwawa Spring Chinook | Wenatchee Summer Chinook | ME/OK Summer Chinook |
|---|---|---|---|---|---|
| Production level | 400,000 yearling smolts | 200,000 subyearlings | 672,000 yearling smolts | 864,000 yearling smolts | 976,000 yearling smolts |
| Broodstock required | 208 adults (not to exceed 33% of population) | 260 adults (not to exceed 33% of population) | 379 adults (not to exceed 33% of population) | 492 adults (not to exceed 33% of the population) | 556 adults (not to exceed 33% of the population) |
| Trapping period | 7 July – 12 Nov | 7 July – 28 Aug | 1 May – 12 Sep | 7 Jul – 12 Sep | 7 Jul – 15 Sep |
| # days/week | 5 | 3 | 4 | 5 | 3 |
| # hours/day | 24 | 16 | 24 | 24 | 16 |
| Broodstock composition | 50% wild; 50% WxW and/or HxW | 100% wild | Sliding scale; minimum 33% wild (depends on the number of wild fish) | 100% wild | 100% wild |
| Trapping site | Dryden Dam (Tumwater will be used if weekly quota not achieved at Dryden Dam) | Tumwater Dam | Tumwater Dam (hatchery fish only) and the Chiwawa Weir (both hatchery and wild fish) | Dryden Dam (Tumwater will be used if weekly quota not achieved at Dryden Dam) | Wells Dam east ladder |

Several biological parameters were measured during broodstock collection at adult collection sites. Those parameters included the date and start and stop time of trapping; number of each species collected for broodstock; origin, size, and sex of trapped fish; age from scale analysis; and pre-spawn mortality. For each species, trap efficiency, extraction rate, and trap operation effectiveness were estimated following procedures in Appendix B in Murdoch and Peven (2006). In addition, a representative sample of most species trapped but not taken for broodstock were sampled for origin, sex, age, and size (stock assessment). All steelhead trapped were sampled.

## 2.2 Within Hatchery Monitoring

Methods for monitoring hatchery activities are described in Appendix C in Murdoch and Peven (2005). Biological information collected from all spawned adult fish included age at maturity, length at maturity, spawn timing, and fecundity of females. In addition, all fish were checked for tags and females were sampled for disease.

Throughout the rearing period in the hatchery, fish were sampled for growth, health, and survival. Each month, lengths and weights were collected from a sample of fish and rearing density indices were calculated. In addition, fish were examined monthly for health problems following standard fish health monitoring practices for hatcheries. Various life-stage survivals were estimated for each hatchery stock. These estimates were then compared to the standard survival rates identified in Table 2.3 to provide insight as to how well the hatchery operations were performing. Failure to achieve a survival standard could indicate a problem with some part of the hatchery program. However, failure to meet a standard may not be indicative of the overall success of the program to meet the goals identified in Section 1.

**Table 2.3.** Standard life-stage survival rates for fish reared within the Chelan PUD hatchery programs.

| Life stage | Standard survival rate (%) |
|---|---|
| Collection-to-spawning (females) | 90 |
| Collection-to-spawning (males) | 85 |
| Unfertilized egg-to-eyed | 92 |
| Unfertilized egg-to-ponding | 98 |
| 30 d after ponding | 97 |
| 100 d after ponding | 93 |
| Ponding-to-release | 90 |
| Transport-to-release | 95 |
| Unfertilized egg-to-release | 81 |

Nearly all hatchery fish from each stock were marked (adipose fin clip) or tagged (coded-wire tag or elastomer tag). Different combinations of marks and tags were used depending on the stock. In addition, about 10,000 juvenile hatchery fish from each stock of steelhead (HxW-early production, HxW-late production, and WxW) and spring Chinook were PIT tagged during late July and September to aid in estimating survival rates (e.g., smolt-to-adult) outside the hatchery. About 15,000 juvenile sockeye were PIT tagged in June.

Lastly, the size and number of fish released were assessed and compared to programmed production levels. The goal of the program is that numbers released and their sizes should fall within 10% of the programmed targets identified in Table 2.4. However, because of constraints due to run size and proportions of wild and hatchery adults, production levels may not be met every year.

**Table 2.4.** Targets for fish released from the Chelan PUD hatchery programs; CV = coefficient of variation.

| Hatchery stock | Release targets | Size targets | | |
|---|---|---|---|---|
| | | Fork length (CV) | Weight (g) | Fish/pound |
| Wenatchee Summer Chinook | 864,000 | 176 (9.0) | 45.4 | 10 |
| Okanogan Summer Chinook | 576,000 | 176 (9.0) | 45.4 | 10 |
| Methow Summer Chinook | 400,000 | 176 (9.0) | 45.4 | 10 |
| Turtle Rock Summer Chinook (yearlings) | 200,000 | 176 (9.0) | 45.4 | 10 |
| Turtle Rock Summer Chinook (subyearlings) | 1,620,000 | 112 (9.0) | 11.4 | 40 |
| Chiwawa Spring Chinook | 672,000 | 176 (9.0) | 37.8 | 12 |
| Wenatchee Sockeye | 200,000 | 133 (9.0) | 22.7 | 20 |

| Hatchery stock | Release targets | Size targets | | |
|---|---|---|---|---|
| | | Fork length (CV) | Weight (g) | Fish/pound |
| Wenatchee Steelhead | 400,000 | 198 (9.0) | 75.6 | 6 |

## 2.3 Juvenile Sampling

Juvenile sampling within streams included operation of rotary smolt traps, snorkel observations, and PIT tagging. Methods for sampling juvenile fish are described in Appendix E in Murdoch and Peven (2005).

Smolt traps were located on the Wenatchee River at river km 9.6 at the West Monitor Bridge (Lower Wenatchee Trap) and about 0.5 km downstream from the mouth of Lake Wenatchee (Upper Wenatchee Trap), and in the Chiwawa River about 1 km upstream from the mouth (Chiwawa Trap). All traps operated throughout the smolt migration period. The Chiwawa Trap operated throughout most of the year (March through November) and not during icing or extreme high flow conditions. The following data were collected at each trap site: water temperature, discharge, number and identification of all species captured, degree of smoltification for anadromous fish, presence of marks and tags, size (fork lengths and weights), and scales from steelhead and sockeye salmon smolts. Trap efficiencies at each trap site were estimated by using mark-recapture trials conducted over a wide range of discharges. Linear models relating discharge and trap efficiencies were developed to estimate daily trap efficiencies during periods when no mark-recapture trials were conducted. The total number of fish migrating past the trap each day was estimated as the quotient of the daily number of fish captured and the estimated daily trap efficiency. Summing the daily totals resulted in the total emigration estimate.

Snorkel observations were used to estimate the number of juvenile spring Chinook salmon, juvenile rainbow/steelhead, and bull trout within the Chiwawa River basin. The focus of the study was on juvenile spring Chinook salmon. Sampling followed a stratified random design with proportional allocation of sites among strata. Strata were identified based on unique combinations of geology, land type, valley bottom type, stream state condition, and habitat types. A total of 189 randomly selected sites were surveyed during August (Table 2.5). Counts of fish within each sampling site were adjusted based on water temperatures. That is, non-linear models that described relationships between water temperatures and detection efficiencies (Hillman et al. 1992) were used to estimate total numbers of fish within sampling sites. These numbers were then converted to densities by dividing total fish numbers by the wetted surface area and water volume of sample sites. Total numbers within a stratum were estimated as the product of fish densities times the total wetted surface or water volume for the stratum. The sum of fish numbers across strata resulted in the total number of fish within the basin. The calculation of total numbers, densities, and degrees of certainty are fully explained in Hillman and Miller (2004).

Working in collaboration with the Integrated Status and Effectiveness Monitoring Program (ISEMP) funded by NOAA Fisheries and Bonneville Power Administration (BPA), crews PIT tagged juvenile wild Chinook and wild and hatchery steelhead throughout the Wenatchee basin. Tags were injected into juvenile fish collected at the Chiwawa Trap, Upper Wenatchee Trap, and the Lower Wenatchee Trap. In addition, fish were collected and tagged in the Chiwawa River upstream from the trap, in Nason Creek, and in the upper Wenatchee River between Tumwater and Lake Wenatchee. The

proposed number of wild spring Chinook and steelhead to be tagged at each location is provided in Table 2.6. The goal of this work was to better understand the life-history characteristics of fish in the Wenatchee Basin and to estimate SARs. This in turn improves the ability to detect potential impacts of the hatchery program on wild fish.

**Table 2.5.** Location of strata and numbers of randomly sampled sites within each strata that were sampled in the Chiwawa River basin in 2007.

| Reach/stratum | River kilometers (RKm) | Number of randomly selected sites |
|---|---|---|
| **Chiwawa River** | | |
| 1 | 0.0-6.1 | 12 |
| 2 | 6.1-8.9 | 6 |
| 3 | 8.9-12.7 | 8 |
| 4 | 12.7-14.3 | 6 |
| 5 | 14.3-17.4 | 4 |
| 6 | 17.4-19.0 | 7 |
| 7 | 19.0-32.2 | 39 |
| 8 | 32.2-40.9 | 22 |
| 9 | 40.9-46.4 | 11 |
| 10 | 46.4-50.1 | 8 |
| **Phelps Creek** | | |
| 1 | 0.0-0.6 | 3 |
| **Chikamin Creek (includes Minnow Creek)** | | |
| 1 | 0.0-1.5 | 29 |
| **Rock Creek** | | |
| 1 | 0.0-1.2 | 12 |
| **Peven Creek (unnamed stream on USGS map)** | | |
| 1 | 0.0-0.1 | 6 |
| **Big Meadow Creek** | | |
| 1 | 0.0-1.6 | 21 |
| **Alder Creek** | | |
| 1 | 0.0-0.1 | 2 |
| **Brush Creek** | | |
| 1 | 0.0-0.1 | 4 |
| **Y Creek** | | |
| 1 | 0.0-0.1 | 2 |

**Table 2.6.** Number of wild spring Chinook and steelhead proposed for tagging at different locations within the Wenatchee Basin, 2007.

| Sampling location | Target sample size | |
|---|---|---|
| | Wild spring Chinook | Wild steelhead |
| Chiwawa Trap | 2,500-8,000 | 500-2,000 |
| Chiwawa River | 500-2,000 | 500-2,000 |
| Upper Wenatchee Trap | 500-1,000 | 50-250 |
| Upper Wenatchee | 500-2,000 | 500-2,000 |
| Nason Creek | 500-2,000 | 500-2,000 |
| Lower Wenatchee Trap | 1,000-2,000 | 500-2,500 |
| **Total** | **5,500-17,000** | **2,550-10,750** |

Survival rates for various juvenile life-stages were calculated based on estimates of seeding levels (total egg deposition), numbers of parr, numbers of emigrants, and numbers of smolts. Total egg deposition was estimated as the product of the number of redds counted in the basin times the mean fecundity of female spawners. Fecundity was estimated from females collected for broodstock using an electronic egg counter. Numbers of emigrants and smolts were estimated at trapping sites and numbers of parr were estimated using snorkel observations only in the Chiwawa Basin. Survival estimates could not be calculated for some stocks (e.g., summer Chinook) because life-stage abundance estimates were lacking.

## 2.4 Spawning/Carcass Surveys

Methods for conducting carcass and spawning ground surveys are detailed in Appendix F in Murdoch and Peven (2005). Information collected during spawning surveys included spawn timing, redd distribution, and redd abundance. Data collected during carcass surveys included sex, size (fork length and postorbital-to-hypural length), scales for aging[1], degree of egg voidance, DNA samples, and identification of marks or tags. The sampling goal for carcasses was 20% of the spawning population. Crews also conducted snorkel surveys to assess the incidence of precocial fish spawning naturally in streams.

Both redd and carcass surveys were conducted in reaches that encompassed the spawning distribution of most populations. Steelhead surveys were the exception. These surveys were conducted within major spawning areas in the basin and therefore may not capture the entire spawning distribution of the population. Steelhead surveys were conducted during March through June in reaches and index areas described in Table 2.7. Total redd counts were estimated by expanding counts within non-index areas by expansion factors developed within index areas.

[1] In this report we use two methods of describing age. One is termed the "European Method." This method has two digits, separated by a period. The first digit represents the number of winters the fish spent in freshwater before emigrating to the sea. The second digit indicates the number of winters the fish spent in the ocean. For example, a fish designated as 1.2 spent one winter in freshwater and two in the ocean. A fish designated as 0.3 emigrated to the ocean in its first year and spent three winters in the ocean. The other method describes the total age of the fish (egg-to-spawning adult, i.e., gravel-to-gravel), so fish demarcated as 0.3 or 1.2 are considered 4-year-olds, from the same brood.

**Table 2.7.** Description of reaches and index areas surveyed for steelhead redds in the Wenatchee Basin.

| Stream | Code | Reach | Index/reference area |
|---|---|---|---|
| Wenatchee River | W2 | Sleepy Hollow Br to L. Cashmere Br | Monitor Boat Rmp to Cashmere Boat Rmp |
| | W6 | Leavenworth Br to Icicle Rd Br | Leavenworth Boat Ramp to Icicle Ck |
| | W8 | Tumwater Dam to Tumwater Br | Swift Boat Ramp to Tumwater Br |
| | W9 | Tumwater Br to Chiwawa R | Tumwater Br to Plain |
| | W10 | Chiwawa R to Lk Wenatchee | Chiwawa Pump St. to Lk Wenatchee |
| Peshastin Creek | P1 | Mouth to Camas Cr | Kings Br to Camas Cr |
| | P2A | Camas Cr to Mouth of Scotty Cr | Ingalls Cr to Ruby Cr |
| | P2 | Camas Cr to Mouth of Scotty Cr | FR7620 to Shaser Cr |
| Ingalls Creek | D1 | Mouth to Trailhead RM 1 | Mouth to Trailhead RM 1 |
| | D2 | Trailhead to Wilderness Bd RM 1.5 | Trailhead to Wilderness Bd RM 1.5 |
| Chiwawa River | C1 | Mouth to Grouse Cr | Mouth to Rd 62 Br RM 6.4 |
| | C2 | Grouse Cr to Rock Cr | Chikamin Cr to Log Jam |
| Clear Creek | V1 | Mouth to Hwy 22 | Mouth to Hwy 22 |
| | V2 | Hwy 22 to Lower Culvert RM 2 | Hwy 22 to Lower Culvert |
| Nason Creek | N1 | Mouth to Kahler Cr Br | Mouth to Swamp Cr |
| | N3 | Hwy 2 Br to Lower RR Br | Hwy 2 Br to Merrit Br |
| | N4 | Lower RR Br to Whitepine Cr | Rayrock to Church Camp |
| Icicle River | I1 | Mouth to Hatchery | Mouth to Boulder Block |
| Little Wenatchee | L2 | Mouth to Lost Cr | Old Fish Weir to Lost Cr |
| | L3 | Lost Cr to Rainy Cr Br | Lost Cr to Rainy Cr Br |
| White River | H2 | Sears Cr Br to Napeequa R | Riprap Bank to Napeequa R |
| | H3 | Napeequa R to Mouth of Panther Cr | Napeequa R to Grasshopper Meadows |
| Napeequa River | Q1 | Mouth to RM 1 | Mouth to RM1 |

Spring Chinook redd and carcass surveys were conducted during August through September in the Chiwawa River (including Rock and Chikamin creeks), Nason Creek, Icicle Creek, Peshastin Creek (including Ingalls Creek), upper Wenatchee River, Little Wenatchee River, and the White River (including the Napeequa River and Panther Creek). Survey reaches for spring Chinook are described in Table 2.8.

**Table 2.8.** Description of reaches surveyed for spring Chinook redds and carcasses in the Wenatchee Basin.

| Stream | Code | Reach | River mile (RM) |
|---|---|---|---|
| Chiwawa River | C1 | Mouth to Grouse Creek | 0.0-11.7 |
| | C2 | Grouse Creek to Rock Creek | 11.7-19.3 |
| | C3 | Rock Creek to Schaefer Creek | 19.3-22.4 |
| | C4 | Schaefer Creek to Atkinson Flats | 22.4-25.6 |
| | C5 | Atkinson Flats to Maple Creek | 25.6-27.0 |
| | C6 | Maple Creek to Trinity | 27.0-30.3 |
| Rock Creek | R1 | Mouth to End | 0.0-0.5 |
| Chikamin Creek | K1 | Mouth to End | 0.0-0.5 |
| Nason Creek | N1 | Mouth to Kahler Creek Bridge | 0.0-3.9 |
| | N2 | Kahler Creek Bridge to Hwy 2 Bridge | 3.9-8.3 |
| | N3 | Hwy 2 Bridge to Lower RR Bridge | 8.3-13.2 |
| | N4 | Lower RR Bridge to Whitepine Creek | 13.2-15.4 |
| Little Wenatchee River | L2 | Old Fish Weir to Lost Creek | 2.7-5.2 |
| | L3 | Lost Creek to Rainy Creek | 5.2-9.2 |
| | L4 | Rainy Creek to Falls | 9.2-Falls |
| White River | H2 | Sears Creek Bridge to Napeequa River | 6.4-11.0 |
| | H3 | Napeequa River to Grasshopper Meadows | 11.0-12.9 |
| Napeequa River | Q1 | Mouth to End | 0.0-1.0 |
| Panther Creek | T1 | Mouth to End | 0.0-0.7 |
| Wenatchee River | W9 | Tumwater Bridge to Chiwawa River | 35.6-48.4 |
| | W10 | Chiwawa River to Lake Wenatchee | 48.4-54.2 |
| Icicle Creek | I1 | Mouth to Boulder Block | 0.0-4.0 |
| Peshastin Creek | P1 | Mouth to Camas Creek | 0.0-5.9 |
| | P2 | Camas Creek to Mouth of Scotty Creek | 5.9-16.3 |
| Ingalls Creek | D1 | Mouth to Trailhead | 0.0-1.0 |

Surveys for live sockeye and carcass were conducted during August through October in the White, Napeequa, and Little Wenatchee rivers. No sockeye redds were counted in 2007. Live fish counts were used to estimate spawning escapements using the area-under-the-curve (AUC) method.

**Table 2.9.** Description of reaches surveyed for sockeye salmon carcasses and live fish in the Wenatchee Basin.

| Stream | Code | Reach | River mile (RM) |
|---|---|---|---|
| Little Wenatchee River | L1 | Mouth to Old Fish Weir | 0.0-2.7 |
| | L2 | Old Fish Weir to Lost Creek | 2.7-5.2 |
| | L3 | Lost Creek to Rainy Creek | 5.2-9.2 |
| White River | H1 | Mouth to Sears Creek Bridge | 0.0-6.4 |
| | H2 | Sears Creek Bridge to Napeequa River | 6.4-11.0 |
| | H3 | Napeequa River to Grasshopper Meadows | 11.0-12.9 |
| Napeequa River | Q1 | Mouth to End | 0.0-1.0 |

Wenatchee summer Chinook surveys were conducted during September through November within ten reaches on the Wenatchee River (Table 2.10). Both peak redd counts and total redd counts were estimated in the Wenatchee River. Total redd counts were only conducted within index areas, not throughout the entire river. Total redd counts for the entire river were estimated by expanding the peak counts within non-index areas by expansion factors developed within index areas.

**Table 2.10.** Description of reaches and index areas surveyed for summer Chinook redds in the Wenatchee Basin.

| Code | Reach | River mile | Index/reference area |
|---|---|---|---|
| W1 | Mouth to Sleepy Hollow Br | 0.0-3.5 | Monitor Br to L. Cashmere Br |
| W2 | Sleepy Hollow Br to L. Cashmere Br | 3.5-9.5 | |
| W3 | L. Cashmere Br to Dryden Dam | 9.5-17.5 | |
| W4 | Dryden Dam to Peshastin Br | 17.5-20.0 | Dryden Dam to Peshastin Br |
| W5 | Peshastin Br to Leavenworth Br | 20.0-23.9 | |
| W6 | Leavenworth Br to Icicle Rd Br | 23.9-26.4 | Icicle to Takeout |
| W7 | Icicle Rd Br to Tumwater Dam | 26.4-30.9 | Swiftwater Campground to Tumwater Br |
| W8 | Tumwater Dam to Tumwater Br | 30.9-35.6 | |
| W9 | Tumwater Br to Chiwawa River | 35.6-48.4 | Swing Pool to Railroad Tunnel |
| W10 | Chiwawa River to Lake Wenatchee | 48.4-54.2 | Swamp to Bridge |

Summer Chinook surveys were also conducted in the Methow, Okanogan, and Similkameen rivers during September through November. Total redd counts were conducted in these rivers. Table 2.11 describes the survey reaches in these rivers.

**Table 2.11.** Description of reaches surveyed for summer Chinook redds and carcasses on the Methow, Okanogan, and Similkameen rivers.

| Stream | Code | Reach | River mile (RM) |
|---|---|---|---|
| Methow River | M1 | Mouth to Methow Bridge | 0.0-14.8 |
| | M2 | Methow Bridge to Carlton Bridge | 14.8-27.2 |
| | M3 | Carlton Bridge to Twisp Bridge | 27.2-39.6 |
| | M4 | Twisp Bridge to MVID | 39.6-44.9 |
| | M5 | MVID to Winthrop Bridge | 44.9-49.8 |
| | M6 | Winthrop Bridge to Hatchery Dam | 49.8-51.6 |
| Okanogan River | O1 | Mouth to Mallot Bridge | 0.0-16.9 |
| | O2 | Mallot Bridge to Okanogan Bridge | 16.9-26.1 |
| | O3 | Okanogan Bridge to Omak Bridge | 26.1-30.7 |
| | O4 | Omak Bridge to Riverside Bridge | 30.7-40.7 |
| | O5 | Riverside Bridge to Tonasket Bridge | 40.7-56.8 |
| | O6 | Tonasket Bridge to Zosel Dam | 56.8-77.4 |
| Similkameen River | S1 | Driscoll Channel to Oroville Bridge | 0.0-1.8 |
| | S2 | Oroville Bridge to Enloe Dam | 1.8-5.7 |

Except for sockeye, total spawning escapements for each population were estimated as the product of total number of redds times the ratio of fish per redd for a specific stock. Fish per redd ratios were estimated as the ratio of males to females sampled at broodstock collection sites. Total spawning escapement for sockeye salmon was estimated using the AUC approach (where escapement = (AUC/redd residence time) x observer efficiency). This method relied on weekly counts of live sockeye and assumed a redd residence time of 11 days (from Hyatt et al. 2006) and an observer efficiency of 100%.[2]

During sockeye carcass surveys in 2007, crews collected tissue samples for genetic analysis. Tissue was collected from the operculum of wild and hatchery carcasses (target of 144 wild and 144 hatchery fish). Sampling within a population was proportional to the distribution of carcasses across survey reaches. That is, samples were collected in all reaches but the number collected within a given reach was proportional to the density of carcasses within that reach. Methods for analyzing these samples are described in Appendix H in Murdoch and Peven (2005).

Derived metrics calculated from carcass surveys, broodstock sampling, stock assessments, and harvest records included proportion of hatchery spawners, stray rates, age-at-maturity, length-at-age, smolt-to-adult survival (SAR), hatchery replacement rates (HRR), exploitation rates, harvest rates, and natural replacement rates (NRR). The expected SARs and HRRs for different stocks raised in the Chelan PUD hatchery programs are provided in Table 2.12. Methods for calculating these variables are described in Appendices D, F, and G in Murdoch and Peven (2005).

[2] Estimates for residence time and observer efficiency are from the literature. These parameters will be estimated in the Wenatchee Basin beginning in 2008.

**Table 2.12.** Expected smolt-to-adult (SAR) and hatchery replacement rates (HRR) for stocks raised in the Chelan PUD Hatchery Programs (from Table 6 in Appendix D in Murdoch and Peven 2005).

| Program | Number of broodstock | Smolts released | SAR | Adult equivalents | Number of smolts/adult | HRR |
|---|---|---|---|---|---|---|
| Chiwawa Spring Chinook | 379 | 672,000 | 0.003 | 2,016 | 333 | 5.3 |
| Wenatchee Summer Chinook | 492 | 864,000 | 0.003 | 2,592 | 333 | 5.3 |
| Similkameen Summer Chinook | 328 | 576,000 | 0.003 | 1,728 | 333 | 5.3 |
| Methow Summer Chinook | 228 | 400,000 | 0.003 | 1,200 | 333 | 5.3 |
| Wenatchee Sockeye | 260 | 200,000 | 0.007 | 1,400 | 143 | 5.4 |
| Wenatchee Steelhead | 208 | 400,000 | 0.010 | 4,000 | 100 | 19.2 |

Derived data that rely on CWTs (e.g., HRR, SAR, stray rates, etc.) are two to four years behind release information because of the lag time for returning adult fish to enter the fishery and the processing of tags. Consequently, complete information on rates and ratios based on CWTs is generally only available for years prior to 2001. In addition, methods for calculating derived variables are still being developed by the Hatchery Evaluation Technical Team (HETT). Therefore, estimates of derived data in this report are subject to change after the HETT and Hatchery Committee decide on standard methods for calculating derived data.

# SECTION 3: WENATCHEE STEELHEAD

## 3.1 Broodstock Sampling

This section focuses on results from sampling 2006 and 2007 brood years of Wenatchee steelhead, which were collected at Dryden and Tumwater dams. The 2006 brood begins the tracking of the life cycle of steelhead released in 2007. The 2007 brood is included because juveniles from this brood are still maintained within the hatchery.

### Origin of Broodstock

A total of 199 Wenatchee steelhead from the 2005 return (2006 brood) were collected at Dryden and Tumwater dams (Table 3.1). About 51% of these were natural origin (adipose fin present, no CWT, and no elastomer tags) fish and the remaining 49% were hatchery origin (pink right, orange right, or green left elastomer tagged) adults. Origin was determined by analyzing scales and/or otoliths. The total number of steelhead spawned from the 2006 return was 162 adults (57% natural origin and 43% hatchery origin).

A total of 176 steelhead were collected from the 2006 return (2007 brood) at Dryden and Tumwater dams; 79 natural origin (adipose fin present, no CWT and no elastomer tags) and 97 hatchery origin (pink right, orange right, or green left elastomer tagged) adults. A total of 134 steelhead were spawned; 57% were natural origin fish and 43% were hatchery fish (Table 3.1). Origins were confirmed by sampling scales and/or otoliths.

**Table 3.1**. Numbers of wild and hatchery steelhead collected for broodstock, numbers that died before spawning, and numbers of steelhead spawned, 1998-2007. Unknown origin fish (i.e., undetermined by scale analysis, no elastomer, CWT, or fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes fish that died of natural causes typically near the end of spawning and were not needed for the program or were immature fish killed at spawning.

| Brood year | Wild steelhead | | | | | Hatchery steelhead | | | | | Total number spawned |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number collected | Prespawn loss | Mortality | Number spawned | Number released | Number collected | Prespawn loss | Mortality | Number spawned | Number released | |
| 1998 | 35 | 0 | 0 | 35 | 0 | 43 | 4 | 2 | 37 | 0 | 72 |
| 1999 | 58 | 5 | 1 | 52 | 0 | 67 | 1 | 2 | 64 | 0 | 116 |
| 2000 | 39 | 2 | 1 | 36 | 0 | 101 | 9 | 12 | 60 | 20 | 96 |
| 2001 | 64 | 5 | 8 | 51 | 0 | 114 | 5 | 6 | 103 | 0 | 154 |
| 2002 | 99 | 0 | 1 | 96 | 2 | 113 | 1 | 0 | 64 | 48 | 160 |
| 2003 | 63 | 10 | 4 | 49 | 0 | 92 | 2 | 0 | 90 | 0 | 139 |
| 2004 | 85 | 3 | 0 | 75 | 7 | 132 | 1 | 0 | 61 | 70 | 136 |
| 2005 | 95 | 8 | 0 | 87 | 0 | 114 | 7 | 1 | 104 | 2 | 191 |
| 2006 | 101 | 5 | 0 | 93 | 3 | 98 | 0 | 0 | 69 | 29 | 162 |
| 2007 | 79 | 0 | 2 | 76 | 1 | 97 | 0 | 14 | 58 | 25 | 134 |
| ***Average*** | ***72*** | ***4*** | ***2*** | ***65*** | ***1*** | ***97*** | ***3*** | ***4*** | ***71*** | ***19*** | ***136*** |

### Age/Length Data

Broodstock ages were determined from examination of scales and/or otoliths. For both the 2006 and 2007 returns, natural origin steelhead consisted primarily of 2-salt adults, while hatchery origin adults for both return years consisted mostly of 1-salt fish (Table 3.2).

**Table 3.2.** Percent of hatchery and wild steelhead of different ages (saltwater ages) collected from broodstock, 1998-2007.

| Return year | Origin | Saltwater age | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 1998 | Wild | 39.4 | 60.6 | 0.0 |
| | Hatchery | 20.9 | 79.1 | 0.0 |
| 1999 | Wild | 50.0 | 48.3 | 1.7 |
| | Hatchery | 81.8 | 18.2 | 0.0 |
| 2000 | Wild | 56.4 | 43.6 | 0.0 |
| | Hatchery | 67.9 | 32.1 | 0.0 |
| 2001 | Wild | 51.7 | 48.3 | 0.0 |
| | Hatchery | 14.9 | 85.1 | 0.0 |
| 2002 | Wild | 55.6 | 44.4 | 0.0 |
| | Hatchery | 94.6 | 5.4 | 0.0 |
| 2003 | Wild | 13.1 | 85.3 | 1.6 |
| | Hatchery | 29.4 | 70.6 | 0.0 |
| 2004 | Wild | 94.8 | 5.2 | 0.0 |
| | Hatchery | 95.2 | 4.8 | 0.0 |
| 2005 | Wild | 22.1 | 77.9 | 0.0 |
| | Hatchery | 20.5 | 79.5 | 0.0 |
| 2006 | Wild | 28.7 | 71.3 | 0.0 |
| | Hatchery | 60.3 | 39.7 | 0.0 |
| 2007 | Wild | 40.3 | 59.3 | 0.0 |
| | Hatchery | 62.1 | 37.9 | 0.0 |
| ***Average*** | ***Wild*** | ***45.3*** | ***54.4*** | ***0.3*** |
| | ***Hatchery*** | ***54.8*** | ***45.2*** | ***0.0*** |

There was little difference between mean lengths of hatchery and natural origin steelhead for both the 2006 and 2007 return years (Table 3.3). Natural origin fish were on average <1 to 5 cm larger than hatchery origin fish of the same age.

**Table 3.3.** Mean fork length (cm) at age (saltwater ages) of hatchery and wild steelhead collected from broodstock, 1998-2007; N = sample size and SD = 1 standard deviation.

| Return year | Origin | Steelhead fork length (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1-Salt | | | 2-Salt | | | 3-Salt | | |
| | | Mean | N | SD | Mean | N | SD | Mean | N | SD |
| 1998 | Wild | 63 | 15 | 4 | 79 | 20 | 5 | - | 0 | - |
| | Hatchery | 61 | 9 | 4 | 73 | 34 | 4 | - | 0 | - |
| 1999 | Wild | 65 | 29 | 5 | 74 | 28 | 5 | 77 | 1 | - |
| | Hatchery | 62 | 54 | 4 | 73 | 12 | 4 | - | 0 | - |
| 2000 | Wild | 64 | 22 | 3 | 74 | 17 | 5 | - | 0 | - |
| | Hatchery | 60 | 57 | 3 | 71 | 27 | 4 | - | 0 | - |
| 2001 | Wild | 61 | 33 | 6 | 77 | 31 | 5 | - | 0 | - |
| | Hatchery | 62 | 17 | 4 | 72 | 97 | 4 | - | 0 | - |
| 2002 | Wild | 64 | 55 | 4 | 77 | 44 | 4 | - | 0 | - |
| | Hatchery | 63 | 106 | 4 | 73 | 6 | 4 | - | 0 | - |
| 2003 | Wild | 69 | 8 | 6 | 77 | 52 | 5 | 91 | 1 | - |
| | Hatchery | 66 | 27 | 4 | 75 | 65 | 4 | - | 0 | - |
| 2004 | Wild | 63 | 73 | 6 | 78 | 4 | 2 | - | 0 | - |
| | Hatchery | 61 | 59 | 3 | 73 | 3 | 1 | - | 0 | - |
| 2005 | Wild | 59 | 21 | 4 | 74 | 74 | 5 | - | 0 | - |
| | Hatchery | 59 | 23 | 4 | 72 | 89 | 4 | - | 0 | - |
| 2006 | Wild | 63 | 27 | 5 | 75 | 67 | 6 | - | 0 | - |
| | Hatchery | 61 | 41 | 4 | 72 | 27 | 5 | - | 0 | - |
| 2007 | Wild | 64 | 31 | 6 | 76 | 46 | 5 | - | 0 | - |
| | Hatchery | 60 | 60 | 4 | 71 | 36 | 5 | - | 0 | - |

### Sex Ratios

Male steelhead in the 2006 return made up about 43% of the adults collected, resulting in an overall male to female ratio of 0.75:1.00 (Table 3.4). For the 2007 return, males made up about 48% of the adults collected, resulting in an overall male to female ratio of 0.93:1.00. On average, the sex ratio is less than the 1:1 ratio assumed in the broodstock protocol (Table 3.4).

**Table 3.4.** Numbers of male and female wild and hatchery steelhead collected for broodstock, 1998-2007. Ratios of males to females are also provided.

| Return year | Number of wild steelhead | | | Number of hatchery steelhead | | | Total M/F ratio |
|---|---|---|---|---|---|---|---|
| | Males (M) | Females (F) | M/F | Males (M) | Females (F) | M/F | |
| 1998 | 13 | 22 | 0.59:1.00 | 15 | 28 | 0.54:1.00 | 0.56:1.00 |
| 1999 | 22 | 36 | 0.61:1.00 | 35 | 32 | 1.09:1.00 | 0.84:1.00 |
| 2000 | 18 | 21 | 0.86:1.00 | 60 | 41 | 1.46:1.00 | 1.26:1.00 |
| 2001 | 38 | 26 | 1.46:1.00 | 40 | 74 | 0.54:1.00 | 0.78:1.00 |
| 2002 | 32 | 67 | 0.48:1.00 | 81 | 32 | 2.53:1.00 | 1.14:1.00 |
| 2003 | 19 | 44 | 0.43:1.00 | 44 | 48 | 0.92:1.00 | 0.68:1.0 |
| 2004 | 43 | 42 | 1.02:1.00 | 90 | 42 | 2.14:1.00 | 1.58:1.00 |
| 2005 | 36 | 59 | 0.61:1.00 | 46 | 68 | 0.68:1.00 | 0.65:1.00 |
| 2006 | 38 | 63 | 0.60:1.00 | 47 | 51 | 0.92:1.00 | 0.75:1.00 |
| 2007 | 36 | 43 | 0.84:1.00 | 49 | 48 | 1.02:1.00 | 0.93:1.00 |
| ***Total*** | ***295*** | ***423*** | ***0.70:1.00*** | ***507*** | ***464*** | ***1.09:1.00*** | ***0.90:1.00*** |

## Fecundity

Fecundities for Wenatchee steelhead returning in 2006 and 2007 averaged 5,492 and 5,660 eggs per female, respectively, which were not greatly different than the 10-year average (Table 3.5). Mean fecundities for the 2006 and 2007 returns were greater than the 5,400 eggs per female assumed in the broodstock protocol.

**Table 3.5.** Mean fecundity of wild, hatchery, and all female steelhead collected for broodstock, 1998-2007.

| Return year | Mean fecundity | | |
|---|---|---|---|
| | Wild | Hatchery | Total |
| 1998 | 6,202 | 5,558 | 5,924 |
| 1999 | 5,691 | 5,186 | 5,424 |
| 2000 | 5,858 | 5,729 | 5,781 |
| 2001 | 5,951 | 6,359 | 6,270 |
| 2002 | 5,776 | 5,262 | 5,626 |
| 2003 | 6,561 | 6,666 | 6,621 |
| 2004 | 5,118 | 5,353 | 5,238 |
| 2005 | 5,545 | 6,061 | 5,832 |
| 2006 | 5,688 | 5,251 | 5,492 |
| 2007 | 5,840 | 5,485 | 5,660 |
| ***Average*** | ***5,823*** | ***5,691*** | ***5,787*** |

## 3.2 Hatchery Rearing

### Rearing History

#### *Number of eggs taken*

Based on the unfertilized egg-to-release survival standard of 81%, a total of 493,827 eggs are required to meet the program release goal of 400,000 smolts. Between 1998 and 2007, the egg take goal was reached 50% of the time (Table 3.6).

**Table 3.6.** Numbers of eggs taken from steelhead broodstock, 1998-2007.

| Brood year | Number of eggs taken |
|---|---|
| 1998 | 224,315 |
| 1999 | 303,083 |
| 2000 | 280,872 |
| 2001 | 549,464 |
| 2002 | 503,030 |
| 2003 | 532,708 |
| 2004 | 408,538 |
| 2005 | 672,667 |
| 2006 | 546,382 |
| 2007 | 462,662 |
| ***Average*** | ***448,372*** |

#### *Number of acclimation days*

Juvenile steelhead were transferred from Chelan FH to Turtle Rock FH in December 2006 and from Eastbank FH to Turtle Rock FH in January 2007. At Turtle Rock FH, juvenile steelhead were reared on Columbia River water (range, 111-148 d) before being trucked and released into the Wenatchee River and tributaries.

Acclimation of Wenatchee juvenile steelhead has occurred on occasion in the Chiwawa Ponds when space is available. At Chiwawa Ponds, steelhead were reared under the same water source as spring Chinook (Chiwawa and Wenatchee River water). Typically, Wenatchee steelhead are reared on Columbia River water from January through April before being trucked and released into the Wenatchee Basin (Table 3.7).

**Table 3.7.** Water source and mean acclimation period for Wenatchee steelhead, brood years 1998-2006.

| Brood year | Release year | Parental origin | Water source | Number of Days |
|---|---|---|---|---|
| 1998 | 1999 | H x H | Wenatchee/Chiwawa | 36 |
| | | H x W | Wenatchee/Chiwawa | 36 |
| | | W x W | Wenatchee/Chiwawa | 36 |
| 1999 | 2000 | H x H | Wenatchee/Chiwawa | 138 |
| | | H x W | Wenatchee/Chiwawa | 138 |
| | | W x W | Wenatchee/Chiwawa | 138 |
| | | H x W | Eastbank | 0 |
| | | W x W | Eastbank | 0 |
| 2000 | 2001 | H x H | Wenatchee/Chiwawa | 122 |
| | | H x W | Wenatchee/Chiwawa | 122 |
| | | H x W | Wenatchee/Chiwawa | 122 |
| | | W x W | Wenatchee/Chiwawa | 122 |
| 2001 | 2002 | H x H | Columbia | 92 |
| | | H x H | Wenatchee/Chiwawa | 63 |
| | | H x W | Columbia | 92 |
| | | H x W | Wenatchee/Chiwawa | 63 |
| | | W x W | Columbia | 153 |
| 2002 | 2003 | H x H | Columbia | 98 |
| | | H x W | Columbia | 98 |
| | | W x W | Columbia | 117 |
| 2003 | 2004 | H x H | Columbia | 88 |
| | | H x W | Wenatchee/Chiwawa | 84 |
| | | W x W | Columbia | 148 |
| 2004 | 2005 | H x H | Columbia | 160 |
| | | H x W | Columbia | 160 |
| | | W x W | Columbia | 160 |
| 2005 | 2006 | H x H | Columbia | 116 |
| | | H x W | Columbia | 113 |
| | | W x W | Columbia | 141 |
| 2006 | 2007 | Early H x W | Columbia | 111 |
| | | Late H x W | Columbia | 112 |
| | | W x W | Columbia | 148 |

## Release Information

### *Numbers released*

The release of 2006 brood Wenatchee steelhead achieved 75% of the 400,000 target goal with about 299,937 fish released directly into the Wenatchee and Chiwawa rivers and Nason Creek (Table 3.8). Distribution of juvenile steelhead released in each of the three basins was determined by the mean proportion of steelhead redds in each basin. About 31.0% and 16.3% of the steelhead were released in Nason Creek and the Chiwawa River, respectively. The balance of the program was split between the Wenatchee River downstream from Tumwater Dam (12.6%) and the Wenatchee River upstream from the dam (40.1%).

**Table 3.8.** Numbers of steelhead smolts released from the hatchery, brood years 1998-2006. The release target for steelhead is 400,000 smolts.

| Brood year | Release year | Number of smolts |
|---|---|---|
| 1998 | 1999 | 172,078 |
| 1999 | 2000 | 175,661 |
| 2000 | 2001 | 184,639 |
| 2001 | 2002 | 335,933 |
| 2002 | 2003 | 302,060 |
| 2003 | 2004 | 374,867 |
| 2004 | 2005 | 294,114 |
| 2005 | 2006 | 452,184 |
| 2006 | 2007 | 299,937 |
| ***Average*** | | ***287,941*** |

### *Numbers elastomer tagged*

Wenatchee hatchery steelhead from the 2006 brood were marked with elastomer tags in the clear tissue posterior of the eye to denote parental origin. About 52% of the juveniles released were also adipose fin clipped (Table 9).

**Table 3.9.** Release location and marking scheme for the 1998-2006 brood Wenatchee steelhead.

| Brood year | Release location | Parental origin | Ad-clip (%) | VIE color/side | Tag rate | Number released |
|---|---|---|---|---|---|---|
| 1998 | Chiwawa River | H x H | 0.0 | Red Left | 0.994 | 52,765 |
| | Chiwawa River | H x W | 0.0 | Green Left | 0.990 | 37,013 |
| | Chiwawa River | W x W | 0.0 | Orange Left | 0.827 | 82,300 |
| 1999 | Wenatchee River | H x H | 0.0 | Green Left | 0.911 | 45,347 |
| | Wenatchee River | H x W | 0.0 | Orange Left | 0.927 | 30,713 |
| | Chiwawa River | H x H | 0.0 | Red Right | 0.936 | 25,622 |
| | Chiwawa River | H x W | 0.0 | Green Right | 0.936 | 43,379 |
| | Chiwawa River | W x W | 0.0 | Orange Right | 0.936 | 30,600 |

| Brood year | Release location | Parental origin | Ad-clip (%) | VIE color/side | Tag rate | Number released |
|---|---|---|---|---|---|---|
| 2000 | Chiwawa River | H x H | 0.0 | Red Left | 0.963 | 33,417 |
| | Chiwawa River | H x W | 0.0 | Green Left | 0.963 | 57,716 |
| | Chiwawa River | H x W | 0.0 | Green Right | 0.949 | 48,029 |
| | Chiwawa River | W x W | 0.0 | Orange Right | 0.949 | 45,477 |
| 2001 | Nason Creek | H x W | 0.0 | Green Right | 0.934 | 75,276 |
| | Nason Creek | W x W | 0.0 | Orange Right | 0.934 | 48,115 |
| | Chiwawa River | H x W | 0.0 | Green Left | 0.895 | 92,487 |
| | Chiwawa River | H x H | 0.0 | Red Left | 0.895 | 120,055 |
| 2002 | Chiwawa River | H x H | 0.0 | Red Left | 0.920 | 156,145 |
| | Chiwawa River | H x W | 0.0 | Green Left | 0.928 | 33,528 |
| | Nason Creek | W x W | 0.0 | Orange Right | 0.928 | 112,387 |
| 2003 | Wenatchee River | H x H | 0.0 | Red Left | 0.968 | 117,663 |
| | Chiwawa River | H x W | 0.0 | Green Left | 0.927 | 191,796 |
| | Nason Creek | W x W | 0.0 | Orange Right | 0.962 | 65,408 |
| 2004 | Wenatchee River | H x H | 0.50 | Red Left | 0.804 | 39,636 |
| | Chiwawa River | H x W | 0.0 | Green Left | 0.977 | 153,959 |
| | Nason Creek | W x W | 0.0 | Pink Right | 0.940 | 100,519 |
| 2005 | Wenatchee River | H x H | 100.0 | Red Left | 0.983 | 104,552 |
| | Wenatchee River | H x W | 61.6 | Green Left | 0.979 | 190,319 |
| | Chiwawa River | H x W | 61.6 | Green Left | 0.979 | 18,634 |
| | Chiwawa River | W x W | 0.0 | Pink Right | 0.969 | 14,124 |
| | Nason Creek | W x W | 0.0 | Pink Right | 0.969 | 124,555 |
| 2006 | Wenatchee River | H x W (early) | 100.0 | Green Right | 0.918 | 66,022 |
| | Wenatchee River | H x W (late) | 67.1 | Green Left | 0.935 | 92,176 |
| | Chiwawa River | H x W (late) | 67.1 | Green Left | 0.935 | 41,240 |
| | Chiwawa River | W x W | 0.0 | Pink Right | 0.945 | 7,500 |
| | Nason Creek | W x W | 0.0 | Pink Right | 0.945 | 92,999 |

### *Numbers PIT tagged*

***2006 Brood Wenatchee Summer Steelhead (WxW)***—A total of 10,019 WxW steelhead were PIT tagged at the Chelan Falls Hatchery between 21 and 23 August 2006 (Table 3.10). The mean size of steelhead tagged was 72 mm; no fish smaller than 60 mm were tagged. Fish were not fed for 24 hours before or after tagging. Four days following tagging, the fish were transferred to raceways

outside the hatchery complex. These fish were transported to the Turtle Rock Hatchery on 4 December. None of these fish were adipose fin clipped.

A total of 9,515 PIT-tagged WxW steelhead were released during spring 2007 (Table 3.10). Of the 10,019 WxW steelhead tagged, 152 died. Most of these (47%) were fish tagged on the third day (23 August). Another 352 shed their tags. Most of these (61%) were also fish tagged on the third day. Most shedding occurred within three weeks after tagging.

The relatively large loss of steelhead and PIT tags from the third tagging group may be related to the short period of time between tagging and being transferred to another raceway. These fish were also off food for a shorter period of time than the other two tagging groups. It is recommended that the time period between tagging and moving be increased for future tagging events.

**Table 3.10.** Summary of PIT-tagging activities for WxW steelhead from the Chelan Falls Hatchery, 2006. Dead fish counted before 15 September likely represent deaths associated with tagging; deaths after 15 September were probably not related to tagging.

| Tagging date | Number of fish tagged | Number of fish that died | | Number of tags shed | Number of tagged fish alive |
|---|---|---|---|---|---|
| | | Before 9/15 | After 9/15 | | |
| 8/21 | 3,301 | 24 | 16 | 74 | 3,187 |
| 8/22 | 3,418 | 24 | 17 | 64 | 3,313 |
| 8/23 | 3,300 | 57 | 14 | 214 | 3,015 |
| ***Total*** | ***10,019*** | ***105*** | ***47*** | ***352*** | ***9,515*** |

***2006 Brood Wenatchee Summer Steelhead (early-spawn HxW)***[3]—A total of 10,035 early-spawn HxW steelhead were PIT tagged at the Eastbank Hatchery (raceway 4) on 5-7 September 2006 (Table 3.11). The mean size of steelhead tagged was 85 mm; no fish smaller than 60 mm were tagged. Fish were not fed for 24 hours before or after tagging. These fish were transported to the Turtle Rock Hatchery in early January 2007. All of these fish were adipose fin clipped.

A total of 9,533 PIT-tagged HxW steelhead were released during spring 2007 (Table 3.11). Of the 10,035 steelhead tagged, 479 died and another 24 shed their tags.

**Table 3.11.** Summary of PIT-tagging activities for early-spawn HxW steelhead from the Eastbank Hatchery, 2006. Dead fish counted before 15 September likely represent deaths associated with tagging; deaths after 15 September were probably not related to tagging.

| Tagging date | Number of fish tagged | Number of fish that died | | Number of tags shed | Number of tagged fish alive |
|---|---|---|---|---|---|
| | | Before 9/15 | After 9/15 | | |
| 9/5 | 3,331 | 2 | 151 | 6 | 3,172 |
| 9/6 | 3,504 | 5 | 173 | 9 | 3,317 |
| 9/7 | 3,200 | 2 | 146 | 9 | 3,044 |
| ***Total*** | ***10,035*** | ***9*** | ***470*** | ***24*** | ***9,533*** |

[3] This is a mixed group consisting of about 55,000 early-spawn HxW and about 15,000 HxH steelhead. Because most (78%) of the fish are HxW juveniles, the group is referred to as "early-spawn HxW."

***2006 Brood Wenatchee Summer Steelhead (HxW)***—A total of 10,031 HxW steelhead were PIT tagged at the Eastbank Hatchery (raceway 3) on 11-13 September 2006 (Table 3.12). The mean size of steelhead tagged was 80 mm; no fish smaller than 60 mm were tagged. Fish were not fed for 24 hours before or after tagging. These fish were transported to the Turtle Rock Hatchery in early January 2007. None of these fish were adipose fin clipped.

A total of 9,089 PIT-tagged HxW steelhead were released during spring 2007 (Table 3.12). Of the 10,031 steelhead tagged, 922 died and another 20 shed their tags. The relatively high mortality rate was associated with a power outage on 7 January 2007, which caused an anoxic condition that killed at least 836 tagged fish in the hatchery.[4]

**Table 3.12.** Summary of PIT-tagging activities for HxW steelhead from the Eastbank Hatchery, 2006. Dead fish counted before 15 September likely represent deaths associated with tagging; deaths after 15 September were probably not related to tagging. A power outage on 7 January 2007 killed about 836 PIT-tagged fish.

| Tagging date | Number of fish tagged | Number of fish that died | | Number of tags shed | Number of tagged fish alive |
|---|---|---|---|---|---|
| | | Before 9/15 | After 9/15 | | |
| 9/11 | 3,315 | 1 | 279 | 6 | 3,029 |
| 9/12 | 3,552 | 1 | 346 | 6 | 3,199 |
| 9/13 | 3,164 | 2 | 293 | 8 | 2,861 |
| ***Total*** | ***10,031*** | ***4*** | ***918*** | ***20*** | ***9,089*** |

***2007 Brood Wenatchee Summer Steelhead (WxW)***—A total of 10,051 steelhead were tagged at the Chelan Hatchery during 24-27 September 2007. These fish came from raceway 2 and consisted of wild x wild crosses.

As of the end of January 2008, a total of 43 tagged steelhead have died and no shed tags have been identified. This leaves a total of 10,008 tagged steelhead alive at the hatchery. These fish were transferred to the Turtle Rock Hatchery on 19 January. They will remain at this facility until release in the spring of 2008.

***2007 Brood Wenatchee Summer Steelhead (HxW-early production)***—A total of 10,052 steelhead were tagged at Eastbank Hatchery between 4 and 13 September 2007. These fish came from raceway 4 and consisted of hatchery x wild-early spawn crosses.

As of the end of January 2008, a total of 48 tagged steelhead have died and another 10 have shed their tags. This leaves an estimated 9,994 tagged steelhead alive at the hatchery. These fish were transferred to the Turtle Rock Hatchery between 4 and 6 February 2008 where they will remain until release in the spring of 2008.

***2007 Brood Wenatchee Summer Steelhead (HxW-late production)***—A total of 10,063 steelhead were tagged at Eastbank Hatchery between 4 and 13 September 2007. These fish came from raceway 3 and consisted of hatchery x wild-late spawn crosses.

[4] Because of the length of the power outage, hatchery personnel began releasing steelhead into the Columbia River. During the release, power was restored and the release ceased. An underdetermined (assumed small) number of steelhead was released into the Columbia River.

As of the end of January 2008, a total of 41 tagged steelhead have died and another 71 have shed their tags. This leaves an estimated 9,951 tagged steelhead alive at the hatchery. These fish were transferred to the Turtle Rock Hatchery between 4 and 6 February 2008 where they will remain until release in the spring of 2008.

### *Fish size and condition at release*

All 2006 brood steelhead were trucked and released as yearling smolts in May of 2007. Of the three parental groups, only the early H x W group exceeded length and weight targets. The late H x W and the W x W group (which is typically the last group ponded and therefore has a shorter rearing period) did not meet size-at-release targets. All three groups did not meet the target for coefficient of variation for fork length (Table 3.13).

**Table 3.13.** Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of steelhead smolts released from the hatchery, brood years 1998-2006. Size targets are provided in the last row of the table.

| Brood year | Release year | Parental origin | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|---|
| | | | Mean | CV | Grams (g) | Fish/pound |
| 1998 | 1999 | H x H | 201 | 11.1 | 92.3 | 5 |
| | | H x W | 190 | 12.8 | 76.9 | 6 |
| | | W x W | 173 | 12.0 | 55.3 | 8 |
| 1999 | 2000 | H x H | 181 | 8.9 | 70.6 | 6 |
| | | H x W | 187 | 7.2 | 75.3 | 6 |
| | | W x W | 184 | 11.3 | 71.5 | 6 |
| 2000 | 2001 | H x H | 218 | 15.2 | 122.4 | 4 |
| | | H x W | 209 | 10.6 | 107.5 | 4 |
| | | W x W | 205 | 10.7 | 100.9 | 5 |
| 2001 | 2002 | H x H | 179 | 17.4 | 67.0 | 7 |
| | | H x W | 192 | 15.6 | 82.8 | 6 |
| | | W x W | 206 | 11.6 | 102.6 | 4 |
| 2002 | 2003 | H x H | 194 | 13.1 | 83.0 | 6 |
| | | H x W | 191 | 13.0 | 77.4 | 6 |
| | | W x W | 180 | 19.1 | 70.3 | 7 |
| 2003 | 2004 | H x H | 191 | 14.4 | 73.1 | 6 |
| | | H x W | 199 | 12.9 | 83.9 | 5 |
| | | W x W | 200 | 11.1 | 90.1 | 5 |
| 2004 | 2005 | H x H | 204 | 11.3 | 87.2 | 6 |
| | | H x W | 202 | 13.5 | 71.9 | 5 |
| | | W x W | 198 | 12.4 | 76.6 | 6 |
| 2005 | 2006 | H x H | 215 | 12.6 | 116.6 | 4 |
| | | H x W | 198 | 11.8 | 86.3 | 5 |

| Brood year | Release year | Parental origin | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|---|
| | | | Mean | CV | Grams (g) | Fish/pound |
| | | W x W | 189 | 15.4 | 55.3 | 6 |
| 2006 | 2007 | H x H (early) | 213 | 12.1 | 109.6 | 4 |
| | | H x W (late) | 186 | 11.8 | 68.3 | 7 |
| | | W x W | 178 | 11.1 | 58.6 | 8 |
| ***Targets*** | | | ***198*** | ***9.0*** | ***75.6*** | ***6*** |

### Survival Estimates

Overall survival of Wenatchee steelhead from green (unfertilized) egg to release was significantly below the standard set for the program, primarily because of poor green egg-to-eyed egg and eyed egg-to-ponding survival (Table 3.14). In addition, nearly 8% of the 2006 brood H x W component died of asphyxiation at Eastbank Hatchery because of a severe January 2007 wind storm that knocked out power to the facility (including pumps) for several hours. The Wenatchee steelhead program, from its inception, has experienced highly variable fertilization rates. It is unknown at this time what mechanisms may be influencing stock performance at these stages. Early post ponding mortality in the W x W group resulting from chronic bacterial cold water disease was abated with treatments of florfenicol.

**Table 3.14.** Hatchery life-stage survival rates (%) for steelhead, brood years 1998-2006. Survival standards or targets are provided in the last row of the table.

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 1998 | 92.0 | 100.0 | 85.5 | 91.7 | 99.2 | 98.8 | 97.8 | 99.9 | 76.7 |
| 1999 | 91.2 | 100.0 | 66.9 | 93.0 | 95.9 | 94.9 | 93.1 | 99.7 | 58.0 |
| 2000 | 83.9 | 96.2 | 77.6 | 86.7 | 99.3 | 98.9 | 97.7 | 99.5 | 65.7 |
| 2001 | 90.0 | 100.0 | 73.0 | 91.8 | 99.1 | 97.8 | 91.3 | 99.7 | 61.1 |
| 2002 | 99.0 | 100.0 | 69.2 | 93.1 | 95.9 | 94.4 | 89.6 | 89.6 | 57.7 |
| 2003 | 87.0 | 96.8 | 86.3 | 83.8 | 97.2 | 94.8 | 97.6 | 85.3 | 70.6 |
| 2004 | 97.6 | 98.5 | 83.4 | 93.7 | 97.8 | 94.1 | 92.2 | 99.9 | 72.0 |
| 2005 | 91.3 | 95.1 | 81.3 | 92.1 | 95.6 | 91.8 | 89.7 | 99.6 | 67.2 |
| 2006 | 99.1 | 95.3 | 73.2 | 85.4 | 95.4 | 94.6 | 87.8 | 98.5 | 54.9 |
| ***Standard*** | ***90.0*** | ***85.0*** | ***92.0*** | ***98.0*** | ***97.0*** | ***93.0*** | ***90.0*** | ***95.0*** | ***81.0*** |

## *3.3 Disease Monitoring*

Rearing of the 2006 brood Wenatchee summer steelhead was typical to previous years with fish being held on Chelan spring, Eastbank well, and Columbia River water before being released directly into Nason Creek and the Chiwawa and Wenatchee rivers. Mortality due to bacterial cold water disease (BCWD) began to increase in the W x W juveniles at Chelan in May, shortly after

ponding. Aggressive Florfenicol treatments appeared to abate the condition and losses resulting from BCWD quickly declined.

## 3.4 Natural Juvenile Productivity

During 2007, juvenile steelhead were sampled at the Upper Wenatchee, Lower Wenatchee, and Chiwawa traps and counted during snorkel surveys within the Chiwawa basin.

### Parr Estimates

A total of 14,073 (±10.5%) subyearling (<100 mm) and 8,448 (±9.7%) yearling (100-200 mm)[5] steelhead/rainbow were estimated in the Chiwawa River basin in August 2007 (Table 3.15 and 3.16). During the survey period 1992-2007, numbers of subyearling and yearling steelhead/rainbow have ranged from 1,410 to 45,727 and 2,533 to 22,128, respectively, in the Chiwawa Basin (Table 3.15 and 3.16; Figure 3.1). Numbers of all fish counted in the Chiwawa Basin are reported in Appendix A.

Juvenile steelhead/rainbow were distributed primarily throughout the lower seven reaches of the Chiwawa River (downstream from Rock Creek). Their densities were highest in the lower portions of the river and in tributaries. Subyearling steelhead/rainbow most often used riffle and multiple channel habitats in the Chiwawa River, although they also associated with woody debris in pool and glide habitat. In tributaries they were generally most abundant in small pools. Those that were observed in riffles selected stations in quiet water behind small and large boulders or occupied stations in quiet water along the stream margin. In pool and multiple-channel habitats, subyearling steelhead/rainbow used the same kinds of habitat as subyearling Chinook.

Yearling steelhead/rainbow most often used pool, riffle, and multiple-channel habitats. Those that used pools were usually in deeper water than subyearling steelhead/rainbow and Chinook. Like subyearling steelhead/rainbow, yearling steelhead/rainbow selected stations in quiet water behind boulders in riffles, but the two age groups rarely occurred together. Yearling steelhead/rainbow appeared to use deeper and faster water than did subyearling steelhead/rainbow.

**Table 3.15.** Total numbers of subyearling steelhead/rainbow trout estimated in different steams in the Chiwawa Basin during snorkel surveys in August 1992-2007; NS = not sampled.

| Sample Year | Chiwawa River | Phelps Creek | Chikamin Creek | Rock Creek | Peven Creek | Big Meadow Creek | Alder Creek | Brush Creek | Y Creek | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1992 | 4,927 | NS | NS | NS | NS | NS | NS | NS | NS | **4,927** |
| 1993 | 3,463 | 0 | 356 | 185 | NS | NS | NS | NS | NS | **4,004** |
| 1994 | 953 | 0 | 256 | 24 | 0 | 177 | 0 | 0 | 0 | **1,410** |
| 1995 | 6,005 | 0 | 744 | 90 | 0 | 371 | 40 | 107 | 0 | **7,357** |
| 1996 | 3,244 | 0 | 71 | 40 | 0 | 763 | 127 | 0 | 0 | **4,245** |
| 1997 | 6,959 | 224 | 84 | 324 | 0 | 1,124 | 58 | 50 | 0 | **8,823** |
| 1998 | 2,972 | 22 | 280 | 96 | 113 | 397 | 18 | 22 | 0 | **3,921** |
| 1999 | 5,060 | 20 | 253 | 189 | 0 | 255 | 34 | 27 | 0 | **5,838** |
| 2000 | NS | NS | NS | NS | NS | NS | NS | NS | NS | **NS** |

[5] A steelhead/rainbow trout larger than 200 mm (8 in) was considered a resident trout.

| Sample Year | Chiwawa River | Phelps Creek | Chikamin Creek | Rock Creek | Peven Creek | Big Meadow Creek | Alder Creek | Brush Creek | Y Creek | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 2001 | 35,759 | 192 | 1,449 | 1,826 | 0 | 6,345 | 156 | 0 | 0 | **45,727** |
| 2002 | 12,137 | 0 | 2,252 | 889 | 0 | 4,948 | 277 | 18 | 0 | **20,521** |
| 2003 | 9,911 | 296 | 996 | 1,166 | 96 | 5,366 | 73 | 116 | 0 | **18,020** |
| 2004 | 8,464 | 110 | 583 | 113 | 40 | 957 | 35 | 78 | 0 | **10,380** |
| 2005 | 4,852 | 120 | 2,931 | 477 | 45 | 2,973 | 65 | 0 | 0 | **11,463** |
| 2006 | 10,669 | 21 | 858 | 872 | 34 | 3,647 | 73 | 71 | 0 | **16,245** |
| 2007 | 8,442 | 53 | 2,137 | 348 | 11 | 2,955 | 65 | 28 | 34 | **14,073** |
| ***Average*** | ***8,254*** | ***76*** | ***946*** | ***474*** | ***26*** | ***2,329*** | ***79*** | ***40*** | ***3*** | ***11,797*** |

**Table 3.16.** Total numbers of yearling steelhead/rainbow trout estimated in different steams in the Chiwawa Basin during snorkel surveys in August 1992-2007; NS = not sampled.

| Sample Year | Chiwawa River | Phelps Creek | Chikamin Creek | Rock Creek | Peven Creek | Big Meadow Creek | Alder Creek | Brush Creek | Y Creek | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1992 | 2,533 | NS | NS | NS | NS | NS | NS | NS | NS | **2,533** |
| 1993 | 2,530 | 0 | 228 | 102 | NS | NS | NS | NS | NS | **2,860** |
| 1994 | 4,972 | 0 | 476 | 296 | 5 | 107 | 0 | 0 | 0 | **5,856** |
| 1995 | 8,769 | 0 | 494 | 71 | 0 | 183 | 0 | 0 | 0 | **9,517** |
| 1996 | 11,381 | 0 | 6 | 27 | 0 | 435 | 0 | 0 | 0 | **11,849** |
| 1997 | 6,574 | 160 | 0 | 105 | 0 | 66 | 0 | 0 | 0 | **6,905** |
| 1998 | 10,403 | 0 | 133 | 49 | 0 | 0 | 0 | 0 | 0 | **10,585** |
| 1999 | 21,779 | 0 | 68 | 201 | 0 | 82 | 0 | 0 | 0 | **22,130** |
| 2000 | NS | NS | NS | NS | NS | NS | NS | NS | NS | **NS** |
| 2001 | 9,368 | 16 | 186 | 407 | 0 | 646 | 0 | 0 | 0 | **10,623** |
| 2002 | 7,200 | 0 | 199 | 165 | 0 | 1,526 | 0 | 0 | 0 | **9,090** |
| 2003 | 4,745 | 362 | 426 | 599 | 0 | 47 | 0 | 0 | 0 | **6,179** |
| 2004 | 7,700 | 107 | 209 | 0 | 0 | 174 | 0 | 0 | 0 | **8,190** |
| 2005 | 4,624 | 63 | 957 | 257 | 0 | 287 | 0 | 0 | 0 | **6,188** |
| 2006 | 7,538 | 76 | 748 | 1,186 | 0 | 985 | 0 | 0 | 0 | **10,533** |
| 2007 | 6,976 | 0 | 945 | 96 | 0 | 431 | 0 | 0 | 0 | **8,448** |
| ***Average*** | ***7,806*** | ***56*** | ***363*** | ***254*** | ***0*** | ***382*** | ***0*** | ***0*** | ***0*** | ***8,766*** |

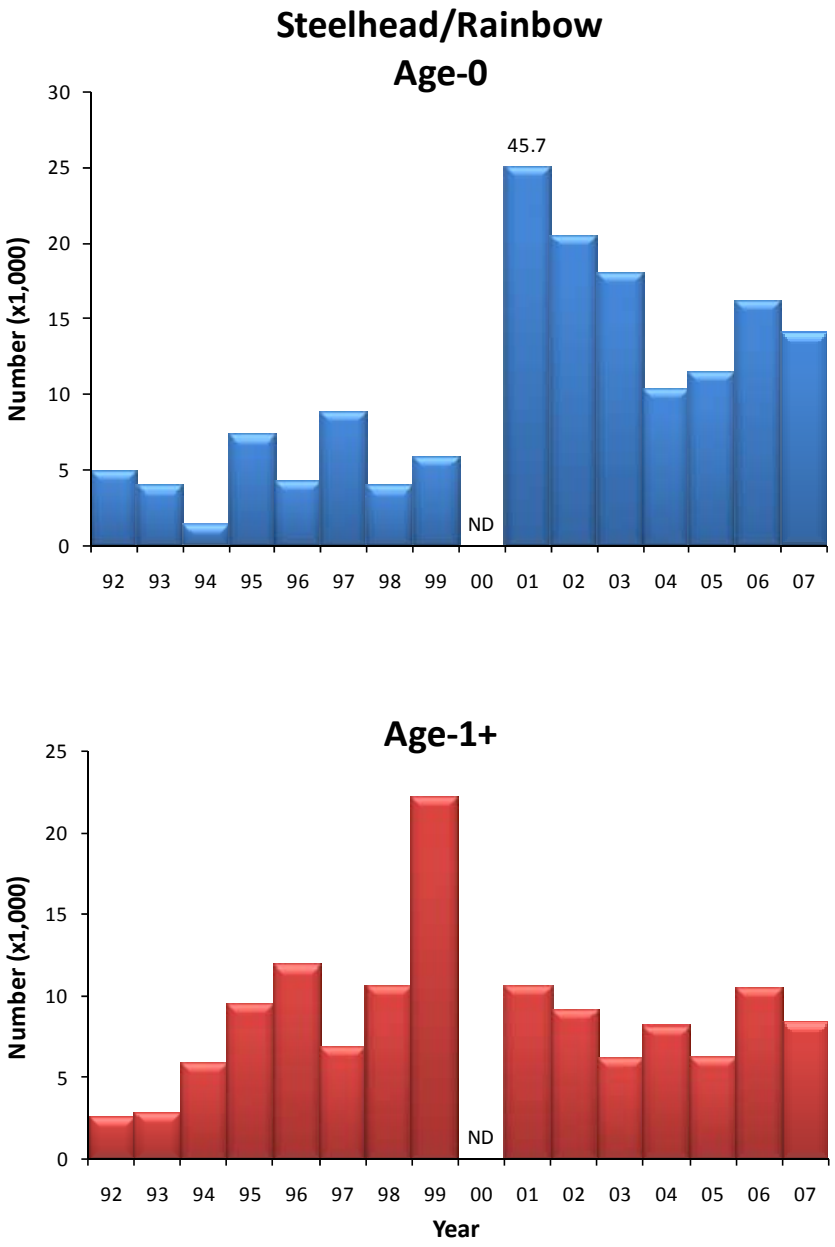


**Figure 3.1.** Numbers of subyearling and yearling steelhead/rainbow trout within the Chiwawa River Basin in August 1992-2007; ND = no data.

## Emigrant and Smolt Estimates

Numbers of steelhead smolts and emigrants were estimated at the Upper Wenatchee, Chiwawa, and Lower Wenatchee traps in 2007.

### *Chiwawa Trap*

The Chiwawa Trap operated between 27 February and 27 November 2007. During that time period the trap was inoperable for 23 days because of high river flows, debris, snow/ice, or mechanical

failure. The trap operated in two different positions depending on stream flow; lower position at flows greater than 12 $m^3/s$ and an upper position at flows less than 12 $m^3/s$. Monthly captures of all fish collected at the Chiwawa Trap are reported in Appendix B.

A total of 152 wild steelhead/rainbow smolts, 1,964 hatchery smolts, and 1,056 wild parr were captured at the Chiwawa Trap. Nearly all (98%) of the hatchery smolts were collected in May, while most (82%) of the wild steelhead smolts were captured during March and April (Figure 3.2). Although steelhead/rainbow parr emigrated throughout the sampling period, most emigrated during March through June and in August (Figure 3.2). No mark-recapture efficiency trials were conducted with steelhead/rainbow at the Chiwawa Trap to estimate total population sizes.

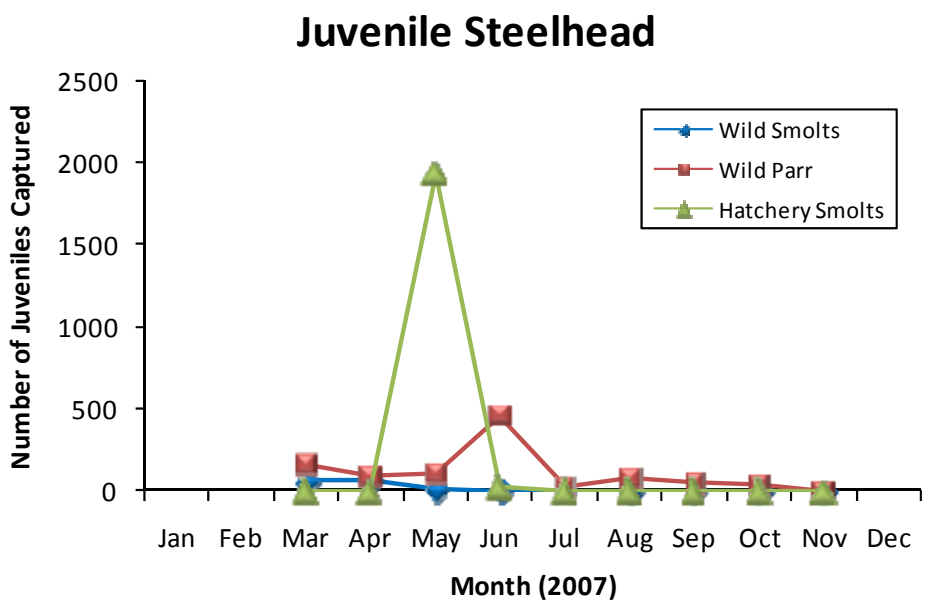


**Figure 3.2.** Monthly captures of wild smolts, wild parr, and hatchery smolt steelhead/rainbow at the Chiwawa Trap, 2007.

### *Upper Wenatchee Trap*

The Upper Wenatchee Trap operated nightly between 4 March and 23 July 2007. During the 4.5-month sampling period, a total of 15 wild steelhead/rainbow smolts, 178 hatchery smolts, and 65 wild parr were captured at the Upper Wenatchee Trap. Monthly captures of all fish collected at the Upper Wenatchee Trap are reported in Appendix B.

### *Lower Wenatchee Trap*

The Lower Wenatchee Trap operated nightly between 1 February and 5 August 2007. During that time period, the trap was inoperable for 14 days because of high river flows, debris, snow/ice, or mechanical failure. During the five-month sampling period, a total of 433 wild steelhead/rainbow smolts, 2,697 hatchery smolts, and 62 wild parr were captured at the Lower Wenatchee Trap. Based on capture efficiencies estimated from the flow model, the total number of wild yearling steelhead/rainbow that emigrated past the Lower Wenatchee Trap was 85,443 (± 94,717). Most of the wild yearling steelhead/rainbow migrated during April and May. Nearly all (98%) the hatchery

yearling steelhead/rainbow migrated during May. Monthly captures of all fish collected at the Lower Wenatchee Trap are reported in Appendix B.

### PIT Tagging Activities

A total of 3,139 juvenile steelhead/rainbow trout (2,950 wild and 189 hatchery) were PIT tagged and released in 2007 throughout the Wenatchee Basin (Table 3.17). Most (67%) of these were tagged in the Chiwawa Basin and in the Wenatchee River between Tumwater and Lake Wenatchee. Few were tagged and released at the Upper Wenatchee trap. A total of 461 juvenile steelhead/rainbow trout were tagged and released at the Lower Wenatchee trap. See Appendix C for a complete list of all fish captured, tagged, lost, and released.

**Table 3.17.** Numbers of wild and hatchery steelhead/rainbow trout that were captured, tagged, and released at different locations within the Wenatchee Basin, 2007. Numbers of fish that died or shed tags are also given.

| Sampling location | Origin | Number captured for tagging | Number tagged | Number that died | Number of shed tags | Total number of fish released |
|---|---|---|---|---|---|---|
| Chiwawa Trap | Wild | 885 | 840 | 8 | 0 | 832 |
| | Hatchery | 4 | 3 | 0 | 0 | 3 |
| | **Total** | **889** | **843** | **8** | **0** | **835** |
| Chiwawa River | Wild | 179 | 167 | 0 | 0 | 167 |
| | Hatchery | 52 | 47 | 0 | 0 | 47 |
| | **Total** | **231** | **214** | **0** | **0** | **214** |
| Upper Wenatchee Trap | Wild | 41 | 38 | 1 | 0 | 37 |
| | Hatchery | 0 | 0 | 0 | 0 | 0 |
| | **Total** | **41** | **38** | **1** | **0** | **37** |
| Upper Wenatchee River | Wild | 1,020 | 1,001 | 0 | 0 | 1,001 |
| | Hatchery | 69 | 64 | 0 | 0 | 64 |
| | **Total** | **1,089** | **1,065** | **0** | **0** | **1,065** |
| Nason Creek[a] | Wild | 483 | 453 | 1 | 0 | 452 |
| | Hatchery | 116 | 75 | 0 | 0 | 75 |
| | **Total** | **599** | **528** | **1** | **0** | **527** |
| Lower Wenatchee Trap | Wild | 473 | 462 | 1 | 0 | 461 |
| | Hatchery | 0 | 0 | 0 | 0 | 0 |
| | **Total** | **473** | **462** | **1** | **0** | **461** |
| ***Totals*** | ***Wild*** | ***3,081*** | ***2,961*** | ***11*** | ***0*** | ***2,950*** |
| | ***Hatchery*** | ***241*** | ***189*** | ***0*** | ***0*** | ***189*** |
| | ***Total*** | ***3,322*** | ***315*** | ***11*** | ***0*** | ***3,139*** |

[a] An additional 1,312 wild steelhead/rainbow were tagged and released by the Yakama Nation at the Nason Creek smolt trap.

## *3.5 Spawning Surveys*

Surveys for steelhead redds were conducted during March through May, 2007, in the Wenatchee River (including Beaver and Chiwaukum creeks), Chiwawa River (including Rock, Chikamin, Meadow, Twin, Alder, and Clear creeks), Nason Creek (including White Pine, Roaring, and an un-named stream), Icicle Creek, Peshastin Creek (including Mill, Ingalls, Ruby, Tronsen, Scotty, Shaser, and Schafer creeks), Little Wenatchee River, and White River (including the Napeequa River and Panther Creek). Surveys were conducted in both index and non-index areas throughout the Wenatchee Basin (see Appendix D for more details).

### Redd Counts

A total of 159 steelhead redds were counted in the Wenatchee Basin in 2007 (Table 3.18). This is about a 60% decrease from the estimate in 2006 (the lower count may be in part related to the poor survey conditions encountered during the spawning surveys in 2007; see Appendix D). Most spawning occurred in Nason Creek (49%) and the Wenatchee River (29%) (Table 3.18; Figure 3.3). Peshastin Creek contained 11% of all redds in the Wenatchee Basin. No redds were observed in the Little Wenatchee River and the number of redds in the Chiwawa Basin was well below the average for that area.

**Table 3.18.** Numbers of steelhead redds estimated within different streams/watersheds within the Wenatchee Basin, 2001-2007; NS = not sampled. Redd counts beginning in 2004 have been conducted within the same areas and with the same methods. Therefore, comparing redd numbers before 2004 with estimates since may not be valid.

| Survey year | Number of steelhead redds | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Chiwawa | Nason | Little Wenatchee | White | Wenatchee River[a] | Icicle | Peshastin | Total |
| 2001 | 25 | 27 | NS | NS | 116 | 19 | NS | **187** |
| 2002 | 80 | 80 | 1 | 0 | 315 | 27 | NS | **503** |
| 2003 | 64 | 121 | 5 | 3 | 248 | 16 | 15 | **472** |
| 2004 | 62 | 127 | 0 | 0 | 151 | 23 | 34 | **397** |
| 2005 | 162 | 412 | 0 | 2 | 459 | 8 | 97 | **1,140** |
| 2006 | 19 | 77 | NS | 0 | 191 | 41 | 67 | **395** |
| 2007 | 11 | 78 | 0 | 1 | 46 | 6 | 17 | **159** |
| ***Average[b]*** | ***64*** | ***174*** | ***0*** | ***1*** | ***212*** | ***20*** | ***54*** | ***523*** |

[a] Includes redds in Beaver and Chiwaukum creeks.
[b] The average is based on estimates from 2004 to present.

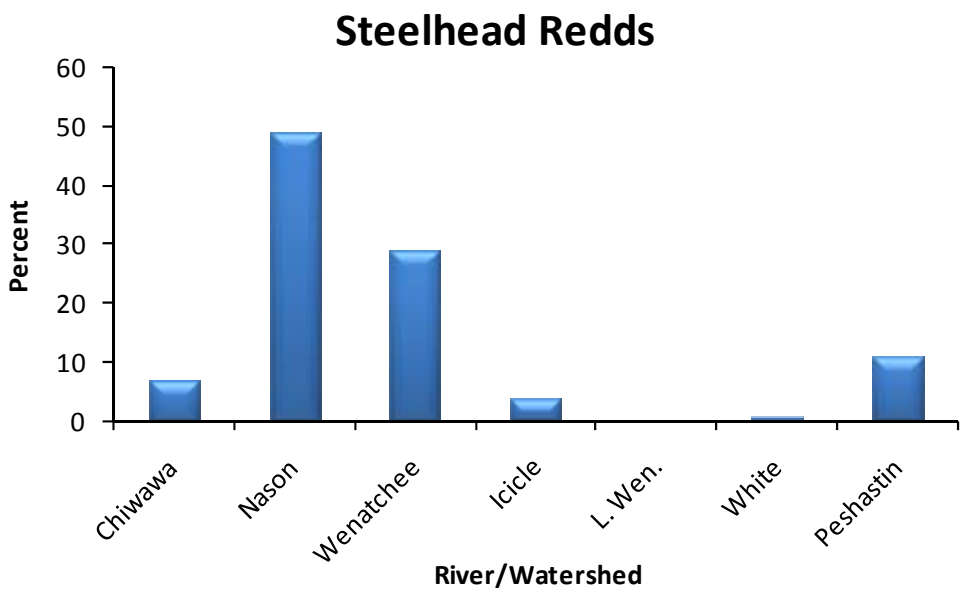


**Figure 3.3.** Percent of the total number of steelhead redds counted in different streams/watersheds within the Wenatchee Basin during March through May, 2007.

### Redd Distribution

Steelhead redds were not evenly distributed among reaches within survey streams in 2007 (Table 3.19). Most of the spawning in the Chiwawa Basin occurred in Reach 1 and in Clear Creek. No redds were observed in Chikamin, Meadow, or Alder creeks. Most of the spawning in the Nason Creek basin occurred in Nason Creek (primarily in Reaches 2 and 3), with no spawning in tributaries. All spawning in the Peshastin Creek basin occurred in Peshastin Creek (mostly in Reach 2). No redds were found in Peshastin Creek tributaries. About 95% of the spawning in the Wenatchee River occurred upstream from Tumwater Dam. Of the 159 total redds estimated in the Wenatchee Basin in 2007, 84% (134 redds) occurred upstream from Tumwater Dam. The remaining 25 redds occurred in the lower Wenatchee River, Peshastin Creek, and Icicle Creek.

**Table 3.19.** Numbers and percentages of steelhead redds counted within different streams/watersheds within the Wenatchee Basin during March through May, 2007.

| Stream/watershed | Reach | Number of redds | Percent of redds within stream/watershed |
|---|---|---|---|
| Chiwawa | Chiwawa 1 | 3 | 27.3 |
| | Rock Creek | -- | -- |
| | Chikamin Creek | 0 | 0.0 |
| | Meadow Creek | 0 | 0.0 |
| | Alder Creek | 0 | 0.0 |
| | Clear Creek | 8 | 72.7 |
| | **Total** | **11** | **100** |
| Nason | Nason 1 | 11 | 14.1 |
| | Nason 2 | 25 | 32.1 |

| Stream/watershed | Reach | Number of redds | Percent of redds within stream/watershed |
|---|---|---|---|
| | Nason 3 | 35 | 44.9 |
| | Nason 4 | 7 | 8.9 |
| | White Pine Creek | 0 | 0.0 |
| | Un-named Creek | 0 | 0.0 |
| | Roaring Creek | 0 | 0.0 |
| | **Total** | **78** | **100** |
| White | White 2 | 0 | 0.0 |
| | White 3 | 1 | 100.0 |
| | Panther Creek | 0 | 0.0 |
| | Naqeequa River | 0 | 0.0 |
| | **Total** | **1** | **100** |
| Icicle | Icicle | 6 | 100.0 |
| | **Total** | **6** | **100** |
| Peshastin | Peshastin 1 | 6 | 35.3 |
| | Peshastin 2 | 11 | 64.7 |
| | Mill Creek | 0 | 0.0 |
| | Ingalls Creek | -- | -- |
| | Tronsen Creek | 0 | 0.0 |
| | Scotty Creek | 0 | 0.0 |
| | Shaser Creek | 0 | 0.0 |
| | Schafer Creek | 0 | 0.0 |
| | **Total** | **17** | **100** |
| Wenatchee | Wenatchee 1 | -- | -- |
| | Wenatchee 2 | 0 | 0.0 |
| | Wenatchee 3 | -- | -- |
| | Wenatchee 4 | -- | -- |
| | Wenatchee 5 | -- | -- |
| | Wenatchee 6 | 2 | 4.4 |
| | Wenatchee 7 | -- | -- |
| | Wenatchee 8 | 0 | 0.0 |
| | Wenatchee 9 | 10 | 21.7 |
| | Wenatchee 10 | 34 | 73.9 |
| | Beaver Creek | 0 | 0.0 |
| | Chiwaukum Creek | -- | -- |
| | **Total** | **46** | **100** |

### Spawn Timing

Steelhead began spawning during the second week of April in the Wenatchee River and Nason Creek and progressed upstream as water temperatures increased. Spawning occurred at temperatures between 3.2 and 6.9°C. Most spawning began when mean daily temperatures reached about 4.2°C. Peak spawning in the Wenatchee River occurred the third week of April, in Peshastin Creek the fourth week of April, and in Nason Creek the first week of May (Figure 3.4).

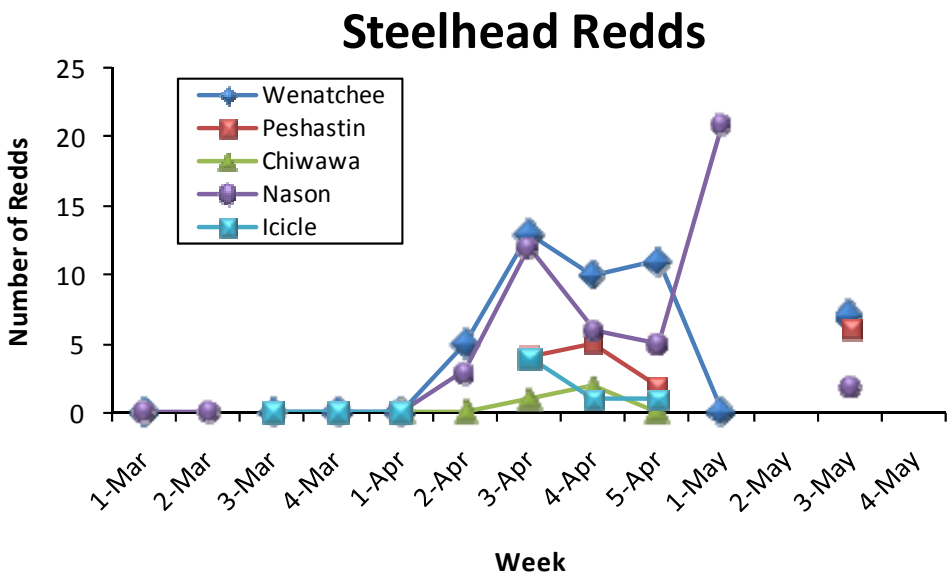


**Figure 3.4.** Numbers of steelhead redds counted during different weeks in different index areas within the Wenatchee Basin, March through May 2007.

### Spawning Escapement

Spawning escapement for steelhead upstream from Tumwater Dam was calculated as the number of redds (upstream from the dam) times the fish per redd ratio (based on sex ratios estimated at Tumwater Dam using video surveillance). The estimated fish per redd ratio for steelhead in 2007 was 1.94 (Table 3.20). Multiplying this ratio by the total number of redds upstream from the dam resulted in a total spawning escapement of 260 steelhead (Table 3.20). This means that of the 657 steelhead counted at Tumwater, only about 40% of them spawned upstream from the dam. This estimate was lower than the average of 50%.

The low estimated spawning escapement in 2007 may have resulted from the difficult survey conditions that biologists experienced in that year. That is, poor survey conditions may have obscured redds that were missed by the biologists. The effect of other factors, such as pre-spawning mortality, fallback, illegal harvest, etc. remain unknown.

**Table 3.20.** Numbers of steelhead counted at Tumwater Dam, fish/redd estimates (based on male-to-female ratios estimated at Tumwater Dam), numbers of steelhead redds counted upstream from Tumwater Dam, total spawning escapement upstream from Tumwater Dam (estimated as the total number of redds times the fish/redd ratio), and the proportion of the Tumwater Dam count that made up the spawning escapement.

| Survey year | Total count at Tumwater Dam | Fish/redd | Number of redds | | | Spawning escapement | Proportion of Tumwater count that spawned |
|---|---|---|---|---|---|---|---|
| | | | Index area | Non-index area | Total redds | | |
| 2001 | 820 | 2.08 | 118 | 19 | 137 | 285 | 0.35 |
| 2002 | 1,720 | 2.68 | 296 | 179 | 475 | 1,273 | 0.74 |
| 2003 | 1,810 | 1.60 | 353 | 88 | 441 | 706 | 0.39 |
| 2004 | 1,869 | 2.21 | 277 | 92 | 369 | 815 | 0.44 |
| 2005 | 2,650 | 1.61 | 828 | 136 | 964 | 1,552 | 0.59 |
| 2006 | 1,053 | 2.05 | 192 | 34 | 226 | 463 | 0.44 |
| 2007 | 657 | 1.94 | 105 | 29 | 134 | 260 | 0.40 |
| ***Average[a]*** | ***1,557*** | ***1.95*** | ***351*** | ***73*** | ***423*** | ***773*** | ***0.50*** |

[a] The average is based on estimates from 2004 to present.

## 3.6 Life History Monitoring

Life history characteristics of steelhead were assessed by examining fish collected at broodstock collection sites, examining videotape at Tumwater Dam, and by reviewing tagging data and fisheries statistics. Some statistics could not be calculated at this time because few fish have been tagged with CWTs. All steelhead released from the hatchery received elastomer tags and about 30,000 were PIT tagged. With the placement of remote PIT tag detectors in spawning streams in 2007, statistics such as origin on spawning grounds, stray rates, and SARs can be estimated more accurately.

### Migration Timing

There was little difference in migration timing of wild and hatchery fish enumerated at Tumwater Dam (Table 3.21; Figure 3.5). Steelhead passed Tumwater Dam during most months with the majority passing during July through October and April. The highest proportion of both wild and hatchery fish migrated during October.

**Table 3.21.** The proportion of wild and hatchery steelhead enumerated at Tumwater Dam during different months of the migration period, 1999-2007. The presence of eroded fins and/or missing adipose fins was used to distinguish hatchery fish from wild fish during video monitoring at Tumwater Dam. Proportions include steelhead collected for broodstock. N = sample size.

| Brood year | Origin | Proportion of steelhead enumerated at Tumwater Dam | | | | | | | | | | | | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | |
| 1999 | Wild | 0.018 | 0.245 | 0.182 | 0.100 | 0.027 | 0.164 | 0.000 | 0.000 | 0.000 | 0.055 | 0.200 | 0.009 | 110 |
| | Hatch | 0.128 | 0.179 | 0.167 | 0.026 | 0.000 | 0.154 | 0.000 | 0.000 | 0.000 | 0.090 | 0.218 | 0.038 | 78 |
| 2000 | Wild | 0.007 | 0.058 | 0.306 | 0.252 | 0.191 | 0.043 | 0.000 | 0.000 | 0.004 | 0.054 | 0.068 | 0.018 | 278 |
| | Hatch | 0.004 | 0.057 | 0.323 | 0.217 | 0.129 | 0.008 | 0.000 | 0.000 | 0.000 | 0.114 | 0.141 | 0.008 | 263 |
| 2001 | Wild | 0.011 | 0.198 | 0.263 | 0.171 | 0.177 | 0.004 | 0.000 | 0.000 | 0.000 | 0.042 | 0.124 | 0.011 | 475 |

| Brood year | Origin | Proportion of steelhead enumerated at Tumwater Dam | | | | | | | | | | | | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Jan | Feb | Mar | Apr | May | |
| | Hatch | 0.000 | 0.120 | 0.133 | 0.104 | 0.219 | 0.016 | 0.000 | 0.000 | 0.003 | 0.110 | 0.258 | 0.037 | 383 |
| 2002 | Wild | 0.001 | 0.144 | 0.127 | 0.162 | 0.218 | 0.158 | 0.006 | 0.000 | 0.001 | 0.068 | 0.096 | 0.018 | 991 |
| | Hatch | 0.001 | 0.015 | 0.056 | 0.195 | 0.366 | 0.196 | 0.001 | 0.000 | 0.003 | 0.040 | 0.098 | 0.029 | 734 |
| 2003 | Wild | 0.000 | 0.153 | 0.376 | 0.155 | 0.066 | 0.002 | 0.040 | 0.056 | 0.042 | 0.050 | 0.054 | 0.006 | 924 |
| | Hatch | 0.001 | 0.073 | 0.140 | 0.086 | 0.047 | 0.010 | 0.053 | 0.208 | 0.066 | 0.208 | 0.107 | 0.003 | 910 |
| 2004 | Wild | 0.006 | 0.100 | 0.110 | 0.132 | 0.312 | 0.084 | 0.000 | 0.000 | 0.005 | 0.035 | 0.204 | 0.013 | 866 |
| | Hatch | 0.010 | 0.112 | 0.085 | 0.117 | 0.291 | 0.039 | 0.000 | 0.000 | 0.003 | 0.062 | 0.224 | 0.060 | 1,038 |
| 2005 | Wild | 0.018 | 0.084 | 0.066 | 0.358 | 0.262 | 0.038 | 0.002 | 0.000 | 0.000 | 0.038 | 0.122 | 0.013 | 1,192 |
| | Hatch | 0.054 | 0.156 | 0.024 | 0.316 | 0.175 | 0.021 | 0.000 | 0.000 | 0.000 | 0.030 | 0.176 | 0.047 | 1,489 |
| 2006 | Wild | 0.011 | 0.076 | 0.026 | 0.048 | 0.485 | 0.045 | 0.000 | 0.003 | 0.005 | 0.087 | 0.195 | 0.018 | 619 |
| | Hatch | 0.000 | 0.087 | 0.012 | 0.089 | 0.417 | 0.043 | 0.000 | 0.060 | 0.006 | 0.161 | 0.105 | 0.019 | 515 |
| 2007 | Wild | 0.000 | 0.117 | 0.229 | 0.236 | 0.125 | 0.010 | 0.003 | 0.000 | 0.013 | 0.036 | 0.210 | 0.021 | 385 |
| | Hatch | 0.003 | 0.092 | 0.020 | 0.069 | 0.102 | 0.007 | 0.003 | 0.000 | 0.020 | 0.102 | 0.507 | 0.076 | 304 |
| ***Average*** | ***Wild*** | ***0.007*** | ***0.120*** | ***0.168*** | ***0.193*** | ***0.231*** | ***0.058*** | ***0.008*** | ***0.009*** | ***0.009*** | ***0.051*** | ***0.132*** | ***0.014*** | ***5,840*** |
| | ***Hatch*** | ***0.018*** | ***0.101*** | ***0.079*** | ***0.171*** | ***0.217*** | ***0.047*** | ***0.009*** | ***0.039*** | ***0.013*** | ***0.091*** | ***0.179*** | ***0.036*** | ***5,710*** |

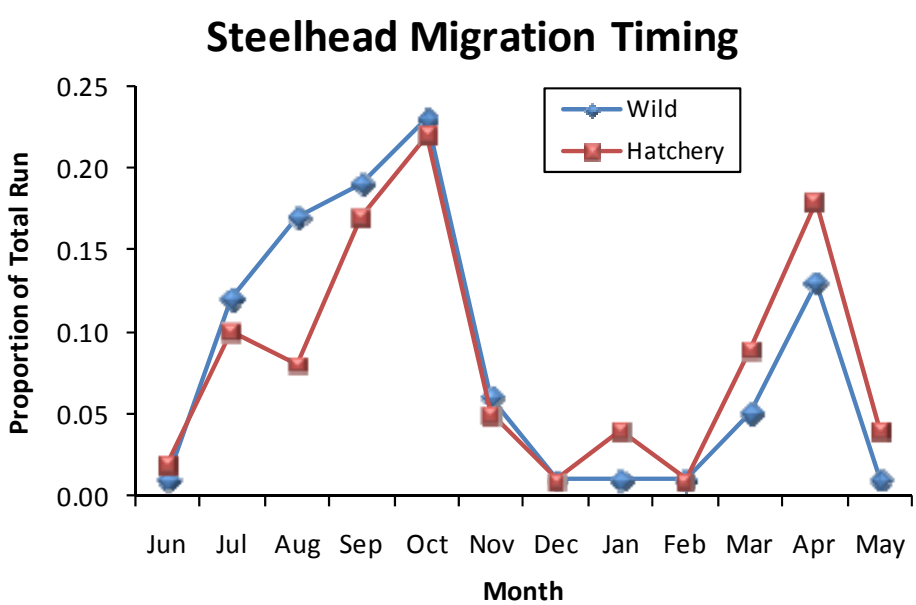


**Figure 3.5**. Proportion of wild and hatchery steelhead sampled at Tumwater Dam for the combined brood years of 1999-2007.

### Age at Maturity

Nearly all steelhead broodstock collected at Tumwater and Dryden dams lived in saltwater 1 to 2 years (saltwater age) (Table 3.22; Figure 3.6). Very few saltwater age-3 fish returned and those that did were wild fish. In general there was little difference between the saltwater age of wild and

hatchery fish. A slightly greater number of wild fish returned as saltwater age-2 fish than age-1 fish. In contrast, a slightly greater number of hatchery fish returned as saltwater-1 fish.

**Table 3.22.** Proportions of wild and hatchery steelhead broodstock of different ages collected at Tumwater and Dryden dams, 1998-2006. Age represents the number of years the fish lived in salt water.

| Sample year | Origin | Saltwater age | | | Sample size |
|---|---|---|---|---|---|
| | | 1 | 2 | 3 | |
| 1998 | Wild | 0.39 | 0.61 | 0.00 | 35 |
| | Hatchery | 0.21 | 0.79 | 0.00 | 43 |
| 1999 | Wild | 0.50 | 0.48 | 0.02 | 58 |
| | Hatchery | 0.82 | 0.18 | 0.00 | 67 |
| 2000 | Wild | 0.56 | 0.44 | 0.00 | 39 |
| | Hatchery | 0.68 | 0.32 | 0.00 | 101 |
| 2001 | Wild | 0.52 | 0.48 | 0.00 | 64 |
| | Hatchery | 0.15 | 0.85 | 0.00 | 114 |
| 2002 | Wild | 0.56 | 0.44 | 0.00 | 99 |
| | Hatchery | 0.95 | 0.05 | 0.00 | 113 |
| 2003 | Wild | 0.13 | 0.85 | 0.02 | 63 |
| | Hatchery | 0.29 | 0.71 | 0.00 | 92 |
| 2004 | Wild | 0.95 | 0.05 | 0.00 | 85 |
| | Hatchery | 0.95 | 0.05 | 0.00 | 132 |
| 2005 | Wild | 0.22 | 0.78 | 0.00 | 95 |
| | Hatchery | 0.21 | 0.79 | 0.00 | 114 |
| 2006 | Wild | 0.29 | 0.71 | 0.00 | 101 |
| | Hatchery | 0.60 | 0.40 | 0.00 | 98 |
| 2007 | Wild | 0.40 | 0.59 | 0.00 | 79 |
| | Hatchery | 0.62 | 0.38 | 0.00 | 97 |
| ***Average*** | ***Wild*** | ***0.45*** | ***0.54*** | ***0.01*** | ***92*** |
| | ***Hatchery*** | ***0.55*** | ***0.45*** | ***0.00*** | ***97*** |

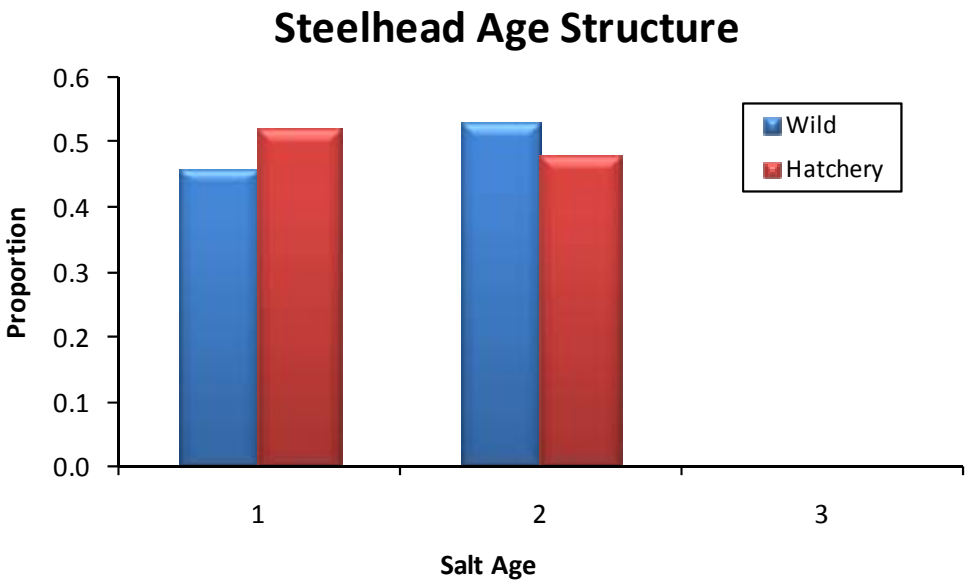


**Figure 3.6.** Proportions of wild and hatchery steelhead of different saltwater ages sampled at Tumwater Dam for the combined years 1998-2006.

### Size at Maturity

On average, hatchery steelhead collected at Tumwater and Dryden dams were about 2 cm smaller than wild steelhead (Table 3.23). This may be related to the fact that slightly more wild steelhead return as saltwater age-2 fish than hatchery steelhead.

**Table 3.23.** Mean fork length (cm) at age (saltwater ages) of hatchery and wild steelhead collected from broodstock, 1998-2007; N = sample size and SD = 1 standard deviation.

| Return year | Origin | Steelhead fork length (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1-Salt | | | 2-Salt | | | 3-Salt | | |
| | | Mean | N | SD | Mean | N | SD | Mean | N | SD |
| 1998 | Wild | 63 | 15 | 4 | 79 | 20 | 5 | - | 0 | - |
| | Hatchery | 61 | 9 | 4 | 73 | 34 | 4 | - | 0 | - |
| 1999 | Wild | 65 | 29 | 5 | 74 | 28 | 5 | 77 | 1 | - |
| | Hatchery | 62 | 54 | 4 | 73 | 12 | 4 | - | 0 | - |
| 2000 | Wild | 64 | 22 | 3 | 74 | 17 | 5 | - | 0 | - |
| | Hatchery | 60 | 57 | 3 | 71 | 27 | 4 | - | 0 | - |
| 2001 | Wild | 61 | 33 | 6 | 77 | 31 | 5 | - | 0 | - |
| | Hatchery | 62 | 17 | 4 | 72 | 97 | 4 | - | 0 | - |
| 2002 | Wild | 64 | 55 | 4 | 77 | 44 | 4 | - | 0 | - |
| | Hatchery | 63 | 106 | 4 | 73 | 6 | 4 | - | 0 | - |
| 2003 | Wild | 69 | 8 | 6 | 77 | 52 | 5 | 91 | 1 | - |
| | Hatchery | 66 | 27 | 4 | 75 | 65 | 4 | - | 0 | - |
| 2004 | Wild | 63 | 73 | 6 | 78 | 4 | 2 | - | 0 | - |

| Return year | Origin | Steelhead fork length (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 1-Salt | | | 2-Salt | | | 3-Salt | | |
| | | Mean | N | SD | Mean | N | SD | Mean | N | SD |
| | Hatchery | 61 | 59 | 3 | 73 | 3 | 1 | - | 0 | - |
| 2005 | Wild | 59 | 21 | 4 | 74 | 74 | 5 | - | 0 | - |
| | Hatchery | 59 | 23 | 4 | 72 | 89 | 4 | - | 0 | - |
| 2006 | Wild | 63 | 27 | 5 | 75 | 67 | 6 | - | 0 | - |
| | Hatchery | 61 | 41 | 4 | 72 | 27 | 5 | - | 0 | - |
| 2007 | Wild | 64 | 31 | 6 | 76 | 46 | 5 | - | 0 | - |
| | Hatchery | 60 | 60 | 4 | 71 | 36 | 5 | - | 0 | - |

### Contribution to Fisheries

Nearly all harvest on Wenatchee steelhead occurs within the Columbia basin. Harvest rates on steelhead in the Lower Columbia River fisheries (both tribal and non-tribal) are generally less than 5-10% (NMFS 2004). WDFW regulates steelhead harvest in the Upper Columbia. Under certain conditions, WDFW may allow a harvest on hatchery steelhead (adipose fin clipped fish). The intent is to reduce the number of hatchery steelhead that exceed habitat seeding levels in spawning areas and to increase the proportion of wild steelhead in spawning populations.

The Hatchery Evaluation Technical Team (HETT) is currently developing methods for calculating harvest rates on Wenatchee steelhead. These methods will be presented to the Hatchery Committee for their review in 2008.

### Origin on Spawning Grounds

At this time, origin of steelhead (wild or hatchery) on spawning grounds cannot be determined precisely. However, based on scales collected during steelhead run composition sampling at Dryden Dam in 2006 (2007 spawners), naturally produced steelhead made up 37% of the escapement. More precise estimates of wild and hatchery spawners within tributaries can be generated after remote PIT tag detectors are installed within spawning tributaries.

### Straying

Stray rates are currently difficult to estimate because fish are not handled on spawning grounds. As remote PIT-tag detectors are installed in spawning streams, we will be able to more accurately determine steelhead stray rates.

### Genetics

A report on the genetic analysis of Wenatchee steelhead will be completed in 2008.

### Natural Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural origin recruits (NOR) to the parent spawning population. For brood years 1989-2001, NRR in the Wenatchee averaged 0.83

(range, 0.07-3.13) (Table 3.24). NRRs for more recent brood years will be calculated as soon as the data are available.

**Table 3.24.** Spawning escapements, natural origin recruits (NOR), and natural replacement rates (NRR) for Wenatchee steelhead, 1989-2001. Numbers of hatchery and wild steelhead were based on radio telemetry results, numbers of steelhead passing Priest and Wells dams, and the number of steelhead harvested or removed fro broodstock. *(The numbers in this table may change as the HETT and HC refine the methods for estimating steelhead escapement, NORs, and NRRs.)*

| Brood year | Spawning escapement | | | NOR | NRR |
|---|---|---|---|---|---|
| | Hatchery | Wild | Total | | |
| 1989 | 1,849 | 1,001 | 2,851 | 348 | 0.122 |
| 1990 | 1,487 | 936 | 2,423 | 342 | 0.141 |
| 1991 | 990 | 481 | 1,471 | 321 | 0.218 |
| 1992 | 1,333 | 888 | 2,221 | 262 | 0.118 |
| 1993 | 2,951 | 566 | 3,516 | 241 | 0.068 |
| 1994 | 985 | 309 | 1,294 | 342 | 0.265 |
| 1995 | 1,637 | 303 | 1,940 | 427 | 0.220 |
| 1996 | 1,036 | 409 | 1,445 | 1,037 | 0.717 |
| 1997 | 245 | 269 | 514 | 1,609 | 3.129 |
| 1998 | 391 | 278 | 668 | 1,225 | 1.832 |
| 1999 | 114 | 268 | 382 | 796 | 2.085 |
| 2000 | 738 | 406 | 1,144 | 1,260 | 1.101 |
| 2001 | 1,065 | 773 | 1,838 | 1,301 | 0.707 |
| ***Average*** | ***1,140*** | ***530*** | ***1,670*** | ***731*** | ***0.825*** |

### Hatchery Replacement Rates

Hatchery replacement rates were estimated as hatchery adult-to-adult returns. These rates should be greater than the NRRs and greater than or equal to 19.2 (the value in BAMP; Murdoch and Peven 2005). In years with data, HRRs and adjusted HRRs were consistently greater than NRRs (Table 3.25). In contrast, HRRs exceeded the BAMP target of 19.2 in only one year and adjusted HRRs exceeded the BAMP target in two of the six years (Table 3.25).

**Table 3.25.** Hatchery replacement rates (HRR), adjusted HRR (for estimated tag loss), NRR, and BAMP target (19.2) for Wenatchee steelhead, 1998-2000. *(The numbers in this table may change as the HETT and HC refine the methods for estimating steelhead HRRs and NRRs.)*

| Brood year | HRR | Adjusted HRR | NRR | BAMP |
|---|---|---|---|---|
| 1998 | 1.89 | 3.49 | 1.83 | 19.2 |
| 1999 | 15.47 | 23.16 | 2.09 | 19.2 |
| 2000 | 2.60 | 3.33 | 1.10 | 19.2 |
| 2001 | 57.97 | 63.37 | 0.71 | 19.2 |
| 2002 | 11.76 | 12.18 | | 19.2 |
| 2003 | 6.56 | 6.56 | | 19.2 |

| Brood year | HRR | Adjusted HRR | NRR | BAMP |
|---|---|---|---|---|
| ***Average*** | ***16.04*** | ***18.68*** | ***1.43*** | ***19.2*** |

### Smolt-to-Adult Survivals

Smolt-to-adult ratios (SARs) are calculated as the number of returning hatchery adults divided by the number of hatchery smolts released. SARs are generally based on CWT returns. However, Wenatchee steelhead have not been extensively tagged with CWTs. Therefore elastomer-tagged fish were used to estimate SARs from release to capture at Priest Rapids Dam. Two different estimates are provided. One (unadjusted) is based on elastomer tag recaptures at Priest Rapids Dam; the other (adjusted) is corrected for tag loss after release (based on the number of unmarked hatchery adults that could not be accounted for). SARs for steelhead may change once a more accurate methodology for estimating adult survival has been developed.

Unadjusted SARs for Wenatchee steelhead ranged from 0.0017 to 0.0307 (mean = 0.0076) for brood years 1996-2003 (Table 3.26). Accounting for post-release tag loss, SARs ranged from 0.0016 to 0.0336 (mean = 0.0105) for brood years 1998-2003.

**Table 3.26.** Smolt-to-adult ratios (SARs) for Wenatchee hatchery steelhead, 1996-2002; NA = not available. Unadjusted estimates were based on elastomer tags recaptured at Priest Rapids Dam. Adjusted estimates were corrected for tag loss after release.

| Brood year | Number released | SAR (unadjusted) | SAR (adjusted) |
|---|---|---|---|
| 1996 | 348,693 | 0.0034 | NA |
| 1997 | 429,422 | 0.0041 | NA |
| 1998 | 172,078 | 0.0009 | 0.0016 |
| 1999 | 175,661 | 0.0110 | 0.0165 |
| 2000 | 184,639 | 0.0017 | 0.0022 |
| 2001 | 335,933 | 0.0307 | 0.0336 |
| 2002 | 302,060 | 0.0063 | 0.0065 |
| 2003 | 374,867 | 0.0027 | 0.0027 |
| ***Average*** | ***278,355*** | ***0.0076*** | ***0.0105*** |

## *3.7 ESA/HCP Compliance*

### Broodstock Collection

Collection of brood year 2006 broodstock for Wenatchee steelhead at Tumwater and Dryden dams began on 5 July and ended on 11 November 2005 and represented a slightly shortened collection duration from the 1 July – 12 November collection period detailed in the 2005 broodstock collection protocol. The broodstock collection protocols specified a total collection of 208 steelhead, including 104 natural-origin steelhead. Actual broodstock collection totaled 199 steelhead collected at Tumwater and Dryden dams, including 101 natural-origin fish (50.8% of the total collection),

consistent with the 2005 protocol and the ESA Permit 1395 target of 50% natural-origin broodstock composition.

About 140 steelhead were handled and released at Dryden Dam during Wenatchee steelhead broodstock collection. These fish were released because the weekly quota for either hatchery or wild steelhead had been attained, but not both, or because they were non-target (red VIE), or they were unidentifiable hatchery-origin steelhead. All steelhead released were allowed to fully recover from the anesthesia and released immediately upstream from the Dryden Dam trap site.

In addition to steelhead encountered at Dryden Dam during steelhead broodstock collection, 121 spring Chinook salmon and four bull trout were captured and released unharmed immediately upstream from the trap facility. Consistent with ESA Section 10 Permit 1395 impact minimization measures, all ESA species handled at this site were subject of water-to-water transfers.

### Hatchery Rearing and Release

Although nearly 8% of the 2006 brood H x W component died of asphyxiation at Eastbank Hatchery because of a power outage associated with a winter storm, the 2006 brood Wenatchee steelhead reared throughout all life-stages without significant mortality events (defined as >10% population mortality associated with a single event). However, the 2006 brood had poor fertilization to eyed-egg and eyed-egg to ponding survival resulting in an unfertilized-to-release survival of 54.9%, considerably less than the program target of 81% (see Section 3.2).

Juvenile rearing occurred at three separate facilities including Eastbank Fish Hatchery, Chelan Falls Fish Hatchery, and Turtle Rock Fish Hatchery. Multiple facilities were used to take advantage of variable water temperatures to manipulate growth of juveniles from different parental crosses. Typically, wild steelhead spawn later than their hatchery cohort and are therefore reared at Chelan Falls Fish Hatchery on warmer water to accelerate their growth so they achieve a size at release similar to HxH and HxW parental cross progeny reared on cooler water at Eastbank Fish Hatchery. All parental cross groups receive final rearing at Turtle Rock Fish Hatchery on Columbia River surface water before direct release (scatter planting) in the Wenatchee River basin.

The 2006 brood steelhead smolt release in the Wenatchee Basin totaled 299,937smolts, representing approximately 75% of the program target of 400,000 smolts identified in the Rocky Reach and Rock Island Dam HCPs and in ESA Section 10 Permit 1395. As specified in ESA Section 10 Permit 1395, all steelhead smolts released were externally marked or tagged and a representative number were PIT tagged (see Section 3.2)

### Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, and 1395, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at Chelan PUD Hatchery facilities during the period 1 January 2007 through 31 December 2007. NPDES monitoring and reporting for Chelan PUD Hatchery Programs during 2007 are provided in Appendix E.

### Smolt and Emigrant Trapping

Per ESA Section 10 Permit No. 1395, the permit holders are authorized a direct take of 20% of the emigrating steelhead population and a lethal take not to exceed 2% of the fish captured (NMFS

2003). Based on the estimated wild steelhead population (smolt trap expansion) and hatchery juvenile steelhead population estimate (hatchery release data) for the Wenatchee Basin, the reported steelhead encounters during 2007 emigration complied with take provisions in the Section 10 permit and are detailed in Table 3.27. Additionally, juvenile fish captured at the trap locations were handled consistent with provisions in ESA Section 10 Permit 1395 Section B.

**Table 3.27.** Estimated take of Upper Columbia River steelhead resulting from juvenile emigration monitoring in the Wenatchee Basin, 2006. NA = not available.

| Trap location | Population estimate | | | | Number trapped | | | | Total | Take allowed by Permit |
|---|---|---|---|---|---|---|---|---|---|---|
| | Wild[a] | Hatchery[b] | Parr[c] | Fry | Wild | Hatchery | Parr | Fry | | |
| **Chiwawa Trap** | | | | | | | | | | |
| Population | NA | 48,890 | NA | NA | 152 | 1,964 | 1,056 | 0 | 3,172 | |
| Encounter rate | NA | NA | NA | NA | NA | 0.0402 | NA | NA | NA | 0.20 |
| Mortality | NA | NA | NA | NA | 0 | 0 | 4 | NA | 4 | |
| Mortality rate | NA | NA | NA | NA | 0.0000 | 0.0000 | 0.0038 | NA | 0.0013 | 0.02 |
| **Upper Wenatchee Trap** | | | | | | | | | | |
| Population | 1,085 | 299,937 | 4,833 | NA | 15 | 178 | 65 | 0 | 258 | |
| Encounter rate | NA | NA | NA | NA | 0.0138 | 0.0006 | 0.0134 | NA | 0.0008 | 0.20 |
| Mortality | NA | NA | NA | NA | 0 | 0 | 0 | 0 | 0 | |
| Mortality rate | NA | NA | NA | NA | 0.0000 | 0.0000 | 0.0000 | NA | 0.0000 | 0.02 |
| **Lower Wenatchee Trap** | | | | | | | | | | |
| Population | 85,443 | 299,937 | 9,839 | NA | 433 | 2,697 | 62 | 0 | 3,192 | |
| Encounter rate | NA | NA | NA | NA | 0.0051 | 0.0090 | 0.0063 | NA | 0.0081 | 0.20 |
| Mortality | NA | NA | NA | NA | 3 | 0 | 1 | NA | 3 | |
| Mortality rate | NA | NA | NA | NA | 0.0069 | 0.0000 | 0.0161 | NA | 0.0009 | 0.02 |
| **Wenatchee Basin Total** | | | | | | | | | | |
| Population | 85,443 | 299,937 | | NA | 600 | 4,869 | 1,183 | 0 | 6,652 | |
| Encounter rate | NA | NA | NA | NA | 0.0070 | 0.0162 | NA | NA | NA | 0.20 |
| Mortality | NA | NA | NA | NA | 3 | 0 | 1 | NA | 7 | |
| Mortality rate | NA | NA | NA | NA | 0.0050 | 0.000 | 0.0008 | NA | 0.0011 | 0.02 |

[a] Smolt production estimates based on juvenile emigration monitoring (Miller 2008).

[b] 2007 smolt release data for the Wenatchee basin.

[c] Estimated parr emigrating past juvenile trap sites (Miller et al. 2008)

### Spawning Surveys

Steelhead spawning ground surveys were conducted in the Wenatchee Basin during 2007, as authorized by ESA Section 10 Permit No. 1395. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential impacts to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

### Stock Assessment at Priest Rapids Dam

Upper Columbia River steelhead stock assessment sampling at Priest Rapids Dam (PRD) is authorized through ESA Section 10 Permit No. 1395 (NMFS 2003). Permit authorizations include interception and biological sampling of 10% of the UCR steelhead passing PRD to determine upriver adult population size, estimate hatchery to wild ratios, determine age-class contribution, and evaluate the need for managing hatchery steelhead consistent with ESA recovery objectives, which include fully seeding spawning habitat with naturally produced Upper Columbia River steelhead supplemented with artificially propagated enhancement steelhead (NMFS 2003). The 2007-08 run-cycle summary is pending the completion of the run-cycle (31 May 2008) and final age-at-return assessment based on scale analysis (will be included as Appendix F).

# SECTION 4: WENATCHEE SOCKEYE SALMON

## 4.1 Broodstock Sampling

This section focuses on results from sampling 2005 and 2006 Wenatchee sockeye broodstock, which were collected at Tumwater Dam. The 2005 brood begins the tracking of the life cycle of sockeye that were released as parr into Lake Wenatchee in 2006 and some of which began smolt migrations in 2007. The 2006 brood is included because juveniles from this brood were released as parr in the lake in 2007. Complete information is not currently available for the 2007 brood (this information will be provided in the 2008 annual report). Collection of sockeye broodstock targets naturally produced fish and equal numbers of male and female fish.

### Origin of Broodstock

The 2005 broodstock consisted of mostly naturally produced sockeye collected at Tumwater Dam between 15 July and 22 August 2005 (Table 4.1). A total of 165 sockeye were spawned of which 159 were naturally produced fish; the remaining six fish were of unknown origin. The 2006 broodstock consisted of mostly naturally produced Wenatchee sockeye salmon collected at Tumwater Dam between 17 July and 3 August 2006 (Table 4.1). A total of 214 naturally produced sockeye were spawned.

**Table 4.1**. Numbers of wild and hatchery sockeye salmon collected for broodstock, numbers that died before spawning, and numbers of sockeye spawned, 1989-2006. Unknown origin fish (i.e., undetermined by scale analysis, no CWT or fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes sockeye that died of natural causes typically near the end of spawning and were not needed for the program, surplus sockeye killed at spawning, sockeye that died but were not recovered from the net pens, and sockeye that may have jumped out of the net pens.

| Brood year | Wild sockeye | | | | | Hatchery sockeye | | | | | Total number spawned |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number collected | Prespawn loss | Mortality | Number spawned | Number released | Number collected | Prespawn loss | Mortality | Number spawned | Number released | |
| 1989 | 299 | 93 | 47 | 115 | 44 | 0 | 0 | 0 | 0 | 0 | 115 |
| 1990 | 333 | 7 | 7 | 302 | 17 | 0 | 0 | 0 | 0 | 0 | 302 |
| 1991 | 357 | 18 | 16 | 199 | 124 | 0 | 0 | 0 | 0 | 0 | 199 |
| 1992 | 362 | 18 | 5 | 320 | 19 | 0 | 0 | 0 | 0 | 0 | 320 |
| 1993 | 307 | 79 | 21 | 207 | 0 | 0 | 0 | 0 | 0 | 0 | 207 |
| 1994 | 329 | 15 | 9 | 236 | 69 | 5 | 0 | 0 | 5 | 0 | 241 |
| 1995 | 218 | 5 | 7 | 194 | 12 | 3 | 0 | 0 | 3 | 0 | 197 |
| 1996 | 291 | 2 | 0 | 225 | 64 | 20 | 0 | 0 | 0 | 20 | 225 |
| 1997 | 283 | 12 | 3 | 192 | 76 | 19 | 0 | 0 | 19 | 0 | 211 |
| 1998 | 225 | 37 | 25 | 122 | 41 | 6 | 0 | 0 | 6 | 0 | 128 |
| 1999 | 90 | 7 | 1 | 79 | 3 | 60 | 0 | 0 | 60 | 0 | 139 |
| 2000 | 256 | 19 | 1 | 170 | 66 | 5 | 0 | 0 | 5 | 0 | 175 |
| 2001 | 252 | 27 | 10 | 200 | 15 | 8 | 1 | 0 | 7 | 0 | 207 |
| 2002 | 257 | 0 | 1 | 256 | 0 | 0 | 0 | 0 | 0 | 0 | 256 |
| 2003 | 261 | 12 | 9 | 198 | 42 | 0 | 0 | 0 | 0 | 0 | 198 |
| 2004 | 211 | 13 | 12 | 177 | 9 | 0 | 0 | 0 | 0 | 0 | 177 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2005 | 243 | 29 | 12 | 166 | 36 | 0 | 0 | 0 | 0 | 0 | 166 |
| 2006 | 260 | 2 | 4 | 214 | 40 | 0 | 0 | 0 | 0 | 0 | 214 |
| ***Average*** | ***269*** | ***22*** | ***11*** | ***198*** | ***38*** | ***6*** | ***0*** | ***0*** | ***6*** | ***1*** | ***204*** |

## Age/Length Data

Ages of sockeye were determined from scales and otoliths collected from broodstock. The 2005 return was comprised primarily of age-4 returning adults (74.2%; Table 4.2). Age-5 adults made up 25.8% of the remaining broodstock. No age-6 fish were collected. The 2006 return consisted primarily of age-5 adults (65.5%; Table 4.2). Age-4 and 6 sockeye made up 34.0% and 0.5% of the 2006 return, respectively.

**Table 4.2.** Percent of hatchery and wild sockeye salmon of different ages (total age) collected from broodstock, 1994-2006.

| Return year | Origin | Total age | | |
|---|---|---|---|---|
| | | 4 | 5 | 6 |
| 1994 | Wild | 57.3 | 41.7 | 1.0 |
| | Hatchery | 40.0 | 60.0 | 0.0 |
| 1995 | Wild | 77.3 | 20.7 | 2.0 |
| | Hatchery | 66.7 | 33.3 | 0.0 |
| 1996 | Wild | 65.8 | 34.2 | 0.0 |
| | Hatchery | 0.0 | 0.0 | 0.0 |
| 1997 | Wild | 86.5 | 13.5 | 0.0 |
| | Hatchery | 57.9 | 42.1 | 0.0 |
| 1998 | Wild | 9.9 | 88.6 | 1.5 |
| | Hatchery | 66.7 | 33.3 | 0.0 |
| 1999 | Wild | 21.8 | 74.7 | 3.5 |
| | Hatchery | 90.0 | 8.3 | 1.7 |
| 2000 | Wild | 97.7 | 2.3 | 0.0 |
| | Hatchery | 100.0 | 0.0 | 0.0 |
| 2001 | Wild | 69.9 | 29.6 | 0.5 |
| | Hatchery | 71.4 | 28.6 | 0.0 |
| 2002 | Wild | 31.6 | 67.6 | 0.8 |
| | Hatchery | 0.0 | 0.0 | 0.0 |
| 2003 | Wild | 2.6 | 90.5 | 6.9 |
| | Hatchery | 0.0 | 0.0 | 0.0 |
| 2004 | Wild | 97.5 | 2.0 | 0.5 |
| | Hatchery | 0.0 | 0.0 | 0.0 |
| 2005 | Wild | 74.2 | 25.8 | 0.0 |
| | Hatchery | 0.0 | 0.0 | 0.0 |
| 2006 | Wild | 34.0 | 65.5 | 0.5 |
| | Hatchery | 0.0 | 0.0 | 0.0 |

| Return year | Origin | Total age | | |
|---|---|---|---|---|
| | | 4 | 5 | 6 |
| ***Average*** | ***Wild*** | ***55.9*** | ***42.8*** | ***1.3*** |
| | ***Hatchery*** | ***70.4*** | ***29.4*** | ***0.2*** |

Lengths of sockeye for the 2005 and 2006 return years are provided in (Table 4.3). Lengths of age-4, 5, and 6 sockeye sampled in 2006 averaged 52, 56, and 56 cm, respectively.

**Table 4.3.** Mean fork length (cm) at age (total age) of hatchery and wild sockeye salmon collected for broodstock, 1994-2006; SD = 1 standard deviation.

| Return year | Origin | Sockeye fork length (cm) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Age-4 | | | Age-5 | | | Age-6 | | |
| | | Mean | N | SD | Mean | N | SD | Mean | N | SD |
| 1994 | Wild | 56 | 125 | 3 | 55 | 91 | 3 | 54 | 2 | 3 |
| | Hatchery | 57 | 2 | 1 | 56 | 3 | 1 | - | 0 | - |
| 1995 | Wild | 51 | 153 | 2 | 55 | 41 | 4 | 54 | 4 | 5 |
| | Hatchery | 53 | 2 | 4 | 59 | 1 | - | - | 0 | - |
| 1996 | Wild | 52 | 146 | 4 | 53 | 76 | 3 | - | 0 | - |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - |
| 1997 | Wild | 50 | 166 | 3 | 53 | 26 | 5 | - | 0 | - |
| | Hatchery | 54 | 11 | 4 | 59 | 8 | 2 | - | 0 | - |
| 1998 | Wild | 51 | 13 | 4 | 55 | 117 | 3 | 53 | 2 | 3 |
| | Hatchery | 52 | 4 | 2 | 55 | 2 | 8 | - | 0 | - |
| 1999 | Wild | 52 | 19 | 4 | 50 | 65 | 4 | 56 | 3 | 1 |
| | Hatchery | 50 | 54 | 3 | 56 | 5 | 4 | 56 | 1 | - |
| 2000 | Wild | 52 | 167 | 2 | 54 | 4 | 3 | - | 0 | - |
| | Hatchery | 54 | 5 | 1 | - | 0 | - | - | 0 | - |
| 2001 | Wild | 54 | 151 | 3 | 56 | 65 | 4 | 58 | 1 | - |
| | Hatchery | 51 | 5 | 5 | 55 | 2 | 4 | - | 0 | - |
| 2002 | Wild | 54 | 77 | 2 | 56 | 165 | 4 | 57 | 2 | 0 |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - |
| 2003 | Wild | 54 | 5 | 4 | 60 | 172 | 2 | 60 | 13 | 4 |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - |
| 2004 | Wild | 53 | 192 | 3 | 56 | 4 | 3 | 63 | 1 | - |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - |
| 2005 | Wild | 51 | 132 | 3 | 57 | 46 | 4 | - | 0 | - |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - |
| 2006 | Wild | 52 | 70 | 3 | 56 | 135 | 4 | 54 | 2 | 3 |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - |

### Sex Ratios

Male sockeye in the 2005 return made up about 54% of the adults collected, resulting in an overall male to female ratio of 1.15:1.00 (Table 4.4). In 2006, males made up about 50% of the adults collected, resulting in an overall male to female ratio of 1.00:1.00. Ratios for both years are at or near the 1:1 ratio target in the broodstock protocol.

**Table 4.4.** Numbers of male and female wild and hatchery sockeye collected for broodstock, 1989-2006. Ratios of males to females are also provided.

| Return year | Number of wild sockeye | | | Number of hatchery sockeye | | | Total M/F ratio* |
|---|---|---|---|---|---|---|---|
| | Males (M) | Females (F) | M/F | Males (M) | Females (F) | M/F | |
| 1989 | 162 | 137 | 1.18:1.00 | - | - | - | 1.18:1.00 |
| 1990 | 177 | 156 | 1.13:1.00 | - | - | - | 1.13:1.00 |
| 1991 | 260 | 97 | 2.68:1.00 | - | - | - | 2.68:1.00 |
| 1992 | 180 | 182 | 0.99:1.00 | - | - | - | 0.99:1.00 |
| 1993 | 130 | 177 | 0.73:1.00 | - | - | - | 0.73:1.00 |
| 1994 | 162 | 167 | 0.97:1.00 | 1 | 4 | 0.25:1.00 | 0.95:1.00 |
| 1995 | 102 | 116 | 0.88:1.00 | 1 | 2 | 0.50:1.00 | 0.87:1.00 |
| 1996 | 150 | 161 | 0.93:1.00 | - | - | - | 0.93:1.00 |
| 1997 | 139 | 144 | 0.97:1.00 | 10 | 9 | 1.11:1.00 | 0.97:1.00 |
| 1998 | 115 | 110 | 1.05:1.00 | 2 | 4 | 0.50:1.00 | 1.03:1.00 |
| 1999 | 22 | 68 | 0.32:1.00 | 37 | 23 | 1.61:1.00 | 0.65:1.00 |
| 2000 | 155 | 101 | 1.53:1.00 | 3 | 2 | 1.50:1.00 | 1.53:1.00 |
| 2001 | 114 | 138 | 0.83:1.00 | 4 | 4 | 1.00:1.00 | 0.83:1.00 |
| 2002 | 128 | 129 | 0.99:1.00 | - | - | - | 0.99:1.00 |
| 2003 | 161 | 100 | 1.61:1.00 | - | - | - | 1.61:1.00 |
| 2004 | 108 | 103 | 1.05:1.00 | - | - | - | 1.05:1.00 |
| 2005 | 130 | 113 | 1.15:1.00 | - | - | - | 1.15:1.00 |
| 2006 | 130 | 130 | 1.00:1.00 | - | - | - | 1.00:1.00 |
| ***Total*** | ***2,525*** | ***2,329*** | ***1.08:1.00*** | ***58*** | ***48*** | ***1.21:1.00*** | ***1.09:1.00*** |

### Fecundity

Fecundities for the 2005 and 2006 returns of sockeye salmon averaged 2,718 and 2,656 eggs per female, respectively (Table 4.5). These fecundities are close to the 18-year average of 2,615. Fecundities for this program are based upon the total (pooled) number of eyed eggs divided by the number of females spawned. Mean fecundities derived from individual fecundities cannot be calculated because of the need to pool three females per incubation tray.

**Table 4.5.** Mean fecundity of female sockeye salmon collected for broodstock, 1989-2006. Fecundities were determined from pooled egg lots and were not identified for individual females.

| Return year | Mean fecundity |
|---|---|
| 1989 | 2,344 |
| 1990 | 2,225 |
| 1991 | 2,598 |
| 1992 | 2,341 |
| 1993 | 2,340 |
| 1994 | 2,798 |
| 1995 | 2,295 |
| 1996 | 2,664 |
| 1997 | 2,447 |
| 1998 | 2,813 |
| 1999 | 2,319 |
| 2000 | 2,673 |
| 2001 | 2,960 |
| 2002 | 2,856 |
| 2003 | 3,511 |
| 2004 | 2,505 |
| 2005 | 2,718 |
| 2006 | 2,656 |
| ***Average*** | ***2,615*** |

## 4.2 Hatchery Rearing

### Rearing History

#### *Number of eggs taken*

Based on the unfertilized egg-to-release survival standard of 81%, a total of 246,914 eggs are required to meet the program release goal of 200,000 smolts. Between 1989 and 2006, the egg take goal was reached in most years (Table 4.6). The number of eggs taken in 2006 was above the egg take target by 18%.

**Table 4.6.** Numbers of eggs taken from sockeye broodstock, 1989-2006.

| Return year | Number of eggs taken |
|---|---|
| 1989 | 133,600 |
| 1990 | 333,779 |
| 1991 | 231,254 |
| 1992 | 381,561 |
| 1993 | 231,700 |

| Return year | Number of eggs taken |
|---|---|
| 1994 | 338,562 |
| 1995 | 247,900 |
| 1996 | 314,390 |
| 1997 | 254,459 |
| 1998 | 163,278 |
| 1999 | 190,732 |
| 2000 | 227,234 |
| 2001 | 301,925 |
| 2002 | 356,982 |
| 2003 | 319,470 |
| 2004 | 225,499 |
| 2005 | 211,985 |
| 2006 | 292,136 |
| 2007 | 292,136 |
| ***Average*** | ***264,247*** |

### *Number of acclimation days*

Wenatchee sockeye have only been acclimated on Lake Wenatchee water. For brood years 1989 through 1998, unfed fry were transferred from Eastbank FH to Lake Wenatchee Net Pens until release (Table 4.7). Juvenile sockeye were reared at Eastbank FH (1999 brood – present) until July in an effort to increase growth before release.

**Table 4.7.** Water source and mean acclimation period for Wenatchee sockeye, brood years 1989-2005.

| Brood year | Release year | Transfer date | Release date | Number of Days | Water source |
|---|---|---|---|---|---|
| 1989 | 1990 | 5-Apr | 24-Oct | 202 | Lake Wenatchee |
| 1990 | 1991 | 10-Apr | 19-Oct | 192 | Lake Wenatchee |
| 1991 | 1992 | 1-Apr | 20-Oct | 202 | Lake Wenatchee |
| 1992 | 1993 | 5-Apr | 7-Sep | 155 | Lake Wenatchee |
| | | 5-Apr | 26-Oct | 204 | Lake Wenatchee |
| 1993 | 1994 | 5-Apr | 1-Sep | 149 | Lake Wenatchee |
| | | 5-Apr | 17-Oct | 195 | Lake Wenatchee |
| 1994 | 1995 | 4-Apr | 15-Sep | 164 | Lake Wenatchee |
| | | 4-Apr | 23-Oct | 202 | Lake Wenatchee |
| 1995 | 1996 | 4-Apr | 25-Oct | 204 | Lake Wenatchee |
| 1996 | 1997 | 4-Apr | 22-Oct | 201 | Lake Wenatchee |
| 1997 | 1998 | 1-Apr | 9-Nov | 222 | Lake Wenatchee |
| 1998 | 1999 | 1-Apr | 29-Oct | 211 | Lake Wenatchee |

| Brood year | Release year | Transfer date | Release date | Number of Days | Water source |
|---|---|---|---|---|---|
| 1999 | 2000 | 25-Jul | 28-Aug | 34 | Lake Wenatchee |
| | | 26-Jul | 1-Nov | 98 | Lake Wenatchee |
| 2000 | 2001 | 2-Jul | 27-Aug | 56 | Lake Wenatchee |
| | | 3-Jul | 27-Sep | 86 | Lake Wenatchee |
| 2001 | 2002 | 15-Jul | 28-Aug | 44 | Lake Wenatchee |
| | | 16-Jul | 22-Sep | 68 | Lake Wenatchee |
| 2002 | 2003 | 30-Jun | 25-Aug | 56 | Lake Wenatchee |
| | | 1-Jul | 22-Oct | 113 | Lake Wenatchee |
| 2003 | 2004 | 6-Jul | 25-Aug | 50 | Lake Wenatchee |
| | | 7-Jul | 3-Nov | 119 | Lake Wenatchee |
| 2004 | 2005 | 5-Jul | 29-Aug | 55 | Lake Wenatchee |
| | | 6-Jul | 2-Nov | 120 | Lake Wenatchee |
| 2005 | 2006 | 11-Jul | 30-Oct | 111 | Lake Wenatchee |

## Release Information

### *Numbers released*

The 2005 Wenatchee sockeye program achieved 70.3% of the 200,000 target goal with about 140,542 fish being released (Table 4.8).

**Table 4.8.** Numbers of sockeye parr released, brood years 1989-2005. The release target for sockeye is 200,000 fish.

| Brood year | Release year | Number released |
|---|---|---|
| 1989 | 1990 | 260,400 |
| 1990 | 1991 | 372,102 |
| 1991 | 1992 | 167,523 |
| 1992 | 1993 | 340,557 |
| 1993 | 1994 | 190,443 |
| 1994 | 1995 | 252,859 |
| 1995 | 1996 | 150,808 |
| 1996 | 1997 | 284,630 |
| 1997 | 1998 | 197,195 |
| 1998 | 1999 | 121,344 |
| 1999 | 2000 | 167,955 |
| 2000 | 2001 | 190,174 |
| 2001 | 2002 | 200,938 |
| 2002 | 2003 | 315,783 |

| Brood year | Release year | Number released |
|---|---|---|
| 2003 | 2004 | 240,459 |
| 2004 | 2005 | 172,923 |
| 2005 | 2006 | 140,542 |
| ***Average*** | | ***221,567*** |

### *Numbers tagged*

A total of 15,049 juvenile sockeye were PIT tagged at the Eastbank Hatchery during 12-20 June 2007. These fish were transported to the Lake Wenatchee net pens on 9 July and released into the lake on 31 October 2007. At the time of release, a total of 65 fish had died and another 220 had shed their tags. Thus, the total number of PIT-tagged sockeye released into the lake was 14,764.

### *Fish size and condition at release*

The 2005 brood sockeye were released as parr in 2006 and emigrated as yearling smolts in spring of 2007. Size at release was 112.0% and 192.5% of the fork length and weight goals, respectively. The 2005 brood year was below the CV goal for length by 16.7% (Table 4.9).

**Table 4.9.** Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of sockeye released, brood years 1989-2005. Size targets are provided in the last row of the table.

| Brood year | Release year | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| 1989 | 1990 | 128 | - | 18.2 | 25 |
| 1990 | 1991 | 131 | - | 18.9 | 24 |
| 1991 | 1992 | 117 | 3.0 | 20.6 | 22 |
| 1992 | 1993 | 73 | 6.8 | 4.2 | 44 |
| 1993 | 1994 | 103 | - | 13.6 | 40 |
| 1994 | 1995 | 75 | 6.1 | 4.5 | 38 |
| 1995 | 1996 | 137 | 8.2 | 14.7 | 30 |
| 1996 | 1997 | 107 | 5.6 | 15.1 | 30 |
| 1997 | 1998 | 122 | 6.1 | 21.3 | 21 |
| 1998 | 1999 | 112 | 5.4 | 17.0 | 27 |
| 1999 | 2000 | 94 | 9.5 | 9.5 | 48 |
| | | 134 | 11.5 | 31.3 | 15 |
| 2000 | 2001 | 123 | 6.5 | 22.3 | 20 |
| | | 146 | 8.4 | 26.0 | 12 |
| 2001 | 2002 | 118 | 7.4 | 20.7 | 22 |
| | | 135 | 7.3 | 30.5 | 15 |
| 2002 | 2003 | 73 | 5.6 | 4.4 | 104 |

| Brood year | Release year | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| | | 118 | 7.7 | 13.7 | 23 |
| | | 145 | 9.4 | 38.6 | 13 |
| 2003 | 2004 | 79 | 4.6 | 4.8 | 96 |
| | | 118 | 5.9 | 17.0 | 26 |
| | | 158 | 8.1 | 44.3 | 10 |
| 2004 | 2005 | 116 | 4.5 | 17.2 | 18 |
| | | 151 | 7.0 | 39.3 | 12 |
| 2005 | 2006 | 149 | 7.5 | 43.7 | 10 |
| ***Targets*** | | ***133*** | ***9.0*** | ***22.7*** | ***20*** |

## Survival Estimates

Overall survival of Wenatchee sockeye from green (unfertilized) egg to release was below the standard set for the program as a result of poor green egg-to-eye and eye-to-ponding survival. Investigations to determine the effects of holding adults on warm surface water at Lake Wenatchee on gamete maturation/viability in addition to reducing negative phototactic behavior at swim up (potential influences on survival at the fertilization to ponding stages) should be considered (Table 4.10).

**Table 4.10.** Hatchery life-stage survival rates (%) for sockeye salmon, brood years 1989-2005. Survival standards or targets are provided in the last row of the table.

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 1989 | 41.6 | 100.0 | 88.1 | 63.9 | 99.2 | 98.9 | 98.1 | 65.2 | 55.2 |
| 1990 | 96.2 | 99.4 | 90.8 | 96.3 | 99.9 | 99.2 | 95.0 | 98.4 | 83.0 |
| 1991 | 91.8 | 94.1 | 79.2 | 94.8 | 99.8 | 99.3 | 96.4 | 96.4 | 72.4 |
| 1992 | 91.1 | 98.8 | 92.3 | 98.0 | 99.9 | 99.8 | 98.6 | 98.8 | 89.2 |
| 1993 | 57.1 | 99.2 | 89.2 | 98.3 | 99.6 | 99.1 | 93.7 | 93.8 | 82.2 |
| 1994 | 89.8 | 99.2 | 79.2 | 96.0 | 99.5 | 98.6 | 98.3 | 98.2 | 74.7 |
| 1995 | 97.5 | 99.1 | 87.5 | 95.0 | 99.0 | 93.3 | 73.2 | 73.2 | 60.8 |
| 1996 | 99.2 | 100.0 | 95.1 | 98.7 | 99.7 | 99.3 | 96.4 | 96.5 | 90.5 |
| 1997 | 92.8 | 99.3 | 84.8 | 97.9 | 97.9 | 97.6 | 95.5 | 94.9 | 79.3 |
| 1998 | 75.4 | 95.5 | 77.7 | 98.4 | 98.6 | 98.2 | 97.1 | 97.2 | 74.3 |
| 1999 | 92.3 | 100.0 | 92.2 | 97.3 | 99.6 | 99.3 | 98.2 | 99.7 | 88.1 |
| 2000 | 84.5 | 98.1 | 93.8 | 97.7 | 96.7 | 96.1 | 91.4 | 96.8 | 83.7 |
| 2001 | 75.4 | 99.2 | 78.5 | 97.6 | 98.0 | 97.6 | 86.9 | 95.1 | 66.6 |

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 2002 | 100.0 | 100.0 | 95.7 | 97.8 | 99.6 | 99.2 | 94.6 | 99.8 | 88.5 |
| 2003 | 91.0 | 98.1 | 87.2 | 96.9 | 99.0 | 98.2 | 94.8 | 95.5 | 80.1 |
| 2004 | 88.7 | 92.6 | 88.0 | 93.1 | 97.9 | 97.4 | 93.7 | 96.1 | 76.7 |
| 2005 | 98.5 | 98.5 | 85.3 | 94.9 | 97.8 | 96.6 | 95.5 | 99.2 | 77.2 |
| ***Standard*** | ***90.0*** | ***85.0*** | ***92.0*** | ***98.0*** | ***97.0*** | ***93.0*** | ***90.0*** | ***95.0*** | ***81.0*** |

## 4.3 Disease Monitoring

Rearing of the 2005 brood sockeye was typical to previous years with fish being held on Lake Wenatchee water in net pens for 111 days before being released directly into the lake. Mortality due to Columnaris began to increase in the juveniles in late August about 2 weeks after the last adult sockeye broodstock were transferred from Tumwater Dam to holding pens at lake Wenatchee. A 2% TM-100 treatment was initiated for control, which abated the condition. No further outbreaks or disease issues were observed or detected.

## 4.4 Natural Juvenile Productivity

During 2007, juvenile sockeye salmon were sampled at the Upper Wenatchee and Lower Wenatchee traps.

### Emigrant and Smolt Estimates

#### *Upper Wenatchee Trap*

The Upper Wenatchee Trap operated nightly between 4 March and 23 July 2007. During the 4.5-month sampling period, a total of 38,628 wild sockeye and 2,387 hatchery sockeye smolts were captured at the Upper Wenatchee Trap. Based on a pooled daily trap efficiency of 1.4% for wild sockeye (based on 9 mark-recapture trials) and 1.4% for hatchery sockeye (based on 5 mark-recapture trials), the total number of smolts that emigrated past the trap in 2007 was 2,797,313 (±131,973) wild and 183,475 (±36,799) hatchery sockeye. This was the first brood year, since 1999, that all hatchery sockeye parr were released at a similar size and time and the third brood year that hatchery smolt estimates for the late release group were greater than the number of fish released. Because the estimated number of hatchery smolts was greater than the number of parr released, we assumed that survival was 100% and adjusted the smolt estimate accordingly (Table 4.11).

Overestimates of hatchery sockeye smolts may be the result of some hatchery fish migrating at age-2 or an underestimate of the actual trap efficiency. We suggest the later, because coded wire tags recovered from outmigrating smolts between 2001 and 2005 indicated that all hatchery smolts emigrated as age-1 fish the spring following release. Additional studies are needed to determine the source of errors in trap efficiency estimates and to find possible alternatives. Monthly captures of all fish and results of capture efficiency tests at the Upper Wenatchee Trap are reported in Appendix B.

**Table 4.11.** Estimated numbers of wild and hatchery sockeye smolts that emigrated from Lake Wenatchee during run years 1997-2007.

| Run year | Numbers of sockeye smolts | |
|---|---|---|
| | Wild smolts | Hatchery smolts |
| 1997 | 55,359 | 28,828 |
| 1998 | 1,447,259 | 55,985 |
| 1999 | 1,944,966 | 112,524 |
| 2000 | 985,490 | 24,684 |
| 2001 | 39,353 | 94,046 |
| 2002 | 729,716 | 121,511 |
| 2003 | 5,303,056 | 140,322 |
| 2004 | 5,771,187 | 216,023 |
| 2005 | 723,413 | 122,399 |
| 2006 | 1,266,971 | 159,500 |
| 2007 | 2,797,313 | 140,542 |
| ***Average*** | ***1,914,917*** | ***110,579*** |

Age classes of wild sockeye smolts were determined from a length frequency analysis based on scales collected randomly each year since 1997 (Table 4.12). For the available run years, most wild sockeye smolts migrated as age 1+ fish. Only in two years (1997 and 2005) did more smolts migrate as age 2+ fish. Relatively few smolts migrated at age 3+.

**Table 4.12.** Age structure and estimated number of wild sockeye smolts that emigrated from Lake Wenatchee, 1997-2007.

| Run year | Proportion of wild smolts | | | Total wild emigrants |
|---|---|---|---|---|
| | Age 1+ | Age 2+ | Age 3+ | |
| 1997 | 0.075 | 0.906 | 0.019 | 55,359 |
| 1998 | 0.955 | 0.037 | 0.008 | 1,447,259 |
| 1999 | 0.619 | 0.381 | 0.000 | 1,944,966 |
| 2000 | 0.599 | 0.400 | 0.001 | 985,490 |
| 2001 | 0.943 | 0.051 | 0.006 | 39,353 |
| 2002 | 0.961 | 0.039 | 0.000 | 729,716 |
| 2003 | 0.740 | 0.260 | 0.000 | 5,303,056 |
| 2004 | 0.929 | 0.071 | 0.000 | 5,771,187 |
| 2005 | 0.168 | 0.707 | 0.125 | 723,413 |
| 2006 | 0.994 | 0.006 | 0.000 | 1,266,971 |
| 2007 | 0.959 | 0.038 | 0.003 | 2,797,313 |
| ***Average*** | ***0.722*** | ***0.263*** | ***0.015*** | ***1,914,917*** |

### *Lower Wenatchee Trap*

The Lower Wenatchee Trap operated nightly between 1 February and 5 August 2007. Due to high river flows, debris, snow/ice, or mechanical failure, trap 1 and trap 2 were inoperable for 14 and 68 days, respectively. During the seven-month sampling period, a total of 6,340 wild sockeye smolts and 248 hatchery sockeye smolts were captured at the Lower Wenatchee Trap. Most of the smolts migrated during April and May. Monthly captures and mortalities of all fish collected at the Lower Wenatchee Trap are reported in Appendix B.

## Freshwater Productivity

Egg-smolt survival estimates for wild sockeye salmon are provided in Table 4.13. Estimates of egg deposition were calculated based on the spawner escapement at Tumwater Dam and the sex ratio and fecundity of the broodstock. Egg-smolt survival rates for brood years 1995-2003 have ranged from 0.012 to 0.212 (mean = 0.092).

**Table 4.13.** Estimated egg deposition (estimated as mean fecundity times estimated number of females), numbers of smolts, and survival rates for wild Wenatchee sockeye salmon, 1995-2006; NA = not available.

| Brood year | Number of females | Mean fecundity | Total eggs | Numbers of wild smolts | | | | Egg-smolt survival |
|---|---|---|---|---|---|---|---|---|
| | | | | Age 1+ | Age 2+ | Age 3+ | Total | |
| 1995 | 2,136 | 2,295 | 4,902,120 | 4,174 | 53,549 | 0 | 57,723 | 0.012 |
| 1996 | 3,767 | 2,664 | 10,035,288 | 1,382,133 | 741,032 | 985 | 2,124,150 | 0.212 |
| 1997 | 5,404 | 2,447 | 13,223,588 | 1,203,934 | 394,196 | 236 | 1,598,366 | 0.121 |
| 1998 | 2,024 | 2,813 | 5,693,512 | 590,309 | 2,007 | 0 | 592,316 | 0.104 |
| 1999 | 513 | 2,319 | 1,189,647 | 37,110 | 28,459 | 0 | 65,569 | 0.055 |
| 2000 | 11,413 | 2,673 | 30,506,949 | 701,257 | 1,378,795 | 0 | 2,080,052 | 0.068 |
| 2001 | 21,685 | 2,960 | 64,187,600 | 4,024,884 | 409,754 | 90,427 | 4,525,065 | 0.070 |
| 2002 | 17,226 | 2,856 | 49,197,456 | 5,361,433 | 511,453 | 0 | 5,872,886 | 0.119 |
| 2003 | 2,158 | 3,511 | 7,576,738 | 166,385 | 7,602 | 8,392 | 182,379 | 0.024 |
| 2004 | 15,469 | 2,505 | 38,749,845 | 1,259,369 | 106,298 | NA | NA | NA |
| 2005 | 5,867 | 2,718 | 15,946,506 | 2,682,623 | NA | NA | NA | NA |
| 2006 | 4,273 | 2,656 | 11,349,088 | NA | NA | NA | NA | NA |
| ***Average*** | ***7,661*** | ***2,701*** | ***20,692,361*** | ***1,583,056*** | ***363,315*** | ***11,116*** | ***1,899,834*** | ***0.092*** |

Juvenile survival rates for hatchery sockeye salmon are provided in Table 4.14. Release-smolt survival rates for brood years 1995-2005 have ranged from 0.000 to 1.000 (mean = 0.556). Egg-smolt survival rates for the same brood years ranged from 0.000 to 0.707 (mean = 0.263). On average, egg-smolt survival of hatchery sockeye is about three times greater than egg-smolt survival of wild sockeye. On three separate occasions, however, the estimated number of hatchery smolts equaled or exceeded the number of hatchery parr released in the lake. As noted above, this suggests that the pooled trap efficiencies are biased high.

**Table 4.14**. Juvenile survival rates for hatchery Wenatchee sockeye, brood years 1995-2005; NA = not available.

| Brood year | Number of eggs | Number of parr released | Date of release | Estimated number of smolts | Egg-smolt survival | Release-smolt survival |
|---|---|---|---|---|---|---|
| 1995 | 247,900 | 150,808 | 10/25/96 | 28,828 | 0.116 | 0.191 |
| 1996 | 314,390 | 284,630 | 10/22/97 | 55,985 | 0.178 | 0.197 |
| 1997 | 254,459 | 197,195 | 11/9/98 | 112,524 | 0.442 | 0.571 |
| 1998 | 163,278 | 121,344 | 10/27/99 | 24,684 | 0.151 | 0.203 |
| 1999 | 190,732 | 84,466 | 8/28/00 | 30,326 | 0.159 | 0.359 |
| | | 83,489 | 11/1/00 | 63,720 | 0.334 | 0.763 |
| 2000 | 227,234 | 92,055 | 8/27/01 | 30,918 | 0.136 | 0.336 |
| | | 98,119 | 9/27/01 | 90,593 | 0.399 | 0.923 |
| 2001 | 301,925 | 96,486 | 8/28/02 | 36,484 | 0.121 | 0.378 |
| | | 104,452 | 9/23/02 | 103,838 | 0.344 | 0.994 |
| 2002 | 356,982 | 98,509 | 6/16/03 | 5,192 | 0.015 | 0.053 |
| | | 104,855 | 8/25/03 | 98,412 | 0.276 | 0.939 |
| | | 112,419 | 10/22/03 | 112,419 | 0.315 | 1.000 |
| 2003 | 319,470 | 32,755 | 6/15/04 | 0 | 0.000 | 0.000 |
| | | 104,879 | 8/25/04 | 19,574 | 0.061 | 0.187 |
| | | 102,825 | 11/3/04 | 102,825 | 0.322 | 1.000 |
| 2004 | 225,499 | 81,428 | 8/29/05 | 159,500 | 0.707 | 0.922 |
| | | 91,495 | 11/2/05 | | | |
| 2005 | 211,985 | 70,386 | 10/30/06 | 140,542 | 0.663 | 1.000 |
| | | 70,156 | 10/30/06 | | | |

## *4.5 Spawning Surveys*

Spawning surveys were conducted in the Little Wenatchee and White (including the Napeequa River) rivers from 30 August to 19 October 2007. Surveys in 2007 only included counting numbers of live sockeye spawners. No redds were counted in 2007 (see Appendix G for more details).

### Spawn Timing

Sockeye began spawning during the first week of September and peaked around the third week of September (Figure 4.1). Peak spawning was determined using the total number of spawners observed on the spawning grounds.

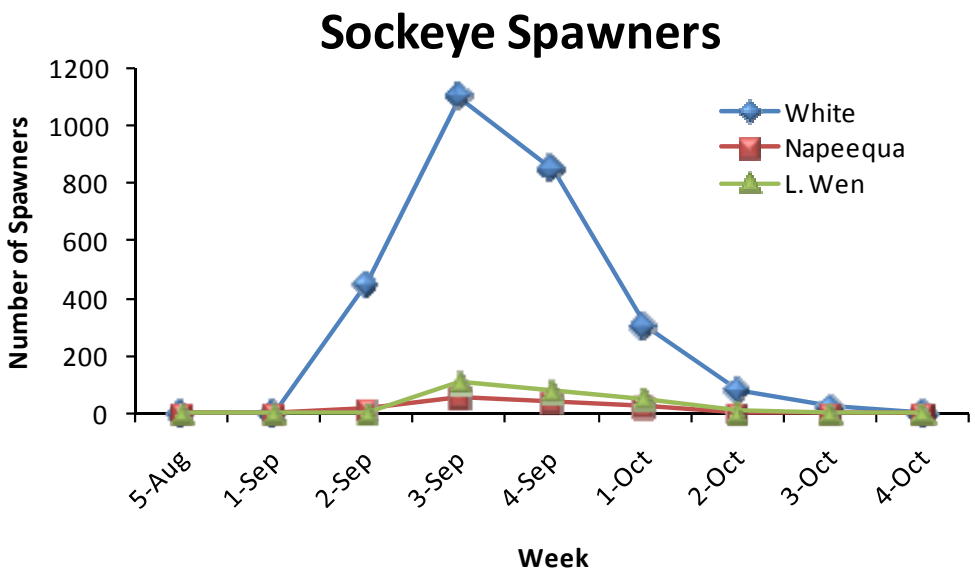


**Figure 4.1.** Numbers of sockeye spawners counted during different weeks in different sampling streams within the Wenatchee Basin, August through October 2007.

## Spawning Escapement

Spawning escapement of sockeye salmon in 2007 was estimated using the area-under-the-curve (AUC) method (i.e., escapement = (AUC/redd residence time) x observer efficiency). This method relied on weekly counts of live sockeye and assumed a redd residence time of 11 days and an observer efficiency of 100%. Both redd residence time and observer efficiency will be evaluated in the Wenatchee Basin in 2008.

### *Area-under-the-curve*

Based on the AUC approach, the estimated total spawning escapement of sockeye in the Wenatchee basin in 2007 was 1,870 (Table 4.15). About 92% of the escapement spawned in the White River (including the Napeequa River).

**Table 4.15.** Peak numbers of live spawners and total spawning escapement estimates for sockeye salmon in the Wenatchee Basin, August through October 2007.

| Sampling area | Peak number of live fish | Spawning escapement |
|---|---|---|
| Little Wenatchee | 102 | 150 |
| White River | 1,183 | 1,720 |
| ***Total*** | ***1,285*** | ***1,870*** |

The spawning escapement of 1,870 Wenatchee sockeye is less than the 1989-2007 average of 15,520 and is one of the lowest on record (Table 4.16).

**Table 4.16.** Spawning escapements for sockeye salmon in the Wenatchee Basin for return years 1989-2007; NA = not available. Total escapements before 2003 were based on counts at Tumwater Dam.

| Return year | Spawning escapement | | |
|---|---|---|---|
| | Little Wenatchee | White | Total |
| 1989 | NA | NA | **28,778** |
| 1990 | NA | NA | **25,177** |
| 1991 | NA | NA | **26,565** |
| 1992 | NA | NA | **22,628** |
| 1993 | NA | NA | **29,952** |
| 1994 | NA | NA | **9,447** |
| 1995 | NA | NA | **4,272** |
| 1996 | NA | NA | **7,534** |
| 1997 | NA | NA | **10,808** |
| 1998 | NA | NA | **4,047** |
| 1999 | NA | NA | **1,025** |
| 2000 | NA | NA | **20,751** |
| 2001 | NA | NA | **29,134** |
| 2002 | NA | NA | **27,565** |
| 2003 | NA | NA | **4,704** |
| 2004 | NA | NA | **25,834** |
| 2005 | NA | NA | **8,582** |
| 2006 | 574 | 5,634 | **6,208** |
| 2007 | 150 | 1,720 | **1,870** |
| ***Average*** | ***362*** | ***3,677*** | ***15,520*** |

## *4.6 Carcass Surveys*

Carcass surveys were conducted in the Little Wenatchee and White (including the Napeequa River) rivers from 10 September to 23 October 2007.

### Number sampled

A total of 383 sockeye carcasses were sampled during August through October, 2007, in the Wenatchee Basin (Table 4.17). This is considerably lower than the 15-year average of 2,256 carcasses. Most of the carcasses sampled in 2007 were collected in the White River basin (96% or 366 carcasses) (Figure 4.2). The remaining 4% were sampled in the Little Wenatchee River (17 carcasses).

**Table 4.17.** Numbers of sockeye carcasses sampled within different streams/watersheds within the Wenatchee Basin, 1989-2006.

| Survey year | Numbers of sockeye carcasses | | | |
|---|---|---|---|---|
| | Little Wenatchee | White | Napeequa | Total |
| 1993 | 90 | 195 | 0 | **285** |
| 1994 | 121 | 165 | 0 | **286** |
| 1995 | 0 | 56 | 0 | **56** |
| 1996 | 43 | 1,387 | 3 | **1,433** |
| 1997 | 69 | 1,425 | 41 | **1,535** |
| 1998 | 61 | 524 | 4 | **589** |
| 1999 | 40 | 186 | 0 | **226** |
| 2000 | 821 | 5,494 | 0 | **6,315** |
| 2001 | 650 | 3,127 | 0 | **3,777** |
| 2002 | 506 | 7,258 | 55 | **7,819** |
| 2003 | 86 | 1,002 | 14 | **1,102** |
| 2004 | 625 | 6,960 | 138 | **7,723** |
| 2005 | 1 | 7 | 0 | **8** |
| 2006 | 101 | 2,158 | 38 | **2,297** |
| 2007 | 17 | 363 | 3 | **383** |
| ***Average*** | ***215*** | ***2,020*** | ***20*** | ***2,256*** |

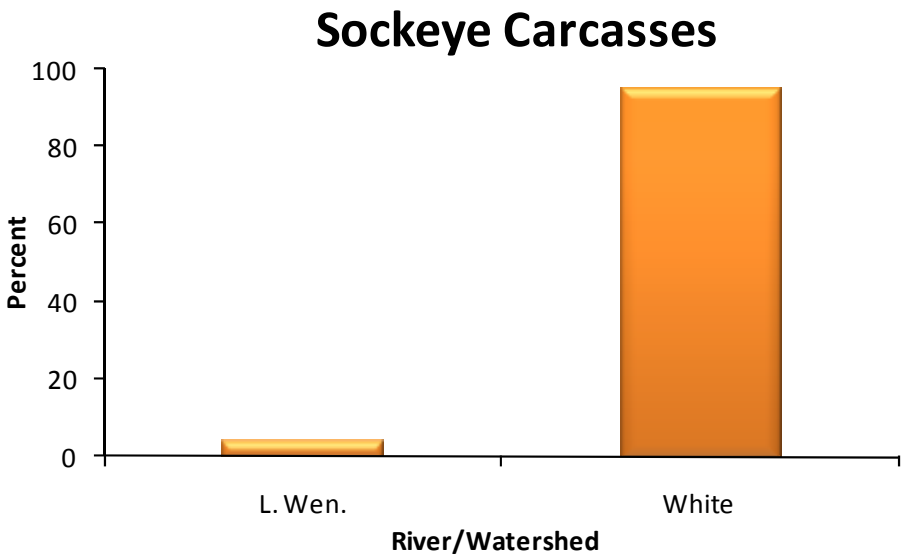


**Figure 4.2.** Percent of the total number of sockeye carcasses sampled in different streams/watersheds within the Wenatchee Basin during August through October, 2007.

### Carcass Distribution and Origin

Sockeye carcasses were not evenly distributed among reaches within survey streams in 2007 (Table 4.18). Carcasses were only found in Reaches 2 (Lost Creek to Rainy Creek) on the Little Wenatchee. Most (99%) of the carcasses sampled in the White River basin were in Reach 2 (Sears Creek Bridge to Napeequa River). About 1% of the carcasses sampled in the White River basin were in the Napeequa River.

**Table 4.18.** Numbers of carcasses sampled within different streams/watersheds within the Wenatchee Basin during August through September, 2007.

| Stream/watershed | Reach | Total carcasses |
|---|---|---|
| Little Wenatchee | Little Wen 1 | 0 |
| | Little Wen 2 | 17 |
| | Little Wen 3 | 0 |
| | **Total** | **17** |
| White | White 1 | 0 |
| | White 2 | 363 |
| | White 3 | 0 |
| | Napeequa 1 | 3 |
| | **Total** | **366** |
| ***Grand Total*** | | ***383*** |

Numbers of wild and hatchery origin sockeye carcasses sampled in 2007 will be available after analysis of marks/tags and scales. Based on the available data (1993-2006), the largest percentage of both wild and hatchery sockeye spawned in Reach 2 on the White River (Table 4.19 and Figure 4.3). However, a greater percentage of wild fish were found in Reach 2 than hatchery fish. The opposite occurred in Reach 2 on the Little Wenatchee. A larger percentage of hatchery fish were found there compared to wild fish.

**Table 4.19.** Numbers of wild and hatchery sockeye carcasses sampled within different reaches in the Wenatchee Basin, 1993-2006. Reach codes are described in Table 2.9.

| Survey year | Origin | Numbers of sockeye carcasses | | | | | |
|---|---|---|---|---|---|---|---|
| | | Little Wenatchee | | White River | | | Total |
| | | L2 | L3 | H1 | H2 | Q1 | |
| 1993 | Wild | 86 | 0 | 0 | 183 | 0 | **269** |
| | Hatchery | 4 | 0 | 0 | 12 | 0 | **16** |
| 1994 | Wild | 112 | 0 | 0 | 155 | 0 | **267** |
| | Hatchery | 9 | 0 | 0 | 9 | 0 | **18** |
| 1995 | Wild | 0 | 0 | 0 | 55 | 0 | **55** |
| | Hatchery | 0 | 0 | 0 | 1 | 0 | **1** |
| 1996 | Wild | 41 | 0 | 0 | 1,299 | 3 | **1,343** |
| | Hatchery | 2 | 0 | 0 | 88 | 0 | **90** |
| 1997 | Wild | 65 | 0 | 0 | 1,411 | 40 | **1,516** |
| | Hatchery | 4 | 0 | 0 | 11 | 1 | **16** |

| Survey year | Origin | Numbers of sockeye carcasses | | | | | |
|---|---|---|---|---|---|---|---|
| | | Little Wenatchee | | White River | | | Total |
| | | L2 | L3 | H1 | H2 | Q1 | |
| 1998 | Wild | 61 | 0 | 0 | 515 | 4 | **580** |
| | Hatchery | 0 | 0 | 0 | 9 | 0 | **9** |
| 1999 | Wild | 30 | 0 | 0 | 164 | 0 | **194** |
| | Hatchery | 10 | 0 | 0 | 22 | 0 | **32** |
| 2000 | Wild | 694 | 0 | 3 | 5,239 | 0 | **5,936** |
| | Hatchery | 127 | 0 | 0 | 252 | 0 | **379** |
| 2001 | Wild | 625 | 0 | 0 | 3,063 | 0 | **3,688** |
| | Hatchery | 25 | 0 | 0 | 64 | 0 | **89** |
| 2002 | Wild | 504 | 0 | 0 | 7,207 | 55 | **7,766** |
| | Hatchery | 2 | 0 | 0 | 51 | 0 | **53** |
| 2003 | Wild | 81 | 0 | 0 | 993 | 14 | **1,088** |
| | Hatchery | 5 | 0 | 0 | 9 | 0 | **14** |
| 2004 | Wild | 606 | 0 | 0 | 6,755 | 166 | **7,527** |
| | Hatchery | 19 | 0 | 0 | 205 | 22 | **246** |
| 2005 | Wild | 201 | 0 | 5 | 2,966 | 21 | **3,193** |
| | Hatchery | 1 | 0 | 0 | 8 | 0 | **9** |
| 2006 | Wild | 80 | 0 | 0 | 2,112 | 36 | **2,228** |
| | Hatchery | 21 | 0 | 0 | 46 | 2 | **69** |
| ***Average*** | ***Wild*** | ***228*** | ***0*** | ***1*** | ***2,294*** | ***24*** | ***2,546*** |
| | ***Hatchery*** | ***16*** | ***0*** | ***0*** | ***56*** | ***2*** | ***74*** |

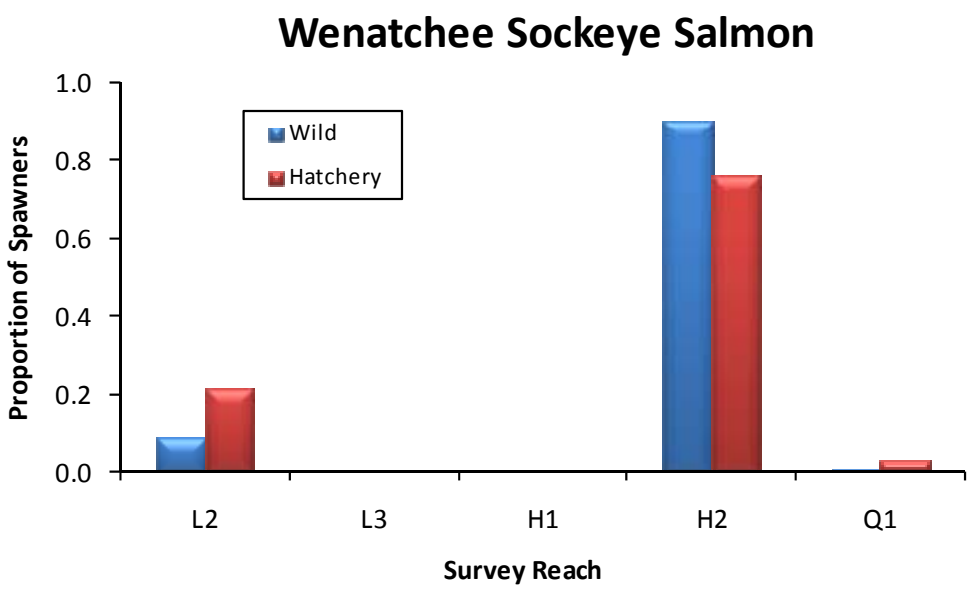


**Figure 4.3**. Distribution of wild and hatchery produced carcasses in different reaches in the Wenatchee Basin, pooled data from 1993-2005. Reach codes are described in Table 2.9; L = Little Wenatchee, H = White River, and Q = Napeequa River.

### Sampling Rate

The sampling rate of sockeye carcasses differed among basins, with a higher sampling rate in the White than in the Little Wenatchee (Table 4.20). Nevertheless, the overall sampling rate for both basins combined equaled the target of 20%.

**Table 4.20**. Numbers of carcasses, estimated spawning escapements, and sampling rates for sockeye salmon in the Wenatchee Basin, 2007.

| Sampling basin | Total number of carcasses | Total spawning escapement | Sampling rate |
|---|---|---|---|
| Little Wenatchee | 17 | 150 | 0.11 |
| White | 366 | 1,720 | 0.21 |
| ***Total*** | ***383*** | ***1,870*** | ***0.20*** |

### Length Data

Mean lengths (POH, cm) of male and female sockeye carcasses sampled during surveys in the Wenatchee Basin in 2007 are provided in Table 4.21. On average, males were slightly smaller than females.

**Table 4.21.** Mean lengths (postorbital-to-hypural length; cm) and standard deviations (in parentheses) of male and female sockeye carcasses sampled in different streams/watersheds in the Wenatchee Basin, 2007; N = number of fish sampled.

| Stream/watershed | Male | | Female | |
|---|---|---|---|---|
| | N | Length (cm) | N | Length (cm) |
| Little Wenatchee River | 0 | -- | 0 | -- |
| White River | 7 | 39.9 (6.8) | 10 | 42.2 (1.7) |
| Napeequa River | 0 | -- | 0 | -- |
| Wenatchee River | 0 | -- | 0 | -- |
| ***Total*** | ***7*** | ***39.9 (6.8)*** | ***10*** | ***42.2 (1.7)*** |

## *4.7 Life History Monitoring*

Life history characteristics of Wenatchee sockeye were assessed by examining carcasses on spawning grounds and fish sampled at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

### Migration Timing

There was little difference in migration timing of hatchery and wild sockeye past Tumwater Dam during the 2007 migration period (Table 4.22). When the data were pooled for the 1998-2007 survey period, there was a difference in migration timing of wild and hatchery sockeye (Table 4.22; Figure 4.4). Most hatchery and wild sockeye migrated upstream past Tumwater dam during July through early August; however, on average, hatchery fish tended to migrate earlier than did wild fish. The peak migration time for hatchery sockeye was the second week of July, while the peak for wild

sockeye was the fourth week of July (Figure 4.4). It should be noted that the return of hatchery sockeye in 2001 was large compared to other years and this return class skewed the pooled estimate to an earlier migration timing. In most other years, there was little difference in migration timing of hatchery and wild sockeye observed at Tumwater Dam.

**Table 4.22.** The proportion of wild and hatchery sockeye observed (with video sampling) passing Tumwater Dam each week from late June through early October, 1998-2007. Data for 1998 through 2003 were based on videotapes and broodstock trapping and may not reflect the actual number of hatchery sockeye salmon. All sockeye were visually examined during trapping from 2004 to present.

| Survey year | Origin | Proportion of sockeye sampled at Tumwater Dam weekly | | | | | | | | | | | | | | | Sample size |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jun | Jul | | | | Aug | | | | | Sep | | | | Oct | |
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | |
| 1998 | Wild | 0.000 | 0.000 | 0.131 | 0.613 | 0.205 | 0.033 | 0.015 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 4,173 |
| | Hatch | 0.000 | 0.000 | 0.129 | 0.355 | 0.258 | 0.097 | 0.097 | 0.065 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 31 |
| 1999 | Wild | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.007 | 0.036 | 0.315 | 0.405 | 0.180 | 0.032 | 0.020 | 0.006 | 0.000 | 0.000 | 908 |
| | Hatch | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.004 | 0.019 | 0.322 | 0.447 | 0.152 | 0.034 | 0.015 | 0.008 | 0.000 | 0.000 | 264 |
| 2000 | Wild | 0.001 | 0.000 | 0.008 | 0.292 | 0.502 | 0.160 | 0.030 | 0.004 | 0.002 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 18,390 |
| | Hatch | 0.005 | 0.002 | 0.029 | 0.292 | 0.453 | 0.178 | 0.035 | 0.003 | 0.003 | 0.000 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 2,589 |
| 2001 | Wild | 0.000 | 0.000 | 0.000 | 0.321 | 0.443 | 0.236 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1,047 |
| | Hatch | 0.000 | 0.156 | 0.426 | 0.162 | 0.114 | 0.084 | 0.044 | 0.005 | 0.005 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 31,586 |
| 2002 | Wild | 0.000 | 0.000 | 0.000 | 0.063 | 0.610 | 0.214 | 0.076 | 0.027 | 0.007 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 0.000 | 27,241 |
| | Hatch | 0.000 | 0.000 | 0.000 | 0.034 | 0.603 | 0.188 | 0.114 | 0.041 | 0.007 | 0.005 | 0.003 | 0.003 | 0.000 | 0.000 | 0.000 | 580 |
| 2003 | Wild | 0.000 | 0.003 | 0.223 | 0.515 | 0.201 | 0.032 | 0.014 | 0.007 | 0.002 | 0.001 | 0.002 | 0.000 | 0.000 | 0.001 | 0.000 | 4,699 |
| | Hatch | 0.003 | 0.000 | 0.176 | 0.408 | 0.288 | 0.077 | 0.035 | 0.011 | 0.003 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 375 |
| 2004 | Wild | 0.000 | 0.063 | 0.469 | 0.302 | 0.112 | 0.025 | 0.010 | 0.011 | 0.001 | 0.003 | 0.002 | 0.001 | 0.001 | 0.000 | 0.000 | 31,409 |
| | Hatch | 0.000 | 0.101 | 0.552 | 0.251 | 0.073 | 0.002 | 0.002 | 0.009 | 0.005 | 0.002 | 0.002 | 0.001 | 0.000 | 0.001 | 0.000 | 1,758 |
| 2005 | Wild | 0.001 | 0.057 | 0.273 | 0.409 | 0.108 | 0.025 | 0.025 | 0.008 | 0.011 | 0.032 | 0.030 | 0.009 | 0.010 | 0.001 | 0.001 | 14,176 |
| | Hatch | 0.000 | 0.214 | 0.167 | 0.190 | 0.071 | 0.000 | 0.071 | 0.095 | 0.024 | 0.024 | 0.048 | 0.048 | 0.000 | 0.000 | 0.048 | 42 |
| 2006 | Wild | 0.000 | 0.000 | 0.012 | 0.423 | 0.441 | 0.059 | 0.042 | 0.015 | 0.005 | 0.001 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 9,151 |
| | Hatch | 0.000 | 0.000 | 0.012 | 0.213 | 0.197 | 0.049 | 0.367 | 0.122 | 0.030 | 0.008 | 0.000 | 0.002 | 0.000 | 0.000 | 0.000 | 507 |
| 2007 | Wild | 0.000 | 0.000 | 0.026 | 0.114 | 0.383 | 0.280 | 0.070 | 0.055 | 0.033 | 0.019 | 0.010 | 0.002 | 0.003 | 0.002 | 0.002 | 2,542 |
| | Hatch | 0.000 | 0.000 | 0.000 | 0.077 | 0.308 | 0.262 | 0.138 | 0.123 | 0.046 | 0.031 | 0.000 | 0.000 | 0.000 | 0.015 | 0.000 | 65 |
| ***Ave*** | ***Wild*** | ***0.000*** | ***0.025*** | ***0.181*** | ***0.280*** | ***0.335*** | ***0.103*** | ***0.035*** | ***0.016*** | ***0.008*** | ***0.007*** | ***0.005*** | ***0.002*** | ***0.001*** | ***0.000*** | ***0.000*** | ***113,736*** |
| | ***Hatch*** | ***0.000*** | ***0.136*** | ***0.386*** | ***0.175*** | ***0.145*** | ***0.088*** | ***0.047*** | ***0.010*** | ***0.008*** | ***0.004*** | ***0.001*** | ***0.001*** | ***0.000*** | ***0.000*** | ***0.000*** | ***37,797*** |

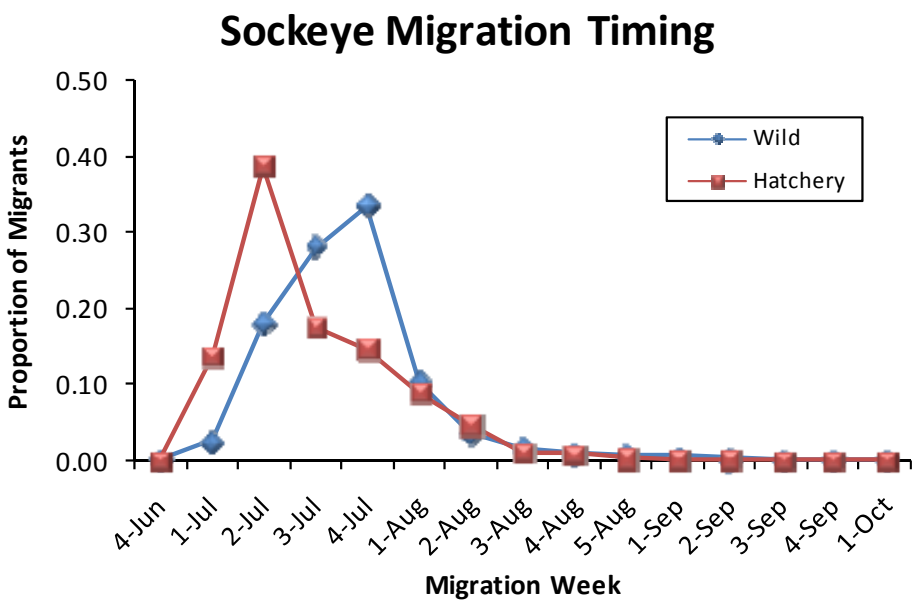


**Figure 4.4**. Proportion of wild and hatchery sockeye observed (using video) passing Tumwater Dam each week during their migration period late-June through early-October; data were pooled over survey years 1998-2007.

### Age at Maturity

Although sample sizes are small, it appears that most wild sockeye returned as age-5 fish, while most hatchery sockeye returned as age-4 fish (Table 4.23; Figure 4.5). Only wild fish have returned at age-6.

**Table 4.23.** Proportions of wild and hatchery sockeye of different ages (total age) sampled in broodstock and on spawning grounds, 1994-2006.

| Survey year | Origin | Total age | | | | | | Sample size |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 | |
| 1994 | Wild | - | - | - | - | - | - | 0 |
| | Hatchery | 0.00 | 0.00 | 0.88 | 0.13 | 0.00 | 0.00 | 16 |
| 1995 | Wild | - | - | - | - | - | - | 0 |
| | Hatchery | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1 |
| 1996 | Wild | - | - | - | - | - | - | 0 |
| | Hatchery | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 82 |
| 1997 | Wild | - | - | - | - | - | - | 0 |
| | Hatchery | 0.00 | 0.00 | 0.77 | 0.23 | 0.00 | 0.00 | 13 |
| 1998 | Wild | 0.00 | 0.08 | 0.85 | 0.08 | 0.00 | 0.00 | 26 |
| | Hatchery | 0.00 | 0.00 | 0.64 | 0.36 | 0.00 | 0.00 | 11 |
| 1999 | Wild | 0.00 | 0.00 | 0.18 | 0.73 | 0.10 | 0.00 | 113 |
| | Hatchery | 0.00 | 0.00 | 0.65 | 0.35 | 0.00 | 0.00 | 31 |

| Survey year | Origin | Total age | | | | | | Sample size |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 | |
| 2000 | Wild | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 1 |
| | Hatchery | 0.00 | 0.00 | 0.98 | 0.02 | 0.00 | 0.00 | 359 |
| 2001 | Wild | 0.00 | 0.00 | 0.76 | 0.24 | 0.00 | 0.00 | 29 |
| | Hatchery | 0.00 | 0.00 | 0.75 | 0.25 | 0.00 | 0.00 | 171 |
| 2002 | Wild | 0.00 | 0.00 | 0.20 | 0.80 | 0.00 | 0.00 | 5 |
| | Hatchery | 0.00 | 0.00 | 0.29 | 0.71 | 0.00 | 0.00 | 63 |
| 2003 | Wild | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 5 |
| | Hatchery | 0.00 | 0.33 | 0.67 | 0.00 | 0.00 | 0.00 | 6 |
| 2004 | Wild | - | - | - | - | - | - | 0 |
| | Hatchery | 0.00 | 0.02 | 0.93 | 0.05 | 0.00 | 0.00 | 244 |
| 2005 | Wild | - | - | - | - | - | - | 0 |
| | Hatchery | 0.00 | 0.13 | 0.75 | 0.13 | 0.00 | 0.00 | 8 |
| 2006 | Wild | 0.00 | 0.00 | 0.34 | 0.65 | 0.01 | 0.00 | 207 |
| | Hatchery | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 65 |
| ***Average*** | ***Wild*** | ***0.00*** | ***0.01*** | ***0.35*** | ***0.61*** | ***0.03*** | ***0.00*** | ***386*** |
| | ***Hatchery*** | ***0.00*** | ***0.01*** | ***0.87*** | ***0.12*** | ***0.00*** | ***0.00*** | ***1,070*** |

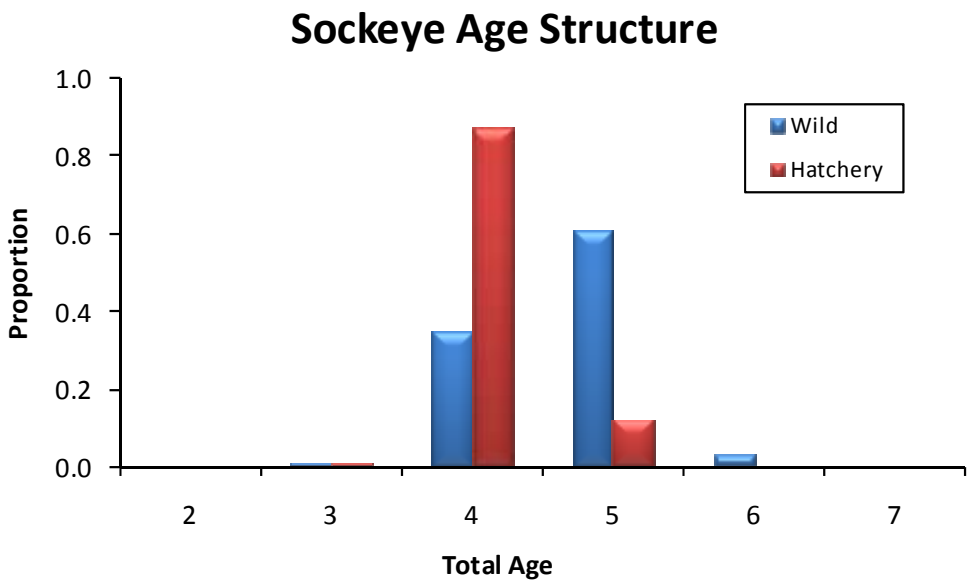


**Figure 4.5.** Proportions of wild and hatchery sockeye salmon of different total ages sampled at Tumwater Dam and on spawning grounds in the Wenatchee Basin for the combined years 1994-2006.

### Size at Maturity

Although sample sizes are small, there was virtually no difference in mean sizes of hatchery and wild sockeye salmon sampled in the Wenatchee Basin (Table 4.24). Future analyses will compare sizes of hatchery and wild fish of the same age groups and gender.

**Table 4.24.** Mean lengths (POH; cm) and variability statistics for wild and hatchery sockeye salmon sampled at Tumwater Dam (broodstock) and on spawning grounds in the Wenatchee Basin, 1994-2006; SD = 1 standard deviation.

| Survey year | Origin | Sample size | Sockeye length (POH; cm) | | | |
|---|---|---|---|---|---|---|
| | | | Mean | SD | Minimum | Maximum |
| 1994 | Wild | 0 | - | - | - | - |
| | Hatchery | 14 | 42 | 3 | 37 | 47 |
| 1995 | Wild | 0 | - | - | - | - |
| | Hatchery | 1 | 53 | - | 53 | 53 |
| 1996 | Wild | 0 | - | - | - | - |
| | Hatchery | 5 | 51 | 3 | 49 | 55 |
| 1997 | Wild | 6 | 40 | 3 | 38 | 45 |
| | Hatchery | 17 | 41 | 3 | 37 | 50 |
| 1998 | Wild | 585 | 43 | 3 | 34 | 50 |
| | Hatchery | 20 | 43 | 3 | 40 | 51 |
| 1999 | Wild | 99 | 42 | 3 | 36 | 50 |
| | Hatchery | 31 | 41 | 3 | 36 | 47 |
| 2000 | Wild | 1 | 48 | - | 48 | 48 |
| | Hatchery | 377 | 40 | 2 | 30 | 49 |
| 2001 | Wild | 29 | 42 | 2 | 38 | 47 |
| | Hatchery | 184 | 43 | 3 | 35 | 51 |
| 2002 | Wild | 5 | 42 | 1 | 40 | 43 |
| | Hatchery | 52 | 44 | 3 | 37 | 49 |
| 2003 | Wild | 5 | 44 | 4 | 38 | 47 |
| | Hatchery | 13 | 42 | 5 | 30 | 48 |
| 2004 | Wild | 0 | - | - | - | - |
| | Hatchery | 230 | 40 | 3 | 33 | 49 |
| 2005 | Wild | 0 | - | - | - | - |
| | Hatchery | 8 | 43 | 9 | 35 | 64 |
| 2006 | Wild | 248 | 45 | 4 | 34 | 52 |
| | Hatchery | 17 | 41 | 5 | 31 | 48 |
| ***Pooled*** | ***Wild*** | ***978*** | ***43*** | ***3*** | ***34*** | ***52*** |
| | ***Hatchery*** | ***969*** | ***43*** | ***4*** | ***30*** | ***64*** |

## Contribution to Fisheries

The total number of hatchery and wild sockeye captured in different fisheries is provided in Tables 4.25 and 4.26. Harvest on hatchery sockeye was minimal during brood years 1989-2001. In contrast, harvest on wild sockeye was relatively high for brood years 1989-1993. Thereafter, harvest was low.

**Table 4.25.** Estimated number and percent (in parentheses) of hatchery Wenatchee sockeye captured in different fisheries.

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational[a] (sport) | |
| 1989 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1990 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1991 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1992 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1993 | 0 (0) | 0 (0) | 0 (0) | 639 (100) | 639 |
| 1994 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1995 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1996 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1997 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1998 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1999 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 2000 | 0 (0) | 0 (0) | 5 (100) | 0 (0) | 5 |
| 2001 | 0 (0) | 0 (0) | 3 (100) | 0 (0) | 3 |

[a] Includes the Lake Wenatchee fishery.

**Table 4.26.** Estimated number and percent (in parentheses) of wild Wenatchee sockeye captured in different fisheries.

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational[a] (sport) | |
| 1989 | 0 (0) | 1,247 (96) | 57 (4) | 0 (0) | 1,304 |
| 1990 | 0 (0) | 1,973 (23) | 79 (1) | 6,523 (76) | 8,575 |
| 1991 | 0 (0) | 1,898 (23) | 56 (1) | 6,311 (76) | 8,265 |
| 1992 | 0 (0) | 893 (20) | 39 (1) | 3,565 (79) | 4,497 |
| 1993 | 0 (0) | 341 (5) | 57 (1) | 6,400 (94) | 6,798 |
| 1994 | 0 (0) | 0 (0) | 85 (100) | 0 (0) | 85 |
| 1995 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1996 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1997 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1998 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1999 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational[a] (sport) | |
| 2000 | | | | | |
| 2001 | | | | | |

[a] Includes the Lake Wenatchee fishery.

### Straying

Stray rates were determined by examining CWTs recovered on spawning grounds within and outside the Wenatchee Basin. Targets for strays based on return year (recovery year) outside the Wenatchee Basin should be less than 5%. The target for brood year strays should also be less than 5%.

There is no record that Wenatchee sockeye have strayed into other spawning areas outside the Wenatchee Basin. This may be related to the lack of carcass surveys in other locations. Nevertheless, the existing data indicate that Wenatchee sockeye stray at a rates less than the target of 5%.

Based on brood year analysis, virtually no Wenatchee sockeye have strayed into non-target spawning areas or hatchery programs (Table 4.27). These data indicate that Wenatchee sockeye stray at rates less than the target of 5%.

**Table 4.27.** Number and percent of hatchery Wenatchee sockeye that homed to target spawning areas and the target hatchery program, and number and percent that strayed to non-target spawning areas and hatchery programs, by brood years 1990-2001. Hatchery sockeye from brood years 1995-1998 were not tagged because of columnaris disease. Percent stays should be less than 5%.

| Brood year | Homing | | | | Straying | | | |
|---|---|---|---|---|---|---|---|---|
| | Target streams | | Target hatchery | | Non-target streams | | Non-target hatcheries | |
| | Number | % | Number | % | Number | % | Number | % |
| 1990 | 402 | 99.5 | 2 | 0.5 | 0 | 0.0 | 0 | 0.0 |
| 1991 | 1 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1992 | 92 | 98.9 | 0 | 0.0 | 0 | 0.0 | 1 | 1.1 |
| 1993 | 29 | 96.7 | 1 | 3.3 | 0 | 0.0 | 0 | 0.0 |
| 1994 | 66 | 94.3 | 4 | 5.7 | 0 | 0.0 | 0 | 0.0 |
| 1995 | - | - | - | - | - | - | - | - |
| 1996 | - | - | - | - | - | - | - | - |
| 1997 | - | - | - | - | - | - | - | - |
| 1998 | - | - | - | - | - | - | - | - |
| 1999 | 65 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2000 | 571 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2001 | 20 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| ***Total*** | ***1,246*** | ***99.4*** | ***7*** | ***0.6*** | ***0*** | ***0.0*** | ***1*** | ***0.1*** |

### Genetics

Genetic studies were conducted to determine the potential impacts of the Wenatchee sockeye supplementation program on natural origin sockeye in the upper Wenatchee Basin (Blankenship et al. 2008; the entire report is appended as Appendix H). Specifically, the objective of the study was to determine if the genetic composition of the Lake Wenatchee sockeye population had been altered by the supplementation program, which was based on the artificial propagation of a small subset of the Wenatchee population. Microsatellite DNA allele frequencies were used to differentiate between temporally replicated collections of natural and hatchery-origin sockeye in the Wenatchee Basin. A total of 13 collections of Wenatchee sockeye were analyzed; eight temporally replicated collections of natural-origin sockeye and five temporally replicated collections of hatchery-origin sockeye. Paired natural-hatchery collections were available from return years 2000, 2001, 2004, 2006, and 2007.

Overall, the study showed that allele frequency distributions were consistent over time, regardless of origin, resulting in small, insignificant measures of genetic differentiation among collections. This indicates that there was no year-to-year differences in allele frequencies between natural and hatchery-origin sockeye. In addition, the analyses found no differences between pre- and post-supplementation collections. Thus, it was concluded that the allele frequencies of the broodstock collections equaled the allele frequency of the natural collections.

### Proportion of Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery origin fish in the natural spawning escapement (pHOS). The ratio pNOB/(pHOS+pNOB) is the Proportion of Natural Influence (PNI). The larger the ratio (PNI), the greater the strength of selection in the natural environment relative to that of the hatchery environment. In order for the natural environment to dominate selection, PNI should be greater than 0.5 (HSRG/WDFW/NWIFC 2004).

For brood years 1989-2005, the PNI was equal to or greater than 0.8 (Table 4.28). This indicates that the natural environment has a greater influence on adaptation of Wenatchee sockeye than does the hatchery environment.

**Table 4.28.** Proportionate natural influence (PNI) of the Wenatchee sockeye supplementation program for brood years 1989-2005. PNI was calculated as the proportion of naturally produced sockeye in the hatchery broodstock (pNOB) divided by the proportion of hatchery sockeye on the spawning grounds (pHOS) plus pNOB. NOS = number of natural origin sockeye on the spawning grounds; HOS = number of hatchery origin sockeye on the spawning grounds; NOB = number of natural origin sockeye collected for broodstock; and HOB = number of hatchery origin sockeye included in hatchery broodstock.

| Brood year | Spawners | | | Broodstock | | | PNI |
|---|---|---|---|---|---|---|---|
| | NOS | HOS | pHOS | NOB | HOB | pNOB | |
| 1989 | 28,778 | 0 | 0.00 | 115 | 0 | 1.00 | 1.0 |
| 1990 | 25,177 | 0 | 0.00 | 302 | 0 | 1.00 | 1.0 |
| 1991 | 26,565 | 0 | 0.00 | 199 | 0 | 1.00 | 1.0 |
| 1992 | 22,628 | 0 | 0.00 | 320 | 0 | 1.00 | 1.0 |

| Brood year | Spawners | | | Broodstock | | | PNI |
|---|---|---|---|---|---|---|---|
| | NOS | HOS | pHOS | NOB | HOB | pNOB | |
| 1993 | 27,226 | 2,726 | 0.09 | 207 | 0 | 1.00 | 0.9 |
| 1994 | 8,840 | 607 | 0.06 | 236 | 5 | 0.98 | 0.9 |
| 1995 | 4,216 | 56 | 0.01 | 199 | 3 | 0.99 | 1.0 |
| 1996 | 7,067 | 467 | 0.06 | 225 | 0 | 1.00 | 0.9 |
| 1997 | 10,722 | 86 | 0.01 | 192 | 19 | 0.91 | 1.0 |
| 1998 | 4,015 | 32 | 0.01 | 151 | 6 | 0.96 | 1.0 |
| 1999 | 894 | 131 | 0.13 | 68 | 60 | 0.53 | 0.8 |
| 2000 | 19,589 | 1,162 | 0.06 | 170 | 5 | 0.97 | 0.9 |
| 2001 | 28,347 | 787 | 0.03 | 200 | 7 | 0.97 | 1.0 |
| 2002 | 27,378 | 187 | 0.01 | 256 | 0 | 1.00 | 1.0 |
| 2003 | 4,814 | 51 | 0.01 | 198 | 0 | 1.00 | 1.0 |
| 2004 | 26,605 | 954 | 0.03 | 180 | 0 | 1.00 | 1.0 |
| 2005 | 13,995 | 39 | 0.00 | 166 | 0 | 1.00 | 1.0 |

## Natural Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural origin recruits (NOR) to the parent spawning population. For brood years 1989-2000, NRR in the Wenatchee averaged 0.96 (range, 0.12-4.23) if harvested fish were not included in the estimate and 1.00 (range, 0.12-4.51) if harvested fish were included in the estimate (Table 4.29).

**Table 4.29.** Spawning escapements, natural origin recruits (NOR), and natural replacement rates (NRR; with and without harvest) for wild sockeye salmon in the Wenatchee basin, 1989-2000. *(The numbers in this table may change as the HETT and HC refine the methods for estimating sockeye NORs, and NRRs.)*

| Brood year | Escapement | NOR | NRR | |
|---|---|---|---|---|
| | | | Harvest not included | Harvest included |
| 1989 | 28,778 | 30,487 | 1.05 | 1.06 |
| 1990 | 25,177 | 6,164 | 0.24 | 0.24 |
| 1991 | 26,565 | 5,908 | 0.22 | 0.22 |
| 1992 | 22,628 | 6,337 | 0.28 | 0.28 |
| 1993 | 29,952 | 13,164 | 0.44 | 0.44 |
| 1994 | 9,447 | 1,188 | 0.13 | 0.13 |
| 1995 | 4,272 | 532 | 0.12 | 0.12 |
| 1996 | 7,534 | 34,009 | 4.23 | 4.51 |
| 1997 | 10,808 | 40,354 | 3.41 | 3.73 |
| 1998 | 4,047 | 16,488 | 3.87 | 4.07 |
| 1999 | 1,025 | 469 | 0.44 | 0.46 |
| 2000 | 20,751 | 35,688 | 1.65 | 1.72 |
| ***Average*** | ***15,915*** | ***15,899*** | ***0.96*** | ***1.00*** |

### Hatchery Replacement Rates

Hatchery replacement rates (HRR) were estimated as hatchery adult-to-adult returns. These rates should be greater than the NRRs and greater than or equal to 5.40 (the value in BAMP; Murdoch and Peven 2005). HRRs exceeded NRRs in 7 of the 12 years of data regardless if harvest was included or not in the estimates (Table 4.30). Hatchery replacement rates for Wenatchee sockeye have equaled or exceeded the BAMP target of 5.40 in only two years if harvest is not included and three years if harvest is included in the estimate (Table 4.30).

**Table 4.30.** Hatchery replacement rates (HRR), NRR, and BAMP target (5.40) for sockeye salmon in the Wenatchee basin, 1989-2000; NA = not available. *(The numbers in this table may change as the HETT and HC refine the methods for estimating sockeye HRRs and NRRs.)*

| Brood year | Harvest not included | | | Harvest included | | |
|---|---|---|---|---|---|---|
| | HRR | NRR | BAMP | HRR | NRR | BAMP |
| 1989 | 11.3 | 1.05 | 5.40 | 13.9 | 1.06 | 5.40 |
| 1990 | 1.6 | 0.24 | 5.40 | 1.6 | 0.24 | 5.40 |
| 1991 | 0.1 | 0.22 | 5.40 | 0.1 | 0.22 | 5.40 |
| 1992 | 1.5 | 0.28 | 5.40 | 1.5 | 0.28 | 5.40 |
| 1993 | 0.3 | 0.44 | 5.40 | 0.3 | 0.44 | 5.40 |
| 1994 | 0.2 | 0.13 | 5.40 | 0.2 | 0.13 | 5.40 |
| 1995 | 0.5 | 0.12 | 5.40 | 0.5 | 0.12 | 5.40 |
| 1996 | 6.0 | 4.23 | 5.40 | 6.3 | 4.51 | 5.40 |
| 1997 | 2.9 | 3.41 | 5.40 | 3.4 | 3.73 | 5.40 |
| 1998 | 0.8 | 3.87 | 5.40 | 0.9 | 4.07 | 5.40 |
| 1999 | 0.4 | 0.44 | 5.40 | 0.4 | 0.46 | 5.40 |
| 2000 | 4.8 | 1.65 | 5.40 | 7.2 | 1.72 | 5.40 |
| ***Average*** | ***2.5*** | ***1.34*** | ***5.40*** | ***3.0*** | ***1.42*** | ***5.40*** |

### Juvenile-to-Adult Survivals

When possible, both parr-to-adult ratios (PAR) and smolt-to-adult ratios (SAR) were calculated for hatchery sockeye salmon. Ratios were calculated as the number of hatchery adults divided by the number of hatchery parr released or the estimated number of smolts emigrating from Lake Wenatchee. Survival ratios were based on CWT returns, when available, or on the estimated number of hatchery adults recovered on the spawning grounds, in broodstock, and harvested. For the available brood years, PARs have ranged from 0.0002 to 0.0136 for hatchery sockeye salmon and SARs have ranged from 0.0007 to 0.0254 (Table 4.31).

**Table 4.31.** Parr-to-adult ratios (PAR) and smolt-to-adult ratios (SAR) for Wenatchee hatchery sockeye salmon, brood years 1990-2002.

| Brood year | Number of parr released | Number of smolts | Estimated adult recaptures | PAR | SAR |
|---|---|---|---|---|---|
| 1989 | 260,400 | | 3,548 | 0.0136 | |
| 1990 | 372,102 | | 500 | 0.0013 | |
| 1991 | 167,523 | | 29 | 0.0002 | |
| 1992 | 340,557 | | 503 | 0.0015 | |
| 1993 | 190,443 | | 84 | 0.0004 | |
| 1994 | 252,859 | | 48 | 0.0002 | |
| 1995 | 150,808 | 28,828 | 107 | 0.0007 | 0.0037 |
| 1996 | 284,630 | 55,985 | 1,421 | 0.0050 | 0.0254 |
| 1997 | 197,195 | 112,524 | 768 | 0.0039 | 0.0068 |
| 1998 | 121,344 | 24,684 | 166 | 0.0014 | 0.0067 |
| 1999 | 167,955 | 94,046 | 66 | 0.0004 | 0.0007 |
| 2000 | 190,174 | 121,511 | 1,399 | 0.0074 | 0.0115 |
| ***Average*** | ***224,666*** | ***72,930*** | ***720*** | ***0.0032*** | ***0.0090*** |

## *4.8 ESA/HCP Compliance*

### Broodstock Collection

The 2005 sockeye broodstock collections at Tumwater Dam occurred concurrently with spring Chinook reproductive success monitoring and evaluation activities (BPA Project No. 2003-039-00) and Wenatchee steelhead broodstock collection activities authorized through ESA permits 1196 and 1395, respectively. No ESA-listed spring Chinook or steelhead takes occurred during sockeye broodstock collections at Tumwater Dam that were outside those authorized through ESA Section 10 permits 1196 and 1395.

### Hatchery Rearing and Release

The 2004 Wenatchee sockeye program released 225,670 juveniles, representing 111% of the program production objective and 100.3% of the 10% production overage allowance in ESA Section 10 Permit 1347.

### Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, and 1395, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. NPDES monitoring and reporting for Chelan PUD Hatchery Programs during 2007 are provided in Appendix E.

### Smolt and Emigrant Trapping

ESA-listed spring Chinook and steelhead were encountered during operation of the upper and lower Wenatchee traps. ESA takes are reported in the steelhead (Section 3.8) and spring Chinook (Section 5.8) sections and will not be repeated here.

### Spawning Surveys

Sockeye spawning ground surveys conducted in the Wenatchee Basin during 2007 were consistent with ESA Section 10 Permit No. 1347. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential impacts to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

# SECTION 5: WENATCHEE (CHIWAWA) SPRING CHINOOK

Although this section of the report focuses on results from monitoring the Chiwawa spring Chinook program, information on spring Chinook collected throughout the Wenatchee basin is also provided.

## 5.1 Broodstock Sampling

This section focuses on results from sampling 2005-2007 Chiwawa spring Chinook broodstock, which were collected at the Chiwawa weir and at Tumwater Dam. Some information for the 2007 return is not available at this time (e.g., age structure and final origin determination). This information will be provided in the 2008 annual report.

### Origin of Broodstock

Hatchery origin adults made up between 65-76% of the Chiwawa spring Chinook broodstock for return years 2005-2007 (Table 5.1). Hatchery origin adults were collected at both Tumwater Dam and the Chiwawa weir. In an effort to partially address straying of Chiwawa spring Chinook to other tributaries in the basin and secondarily to ensure meeting adult collection quotas, hatchery origin adults were collected to the greatest extent possible at Tumwater Dam. Natural origin fish were collected only at the Chiwawa weir. Broodstock were trapped at Tumwater Dam from late May through August and at the Chiwawa weir from mid June through August.

**Table 5.1**. Numbers of wild and hatchery Chiwawa spring Chinook collected for broodstock, numbers that died before spawning, and numbers of Chinook spawned, 1989-2007. Unknown origin fish (i.e., undetermined by scale analysis, no CWT or fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes fish that died of natural causes typically near the end of spawning and were not needed for the program or were surplus fish killed at spawning.

| Brood year | Wild spring Chinook | | | | | Hatchery spring Chinook | | | | | Total number spawned |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number collected | Prespawn loss | Mortality | Number spawned | Number released | Number collected | Prespawn loss | Mortality | Number spawned | Number released | |
| 1989 | 28 | 0 | 0 | 28 | 0 | 0 | 0 | 0 | 0 | 0 | 28 |
| 1990 | 19 | 1 | 0 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 18 |
| 1991 | 32 | 0 | 5 | 27 | 0 | 0 | 0 | 0 | 0 | 0 | 27 |
| 1992 | 113 | 0 | 0 | 78 | 35 | 0 | 0 | 0 | 0 | 0 | 78 |
| 1993 | 100 | 3 | 3 | 94 | 0 | 0 | 0 | 0 | 0 | 0 | 94 |
| 1994 | 9 | 0 | 1 | 8 | 0 | 4 | 0 | 0 | 4 | 0 | 12 |
| 1995 | No Program | | | | | | | | | | |
| 1996 | 8 | 0 | 0 | 8 | 0 | 10 | 0 | 0 | 10 | 0 | 18 |
| 1997 | 37 | 0 | 5 | 32 | 0 | 83 | 1 | 3 | 79 | 0 | 111 |
| 1998 | 13 | 0 | 0 | 13 | 0 | 35 | 1 | 0 | 34 | 0 | 47 |
| 1999 | No Program | | | | | | | | | | |
| 2000 | 10 | 0 | 1 | 9 | 0 | 38 | 1 | 16 | 21 | 0 | 30 |
| 2001 | 115 | 2 | 0 | 113 | 0 | 267 | 8 | 0 | 259 | 0 | 372 |
| 2002 | 21 | 0 | 1 | 20 | 0 | 63 | 1 | 11 | 51 | 0 | 71 |
| 2003 | 44 | 1 | 2 | 41 | 0 | 75 | 2 | 20 | 53 | 0 | 94 |
| 2004 | 100 | 1 | 16 | 83 | 0 | 196 | 30 | 34 | 132 | 0 | 215 |
| 2005 | 98 | 1 | 6 | 91 | 0 | 185 | 3 | 1 | 181 | 0 | 279 |

| Brood year | Wild spring Chinook | | | | | Hatchery spring Chinook | | | | | Total number spawned |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number collected | Prespawn loss | Mortality | Number spawned | Number released | Number collected | Prespawn loss | Mortality | Number spawned | Number released | |
| 2006 | 95 | 0 | 4 | 91 | 0 | 303 | 0 | 29 | 224 | 50 | 315 |
| 2007 | 45 | 1 | 1 | 43 | 0 | 124 | 2 | 18 | 104 | 0 | 147 |
| ***Average[a]*** | ***52*** | ***1*** | ***3*** | ***47*** | ***2*** | ***81*** | ***3*** | ***8*** | ***68*** | ***3*** | ***115*** |

[a] Origin determinations should be considered preliminary pending scale analyses.

## Age/Length Data

Ages were determined from scales and/or coded wire tags (CWT) collected from broodstock. For both the 2005 and 2006 returns, most adults, regardless of origin, were age-4 Chinook (Table 5.2). A larger percentage of the age-5 Chinook were natural origin fish, whereas a larger percentage of the age-3 fish were hatchery origin fish.

**Table 5.2.** Percent of hatchery and wild spring Chinook of different ages (total age) collected from broodstock, 1991-2006.

| Return year | Origin | Total age | | | |
|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 |
| 1991 | Wild | 0.0 | 15.6 | 59.4 | 25.0 |
| | Hatchery | 0.0 | 0.0 | 0.0 | 0.0 |
| 1992 | Wild | 0.0 | 0.0 | 0.0 | 0.0 |
| | Hatchery | 0.0 | 0.0 | 0.0 | 0.0 |
| 1993 | Wild | 0.0 | 0.0 | 22.0 | 78.0 |
| | Hatchery | 0.0 | 0.0 | 0.0 | 0.0 |
| 1994 | Wild | 0.0 | 0.0 | 28.6 | 71.4 |
| | Hatchery | 0.0 | 0.0 | 50.0 | 50.0 |
| 1995 | Wild | No program | | | |
| | Hatchery | | | | |
| 1996 | Wild | 0.0 | 28.6 | 71.4 | 0.0 |
| | Hatchery | 0.0 | 50.0 | 50.0 | 0.0 |
| 1997 | Wild | 0.0 | 0.0 | 87.5 | 12.5 |
| | Hatchery | 0.0 | 1.2 | 98.8 | 0.0 |
| 1998 | Wild | 0.0 | 0.0 | 63.6 | 36.4 |
| | Hatchery | 0.0 | 0.0 | 62.9 | 37.1 |
| 1999 | Wild | No program | | | |
| | Hatchery | | | | |
| 2000 | Wild | 0.0 | 20.0 | 70.0 | 10.0 |
| | Hatchery | 0.0 | 76.3 | 23.7 | 0.0 |
| 2001 | Wild | 0.0 | 2.8 | 94.4 | 2.8 |
| | Hatchery | 0.0 | 1.5 | 98.5 | 0.0 |
| 2002 | Wild | 0.0 | 0.0 | 66.7 | 33.3 |

| Return year | Origin | Total age | | | |
|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 |
| | Hatchery | 0.0 | 0.0 | 93.4 | 6.6 |
| 2003 | Wild | 0.0 | 27.0 | 2.7 | 70.3 |
| | Hatchery | 0.0 | 21.3 | 5.3 | 73.3 |
| 2004 | Wild | 1.1 | 4.3 | 89.4 | 5.3 |
| | Hatchery | 0.0 | 36.9 | 63.1 | 0.0 |
| 2005 | Wild | 0.0 | 1.1 | 84.5 | 14.4 |
| | Hatchery | 0.0 | 4.3 | 94.6 | 1.1 |
| 2006 | Wild | 0.0 | 1.1 | 71.1 | 27.8 |
| | Hatchery | 0.0 | 1.4 | 81.3 | 17.3 |
| ***Average*** | ***Wild*** | ***0.2*** | ***4.4*** | ***67.5*** | ***28.0*** |
| | ***Hatchery*** | ***0.0*** | ***11.2*** | ***78.7*** | ***10.2*** |

There was little difference in mean lengths between hatchery and natural origin broodstock of age-4 and 5 Chinook in 2005 and 2006 (Table 5.3). Additionally, for the 2005 and 2006 returns, there was little difference in mean lengths for age-3 natural origin fish. There was, however, a relatively large difference in mean lengths in age-3 hatchery origin fish (7 cm difference) between 2005 and 2006.

**Table 5.3.** Mean fork length (cm) at age (total age) of hatchery and wild spring Chinook collected from broodstock, 1991-2006; N = sample size and SD = 1 standard deviation.

| Return year | Origin | Spring Chinook fork length (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Age-2 | | | Age-3 | | | Age-4 | | | Age-5 | | |
| | | Mean | N | SD | Mean | N | SD | Mean | N | SD | Mean | N | SD |
| 1991 | Wild | - | 0 | - | - | 5 | - | - | 19 | - | - | 8 | - |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - | - | 0 | - |
| 1992 | Wild | - | 0 | - | - | 0 | - | - | 0 | - | - | 0 | - |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - | - | 0 | - |
| 1993 | Wild | - | 0 | - | - | 0 | - | 79 | 22 | 3 | 92 | 78 | 4 |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - | - | 0 | - |
| 1994 | Wild | - | 0 | - | - | 0 | - | 79 | 2 | 3 | 96 | 5 | 6 |
| | Hatchery | - | 0 | - | - | 0 | - | 82 | 2 | 11 | 91 | 2 | 3 |
| 1995 | Wild | No program | | | | | | | | | | | |
| | Hatchery | | | | | | | | | | | | |
| 1996 | Wild | - | 0 | - | 51 | 2 | 1 | 79 | 5 | 7 | - | 0 | - |
| | Hatchery | - | 0 | - | 56 | 5 | 4 | 74 | 5 | 6 | - | 0 | - |
| 1997 | Wild | - | 0 | - | - | 0 | - | 80 | 28 | 5 | 99 | 4 | 8 |
| | Hatchery | - | 0 | - | 56 | 1 | - | 82 | 82 | 4 | - | 0 | - |
| 1998 | Wild | - | 0 | - | - | 0 | - | 78 | 7 | 13 | 83 | 4 | 18 |
| | Hatchery | - | 0 | - | - | 0 | - | 77 | 22 | 8 | 93 | 13 | 7 |

| Return year | Origin | Spring Chinook fork length (cm) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Age-2 | | | Age-3 | | | Age-4 | | | Age-5 | | |
| | | Mean | N | SD | Mean | N | SD | Mean | N | SD | Mean | N | SD |
| 1999 | Wild | No program | | | | | | | | | | | |
| | Hatchery | | | | | | | | | | | | |
| 2000 | Wild | - | 0 | - | 51 | 2 | 3 | 82 | 7 | 4 | 98 | 1 | - |
| | Hatchery | - | 0 | - | 58 | 29 | 7 | 79 | 9 | 8 | - | 0 | - |
| 2001 | Wild | - | 0 | - | 49 | 3 | 6 | 82 | 101 | 6 | 95 | 3 | 3 |
| | Hatchery | - | 0 | - | 56 | 4 | 7 | 83 | 261 | 5 | - | 0 | - |
| 2002 | Wild | - | 0 | - | - | 0 | - | 79 | 12 | 4 | 96 | 6 | 10 |
| | Hatchery | - | 0 | - | - | 0 | - | 81 | 57 | 6 | 94 | 4 | 9 |
| 2003 | Wild | - | 0 | - | 55 | 10 | 5 | 83 | 1 | - | 99 | 26 | 6 |
| | Hatchery | - | 0 | - | 59 | 16 | 5 | 86 | 4 | 18 | 96 | 55 | 6 |
| 2004 | Wild | 47 | 1 | - | 57 | 4 | 4 | 80 | 84 | 5 | 95 | 5 | 9 |
| | Hatchery | - | 0 | - | 49 | 72 | 6 | 79 | 123 | 6 | - | 0 | - |
| 2005 | Wild | - | 0 | - | 49 | 1 | - | 80 | 82 | 6 | 96 | 14 | 8 |
| | Hatchery | - | 0 | - | 56 | 8 | 5 | 82 | 175 | 6 | 93 | 2 | 2 |
| 2006 | Wild | - | 0 | - | 48 | 1 | - | 80 | 64 | 7 | 96 | 25 | 5 |
| | Hatchery | - | 0 | - | 49 | 4 | 4 | 80 | 240 | 6 | 95 | 51 | 7 |

## Sex Ratios

Male spring Chinook in 2005-2007 return years made up about 52%, 43%, and 51%, respectively, of the adults collected. This resulted in overall male to female ratios of 1.08:1.00, 0.77:1.00, and 1.04:1.00, respectively (Table 5.4). Only returns in 2006 were below the 1:1 ratio target in the broodstock protocol. For the 2005 and 2006 return years, natural origin fish consisted of a slightly higher proportion of males than did hatchery origin fish (Table 5.4.).

**Table 5.4.** Numbers of male and female wild and hatchery spring Chinook collected for broodstock, 1989-2007. Ratios of males to females are also provided.

| Return year | Number of wild spring Chinook | | | Number of hatchery spring Chinook | | | Total M/F ratio |
|---|---|---|---|---|---|---|---|
| | Males (M) | Females (F) | M/F | Males (M) | Females (F) | M/F | |
| 1989 | 11 | 17 | 0.65:1.00 | - | - | - | 0.65:1.00 |
| 1990 | 7 | 12 | 0.58:1.00 | - | - | - | 0.58:1.00 |
| 1991 | 13 | 19 | 0.68:1.00 | - | - | - | 0.68:1.00 |
| 1992 | 39 | 39 | 1.00:1.00 | - | - | - | 1.00:1.00 |
| 1993 | 50 | 50 | 1.00:1.00 | - | - | - | 1.00:1.00 |
| 1994 | 5 | 4 | 1.25:1.00 | 2 | 2 | 1.00:1.00 | 1.17:1.00 |
| 1995 | No program | | | | | | |
| 1996 | 6 | 2 | 3.00:1.00 | 8 | 2 | 4.00:1.00 | 3.50:1.00 |
| 1997 | 14 | 23 | 0.61:1.00 | 34 | 49 | 0.69:1.00 | 0.67:1.00 |

| Return year | Number of wild spring Chinook | | | Number of hatchery spring Chinook | | | Total M/F ratio |
|---|---|---|---|---|---|---|---|
| | Males (M) | Females (F) | M/F | Males (M) | Females (F) | M/F | |
| 1998 | 9 | 4 | 2.25:1.00 | 18 | 17 | 1.06:1.00 | 1.29:1.00 |
| 1999 | No program | | | | | | |
| 2000 | 5 | 5 | 1.00:1.00 | 32 | 6 | 5.33:1.00 | 3.36:1.00 |
| 2001 | 45 | 70 | 0.64:1.00 | 90 | 177 | 0.51:1.00 | 0.55:1.00 |
| 2002 | 9 | 12 | 0.75:1.00 | 30 | 33 | 0.91:1.00 | 0.87:1.00 |
| 2003 | 28 | 16 | 1.75:1.00 | 42 | 33 | 1.27:1.00 | 1.43:1.00 |
| 2004 | 58 | 42 | 1.38:1.00 | 102 | 94 | 1.09:1.00 | 1.18:1.00 |
| 2005 | 58 | 40 | 1.45:1.00 | 89 | 96 | 0.93:1.00 | 1.08:1.00 |
| 2006 | 49 | 46 | 1.07:1.00 | 123 | 179 | 0.69:1.00 | 0.77:1.00 |
| 2007 | 20 | 25 | 0.80:1.00 | 66 | 58 | 1.14:1.00 | 1.04:1.00 |
| ***Total*** | ***426*** | ***426*** | ***1.00:1.00*** | ***636*** | ***746*** | ***0.85:1.00*** | ***0.91:1.00*** |

## Fecundity

Mean fecundities for the 2005-2007 returns of spring Chinook ranged from 4,324-4,387 eggs per female (Table 5.5). These fecundities were less than the overall average of 4,786 eggs per female, but were close to the expected fecundity of 4,400 eggs per female assumed in the broodstock protocol. For the three return years, natural origin Chinook produced more eggs per female than did hatchery origin fish (Table 5.5). This could be attributed to differences in size and age of hatchery and natural origin fish described above.

**Table 5.5.** Mean fecundity of wild, hatchery, and all female spring Chinook collected for broodstock, 1989-2007; NA = not available.

| Return year | Mean fecundity | | |
|---|---|---|---|
| | Wild | Hatchery | Total |
| 1989* | NA | NA | 2,832 |
| 1990* | NA | NA | 5,024 |
| 1991* | NA | NA | 4,600 |
| 1992* | NA | NA | 5,199[a] |
| 1993* | NA | NA | 5,249 |
| 1994* | NA | NA | 5,923 |
| 1995 | No program | | |
| 1996* | NA | NA | 4,645 |
| 1997 | 4,752 | 4,479 | 4,570 |
| 1998 | 5,157 | 5,376 | 5,325 |
| 1999 | No program | | |
| 2000 | 5,028 | 5,019 | 5,023 |
| 2001 | 4,530 | 4,663 | 4,624 |
| 2002 | 5,024 | 4,506 | 4,654 |

| Return year | Mean fecundity | | |
|---|---|---|---|
| | Wild | Hatchery | Total |
| 2003 | 6,191 | 5,651 | 5,844 |
| 2004 | 4,846 | 4,775 | 4,799 |
| 2005 | 4,365 | 4,312 | 4,327 |
| 2006 | 4,773 | 4,151 | 4,324 |
| 2007 | 4,722 | 4,240 | 4,387 |
| ***Average*** | ***4,939*** | ***4,717*** | ***4,785*** |

* Individual fecundities were not tracked with females until 1997.
[a] Estimated as the mean of fecundities two years before and two years after 1992.

## 5.2 Hatchery Rearing

### Rearing History

#### *Number of eggs taken*

Based on the unfertilized egg-to-release survival standard of 81%, a total of 829,630 eggs are required to meet the program release goal of 672,000 smolts. Between 1989 and 2007, the egg take goal was reached in one of those years (Table 5.6). The green egg takes for 2005-2007 brood years were 65%, 90%, and 43% of program goals, respectively.

ESA Permit 1196 sets limits on the percentage of the total run, natural origin run, and a minimum contribution of natural origin fish that must be in the broodstock. Applying these criteria to the low total abundance of spring Chinook salmon to the Chiwawa basin and the low abundance of natural origin fish returning to the basin has resulted in the program not meeting production goals.

**Table 5.6.** Numbers of eggs taken from spring Chinook broodstock, 1989-2007.

| Return year | Number of eggs taken |
|---|---|
| 1989 | 45,311 |
| 1990 | 60,287 |
| 1991 | 73,601 |
| 1992 | 111,624 |
| 1993 | 257,208 |
| 1994 | 35,539 |
| 1995 | No program |
| 1996 | 18,579 |
| 1997 | 312,182 |
| 1998 | 90,521 |
| 1999 | No program |
| 2000 | 55,256 |
| 2001 | 1,099,630 |

| Return year | Number of eggs taken |
|---|---|
| 2002 | 196,186 |
| 2003 | 247,501 |
| 2004 | 538,176 |
| 2005 | 536,490 |
| 2006 | 744,344 |
| 2007 | 359,739 |
| ***Average*** | ***281,304*** |

### *Number of acclimation days*

Early rearing of the 2005 brood Chiwawa spring Chinook was similar to previous years with fish being held on well water before being transferred to Chiwawa Ponds for final acclimation. Beginning in 2006 (2005 brood acclimation), modifications were made to the Chiwawa FH intakes so that Wenatchee River water could be applied to the Chiwawa River intakes during severe cold periods to prevent the formation of frazzle ice. During acclimation of the 2005 brood, fish were acclimated for 202-232 days (depending on volitional or forced release) on Chiwawa River water, with 98 of those days containing a small percentage of Wenatchee River water (Table 5.7). Unlike in previous years, at no time was this brood on 100% Wenatchee River water.

**Table 5.7.** Number of days spring Chinook broods were acclimated and water source, brood years 1989-2005; NA = not available.

| Brood year | Release year | Transfer date | Release date | Number of days and water source | | |
|---|---|---|---|---|---|---|
| | | | | Total | Chiwawa | Wenatchee |
| 1989 | 1991 | 19-Oct | 11-May | 204 | NA | NA |
| 1990 | 1992 | 13-Sep | 27-Apr | 227 | NA | NA |
| 1991 | 1993 | 24-Sep | 24-Apr | 212 | NA | NA |
| 1992 | 1994 | 30-Sep | 20-Apr | 202 | NA | NA |
| 1993 | 1995 | 28-Sep | 20-Apr | 204 | NA | NA |
| 1994 | 1996 | 1-Oct | 25-Apr | 207 | NA | NA |
| 1995 | 1997 | No Program | | | | |
| 1996 | 1998 | 25-Sep | 29-Apr | 216 | NA | NA |
| 1997 | 1999 | 28-Sep | 22-Apr | 206 | NA | NA |
| 1998 | 2000 | 27-Sep | 24-Apr | 210 | NA | NA |
| 1999 | 2001 | No Program | | | | |
| 2000 | 2002 | 26-Sep | 25-Apr | 211 | NA | NA |
| 2001 | 2003 | 22-Oct | 1-May | 191 | NA | NA |
| 2002 | 2004 | 25-Sep | 2-May | 220 | NA | NA |

| Brood year | Release year | Transfer date | Release date | Number of days and water source | | |
|---|---|---|---|---|---|---|
| | | | | Total | Chiwawa | Wenatchee |
| 2003 | 2005 | 30-Sep | 3-May | 215 | NA | NA |
| 2004 | 2006 | 3 –Sep | 1-May | 240 | 88-104 | 124 |
| 2005 | 2007 | 25-Sep | 1-May | 217 | 217 | 98[a] |
| | | 26-Sep | 16-Apr-15-May | 202-232 | 202-232 | 98[a] |
| ***Average*** | | | | ***213*** | ***169*** | ***111*** |

[a] Represents the number of days Wenatchee River water was applied to the Chiwawa River intake screen to prevent the formation of frazzle ice.

## Release Information

### *Numbers released*

The 2005 brood Chiwawa spring Chinook program achieved 73.5% of the 672,000 target goal with about 494,012 fish being released into the Chiwawa River (Table 5.8). Fish were released in two groups; a volitional release for about one month with the mid-point coinciding with a new moon phase and a forced release also coinciding with the new moon phase. The intent of the two releases is to evaluate the efficacy of release methodology on smolt to adult survival as well as decrease the potential for interactions with naturally produced fish. Fish that were allowed to volitionally migrate on their own may have faster emigration rates, higher smolt to smolt survival, and may be less likely to interact with their natural cohorts. This was the last year for this comparison. Future releases will be volitional unless adult return data indicate that forced release is more favorable than volitional release.

**Table 5.8.** Numbers of spring Chinook smolts released from the hatchery, 1989-2005. The release target for Chiwawa spring Chinook is 672,000 smolts.

| Brood year | Release year | Number of smolts |
|---|---|---|
| 1989 | 1991 | 43,000 |
| 1990 | 1992 | 53,170 |
| 1991 | 1993 | 62,138 |
| 1992 | 1994 | 85,113 |
| 1993 | 1995 | 223,610 |
| 1994 | 1996 | 27,226 |
| 1995 | 1997 | No program |
| 1996 | 1998 | 15,176 |
| 1997 | 1999 | 266,148 |
| 1998 | 2000 | 75,906 |
| 1999 | 2001 | No program |
| 2000 | 2002 | 47,104 |
| 2001 | 2003 | 377,544 |

| Brood year | Release year | Number of smolts |
|---|---|---|
| 2002 | 2004 | 149,668 |
| 2003 | 2005 | 222,131 |
| 2004 | 2006 | 494,517 |
| 2005 | 2006 | 494,012 |
| ***Average*** | | ***175,764*** |

### *Numbers tagged*

The 2005 brood Chiwawa spring Chinook were 98.6% and 98.8% CWT and adipose fin clipped for the volitional and forced release groups, respectively. In addition, a total of 10,063 juveniles from the 2005 brood were PIT tagged and adipose-fin clipped at Eastbank Hatchery during 28-30 August 2006 (Table 5.9). Of these, 5,032 came from pond 12 and 5,031 from pond 13. Tagged fish from pond 12 were transported to the Chiwawa Hatchery on 25 and 26 September, while those from pond 13 were transported on 27 and 28 September. During spring, 2007, one group of 4,988 tagged Chinook was released volitionally and another group of 4,993 was forced released. Of the total number of spring Chinook PIT tagged (10,063), 74 died and eight others shed their tags (Table 5.9). Some of the mortality was associated with a river otter that was observed moving in and out of the raceways during the winter.[6]

**Table 5.9.** Summary of PIT tagging activities for spring Chinook (2005 brood) at the Eastbank Hatchery, 2006. Dead fish counted before 15 September likely represent deaths associated with tagging.

| Rearing Pond | Number of fish tagged | Number of fish that died | | Number of tags shed | Number of tagged fish released |
|---|---|---|---|---|---|
| | | Before 9/15 | After 9/15 | | |
| 12 | 5,032 | 4 | 32 | 3 | 4,993 |
| 13 | 5,031 | 5 | 33 | 5 | 4,988 |
| ***Total*** | ***10,063*** | ***9*** | ***65*** | ***8*** | ***9,981*** |

In 2007, a total of 10,055 spring Chinook from the 2006 brood were PIT tagged at the Eastbank Hatchery during 24-26 July 2007. These fish were transferred to the Chiwawa raceways on 26-27 September. As of the end of January 2008, a total of 97 tagged fish have died and another 9 fish have shed their tags. This leaves an estimated 9,949 tagged spring Chinook alive. These fish will be released in spring of 2008 with the rest of the 2006 brood.

### *Fish size and condition at release*

Spring Chinook from the 2005 brood were released as yearling smolts between 16 April and 15 May of 2007. Size at release for both groups was below the targets established for the program. However, the coefficient of variation for fork length was below the target indicating fish were released with an acceptable size distribution (Table 5.10).

[6] PIT tags were found in otter scat. These tags were removed from the data files.

**Table 5.10.** Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of spring Chinook smolts released from the hatchery, 1989-2005. Size targets are provided in the last row of the table.

| Brood year | Release year | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| 1989 | 1991 | 147 | 4.4 | 37.8 | 12 |
| 1990 | 1992 | 137 | 5.0 | 32.4 | 14 |
| 1991 | 1993 | 135 | 4.2 | 30.3 | 15 |
| 1992 | 1994 | 133 | 5.0 | 28.4 | 16 |
| 1993 | 1995 | 136 | 4.5 | 30.2 | 15 |
| 1994 | 1996 | 139 | 7.1 | 34.4 | 13 |
| 1995 | 1997 | No Program | | | |
| 1996 | 1998 | 157 | 5.3 | 52.1 | 9 |
| 1997 | 1999 | 146 | 7.2 | 38.7 | 12 |
| 1998 | 2000 | 143 | 9.1 | 39.5 | 12 |
| 1999 | 2001 | No Program | | | |
| 2000 | 2002 | 150 | 6.8 | 46.7 | 10 |
| 2001 | 2003 | 142 | 7.1 | 37.6 | 12 |
| 2002 | 2004 | 146 | 8.5 | 40.3 | 11 |
| 2003 | 2005 | 161 | 6.1 | 50.2 | 9 |
| 2004 | 2006 | 143 | 4.9 | 36.7 | 12 |
| 2005 | 2007 | 136[a] | 4.6 | 30.8 | 15 |
| | | 129[b] | 5.8 | 26.6 | 17 |
| ***Targets*** | | ***176*** | ***9.0*** | ***37.8*** | ***12*** |

[a] Forced release group.
[b] Volitional release group.

## Survival Estimates

Overall survival of Chiwawa spring Chinook from green (unfertilized) egg to release was at or above the standard set for the program in all categories (Table 5.11). Pre-spawn survival of adults was also above the standard set for the program.

**Table 5.11.** Hatchery life-stage survival rates (%) for spring Chinook, brood years 1989-2005. Survival standards or targets are provided in the last row of the table.

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 1989 | 100.0 | 100.0 | 98.0 | 99.1 | 99.1 | 99.0 | 96.4 | 99.3 | 93.6 |
| 1990 | 100.0 | 85.7 | 91.8 | 98.1 | 99.5 | 98.9 | 97.9 | 99.2 | 88.2 |
| 1991 | 100.0 | 100.0 | 94.4 | 96.1 | 99.6 | 97.9 | 93.2 | 95.0 | 84.5 |
| 1992 | 100.0 | 100.0 | 98.4 | 96.7 | 99.9 | 99.9 | 80.0 | 80.6 | 76.2 |
| 1993 | 96.0 | 98.0 | 89.7 | 98.0 | 99.7 | 99.3 | 98.9 | 99.7 | 86.9 |

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 1994 | 100.0 | 100.0 | 98.6 | 100.0 | 99.8 | 99.4 | 77.0 | 78.9 | 75.9 |
| 1995 | No program | | | | | | | | |
| 1996 | 100.0 | 100.0 | 88.3 | 100.0 | 93.8 | 93.0 | 89.9 | 97.7 | 79.4 |
| 1997 | 98.6 | 100.0 | 93.2 | 95.7 | 98.3 | 99.6 | 95.6 | 99.3 | 85.3 |
| 1998 | 95.2 | 100.0 | 94.5 | 99.0 | 98.5 | 98.3 | 89.6 | 99.1 | 83.9 |
| 1999 | No program | | | | | | | | |
| 2000 | 100.0 | 100.0 | 91.0 | 98.1 | 97.2 | 96.6 | 95.4 | 99.3 | 85.2 |
| 2001 | 97.6 | 97.0 | 88.9 | 98.1 | 99.7 | 99.6 | 51.3 | 51.8 | 44.7 |
| 2002 | 97.8 | 100.0 | 82.1 | 98.0 | 97.4 | 96.7 | 94.8 | 99.1 | 76.3 |
| 2003 | 93.9 | 100.0 | 93.2 | 97.7 | 99.5 | 99.3 | 98.5 | 98.1 | 89.7 |
| 2004 | 97.8 | 82.5 | 93.3 | 98.4 | 98.8 | 94.3 | 93.9 | 97.2 | 86.2 |
| 2005 | 97.1 | 100.0 | 95.9 | 98.0 | 99.2 | 99.0 | 97.9 | 99.1 | 92.1 |
| ***Standard*** | ***90.0*** | ***85.0*** | ***92.0*** | ***98.0*** | ***97.0*** | ***93.0*** | ***90.0*** | ***95.0*** | ***81.0*** |

## 5.3 Disease Monitoring

Mortality from external fungus within the 2005 brood began to increase in juveniles in late October 2006. A 14-day formalin treatment was effective in controlling the fungus. No additional health issues were encountered.

## 5.4 Natural Juvenile Productivity

During 2007, juvenile spring Chinook were sampled at the Upper Wenatchee, Lower Wenatchee, and Chiwawa traps and counted during snorkel surveys within the Chiwawa Basin.

### Parr Estimates

A total of 60,752 (±12.2%) subyearling and 41 (±48.8%) yearling spring Chinook were estimated in the Chiwawa River basin in August 2007 (Table 5.12 and 5.13). During the survey period 1992-2007, numbers of subyearling and yearling Chinook have ranged from 5,815 to 134,872 and 5 to 563, respectively, in the Chiwawa Basin (Table 5.12 and 5.13; Figure 5.1). Numbers of all fish counted in the Chiwawa basin are reported in Appendix A.

**Table 5.12.** Total numbers of subyearling spring Chinook estimated in different steams in the Chiwawa Basin during snorkel surveys in August 1992-2007; NS = not sampled.

| Sample Year | Number of subyearling spring Chinook | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Chiwawa River | Phelps Creek | Chikamin Creek | Rock Creek | Peven Creek | Big Meadow Creek | Alder Creek | Brush Creek | Y Creek | Total |
| 1992 | 45,483 | NS | NS | NS | NS | NS | NS | NS | NS | **45,483** |
| 1993 | 77,269 | 0 | 1,258 | 586 | NS | NS | NS | NS | NS | **79,113** |
| 1994 | 53,492 | 0 | 398 | 474 | 68 | 624 | 0 | 0 | 0 | **55,056** |
| 1995 | 52,775 | 0 | 1,346 | 210 | 0 | 683 | 67 | 160 | 0 | **55,241** |
| 1996 | 5,500 | 0 | 29 | 10 | 0 | 248 | 28 | 0 | 0 | **5,815** |
| 1997 | 15,438 | 0 | 56 | 92 | 0 | 480 | 0 | 0 | 0 | **16,066** |
| 1998 | 65,875 | 0 | 1,468 | 496 | 57 | 506 | 0 | 13 | 0 | **68,415** |
| 1999 | 40,051 | 0 | 366 | 592 | 0 | 598 | 22 | 0 | 0 | **41,629** |
| 2000 | NS | NS | NS | NS | NS | NS | NS | NS | NS | **NS** |
| 2001 | 106,753 | 168 | 2,077 | 2,855 | 354 | 2,332 | 78 | 0 | 0 | **114,617** |
| 2002 | 117,230 | 75 | 8,233 | 2,953 | 636 | 5,021 | 429 | 0 | 297 | **134,874** |
| 2003 | 80,250 | 4,508 | 1,570 | 3,255 | 118 | 1,510 | 22 | 45 | 0 | **91,278** |
| 2004 | 43,360 | 102 | 717 | 215 | 54 | 637 | 21 | 71 | 0 | **45,177** |
| 2005 | 45,999 | 71 | 2,092 | 660 | 17 | 792 | 0 | 0 | 0 | **49,631** |
| 2006 | 73,478 | 113 | 2,500 | 1,681 | 51 | 1,890 | 62 | 127 | 0 | **79,902** |
| 2007 | 53,863 | 125 | 5,235 | 870 | 51 | 538 | 20 | 28 | 22 | **60,752** |
| ***Average*** | ***58,454*** | ***369*** | ***1,953*** | ***1,068*** | ***108*** | ***1,220*** | ***58*** | ***34*** | ***25*** | ***62,870*** |

**Table 5.13.** Total numbers of yearling spring Chinook estimated in different steams in the Chiwawa Basin during snorkel surveys in August 1992-2007; NS = not sampled.

| Sample Year | Number of yearling spring Chinook | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Chiwawa River | Phelps Creek | Chikamin Creek | Rock Creek | Peven Creek | Big Meadow Creek | Alder Creek | Brush Creek | Y Creek | Total |
| 1992 | 563 | NS | NS | NS | NS | NS | NS | NS | NS | **563** |
| 1993 | 174 | 0 | 0 | 0 | NS | NS | NS | NS | NS | **174** |
| 1994 | 14 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | **18** |
| 1995 | 13 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **13** |
| 1996 | 22 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **22** |
| 1997 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **5** |
| 1998 | 63 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **63** |
| 1999 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **41** |
| 2000 | NS | NS | NS | NS | NS | NS | NS | NS | NS | **NS** |
| 2001 | 66 | 0 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | **69** |
| 2002 | 32 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **32** |
| 2003 | 134 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **134** |
| 2004 | 14 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | **21** |
| 2005 | 62 | 0 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | **79** |

| Sample Year | Number of yearling spring Chinook | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Chiwawa River | Phelps Creek | Chikamin Creek | Rock Creek | Peven Creek | Big Meadow Creek | Alder Creek | Brush Creek | Y Creek | Total |
| 2006 | 345 | 0 | 0 | 43 | 0 | 0 | 0 | 0 | 0 | **388** |
| 2007 | 41 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **41** |
| ***Average*** | ***106*** | ***0*** | ***1*** | ***3*** | ***0*** | ***1*** | ***0*** | ***0*** | ***0*** | ***111*** |

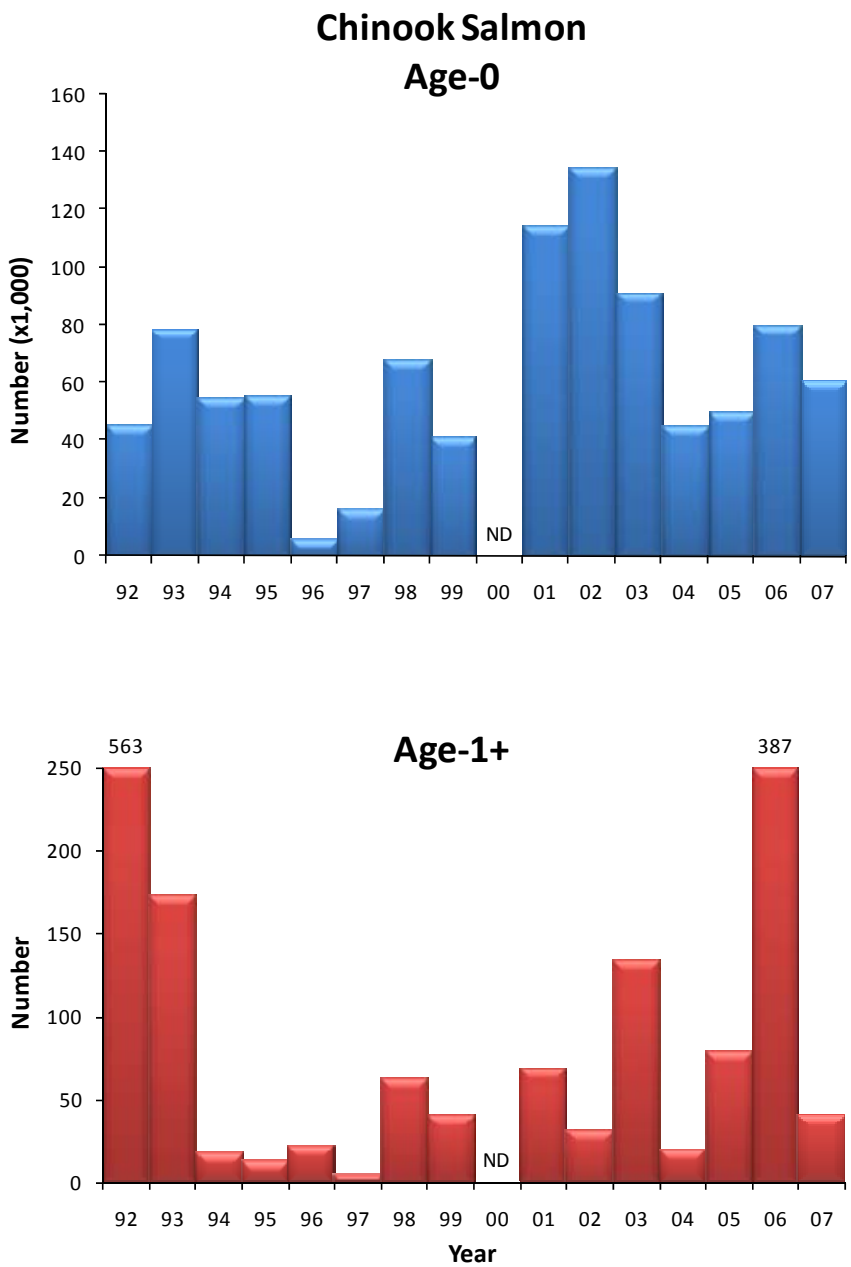


**Figure 5.1.** Numbers of subyearling and yearling Chinook salmon within the Chiwawa River Basin in August 1992-2007; ND = no data.

Juvenile Chinook were distributed contagiously among reaches in the Chiwawa River. Their densities were highest in the upper portions of the basin; although the highest density occurred in Chikamin Creek (7,387 fish/ha). Juvenile Chinook were most abundant in multiple channels and least abundant in glides. Most Chinook associated closely with woody debris in multiple channels. These sites (multiple channels) made up 29% of the total area of the Chiwawa Basin, but they provided habitat for 40% of all the subyearling Chinook in the basin in 2007. In contrast, riffles made up 47% of the total area, but provided habitat for only 12% of all juvenile Chinook in the Chiwawa Basin. Pools made up 17% of the total area and provided habitat for 46% of all juvenile Chinook in the basin. Virtually no Chinook used glides that lacked woody debris.

Mean densities of juvenile Chinook in two reaches of the Chiwawa River were generally less than those in corresponding reference areas (Nason Creek and the Little Wenatchee River) (Figure 5.2). Within both the Chiwawa River and its reference areas, pools and multiple channels consistently had the highest densities of juvenile Chinook.

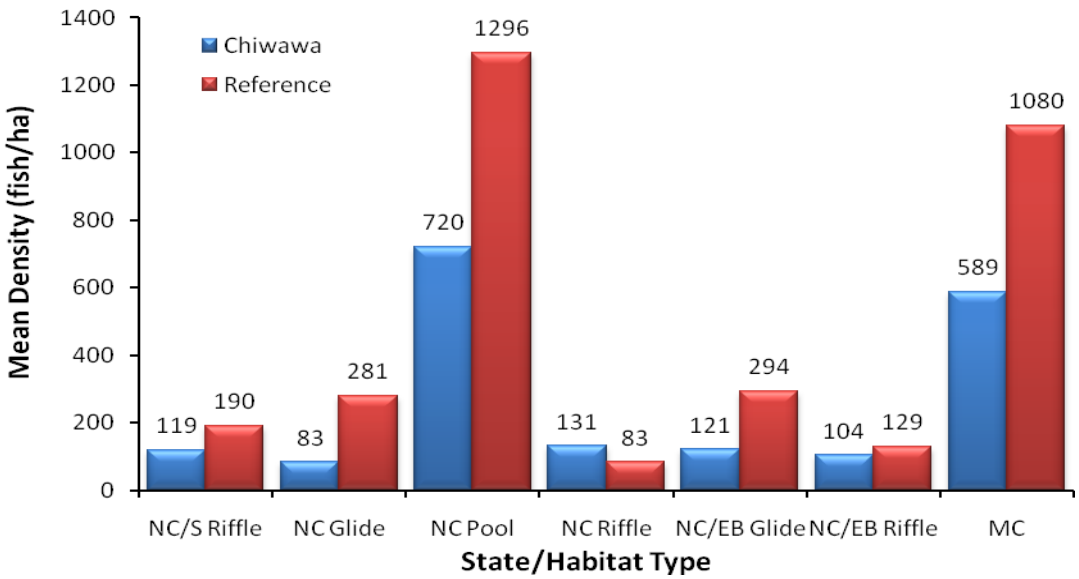


**Figure 5.2**. Comparison of the 14-year means of subyearling spring Chinook densities within state/habitat types in reaches 3 and 8 of the Chiwawa River and their matched reference areas on Nason Creek and the Little Wenatchee River. NC = natural channel; S = straight channel; EB = eroded banks; MC = multiple channel.

### Smolt and Emigrant Estimates

Numbers of spring Chinook smolts and emigrants were estimated at the Upper Wenatchee, Chiwawa, and Lower Wenatchee traps in 2007.

### *Chiwawa Trap*

The Chiwawa Trap operated between 27 February and 27 November 2007. During that time period the trap was inoperable for 23 days because of high river flows, debris, snow/ice, or mechanical failure. The trap operated in two different positions depending on stream flow; lower position at flows greater than 12 $m^3/s$ and an upper position at flows less than 12 $m^3/s$. Daily trap efficiencies were estimated from two regression models depending on trap position and age class of fish (e.g., subyearling and yearling). The daily number of fish captured was expanded by the estimated trap efficiency to estimate daily total emigration. Monthly captures of all fish and results of mark-recapture efficiency tests at the Chiwawa Trap are reported in Appendix B.

Wild yearling spring Chinook (2005 brood year) were primarily captured from March to June 2007 (Figure 5.3). Based on capture efficiencies estimated from the flow model, the total number of wild yearling Chinook emigrating from the Chiwawa River was 69,064 (±35,747). Combining the total number of subyearling spring Chinook (108,595) that emigrated during the fall of 2006 with the total number of yearling Chinook (69,064) that emigrated during 2007 resulted in a total emigrant estimate of 177,659 (±74,108) spring Chinook for the 2005 brood year (Table 5.14).

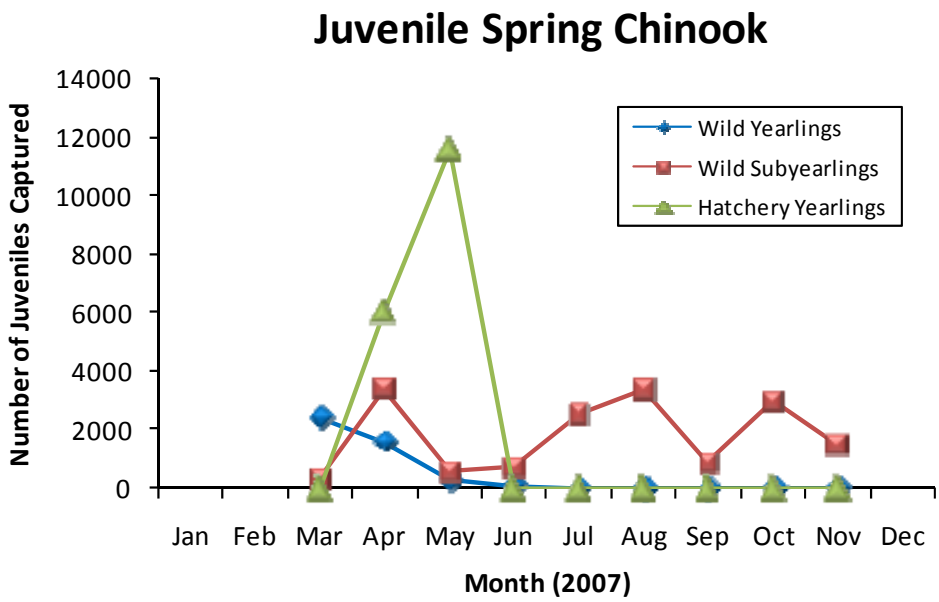


**Figure 5.3.** Monthly captures of wild subyearling, wild yearling, and hatchery yearling spring Chinook at the Chiwawa Trap, 2007.

**Table 5.14.** Numbers of juvenile spring Chinook at different life stages in the Chiwawa Basin for brood years 1991-2007; NS = not sampled.

| Brood year | Number of redds | Egg deposition | Number of parr | Number of smolts produced within Chiwawa Basin[a] | Total number of smolts[b] | Number of emigrants |
|---|---|---|---|---|---|---|
| 1991 | 104 | 478,400 | 45,483[c] | 42,525 | 42,525 | NS |
| 1992 | 302 | 1,570,098 | 79,113 | 39,723 | 56,763 | 65,541 |

| Brood year | Number of redds | Egg deposition | Number of parr | Number of smolts produced within Chiwawa Basin[a] | Total number of smolts[b] | Number of emigrants |
|---|---|---|---|---|---|---|
| 1993 | 106 | 556,394 | 55,056 | 8,662 | 17,926 | 22,698 |
| 1994 | 82 | 485,686 | 55,240 | 16,472 | 22,145 | 25,067 |
| 1995 | 13 | 66,248 | 5,815 | 3,830 | 5,230 | 5,951 |
| 1996 | 23 | 106,835 | 16,066 | 15,475 | 17,922 | 19,183 |
| 1997 | 82 | 374,740 | 68,415 | 28,334 | 39,044 | 44,562 |
| 1998 | 41 | 218,325 | 41,629 | 23,068 | 24,953 | 25,923 |
| 1999 | 34 | 166,090 | NS | 10,661 | 13,953 | 15,649 |
| 2000 | 128 | 642,944 | 114,617 | 40,831 | 50,634 | 55,685 |
| 2001 | 1,078 | 4,984,672 | 134,874 | 86,482 | 389,940 | 546,266 |
| 2002 | 345 | 1,605,630 | 91,278 | 90,948 | 152,547 | 184,279 |
| 2003 | 111 | 648,684 | 45,177 | 16,755 | 27,897 | 33,637 |
| 2004 | 241 | 1,156,559 | 49,631 | 72,080 | 101,172 | 116,158 |
| 2005 | 332 | 1,436,564 | 79,902 | 69,064 | 140,737 | 177,659 |
| 2006 | 297 | 1,284,228 | 60,752 | - | - | - |
| 2007 | 283 | 1,241,521 | - | - | - | - |
| ***Average*** | ***212*** | ***1,001,389*** | ***62,870*** | ***37,661*** | ***73,567*** | ***95,590*** |

[a] The estimated number of smolts (yearlings) that are produced entirely within the Chiwawa Basin. Smolt estimates for brood years 1992-1996 were calculated with a mark-recapture model; brood years 1997-2005 were calculated with a flow model.
[b] These numbers represent Chiwawa smolts produced within the entire Wenatchee Basin. This assumes that 66% of the subyearling migrants from the Chiwawa basin survive to smolt in the Wenatchee Basin, regardless of the number of subyearling migrants (i.e., no density dependence). Smolt estimates for brood years 1992-1996 were calculated with a mark-recapture model; brood years 1997-2005 were calculated with a flow model.
[c] Estimate only includes numbers of Chinook in the Chiwawa River. Tributaries were not sampled at that time.

Wild subyearling spring Chinook (2006 brood year) were captured between 8 June and 27 November 2007. Based on capture efficiencies estimated from the flow model for both the upper position and lower position, the total number of wild subyearling (fry and parr) Chinook from the Chiwawa River was 70,262 (±19,317). Removing fry from the estimate, a total of 62,922 (±13,424) parr emigrated from the Chiwawa Basin in 2007. Although subyearlings migrated during most months of sampling, the majority (63%) migrated during August, September, and October (Figure 5.3).

Yearling spring Chinook sampled in 2007 averaged 91 mm in length, 8.6 g in weight, and had a mean condition of 1.10 (Table 5.15). These size estimates were similar to the overall mean of yearling spring Chinook sampled in previous years (overall means: 94 mm, 9.4 g, and condition of 1.10). Subyearling spring Chinook sampled in 2007 at the Chiwawa Trap averaged 72 mm in length, averaged 4.5 g, and had a mean condition of 1.13 (Table 5.15). These sizes comport well with the overall mean of subyearling spring Chinook sampled in previous years (overall means, 77 mm, 5.7 g, and condition of 1.10).

**Table 5.15.** Mean fork length (mm), weight (g), and condition factor of subyearling and yearling spring Chinook collected in the Chiwawa Trap, 1996-2007. Numbers in parentheses indicate 1 standard deviation.

| Sample year | Life stage | Sample size[a] | Mean size | | |
|---|---|---|---|---|---|
| | | | Length (mm) | Weight (g) | Condition (K) |
| 1996 | Subyearling | 514 | 78 (25) | 6.9 (4.2) | 1.11 (0.11) |
| | Yearling | 1,589 | 94 (9) | 9.5 (3.0) | 1.11 (0.08) |
| 1997 | Subyearling | 840 | 86 (8) | 7.5 (2.1) | 1.16 (0.08) |
| | Yearling | 1,114 | 100 (7) | 10.2 (2.6) | 1.02 (0.10) |
| 1998 | Subyearling | 3,743 | 82 (11) | 6.2 (2.2) | 1.08 (0.09) |
| | Yearling | 2,663 | 97 (7) | 10.3 (2.8) | 1.12 (0.23) |
| 1999 | Subyearling | 569 | 89 (9) | 8.5 (2.4) | 1.15 (0.07) |
| | Yearling | 3,664 | 95 (8) | 9.6 (3.4) | 1.09 (0.19) |
| 2000 | Subyearling | 1,810 | 85 (10) | 7.4 (2.4) | 1.15 (0.10) |
| | Yearling | 1,891 | 97 (8) | 10.5 (5.2) | 1.13 (0.07) |
| 2001 | Subyearling | 4,657 | 82 (11) | 6.6 (3.4) | 1.14 (0.09) |
| | Yearling | 2,935 | 97 (7) | 10.5 (2.4) | 1.15 (0.08) |
| 2002 | Subyearling | 6,130 | 64 (12) | 3.0 (1.6) | 1.06 (0.10) |
| | Yearling | 1,735 | 94 (8) | 9.0 (2.3) | 1.09 (0.08) |
| 2003 | Subyearling | 3,679 | 64 (12) | 3.2 (1.7) | 1.08 (0.10) |
| | Yearling | 2,657 | 87 (9) | 7.2 (3.5) | 1.07 (0.10) |
| 2004 | Subyearling | 2,278 | 75 (16) | 4.3 (2.1) | 0.92 (0.16) |
| | Yearling | 1,032 | 91 (9) | 8.5 (2.7) | 1.09 (0.10) |
| 2005 | Subyearling | 2,702 | 73 (12) | 4.6 (2.2) | 1.08 (0.09) |
| | Yearling | 803 | 96 (9) | 9.9 (2.8) | 1.08 (0.08) |
| 2006 | Subyearling | 3,462 | 76 (11) | 5.1 (2.0) | 1.12 (0.21) |
| | Yearling | 4,645 | 95 (7) | 9.4 (2.3) | 1.10 (0.13) |
| 2007 | Subyearling | 1,718 | 72 (11.5) | 4.5 (2.1) | 1.13 (0.16) |
| | Yearling | 2,245 | 91 (7.8) | 8.6 (2.5) | 1.10 (0.09) |
| ***Average*** | ***Subyearling*** | ***2,675*** | ***77.2*** | ***5.7*** | ***1.10*** |
| | ***Yearling*** | ***2,248*** | ***94.4*** | ***9.4*** | ***1.10*** |

[a] Sample size represents the number of fish that were measured for both length and weight.

### *Upper Wenatchee Trap*

The Upper Wenatchee Trap operated nightly between 4 March and 23 July 2007. During the five-month sampling period, a total of 1,597 wild yearling Chinook, 213 wild subyearling Chinook, and 750 hatchery yearling Chinook were captured at the Upper Wenatchee Trap. Monthly captures of all fish collected at the Upper Wenatchee Trap are reported in Appendix B.

### *Lower Wenatchee Trap*

The Lower Wenatchee Trap operated nightly between 1 February and 5 August 2007. During that time period the trap was inoperable for 14 days because of high river flows, debris, snow/ice, or

mechanical failure. During the seven-month sampling period, a total of 1,906 wild yearling Chinook, 86,142 wild subyearling Chinook (mostly summer Chinook), and 45,467 hatchery yearling Chinook were captured at the Lower Wenatchee Trap. Based on capture efficiencies estimated from the flow model, the total number of wild yearling Chinook that emigrated past the Lower Wenatchee Trap was 311,699 (±293,886). The majority (53%) of these fish emigrated during March. Monthly captures of all fish collected at the Lower Wenatchee Trap are reported in Appendix B.

### PIT Tagging Activities

A total of 13,980 juvenile Chinook (6,239 subyearling and 7,741 yearlings) were PIT tagged and released in 2007 throughout the Wenatchee Basin (Table 5.16). Most of these (77%) were tagged in the Chiwawa Basin (10,796 at the trap and 20 upstream from the trap). Few were tagged and released in Nason Creek or the upper Wenatchee River. A total of 1,641 yearling Chinook were tagged and released at the Lower Wenatchee trap. See Appendix C for a complete list of all fish captured, tagged, lost, and released.

**Table 5.16.** Numbers of wild Chinook that were captured, tagged, and released at different locations within the Wenatchee Basin, 2007. Numbers of fish that died or shed tags are also given.

| Sampling location | Life stage | Number captured for tagging | Number tagged | Number that died | Number of shed tags | Total number of fish released |
|---|---|---|---|---|---|---|
| Chiwawa Trap | Subyearling | 6,676 | 6,155 | 17 | 1 | 6,137 |
| | Yearling | 4,798 | 4,689 | 30 | 0 | 4,659 |
| | **Total** | **11,474** | **10,844** | **47** | **1** | **10,796** |
| Chiwawa River | Subyearling | 23 | 21 | 1 | 0 | 20 |
| | Yearling | 1 | 0 | 0 | 0 | 0 |
| | **Total** | **24** | **21** | **1** | **0** | **20** |
| Upper Wenatchee Trap | Subyearling | 21 | 20 | 5 | 0 | 15 |
| | Yearling | 1,493 | 1,456 | 21 | 1 | 1,434 |
| | **Total** | **1,514** | **1,476** | **26** | **1** | **1,449** |
| Upper Wenatchee River | Subyearling | 68 | 61 | 0 | 0 | 61 |
| | Yearling | 0 | 0 | 0 | 0 | 0 |
| | **Total** | **68** | **61** | **0** | **0** | **61** |
| Nason Creek[a] | Subyearling | 7 | 7 | 1 | 0 | 6 |
| | Yearling | 7 | 7 | 0 | 0 | 7 |
| | **Total** | **14** | **14** | **1** | **0** | **13** |
| Lower Wenatchee Trap | Subyearling | 0 | 0 | 0 | 0 | 0 |
| | Yearling | 1,690 | 1,646 | 5 | 0 | 1,641 |
| | **Total** | **1,690** | **1,646** | **5** | **0** | **1,641** |
| ***Totals*** | ***Subyearling*** | ***6,795*** | ***6,264*** | ***24*** | ***1*** | ***6,239*** |
| | ***Yearling*** | ***7,989*** | ***7,798*** | ***56*** | ***1*** | ***7,741*** |
| | ***Total*** | ***14,784*** | ***14,062*** | ***80*** | ***2*** | ***13,980*** |

[a] An additional 489 wild subyearling and 582 wild yearling Chinook were tagged and released by the Yakama Nation at the Nason Creek smolt trap.

### Freshwater Productivity

Both productivity and survival estimates for different life stages of spring Chinook in the Chiwawa Basin are provided in Table 5.17. Estimates for brood year 2005 fall within the ranges estimated over the period of brood years 1991-2004. During that period, freshwater productivities ranged from 125-1,015 parr/redd, 169-779 smolts/redd, and 214-834 emigrants/redd. Survivals during the same period ranged from 2.7-19.1% for egg-parr, 3.2-16.8% for egg-smolt, and 4.1-18.0% for egg-emigrants. Overwinter survival rates for juvenile spring Chinook within the Chiwawa Basin have ranged from 15.7-100.0%.

**Table 5.17.** Productivity (fish/redd) and survival (%) estimates for different juvenile life stages of spring Chinook in the Chiwawa Basin for brood years 1991-2006; ND = no data. These estimates were derived from data in Table 5.14.

| Brood year | Parr/Redd | Smolts/Redd[a] | Emigrants/ Redd | Egg-Parr (%) | Parr-Smolt[b] (%) | Egg-Smolt[a] (%) | Egg-Emigrant (%) |
|---|---|---|---|---|---|---|---|
| 1991 | 437 | 409 | ND | 9.5 | 93.5 | 8.9 | ND |
| 1992 | 262 | 188 | 217 | 5.0 | 50.2 | 3.6 | 4.2 |
| 1993 | 519 | 169 | 214 | 9.9 | 15.7 | 3.2 | 4.1 |
| 1994 | 674 | 270 | 306 | 11.4 | 29.8 | 4.6 | 5.2 |
| 1995 | 447 | 402 | 458 | 8.8 | 65.9 | 7.9 | 9.0 |
| 1996 | 699 | 779 | 834 | 15.0 | 96.3 | 16.8 | 18.0 |
| 1997 | 834 | 476 | 543 | 18.3 | 41.4 | 10.4 | 11.9 |
| 1998 | 1,015 | 609 | 632 | 19.1 | 55.4 | 11.4 | 11.9 |
| 1999 | ND | 410 | 460 | ND | ND | 8.4 | 9.4 |
| 2000 | 895 | 396 | 435 | 17.8 | 35.6 | 7.9 | 8.7 |
| 2001 | 125 | 362 | 507 | 2.7 | 64.1 | 7.8 | 11.0 |
| 2002 | 265 | 442 | 534 | 5.7 | 99.6 | 9.5 | 11.5 |
| 2003 | 407 | 251 | 303 | 7.0 | 37.1 | 4.3 | 5.2 |
| 2004 | 206 | 420 | 482 | 4.3 | 100.0 | 8.7 | 10.0 |
| 2005 | 241 | 424 | 535 | 5.6 | 86.4 | 9.8 | 12.4 |
| 2006 | 205 | - | - | 4.7 | - | - | - |
| ***Average*** | ***287*** | ***365*** | ***459*** | ***6.0*** | ***62.8*** | ***7.6*** | ***9.5*** |

[a] These estimates include Chiwawa smolts produced within the Wenatchee Basin. This assumes that 66% of the subyearling migrants survive to smolt, regardless of the number of subyearling migrants (i.e., no density dependence). Smolt estimates for brood years 1992-1996 were calculated with a mark-recapture model; brood years 1997-2005 were calculated with a flow model.

[b] These estimates represent overwinter survival within the Chiwawa Basin. It does not include Chiwawa smolts produced outside the Chiwawa Basin. As noted in footnote 1, smolts/redd and egg-smolt survival include Chiwawa smolts produced in the Wenatchee basin.

Seeding level (egg deposition) explained most of the variability in productivity and survival of juvenile spring Chinook in the Chiwawa Basin. That is, for estimates based on "within-Chiwawa-Basin" life stages (e.g., parr and within-Chiwawa-Basin smolts), survival and productivity decreased as seeding levels increased (Figure 5.4). This suggests that density dependence regulates juvenile

productivity and survival within the Chiwawa Basin. This form of population regulation is less apparent with total smolts (i.e., Chiwawa smolts produced within the Wenatchee Basin) and total emigrants. However, one would expect the number of emigrants to increases as seeding levels exceed the capacity of the Chiwawa Basin.

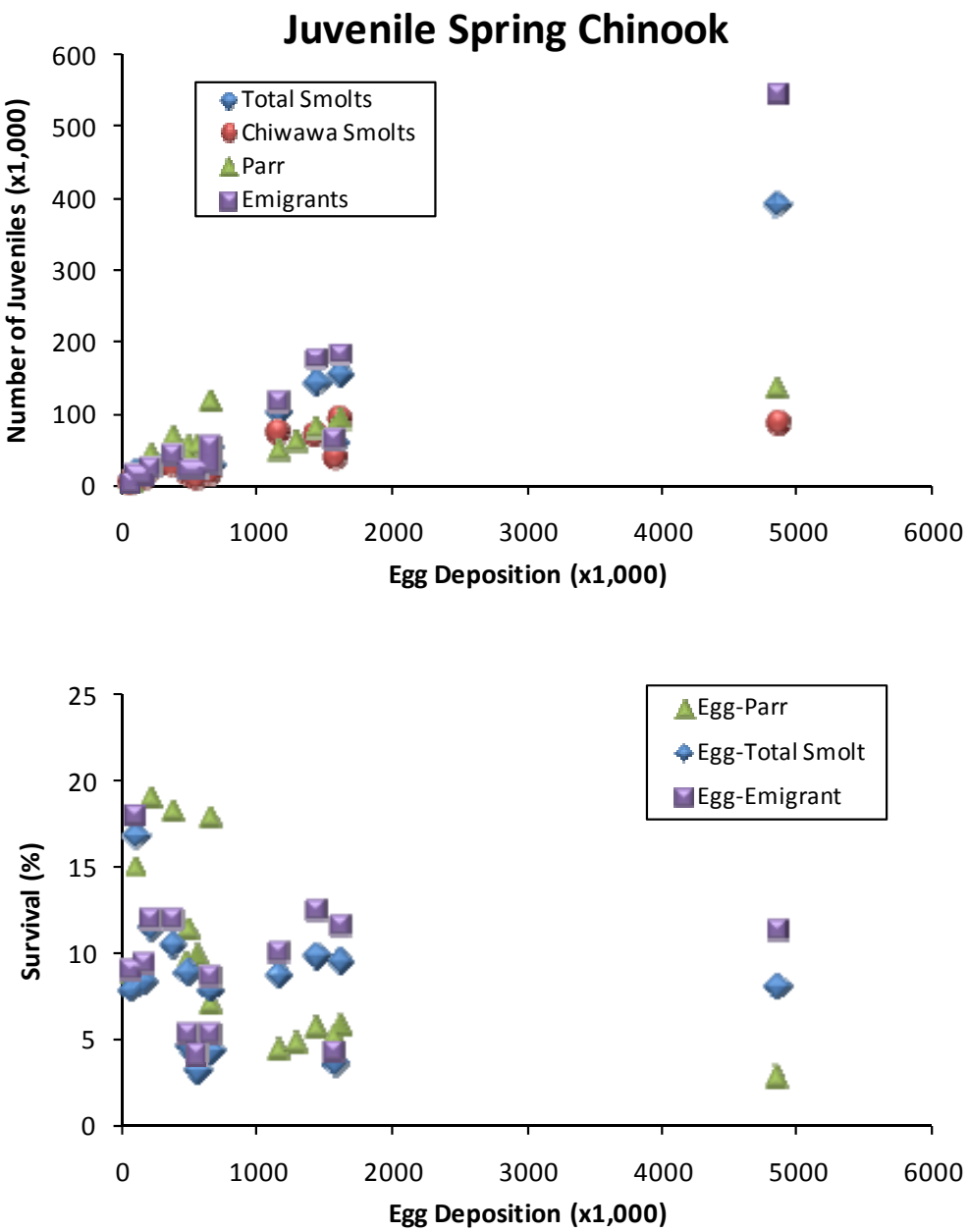


**Figure 5.4.** Relationships between seeding levels (egg deposition) and juvenile life-stage survivals and productivities for Chiwawa spring Chinook, 1991-2006. Total smolts are Chiwawa smolts produced within and outside the Chiwawa Basin (assumes a 66% survival on subyearling emigrants). Chiwawa smolts are smolts produced only in the Chiwawa Basin.

## 5.5 Spawning Surveys

Surveys for spring Chinook redds were conducted during August through September, 2007, in the Chiwawa River (including Rock and Chikamin creeks), Nason Creek, Icicle Creek, Peshastin Creek (including Ingalls Creek), Upper Wenatchee River (including Chiwaukum Creek), Little Wenatchee River, and White River (including the Napeequa River and Panther Creek).

### Redd Counts

A total of 466 spring Chinook redds were counted in the Wenatchee Basin in 2007 (Table 5.18). This is lower than the average of 503 redds counted during the period 1989-2007 in the Wenatchee Basin. Most spawning occurred in the Chiwawa River (61% or 283 redds) (Table 5.18; Figure 5.5). Nason Creek contained 22% (101 redds), Little Wenatchee contained 5% (22 redds), White River contained 4% (20 redds), Icicle contained 4% (17 redds), and the Upper Wenatchee River and Peshastin Creek each contained 2%.

**Table 5.18.** Numbers of spring Chinook redds counted within different streams/watersheds within the Wenatchee Basin, 1989-2007. Redd counts in Peshastin Creek in 2001 and 2002 (*) were elevated because the U.S. Fish and Wildlife Service planted 487 and 350 spring Chinook adults, respectively, into the stream. These counts were not included in the total or average calculations.

| Sample year | Number of spring Chinook redds | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Chiwawa | Nason | Little Wenatchee | White | Wenatchee River | Icicle | Peshastin | Total |
| 1989 | 314 | 98 | 45 | 64 | 94 | 24 | NS | **639** |
| 1990 | 255 | 103 | 30 | 22 | 36 | 50 | 4 | **500** |
| 1991 | 104 | 67 | 18 | 21 | 41 | 40 | 1 | **292** |
| 1992 | 302 | 81 | 35 | 35 | 38 | 37 | 0 | **528** |
| 1993 | 106 | 223 | 61 | 66 | 86 | 53 | 5 | **600** |
| 1994 | 82 | 27 | 7 | 3 | 6 | 15 | 0 | **140** |
| 1995 | 13 | 7 | 0 | 2 | 1 | 9 | 0 | **32** |
| 1996 | 23 | 33 | 3 | 12 | 1 | 12 | 1 | **85** |
| 1997 | 82 | 55 | 8 | 15 | 15 | 33 | 1 | **209** |
| 1998 | 41 | 29 | 8 | 5 | 0 | 11 | 0 | **94** |
| 1999 | 34 | 8 | 3 | 1 | 2 | 6 | 0 | **54** |
| 2000 | 128 | 100 | 9 | 8 | 37 | 68 | 0 | **350** |
| 2001 | 1,078 | 374 | 74 | 104 | 218 | 88 | 173* | **2,109** |
| 2002 | 345 | 294 | 42 | 42 | 64 | 245 | 107* | **1,139** |
| 2003 | 111 | 83 | 12 | 15 | 24 | 18 | 60 | **323** |
| 2004 | 241 | 169 | 13 | 22 | 46 | 30 | 55 | **576** |
| 2005 | 332 | 193 | 64 | 86 | 143 | 8 | 3 | **829** |
| 2006 | 297 | 152 | 21 | 31 | 27 | 50 | 10 | **588** |
| 2007 | 283 | 101 | 22 | 20 | 12 | 17 | 11 | **466** |
| ***Average*** | ***220*** | ***116*** | ***25*** | ***30*** | ***47*** | ***43*** | ***9*** | ***503*** |

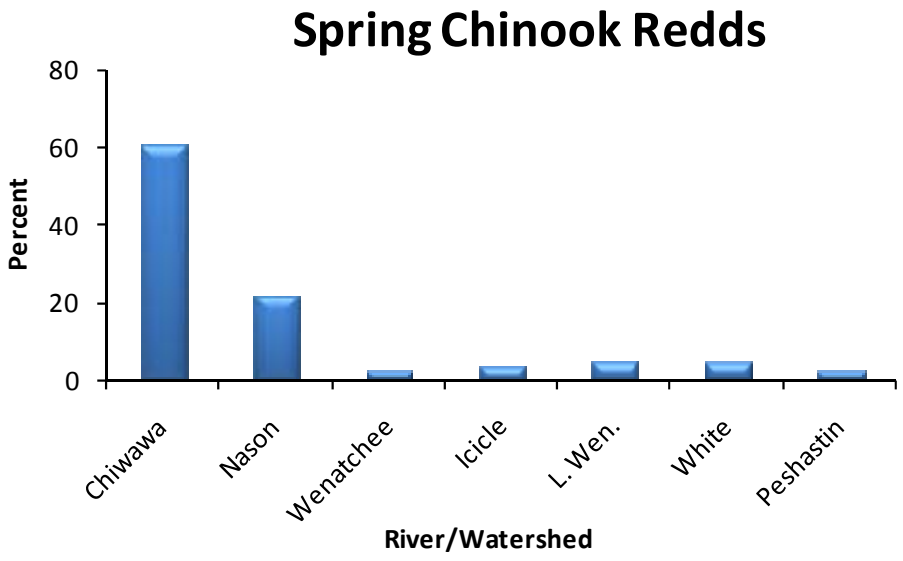


**Figure 5.5.** Percent of the total number of spring Chinook redds counted in different streams/watersheds within the Wenatchee Basin during August through September, 2007.

### Redd Distribution

Spring Chinook redds were not evenly distributed among reaches within survey streams in 2007 (Table 5.19). Most of the spawning in the Chiwawa Basin occurred in Reaches 1, 2, 5, and 6. Over half of all the spawning in the Chiwawa Basin occurred in the lower two reaches (RM 0.0-19.3; from the mouth to Rock Creek). Few fish spawned in Rock and Chikamin creeks. The spatial distribution of redds in Nason Creek was more even than in the Chiwawa basin, with the proportion of redds ranging from 0.22 to 0.29 among the four reaches in Nason Creek. Nearly 82% of all spawning in the Little Wenatchee River occurred in Reach 3 (RM 5.2-9.2; Lost Creek to Rainy Creek). On the White River, 80% occurred in Reach 3 (RM 11.0-12.9; Napeequa River to Grasshopper Meadows). Nearly all the spawning in the Wenatchee River occurred upstream from the mouth of the Chiwawa River. Of the few fish that spawned in the Peshastin Creek watershed, Chinook placed nearly equal numbers of redds in Ingalls Creek and the lower reach of Peshastin Creek.

**Table 5.19.** Numbers and percentages of spring Chinook redds counted within different streams/watersheds within the Wenatchee Basin during August through September, 2007.

| Stream/watershed | Reach | Number of redds | Percent of redds within stream/watershed |
|---|---|---|---|
| Chiwawa | Chiwawa 1 | 44 | 15.6 |
| | Chiwawa 2 | 122 | 43.1 |
| | Chiwawa 3 | 9 | 3.2 |
| | Chiwawa 4 | 28 | 9.9 |
| | Chiwawa 5 | 30 | 10.6 |
| | Chiwawa 6 | 44 | 15.6 |
| | Rock 1 | 5 | 1.8 |
| | Chikamin 1 | 1 | 0.4 |
| | **Total** | **283** | **100.0** |
| Nason | Nason 1 | 22 | 21.8 |
| | Nason 2 | 29 | 28.7 |
| | Nason 3 | 28 | 27.7 |
| | Nason 4 | 22 | 21.8 |
| | **Total** | **101** | **100.0** |
| Little Wenatchee | Little Wen 2 | 4 | 18.2 |
| | Little Wen 3 | 18 | 81.8 |
| | **Total** | **22** | **100.0** |
| White | White 2 | 2 | 10.0 |
| | White 3 | 16 | 80.0 |
| | Napeequa 1 | 0 | 0.0 |
| | Panther 1 | 2 | 10.0 |
| | **Total** | **20** | **100.0** |
| Wenatchee River | Wen 9 | 1 (+1 in Chiwaukum Creek) | 16.7 |
| | Wen 10 | 10 | 83.3 |
| | **Total** | **12** | **100.0** |
| Icicle | Icicle 1 | 17 | 100.0 |
| | **Total** | **17** | **100.0** |
| Peshastin | Peshastin 1 | 5 | 45.5 |
| | Peshastin 2 | 0 | 0.0 |
| | Ingalls | 6 | 54.5 |
| | **Total** | **11** | **100.0** |
| ***Grand Total*** | | ***466*** | |

## Spawn Timing

Spring Chinook began spawning during the second week of August in the Chiwawa River, White River, and Nason Creek, the third week on the Little Wenatchee River, and the fifth week on the

Upper Wenatchee River (Figure 5.6). Spawning generally peaked the fourth or fifth week of August in all systems except the Upper Wenatchee. Because of warmer water temperatures, peak spawning in the Wenatchee River occurred during the first week of September. All spawning was completed by the end of September.

The temporal distribution of spawning activity in the Chiwawa River in 2007 occurred slightly earlier compared to the 16-year mean spawning distribution (Figure 5.7). The greatest difference in distributions was noted in late August and September. Compared with the 16-year distribution, the 2007 distribution showed a less spiked spawning activity and activity in 2007 ended about one week earlier compared to the mean.

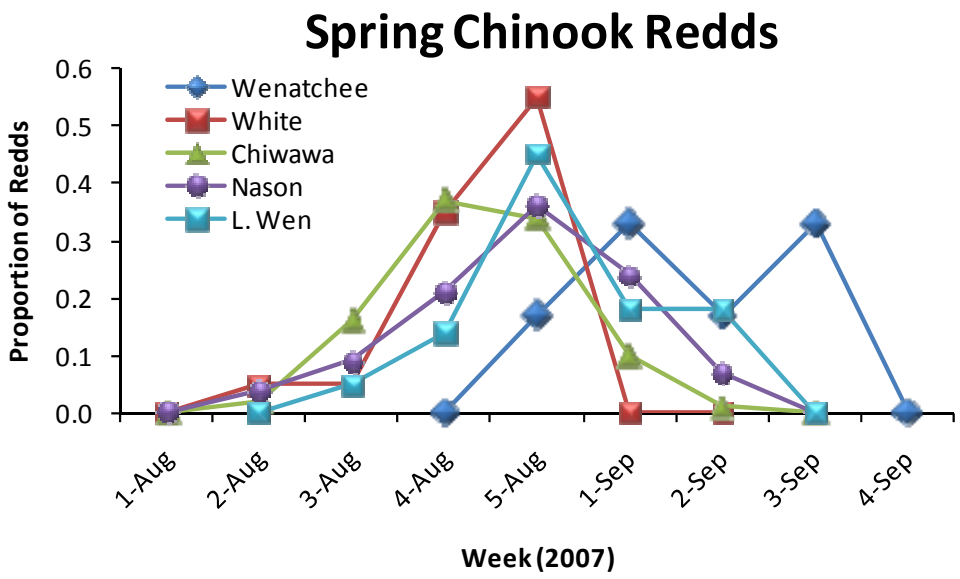


**Figure 5.6.** Proportion of spring Chinook redds counted during different weeks in different sampling streams within the Wenatchee Basin, August through September 2007.

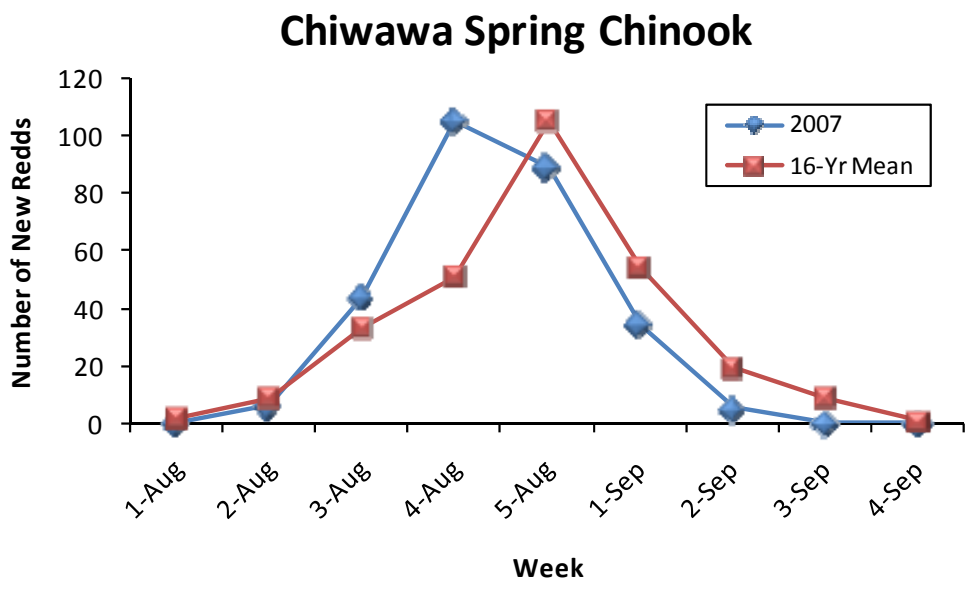


**Figure 5.7.** Comparison of the number of new spring Chinook redds counted during different weeks in the Chiwawa Basin, August through September, 2007, to the 16-year average.

### Spawning Escapement

Spawning escapement for spring Chinook was calculated as the number of redds times the male-to-female ratio (i.e., fish per redd expansion factor) estimated from broodstock and fish sampled at adult trapping sites. The estimated fish per redd ratio for spring Chinook upstream from Tumwater in 2007 was 4.58 (based on sex ratios estimated at Tumwater Dam). The estimated fish per redd ratio for spring Chinook downstream from Tumwater (Icicle and Peshastin creeks) was 1.86 (derived from broodstock collected at the Leavenworth National Fish Hatchery). Multiplying these ratios by the number of redds counted in the Wenatchee Basin resulted in a total spawning escapement of 2,059 spring Chinook (Table 5.20). The Chiwawa Basin had the highest spawning escapement (1,296 Chinook), while Peshastin Creek and the Upper Wenatchee had the lowest.

**Table 5.20.** Number of redds, fish per redd ratios, and total spawning escapement for spring Chinook in the Wenatchee Basin, 2007. Spawning escapement was estimated as the product of redds times fish per redd.

| Sampling area | Total number of redds | Fish/redd | Total spawning escapement |
|---|---|---|---|
| Chiwawa | 283 | 4.58 | 1,296 |
| Nason | 101 | 4.58 | 463 |
| Upper Wenatchee River | 12 | 4.58 | 55 |
| Icicle | 17 | 1.86 | 32 |
| Little Wenatchee | 22 | 4.58 | 101 |
| White | 20 | 4.58 | 92 |
| Peshastin | 11 | 1.86 | 20 |
| ***Total*** | ***466*** | | ***2,059*** |

The estimated total spawning escapement of 2,059 spring Chinook in 2007 was greater than the 1989-2007 average of 1,157 spring Chinook (Table 5.21). The large escapement in the Chiwawa Basin in 2007 was almost three times the escapement in Nason Creek, the second most abundant stream in the Wenatchee Basin (Table 5.21).

**Table 5.21.** Spawning escapements for spring Chinook in the Wenatchee Basin for return years 1989-2007; NA = not available.

| Return year | Upper basin spawning escapement | | | | | | Lower basin spawning escapement | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fish/redd | Chiwawa | Nason | Little Wenatchee | White | Wenatchee River | Fish/redd | Icicle | Peshastin | |
| 1989 | 2.27 | 713 | 222 | 102 | 145 | 213 | 2.27 | 54 | NA | **1,449** |
| 1990 | 2.24 | 571 | 231 | 67 | 49 | 81 | 2.24 | 112 | 9 | **1,120** |
| 1991 | 2.33 | 242 | 156 | 42 | 49 | 96 | 2.33 | 93 | 2 | **680** |
| 1992 | 2.24 | 676 | 181 | 78 | 78 | 85 | 2.24 | 83 | 0 | **1,181** |
| 1993 | 2.20 | 233 | 491 | 134 | 145 | 189 | 2.20 | 117 | 11 | **1,320** |
| 1994 | 2.24 | 184 | 60 | 16 | 7 | 13 | 2.24 | 34 | 0 | **314** |
| 1995 | 2.51 | 33 | 18 | 0 | 5 | 3 | 2.51 | 23 | 0 | **82** |
| 1996 | 2.53 | 58 | 83 | 8 | 30 | 3 | 2.53 | 30 | 3 | **215** |
| 1997 | 2.22 | 182 | 122 | 18 | 33 | 33 | 2.22 | 73 | 2 | **463** |
| 1998 | 2.21 | 91 | 64 | 18 | 11 | 0 | 2.21 | 24 | 0 | **208** |
| 1999 | 2.77 | 94 | 22 | 8 | 3 | 6 | 2.77 | 17 | 0 | **150** |
| 2000 | 2.44 | 312 | 244 | 22 | 20 | 90 | 2.44 | 166 | 0 | **854** |
| 2001 | 2.31 | 2,490 | 864 | 171 | 240 | 504 | 2.31 | 203 | 365 | **4,837** |
| 2002 | 2.05 | 707 | 603 | 86 | 86 | 131 | 2.05 | 502 | 223 | **2,338** |
| 2003 | 2.43 | 270 | 202 | 29 | 36 | 58 | 2.43 | 44 | 146 | **785** |
| 2004 | 3.56 | 858 | 507 | 39 | 66 | 138 | 1.79 | 54 | 97 | **1,759** |
| 2005 | 1.80 | 598 | 347 | 115 | 155 | 257 | 1.75 | 14 | 5 | **1,491** |
| 2006 | 1.78 | 529 | 271 | 37 | 55 | 48 | 1.80 | 90 | 18 | **1,048** |
| 2007 | 4.48 | 1,296 | 463 | 101 | 92 | 55 | 1.86 | 32 | 20 | **2,059** |
| ***Average*** | ***2.45*** | ***534*** | ***271*** | ***57*** | ***69*** | ***105*** | ***2.22*** | ***93*** | ***50*** | ***1,176*** |

## *5.6 Carcass Surveys*

Surveys for spring Chinook carcasses were conducted during August through September in the Chiwawa River (including Rock and Chikamin creeks), Nason Creek, Icicle Creek, Peshastin Creek (including Ingalls Creek), Upper Wenatchee River, Little Wenatchee River, and White River (including the Napeequa River and Panther Creek).

### Number sampled

A total of 526 spring Chinook carcasses were sampled during August through September in the Wenatchee Basin (Table 5.22). Most were sampled in the Chiwawa Basin (48% or 250 carcasses) and Nason Creek (38% or 201 carcasses) (Figure 5.8). A total of 25 carcasses were sampled in the

upper Wenatchee River, 16 in the Little Wenatchee, 15 in Icicle, 13 in the White River, and 6 in Peshastin Creek.

**Table 5.22.** Numbers of spring Chinook carcasses sampled within different streams/watersheds within the Wenatchee Basin, 1996-2007.

| Survey year | Number of spring Chinook carcasses | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Chiwawa | Nason | Little Wenatchee | White | Wenatchee River | Icicle | Peshastin | Total |
| 1996 | 22 | 3 | 0 | 2 | 0 | 1 | 0 | **28** |
| 1997 | 13 | 42 | 3 | 8 | 1 | 28 | 1 | **96** |
| 1998 | 24 | 25 | 3 | 2 | 1 | 6 | 0 | **61** |
| 1999 | 15 | 5 | 0 | 0 | 2 | 1 | 0 | **23** |
| 2000 | 122 | 110 | 8 | 1 | 37 | 52 | 0 | **330** |
| 2001 | 751 | 388 | 68 | 74 | 213 | 163 | 63 | **1,720** |
| 2002 | 190 | 292 | 30 | 24 | 34 | 91 | 49 | **710** |
| 2003 | 70 | 100 | 8 | 8 | 12 | 37 | 42 | **277** |
| 2004 | 178 | 186 | 1 | 13 | 29 | 16 | 40 | **463** |
| 2005 | 391 | 217 | 48 | 52 | 120 | 2 | 0 | **830** |
| 2006 | 241 | 190 | 13 | 25 | 15 | 7 | 0 | **491** |
| 2007 | 250 | 201 | 16 | 13 | 25 | 15 | 6 | **526** |
| ***Average*** | ***189*** | ***147*** | ***17*** | ***19*** | ***41*** | ***35*** | ***17*** | ***463*** |

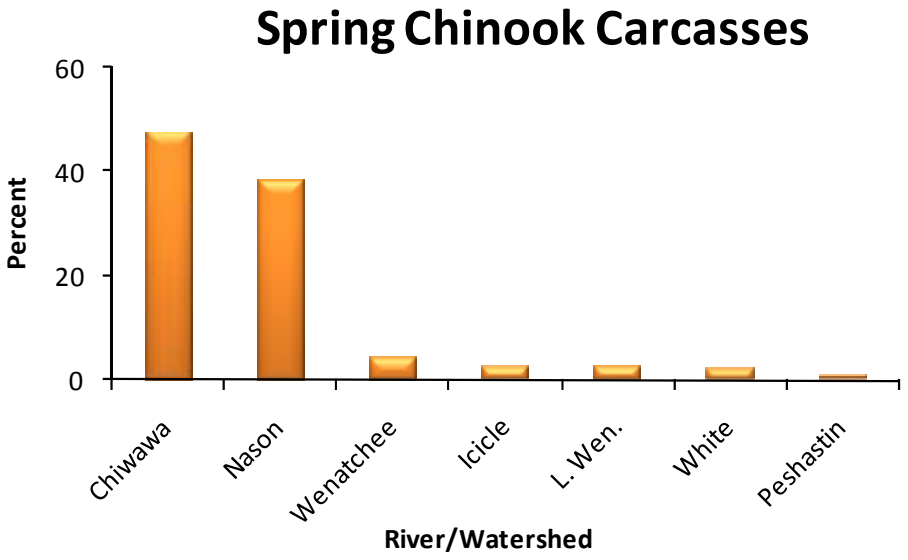


**Figure 5.8.** Percent of the total number of spring Chinook carcasses sampled in different streams/watersheds within the Wenatchee Basin during August through September, 2007.

### Carcass Distribution and Origin

Spring Chinook carcasses were not evenly distributed among reaches within survey streams in 2007 (Table 5.23). Most of the carcasses in the Chiwawa Basin occurred in Reaches 1 and 2 (downstream from Rock Creek). In Nason Creek, most carcasses (45%) were collected in Reach 2 and the fewest (10%) in Reach 4. Nearly 94% of all carcasses sampled in the Little Wenatchee River occurred in Reach 3 (Lost Creek to Rainy Creek). On the White River, about 77% occurred in Reach 3 (Napeequa River to Grasshopper Meadows). Almost all carcasses sampled in the Wenatchee River were found upstream from the mouth of the Chiwawa River. All fish sampled in the Peshastin Creek watershed were in Reach 1 (mouth to Camas Creek).

**Table 5.23.** Numbers and percentages of carcasses sampled within different streams/watersheds within the Wenatchee Basin during August through September, 2007.

| Stream/watershed | Reach | Total carcasses | Percent of carcasses within stream/watershed |
|---|---|---|---|
| Chiwawa | Chiwawa 1 | 45 | 18.0 |
| | Chiwawa 2 | 133 | 53.2 |
| | Chiwawa 3 | 18 | 7.2 |
| | Chiwawa 4 | 18 | 7.2 |
| | Chiwawa 5 | 20 | 8.0 |
| | Chiwawa 6 | 14 | 5.6 |
| | Rock 1 | 0 | 0.0 |
| | Chikamin 1 | 2 | 0.8 |
| | **Total** | **250** | **100.0** |
| Nason | Nason 1 | 56 | 27.9 |
| | Nason 2 | 90 | 44.8 |
| | Nason 3 | 34 | 16.9 |
| | Nason 4 | 21 | 10.4 |
| | **Total** | **201** | **100.0** |
| Little Wenatchee | Little Wen 2 | 1 | 6.3 |
| | Little Wen 3 | 15 | 93.7 |
| | **Total** | **16** | **100.0** |
| White | White 2 | 1 | 7.7 |
| | White 3 | 10 | 76.9 |
| | Napeequa 1 | 0 | 0.0 |
| | Panther 1 | 2 | 15.4 |
| | **Total** | **13** | **100.0** |
| Wenatchee River | Wen 9 | 3 | 12.0 |
| | Wen 10 | 22 | 88.0 |
| | **Total** | **25** | **100.0** |
| Icicle | Icicle 1 | 15 | 100.0 |
| | **Total** | **15** | **100.0** |
| Peshastin | Peshastin 1 | 6 | 100.0 |

| Stream/watershed | Reach | Total carcasses | Percent of carcasses within stream/watershed |
|---|---|---|---|
| | Peshastin 2 | 0 | 0.0 |
| | Ingalls | 0 | 0.0 |
| | **Total** | **6** | **100.0** |
| ***Grand Total*** | | ***526*** | |

Of the 526 carcasses sampled in 2007, 82% were hatchery fish (Table 5.24; these numbers may change after analysis of CWTs and scales). In the Chiwawa Basin, the spatial distribution of hatchery and wild fish was not equal (Table 5.24). A larger percentage of hatchery fish were found in the lower reaches (C1 and C2; Mouth to Rock Creek) than were wild fish (88% hatchery and 12% naturally produced). This general trend was also apparent in the pooled data (Figure 5.9).

**Table 5.24.** Numbers of wild and hatchery spring Chinook carcasses sampled within different reaches in the Chiwawa Basin, 1993-2007. See Table 2.8 for description of survey reaches.

| Survey year | Origin | Survey Reach | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | C-1 | C-2 | C-3 | C-4 | C-5 | C-6 | Chikamin | Rock | |
| 1993 | Wild | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | Hatchery | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **1** |
| 1994 | Wild | 0 | 6 | 0 | 2 | 0 | 1 | 0 | 0 | **9** |
| | Hatchery | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | **4** |
| 1995 | Wild | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| | Hatchery | 2 | 3 | 0 | 1 | 0 | 0 | 0 | 0 | **6** |
| 1996 | Wild | 11 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | **14** |
| | Hatchery | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **6** |
| 1997 | Wild | 5 | 2 | 0 | 1 | 0 | 0 | 0 | 0 | **8** |
| | Hatchery | 3 | 1 | 0 | 0 | 0 | 1 | 1 | 3 | **9** |
| 1998 | Wild | 0 | 3 | 5 | 1 | 2 | 4 | 0 | 0 | **15** |
| | Hatchery | 1 | 3 | 2 | 0 | 1 | 1 | 0 | 0 | **8** |
| 1999 | Wild | 1 | 8 | 0 | 5 | 0 | 0 | 0 | 0 | **14** |
| | Hatchery | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | **1** |
| 2000 | Wild | 25 | 27 | 1 | 1 | 1 | 1 | 0 | 0 | **56** |
| | Hatchery | 42 | 12 | 0 | 0 | 0 | 2 | 0 | 0 | **56** |
| 2001 | Wild | 24 | 57 | 15 | 40 | 16 | 20 | 1 | 3 | **176** |
| | Hatchery | 164 | 284 | 19 | 58 | 14 | 21 | 8 | 0 | **568** |
| 2002 | Wild | 15 | 11 | 9 | 6 | 7 | 5 | 2 | 0 | **55** |
| | Hatchery | 46 | 40 | 12 | 5 | 1 | 15 | 14 | 4 | **137** |
| 2003 | Wild | 7 | 13 | 0 | 11 | 3 | 2 | 0 | 0 | **36** |
| | Hatchery | 14 | 14 | 0 | 3 | 1 | 0 | 0 | 0 | **32** |
| 2004 | Wild | 23 | 48 | 2 | 11 | 7 | 3 | 0 | 1 | **95** |
| | Hatchery | 46 | 21 | 1 | 1 | 1 | 3 | 0 | 2 | **75** |
| 2005 | Wild | 16 | 36 | 3 | 4 | 3 | 2 | 0 | 0 | **64** |
| | Hatchery | 170 | 132 | 7 | 7 | 4 | 3 | 0 | 1 | **324** |

| Survey year | Origin | Survey Reach | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | C-1 | C-2 | C-3 | C-4 | C-5 | C-6 | Chikamin | Rock | |
| 2006 | Wild | 10 | 17 | 2 | 8 | 4 | 3 | 1 | 0 | **45** |
| | Hatchery | 84 | 75 | 5 | 7 | 6 | 13 | 3 | 3 | **196** |
| 2007 | Wild | 3 | 20 | 3 | 4 | 4 | 2 | 0 | 0 | **36** |
| | Hatchery | 42 | 113 | 15 | 14 | 16 | 12 | 2 | 0 | **214** |
| ***Average*** | ***Wild*** | ***9*** | ***17*** | ***3*** | ***6*** | ***3*** | ***3*** | ***0*** | ***0*** | ***42*** |
| | ***Hatchery*** | ***41*** | ***47*** | ***4*** | ***7*** | ***3*** | ***5*** | ***2*** | ***1*** | ***109*** |

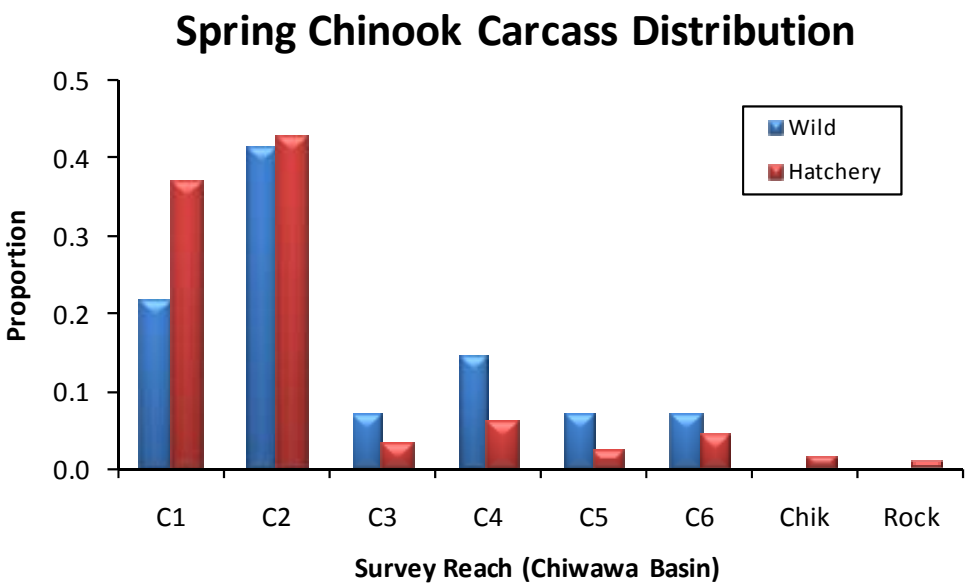


**Figure 5.9**. Distribution of wild and hatchery produced carcasses in different reaches in the Chiwawa Basin, 1993-2007; Chik = Chikamin Creek. Reach codes are described in Table 2.8.

### Sampling Rate

Overall, 26% of the estimated total spawning escapement of spring Chinook in the Wenatchee Basin was sampled in 2007 (Table 5.25). Sampling rates among streams/watershed varied from 14 to 47%.

**Table 5.25.** Number of redds and carcasses, total spawning escapement, and sampling rates for spring Chinook salmon in the Wenatchee Basin, 2007.

| Sampling area | Total number of redds | Total number of carcasses | Total spawning escapement | Sampling rate |
|---|---|---|---|---|
| Chiwawa | 283 | 250 | 1,296 | 0.19 |
| Nason | 101 | 201 | 463 | 0.43 |
| Upper Wenatchee | 12 | 25 | 55 | 0.46 |
| Icicle | 17 | 15 | 32 | 0.47 |
| Little Wenatchee | 22 | 16 | 101 | 0.16 |
| White | 20 | 13 | 92 | 0.14 |

| | | | | |
|---|---|---|---|---|
| Peshastin | 11 | 6 | 20 | 0.30 |
| ***Total*** | ***466*** | ***526*** | ***2,059*** | ***0.26*** |

### Length Data

Mean lengths (POH, cm) of male and female spring Chinook carcasses sampled during surveys in the Wenatchee Basin in 2007 are provided in Table 5.26. The average size of males and females sampled in the Wenatchee Basin were 51 and 63 cm, respectively.

**Table 5.26.** Mean lengths (postorbital-to-hypural length; cm) and standard deviations (in parentheses) of male and female spring Chinook carcasses sampled in different streams/watersheds in the Wenatchee Basin, 2007.

| Stream/watershed | Mean lengths (cm) | |
|---|---|---|
| | Male | Female |
| Chiwawa | 55 (14) | 63 (5) |
| Nason | 48 (10) | 63 (5) |
| Upper Wenatchee | 48 (6) | 62 (4) |
| Icicle | 46 (9) | 37 (0) |
| Little Wenatchee | 58 (20) | 67 (7) |
| White | 64 (15) | 70 (7) |
| Peshastin | 56 (11) | 65 (0) |
| ***Total*** | ***51 (13)*** | ***63 (6)*** |

## *5.7 Life History Monitoring*

Life history characteristics of spring Chinook were assessed by examining carcasses on spawning grounds and fish collected at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

### Age at Maturity

Most of the wild and hatchery spring Chinook sampled during the period 1994-2007 in the Chiwawa Basin were age-4 fish (total age) (Table 5.27; Figure 5.10). On average, hatchery fish made up a higher percentage of age-3 and 4 Chinook than did wild fish. In contrast, a higher proportion of age-5 wild fish returned than did age-5 hatchery fish. Thus, wild fish tended to return at an older age than hatchery fish.

**Table 5.27.** Proportions of wild and hatchery spring Chinook of different ages (total age) sampled on spawning grounds in the Chiwawa Basin, 1994-2007.

| Sample year | Origin | Total age | | | | | Sample size |
|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | |
| 1994 | Wild | 0.00 | 0.00 | 0.33 | 0.67 | 0.00 | 9 |
| | Hatchery | 0.00 | 0.20 | 0.00 | 0.80 | 0.00 | 5 |
| 1995 | Wild | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | Hatchery | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 2 |
| 1996 | Wild | 0.00 | 0.36 | 0.64 | 0.00 | 0.00 | 14 |
| | Hatchery | 0.00 | 0.83 | 0.17 | 0.00 | 0.00 | 6 |
| 1997 | Wild | 0.00 | 0.00 | 0.75 | 0.25 | 0.00 | 8 |
| | Hatchery | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 9 |
| 1998 | Wild | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 15 |
| | Hatchery | 0.00 | 0.00 | 0.13 | 0.88 | 0.00 | 8 |
| 1999 | Wild | 0.00 | 0.07 | 0.50 | 0.43 | 0.00 | 14 |
| | Hatchery | 0.00 | 0.00 | 0.00 | 1.00 | 0.00 | 1 |
| 2000 | Wild | 0.00 | 0.02 | 0.95 | 0.03 | 0.00 | 56 |
| | Hatchery | 0.00 | 0.50 | 0.50 | 0.00 | 0.00 | 52 |
| 2001 | Wild | 0.00 | 0.01 | 0.95 | 0.04 | 0.00 | 176 |
| | Hatchery | 0.00 | 0.02 | 0.98 | 0.00 | 0.00 | 571 |
| 2002 | Wild | 0.00 | 0.00 | 0.56 | 0.44 | 0.00 | 55 |
| | Hatchery | 0.00 | 0.00 | 0.91 | 0.09 | 0.00 | 128 |
| 2003 | Wild | 0.00 | 0.09 | 0.00 | 0.91 | 0.00 | 36 |
| | Hatchery | 0.00 | 0.19 | 0.03 | 0.78 | 0.00 | 32 |
| 2004 | Wild | 0.00 | 0.02 | 0.97 | 0.01 | 0.00 | 92 |
| | Hatchery | 0.00 | 0.44 | 0.56 | 0.00 | 0.00 | 45 |
| 2005 | Wild | 0.00 | 0.01 | 0.76 | 0.24 | 0.00 | 131 |
| | Hatchery | 0.00 | 0.02 | 0.98 | 0.00 | 0.00 | 685 |
| 2006 | Wild | 0.00 | 0.02 | 0.80 | 0.17 | 0.00 | 139 |
| | Hatchery | 0.01 | 0.02 | 0.64 | 0.33 | 0.00 | 303 |
| 2007 | Wild | 0.00 | 0.14 | 0.42 | 0.44 | 0.00 | 78 |
| | Hatchery | 0.00 | 0.32 | 0.60 | 0.08 | 0.00 | 251 |
| ***Average*** | ***Wild*** | ***0.00*** | ***0.04*** | ***0.74*** | ***0.22*** | ***0.00*** | ***823*** |
| | ***Hatchery*** | ***0.00*** | ***0.08*** | ***0.84*** | ***0.08*** | ***0.00*** | ***2,098*** |

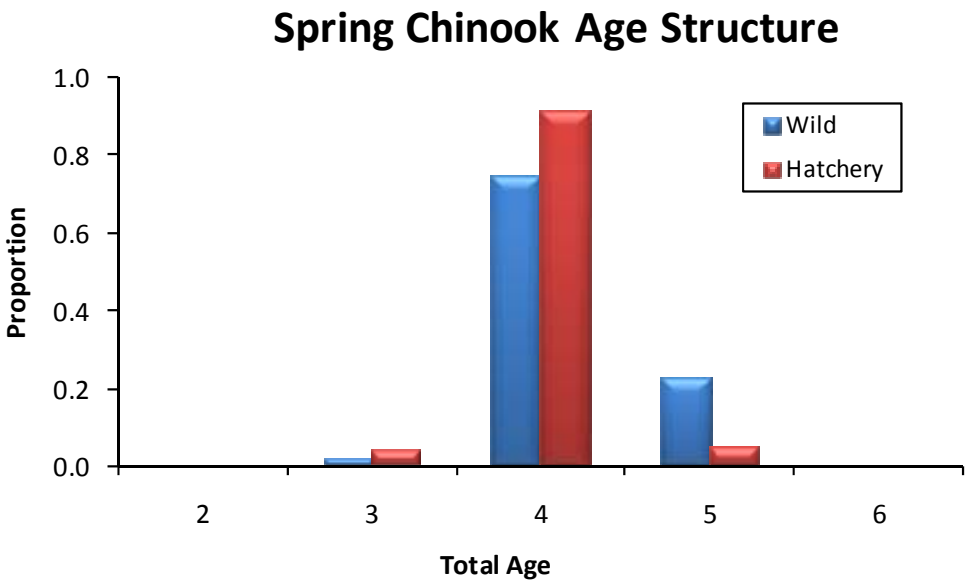


**Figure 5.10.** Proportions of wild and hatchery spring Chinook of different total ages sampled at the Chiwawa Weir and on spawning grounds in the Chiwawa Basin for the combined years 1994-2006.

### Size at Maturity

On average, hatchery and wild spring Chinook of a given age differed slightly in length (Table 5.28). For example, wild age-5 fish were larger on average than the age-5 hatchery fish. In contrast, hatchery age-3 and 4 Chinook were generally larger than age-3 and 4 wild fish.

**Table 5.28.** Mean lengths (POH in cm; ±1SD) and sample sizes (in parentheses) of different ages (total age) of male and female spring Chinook of wild and hatchery origin sampled in the Chiwawa basin, 1994-2006.

| Brood year | Total age | Mean length (cm) | | | |
|---|---|---|---|---|---|
| | | Male | | Female | |
| | | Wild | Hatchery | Wild | Hatchery |
| 1994 | 3 | | | | 43 ±0 (1) |
| | 4 | | | 62 ±3 (3) | |
| | 5 | 76 ±0 (1) | | 73 ±2 (5) | |
| | 6 | | | | |
| 1995 | 3 | | | | |
| | 4 | | 61 ±5 (5) | | |
| | 5 | | | | |
| | 6 | | | | |
| 1996 | 3 | 45 ±3 (5) | 49 ±7 (54) | | |
| | 4 | 69 ±4 (6) | 69 ±0 (1) | 67 ±8 (2) | |
| | 5 | | | | |
| | 6 | | | | |
| 1997 | 3 | | | | |
| | 4 | 61 ±1 (2) | 68 ±0 (1) | 67 ±5 (3) | 63 ±3 (8) |

| Brood year | Total age | Mean length (cm) | | | |
|---|---|---|---|---|---|
| | | Male | | Female | |
| | | Wild | Hatchery | Wild | Hatchery |
| | 5 | 67 ±5 (2) | | | |
| | 6 | | | | |
| 1998 | 3 | | | | |
| | 4 | | | | 54 ±0 (1) |
| | 5 | 77 ±7 (8) | 75 ±4 (4) | 74 ±4 (7) | 76 ±4 (3) |
| | 6 | | | | |
| 1999 | 3 | 44 ±0 (1) | | | |
| | 4 | 61 ±0 (1) | | 64 ±3 (6) | |
| | 5 | 76 ±5 (3) | | 72 ±5 (3) | 66 ±0 (1) |
| | 6 | | | | |
| 2000 | 3 | | 46 ±3 (17) | | 50 ±7 (3) |
| | 4 | 60 ±8 (23) | 62 ±5 (5) | 61 ±5 (26) | 62 ±3 (20) |
| | 5 | 77 ±1 (2) | | | |
| | 6 | | | | |
| 2001 | 3 | 37 ±0 (1) | 42 ±4 (11) | 41 ±0 (1) | 60 ±0 (1) |
| | 4 | 63 ±5 (57) | 65 ±5 (151) | 62 ±34 (110) | 63 ±4 (407) |
| | 5 | 75 ±5 (2) | 83 ±0 (1) | 76 ±1 (5) | |
| | 6 | | | | |
| 2002 | 3 | | | | |
| | 4 | 64 ±4 (14) | 66 ±5 (46) | 60 ±4 (15) | 63 ±4 (71) |
| | 5 | 80 ±6 (13) | 75 ±5 (4) | 72 ±3 (12) | 73 ±6 (6) |
| | 6 | | | | |
| 2003 | 3 | 45 ±2 (3) | 45 ±1 (6) | | |
| | 4 | | 63 ±0 (1) | | |
| | 5 | 78 ±5 (12) | 74 ±8 (11) | 75 ±3 (19) | 72 ±5 (14) |
| | 6 | | | | |
| 2004 | 3 | 43 ±3 (2) | 43 ±4 (20) | | |
| | 4 | 62 ±7 (44) | 67 ±5 (3) | 62 ±3 (45) | 64 ±5 (22) |
| | 5 | | | 74 ±0 (1) | |
| | 6 | | | | |
| 2005 | 3 | | 43 ±5 (11) | | |
| | 4 | 61 ±5 (17) | 64 ±6 (101) | 61 ±4 (34) | 61 ±4 (206) |
| | 5 | 74 ±5 (4) | | 71 ±3 (9) | |
| | 6 | | | | |
| 2006 | 3 | 43 ±0 (1) | 43 ±2 (6) | | |
| | 4 | 64 ±3 (6) | 61 ±5 (44) | 60 ±3 (17) | 59 ±4 (105) |
| | 5 | 74 ±6 (8) | 75 ±6 (10) | 70 ±4 (12) | 70± 4 (23) |
| | 6 | | | | |
| 2007 | 3 | 39 ±3 (5) | 45 ±7 (71) | | 50 ±3 (4) |
| | 4 | 60 ±4 (4) | 66 ±5 (34) | 60 ±4 (6) | 62 ±4 (91) |

| Brood year | Total age | Mean length (cm) | | | |
|---|---|---|---|---|---|
| | | Male | | Female | |
| | | Wild | Hatchery | Wild | Hatchery |
| | 5 | 78 ±6 (13) | 75 ±5 (7) | 71 ±3 (8) | 72 ±5 (6) |
| | 6 | | | | |

## Contribution to Fisheries

Nearly all the harvest on Chiwawa spring Chinook occurs within the Columbia Basin. Ocean catch records (Pacific Fishery Management Council) indicate that virtually no Upper Columbia spring Chinook are taken in ocean fisheries. Most of the harvest on Chiwawa spring Chinook occurs in the Lower Columbia River fisheries, which are managed by the states and tribes pursuant to management plans developed in *U.S. v Oregon*. The Lower Columbia River fisheries occur during what is referred to in *U.S. v Oregon* as the winter, spring, and summer seasons, which begin in February and ends July 31 of each year. The treaty fishery occurs exclusively in Zone 6, the area between Bonneville and McNary dams; the non-treaty commercial fisheries occur in Zones 1-5, which are downstream from Bonneville Dam. The non-treaty recreational (sport) fishery occurs in the lower mainstem.

The total number of spring Chinook captured in different fisheries has been relatively low (Table 5.29). Larger numbers of spring Chinook were taken from the 1997 and 1998 brood years because those years produced large escapements.

**Table 5.29.** Estimated number and percent (in parentheses) of Chiwawa spring Chinook captured in different fisheries; NA = not available.

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational[a] (sport) | |
| 1989 | 3 (13) | 5 (21) | 0 (0) | 16 (67) | 24 |
| 1990 | 0 (0) | 0 (0) | 0 (0) | 18 (100) | 18 |
| 1991 | 0 (0) | 3 (100) | 0 (0) | 0 (0) | 3 |
| 1992 | 0 (0) | 1 (100) | 0 (0) | 0 (0) | 1 |
| 1993 | 3 (75) | 1 (25) | 0 (0) | 0 (0) | 4 |
| 1994 | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 |
| 1995 | NA | NA | NA | NA | NA |
| 1996 | 0 (0) | 2 (100) | 0 (0) | 0 (0) | 2 |
| 1997 | 1 (0) | 1 (0) | 287 (71) | 115 (28) | 404 |
| 1998 | 9 (5) | 7 (4) | 52 (30) | 108 (61) | 176 |
| 1999 | NA | NA | NA | NA | NA |
| 2000 | 0 (0) | 0 (0) | 17 (63) | 10 (37) | 27 |
| 2001 | 17 (61) | 0 (0) | 3 (11) | 8 (29) | 28 |

[a] Includes the Wanapum fishery.

### Straying

Stray rates were determined by examining CWTs recovered on spawning grounds within and outside the Wenatchee Basin. Targets for strays based on return year (recovery year) within the Wenatchee Basin should be less than 10% and targets for strays outside the Wenatchee Basin should be less than 5%. The target for brood year stray rates should be less than 5%.

Rates of Chiwawa spring Chinook straying into non-target spawning areas within the Wenatchee Basin have been high in some years and exceeded the target of 10% (Table 5.30). They have strayed into spawning areas on Nason Creek, the White River, the Little Wenatchee River, and the Upper Wenatchee River. On average, stray rates are typically highest in Nason Creek and the Upper Wenatchee River. Stray rates of Chiwawa spring Chinook should decrease with the change in source water that was implemented in 2006-2007 for the Chiwawa rearing ponds.

**Table 5.30.** Number and percent of spawning escapement in other non-target spawning streams within the Wenatchee Basin that consisted of Chiwawa spring Chinook, return years 1992-2005. For example, for return year 2001, 24.9% of the spring Chinook spawning escapement in Nason Creek consisted of Chiwawa spring Chinook. Percent strays should be less than 10%.

| Return year | Nason Creek | | Icicle Creek | | Upper Wenatchee | | White River | | Little Wenatchee | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % | Number | % | Number | % |
| 1992 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1993 | 61 | 12.4 | 0 | 0.0 | 34 | 18.0 | 7 | 4.8 | 0 | 0.0 |
| 1994 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1995 | 0 | 0.0 | 0 | 0.0 | 2 | 66.7 | 0 | 0.0 | 0 | 0.0 |
| 1996 | 25 | 30.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1997 | 55 | 45.1 | 8 | 11.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1998 | 3 | 4.7 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1999 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2000 | 45 | 18.4 | 0 | 0.0 | 31 | 34.4 | 0 | 0.0 | 6 | 27.3 |
| 2001 | 211 | 24.4 | 0 | 0.0 | 271 | 53.8 | 46 | 19.2 | 53 | 31.0 |
| 2002 | 188 | 31.2 | 10 | 2.0 | 60 | 45.8 | 14 | 16.3 | 21 | 24.4 |
| 2003 | 14 | 6.9 | 0 | 0.0 | 30 | 51.7 | 0 | 0.0 | 0 | 0.0 |
| 2004 | 139 | 27.4 | 0 | 0.0 | 54 | 39.1 | 1 | 1.5 | 0 | 0.0 |
| 2005 | 252 | 72.6 | 7 | 13.0 | 256 | 99.6 | 106 | 68.4 | 65 | 56.5 |
| ***Total*** | ***993*** | ***26.1*** | ***25*** | ***1.8*** | ***738*** | ***48.9*** | ***174*** | ***19.0*** | ***145*** | ***19.5*** |

Rates of Chiwawa spring Chinook straying into basins outside the Wenatchee have been low (Table 5.31). Chiwawa spring Chinook have strayed into the Methow and Entiat basins. During return year 2002, their stray rate exceeded the target of 0.05 in the Entiat Basin. Stray rates of Chiwawa spring Chinook should decrease with the change in source water that was implemented in 2006-2007 for the Chiwawa rearing ponds.

**Table 5.31.** Number and percent of spawning escapements within other non-target basins that consisted of Chiwawa spring Chinook, return years 1992-2005. For example, for return year 2002, 12.6% of the spring Chinook spawning escapement in the Entiat Basin consisted of Chiwawa spring Chinook. Percent strays should be less than 5%. NS = not sampled; NA = not available.

| Return year | Methow Basin | | Entiat Basin | |
|---|---|---|---|---|
| | Number | % | Number | % |
| 1992 | 0 | 0.0 | 0 | 0.0 |
| 1993 | 0 | 0.0 | 0 | 0.0 |
| 1994 | 0 | 0.0 | 0 | 0.0 |
| 1995 | 0 | 0.0 | 0 | 0.0 |
| 1996 | NS | NS | 0 | 0.0 |
| 1997 | 0 | 0.0 | 0 | 0.0 |
| 1998 | NS | NS | 0 | 0.0 |
| 1999 | 0 | 0.0 | 0 | 0.0 |
| 2000 | 0 | 0.0 | 1 | 0.6 |
| 2001 | 0 | 0.0 | 1 | 0.2 |
| 2002 | 0 | 0.0 | 34 | 12.6 |
| 2003 | 0 | 0.0 | 0 | 0.0 |
| 2004 | 0 | 0.0 | 0 | 0.0 |
| 2005 | 10 | 0.7 | 4 | NA |
| ***Total*** | ***10*** | ***0.0*** | ***36*** | ***1.9*** |

On average, about 36% of the returns have strayed into non-target spawning areas, exceeding the target of 5% (Table 5.32). Depending on brood year, percent strays into non-target spawning areas have ranged from 0-81%. Few (<1%) have strayed into non-target hatchery programs. Stray rates of Chiwawa spring Chinook should decrease with the change in source water that was implemented in 2006-2007 for the Chiwawa rearing ponds.

**Table 5.32.** Number and percent of Chiwawa spring Chinook that homed to target spawning areas and the target hatchery program, and number and percent that strayed to non-target spawning areas and non-target hatchery programs, by brood years 1989-2001. Percent stays should be less than 5%.

| Brood year | Homing | | | | Straying | | | |
|---|---|---|---|---|---|---|---|---|
| | Target stream | | Target hatchery | | Non-target streams | | Non-target hatcheries | |
| | Number | % | Number | % | Number | % | Number | % |
| 1989 | 58 | 35.4 | 1 | 0.6 | 102 | 62.2 | 3 | 1.8 |
| 1990 | 0 | 0.0 | 1 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| 1991 | 29 | 87.9 | 0 | 0.0 | 2 | 6.1 | 2 | 6.1 |
| 1992 | 2 | 6.5 | 4 | 12.9 | 25 | 80.6 | 0 | 0.0 |
| 1993 | 134 | 47.5 | 82 | 29.1 | 63 | 22.3 | 3 | 1.1 |
| 1994 | 4 | 19.0 | 14 | 66.7 | 3 | 14.3 | 0 | 0.0 |
| 1995 | No program | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1996 | 58 | 75.3 | 7 | 9.1 | 12 | 15.6 | 0 | 0.0 |
| 1997 | 1,242 | 55.6 | 298 | 13.4 | 687 | 30.8 | 5 | 0.2 |
| 1998 | 553 | 55.8 | 109 | 11.0 | 329 | 33.2 | 0 | 0.0 |
| 1999 | No program | | | | | | | |
| 2000 | 144 | 42.6 | 115 | 34.0 | 79 | 23.4 | 0 | 0.0 |
| 2001 | 573 | 35.2 | 237 | 14.5 | 817 | 50.1 | 3 | 0.2 |
| ***Total*** | ***2,797*** | ***48.2*** | ***868*** | ***15.0*** | ***2,119*** | ***36.5*** | ***16*** | ***0.3*** |

### Genetics

Genetic studies were conducted to determine the potential impacts of the Chiwawa Supplementation Program on natural origin spring Chinook in the upper Wenatchee Basin (Blankenship et al. 2007; the entire report is appended as Appendix I). Microsatellite DNA allele frequencies collected from temporally replicated natural and hatchery origin spring Chinook were used to statistically assign individual fish to specific demes (locations) within the Wenatchee population. In addition, genetic effects of the hatchery program were assessed by examining relationships between census and effective population sizes ($N_e$) from samples collected before and after supplementation.

Overall, this work showed that although allele frequencies within and between natural and hatchery origin spring Chinook were significantly different, there was no evidence (i.e., robust signal) that the difference was the result of the hatchery program. Rather, the differences were more likely the result of life history characteristics. However, there was an increasing trend toward homogenization of the allele frequencies of the natural and hatchery origin fish that comprised the broodstock, even though there was consistent year-to-year variation in allele frequencies among hatchery and natural origin fish. In addition, there were no robust signals indicating that hatchery-origin hatchery broodstock, hatchery-origin natural spawners, natural-origin hatchery broodstock, and natural-origin natural spawners were substantially different from each other. Finally, the $N_e$ estimate of 387 was only slightly larger than the pre-hatchery $N_e$ (based on demographic data from 1989-1992), which means that the Chiwawa hatchery program has not reduced the $N_e$ of the Wenatchee spring Chinook population.

Significant differences in allele frequencies were observed within and among major spawning areas in the Upper Wenatchee Basin. However, these differences made up only a very small portion of the overall variation, indicating genetic similarity among the major spawning areas. There was no evidence that the Chiwawa program has changed the genetic structure (allele frequency) of spring Chinook in Nason Creek and the White River, despite the presence of hatchery origin spawners in both systems.

### Proportion of Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery origin fish in the natural spawning escapement (pHOS). The ratio pNOB/(pHOS+pNOB) is the Proportion of Natural Influence (PNI). The larger the ratio (PNI), the

greater the strength of selection in the natural environment relative to that of the hatchery environment. In order for the natural environment to dominate selection, PNI should be greater than 0.5 (HSRG/WDFW/NWIFC 2004).

For brood years 1989-1996, the PNI was greater than 0.50, indicating that the natural environment had a greater influence on adaptation of Chiwawa spring Chinook than did the hatchery environment (Table 5.33). For brood years 1997-2006, however, the PNI was generally less than 0.50, indicating that the hatchery environment had a greater influence on adaptation than did the natural environment.

**Table 5.33.** Proportionate natural influence (PNI) of the Chiwawa spring Chinook supplementation program for brood years 1989-2006. PNI was calculated as the proportion of naturally produced Chinook in the hatchery broodstock (pNOB) divided by the proportion of hatchery Chinook on the spawning grounds (pHOS) plus pNOB. NOS = number of natural origin Chinook on the spawning grounds; HOS = number of hatchery origin Chinook on the spawning grounds; NOB = number of natural origin Chinook collected for broodstock; and HOB = number of hatchery origin Chinook included in hatchery broodstock.

| Brood year | Spawners | | | Broodstock | | | PNI |
|---|---|---|---|---|---|---|---|
| | NOS | HOS | pHOS | NOB | HOB | pNOB | |
| 1989 | 713 | 0 | 0.00 | 28 | 0 | 1.00 | 1.00 |
| 1990 | 571 | 0 | 0.00 | 18 | 0 | 1.00 | 1.00 |
| 1991 | 242 | 0 | 0.00 | 27 | 0 | 1.00 | 1.00 |
| 1992 | 676 | 0 | 0.00 | 78 | 0 | 1.00 | 1.00 |
| 1993 | 76 | 157 | 0.67 | 94 | 0 | 1.00 | 0.60 |
| 1994 | 132 | 52 | 0.28 | 8 | 4 | 0.67 | 0.70 |
| 1995 | 6 | 26 | 0.81 | No Program | | | |
| 1996 | 53 | 5 | 0.08 | 8 | 10 | 0.44 | 0.84 |
| 1997 | 74 | 108 | 0.59 | 32 | 79 | 0.29 | 0.33 |
| 1998 | 52 | 39 | 0.43 | 13 | 34 | 0.28 | 0.39 |
| 1999 | 71 | 23 | 0.25 | No Program | | | |
| 2000 | 203 | 109 | 0.35 | 9 | 21 | 0.30 | 0.46 |
| 2001 | 680 | 1,810 | 0.73 | 113 | 259 | 0.30 | 0.29 |
| 2002 | 220 | 487 | 0.69 | 20 | 51 | 0.28 | 0.29 |
| 2003 | 165 | 105 | 0.39 | 41 | 53 | 0.44 | 0.53 |
| 2004 | 596 | 305 | 0.34 | 83 | 132 | 0.39 | 0.53 |
| 2005 | 134 | 518 | 0.79 | 91 | 181 | 0.33 | 0.30 |
| 2006 | 116 | 412 | 0.78 | 91 | 224 | 0.29 | 0.27 |

### Natural Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural origin recruits (NOR) to the parent spawning population. For brood years 1989-2000, NRR in the Chiwawa averaged 0.68 (range, 0.03-4.48) if harvested fish were not include in the estimate and 0.89 (range, 0.03-6.71) if harvested fish were included in the estimate (Table 5.34). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

**Table 5.34.** Spawning escapements, natural origin recruits (NOR), and natural replacement rates (NRR) for spring Chinook in the Chiwawa Basin, 1989-2000. *(The numbers in this table may change as the HETT and HC refine the methods for estimating Chiwawa spring Chinook NORs, and NRRs.)*

| Brood year | Spawning escapement | Harvest not included | | Harvest included | |
|---|---|---|---|---|---|
| | | NOR | NRR | NOR | NRR |
| 1989 | 713 | 175 | 0.24 | 220 | 0.31 |
| 1990 | 571 | 45 | 0.08 | 61 | 0.11 |
| 1991 | 242 | 6 | 0.03 | 8 | 0.03 |
| 1992 | 676 | 51 | 0.08 | 54 | 0.08 |
| 1993 | 233 | 173 | 0.74 | 188 | 0.81 |
| 1994 | 184 | 55 | 0.30 | 60 | 0.32 |
| 1995 | 33 | 46 | 1.41 | 51 | 1.58 |
| 1996 | 58 | 167 | 2.88 | 213 | 3.66 |
| 1997 | 182 | 816 | 4.48 | 1,222 | 6.71 |
| 1998 | 91 | 276 | 3.05 | 372 | 4.10 |
| 1999 | 94 | 5 | 0.05 | 6 | 0.06 |
| 2000 | 312 | 505 | 1.62 | 573 | 1.83 |
| ***Average*** | ***282*** | ***193*** | ***0.68*** | ***252*** | ***0.89*** |

## Hatchery Replacement Rates

Hatchery replacement rates were estimated as hatchery adult-to-adult returns. These rates should be greater than the NRRs and greater than or equal to 5.30 (the value in BAMP; Murdoch and Peven 2005). In most years, HRRs were greater than NRRs, regardless if harvest was or was not included (Table 5.35). In contrast, HRRs exceeded the BAMP target of 5.3 in only four years (brood years 1989, 1997, 1998, and 2000).

**Table 5.35.** Hatchery replacement rates (HRR), NRR, and BAMP target (5.30) for spring Chinook in the Chiwawa Basin, 1989-2000; NA = not available. *(The numbers in this table may change as the HETT and HC refine the methods for estimating Chiwawa spring Chinook HRRs and NRRs.)*

| Brood year | Harvest not included | | | Harvest included | | |
|---|---|---|---|---|---|---|
| | HRR | NRR | BAMP | HRR | NRR | BAMP |
| 1989 | 5.86 | 0.24 | 5.30 | 6.71 | 0.31 | 5.30 |
| 1990 | 0.05 | 0.13 | 5.30 | 1.00 | 0.18 | 5.30 |
| 1991 | 1.03 | 0.03 | 5.30 | 1.13 | 0.03 | 5.30 |
| 1992 | 0.40 | 0.08 | 5.30 | 0.41 | 0.08 | 5.30 |
| 1993 | 2.50 | 0.74 | 5.30 | 2.53 | 0.81 | 5.30 |
| 1994 | 1.75 | 0.30 | 5.30 | 1.75 | 0.32 | 5.30 |
| 1995 | NP | 1.41 | 5.30 | NP | 1.58 | 5.30 |
| 1996 | 4.28 | 2.86 | 5.30 | 4.39 | 3.65 | 5.30 |
| 1997 | 18.60 | 4.39 | 5.30 | 21.97 | 6.61 | 5.30 |
| 1998 | 20.65 | 3.05 | 5.30 | 24.31 | 4.10 | 5.30 |

| Brood year | Harvest not included | | | Harvest included | | |
|---|---|---|---|---|---|---|
| | HRR | NRR | BAMP | HRR | NRR | BAMP |
| 1999 | NP | 0.05 | 5.30 | NP | 0.06 | 5.30 |
| 2000 | 7.04 | 1.62 | 5.30 | 7.60 | 1.83 | 5.30 |
| 2001 | 4.27 | | 5.30 | 4.34 | | 5.30 |
| ***Average*** | ***6.5*** | ***0.73*** | ***5.30*** | ***7.2*** | ***0.95*** | ***5.30*** |

## Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adults divided by the number of hatchery smolts released. SARs were based on CWT returns. For the available brood years, SARs have ranged from 0.00036 to 0.01538 for hatchery spring Chinook (Table 5.36).

**Table 5.36.** Smolt-to-adult ratios (SARs) for Chiwawa hatchery spring Chinook.

| Brood year | Number of smolts released | Estimated adult captures | SAR |
|---|---|---|---|
| 1989 | 42,707 | 188 | 0.00440 |
| 1990 | 52,798 | 19 | 0.00036 |
| 1991 | 61,088 | 36 | 0.00059 |
| 1992 | 82,976 | 31 | 0.00037 |
| 1993 | 221,316 | 284 | 0.00128 |
| 1994 | 27,135 | 21 | 0.00077 |
| 1995 | No hatchery program | | |
| 1996 | 12,767 | 67 | 0.00525 |
| 1997 | 259,585 | 2,576 | 0.00992 |
| 1998 | 71,571 | 1,101 | 0.01538 |
| 1999 | No hatchery program | | |
| 2000 | 46,726 | 363 | 0.00777 |
| 2001 | 374,129 | 1,644 | 0.00439 |
| ***Average*** | ***113,891*** | ***575*** | ***0.00505*** |

## *5.8 ESA/HCP Compliance*

### Broodstock Collection

The collection of 2005 Brood Chiwawa River spring Chinook broodstock was consistent with the 2005 Upper Columbia River Salmon and Steelhead Broodstock Objectives and site-based broodstock collection protocols. Specifically, broodstock collection targeted hatchery origin fish at Tumwater Dam and the Chiwawa Weir, while only natural origin spring Chinook were collected at the Chiwawa Weir. In-season adjustments were made to the number of hatchery and natural origin spring Chinook collected for bloodstock and were based on in-season escapement monitoring at Tumwater Dam and estimated Chiwawa run-escapement.

Broodstock collection at Tumwater Dam began 17 May 2005 and concluded on 26 May 2005, and totaled 40 hatchery-origin, coded-wire tagged spring Chinook. Collection was implemented concurrent with trapping, sampling, and tagging associated with the spring Chinook reproductive success study (BPA project No. 2003-039-00). Trapping at the Chiwawa Weir began on 7 June 2005 and concluded on 30 August 2005. Broodstock were collected between 7 June 2005 and 30 August 2005 and totaled 241 spring Chinook, including 96 and 145 natural and hatchery origin Chinook, respectively. Trapping at the Chiwawa Weir generally followed a 4-up and 3-down schedule, and operated only as needed to meet weekly collection objectives, consistent with the 2005 collection protocol or as adjusted based on in-season run escapement monitoring and ESA Section 10 Permit 1196 requirements.

Both passive (low abundance periods) and active (high abundance periods) trapping were used to collect spring Chinook at Tumwater Dam. During passive trapping, the trap was checked and fish processed several times per day. At the Chiwawa Weir, the trap was operated passively, checked several times per day, and fish processed once daily. All spring Chinook, steelhead, and bull trout that were captured were anesthetized with tricaine methanesulfonate (MS-222) and subject to water-to-water transfers during handling. All fish were allowed to fully recover before release.

The estimated escapement of 2005 spring Chinook past Tumwater Dam totaled 3,827 adult and jack spring Chinook (Murdoch et al. 2006). In 2005, the Wenatchee Basin experienced severe drought conditions that adversely affected pre-spawn survival. Murdoch et al. (2006) estimated pre-spawn survival of natural and hatchery origin spring Chinook migrating past Tumwater Dam at 50.4% and 41.7% respectively. Based on 2005 spawning ground data (redd and carcass surveys) an estimated 135 natural-origin spring Chinook spawned in the Chiwawa River Basin (Murdoch et al. 2006). Assuming the pre-spawn survival of Chiwawa River natural-origin spring Chinook was similar to the at-large population upstream from Tumwater Dam (50.4%), combined with the 96 natural-origin Chinook extracted for broodstock, the natural-origin run-escapement to the Chiwawa Basin totaled 364 spring Chinook (i.e., (135/0.504) + 96 = 364). The 2005 broodstock collection of 281 spring Chinook (96 natural origin and 185 hatchery origin) represents 26.4% of the estimated 2005 natural-origin Chiwawa spring Chinook escapement past Tumwater Dam and 7.3% of the run escapement of spring Chinook above Tumwater Dam. The estimated broodstock extraction rate of natural-origin Chiwawa spring Chinook and overall extraction of spring Chinook above Tumwater Dam comply with provisions of ESA Permit 1196.

In addition to spring Chinook collected at the Chiwawa Weir for broodstock, an additional 630 spring Chinook were handled and released as a function of targeting weekly quota collections for

natural and hatchery origin spring Chinook, and as a function of maintaining, at minimum, 33% natural-origin spring Chinook in the broodstock. Additionally, 283 bull trout were captured and released. To minimize fallback or impingement on the weir, all spring Chinook and bull trout were released unharmed about 10 kilometers upstream from the weir.

### Hatchery Rearing and Release

The rearing and release of 2005 Chiwawa spring Chinook was completed without incident. No mortality events occurred that exceeded 10% of the population. Fish were acclimated on Wenatchee River water and to the extent possible on Chiwawa River water (see Section 5.2).

The release of 2005 brood Chiwawa spring Chinook smolts totaled 494,012 spring Chinook, representing 73.5% of program objective and complied with ESA Section 10 Permit 1196 production level of 672,000 smolts.

### Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, and 1395, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at Chelan PUD Hatchery facilities during the period 1 January 2007 through 31 December 2007. NPDES monitoring and reporting for Chelan PUD Hatchery Programs during 2007 are provided in Appendix E.

### Smolt and Emigrant Trapping

Per ESA Section 10 Permit No. 1196, the permit holders are authorized a direct take of 20% of the emigrating spring Chinook population during juvenile emigration monitoring and a lethal take not to exceed 2% of the fish captured (NMFS 2003). Based on the estimated wild spring Chinook population (smolt trap expansion) and hatchery juvenile spring Chinook population estimate (hatchery release data) for the Wenatchee Basin, the reported spring Chinook encounters during 2007 emigration monitoring complied with take provisions in the Section 10 permit, not withstanding sub-yearling spring Chinook encounters at the Chiwawa Weir. Sub-yearling spring Chinook encounters at the Chiwawa Weir reported an encounter rate of 0.2583, representing 129% of Permit 1196 encounter rate of 0.2000. Although the Chiwawa trap encountered greater than 20% of the estimated sub-yearling spring Chinook emigrating past the weir, it is likely that only a portion of the sub-yearling spring Chinook from the 2006 brood emigrated past the weir and out of the Chiwawa River; therefore, the reported encounter rate should be considered a maximum and the true encounter rate of the sub-yearling population was likely less than the 0.2583 reported for 2007. At the conclusion of the 2008 juvenile emigration monitoring, an overall encounter rate for 2006 brood spring Chinook will be assessed and reported in the 2008 annual report. Spring Chinook encounter and mortality rates for each trap site (including PIT tag mortalities) are detailed in Table 5.37. Additionally, juvenile fish captured at the trap locations were handled consistent with provisions in ESA Section 10 Permit 1196, Section B.

**Table 5.37.** Estimated take of Upper Columbia River spring Chinook resulting from juvenile emigration monitoring in the Wenatchee Basin, 2007.

| Trap location | Population estimate | | | Number trapped | | | Total | Take allowed under Permit |
|---|---|---|---|---|---|---|---|---|
| | Wild[a] | Hatchery[b] | Subyearling | Wild[a] | Hatchery[b] | Subyearling | | |
| **Chiwawa Trap** | | | | | | | | |
| Population | 69,064 | 494,012 | 62,922 | 4,433 | 17,634 | 16,250 | 38,317 | |
| Encounter rate | NA | NA | NA | 0.0642 | 0.0357 | 0.2583 | 0.0612 | 0.20 |
| Mortality[e] | NA | NA | NA | 39 | 0 | 147 | 139 | |
| Mortality rate | NA | NA | NA | 0.0088 | 0.0000 | 0.0090 | 0.0036 | 0.02 |
| **Upper Wenatchee Trap** | | | | | | | | |
| Population | NA | 69,102 | NA | 1,597 | 750 | 213 | 2,560 | |
| Encounter rate | NA | NA | NA | NA | 0.0109 | NA | NA | 0.20 |
| Mortality [e] | NA | NA | NA | 35 | 0 | 5 | 40 | |
| Mortality rate | NA | NA | NA | 0.0219 | 0.0000 | 0.0235 | 0.0156 | 0.02 |
| **Lower Wenatchee Trap** | | | | | | | | |
| Population | 311,699 | 563,114 | NA | 1,906 | 10,730[c] | NA[d] | 12,636 | |
| Encounter rate | NA | NA | NA | 0.0061 | 0.0191 | NA | 0.0144 | 0.20 |
| Mortality[e] | NA | NA | NA | 10 | 0 | 0 | 10 | |
| Mortality rate | NA | NA | NA | 0.0052 | 0.0000 | 0.0000 | 0.0008 | 0.02 |
| **Wenatchee Basin Total** | | | | | | | | |
| Population | 311,699 | 563,114 | NA | 7,936 | 29,114 | 16,463 | 53,513 | |
| Encounter rate | NA | NA | NA | 0.0255 | 0.0517 | NA | NA | 0.20 |
| Mortality[e] | NA | NA | NA | 84 | 0 | 152 | 236 | |
| Mortality rate | NA | NA | NA | .00106 | 0.0000 | 0.0092 | 0.0044 | 0.02 |

[a] Smolt population estimate derived from juvenile emigration trap data.

[b] 2007 smolt release data for the Wenatchee basin.

[c] Derived estimate based on the proportion of ESA-listed hatchery spring Chinook within the total hatchery yearling Chinook released in the Wenatchee basin during 2007.

[d] Based on size, date of capture, and location of capture, subyearling Chinook encountered at the Lower Wenatchee Trap are categorized as summer Chinook.

[e] Combined trapping and PIT tagging mortality.

## Spawning Surveys

Spring Chinook spawning ground surveys were conducted in the Wenatchee basin during 2007, as authorized by ESA Section 10 Permit 1196. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential impacts to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

### Spring Chinook Reproductive Success Study

ESA Section 10 Permit 1196 specifically provides authorization to capture, anesthetize, biologically sample, PIT tag, and release adult spring Chinook at Tumwater Dam for reproductive success studies and general program monitoring. During 2005, 2006, and 2007, all spring Chinook passing Tumwater Dam were enumerated, anesthetize, biologically sampled, PIT tagged, and released (not including hatchery-origin Chinook retained for broodstock) as a component of the reproductive success study (BPA Project No. 2003-039-00). Please refer the Murdoch et al. (2006) and Murdoch et al. (2007) for complete details of the methods and results of the spring Chinook reproductive success study for 2005 and 2006. Results of the 2007 study year will be available pending completion of the 2007 annual report for this project.

# SECTION 6: WENATCHEE SUMMER CHINOOK

## 6.1 Broodstock Sampling

This section focuses on results from sampling 2005-2006 Wenatchee summer Chinook broodstock, which were collected at Dryden and Tumwater dams. Complete information is not currently available for the 2007 brood (this information will be provided in the 2008 annual report).

### Origin of Broodstock

Both the 2005 and 2006 broodstock consisted almost entirely of natural origin (adipose fin present) summer Chinook (Table 6.1). Less than 1% of the fish spawned were hatchery origin fish (hatchery origin was determined by examination of scales and/or CWTs). About 5% of the fish spawned were of unknown origin.

**Table 6.1**. Numbers of wild and hatchery summer Chinook collected for broodstock, numbers that died before spawning, and numbers of Chinook spawned in the Wenatchee Basin, 1989-2006. Unknown origin fish (i.e., undetermined by scale analysis, no CWT or fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes fish that died of natural causes typically near the end of spawning and were not needed for the program and surplus fish killed at spawning.

| Brood year | Wild summer Chinook | | | | | Hatchery summer Chinook | | | | | Total number spawned |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number collected | Prespawn loss | Mortality | Number spawned | Number released | Number collected | Prespawn loss | Mortality | Number spawned | Number released | |
| 1989 | 346 | 29 | 27 | 290 | 0 | 0 | 0 | 0 | 0 | 0 | 290 |
| 1990 | 87 | 6 | 24 | 57 | 0 | 0 | 0 | 0 | 0 | 0 | 57 |
| 1991 | 128 | 9 | 14 | 105 | 0 | 0 | 0 | 0 | 0 | 0 | 105 |
| 1992 | 341 | 48 | 19 | 274 | 0 | 0 | 0 | 0 | 0 | 0 | 274 |
| 1993 | 480 | 28 | 46 | 406 | 0 | 44 | 0 | 0 | 44 | 0 | 450 |
| 1994 | 363 | 29 | 1 | 333 | 0 | 55 | 1 | 0 | 54 | 0 | 387 |
| 1995 | 382 | 15 | 4 | 363 | 0 | 16 | 0 | 0 | 16 | 0 | 378 |
| 1996 | 331 | 34 | 34 | 263 | 0 | 3 | 0 | 0 | 3 | 0 | 266 |
| 1997 | 225 | 14 | 6 | 205 | 0 | 15 | 1 | 1 | 13 | 0 | 218 |
| 1998 | 378 | 40 | 39 | 299 | 0 | 94 | 4 | 12 | 78 | 0 | 377 |
| 1999 | 250 | 7 | 1 | 242 | 0 | 238 | 1 | 1 | 236 | 0 | 478 |
| 2000 | 298 | 18 | 5 | 275 | 0 | 194 | 7 | 7 | 180 | 0 | 455 |
| 2001 | 311 | 41 | 60 | 210 | 0 | 182 | 8 | 38 | 136 | 0 | 346 |
| 2002 | 469 | 28 | 32 | 409 | 0 | 13 | 1 | 2 | 10 | 0 | 419 |
| 2003 | 488 | 90 | 61 | 337 | 0 | 8 | 1 | 0 | 7 | 0 | 344 |
| 2004 | 494 | 24 | 46 | 424 | 0 | 2 | 0 | 0 | 2 | 0 | 426 |
| 2005 | 491 | 29 | 19 | 397 | 46 | 3 | 0 | 0 | 3 | 0 | 400 |
| 2006 | 483 | 29 | 21 | 433 | 0 | 5 | 1 | 0 | 4 | 0 | 437 |
| ***Average*** | ***353*** | ***29*** | ***26*** | ***296*** | ***3*** | ***48*** | ***1*** | ***3*** | ***44*** | ***0*** | ***339*** |

### Age/Length Data

Ages of summer Chinook broodstock were determined from analysis of scales and/or CWTs. Broodstock collected from the 2005 return consisted primarily of age-4 natural origin Chinook (54%). Age-5 natural origin fish made up 35% of the broodstock, while age-3 and 6 fish collectively made up 11% (Table 6.2). Note that according to broodstock protocol, age-3 males are limited to no more than 10% of the total broodstock collection. The three hatchery Chinook included in the broodstock were age-5 fish.

Broodstock collected from the 2006 return consisted primarily of age-5 natural origin Chinook (81%). Age-4 natural origin fish made up 15% of the broodstock, while age-2, 3, and 6 fish collectively made up 3% (Table 6.2). Of the five hatchery Chinook included in the broodstock, 80% were age-5 and 20% were age-6 fish.

**Table 6.2.** Percent of hatchery and wild Wenatchee summer Chinook of different ages (total age) collected from broodstock in the Wenatchee Basin, 1991-2006.

| Return Year | Origin | Total age | | | | |
|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 |
| 1991 | Wild | 0.0 | 4.6 | 36.8 | 57.5 | 1.1 |
| | Hatchery | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1992 | Wild | 0.0 | 2.6 | 40.4 | 50.9 | 6.1 |
| | Hatchery | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1993 | Wild | 0.0 | 1.5 | 36.0 | 60.3 | 2.2 |
| | Hatchery | 0.0 | 0.0 | 93.0 | 7.0 | 0.0 |
| 1994 | Wild | 0.0 | 1.0 | 33.7 | 64.3 | 1.0 |
| | Hatchery | 0.0 | 0.0 | 1.9 | 98.1 | 0.0 |
| 1995 | Wild | 0.0 | 3.3 | 18.9 | 76.6 | 1.2 |
| | Hatchery | 0.0 | 0.0 | 0.0 | 0.0 | 100.0 |
| 1996 | Wild | 0.0 | 4.6 | 40.1 | 53.3 | 2.0 |
| | Hatchery | 0.0 | 0.0 | 33.3 | 66.7 | 0.0 |
| 1997 | Wild | 0.0 | 2.3 | 42.6 | 53.2 | 1.9 |
| | Hatchery | 0.0 | 26.7 | 66.7 | 6.6 | 0.0 |
| 1998 | Wild | 0.0 | 5.5 | 34.8 | 58.6 | 1.1 |
| | Hatchery | 0.0 | 5.4 | 68.5 | 19.6 | 6.5 |
| 1999 | Wild | 0.5 | 1.9 | 39.0 | 56.3 | 2.4 |
| | Hatchery | 0.0 | 1.3 | 23.2 | 72.1 | 2.4 |
| 2000 | Wild | 2.6 | 6.3 | 24.6 | 66.5 | 0.0 |
| | Hatchery | 0.0 | 23.6 | 15.2 | 42.9 | 18.3 |
| 2001 | Wild | 0.3 | 16.4 | 53.9 | 27.7 | 1.7 |
| | Hatchery | 0.0 | 6.3 | 80.6 | 10.0 | 3.1 |
| 2002 | Wild | 1.6 | 8.4 | 61.1 | 28.3 | 0.6 |
| | Hatchery | 0.0 | 0.0 | 41.7 | 58.3 | 0.0 |
| 2003 | Wild | 0.9 | 2.8 | 31.4 | 64.9 | 0.0 |

| Return Year | Origin | Total age | | | | |
|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 |
| | Hatchery | 0.0 | 12.5 | 25.0 | 62.5 | 0.0 |
| 2004 | Wild | 0.2 | 3.6 | 10.1 | 84.0 | 2.1 |
| | Hatchery | 0.0 | 0.0 | 50.0 | 50.0 | 0.0 |
| 2005 | Wild | 0.0 | 4.3 | 53.5 | 35.1 | 7.1 |
| | Hatchery | 0.0 | 0.0 | 0.0 | 100.0 | 0.0 |
| 2006 | Wild | 1.4 | 0.9 | 14.9 | 81.8 | 1.0 |
| | Hatchery | 0.0 | 0.0 | 0.0 | 80.0 | 20.0 |
| ***Average*** | ***Wild*** | ***0.5*** | ***4.8*** | ***36.8*** | ***56.1*** | ***1.9*** |
| | ***Hatchery*** | ***0.0*** | ***8.2*** | ***40.2*** | ***43.2*** | ***8.4*** |

Mean lengths of natural origin summer Chinook of a given age differed little between return years 2005 and 2006 (Table 6.3). Mean lengths of age-3 to 6 Chinook differed between years by about 5 cm, 2 cm, 4 cm, and 5 cm, respectively. What few hatchery fish that were included in broodstock were similar in size to natural origin fish (Table 6.3).

**Table 6.3.** Mean fork length (cm) at age (total age) of hatchery and wild Wenatchee summer Chinook collected from broodstock in the Wenatchee Basin, 1991-2006; N = sample size and SD = 1 standard deviation.

| Return year | Origin | Summer Chinook fork length (cm) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Age-2 | | | Age-3 | | | Age-4 | | | Age-5 | | | Age-6 | | |
| | | Mean | N | SD | Mean | N | SD | Mean | N | SD | Mean | N | SD | Mean | N | SD |
| 1991 | Wild | - | 0 | - | - | 4 | - | - | 32 | - | - | 50 | - | - | 1 | - |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - | - | 0 | - | - | 0 | - |
| 1992 | Wild | - | NA | - | - | NA | - | - | NA | - | - | NA | - | - | NA | - |
| | Hatchery | - | NA | - | - | NA | - | - | NA | - | - | NA | - | - | NA | - |
| 1993 | Wild | - | 0 | - | 68 | 6 | 10 | 84 | 142 | 9 | 98 | 238 | 6 | 100 | 9 | 6 |
| | Hatchery | - | 0 | - | - | 0 | - | 79 | 41 | 8 | 101 | 3 | 8 | - | 0 | - |
| 1994 | Wild | - | 0 | - | 74 | 3 | 5 | 86 | 101 | 8 | 96 | 193 | 7 | 106 | 3 | 7 |
| | Hatchery | - | 0 | - | - | 0 | - | 75 | 1 | - | 90 | 53 | 8 | - | 0 | - |
| 1995 | Wild | - | 0 | - | 66 | 11 | 8 | 85 | 64 | 7 | 97 | 255 | 6 | 106 | 4 | 7 |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - | - | 0 | - | 91 | 16 | 8 |
| 1996 | Wild | - | 0 | - | 69 | 14 | 5 | 86 | 121 | 6 | 97 | 161 | 6 | 104 | 6 | 5 |
| | Hatchery | - | 0 | - | - | 0 | - | 63 | 1 | - | 96 | 2 | 4 | - | 0 | - |
| 1997 | Wild | - | 0 | - | 54 | 5 | 10 | 85 | 92 | 7 | 98 | 115 | 7 | 97 | 4 | 9 |
| | Hatchery | - | 0 | - | 46 | 4 | 2 | 74 | 10 | 4 | 98 | 1 | - | - | 0 | - |
| 1998 | Wild | - | 0 | - | 66 | 19 | 9 | 85 | 120 | 7 | 99 | 201 | 7 | 106 | 4 | 7 |

| Return year | Origin | Summer Chinook fork length (cm) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Age-2 | | | Age-3 | | | Age-4 | | | Age-5 | | | Age-6 | | |
| | | Mean | N | SD | Mean | N | SD | Mean | N | SD | Mean | N | SD | Mean | N | SD |
| | Hatchery | - | 0 | - | 53 | 5 | 2 | 77 | 63 | 8 | 95 | 19 | 8 | 98 | 6 | 8 |
| 1999 | Wild | 42 | 1 | - | 65 | 4 | 6 | 86 | 83 | 6 | 97 | 120 | 7 | 103 | 5 | 8 |
| | Hatchery | - | 0 | - | 52 | 3 | 6 | 79 | 55 | 7 | 90 | 171 | 6 | 100 | 8 | 6 |
| 2000 | Wild | 43 | 7 | 4 | 60 | 17 | 7 | 84 | 67 | 5 | 98 | 181 | 6 | - | 0 | - |
| | Hatchery | - | 0 | - | 53 | 47 | 7 | 76 | 29 | 8 | 94 | 83 | 7 | 102 | 35 | 9 |
| 2001 | Wild | 48 | 1 | - | 66 | 48 | 7 | 88 | 155 | 7 | 97 | 80 | 6 | 102 | 5 | 3 |
| | Hatchery | - | 0 | - | 51 | 10 | 3 | 75 | 132 | 8 | 91 | 17 | 8 | 100 | 5 | 8 |
| 2002 | Wild | 48 | 7 | 4 | 64 | 37 | 8 | 89 | 270 | 7 | 100 | 125 | 7 | 99 | 3 | 13 |
| | Hatchery | - | 0 | - | - | 0 | - | 78 | 5 | 8 | 95 | 7 | 5 | - | 0 | - |
| 2003 | Wild | 41 | 4 | 2 | 58 | 13 | 4 | 87 | 144 | 8 | 100 | 297 | 7 | - | 0 | - |
| | Hatchery | - | 0 | - | 40 | 1 | - | 78 | 2 | 4 | 101 | 5 | 8 | - | 0 | - |
| 2004 | Wild | 51 | 1 | - | 69 | 17 | 5 | 84 | 47 | 8 | 99 | 392 | 6 | 109 | 10 | 7 |
| | Hatchery | - | 0 | - | - | 0 | - | 84 | 1 | - | 108 | 1 | - | | | |
| 2005 | Wild | - | 0 | - | 68 | 20 | 7 | 86 | 247 | 8 | 95 | 162 | 6 | 101 | 33 | 6 |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - | 90 | 3 | 9 | - | 0 | - |
| 2006 | Wild | 44 | 6 | 6 | 63 | 4 | 11 | 88 | 66 | 7 | 99 | 363 | 6 | 96 | 5 | 7 |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - | 99 | 4 | 7 | 100 | 1 | - |

## Sex Ratios

Male summer Chinook in the 2005 broodstock made up about 59% of the adults collected, resulting in an overall male to female ratio of 1.45:1.00 (Table 6.4.). In 2006, males made up about 49% of the adults collected, resulting in an overall male to female ratio of 0.95:1.00 (Table 6.4). The ratio in 2006 was similar to the 1:1 ratio goal in the broodstock protocol.

**Table 6.4.** Numbers of male and female wild and hatchery summer Chinook collected for broodstock in the Wenatchee Basin, 1989-2006. Ratios of males to females are also provided.

| Return year | Number of wild summer Chinook | | | Number of hatchery summer Chinook | | | Total M/F ratio |
|---|---|---|---|---|---|---|---|
| | Males (M) | Females (F) | M/F | Males (M) | Females (F) | M/F | |
| 1989 | 166 | 180 | 0.92:1.00 | 0 | 0 | - | 0.92:1.00 |
| 1990 | 45 | 39 | 1.15:1.00 | 0 | 0 | - | 1.15:1.00 |
| 1991 | 60 | 68 | 0.88:1.00 | 0 | 0 | - | 0.88:1.00 |
| 1992 | 154 | 187 | 0.82:1.00 | 0 | 0 | - | 0.82:1.00 |
| 1993 | 208 | 228 | 0.91:1.00 | 35 | 9 | 3.89:1.00 | 1.03:1.00 |

| Return year | Number of wild summer Chinook | | | Number of hatchery summer Chinook | | | Total M/F ratio |
|---|---|---|---|---|---|---|---|
| | Males (M) | Females (F) | M/F | Males (M) | Females (F) | M/F | |
| 1994 | 158 | 179 | 0.88:1.00 | 24 | 31 | 0.77:1.00 | 0.87:1.00 |
| 1995 | 169 | 213 | 0.79:1.00 | 1 | 15 | 0.07:1.00 | 0.75:1.00 |
| 1996 | 150 | 181 | 0.83:1.00 | 2 | 1 | 2.00:1.00 | 0.84:1.00 |
| 1997 | 104 | 121 | 0.86:1.00 | 15 | 0 | - | 0.98:1.00 |
| 1998 | 211 | 167 | 1.26:1.00 | 64 | 30 | 2.13:1.00 | 1.40:1.00 |
| 1999 | 130 | 120 | 1.08:1.00 | 108 | 130 | 0.83:1.00 | 0.95:1.00 |
| 2000 | 153 | 145 | 1.06:1.00 | 112 | 82 | 1.37:1.00 | 1.17:1.00 |
| 2001 | 187 | 124 | 1.51:1.00 | 132 | 50 | 2.64:1.00 | 1.83:1.00 |
| 2002 | 266 | 203 | 1.31:1.00 | 5 | 8 | 0.63:1.00 | 1.28:1.00 |
| 2003 | 270 | 218 | 1.24:1.00 | 5 | 3 | 1.67:1.00 | 1.24:1.00 |
| 2004 | 230 | 264 | 0.87:1.00 | 1 | 1 | 1.00:1.00 | 0.87:1.00 |
| 2005 | 291 | 200 | 1.46:1.00 | 2 | 1 | 2.00:1.00 | 1.45:1.00 |
| 2006 | 237 | 246 | 0.96:1.00 | 1 | 4 | 0.25:1.00 | 0.95:1.00 |
| ***Total*** | ***3,189*** | ***3,083*** | ***1.03:1.00*** | ***507*** | ***365*** | ***1.39:1.00*** | ***1.07:1.00*** |

## Fecundity

Fecundities for the 2005 and 2006 returns of summer Chinook averaged 5,050 and 5,133 eggs per female, respectively (Table 6.5). These values are close to the 18-year average of 5,189 eggs per female. Mean observed fecundities for the 2005 and 2006 returns were above the expected fecundity of 5,000 eggs per female assumed in the broodstock protocol.

**Table 6.5.** Mean fecundity of wild, hatchery, and all female summer Chinook collected for broodstock in the Wenatchee Basin, 1989-2006; NA = not available.

| Return year | Mean fecundity | | |
|---|---|---|---|
| | Wild | Hatchery | Total |
| 1989* | NA | NA | 5,280 |
| 1990* | NA | NA | 5,436 |
| 1991* | NA | NA | 4,333 |
| 1992* | NA | NA | 5,307 |
| 1993* | NA | NA | 5,177 |
| 1994* | NA | NA | 5,899 |
| 1995* | NA | NA | 4,402 |
| 1996* | NA | NA | 4,941 |
| 1997 | 5,385 | 5,272 | 5,390 |
| 1998 | 5,393 | 4,825 | 5,297 |
| 1999 | 5,036 | 4,942 | 4,987 |
| 2000 | 5,464 | 5,403 | 5,441 |
| 2001 | 5,280 | 4,647 | 5,097 |

| | | | |
|---|---|---|---|
| 2002 | 5,502 | 5,027 | 5,484 |
| 2003 | 5,357 | 5,696 | 5,361 |
| 2004 | 5,372 | 6,681 | 5,377 |
| 2005 | 5,045 | 6,391 | 5,053 |
| 2006 | 5,126 | 5,633 | 5,133 |
| ***Average*** | ***5,296*** | ***5,452*** | ***5,189*** |

* Individual fecundities were not tracked with females until 1997.

## 6.2 Hatchery Rearing

### Rearing History

#### *Number of eggs taken*

Based on the unfertilized egg-to-release survival standard of 81%, a total of 1,066,667 eggs are required to meet the program release goal of 864,000 smolts. Between 1989 and 2006, the egg take goal was reached in five of those years (Table 6.6).

**Table 6.6.** Numbers of eggs taken from Wenatchee summer Chinook broodstock, 1989-2006.

| Return year | Number of eggs taken |
|---|---|
| 1989 | 829,012 |
| 1990 | 163,109 |
| 1991 | 247,000 |
| 1992 | 827,911 |
| 1993 | 1,133,852 |
| 1994 | 999,364 |
| 1995 | 949,531 |
| 1996 | 756,000 |
| 1997 | 554,617 |
| 1998 | 854,997 |
| 1999 | 1,182,130 |
| 2000 | 1,113,159 |
| 2001 | 733,882 |
| 2002 | 1,049,255 |
| 2003 | 901,095 |
| 2004 | 1,311,051 |
| 2005 | 883,669 |
| 2006 | 1,190,757 |
| ***Average*** | ***871,133*** |

### *Number of acclimation days*

The 2006 brood Wenatchee summer Chinook were transferred to Dryden Pond on 15 March 2007. These fish received 46 days of acclimation on Wenatchee River water before being released on 30 April 2007 (Table 6.7). In recent years, a small proportion of the brood has been reared separately (high ELISA) and has received no acclimated period (i.e., these fish were released directly into the Wenatchee River). These data are not shown in Table 6.7. No such releases occurred in 2007.

**Table 6.7.** Number of days Wenatchee summer Chinook were acclimated at Dryden Pond, brood years 1989-2005. Numbers in parenthesis represents the number of days fish reared at Chiwawa Ponds.

| Brood year | Release year | Transfer date | Release date | Number of days |
|---|---|---|---|---|
| 1989 | 1991 | 2-Mar | 7-May | 66 |
| 1990 | 1992 | 19-Feb | 2-May | 73 |
| 1991 | 1993 | 10-Mar | 8-May | 59 |
| 1992 | 1994 | 1-Mar | 6-May | 66 |
| 1993 | 1995 | 3-Mar | 1-May | 59 |
| 1994 | 1996 | 2-Oct | 6-May | 217 (154) |
| | | 5-Mar | 6-May | 62 |
| 1995 | 1997 | 16-Oct | 8-May | 205 (139) |
| | | 27-Feb | 8-May | 70 |
| 1996 | 1998 | 6-Oct | 28-Apr | 204 (142) |
| | | 25-Feb | 28-Apr | 62 |
| 1997 | 1999 | 23-Feb | 27-Apr | 63 |
| 1998 | 2000 | 5-Mar | 1-May | 57 |
| 1999 | 2001 | 8-Mar | 23-Apr | 46 |
| 2000 | 2002 | 1-Mar | 6-May | 66 |
| 2001 | 2003 | 19-Feb | 23-Apr | 63 |
| 2002 | 2004 | 5-Mar | 23-Apr | 49 |
| 2003 | 2005 | 15-Mar | 25-Apr | 41 |
| 2004 | 2006 | 25-Mar | 27-Apr | 33 |
| 2005 | 2007 | 15-Mar | 30-Apr | 46 |
| ***Average*** | | | | ***80*** |

## Release Information

### *Numbers released*

The 2005 Wenatchee summer Chinook program achieved 74.6% of the 864,000 target goal with about 644,182 fish being released (Table 6.8). The underage was related to lower than expected fertilization rates.

**Table 6.8.** Numbers of Wenatchee summer Chinook smolts released from the hatchery, 1989-2005. The release target for Wenatchee summer Chinook is 864,000 smolts.

| Brood year | Release year | Number of smolts |
|---|---|---|
| 1989 | 1991 | 720,000 |
| 1990 | 1992 | 124,440 |
| 1991 | 1993 | 191,179 |
| 1992 | 1994 | 627,331 |
| 1993 | 1995 | 900,429 |
| 1994 | 1996 | 797,350 |
| 1995 | 1997 | 687,439 |
| 1996 | 1998 | 600,127 |
| 1997 | 1999 | 438,223 |
| 1998 | 2000 | 649,612 |
| 1999 | 2001 | 1,005,554 |
| 2000 | 2002 | 929,496 |
| 2001 | 2003 | 604,668 |
| 2002 | 2004 | 835,645 |
| 2003 | 2005 | 653,764 |
| 2004 | 2006 | 892,926 |
| 2005 | 2007 | 644,182 |
| ***Average*** | | ***664,845*** |

### *Numbers tagged*

The 2005 brood Wenatchee summer Chinook were 96.0% CWT and adipose fin-clipped, but were not PIT tagged.

### *Fish size and condition at release*

Summer Chinook from the 2005 brood were released as yearling smolts on 30 April 2007. Size at release of the acclimated population was 86.9% and 89.4% of the target fork length and weight goals, respectively. This brood year exceeded the target CV for length by 81.1% (Table 6.9). Since the program began, Wenatchee summer Chinook have not met the target length and CV values. The target weight (fish/pound or FPP) of juvenile fish has been met occasionally.

**Table 6.9.** Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Wenatchee summer Chinook smolts released from the hatchery, brood years 1989-2005; NA = not available. Size targets are provided in the last row of the table.

| Brood year | Release year | Fork length (cm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| 1989 | 1991 | 158 | 13.7 | 45.4 | 10 |
| 1990 | 1992 | 155 | 14.2 | 45.4 | 10 |
| 1991 | 1993 | 156 | 15.5 | 42.3 | 11 |

| Brood year | Release year | Fork length (cm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| 1992 | 1994 | 152 | 13.1 | 40.1 | 10 |
| 1993 | 1995 | 149 | NA | 34.9 | 13 |
| 1994 | 1996 | 138 | NA | 21.7 | 21 |
| 1995 | 1997 | 149 | 12.2 | 42.5 | 11 |
| 1996 | 1998 | 151 | 16.6 | 43.2 | 10 |
| 1997 | 1999 | 154 | 10.1 | 42.8 | 11 |
| 1998 | 2000 | 166 | 9.7 | 53.1 | 9 |
| 1999 | 2001 | 137 | 16.1 | 29.0 | 16 |
| 2000 | 2002 | 148 | 14.6 | 37.1 | 12 |
| 2001 | 2003 | 148 | NA | 38.9 | 12 |
| 2002 | 2004 | 146 | 15.1 | 37.3 | 14 |
| 2003 | 2005 | 147 | 13.2 | 36.5 | 12 |
| 2004 | 2006 | 147 | 10.7 | 35.4 | 13 |
| 2005 | 2007 | 153 | 16.3 | 40.6 | 11 |
| ***Targets*** | | ***176*** | ***9.0*** | ***45.4*** | ***10*** |

## Survival Estimates

Overall survival of the 2005 brood Wenatchee summer Chinook from green (unfertilized) egg to release was considerably below the standard set for the program primarily because of poor green egg-to-eye survival (Table 6.10).

**Table 6.10.** Hatchery life-stage survival rates (%) for Wenatchee summer Chinook, brood years 1989-2005. Survival standards or targets are provided in the last row of the table.

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 1989 | 90.0 | 93.4 | 90.9 | 97.0 | 99.7 | 99.3 | 98.5 | 99.4 | 86.9 |
| 1990 | 89.7 | 95.6 | 80.9 | 96.6 | 99.6 | 99.2 | 97.7 | 98.8 | 76.3 |
| 1991 | 88.2 | 98.3 | 86.9 | 96.1 | 99.3 | 98.5 | 94.9 | 98.1 | 79.2 |
| 1992 | 84.3 | 92.2 | 79.8 | 97.8 | 99.9 | 99.9 | 97.1 | 98.1 | 75.7 |
| 1993 | 92.4 | 95.9 | 84.2 | 97.5 | 99.6 | 99.3 | 96.7 | 98.8 | 79.4 |
| 1994 | 90.7 | 95.3 | 83.7 | 100 | 99.2 | 97.0 | 95.3 | 98.4 | 79.8 |
| 1995 | 94.7 | 98.2 | 86.0 | 100 | 96.7 | 96.4 | 74.9 | 90.8 | 64.4 |
| 1996 | 84.6 | 96.1 | 84.1 | 100 | 97.9 | 97.7 | 94.4 | 97.7 | 79.4 |
| 1997 | 89.3 | 98.3 | 82.6 | 97.3 | 97.1 | 96.9 | 98.3 | 98.2 | 79.0 |
| 1998 | 85.3 | 94.6 | 80.9 | 98.3 | 99.4 | 98.6 | 95.6 | 99.8 | 76.0 |
| 1999 | 98.4 | 98.3 | 90.4 | 97.9 | 98.1 | 97.9 | 96.2 | 99.4 | 85.1 |
| 2000 | 93.0 | 96.6 | 88.3 | 98.0 | 99.6 | 99.3 | 96.5 | 98.9 | 83.5 |

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 2001 | 87.4 | 91.5 | 90.6 | 97.7 | 99.8 | 99.6 | 93.1 | 93.3 | 82.4 |
| 2002 | 93.8 | 94.1 | 85.1 | 99.8 | 98.1 | 97.6 | 93.7 | 96.5 | 79.6 |
| 2003 | 77.4 | 85.1 | 80.5 | 98.1 | 99.6 | 99.1 | 91.9 | 93.5 | 72.6 |
| 2004 | 92.8 | 97.8 | 85.7 | 87.8 | 99.9 | 99.6 | 86.6 | 92.1 | 65.1 |
| 2005 | 97.3 | 89.6 | 83.5 | 98.0 | 99.7 | 99.4 | 89.1 | 99.5 | 72.9 |
| ***Standard*** | ***90.0*** | ***85.0*** | ***92.0*** | ***98.0*** | ***97.0*** | ***93.0*** | ***90.0*** | ***95.0*** | ***81.0*** |

## 6.3 Disease Monitoring

Rearing of the 2005 brood Wenatchee summer Chinook was similar to previous years with fish being held on well water before being transferred to Dryden Pond for final acclimation in March 2007. Fish began being transferred to Dryden pond 15 March and ended 23 March. No significant disease issues were encountered during rearing or acclimation.

## 6.4 Natural Juvenile Productivity

During 2007, juvenile summer Chinook were sampled at the Lower Wenatchee Trap located at the West Monitor Bridge.

### Emigrant Estimates

The Lower Wenatchee Trap operated nightly between 1 February and 5 August 2007. During that time period, trap 1 and trap 2 were inoperable for 14 and 68 days, respectively, because of high river flows, debris, snow/ice, or mechanical failure. During the seven-month sampling period, a total of 86,142 wild subyearling Chinook were captured at the Lower Wenatchee Trap. Based on capture efficiencies estimated from the flow model, the total number of wild subyearling Chinook that emigrated past the Lower Wenatchee Trap was 9,590,969 (±1,859,544). Most of these fish emigrated during May and June (Figure 6.1). Monthly captures and mortalities of all fish collected at the Lower Wenatchee Trap are reported in Appendix B.

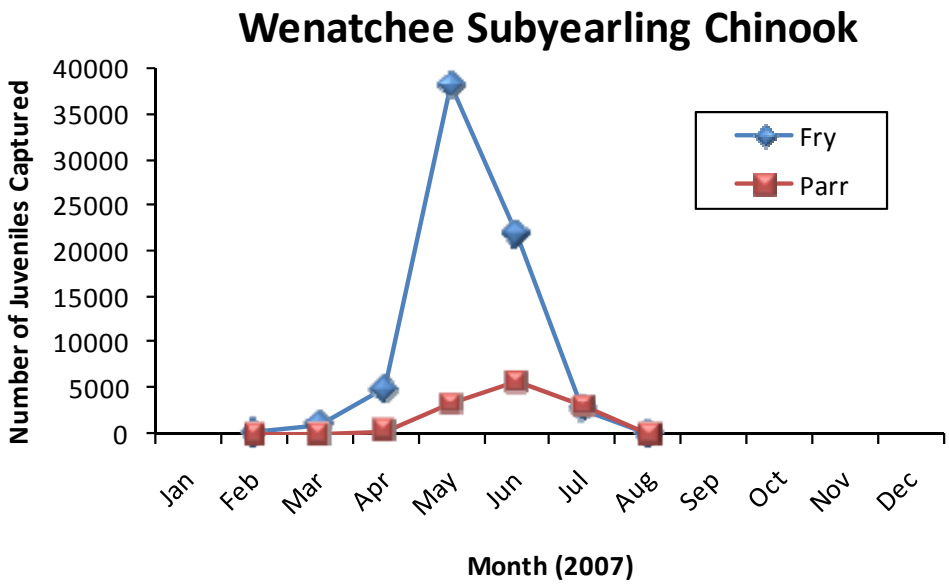


**Figure 6.1.** Numbers of wild subyearling Chinook captured at the Lower Wenatchee Trap during February through August, 2007.

## *6.5 Spawning Surveys*

Surveys for Wenatchee summer Chinook redds were conducted from late September to mid-November, 2007, in the Wenatchee River and Icicle Creek. Both peak counts and total counts (based on a peak count expansion factor; Murdoch and Peven 2005) were conducted in the river (see Appendix G for more details).

### Redd Counts

A peak count of 1,870 summer Chinook redds was estimated in 2007 based on ground surveys conducted in the Wenatchee River and Icicle Creek (Table 6.11). A total redd count of 1,970 redds was estimated in 2007 based on expanded peak counts in the Wenatchee River and Icicle Creek (Table 6.11). The peak count in 2007 was the lowest count since the late 1990s.

**Table 6.11.** Peak and total numbers of redds counted in the Wenatchee River, 1989-2006; NA = not available.

| Survey year | Peak redd count | Total redd count |
|---|---|---|
| 1989 | 3,331 | NA |
| 1990 | 2,479 | NA |
| 1991 | 2,180 | NA |
| 1992 | 2,328 | NA |
| 1993 | 2,334 | NA |
| 1994 | 2,426 | NA |
| 1995 | 1,872 | NA |
| 1996 | 1,435 | NA |
| 1997 | 1,388 | NA |

| Survey year | Peak redd count | Total redd count |
|---|---|---|
| 1998 | 1,660 | NA |
| 1999 | 2,188 | NA |
| 2000 | 2,022 | NA |
| 2001 | 2,857 | NA |
| 2002 | 5,419 | NA |
| 2003 | 4,328 | NA |
| 2004 | 3,764 | 5,804 |
| 2005 | 3,327 | NA |
| 2006* | 7,233 | 8,896 |
| 2007* | 1,870 | 1,970 |
| ***Average*** | ***2,865*** | ***5,557*** |

* Peak and total counts include 68 and 13 redds counted in Icicle Creek in 2006 and 2007, respectively.

### Redd Distribution

Summer Chinook redds were not evenly distributed among reaches within the Wenatchee Basin in 2007 (Table 6.12; Figure 6.2). Most of the spawning occurred upstream from the Leavenworth Bridge in Reaches 6, 9, and 10. The highest density of redds occurred in Reach 6 near the confluence of the Icicle River.

**Table 6.12.** Peak and total numbers of summer Chinook redds counted in different reaches in the Wenatchee Basin during September through mid-November, 2007. Reach codes are described in Table 2.10.

| Survey reach | Peak redd count | Total redd count |
|---|---|---|
| Wenatchee 1 | 7 | 6 |
| Wenatchee 2 | 61 | 49 |
| Wenatchee 3 | 172 | 138 |
| Wenatchee 4 | 34 | 39 |
| Wenatchee 5 | 45 | 52 |
| Wenatchee 6 | 873 | 933 |
| Wenatchee 7 | 107 | 144 |
| Wenatchee 8 | 61 | 82 |
| Wenatchee 9 | 280 | 306 |
| Wenatchee 10 | 217 | 208 |
| Icicle Creek | 13 | 13 |
| ***Totals*** | ***1,870*** | ***1,970*** |

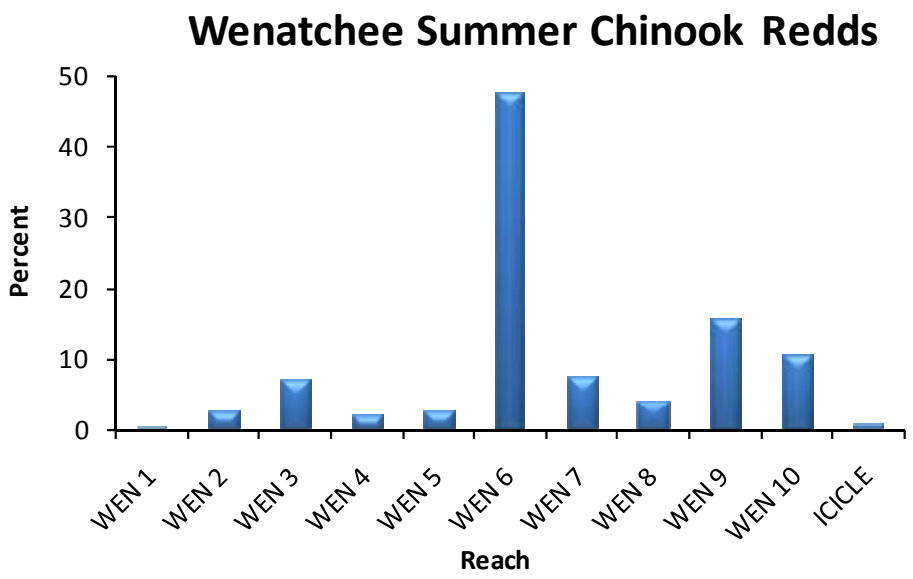


**Figure 6.2.** Percent of the total number of summer Chinook redds counted in different reaches in the Wenatchee Basin during September through mid-November, 2007. Reach codes are described in Table 2.10.

### Spawn Timing

In 2007, spawning in the Wenatchee River began the last week of September, peaked in the middle of October, and ended in early November (Figure 6.3).

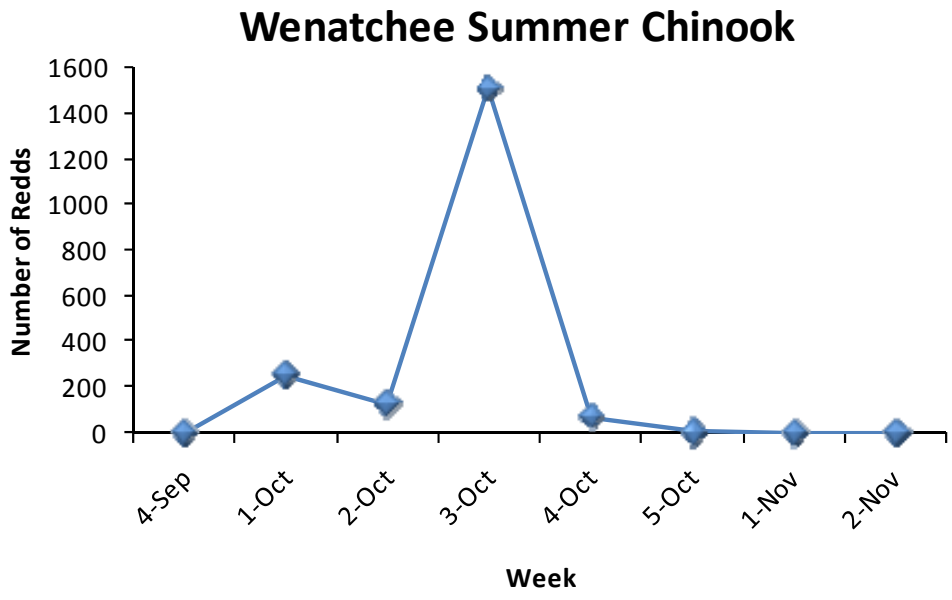


**Figure 6.3.** Number of summer Chinook redds counted during different weeks in the Wenatchee River, September through mid-November 2007.

### Spawning Escapement

Spawning escapement for Wenatchee summer Chinook was calculated as the total (or peak) number of redds times the fish per redd ratio estimated from broodstock and fish sampled at adult trapping sites. The estimated fish per redd ratio for summer Chinook in 2007 was 2.33. Multiplying this ratio by the number of redds counted in the Wenatchee Basin resulted in a total spawning escapement of 4,590 summer Chinook (Table 6.13). This was the fourth lowest escapement since 1989.

**Table 6.13.** Spawning escapements for summer Chinook in the Wenatchee Basin, return years 1989-2007.

| Return year | Fish/Redd | Redds | Total spawning escapement |
|---|---|---|---|
| 1989 | 3.40 | 3,331 | 11,325 |
| 1990 | 3.50 | 2,479 | 8,677 |
| 1991 | 3.70 | 2,180 | 8,066 |
| 1992 | 4.00 | 2,328 | 9,312 |
| 1993 | 3.20 | 2,334 | 7,469 |
| 1994 | 3.30 | 2,426 | 8,006 |
| 1995 | 3.30 | 1,872 | 6,178 |
| 1996 | 3.40 | 1,435 | 4,879 |
| 1997 | 3.40 | 1,388 | 4,719 |
| 1998 | 2.40 | 1,660 | 3,984 |
| 1999 | 2.00 | 2,188 | 4,376 |
| 2000 | 2.17 | 2,022 | 4,388 |
| 2001 | 3.20 | 2,857 | 9,142 |
| 2002 | 2.30 | 5,419 | 12,464 |
| 2003 | 2.24 | 4,328 | 9,695 |
| 2004 | 2.15 | 3,764 | 8,093 |
| 2005 | 2.46 | 3,327 | 8,184 |
| 2006 | 2.00 | 8,896 | 17,792 |
| 2007 | 2.33 | 1,970 | 4,590 |
| ***Average*** | ***2.87*** | ***2,958*** | ***7,965*** |

## *6.6 Carcass Surveys*

Surveys for Wenatchee summer Chinook carcasses were conducted during late September to mid-November, 2007, in the Wenatchee River and Icicle Creek.

### Number sampled

A total of 844 summer Chinook carcasses were sampled during September through mid-November in the Wenatchee Basin in 2007 (Table 6.14).

**Table 6.14**. Numbers of summer Chinook carcasses sampled within each survey reach in the Wenatchee Basin, 1993-2007. Reach codes are described in Table 2.10.

| Survey year | Number of summer Chinook carcasses | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **W-1** | **W-2** | **W-3** | **W-4** | **W-5** | **W-6** | **W-7** | **W-8** | **W-9** | **W-10** | **Icicle** | **Total** |
| 1993 | 61 | 138 | 627 | 12 | 77 | 141 | 202 | 38 | 0 | 0 | 0 | **1,296** |
| 1994 | 0 | 6 | 22 | 1 | 17 | 48 | 18 | 47 | 125 | 1 | 0 | **285** |
| 1995 | 0 | 10 | 14 | 0 | 0 | 111 | 49 | 36 | 19 | 0 | 0 | **239** |
| 1996 | 0 | 5 | 67 | 39 | 9 | 190 | 26 | 30 | 41 | 0 | 0 | **407** |
| 1997 | 1 | 44 | 118 | 4 | 28 | 288 | 7 | 71 | 67 | 13 | 0 | **641** |
| 1998 | 6 | 74 | 141 | 3 | 0 | 248 | 28 | 346 | 324 | 59 | 0 | **1,229** |
| 1999 | 0 | 160 | 97 | 15 | 31 | 857 | 61 | 133 | 171 | 72 | 0 | **1,597** |
| 2000 | 7 | 109 | 165 | 7 | 79 | 651 | 75 | 111 | 159 | 193 | 0 | **1,556** |
| 2001 | 0 | 45 | 127 | 26 | 0 | 323 | 33 | 110 | 87 | 81 | 0 | **832** |
| 2002 | 0 | 238 | 170 | 0 | 196 | 809 | 0 | 306 | 520 | 155 | 6 | **2,400** |
| 2003 | 6 | 323 | 164 | 61 | 132 | 673 | 56 | 237 | 482 | 47 | 36 | **2,217** |
| 2004 | 8 | 141 | 181 | 157 | 158 | 975 | 87 | 312 | 428 | 366 | 5 | **2,818** |
| 2005 | 8 | 85 | 106 | 39 | 46 | 707 | 70 | 140 | 353 | 257 | 7 | **1,818** |
| 2006 | 22 | 140 | 160 | 64 | 112 | 953 | 435 | 343 | 703 | 658 | 18 | **3,608** |
| 2007 | 3 | 15 | 49 | 9 | 26 | 475 | 38 | 39 | 96 | 91 | 3 | **844** |
| ***Mean*** | ***8*** | ***102*** | ***147*** | ***29*** | ***61*** | ***497*** | ***79*** | ***153*** | ***238*** | ***133*** | ***5*** | ***1,452*** |

### Carcass Distribution and Origin

Summer Chinook carcasses were not evenly distributed among reaches within survey streams in the Wenatchee Basin in 2007 (Table 6.14; Figure 6.4). Most of the carcasses in the Wenatchee Basin were found upstream from the Leavenworth Bridge. The highest percentage of carcasses (56%) was sampled in Reach 6 near the confluence of the Icicle River.

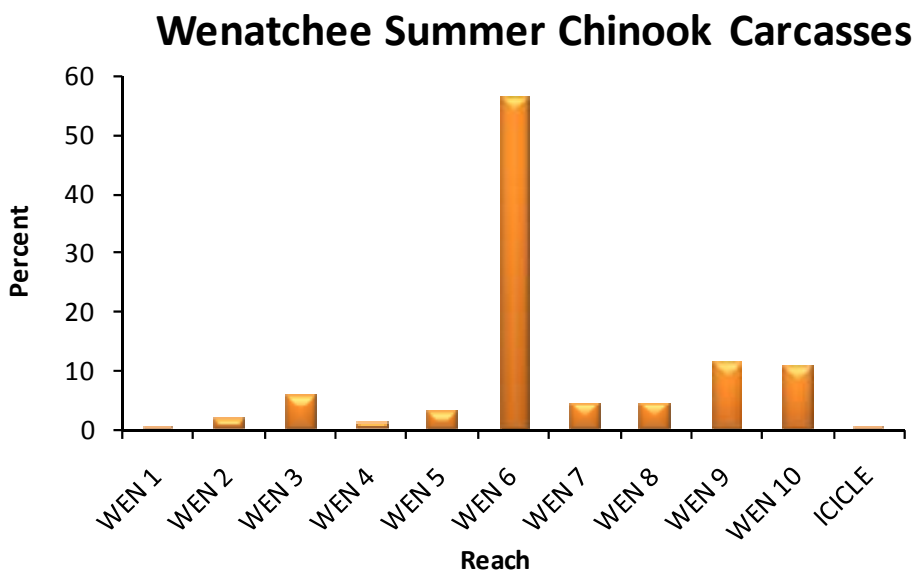


**Figure 6.4.** Percent of summer Chinook carcasses sampled within different reaches in the Wenatchee Basin during September through mid-November, 2007. Reach codes are described in Table 2.10.

Numbers of wild and hatchery origin summer Chinook carcasses sampled in 2007 will be available after analysis of CWTs and scales. Based on the available data (1993-2006), most fish, regardless of origin, were found in Reach 6 (Leavenworth Bridge to Icicle Road Bridge) (Table 6.15). However, a larger percentage of hatchery fish were found in that reach than were wild fish (Figure 6.5). In contrast, a larger percentage of wild fish were found in reaches upstream from the Icicle Road Bridge.

**Table 6.15.** Numbers of wild and hatchery summer Chinook carcasses sampled within different reaches in the Wenatchee Basin, 1993-2006.

| Survey year | Origin | Survey reach | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | W-1 | W-2 | W-3 | W-4 | W-5 | W-6 | W-7 | W-8 | W-9 | W-10 | Icicle | |
| 1993 | Wild | 52 | 133 | 591 | 11 | 77 | 124 | 200 | 37 | 0 | 0 | 0 | **1,225** |
| | Hatchery | 9 | 5 | 36 | 1 | 0 | 17 | 2 | 1 | 0 | 0 | 0 | **71** |
| 1994 | Wild | 0 | 2 | 15 | 1 | 15 | 34 | 18 | 47 | 124 | 1 | 0 | **257** |
| | Hatchery | 0 | 4 | 7 | 0 | 2 | 14 | 0 | 0 | 1 | 0 | 0 | **28** |
| 1995 | Wild | 0 | 4 | 11 | 0 | 0 | 99 | 49 | 34 | 19 | 0 | 0 | **216** |
| | Hatchery | 0 | 6 | 3 | 0 | 0 | 12 | 0 | 2 | 0 | 0 | 0 | **23** |
| 1996 | Wild | 0 | 5 | 65 | 37 | 8 | 181 | 26 | 30 | 41 | 0 | 0 | **393** |
| | Hatchery | 0 | 0 | 2 | 2 | 1 | 9 | 0 | 0 | 0 | 0 | 0 | **14** |
| 1997 | Wild | 1 | 35 | 104 | 4 | 21 | 242 | 7 | 71 | 66 | 13 | 0 | **564** |
| | Hatchery | 0 | 9 | 14 | 0 | 7 | 46 | 0 | 0 | 1 | 0 | 0 | **77** |
| 1998 | Wild | 6 | 55 | 106 | 2 | 0 | 169 | 25 | 325 | 297 | 56 | 0 | **1,041** |
| | Hatchery | 0 | 19 | 35 | 1 | 0 | 79 | 3 | 21 | 27 | 3 | 0 | **188** |
| 1999 | Wild | 0 | 79 | 55 | 7 | 14 | 525 | 51 | 124 | 155 | 68 | 0 | **1,078** |

| Survey year | Origin | Survey reach | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | W-1 | W-2 | W-3 | W-4 | W-5 | W-6 | W-7 | W-8 | W-9 | W-10 | Icicle | |
| | Hatchery | 0 | 81 | 42 | 8 | 17 | 332 | 10 | 9 | 16 | 4 | 0 | **519** |
| 2000 | Wild | 4 | 68 | 102 | 6 | 51 | 443 | 68 | 100 | 154 | 186 | 0 | **1,182** |
| | Hatchery | 3 | 41 | 63 | 1 | 28 | 208 | 7 | 11 | 5 | 7 | 0 | **374** |
| 2001 | Wild | 0 | 33 | 88 | 4 | 0 | 230 | 29 | 108 | 83 | 78 | 0 | **653** |
| | Hatchery | 0 | 12 | 39 | 22 | 0 | 93 | 4 | 2 | 4 | 3 | 0 | **179** |
| 2002 | Wild | 0 | 140 | 110 | 0 | 94 | 440 | 0 | 295 | 514 | 150 | 4 | **1,747** |
| | Hatchery | 0 | 98 | 60 | 0 | 102 | 369 | 0 | 11 | 6 | 5 | 2 | **653** |
| 2003 | Wild | 5 | 218 | 118 | 21 | 94 | 425 | 52 | 223 | 445 | 46 | 11 | **1,658** |
| | Hatchery | 1 | 105 | 46 | 40 | 38 | 248 | 4 | 14 | 37 | 1 | 25 | **559** |
| 2004 | Wild | 7 | 108 | 151 | 102 | 97 | 640 | 74 | 282 | 416 | 357 | 0 | **2,234** |
| | Hatchery | 1 | 33 | 30 | 55 | 61 | 335 | 13 | 30 | 12 | 9 | 5 | **584** |
| 2005 | Wild | 4 | 49 | 78 | 24 | 26 | 397 | 66 | 125 | 336 | 243 | 0 | **1,348** |
| | Hatchery | 4 | 36 | 28 | 15 | 20 | 310 | 4 | 15 | 17 | 14 | 7 | **470** |
| 2006 | Wild | 16 | 108 | 133 | 46 | 80 | 753 | 426 | 336 | 700 | 654 | 5 | **3,257** |
| | Hatchery | 6 | 32 | 27 | 18 | 32 | 200 | 9 | 7 | 3 | 4 | 13 | **351** |
| ***Average*** | ***Wild*** | ***7*** | ***74*** | ***123*** | ***19*** | ***41*** | ***336*** | ***78*** | ***153*** | ***239*** | ***132*** | ***1*** | ***1,204*** |
| | ***Hatchery*** | ***2*** | ***34*** | ***31*** | ***12*** | ***22*** | ***162*** | ***4*** | ***9*** | ***9*** | ***4*** | ***4*** | ***292*** |

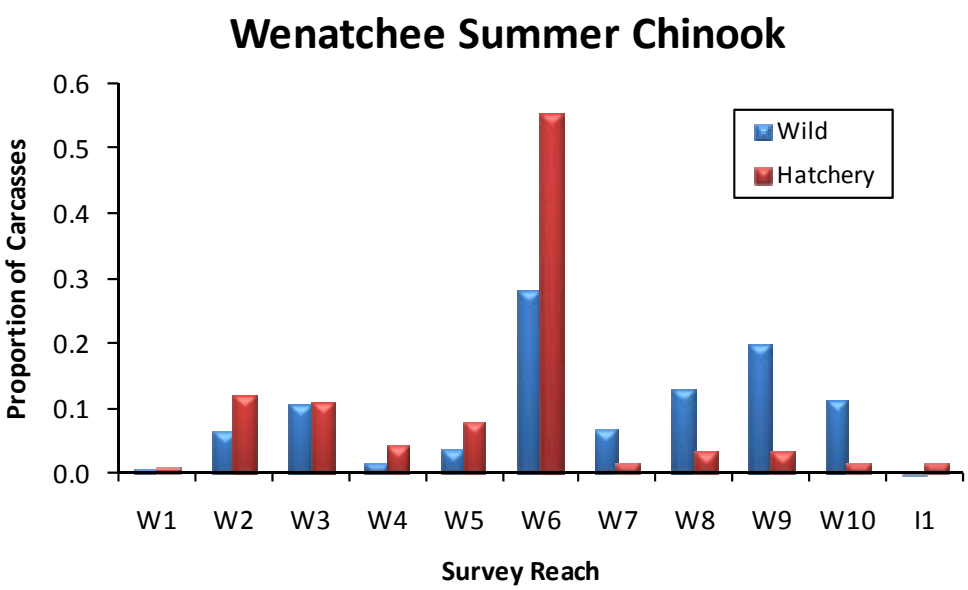


**Figure 6.5.** Distribution of wild and hatchery produced carcasses in different reaches in the Wenatchee Basin, 1993-2006. Reach codes are described in Table 2.10.

### Sampling Rate

If escapement is based on total numbers of redds, then about 18% of the total spawning escapement of summer Chinook in the Wenatchee Basin was sampled in 2007 (Table 6.16). Sampling rates among survey reaches varied from 9 to 27%.

**Table 6.16.** Number of redds and carcasses, total spawning escapement, and sampling rates for summer Chinook in the Wenatchee Basin, 2007.

| Sampling reach | Total number of redds | Total number of carcasses | Total spawning escapement | Sampling rate |
|---|---|---|---|---|
| Wenatchee 1 | 6 | 3 | 14 | 0.21 |
| Wenatchee 2 | 49 | 15 | 114 | 0.13 |
| Wenatchee 3 | 138 | 49 | 322 | 0.15 |
| Wenatchee 4 | 39 | 9 | 91 | 0.10 |
| Wenatchee 5 | 52 | 26 | 121 | 0.21 |
| Wenatchee 6 | 933 | 475 | 2,174 | 0.22 |
| Wenatchee 7 | 144 | 38 | 336 | 0.11 |
| Wenatchee 8 | 82 | 39 | 191 | 0.20 |
| Wenatchee 9 | 306 | 96 | 713 | 0.13 |
| Wenatchee 10 | 208 | 91 | 485 | 0.19 |
| Icicle Creek | 13 | 3 | 30 | 0.10 |
| ***Total*** | ***1,970*** | ***844*** | ***4,590*** | ***0.18*** |

### Length Data

Mean lengths (POH, cm) of male and female summer Chinook carcasses sampled during surveys in the Wenatchee Basin in 2007 are provided in Table 6.17. The average size of males and females sampled in the Wenatchee basin were 69 cm and 73 cm, respectively.

**Table 6.17.** Mean lengths (postorbital-to-hypural length; cm) and standard deviations (in parentheses) of male and female summer Chinook carcasses sampled in different streams/watersheds in the Wenatchee Basin, 2007.

| Stream/watershed | Mean length (cm) | |
|---|---|---|
| | Male | Female |
| Wenatchee 1 | 74 (4) | - |
| Wenatchee 2 | 74 (7) | 76 (5) |
| Wenatchee 3 | 75 (10) | 75 (6) |
| Wenatchee 4 | 64 (15) | 73 (5) |
| Wenatchee 5 | 72 (11) | 71 (6) |
| Wenatchee 6 | 68 (11) | 72 (6) |
| Wenatchee 7 | 72 (11) | 75 (5) |
| Wenatchee 8 | 65 (15) | 77 (5) |
| Wenatchee 9 | 73 (11) | 75 (4) |

| Stream/watershed | Mean length (cm) | |
|---|---|---|
| | Male | Female |
| Wenatchee 10 | 69 (11) | 75 (4) |
| Icicle Creek | - | - |
| ***Total*** | ***69 (11)*** | ***73 (5)*** |

## 6.7 Life History Monitoring

Life history characteristics of Wenatchee summer Chinook were assessed by examining carcasses on spawning grounds and fish collected or examined at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

### Age at Maturity

Most of the wild and hatchery summer Chinook sampled during the period 1993-2006 in the Wenatchee Basin were age-5 fish (total age) (Table 6.18; Figure 6.6). A higher percentage of age-4 wild Chinook returned to the basin than did age-4 hatchery Chinook. In contrast, a higher proportion of age-6 hatchery fish returned than did age-6 wild fish. Thus, a higher percentage of hatchery fish returned at an older age than did wild fish.

**Table 6.18.** Proportions of wild and hatchery summer Chinook of different ages (total age) sampled on spawning grounds in the Wenatchee Basin, 1993-2006.

| Sample year | Origin | Total age | | | | | | Sample size |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 | |
| 1993 | Wild | 0.00 | 0.03 | 0.42 | 0.55 | 0.00 | 0.00 | 1,224 |
| | Hatchery | 0.00 | 0.03 | 0.91 | 0.06 | 0.00 | 0.00 | 69 |
| 1994 | Wild | 0.01 | 0.03 | 0.44 | 0.52 | 0.00 | 0.00 | 257 |
| | Hatchery | 0.00 | 0.00 | 0.12 | 0.88 | 0.00 | 0.00 | 25 |
| 1995 | Wild | 0.00 | 0.03 | 0.19 | 0.74 | 0.05 | 0.00 | 216 |
| | Hatchery | 0.00 | 0.00 | 0.00 | 0.05 | 0.95 | 0.00 | 22 |
| 1996 | Wild | 0.00 | 0.02 | 0.36 | 0.60 | 0.02 | 0.00 | 513 |
| | Hatchery | 0.00 | 0.00 | 0.45 | 0.18 | 0.27 | 0.09 | 22 |
| 1997 | Wild | 0.00 | 0.01 | 0.38 | 0.57 | 0.03 | 0.00 | 562 |
| | Hatchery | 0.00 | 0.05 | 0.20 | 0.66 | 0.08 | 0.00 | 74 |
| 1998 | Wild | 0.00 | 0.03 | 0.34 | 0.62 | 0.01 | 0.00 | 1,041 |
| | Hatchery | 0.00 | 0.03 | 0.51 | 0.40 | 0.06 | 0.00 | 187 |
| 1999 | Wild | 0.00 | 0.01 | 0.43 | 0.55 | 0.01 | 0.00 | 1,087 |
| | Hatchery | 0.00 | 0.01 | 0.16 | 0.81 | 0.03 | 0.00 | 512 |
| 2000 | Wild | 0.01 | 0.04 | 0.27 | 0.68 | 0.00 | 0.00 | 1,182 |
| | Hatchery | 0.00 | 0.07 | 0.12 | 0.65 | 0.15 | 0.00 | 342 |
| 2001 | Wild | 0.00 | 0.08 | 0.59 | 0.32 | 0.01 | 0.00 | 653 |
| | Hatchery | 0.00 | 0.05 | 0.76 | 0.15 | 0.04 | 0.00 | 182 |

| Sample year | Origin | Total age | | | | | | Sample size |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 | |
| 2002 | Wild | 0.00 | 0.03 | 0.66 | 0.31 | 0.00 | 0.00 | 1,747 |
| | Hatchery | 0.00 | 0.01 | 0.19 | 0.78 | 0.02 | 0.00 | 643 |
| 2003 | Wild | 0.00 | 0.02 | 0.34 | 0.64 | 0.00 | 0.00 | 1,649 |
| | Hatchery | 0.00 | 0.06 | 0.11 | 0.75 | 0.09 | 0.00 | 522 |
| 2004 | Wild | 0.00 | 0.06 | 0.13 | 0.80 | 0.01 | 0.00 | 2,234 |
| | Hatchery | 0.00 | 0.09 | 0.57 | 0.25 | 0.09 | 0.00 | 561 |
| 2005 | Wild | 0.00 | 0.04 | 0.60 | 0.32 | 0.04 | 0.00 | 1,186 |
| | Hatchery | 0.00 | 0.02 | 0.10 | 0.86 | 0.02 | 0.00 | 451 |
| 2006 | Wild | 0.00 | 0.01 | 0.15 | 0.84 | 0.01 | 0.00 | 2,972 |
| | Hatchery | 0.00 | 0.02 | 0.17 | 0.26 | 0.55 | 0.00 | 299 |
| ***Average*** | ***Wild*** | ***0.00*** | ***0.03*** | ***0.38*** | ***0.58*** | ***0.01*** | ***0.00*** | ***1,180*** |
| | ***Hatchery*** | ***0.00*** | ***0.03*** | ***0.31*** | ***0.48*** | ***0.17*** | ***0.00*** | ***279*** |

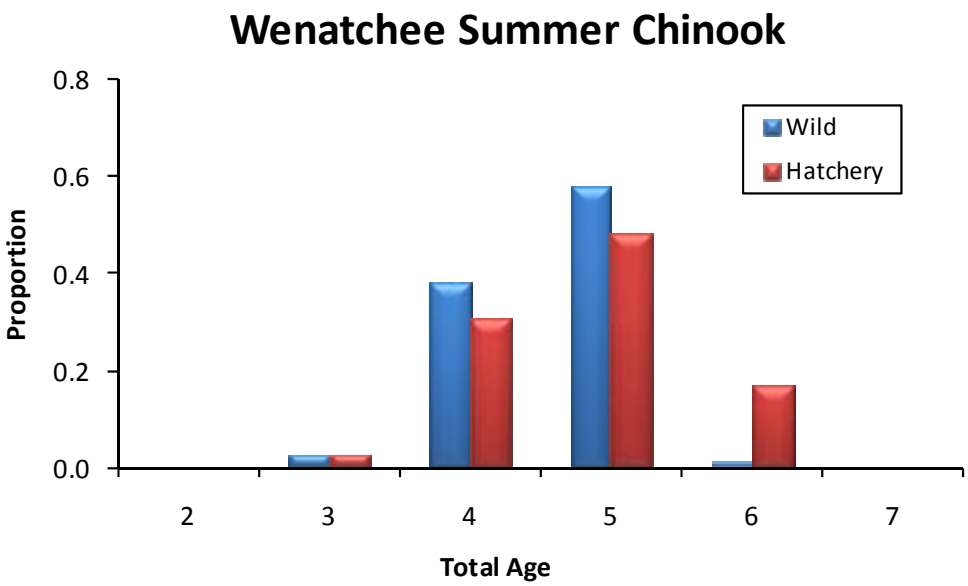


**Figure 6.6.** Proportions of wild and hatchery summer Chinook of different total ages sampled at broodstock collection sites and on spawning grounds in the Wenatchee Basin for the combined years 1993-2006.

### Size at Maturity

On average, hatchery summer Chinook were about 5 cm smaller than wild summer Chinook sampled in the Wenatchee Basin (Table 6.19). This is interesting given that a slightly higher percentage of hatchery fish returned as age-5 and 6 fish than did wild fish. Future analyses will compare sizes of hatchery and wild fish of the same age groups and gender.

**Table 6.19.** Mean lengths (POH; cm) and variability statistics for wild and hatchery summer Chinook sampled in the Wenatchee Basin, 1993-2006; SD = 1 standard deviation.

| Sample year | Origin | Sample size | Summer Chinook length (POH; cm) | | | |
|---|---|---|---|---|---|---|
| | | | Mean | SD | Minimum | Maximum |
| 1993 | Wild | 1,344 | 73 | 8 | 33 | 94 |
| | Hatchery | 68 | 61 | 9 | 37 | 83 |
| 1994 | Wild | 276 | 73 | 8 | 31 | 89 |
| | Hatchery | 25 | 70 | 8 | 54 | 85 |
| 1995 | Wild | 225 | 75 | 7 | 48 | 87 |
| | Hatchery | 23 | 74 | 7 | 57 | 85 |
| 1996 | Wild | 210 | 74 | 7 | 43 | 92 |
| | Hatchery | 9 | 66 | 12 | 52 | 84 |
| 1997 | Wild | 615 | 74 | 8 | 29 | 99 |
| | Hatchery | 78 | 69 | 10 | 29 | 83 |
| 1998 | Wild | 1,179 | 73 | 8 | 28 | 97 |
| | Hatchery | 188 | 67 | 10 | 37 | 87 |
| 1999 | Wild | 1,218 | 72 | 8 | 29 | 95 |
| | Hatchery | 518 | 71 | 8 | 26 | 94 |
| 2000 | Wild | 1,302 | 71 | 10 | 24 | 94 |
| | Hatchery | 369 | 69 | 11 | 33 | 91 |
| 2001 | Wild | 730 | 70 | 9 | 30 | 93 |
| | Hatchery | 179 | 63 | 10 | 28 | 86 |
| 2002 | Wild | 1,914 | 72 | 8 | 39 | 94 |
| | Hatchery | 653 | 71 | 8 | 34 | 95 |
| 2003 | Wild | 1,950 | 74 | 9 | 24 | 105 |
| | Hatchery | 546 | 69 | 10 | 26 | 97 |
| 2004 | Wild | 2,571 | 72 | 9 | 32 | 98 |
| | Hatchery | 580 | 59 | 11 | 25 | 91 |
| 2005 | Wild | 1,352 | 69 | 7 | 41 | 92 |
| | Hatchery | 469 | 69 | 8 | 39 | 91 |
| 2006 | Wild | 3,249 | 74 | 6 | 29 | 99 |
| | Hatchery | 350 | 71 | 9 | 35 | 90 |
| ***Pooled*** | ***Wild*** | ***18,135*** | ***73*** | ***8*** | ***24*** | ***105*** |
| | ***Hatchery*** | ***4,055*** | ***68*** | ***10*** | ***25*** | ***97*** |

### Contribution to Fisheries

Most of the harvest on Wenatchee summer Chinook occurred in the ocean (Table 6.20). Ocean harvest has made up 50% to 100% of all Wenatchee summer Chinook harvested. Total harvest on early brood years (1990-1993) was much lower than for later brood years (1997-2000).

**Table 6.20.** Estimated number and percent (in parentheses) of Wenatchee summer Chinook captured in different fisheries.

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational (sport) | |
| 1989 | 1,461 (50) | 1,292 (44) | 140 (5) | 20 (1) | 2,913 |
| 1990 | 30 (100) | 0 (0) | 0 (0) | 0 (0) | 30 |
| 1991 | 30 (63) | 0 (0) | 0 (0) | 18 (38) | 48 |
| 1992 | 144 (79) | 39 (21) | 0 (0) | 0 (0) | 183 |
| 1993 | 44 (64) | 25 (36) | 0 (0) | 0 (0) | 69 |
| 1994 | 626 (91) | 57 (8) | 7 (1) | 0 (0) | 690 |
| 1995 | 507 (97) | 3 (1) | 11 (2) | 0 (0) | 521 |
| 1996 | 179 (95) | 0 (0) | 3 (2) | 6 (3) | 188 |
| 1997 | 2,913 (94) | 37 (1) | 31 (1) | 106 (3) | 3,087 |
| 1998 | 4,947 (93) | 5 (0) | 96 (2) | 280 (5) | 5,340 |
| 1999 | 1,606 (86) | 5 (0) | 158 (8) | 100 (5) | 1,869 |
| 2000 | 7,869 (79) | 10 (0) | 976 (10) | 1,117 (11) | 9,972 |
| 2001 | 993 (71) | 1 (0) | 160 (11) | 251 (18) | 1,405 |

## Straying

Stray rates were determined by examining CWTs recovered on spawning grounds within and outside the Wenatchee Basin. Targets for strays based on return year (recovery year) and brood year should be less than 5%.

On average, rates of Wenatchee summer Chinook straying into basins outside the Wenatchee have been low (Table 6.21). Although Wenatchee summer Chinook have strayed into other spawning areas, straying has generally been less than 5%. In three different years, Wenatchee strays have made up more than 5% of the spawning escapement in the Methow Basin and the Chelan tailrace. They made up more than 5% of the spawning escapement in the Entiat Basin in one year.

**Table 6.21.** Number and percent of spawning escapements within other non-target basins that consisted of Wenatchee summer Chinook, return years 1994-2004. For example, for return year 2000, 3% of the summer Chinook escapement in the Methow Basin consisted of Wenatchee summer Chinook. Percent strays should be less than 5%.

| Return year | Methow | | Okanogan | | Chelan | | Entiat | | Hanford Reach | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % | Number | % | Number | % |
| 1994 | 0 | 0.0 | 75 | 1.9 | - | - | - | - | - | - |
| 1995 | 0 | 0.0 | 0 | 0.0 | - | - | - | - | - | - |
| 1996 | 0 | 0.0 | 0 | 0.0 | - | - | - | - | - | - |
| 1997 | 0 | 0.0 | 0 | 0.0 | - | - | - | - | - | - |
| 1998 | 35 | 5.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1999 | 23 | 2.3 | 3 | 0.1 | 0 | 0.0 | 0 | 0.0 | 23 | 0.1 |

| Return year | Methow | | Okanogan | | Chelan | | Entiat | | Hanford Reach | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % | Number | % | Number | % |
| 2000 | 36 | 3.0 | 13 | 0.4 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2001 | 163 | 5.9 | 57 | 0.5 | 30 | 3.0 | 0 | 0.0 | 0 | 0.0 |
| 2002 | 153 | 3.3 | 53 | 0.4 | 40 | 6.9 | 74 | 14.8 | 0 | 0.0 |
| 2003 | 80 | 2.0 | 24 | 0.7 | 44 | 10.5 | 0 | 0.0 | 26 | 0.0 |
| 2004 | 113 | 5.1 | 42 | 0.6 | 30 | 7.1 | 0 | 0.0 | 0 | 0.0 |
| ***Total*** | ***603*** | ***3.0*** | ***267*** | ***0.5*** | ***144*** | ***4.4*** | ***74*** | ***3.2*** | ***49*** | ***0.0*** |

On average, about 9.8% of the returns have strayed into non-target spawning areas, exceeding the target of 5% (Table 6.22). Depending on brood year, percent strays into non-target spawning areas have ranged from 0-23.7%. In addition, on average, about 7% have strayed into non-target hatchery programs.

**Table 6.22.** Number and percent of Wenatchee summer Chinook that homed to target spawning areas and the target hatchery program, and number and percent that strayed to non-target spawning areas and non-target hatchery programs, by brood years 1989-2001. Percent stays should be less than 5%.

| Brood year | Homing | | | | Straying | | | |
|---|---|---|---|---|---|---|---|---|
| | Target stream | | Target hatchery | | Non-target streams | | Non-target hatcheries | |
| | Number | % | Number | % | Number | % | Number | % |
| 1989 | 1,352 | 62.9 | 60 | 2.8 | 75 | 3.5 | 662 | 30.8 |
| 1990 | 74 | 84.1 | 1 | 1.1 | 0 | 0.0 | 13 | 14.8 |
| 1991 | 14 | 60.9 | 1 | 4.3 | 0 | 0.0 | 8 | 34.8 |
| 1992 | 375 | 84.8 | 7 | 1.6 | 0 | 0.0 | 60 | 13.6 |
| 1993 | 67 | 72.8 | 9 | 9.8 | 4 | 4.3 | 12 | 13.0 |
| 1994 | 890 | 71.8 | 205 | 16.5 | 56 | 4.5 | 88 | 7.1 |
| 1995 | 748 | 74.8 | 139 | 13.9 | 42 | 4.2 | 71 | 7.1 |
| 1996 | 261 | 70.4 | 42 | 11.3 | 53 | 14.3 | 15 | 4.0 |
| 1997 | 3,609 | 85.8 | 171 | 4.1 | 389 | 9.2 | 38 | 0.9 |
| 1998 | 1,790 | 82.0 | 11 | 0.5 | 317 | 14.5 | 64 | 2.9 |
| 1999 | 502 | 81.0 | 0 | 0.0 | 110 | 17.7 | 8 | 1.3 |
| 2000 | 1,898 | 82.9 | 0 | 0.0 | 357 | 15.6 | 35 | 1.5 |
| 2001 | 184 | 75.1 | 0 | 0.0 | 58 | 23.7 | 3 | 1.2 |
| ***Total*** | ***11,764*** | ***78.7*** | ***646*** | ***4.3*** | ***1,461*** | ***9.8*** | ***1,077*** | ***7.2*** |

### Genetics

Tissue (operculum) samples were collected from 144 wild and 144 hatchery summer Chinook in the Wenatchee basin in 2006. Results from these samples should be available in 2008.

### Proportion of Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery origin fish in the natural spawning escapement (pHOS). The ratio pNOB/(pHOS+pNOB) is the Proportion of Natural Influence (PNI). The larger the ratio (PNI), the greater the strength of selection in the natural environment relative to that of the hatchery environment. In order for the natural environment to dominate selection, PNI should be greater than 0.5 (HSRG/WDFW/NWIFC 2004).

For brood years 1989-2005, the PNI was equal to or greater than 0.6 (Table 6.23). This indicates that the natural environment has a greater influence on adaptation of Wenatchee summer Chinook than does the hatchery environment.

**Table 6.23.** Proportionate natural influence (PNI) of the Wenatchee summer Chinook supplementation program for brood years 1989-2005. PNI was calculated as the proportion of naturally produced Chinook in the hatchery broodstock (pNOB) divided by the proportion of hatchery Chinook on the spawning grounds (pHOS) plus pNOB. NOS = number of natural origin Chinook on the spawning grounds; HOS = number of hatchery origin Chinook on the spawning grounds; NOB = number of natural origin Chinook collected for broodstock; and HOB = number of hatchery origin Chinook included in hatchery broodstock.

| Brood year | Spawners | | | Broodstock | | | PNI |
|---|---|---|---|---|---|---|---|
| | NOS | HOS | pHOS | NOB | HOB | pNOB | |
| 1989 | 11,325 | 0 | 0.00 | 290 | 0 | 1.00 | 1.00 |
| 1990 | 8,677 | 0 | 0.00 | 61 | 0 | 1.00 | 1.00 |
| 1991 | 8,066 | 0 | 0.00 | 104 | 0 | 1.00 | 1.00 |
| 1992 | 9,312 | 0 | 0.00 | 274 | 0 | 1.00 | 1.00 |
| 1993 | 7,076 | 393 | 0.05 | 406 | 44 | 0.90 | 0.95 |
| 1994 | 7,296 | 709 | 0.09 | 333 | 54 | 0.86 | 0.91 |
| 1995 | 5,607 | 571 | 0.09 | 363 | 16 | 0.96 | 0.91 |
| 1996 | 4,687 | 192 | 0.04 | 263 | 3 | 0.99 | 0.96 |
| 1997 | 4,216 | 503 | 0.11 | 205 | 13 | 0.94 | 0.90 |
| 1998 | 3,451 | 533 | 0.13 | 299 | 78 | 0.79 | 0.86 |
| 1999 | 3,019 | 1,357 | 0.31 | 242 | 236 | 0.51 | 0.62 |
| 2000 | 3,450 | 998 | 0.22 | 275 | 180 | 0.60 | 0.73 |
| 2001 | 7,303 | 1,839 | 0.20 | 210 | 136 | 0.61 | 0.75 |
| 2002 | 9,136 | 3,328 | 0.27 | 409 | 10 | 0.98 | 0.78 |
| 2003 | 7,601 | 2,094 | 0.22 | 337 | 7 | 0.98 | 0.82 |
| 2004 | 6,442 | 1,651 | 0.20 | 424 | 2 | 1.00 | 0.83 |
| 2005 | 6,060 | 2,125 | 0.26 | 397 | 3 | 0.99 | 0.79 |

### Natural Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural origin recruits (NOR) to the parent spawning population. For brood years 1989-2000, NRR for summer Chinook in the

Wenatchee averaged 0.89 (range, 0.39-3.01) if harvested fish were not include in the estimate and 2.15 (range, 0.63-10.65) if harvested fish were included in the estimate (Table 6.24). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

**Table 6.24.** Spawning escapements, natural origin recruits (NOR), and natural replacement rates (NRR; with and without harvest) for wild summer Chinook in the Wenatchee basin, 1989-2000. *(The numbers in this table may change as the HETT and HC refine the methods for estimating summer Chinook NORs and NRRs.)*

| Brood year | Spawning escapement | Harvest not included | | Harvest included | |
|---|---|---|---|---|---|
| | | NOR | NRR | NOR | NRR |
| 1989 | 11,325 | 8,995 | 0.79 | 15,645 | 1.38 |
| 1990 | 8,677 | 8,063 | 0.93 | 11,688 | 1.35 |
| 1991 | 8,066 | 4,487 | 0.56 | 7,112 | 0.88 |
| 1992 | 9,312 | 4,601 | 0.49 | 6,726 | 0.72 |
| 1993 | 7,469 | 4,102 | 0.55 | 5,346 | 0.72 |
| 1994 | 8,006 | 3,151 | 0.39 | 5,051 | 0.63 |
| 1995 | 6,178 | 4,025 | 0.65 | 8,010 | 1.30 |
| 1996 | 4,879 | 3,406 | 0.70 | 9,194 | 1.88 |
| 1997 | 4,719 | 7,526 | 1.59 | 23,626 | 5.01 |
| 1998 | 3,984 | 12,009 | 3.01 | 42,431 | 10.65 |
| 1999 | 4,376 | 8,732 | 2.00 | 30,580 | 6.99 |
| 2000 | 4,388 | 3,118 | 0.71 | 9,593 | 2.19 |
| ***Average*** | ***6,782*** | ***6,018*** | ***0.89*** | ***14,584*** | ***2.15*** |

### Hatchery Replacement Rates

Hatchery replacement rates were estimated as hatchery adult-to-adult returns. These rates should be greater than the NRRs and greater than or equal to 5.30 (the value in BAMP; Murdoch and Peven 2005). HRRs exceeded NRRs in 8 or 9 of the 12 years of data, depending on if harvest was or was not included in the estimate (Table 6.25). Hatchery replacement rates (harvest included in the estimate) for Wenatchee summer Chinook have exceeded the BAMP target of 5.30 in 2 or 5 of the 12 years of data depending on if harvest was or was not included in the estimate (Table 6.25).

**Table 6.25.** Hatchery replacement rates (HRR), NRR, and BAMP target (5.30) for summer Chinook in the Wenatchee basin, 1989-2000. *(The numbers in this table may change as the HETT and HC refine the methods for estimating summer Chinook HRRs and NRRs.)*

| Brood year | Harvest not included | | | Harvest included | | |
|---|---|---|---|---|---|---|
| | HRR | NRR | BAMP | HRR | NRR | BAMP |
| 1989 | 6.21 | 0.79 | 5.30 | 14.62 | 1.38 | 5.30 |
| 1990 | 1.01 | 0.93 | 5.30 | 1.36 | 1.35 | 5.30 |
| 1991 | 0.18 | 0.56 | 5.30 | 0.55 | 0.88 | 5.30 |
| 1992 | 1.32 | 0.49 | 5.30 | 1.87 | 0.72 | 5.30 |
| 1993 | 0.19 | 0.55 | 5.30 | 0.33 | 0.72 | 5.30 |
| 1994 | 3.48 | 0.39 | 5.30 | 5.52 | 0.63 | 5.30 |
| 1995 | 2.49 | 0.65 | 5.30 | 3.78 | 1.30 | 5.30 |
| 1996 | 1.11 | 0.70 | 5.30 | 1.67 | 1.88 | 5.30 |
| 1997 | 17.53 | 1.59 | 5.30 | 30.39 | 5.01 | 5.30 |
| 1998 | 4.60 | 3.01 | 5.30 | 15.87 | 10.65 | 5.30 |
| 1999 | 1.22 | 2.00 | 5.30 | 4.88 | 6.99 | 5.30 |
| 2000 | 4.65 | 0.71 | 5.30 | 24.87 | 2.19 | 5.30 |
| ***Average*** | ***3.51*** | ***0.89*** | ***5.30*** | ***9.41*** | ***2.15*** | ***5.30*** |

### Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adults divided by the number of hatchery smolts released. SARs were based on CWT returns. For the available brood years, SARs have ranged from 0.00037 to 0.01669 for hatchery summer Chinook in the Wenatchee basin (Table 6.26).

**Table 6.26.** Smolt-to-adult ratios (SARs) for Wenatchee hatchery summer Chinook.

| Brood year | Number of smolts released | Estimated adult captures | SAR |
|---|---|---|---|
| 1989 | 144,905 | 1,017 | 0.00702 |
| 1990 | 119,214 | 115 | 0.00096 |
| 1991 | 190,371 | 71 | 0.00037 |
| 1992 | 605,055 | 610 | 0.00101 |
| 1993 | 210,626 | 161 | 0.00076 |
| 1994 | 452,340 | 1,904 | 0.00421 |
| 1995 | 668,409 | 1,488 | 0.00223 |
| 1996 | 585,590 | 551 | 0.00094 |
| 1997 | 434,645 | 7,256 | 0.01669 |
| 1998 | 641,109 | 7,449 | 0.01162 |
| 1999 | 988,328 | 2,466 | 0.00250 |
| 2000 | 903,368 | 11,960 | 0.01324 |

| Brood year | Number of smolts released | Estimated adult captures | SAR |
|---|---|---|---|
| 2001 | 596,618 | 1,643 | 0.00275 |
| ***Average*** | ***503,121*** | ***2,822*** | ***0.00561*** |

## *6.8 ESA/HCP Compliance*

### Broodstock Collection

Per the 2005 broodstock collection protocol, 492 natural origin (adipose fin present) adults were targeted for collection at Dryden and Tumwater dams. Because of inventory errors during collection, the actual 2005 collection totaled 494 summer Chinook. Collection at Dryden Dam began 5 June 2005 and concluded 15 August 2005 and accounted for the entire 2005 BY broodstock collection.

Summer Chinook and steelhead broodstock collections occurred concurrently at Dryden Dam; therefore, steelhead and spring Chinook encounters at Dryden Dam during Wenatchee summer Chinook broodstock collection were attributable to steelhead broodstock collections authorized under ESA Permit 1395 take authorizations. No steelhead or spring Chinook takes were associated with the Wenatchee summer Chinook collection.

Consistent with impact minimization measures in ESA Permit 1347, all ESA-listed species handled during summer Chinook broodstock collection were subject to water-to-water transfers or anesthetized if removed from water during handling.

### Hatchery Rearing and Release

The 2005 Wenatchee summer Chinook program released an estimated 664,182 smolts, representing 74.6% of the 864,000 programmed production and was compliant with the maximum production levels identified in ESA Section 10 Permit 1347.

### Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, and 1395, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at Chelan PUD Hatchery facilities during the period 1 January 2007 through 31 December 2007. NPDES monitoring and reporting for Chelan PUD Hatchery Programs during 2007 are provided in Appendix E.

### Smolt and Emigrant Trapping

ESA-listed spring Chinook and steelhead were encountered during operation of the Lower Wenatchee Trap. ESA takes are reported in the steelhead (Section 3.8) and spring Chinook (Section 5.8) sections and are not repeated here.

### Spawning Surveys

Summer Chinook spawning ground surveys conducted in the Wenatchee Basin during 2007 were consistent with ESA Section 10 Permit No. 1347. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential impacts to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

# SECTION 7: METHOW SUMMER CHINOOK

## 7.1 Broodstock Sampling

This section focuses on results from sampling 2005-2006 Methow summer Chinook broodstock, which were collected in the East Ladder of Wells Dam. Summer Chinook adults collected at Wells Dam are also used in the Okanogan/Similkameen supplementation program. Complete information is not currently available for the 2007 return (this information will be provided in the 2008 annual report).

### Origin of Broodstock

Both 2005 and 2006 broodstock consisted almost entirely of natural origin (adipose fin present) summer Chinook (Table 7.1). These fish were used for both the Methow and Okanogan supplementation programs. Less than 2% of the fish spawned were hatchery origin fish (hatchery origin was determined by examination of scales and CWTs).

**Table 7.1**. Numbers of wild and hatchery summer Chinook collected for broodstock, numbers that died before spawning, and numbers of Chinook spawned for the Methow/Okanogan programs, 1989-2006. Unknown origin fish (i.e., undetermined by scale analysis, no CWT or fin clips, and no additional hatchery marks) were considered naturally produced. Mortality includes fish that died of natural causes typically near the end of spawning and were not needed for the program and surplus fish killed at spawning.

| Brood year | Wild summer Chinook | | | | | Hatchery summer Chinook | | | | | Total number spawned |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Number collected | Prespawn loss | Mortality | Number spawned | Number released | Number collected | Prespawn loss | Mortality | Number spawned | Number released | |
| 1989[a] | 1,419 | 72 | - | 1,297 | - | 341 | 17 | - | 312 | - | 1,609 |
| 1990[a] | 864 | 34 | - | 828 | - | 214 | 8 | - | 206 | - | 1,034 |
| 1991[a] | 1,003 | 59 | - | 924 | - | 341 | 20 | - | 314 | - | 1,238 |
| 1992[a] | 312 | 6 | - | 297 | - | 428 | 9 | - | 406 | - | 703 |
| 1993[a] | 813 | 48 | - | 681 | - | 464 | 28 | - | 388 | - | 1,069 |
| 1994 | 385 | 33 | 11 | 341 | 12 | 266 | 15 | 7 | 244 | 1 | 585 |
| 1995 | 254 | 13 | 10 | 173 | 58 | 351 | 28 | 9 | 240 | 74 | 413 |
| 1996 | 316 | 15 | 11 | 290 | 0 | 234 | 2 | 9 | 223 | 0 | 513 |
| 1997 | 214 | 11 | 5 | 198 | 0 | 308 | 24 | 20 | 264 | 0 | 462 |
| 1998 | 239 | 28 | 58 | 153 | 0 | 348 | 18 | 119 | 211 | 0 | 364 |
| 1999 | 248 | 5 | 19 | 224 | 0 | 307 | 2 | 16 | 289 | 0 | 513 |
| 2000 | 184 | 15 | 5 | 164 | 0 | 373 | 17 | 17 | 339 | 0 | 503 |
| 2001 | 135 | 8 | 36 | 91 | 0 | 423 | 29 | 128 | 266 | 0 | 357 |
| 2002 | 270 | 2 | 21 | 247 | 0 | 285 | 11 | 33 | 241 | 0 | 488 |
| 2003 | 449 | 14 | 53 | 381 | 0 | 112 | 2 | 9 | 101 | 0 | 482 |
| 2004 | 541 | 23 | 12 | 506 | 0 | 17 | 0 | 1 | 16 | 0 | 522 |
| 2005 | 551 | 29 | 76 | 391 | 55 | 12 | 2 | 0 | 9 | 1 | 400 |
| 2006 | 579 | 50 | 10 | 500 | 19 | 12 | 2 | 0 | 10 | 0 | 510 |
| ***Average[b]*** | ***336*** | ***19*** | ***25*** | ***281*** | ***11*** | ***234*** | ***12*** | ***28*** | ***189*** | ***6*** | ***470*** |

[a] Number of fish spawned and collected during these years included fish retained from the right- and left-bank ladder traps at Wells Dam and fish collected from the volunteer channel. There was no distinction made between fish collected at trap locations and program (i.e., aggregated population used for Wells, Methow, and Okanogan summer Chinook programs).

[b] Because of bias from aggregating the spawning population from 1989-1993, averages are based on adult numbers collected from 1994-2006.

### Age/Length Data

Ages of summer Chinook broodstock were determined from analysis of scales and/or CWTs. Broodstock collected from the 2005 return consisted primarily of age-4 natural origin Chinook (70%). Age-4 natural origin fish made up 17% of the broodstock, while age-5 and 6 fish collectively made up 13% (Table 7.2). The three hatchery Chinook included in the broodstock were age-5 fish. Note that according to broodstock protocol, age-3 males are limited to no more than 10% of the total broodstock collection.

Broodstock collected from the 2006 return consisted primarily of age-4 and age-5 natural origin Chinook (92%). Age-2, 3, and 6 natural origin fish collectively made up 6% of the broodstock (Table 7.2). The six hatchery Chinook included in the broodstock were age-5 fish.

**Table 7.2.** Percent of hatchery and wild summer Chinook of different ages (total age) collected from broodstock for the Methow/Okanogan programs, 1991-2006.

| Return Year | Origin | Total age | | | | |
|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 |
| 1991 | Wild | 0.5 | 6.8 | 35.1 | 55.4 | 2.2 |
| | Hatchery | 0.5 | 5.1 | 36.2 | 49.0 | 9.2 |
| 1992 | Wild | 0.0 | 13.1 | 36.2 | 50.7 | 0.0 |
| | Hatchery | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 1993 | Wild | 0.0 | 3.9 | 75.3 | 20.8 | 0.0 |
| | Hatchery | 0.0 | 1.0 | 85.9 | 13.1 | 0.0 |
| 1994 | Wild | 3.1 | 9.7 | 26.3 | 60.3 | 0.6 |
| | Hatchery | 0.0 | 14.7 | 11.3 | 74.0 | 0.0 |
| 1995 | Wild | 0.0 | 4.6 | 15.2 | 75.6 | 4.6 |
| | Hatchery | 0.0 | 0.4 | 13.0 | 25.6 | 61.0 |
| 1996 | Wild | 0.0 | 8.4 | 56.6 | 30.4 | 4.6 |
| | Hatchery | 0.0 | 3.0 | 31.0 | 47.0 | 19.0 |
| 1997 | Wild | 1.0 | 9.3 | 52.9 | 34.8 | 2.0 |
| | Hatchery | 0.0 | 20.7 | 10.8 | 62.0 | 6.5 |
| 1998 | Wild | 2.0 | 14.1 | 54.8 | 29.1 | 0.0 |
| | Hatchery | 2.3 | 18.5 | 56.6 | 15.9 | 6.7 |
| 1999 | Wild | 4.7 | 5.1 | 53.7 | 36.0 | 0.5 |
| | Hatchery | 0.3 | 3.6 | 28.0 | 66.1 | 2.0 |
| 2000 | Wild | 0.6 | 14.0 | 28.7 | 56.1 | 0.6 |
| | Hatchery | 0.0 | 27.0 | 14.3 | 54.3 | 4.3 |
| 2001 | Wild | 7.1 | 26.0 | 52.0 | 11.8 | 3.1 |
| | Hatchery | 0.3 | 19.8 | 68.1 | 9.5 | 2.3 |
| 2002 | Wild | 0.4 | 17.4 | 66.0 | 16.2 | 0.0 |
| | Hatchery | 0.0 | 2.4 | 39.4 | 58.2 | 0.0 |

| Return Year | Origin | Total age | | | | |
|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 |
| 2003 | Wild | 0.7 | 3.9 | 65.9 | 29.5 | 0.0 |
| | Hatchery | 0.9 | 5.6 | 18.5 | 69.4 | 5.6 |
| 2004 | Wild | 0.8 | 15.3 | 11.6 | 72.1 | 0.2 |
| | Hatchery | 0.0 | 6.7 | 53.3 | 33.3 | 6.7 |
| 2005 | Wild | 0.0 | 17.2 | 69.9 | 11.0 | 1.9 |
| | Hatchery | 0.0 | 1.0 | 40.0 | 50.0 | 0.0 |
| 2006 | Wild | 1.6 | 3.0 | 41.0 | 52.9 | 1.5 |
| | Hatchery | 0.0 | 16.7 | 25.0 | 50.0 | 8.3 |
| ***Average*** | ***Wild*** | ***1.4*** | ***10.7*** | ***46.3*** | ***40.2*** | ***1.4*** |
| | ***Hatchery*** | ***0.3*** | ***9.7*** | ***35.4*** | ***45.2*** | ***8.8*** |

Mean lengths of natural origin summer Chinook of a given age differed little between 2005 and 2006 (Table 7.3). For all age groups, mean lengths of natural origin adults were larger than hatchery origin fish of the same age (Table 7.3). These differences may be related to the small sample size of hatchery origin fish (i.e., few hatchery fish were included in the broodstock).

**Table 7.3.** Mean fork length (cm) at age (total age) of hatchery and wild Methow/Okanogan summer Chinook collected from broodstock for the Methow/Okanogan programs, 1991-2006; N = sample size and SD = 1 standard deviation.

| Return year | Origin | Summer Chinook fork length (cm) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Age-2 | | | Age-3 | | | Age-4 | | | Age-5 | | | Age-6 | | |
| | | Mean | N | SD | Mean | N | SD | Mean | N | SD | Mean | N | SD | Mean | N | SD |
| 1991 | Wild | 47 | 1 | - | 68 | 15 | 6 | 82 | 78 | 10 | 94 | 123 | 8 | 97 | 5 | 5 |
| | Hatchery | 47 | 1 | - | 49 | 10 | 6 | 78 | 71 | 5 | 91 | 96 | 8 | 96 | 18 | 6 |
| 1992 | Wild | - | 0 | - | 55 | 9 | 5 | 69 | 25 | 6 | 78 | 35 | 6 | - | 0 | - |
| | Hatchery | - | 0 | - | - | 0 | - | - | 0 | - | - | 0 | - | - | 0 | - |
| 1993 | Wild | - | 0 | - | 72 | 3 | 4 | 86 | 58 | 7 | 98 | 16 | 5 | - | 0 | - |
| | Hatchery | - | 0 | - | 42 | 1 | - | 76 | 85 | 8 | 88 | 13 | 6 | - | 0 | - |
| 1994 | Wild | 42 | 10 | 6 | 51 | 31 | 7 | 80 | 84 | 9 | 93 | 193 | 8 | 104 | 2 | 13 |
| | Hatchery | - | 0 | - | 49 | 38 | 5 | 76 | 29 | 7 | 88 | 191 | 7 | - | 0 | - |
| 1995 | Wild | - | 0 | - | 67 | 6 | 8 | 79 | 20 | 9 | 96 | 99 | 5 | 94 | 6 | 5 |
| | Hatchery | - | 0 | - | 52 | 1 | - | 73 | 32 | 9 | 89 | 63 | 9 | 95 | 150 | 8 |
| 1996 | Wild | - | 0 | - | 68 | 22 | 9 | 83 | 149 | 8 | 95 | 80 | 7 | 101 | 12 | 5 |
| | Hatchery | - | 0 | - | 52 | 7 | 10 | 77 | 72 | 7 | 90 | 109 | 8 | 100 | 44 | 7 |
| 1997 | Wild | 36 | 2 | 6 | 60 | 19 | 7 | 85 | 108 | 8 | 96 | 71 | 7 | 98 | 4 | 11 |
| | Hatchery | - | 0 | - | 45 | 63 | 5 | 71 | 33 | 9 | 92 | 189 | 7 | 97 | 20 | 7 |

| Return year | Origin | Summer Chinook fork length (cm) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Age-2 | | | Age-3 | | | Age-4 | | | Age-5 | | | Age-6 | | |
| | | Mean | N | SD | Mean | N | SD | Mean | N | SD | Mean | N | SD | Mean | N | SD |
| 1998 | Wild | 43 | 4 | 6 | 59 | 23 | 6 | 83 | 107 | 7 | 96 | 58 | 7 | - | 0 | - |
| | Hatchery | 42 | 8 | 7 | 50 | 64 | 6 | 74 | 190 | 8 | 92 | 54 | 8 | 98 | 23 | 5 |
| 1999 | Wild | 38 | 10 | 3 | 64 | 11 | 8 | 82 | 115 | 8 | 96 | 77 | 6 | 104 | 1 | - |
| | Hatchery | 37 | 1 | - | 53 | 11 | 9 | 75 | 92 | 7 | 91 | 204 | 6 | 98 | 6 | 5 |
| 2000 | Wild | 39 | 1 | - | 66 | 23 | 7 | 83 | 47 | 6 | 96 | 92 | 5 | 95 | 1 | - |
| | Hatchery | - | 0 | - | 54 | 100 | 7 | 78 | 53 | 8 | 93 | 201 | 6 | 99 | 16 | 6 |
| 2001 | Wild | 40 | 9 | 3 | 65 | 33 | 8 | 87 | 66 | 8 | 93 | 15 | 5 | 97 | 4 | 16 |
| | Hatchery | 44 | 1 | - | 51 | 79 | 7 | 78 | 271 | 8 | 93 | 38 | 7 | 102 | 9 | 5 |
| 2002 | Wild | 56 | 1 | - | 65 | 44 | 7 | 88 | 167 | 6 | 100 | 41 | 7 | - | 0 | - |
| | Hatchery | - | 0 | - | 45 | 6 | 5 | 76 | 100 | 7 | 95 | 148 | 5 | - | 0 | - |
| 2003 | Wild | 43 | 3 | 6 | 61 | 16 | 6 | 87 | 268 | 7 | 99 | 120 | 6 | - | 0 | - |
| | Hatchery | 49 | 1 | - | 55 | 6 | 9 | 73 | 20 | 8 | 91 | 75 | 7 | 102 | 6 | 9 |
| 2004 | Wild | 51 | 4 | 4 | 67 | 78 | 6 | 81 | 59 | 6 | 97 | 368 | 7 | 99 | 1 | - |
| | Hatchery | - | 0 | - | 52 | 1 | - | 70 | 8 | 5 | 97 | 5 | 8 | 109 | 1 | - |
| 2005 | Wild | - | 0 | - | 68 | 89 | 6 | 83 | 363 | 8 | 94 | 57 | 6 | 101 | 10 | 7 |
| | Hatchery | - | 0 | - | 55 | 1 | - | 70 | 4 | 4 | 89 | 5 | 4 | - | 0 | - |
| 2006 | Wild | 48 | 9 | 3 | 69 | 16 | 4 | 88 | 222 | 7 | 97 | 286 | 6 | 97 | 8 | 6 |
| | Hatchery | - | 0 | - | 52 | 2 | 0 | 80 | 3 | 3 | 88 | 6 | 7 | 94 | 1 | - |

## Sex Ratios

Male summer Chinook in the 2005 broodstock made up about 66% of the adults collected, resulting in an overall male to female ratio of 1.93:1.00 (Table 7.4.). In 2006, males made up about 50% of the adults collected, resulting in an overall male to female ratio of 1.00:1.00 (Table 7.4). The ratio for the 2005 broodstock was larger than the assumed 1:1 ratio goal in the broodstock protocol; the ratio for the 2006 broodstock equaled the assumed 1:1 ratio.

**Table 7.4.** Numbers of male and female wild and hatchery summer Chinook collected for broodstock at Wells Dam for the Methow/Okanogan programs, 1991-2006. Ratios of males to females are also provided.

| Return year | Number of wild summer Chinook | | | Number of hatchery summer Chinook | | | Total M/F ratio |
|---|---|---|---|---|---|---|---|
| | Males (M) | Females (F) | M/F | Males (M) | Females (F) | M/F | |
| 1989[a] | 752 | 667 | 1.13:1.00 | 181 | 160 | 1.13:1.00 | 1.13:1.00 |
| 1990[a] | 381 | 482 | 0.79:1.00 | 95 | 120 | 0.79:1.00 | 0.79:1.00 |
| 1991[a] | 443 | 559 | 0.79:1.00 | 151 | 191 | 0.79:1.00 | 0.79:1.00 |
| 1992[a] | 349 | 318 | 1.10:1.00 | 38 | 35 | 1.09:1.00 | 1.10:1.00 |
| 1993[a] | 513 | 300 | 1.71:1.00 | 293 | 171 | 1.71:1.00 | 1.71:1.00 |

| Return year | Number of wild summer Chinook | | | Number of hatchery summer Chinook | | | Total M/F ratio |
|---|---|---|---|---|---|---|---|
| | Males (M) | Females (F) | M/F | Males (M) | Females (F) | M/F | |
| 1994 | 205 | 180 | 1.14:1.00 | 165 | 101 | 1.63:1.00 | 1.32:1.00 |
| 1995 | 103 | 149 | 0.69:1.00 | 158 | 197 | 0.80:1.00 | 0.75:1.00 |
| 1996 | 178 | 138 | 1.29:1.00 | 132 | 102 | 1.29:1.00 | 1.29:1.00 |
| 1997 | 102 | 112 | 0.91:1.00 | 174 | 134 | 1.30:1.00 | 1.12:1.00 |
| 1998 | 130 | 109 | 1.19:1.00 | 263 | 85 | 3.09:1.00 | 2.03:1.00 |
| 1999 | 138 | 110 | 1.25:1.00 | 161 | 146 | 1.10:1.00 | 1.17:1.00 |
| 2000 | 82 | 102 | 0.80:1.00 | 243 | 130 | 1.87:1.00 | 1.40:1.00 |
| 2001 | 89 | 46 | 1.93:1.00 | 311 | 112 | 2.78:1.00 | 2.53:1.00 |
| 2002 | 166 | 104 | 1.60:1.00 | 149 | 136 | 1.10:1.00 | 1.31:1.00 |
| 2003 | 255 | 194 | 1.31:1.00 | 61 | 51 | 1.20:1.00 | 1.29:1.00 |
| 2004 | 263 | 278 | 0.95:1.00 | 12 | 5 | 2.40:1.00 | 0.97:1.00 |
| 2005 | 365 | 186 | 1.96:1.00 | 6 | 6 | 1.00:1.00 | 1.93:1.00 |
| 2006 | 287 | 292 | 0.98:1.00 | 9 | 3 | 3.00:1.00 | 1.00:1.00 |
| ***Total[b]*** | ***2,363*** | ***2,000*** | ***1.18:1.00*** | ***1,844*** | ***1,208*** | ***1.52:1.00*** | ***1.31:1.00*** |

[a] Numbers and male to female ratios were derived from the aggregate population collected at Wells Fish Hatchery volunteer channel and left- and right-ladder traps at Wells Dam.

[b] Total values were derived from 1994-2006 data to exclude aggregate population bias from 1989-1993 returns.

### Fecundity

Fecundities for the 2005 and 2006 summer Chinook broodstock averaged 4,553 and 4,854 eggs per female, respectively (Table 7.5). These values are close to the overall average of 4,976 eggs per female. Mean observed fecundity for the 2005 and 2006 returns fell short of the expected fecundity of 5,000 eggs per female assumed in the broodstock protocol.

**Table 7.5.** Mean fecundity of wild, hatchery, and all female summer Chinook collected for broodstock at Wells Dam for the Methow/Okanogan programs, 1989-2006; NA = not available.

| Return year | Mean fecundity | | |
|---|---|---|---|
| | Wild | Hatchery | Total |
| 1989* | NA | NA | 4,750 |
| 1990* | NA | NA | 4,838 |
| 1991* | NA | NA | 4,819 |
| 1992* | NA | NA | 4,804 |
| 1993* | NA | NA | 4,849 |
| 1994* | NA | NA | 5,907 |
| 1995* | NA | NA | 4,930 |
| 1996* | NA | NA | 4,870 |
| 1997 | 5,166 | 5,296 | 5,237 |
| 1998 | 5,043 | 4,595 | 4,833 |
| 1999 | 4,897 | 4,923 | 4,912 |

| Return year | Mean fecundity | | |
|---|---|---|---|
| | Wild | Hatchery | Total |
| 2000 | 5,122 | 5,206 | 5,170 |
| 2001 | 5,040 | 4,608 | 4,735 |
| 2002 | 5,306 | 5,258 | 5,279 |
| 2003 | 5,090 | 4,941 | 5,059 |
| 2004 | 5,130 | 5,118 | 5,130 |
| 2005 | 4,545 | 4,889 | 4,553 |
| 2006 | 4,854 | 4,824 | 4,854 |
| ***Average*** | ***5,019*** | ***4,966*** | ***4,976*** |

* Individual fecundities were not assigned to females until 1997 brood.

## 7.2 Hatchery Rearing

### Rearing History

#### *Number of eggs taken*

Based on the unfertilized egg-to-release survival standard of 81%, a total of 493,827 eggs are needed to meet the program release goal of 400,000 smolts. Between 1989 and 2006, the egg take goal was reached in five of those years (Table 7.6).

**Table 7.6.** Numbers of eggs taken from summer Chinook broodstock collected at Wells Dam for the Methow/Okanogan programs, 1989-2006.

| Return year | Number of eggs taken |
|---|---|
| 1989 | 482,800 |
| 1990 | 464,097 |
| 1991 | 586,594 |
| 1992 | 486,260 |
| 1993 | 531,490 |
| 1994 | 595,390 |
| 1995 | 491,000 |
| 1996 | 448,000 |
| 1997 | 401,162 |
| 1998 | 389,346 |
| 1999 | 483,726 |
| 2000 | 403,268 |
| 2001 | 279,272 |
| 2002 | 466,530 |
| 2003 | 473,681 |
| 2004 | 537,210 |
| 2005 | 305,826 |

| Return year | Number of eggs taken |
|---|---|
| 2006 | 509,334 |
| ***Average*** | ***463,378*** |

### *Number of acclimation days*

Rearing of the 2005 brood Methow summer Chinook was similar to previous years with fish being held on well water before being transferred to Carlton Pond for final acclimation on Methow River water in March 2007 (Table 7.7). Groups of the 1994 and 1995 broods were reared for longer durations at Methow FH on Methow River water.

**Table 7.7.** Number of days Methow summer Chinook were acclimated at Carlton Pond, brood years 1989-2005.

| Brood year | Release year | Transfer date | Release date | Number of days |
|---|---|---|---|---|
| 1989 | 1991 | 15-Mar | 6-May | 52 |
| 1990 | 1992 | 26-Feb | 28-Apr | 61 |
| 1991 | 1993 | 10-Mar | 23-Apr | 44 |
| 1992 | 1994 | 4-Mar | 21-Apr | 48 |
| 1993 | 1995 | 18-Mar | 2-May | 45 |
| 1994 | 1996 | 25-Sep | 28-Apr | 215 |
| | | 19-Mar | 28-Apr | 40 |
| 1995 | 1997 | 22-Oct | 8-Apr | 168 |
| | | 19-Mar | 22-Apr | 34 |
| 1996 | 1998 | 9-Mar | 14-Apr | 36 |
| 1997 | 1999 | 10-Mar | 20-Apr | 41 |
| 1998 | 2000 | 19-Mar | 2-May | 44 |
| 1999 | 2001 | 18-Mar | 18-Apr | 31 |
| 2000 | 2002 | 28-Mar | 1-May | 34 |
| 2001 | 2003 | 27-Mar | 24-Apr | 28 |
| 2002 | 2004 | 16-Mar | 24-Apr | 39 |
| 2003 | 2005 | 18-Mar | 21-Apr | 34 |
| 2004 | 2006 | 12-Mar | 22-Apr | 41 |
| 2005 | 2007 | 12-Mar | 15-Apr – 8-May | 34-57 |
| ***Average*** | | | | ***57*** |

## Release Information

### *Numbers released*

The 2005 Methow summer Chinook program achieved 65.8% of the 400,000 target goal with about 263,273 fish being volitionally released between 15 April and 8 May 2007 (Table 7.8). The volitional release was terminated seven days short of the scheduled volitional release period and remaining fish were forced out of the acclimation site because of inundation of the acclimation site with flood waters, which backed-up into the facility through the out-fall channel.

**Table 7.8.** Numbers of Methow summer Chinook smolts released from the hatchery, brood years 1989-2005. The release target for Methow summer Chinook is 400,000 smolts.

| Brood year | Release year | Number of smolts |
|---|---|---|
| 1989 | 1991 | 420,000 |
| 1990 | 1992 | 391,650 |
| 1991 | 1993 | 540,900 |
| 1992 | 1994 | 402,641 |
| 1993 | 1995 | 433,375 |
| 1994 | 1996 | 406,560 |
| 1995 | 1997 | 353,182 |
| 1996 | 1998 | 298,844 |
| 1997 | 1999 | 384,909 |
| 1998 | 2000 | 205,269 |
| 1999 | 2001 | 424,363 |
| 2000 | 2002 | 336,762 |
| 2001 | 2003 | 248,595 |
| 2002 | 2004 | 399,975 |
| 2003 | 2005 | 354,699 |
| 2004 | 2006 | 400,579 |
| 2005 | 2007 | 263,723 |
| ***Average*** | | ***368,590*** |

### *Numbers tagged*

The 2005 brood Methow summer Chinook were 98.9% CWT and adipose fin-clipped, but were not PIT tagged.

### *Fish size and condition at release*

Fish were volitionally released as yearling smolts in April 2007. Size at release of the acclimated population was 89.8% and 93.0% of the target fork length and weight goals, respectively (Table 7.9). This brood year exceeded the CV of length goal by 67%.

**Table 7.9.** Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Methow summer Chinook smolts released from the hatchery, brood years 1991-2005. Size targets are provided in the last row of the table.

| Brood year | Release year | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| 1991 | 1993 | 152 | 13.6 | 40.3 | 11 |
| 1992 | 1994 | 145 | 16.0 | 37.2 | 12 |
| 1993 | 1995 | 154 | 8.6 | 37.1 | 12 |
| 1994 | 1996 | 163 | 8.2 | 48.2 | 9 |
| 1995 | 1997 | 141 | 9.6 | 37.0 | 12 |

| Brood year | Release year | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| 1996 | 1998 | 199 | 13.1 | 105.1 | 4 |
| 1997 | 1999 | 153 | 7.6 | 39.5 | 12 |
| 1998 | 2000 | 164 | 8.7 | 51.7 | 9 |
| 1999 | 2001 | 153 | 9.3 | 41.5 | 11 |
| 2000 | 2002 | 170 | 10.2 | 54.2 | 8 |
| 2001 | 2003 | 167 | 7.4 | 52.7 | 9 |
| 2002 | 2004 | 148 | 13.1 | 35.7 | 13 |
| 2003 | 2005 | 148 | 10.1 | 35.5 | 13 |
| 2004 | 2006 | 142 | 9.8 | 31.1 | 15 |
| 2005 | 2007 | 158 | 15 | 42.2 | 11 |
| ***Targets*** | | ***176*** | ***9.0*** | ***45.4*** | ***10*** |

## Survival Estimates

Overall survival of the Methow summer Chinook from green (unfertilized) egg to release was above the standard set for the program (Table 7.10). Lower than anticipated survival at the fertilized to eyed-egg and eyed-egg to ponding stage prevented the program from exceeding those respective target survival rates. Currently it is unknown if gamete viability is gender biased or is uniform between sexes and more influenced by between-year environmental variations.

It is important to note that the Methow summer Chinook program typically receives progeny from the highest ELISA females, while the lowest titer progeny are reserved for the Okanogan program. The inability to effectively manage BKD at Similkameen Pond during the winter months precludes an even mix of progeny for a given brood year between the two programs.

**Table 7.10.** Hatchery life-stage survival rates (%) for Methow summer Chinook, brood years 1989-2005. Survival standards or targets are provided in the last row of the table.

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 1989[a] | 89.8 | 99.5 | 89.9 | 96.7 | 99.7 | 99.4 | 73.3 | 98.5 | 63.7 |
| 1990[a] | 93.9 | 99.0 | 84.9 | 97.1 | 81.2 | 80.6 | 97.7 | 99.5 | 80.5 |
| 1991[a] | 93.1 | 95.5 | 88.2 | 98.0 | 99.4 | 99.1 | 97.5 | 99.6 | 84.2 |
| 1992[a] | 96.9 | 99.0 | 87.8 | 98.0 | 99.9 | 99.9 | 90.9 | 98.3 | 78.2 |
| 1993[a] | 82.2 | 99.4 | 85.4 | 97.6 | 99.8 | 99.5 | 92.0 | 99.4 | 76.7 |
| 1994 | 96.1 | 90.0 | 86.6 | 100.0 | 98.1 | 97.4 | 73.1 | 99.1 | 63.3 |
| 1995 | 91.9 | 96.2 | 98.2 | 84.1 | 96.5 | 96.2 | 92.7 | 89.6 | 76.6 |
| 1996 | 95.4 | 98.1 | 83.2 | 100.0 | 97.7 | 96.9 | 86.5 | 89.0 | 72.0 |
| 1997 | 91.9 | 94.6 | 86.1 | 98.4 | 98.7 | 98.3 | 98.8 | 99.7 | 83.7 |
| 1998 | 84.0 | 96.2 | 54.1 | 98.0 | 99.4 | 98.9 | 96.6 | 99.9 | 51.2 |
| 1999 | 98.8 | 98.7 | 92.9 | 96.9 | 98.0 | 97.6 | 96.9 | 99.9 | 87.2 |

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 2000 | 90.5 | 96.9 | 89.2 | 98.1 | 98.5 | 98.3 | 94.6 | 94.4 | 82.6 |
| 2001 | 96.2 | 92.3 | 89.1 | 97.6 | 97.2 | 97.1 | 97.5 | 99.8 | 84.8 |
| 2002 | 97.1 | 98.1 | 88.3 | 99.9 | 97.7 | 97.5 | 96.7 | 99.9 | 85.3 |
| 2003 | 96.7 | 97.5 | 82.8 | 98.2 | 99.7 | 99.2 | 93.7 | 99.9 | 76.2 |
| 2004 | 93.6 | 98.2 | 84.0 | 97.8 | 99.6 | 99.2 | 98.3 | 98.5 | 80.8 |
| 2005 | 97.0 | 89.6 | 88.0 | 95.5 | 99.6 | 98.9 | 96.6 | 99.9 | 84.6 |
| ***Standard*** | ***90.0*** | ***85.0*** | ***92.0*** | ***98.0*** | ***97.0*** | ***93.0*** | ***90.0*** | ***95.0*** | ***81.0*** |

[a] Survival rates were calculated from aggregate population collected at Wells Fish Hatchery volunteer channel and left- and right-ladder traps at Wells Dam.

## 7.3 Disease Monitoring

No disease concerns were detected or observed in the 2004 brood. Progeny did receive a 4.5% Aqua-100 prophylactic treatment for BKD in July 2006. No Erythromycin toxicity was detected.

## 7.4 Spawning Surveys

Surveys for Methow summer Chinook redds were conducted from late September to mid-November, 2007, in the Methow River. Total redd counts (not peak counts) were conducted in the river (see Appendix J for more details).

### Redd Counts

A total of 620 summer Chinook redds were counted in the Methow River in 2007 (Table 7.11). This was higher than the 19-year average of 586 redds.

**Table 7.11.** Total number of redds counted in the Methow River, 1989-2007.

| Survey year | Total redd count |
|---|---|
| 1989 | 167* |
| 1990 | 409* |
| 1991 | 153 |
| 1992 | 107 |
| 1993 | 154 |
| 1994 | 310 |
| 1995 | 357 |
| 1996 | 181 |
| 1997 | 205 |
| 1998 | 225 |
| 1999 | 448 |
| 2000 | 500 |
| 2001 | 675 |

| Survey year | Total redd count |
|---|---|
| 2002 | 2,013 |
| 2003 | 1,624 |
| 2004 | 973 |
| 2005 | 874 |
| 2006 | 1,353 |
| 2007 | 620 |
| ***Average*** | ***597*** |

* Total counts based on expanded aerial counts.

### Redd Distribution

Summer Chinook redds were not evenly distributed among the seven reaches in the Methow River. Most redds (73%) were located in reaches downstream from the town of Twisp and in Reach 5 between Methow Valley Irrigation Diversion (MVID) and the Winthrop Bridge (Table 7.12; Figure 7.1). Few summer Chinook spawned upstream from the Winthrop Bridge in Reaches 6 and 7.

**Table 7.12.** Total number of summer Chinook redds counted in different reaches on the Methow River during September through early November, 2006. Reach codes are described in Table 2.11.

| Survey reach | Total redd count | Percent |
|---|---|---|
| Methow 1 | 170 | 27 |
| Methow 2 | 132 | 21 |
| Methow 3 | 155 | 25 |
| Methow 4 | 52 | 8 |
| Methow 5 | 108 | 17 |
| Methow 6 | 3 | 1 |
| Methow 7 | 0 | 0 |
| ***Totals*** | ***620*** | ***100*** |

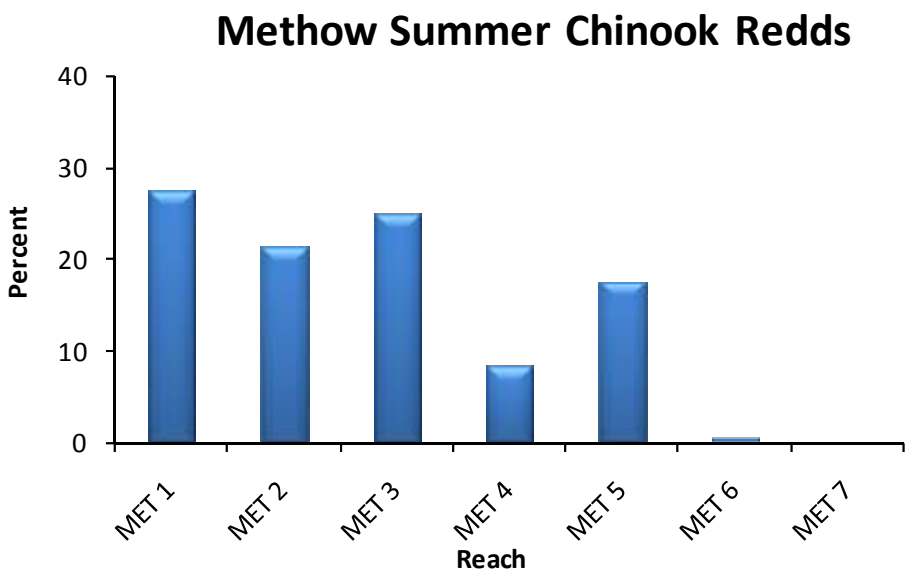


**Figure 7.1.** Percent of the total number of summer Chinook redds counted in different reaches on the Methow River during September through mid-November, 2007. Reach codes are described in Table 2.11.

### Spawn Timing

Spawning in 2007 began the first week of October, peaked the second week of October, and ended after the first week of November (Figure 7.2). Stream temperatures in the Methow River, when spawning began, varied from 7-10°C. Peak spawning occurred in the upper reaches of the Methow River during the second week of October and in the lower reaches the following week. The temporal distribution of spawning activity in 2007 comported well with the 16-year average (Figure 7.2).

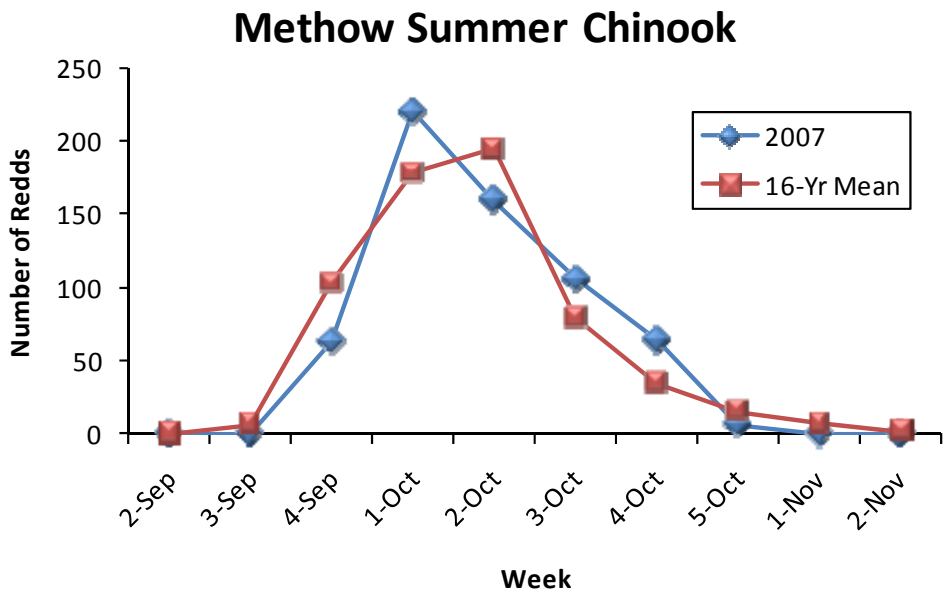


**Figure 7.2.** Comparison of the number of new summer Chinook redds counted during different weeks in the Methow River, September through mid-November 2007, to the 16-year average.

### Spawning Escapement

Spawning escapement for Methow summer Chinook was calculated as the total number of redds times the fish per redd ratio estimated from fish sampled at Wells Dam. The estimated fish per redd ratio for Methow summer Chinook in 2007 was 2.20. Multiplying this ratio by the number of redds counted in the Methow River resulted in a total spawning escapement of 1,364 summer Chinook (Table 7.13).

**Table 7.13.** Spawning escapements for summer Chinook in the Methow River for return years 1989-2007.

| Return year | Fish/Redd | Redds | Total spawning escapement |
|---|---|---|---|
| 1989* | 3.30 | 167 | 552 |
| 1990* | 3.40 | 409 | 1,391 |
| 1991* | 3.70 | 153 | 566 |
| 1992* | 4.30 | 107 | 460 |
| 1993* | 3.30 | 154 | 508 |
| 1994* | 3.50 | 310 | 1,085 |
| 1995* | 3.40 | 357 | 1,214 |
| 1996* | 3.40 | 181 | 615 |
| 1997* | 3.40 | 205 | 697 |
| 1998 | 3.00 | 225 | 675 |
| 1999 | 2.20 | 448 | 986 |
| 2000 | 2.40 | 500 | 1,200 |
| 2001 | 4.10 | 675 | 2,768 |

| Return year | Fish/Redd | Redds | Total spawning escapement |
|---|---|---|---|
| 2002 | 2.30 | 2,013 | 4,630 |
| 2003 | 2.42 | 1,624 | 3,930 |
| 2004 | 2.25 | 973 | 2,189 |
| 2005 | 2.93 | 874 | 2,561 |
| 2006 | 2.02 | 1,353 | 2,733 |
| 2007 | 2.20 | 620 | 1,364 |
| ***Average*** | ***3.03*** | ***597*** | ***1,585*** |

* Spawning escapement was calculated using the "Modified Meekin Method" (i.e., 3.1 x jack multiplier).

## 7.5 Carcass Surveys

Surveys for Methow summer Chinook carcasses were conducted during late September to mid-November, 2007, in the Methow River (see Appendix J for more details).

### Number sampled

A total of 456 summer Chinook carcasses were sampled during September through mid-November in the Methow River (Table 7.14).

**Table 7.14**. Numbers of summer Chinook carcasses sampled within each survey reach on the Methow River, 1991-2007. Reach codes are described in Table 2.11.

| Survey year | Number of summer Chinook carcasses | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | M-1 | M-2 | M-3 | M-4 | M-5 | M-6 | M-7 | Total |
| 1991 | 0 | 12 | 8 | 4 | 2 | 0 | 0 | **26** |
| 1992 | 8 | 8 | 19 | 0 | 17 | 1 | 0 | **53** |
| 1993 | 19 | 25 | 14 | 2 | 5 | 0 | 0 | **65** |
| 1994[a] | 43 | 33 | 20 | 5 | 13 | 0 | 0 | **114** |
| 1995 | 14 | 33 | 58 | 7 | 7 | 0 | 0 | **119** |
| 1996 | 6 | 30 | 46 | 5 | 2 | 0 | 0 | **89** |
| 1997 | 6 | 12 | 38 | 2 | 19 | 1 | 0 | **78** |
| 1998 | 90 | 84 | 99 | 17 | 30 | 0 | 0 | **320** |
| 1999 | 47 | 144 | 232 | 32 | 37 | 12 | 2 | **506** |
| 2000 | 62 | 118 | 105 | 9 | 99 | 5 | 0 | **398** |
| 2001 | 392 | 275 | 88 | 14 | 76 | 11 | 1 | **857** |
| 2002 | 551 | 318 | 518 | 164 | 219 | 34 | 10 | **1,814** |
| 2003 | 115 | 383 | 317 | 115 | 128 | 5 | 0 | **1,063** |
| 2004 | 40 | 173 | 187 | 82 | 92 | 2 | 1 | **577** |
| 2005 | 154 | 173 | 182 | 42 | 112 | 3 | 0 | **666** |
| 2006 | 121 | 149 | 111 | 56 | 146 | 3 | 1 | **587** |
| 2007 | 135 | 131 | 108 | 27 | 55 | 0 | 0 | **456** |
| ***Average*** | ***106*** | ***124*** | ***126*** | ***34*** | ***62*** | ***5*** | ***1*** | ***346*** |

[a] An additional 113 carcasses were sampled, but reach was not identified.

### Carcass Distribution and Origin

Summer Chinook carcasses were not evenly distributed among reaches within the Methow River in 2007 (Table 7.14; Figure 7.3). Most of the carcasses in the Methow River were found downstream from Twisp. The highest percentage of carcasses (30%) was sampled in Reach 1 downstream from the town of Methow.

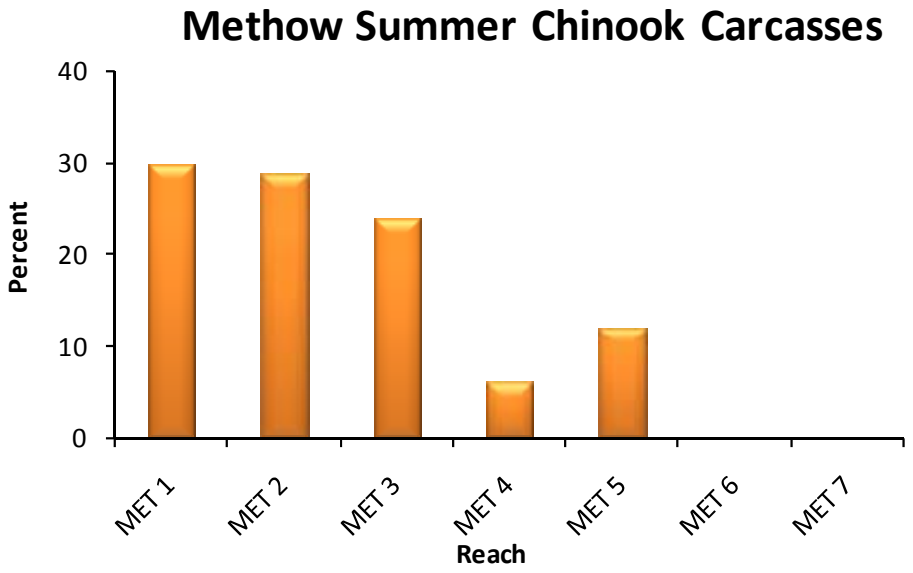


**Figure 7.3.** Percent of summer Chinook carcasses sampled within different reaches on the Methow River during September through mid-November, 2007. Reach codes are described in Table 2.11.

Numbers of wild and hatchery origin summer Chinook carcasses sampled in 2007 will be available after analysis of CWTs and scales. Based on the available data (1991-2006), hatchery and wild summer Chinook carcasses were not distributed equally among the reaches in the Methow River (Table 7.15). A larger percentage of hatchery carcasses occurred in the lower reaches, while a larger percentage of wild summer Chinook carcasses occurred in upstream reaches (Figure 7.4).

**Table 7.15.** Numbers of wild and hatchery summer Chinook carcasses sampled within different reaches on the Methow River, 1991-2006.

| Survey year | Origin | Survey reach | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | M-1 | M-2 | M-3 | M-4 | M-5 | M-6 | M-7 | |
| 1991 | Wild | 0 | 12 | 8 | 4 | 2 | 0 | 0 | **26** |
| | Hatchery | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| 1992 | Wild | 8 | 8 | 19 | 0 | 17 | 1 | 0 | **53** |
| | Hatchery | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** |
| 1993 | Wild | 11 | 15 | 9 | 0 | 3 | 0 | 0 | **38** |

| Survey year | Origin | Survey reach | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | | M-1 | M-2 | M-3 | M-4 | M-5 | M-6 | M-7 | |
| | Hatchery | 8 | 7 | 5 | 2 | 2 | 0 | 0 | **24** |
| 1994 | Wild | 21 | 17 | 8 | 4 | 9 | 0 | 0 | **59** |
| | Hatchery | 20 | 15 | 11 | 0 | 3 | 0 | 0 | **49** |
| 1995 | Wild | 6 | 9 | 27 | 7 | 5 | 0 | 0 | **54** |
| | Hatchery | 7 | 24 | 25 | 0 | 1 | 0 | 0 | **57** |
| 1996 | Wild | 1 | 20 | 29 | 4 | 2 | 0 | 0 | **56** |
| | Hatchery | 5 | 7 | 11 | 1 | 0 | 0 | 0 | **24** |
| 1997 | Wild | 5 | 5 | 28 | 1 | 17 | 0 | 0 | **56** |
| | Hatchery | 1 | 4 | 7 | 1 | 2 | 1 | 0 | **16** |
| 1998 | Wild | 41 | 46 | 70 | 9 | 23 | 0 | 0 | **189** |
| | Hatchery | 48 | 36 | 28 | 6 | 5 | 0 | 0 | **123** |
| 1999 | Wild | 27 | 79 | 110 | 14 | 17 | 4 | 2 | **253** |
| | Hatchery | 15 | 57 | 102 | 17 | 13 | 7 | 0 | **211** |
| 2000 | Wild | 23 | 78 | 74 | 7 | 72 | 3 | 0 | **257** |
| | Hatchery | 37 | 33 | 20 | 1 | 16 | 2 | 0 | **109** |
| 2001 | Wild | 49 | 102 | 54 | 9 | 66 | 11 | 1 | **292** |
| | Hatchery | 330 | 157 | 32 | 4 | 6 | 0 | 0 | **529** |
| 2002 | Wild | 124 | 163 | 362 | 129 | 183 | 34 | 9 | **1,004** |
| | Hatchery | 412 | 141 | 138 | 24 | 22 | 0 | 1 | **738** |
| 2003 | Wild | 33 | 123 | 176 | 63 | 85 | 3 | 0 | **483** |
| | Hatchery | 80 | 122 | 127 | 38 | 36 | 2 | 0 | **405** |
| 2004 | Wild | 14 | 108 | 144 | 61 | 73 | 1 | 0 | **401** |
| | Hatchery | 24 | 52 | 28 | 17 | 12 | 1 | 1 | **135** |
| 2005 | Wild | 62 | 99 | 133 | 33 | 107 | 3 | 0 | **437** |
| | Hatchery | 92 | 74 | 49 | 9 | 5 | 0 | 0 | **229** |
| 2006 | Wild | 68 | 103 | 83 | 49 | 131 | 3 | 1 | **438** |
| | Hatchery | 53 | 46 | 28 | 7 | 15 | 0 | 0 | **149** |
| ***Average*** | ***Wild*** | ***31*** | ***62*** | ***83*** | ***25*** | ***51*** | ***4*** | ***1*** | ***256*** |
| | ***Hatchery*** | ***71*** | ***48*** | ***38*** | ***8*** | ***9*** | ***1*** | ***0*** | ***175*** |

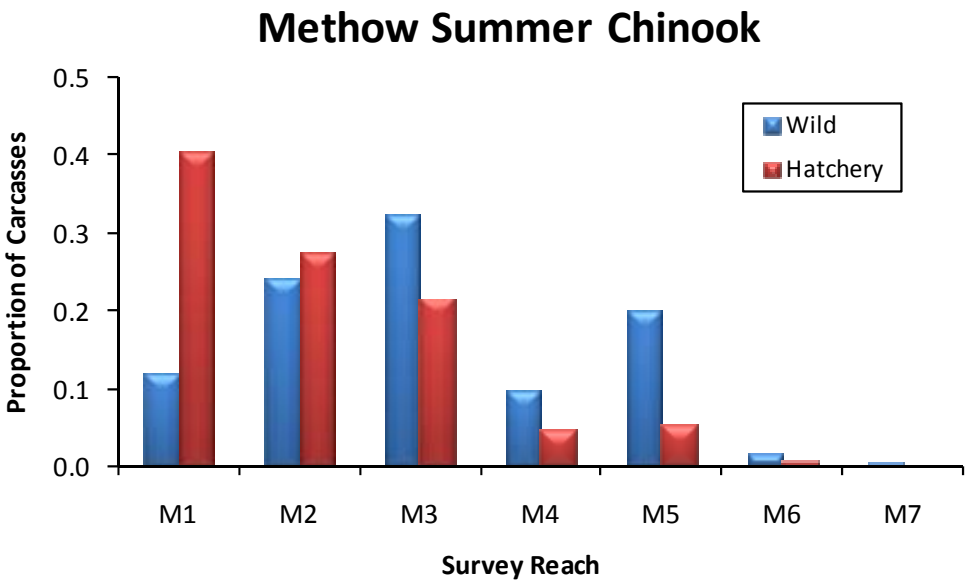


**Figure 7.4.** Distribution of wild and hatchery produced carcasses in different reaches on the Methow River, 1993-2006. Reach codes are described in Table 2.11.

### Sampling Rate

Overall, 33% of the total spawning escapement of summer Chinook in the Methow Basin was sampled in 2007 (Table 7.16). Sampling rates among survey reaches varied from 0 to 45%.

**Table 7.16.** Number of redds and carcasses, total spawning escapement, and sampling rates for summer Chinook in the Methow Basin, 2007. Reach codes are described in Table 2.11.

| Survey reach | Total number of redds | Total number of carcasses | Total spawning escapement | Sampling rate |
|---|---|---|---|---|
| Methow 1 | 170 | 135 | 374 | 0.36 |
| Methow 2 | 132 | 131 | 290 | 0.45 |
| Methow 3 | 155 | 108 | 341 | 0.32 |
| Methow 4 | 52 | 27 | 114 | 0.24 |
| Methow 5 | 108 | 55 | 238 | 0.23 |
| Methow 6 | 3 | 0 | 7 | 0.00 |
| Methow 7 | 0 | 0 | 0 | - |
| ***Total*** | ***620*** | ***456*** | ***1,364*** | ***0.33*** |

### Length Data

Mean lengths (POH, cm) of male and female summer Chinook carcasses sampled during surveys on the Methow River in 2007 are provided in Table 7.17. The average size of males and females sampled in the Methow River were 67 cm and 72 cm, respectively.

**Table 7.17.** Mean lengths (postorbital-to-hypural length; cm) and standard deviations (in parentheses) of male and female summer Chinook carcasses sampled in different reaches on the Methow River, 2007. Reach codes are described in Table 2.11.

| Stream/watershed | Mean length (cm) | |
|---|---|---|
| | Male | Female |
| Methow 1 | 66.7 (11.2) | 70.1 (7.9) |
| Methow 2 | 66.7 (12.7) | 72.4 (6.0) |
| Methow 3 | 68.0 (14.2) | 73.2 (6.8) |
| Methow 4 | 66.5 (10.4) | 73.1 (8.5) |
| Methow 5 | 71.9 (12.1) | 74.0 (6.0) |
| Methow 6 | - | - |
| Methow 7 | - | - |
| ***Total*** | ***67.4 (12.5)*** | ***72.1 (7.1)*** |

## 7.6 Life History Monitoring

Life history characteristics of Methow summer Chinook were assessed by examining carcasses on spawning grounds and fish collected or examined at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

### Age at Maturity

Most of the wild and hatchery summer Chinook sampled during the period 1993-2006 in the Methow River were age-4 and 5 fish (total age) (Table 7.18; Figure 7.5). A higher percentage of age-4 wild Chinook returned to the basin than did age-4 hatchery Chinook. In contrast, a higher proportion of age-5 and 6 hatchery fish returned than did age-5 and 6 wild fish. Thus, a higher percentage of hatchery fish returned at an older age than did wild fish.

**Table 7.18.** Proportions of wild and hatchery summer Chinook of different ages (total age) sampled on spawning grounds in the Methow River, 1993-2006.

| Survey year | Origin | Total age | | | | | | Sample size |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 | |
| 1993 | Wild | 0.00 | 0.05 | 0.34 | 0.58 | 0.03 | 0.00 | 38 |
| | Hatchery | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 20 |
| 1994 | Wild | 0.01 | 0.02 | 0.53 | 0.44 | 0.00 | 0.00 | 101 |
| | Hatchery | 0.00 | 0.00 | 0.07 | 0.93 | 0.00 | 0.00 | 111 |
| 1995 | Wild | 0.00 | 0.02 | 0.07 | 0.89 | 0.02 | 0.00 | 54 |
| | Hatchery | 0.00 | 0.02 | 0.04 | 0.43 | 0.52 | 0.00 | 56 |
| 1996 | Wild | 0.00 | 0.04 | 0.46 | 0.41 | 0.09 | 0.00 | 56 |
| | Hatchery | 0.00 | 0.00 | 0.04 | 0.48 | 0.43 | 0.04 | 23 |
| 1997 | Wild | 0.00 | 0.00 | 0.36 | 0.63 | 0.02 | 0.00 | 56 |
| | Hatchery | 0.00 | 0.13 | 0.06 | 0.56 | 0.25 | 0.00 | 16 |

| Survey year | Origin | Total age | | | | | | Sample size |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 | |
| 1998 | Wild | 0.00 | 0.13 | 0.52 | 0.34 | 0.00 | 0.00 | 188 |
| | Hatchery | 0.00 | 0.02 | 0.52 | 0.42 | 0.03 | 0.00 | 123 |
| 1999 | Wild | 0.00 | 0.02 | 0.59 | 0.39 | 0.01 | 0.00 | 253 |
| | Hatchery | 0.00 | 0.00 | 0.07 | 0.90 | 0.03 | 0.00 | 209 |
| 2000 | Wild | 0.00 | 0.05 | 0.15 | 0.80 | 0.00 | 0.00 | 257 |
| | Hatchery | 0.00 | 0.10 | 0.22 | 0.57 | 0.11 | 0.00 | 97 |
| 2001 | Wild | 0.01 | 0.15 | 0.59 | 0.24 | 0.02 | 0.00 | 292 |
| | Hatchery | 0.00 | 0.11 | 0.60 | 0.26 | 0.04 | 0.00 | 528 |
| 2002 | Wild | 0.00 | 0.04 | 0.66 | 0.29 | 0.00 | 0.00 | 1,004 |
| | Hatchery | 0.00 | 0.01 | 0.41 | 0.57 | 0.01 | 0.00 | 733 |
| 2003 | Wild | 0.00 | 0.01 | 0.43 | 0.55 | 0.00 | 0.00 | 483 |
| | Hatchery | 0.00 | 0.02 | 0.07 | 0.88 | 0.03 | 0.00 | 394 |
| 2004 | Wild | 0.00 | 0.04 | 0.08 | 0.86 | 0.01 | 0.00 | 401 |
| | Hatchery | 0.00 | 0.08 | 0.29 | 0.30 | 0.33 | 0.00 | 134 |
| 2005 | Wild | 0.00 | 0.03 | 0.58 | 0.34 | 0.05 | 0.00 | 410 |
| | Hatchery | 0.00 | 0.08 | 0.30 | 0.61 | 0.01 | 0.00 | 220 |
| 2006 | Wild | 0.00 | 0.02 | 0.18 | 0.78 | 0.02 | 0.00 | 379 |
| | Hatchery | 0.00 | 0.00 | 0.22 | 0.48 | 0.29 | 0.00 | 129 |
| ***Average*** | ***Wild*** | ***0.00*** | ***0.04*** | ***0.45*** | ***0.49*** | ***0.01*** | ***0.00*** | ***3,972*** |
| | ***Hatchery*** | ***0.00*** | ***0.04*** | ***0.33*** | ***0.57*** | ***0.07*** | ***0.00*** | ***2,793*** |

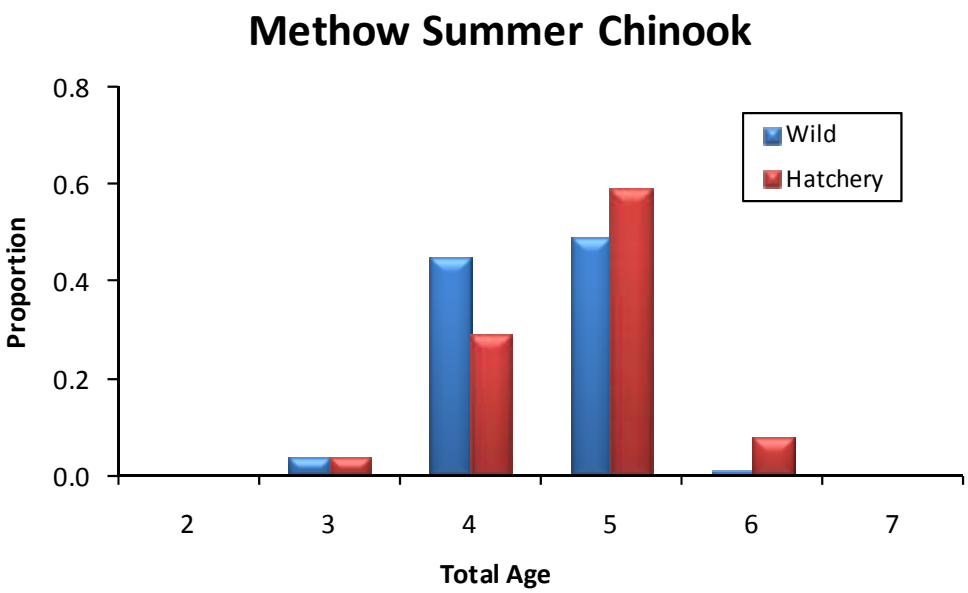


**Figure 7.5.** Proportions of wild and hatchery summer Chinook of different total ages sampled at broodstock collection sites and on spawning grounds in the Methow River for the combined years 1993-2006.

### Size at Maturity

On average, hatchery summer Chinook were about 4 cm smaller than wild summer Chinook sampled in the Methow Basin (Table 7.19). This is interesting given that a slightly higher percentage of hatchery fish returned as age-5 and 6 fish than did wild fish. Future analyses will compare sizes of hatchery and wild fish of the same age groups and gender.

**Table 7.19.** Mean lengths (POH; cm) and variability statistics for wild and hatchery summer Chinook sampled in the Methow Basin, 1993-2006; SD = 1 standard deviation.

| Survey year | Origin | Sample size | Summer Chinook length (POH; cm) | | | |
|---|---|---|---|---|---|---|
| | | | Mean | SD | Minimum | Maximum |
| 1993 | Wild | 41 | 74 | 9 | 51 | 89 |
| | Hatchery | 24 | 62 | 8 | 36 | 80 |
| 1994 | Wild | 112 | 69 | 8 | 35 | 87 |
| | Hatchery | 114 | 67 | 5 | 43 | 77 |
| 1995 | Wild | 62 | 74 | 6 | 52 | 88 |
| | Hatchery | 57 | 73 | 7 | 46 | 85 |
| 1996 | Wild | 64 | 70 | 11 | 34 | 91 |
| | Hatchery | 23 | 72 | 7 | 58 | 85 |
| 1997 | Wild | 62 | 76 | 9 | 35 | 90 |
| | Hatchery | 16 | 68 | 15 | 33 | 87 |
| 1998 | Wild | 196 | 67 | 10 | 38 | 97 |
| | Hatchery | 123 | 63 | 10 | 37 | 87 |
| 1999 | Wild | 293 | 66 | 8 | 43 | 99 |
| | Hatchery | 211 | 66 | 7 | 26 | 89 |
| 2000 | Wild | 288 | 74 | 8 | 37 | 89 |
| | Hatchery | 109 | 68 | 12 | 24 | 87 |
| 2001 | Wild | 328 | 67 | 10 | 29 | 86 |
| | Hatchery | 529 | 63 | 10 | 31 | 87 |
| 2002 | Wild | 1,076 | 70 | 8 | 37 | 94 |
| | Hatchery | 738 | 67 | 9 | 33 | 87 |
| 2003 | Wild | 543 | 71 | 8 | 35 | 88 |
| | Hatchery | 405 | 69 | 8 | 35 | 89 |
| 2004 | Wild | 442 | 73 | 7 | 38 | 89 |
| | Hatchery | 135 | 65 | 12 | 34 | 85 |
| 2005 | Wild | 437 | 69 | 8 | 45 | 86 |
| | Hatchery | 229 | 64 | 9 | 36 | 79 |
| 2006 | Wild | 438 | 73 | 7 | 35 | 92 |
| | Hatchery | 149 | 69 | 8 | 38 | 91 |
| ***Pooled*** | ***Wild*** | ***4,382*** | ***71*** | ***8*** | ***29*** | ***99*** |
| | ***Hatchery*** | ***2,862*** | ***67*** | ***9*** | ***24*** | ***91*** |

### Contribution to Fisheries

Most of the harvest on Methow summer Chinook occurred in the Ocean (Table 7.20). Ocean harvest has made up 13% to 98% of all Methow summer Chinook harvested. Brood years 1998 and 1998 provided the largest harvests, while brood year 1996 provided the lowest.

**Table 7.20.** Estimated number and percent (in parentheses) of Methow summer Chinook captured in different fisheries.

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational (sport) | |
| 1989 | 1,056 (53) | 805 (40) | 79 (4) | 66 (3) | 2,006 |
| 1990 | 60 (59) | 37 (37) | 4 (4) | 0 (0) | 101 |
| 1991 | 12 (20) | 49 (80) | 0 (0) | 0 (0) | 61 |
| 1992 | 17 (55) | 14 (45) | 0 (0) | 0 (0) | 31 |
| 1993 | 14 (58) | 8 (33) | 2 (8) | 0 (0) | 24 |
| 1994 | 139 (79) | 32 (18) | 3 (2) | 1 (1) | 175 |
| 1995 | 58 (98) | 0 (0) | 1 (2) | 0 (0) | 59 |
| 1996 | 11 (92) | 1 (8) | 0 (0) | 0 (0) | 12 |
| 1997 | 213 (88) | 4 (2) | 3 (1) | 21 (9) | 241 |
| 1998 | 1,773 (84) | 0 (0) | 102 (5) | 234 (11) | 2,118 |
| 1999 | 2 (13) | 0 (0) | 13 (87) | 0 (0) | 15 |
| 2000 | 375 (80) | 0 (0) | 65 (14) | 27 (6) | 467 |
| 2001 | 328 (62) | 0 (0) | 68 (13) | 129 (25) | 525 |

### Straying

Stray rates were determined by examining CWTs recovered on spawning grounds within and outside the Methow Basin. Targets for strays based on return year (recovery year) and brood year should be less than 5%.

Rates of Methow summer Chinook straying into basins outside the Methow have been very low (Table 7.21). Although a few Methow summer Chinook have strayed into the Okanogan Basin, Chelan tailrace, and Hanford Reach, staying has consistently been less than 5%.

**Table 7.21.** Number and percent of spawning escapements within other non-target basins that consisted of Methow summer Chinook, return years 1994-2004. For example, for return year 2002, 0.4% of the summer Chinook escapement in the Okanogan Basin consisted of Methow summer Chinook. Percent strays should be less than 5%.

| Return year | Wenatchee | | Okanogan | | Chelan | | Entiat | | Hanford Reach | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % | Number | % | Number | % |
| 1994 | 0 | 0.0 | 72 | 1.8 | - | - | - | - | - | - |
| 1995 | 0 | 0.0 | 9 | 0.3 | - | - | - | - | - | - |
| 1996 | 0 | 0.0 | 0 | 0.0 | - | - | - | - | - | - |
| 1997 | 0 | 0.0 | 0 | 0.0 | - | - | - | - | - | - |

| Return year | Wenatchee | | Okanogan | | Chelan | | Entiat | | Hanford Reach | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % | Number | % | Number | % |
| 1998 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1999 | 0 | 0.0 | 6 | 0.2 | 0 | 0.0 | 0 | 0.0 | 7 | 0.0 |
| 2000 | 0 | 0.0 | 3 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2001 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 7 | 0.0 |
| 2002 | 0 | 0.0 | 54 | 0.4 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2003 | 0 | 0.0 | 1 | 0.0 | 6 | 1.4 | 0 | 0.0 | 0 | 0.0 |
| 2004 | 0 | 0.0 | 7 | 0.1 | 3 | 0.7 | 0 | 0.0 | 0 | 0.0 |
| ***Total*** | ***0*** | ***0.0*** | ***152*** | ***0.3*** | ***9*** | ***0.3*** | ***0*** | ***0.0*** | ***14*** | ***0.0*** |

On average, about 3.9% of the returns have strayed into non-target spawning areas, falling below the target of 5% (Table 7.22). Depending on brood year, percent strays into non-target spawning areas have ranged from 0-10.8%. Few (<2% on average) have strayed into non-target hatchery programs.

**Table 7.22.** Number and percent of Methow summer Chinook that homed to target spawning areas and the target hatchery program, and number and percent that strayed to non-target spawning areas and non-target hatchery programs, by brood years 1989-2001. Percent stays should be less than 5%.

| Brood year | Homing | | | | Straying | | | |
|---|---|---|---|---|---|---|---|---|
| | Target stream | | Target hatchery | | Non-target streams | | Non-target hatcheries | |
| | Number | % | Number | % | Number | % | Number | % |
| 1989 | 773 | 55.7 | 459 | 33.0 | 81 | 5.8 | 76 | 5.5 |
| 1990 | 199 | 70.6 | 81 | 28.7 | 0 | 0.0 | 2 | 0.7 |
| 1991 | 82 | 65.6 | 43 | 34.4 | 0 | 0.0 | 0 | 0.0 |
| 1992 | 68 | 63.0 | 40 | 37.0 | 0 | 0.0 | 0 | 0.0 |
| 1993 | 25 | 65.8 | 10 | 26.3 | 3 | 7.9 | 0 | 0.0 |
| 1994 | 419 | 79.7 | 94 | 17.9 | 13 | 2.5 | 0 | 0.0 |
| 1995 | 126 | 81.8 | 28 | 18.2 | 0 | 0.0 | 0 | 0.0 |
| 1996 | 57 | 93.4 | 4 | 6.6 | 0 | 0.0 | 0 | 0.0 |
| 1997 | 379 | 93.8 | 7 | 1.7 | 18 | 4.5 | 0 | 0.0 |
| 1998 | 1,653 | 94.7 | 32 | 1.8 | 60 | 3.4 | 0 | 0.0 |
| 1999 | 18 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2000 | 167 | 90.3 | 4 | 2.2 | 14 | 7.6 | 0 | 0.0 |
| 2001 | 78 | 83.9 | 4 | 4.3 | 10 | 10.8 | 1 | 1.1 |
| ***Total*** | ***4,044*** | ***78.9*** | ***806*** | ***15.7*** | ***199*** | ***3.9*** | ***79*** | ***1.5*** |

## Genetics

Tissue (operculum) samples were collected from 144 wild and 144 hatchery summer Chinook in the Methow basin in 2006. Results from these samples should be available in 2009.

### Proportion of Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery origin fish in the natural spawning escapement (pHOS). The ratio pNOB/(pHOS+pNOB) is the Proportion of Natural Influence (PNI). The larger the ratio (PNI), the greater the strength of selection in the natural environment relative to that of the hatchery environment. In order for the natural environment to dominate selection, PNI should be greater than 0.5 (HSRG/WDFW/NWIFC 2004).

For brood years 1989-2005, the PNI was equal to or greater than 0.5 in all but three years (Table 7.23). This indicates that the natural environment has a greater influence on adaptation of Methow summer Chinook than does the hatchery environment.

**Table 7.23.** Proportionate natural influence (PNI) of the Methow summer Chinook supplementation program for brood years 1989-2005. PNI was calculated as the proportion of naturally produced Chinook in the hatchery broodstock (pNOB) divided by the proportion of hatchery Chinook on the spawning grounds (pHOS) plus pNOB. NOS = number of natural origin Chinook on the spawning grounds; HOS = number of hatchery origin Chinook on the spawning grounds; NOB = number of natural origin Chinook collected for broodstock; and HOB = number of hatchery origin Chinook included in hatchery broodstock.

| Brood year | Spawners | | | Broodstock | | | PNI |
|---|---|---|---|---|---|---|---|
| | NOS | HOS | pHOS | NOB | HOB | pNOB | |
| 1989 | 620 | 0 | 0.00 | 1,297 | 312 | 0.81 | 1.00 |
| 1990 | 1,391 | 0 | 0.00 | 828 | 206 | 0.80 | 1.00 |
| 1991 | 566 | 0 | 0.00 | 924 | 314 | 0.75 | 1.00 |
| 1992 | 460 | 0 | 0.00 | 297 | 406 | 0.42 | 1.00 |
| 1993 | 310 | 198 | 0.39 | 681 | 388 | 0.64 | 0.62 |
| 1994 | 574 | 511 | 0.47 | 341 | 244 | 0.58 | 0.55 |
| 1995 | 565 | 649 | 0.53 | 173 | 240 | 0.42 | 0.44 |
| 1996 | 424 | 192 | 0.31 | 290 | 223 | 0.57 | 0.64 |
| 1997 | 513 | 184 | 0.26 | 198 | 264 | 0.43 | 0.62 |
| 1998 | 432 | 243 | 0.36 | 153 | 211 | 0.42 | 0.54 |
| 1999 | 536 | 449 | 0.46 | 224 | 289 | 0.44 | 0.49 |
| 2000 | 838 | 362 | 0.30 | 164 | 339 | 0.33 | 0.52 |
| 2001 | 1,051 | 1,712 | 0.62 | 91 | 266 | 0.25 | 0.29 |
| 2002 | 2,512 | 2,118 | 0.46 | 247 | 241 | 0.51 | 0.53 |
| 2003 | 2,232 | 1,698 | 0.43 | 381 | 101 | 0.79 | 0.65 |
| 2004 | 1,632 | 577 | 0.26 | 506 | 16 | 0.97 | 0.79 |
| 2005 | 1,675 | 886 | 0.35 | 391 | 9 | 0.98 | 0.74 |

### Natural Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural origin recruits (NOR) to the parent spawning population. For brood years 1989-2000, NRR for summer Chinook in the Methow

averaged 1.60 (range, 0.54-6.08) if harvested fish were not include in the estimate and 4.51 (range, 0.77-21.25) if harvested fish were included in the estimate (Table 7.24). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

**Table 7.24.** Spawning escapements, natural origin recruits (NOR), and natural replacement rates (NRR; with and without harvest) for wild summer Chinook in the Methow Basin, 1989-2000. *(The numbers in this table may change as the HETT and HC refine the methods for estimating summer Chinook NORs and NRRs.)*

| Brood year | Spawning escapement | Harvest not included | | Harvest included | |
|---|---|---|---|---|---|
| | | NOR | NRR | NOR | NRR |
| 1989 | 552 | 754 | 1.36 | 1,286 | 2.33 |
| 1990 | 1,391 | 776 | 0.56 | 1,070 | 0.77 |
| 1991 | 566 | 342 | 0.60 | 541 | 0.96 |
| 1992 | 460 | 649 | 1.41 | 985 | 2.14 |
| 1993 | 508 | 575 | 1.13 | 763 | 1.50 |
| 1994 | 1,085 | 632 | 0.58 | 956 | 0.88 |
| 1995 | 1,214 | 1,226 | 1.01 | 2,420 | 1.99 |
| 1996 | 615 | 785 | 1.28 | 2,078 | 3.38 |
| 1997 | 697 | 2,282 | 3.27 | 7,143 | 10.25 |
| 1998 | 675 | 4,101 | 6.08 | 14,344 | 21.25 |
| 1999 | 986 | 3,180 | 3.23 | 11,295 | 11.46 |
| 2000 | 1,200 | 649 | 0.54 | 2,005 | 1.67 |
| ***Average*** | ***829*** | ***1,329*** | ***1.60*** | ***3,741*** | ***4.51*** |

### Hatchery Replacement Rates

Hatchery replacement rates were estimated as hatchery adult-to-adult returns. These rates should be greater than the NRRs and greater than or equal to 5.30 (the value in BAMP; Murdoch and Peven 2005). HRRs exceeded NRRs in four or five of the 12 years of data depending on if harvest was or was not included in the estimate (Table 7.25). Hatchery replacement rates for Methow summer Chinook have exceeded the BAMP target of 5.30 in two of the 12 years of data, regardless if harvest is or is not included in the estimate.

**Table 7.25.** Hatchery replacement rates (HRR), NRR, and BAMP target (5.30) for summer Chinook in the Methow Basin, 1989-2000. *(The numbers in this table may change as the HETT and HC refine the methods for estimating summer Chinook HRRs and NRRs.)*

| Brood year | Harvest not included | | | Harvest included | | |
|---|---|---|---|---|---|---|
| | HRR | NRR | BAMP | HRR | NRR | BAMP |
| 1989 | 6.88 | 1.36 | 5.30 | 16.81 | 2.33 | 5.30 |
| 1990 | 1.40 | 0.56 | 5.30 | 1.90 | 0.77 | 5.30 |
| 1991 | 0.47 | 0.60 | 5.30 | 0.70 | 0.96 | 5.30 |
| 1992 | 0.50 | 1.41 | 5.30 | 0.65 | 2.14 | 5.30 |
| 1993 | 0.16 | 1.13 | 5.30 | 0.26 | 1.50 | 5.30 |
| 1994 | 1.95 | 0.58 | 5.30 | 2.60 | 0.88 | 5.30 |
| 1995 | 0.61 | 1.01 | 5.30 | 0.84 | 1.99 | 5.30 |
| 1996 | 0.30 | 1.28 | 5.30 | 0.35 | 3.38 | 5.30 |
| 1997 | 1.98 | 3.27 | 5.30 | 3.14 | 10.25 | 5.30 |
| 1998 | 7.43 | 6.08 | 5.30 | 16.45 | 21.25 | 5.30 |
| 1999 | 0.10 | 3.23 | 5.30 | 0.17 | 11.46 | 5.30 |
| 2000 | 0.84 | 0.54 | 5.30 | 2.94 | 1.67 | 5.30 |
| ***Average*** | ***1.84*** | ***1.60*** | ***5.30*** | ***3.76*** | ***4.51*** | ***5.30*** |

### Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adults divided by the number of hatchery smolts released. SARs were based on CWT returns. For the available brood years, SARs have ranged from 0.00008 to 0.01890 for hatchery summer Chinook in the Methow Basin (Table 7.26).

**Table 7.26.** Smolt-to-adult ratios (SARs) for Methow summer Chinook; NA = not available.

| Brood year | Number of smolts released | Estimated adult captures | SAR |
|---|---|---|---|
| 1989 | 358,237 | 2,881 | 0.00804 |
| 1990 | 371,483 | 366 | 0.00099 |
| 1991 | 377,097 | 130 | 0.00034 |
| 1992 | 392,636 | 138 | 0.00035 |
| 1993 | 200,345 | 62 | 0.00031 |
| 1994 | 400,488 | 696 | 0.00174 |
| 1995 | 344,974 | 211 | 0.00061 |
| 1996 | 289,880 | 72 | 0.00025 |
| 1997 | 380,430 | 641 | 0.00168 |
| 1998 | 202,559 | 3,829 | 0.01890 |
| 1999 | 422,473 | 33 | 0.00008 |
| 2000 | 334,337 | 651 | 0.00195 |

| Brood year | Number of smolts released | Estimated adult captures | SAR |
|---|---|---|---|
| 2001 | 246,159 | 616 | 0.00250 |
| ***Average*** | ***332,392*** | ***794*** | ***0.00239*** |

## 7.7 ESA/HCP Compliance

### Broodstock Collection

Summer Chinook adults collected at Wells Dam are used for both the Methow and Okanogan supplementation programs. Per the 2005 broodstock collection protocol, 556 natural origin (adipose fin present) adults were targeted for collection between 5 July and 14 September at the East Ladder of Wells Dam. Actual collections occurred between 5 July and 12 September and totaled 563 summer Chinook. The overage in adult broodstock collection was attributable to errors in enumeration during collection. ESA Permit 1347 provides authorization to collect Methow and Okanogan summer Chinook at Wells Dam three days per week and up to 16 hours per day from July through November. During 2005, broodstock collection activities encompassed a total of 15 days, representing 23% of the allowable trapping days allowed under ESA Permit 1347.

Collection of Methow and Okanogan summer Chinook broodstock at Wells Dam occurred concurrently with collection of summer steelhead for the Wells steelhead program authorized under ESA Section 10 Permit 1395. Encounters with steelhead and spring Chinook during Methow and Okanogan summer Chinook broodstock collections did not result in takes that were outside those authorized in Permit 1347 and in Permit 1395 for the Wells Steelhead program. Steelhead encountered during summer Chinook collections that were not required for steelhead broodstock were passed at the trap site and were not physically handled. Any spring Chinook encountered during summer Chinook broodstock activities were also passed without handling.

### Hatchery Rearing and Release

The 2005 brood Okanogan/Similkameen summer Chinook reared throughout their juvenile life-stages at Eastbank Fish Hatchery and the Carlton Acclimation pond without incident (see section 7.2). The 2005 brood smolt release totaled 263,723 summer Chinook, representing 65.8% of the production objective and complied with the maximum production levels identified in ESA Section 10 Permit 1347. The 2005 brood smolt production level was less than the program production level primarily because of a male-skewed sex ratio in the broodstock (Table 7.4).

### Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, and 1395, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at Chelan PUD Hatchery facilities during the period 1 January 2007 through 31 December 2007. NPDES monitoring and reporting for Chelan PUD Hatchery Programs during 2007 are provided in Appendix E.

### Spawning Surveys

Summer Chinook spawning ground surveys conducted in the Methow Basin during 2007 were consistent with ESA Section 10 Permit No. 1347. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential impacts to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

# SECTION 8: OKANOGAN/SIMILKAMEEN SUMMER CHINOOK

## 8.1 Broodstock Sampling

Summer Chinook broodstock for the Okanogan/Similkameen and Methow programs is collected in the East Ladder of Wells Dam. Refer to Section 7.1 for information on the origin, age and length, sex ratios, and fecundity of summer Chinook broodstock collected at Wells Dam.

## 8.2 Hatchery Rearing

### Rearing History

#### *Number of eggs taken*

Based on the unfertilized egg-to-release survival standard of 81%, a total of 711,111 eggs are required to meet the program release goal of 576,000 smolts. Between 1989 and 2006, the egg take goal was reached in ten of those years (Table 8.1).

**Table 8.1.** Numbers of eggs taken from summer Chinook broodstock collected at Wells Dam for the Okanogan program, 1989-2006.

| Return year | Number of eggs taken |
|---|---|
| 1989 | 724,200 |
| 1990 | 696,144 |
| 1991 | 879,892 |
| 1992 | 729,389 |
| 1993 | 797,234 |
| 1994 | 893,086 |
| 1995 | 736,500 |
| 1996 | 672,000 |
| 1997 | 601,744 |
| 1998 | 584,018 |
| 1999 | 725,589 |
| 2000 | 645,403 |
| 2001 | 418,907 |
| 2002 | 718,599 |
| 2003 | 710,521 |
| 2004 | 805,814 |
| 2005 | 452,928 |
| 2006 | 757,350 |
| ***Average*** | ***697,507*** |

### *Number of acclimation days*

Fish were volitionally released from Similkameen Pond as yearling smolts beginning in April 2007. Fish acclimated at Similkameen were held for 179 to 200 days (Table 8.2). Any fish that may have survived over the winter at Bonaparte Pond reared for about 156 days on Okanogan River water.

**Table 8.2.** Number of days Okanogan summer Chinook broods were acclimated at Similkameen and Bonaparte ponds, brood years 1989-2005.

| Brood year | Release year | Rearing facility | Transfer date | Release date | Number of days |
|---|---|---|---|---|---|
| 1989 | 1991 | Similkameen | 29-Oct | 7-May | 190 |
| 1990 | 1992 | Similkameen | 5-Nov | 25-Apr | 171 |
| 1991 | 1993 | Similkameen | 1-Nov | 9-Apr | 159 |
| 1992 | 1994 | Similkameen | 2-Nov | 1-Apr | 150 |
| | | | 26-Feb | 1-Apr | 34 |
| 1993 | 1995 | Similkameen | 24-Oct | 1-Apr | 159 |
| | | | 24-Feb | 1-Apr | 36 |
| 1994 | 1996 | Similkameen | 30-Oct | 6-Apr | 158 |
| | | | 14-Mar | 6-Apr | 23 |
| 1995 | 1997 | Similkameen | 1-Oct | 1-Apr | 182 |
| 1996 | 1998 | Similkameen | 10-Oct | 15-Mar | 156 |
| 1997 | 1999 | Similkameen | 7-Oct | 19-Apr | 194 |
| 1998 | 2000 | Similkameen | 5-Oct | 19-Apr | 196 |
| 1999 | 2001 | Similkameen | 5-Oct | 18-Apr | 195 |
| 2000 | 2002 | Similkameen | 10-Oct | 8-Apr | 180 |
| 2001 | 2003 | Similkameen | 1-Oct | 29-Apr | 210 |
| 2002 | 2004 | Similkameen | 9-Nov | 23-Apr | 165 |
| 2003 | 2005 | Similkameen | 19-Oct | 28-Apr | 191 |
| 2004 | 2006 | Similkameen | 26-Oct | 23-Apr | 179 |
| 2005 | 2007 | Bonaparte | 6-Nov | 11-Apr | 156 |
| | | Similkameen | 25-Oct | 18-Apr – 9-May | 179-200 |
| ***Average*** | | | | | ***157*** |

## Release Information

### *Numbers released*

The 2005 Okanogan summer Chinook program achieved 47.9% of the 576,000 target goal with about 275,919 fish being released volitionally between 18 April and 9 May (Table 8.3) in the Similkameen River. Of the estimated 100,146 fish transferred to Bonaparte Pond, some unknown

number may have survived; although, based on observations by fish health personnel, it is assumed that no fish survived. With damage to the water screens by ice, which could have allowed some fish to escape undetected, and a significant die off resulting from bacterial gill disease (BGD; treatment was also compounded by surface ice), it is unlikely that many fish survived over the winter at Bonaparte Pond.

**Table 8.3.** Numbers of Okanogan summer Chinook smolts released from the Similkameen and Bonaparte ponds, brood years 1989-2005. The release target for Okanogan summer Chinook is 576,000 smolts.

| Brood year | Release year | Rearing facility | Number of smolts |
|---|---|---|---|
| 1989 | 1991 | Similkameen | 352,600 |
| 1990 | 1992 | Similkameen | 540,000 |
| 1991 | 1993 | Similkameen | 675,500 |
| 1992 | 1994 | Similkameen | 548,182 |
| 1993 | 1995 | Similkameen | 586,000 |
| 1994 | 1996 | Similkameen | 536,299 |
| 1995 | 1997 | Similkameen | 587,000 |
| 1996 | 1998 | Similkameen | 507,913 |
| 1997 | 1999 | Similkameen | 589,591 |
| 1998 | 2000 | Similkameen | 293,191 |
| 1999 | 2001 | Similkameen | 630,463 |
| 2000 | 2002 | Similkameen | 532,453 |
| 2001 | 2003 | Similkameen | 26,642 |
| 2002 | 2004 | Similkameen | 388,589 |
| 2003 | 2005 | Similkameen | 579,019 |
| 2004 | 2006 | Similkameen | 703,359 |
| 2005 | 2007 | Bonaparte | 0 (assumed) |
| | | Similkameen | 275,919 |
| ***Average*** | | | ***491,336*** |

### *Numbers tagged*

The 2005 brood Okanogan summer Chinook from the Bonaparte and Similkameen facilities were 96.0% and 98.6% CWT and adipose fin-clipped, respectively. Neither group was PIT tagged.

### *Fish size and condition at release*

Size at release of the Similkameen population was 75.0% and 57.0% of the target fork length and weight, respectively. The target CV for fork length was exceeded by 7% (Table 8.4). Size-at-release data were not collected for the Bonaparte fish.

**Table 8.4.** Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Okanogan summer Chinook smolts released from the hatchery, brood years 1989-2005. Size targets are provided in the last row of the table.

| Brood year | Release year | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| 1989 | 1991 | - | - | 41.3 | 11 |
| 1990 | 1992 | 143 | 9.5 | 37.8 | 12 |
| 1991 | 1993 | 125 | 15.5 | 22.4 | 20 |
| 1992 | 1994 | 120 | 15.4 | 20.7 | 22 |
| 1993 | 1995 | 132 | - | 23.2 | 20 |
| 1994 | 1996 | 136 | 16.0 | 29.6 | 15 |
| 1995 | 1997 | 137 | 8.2 | 32.8 | 14 |
| 1996 | 1998 | 127 | 12.8 | 26.2 | 17 |
| 1997 | 1999 | 144 | 9.9 | 36.0 | 13 |
| 1998 | 2000 | 148 | 5.9 | 41.0 | 11 |
| 1999 | 2001 | 141 | 15.7 | 35.4 | 13 |
| 2000 | 2002 | 121 | 13.4 | 20.4 | 22 |
| 2001 | 2003 | 132 | 8.2 | 25.7 | 18 |
| 2002 | 2004 | 119 | 13.4 | 20.8 | 22 |
| 2003 | 2005 | 133 | 10.6 | 28.9 | 16 |
| 2004 | 2006 | 132 | 9.9 | 29.8 | 15 |
| 2005 | 2007 | 132 | 9.6 | 25.9 | 18 |
| ***Targets*** | | ***176*** | ***9.0*** | ***45.4*** | ***10*** |

## Survival Estimates

Overall survival of Okanogan summer Chinook (not including the Bonaparte component) from green (unfertilized) egg to release was slightly above the standard set for the program (Table 8.5). Lower than expected green egg-to-eye survival further reduced the overall survival performance. Currently, it is unknown if gamete viability is gender biased or is uniform between sexes and more influenced by between-year environmental variations.

Post transfer survival of the Bonaparte group was considerably lower than expected (Table 8.5). Disease (BGD primarily), the inability to treat BGD because of extended presence of surface ice, and damage to water screens by ice suggests that few if any fish survived.

**Table 8.5.** Hatchery life-stage survival rates (%) for Okanogan summer Chinook, brood years 1989-2005. Survival standards or targets are provided in the last row of the table.

| Brood year | Rearing facility | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Female | Male | | | | | | | |
| 1989[a] | Similkameen | 89.8 | 99.5 | 89.9 | 96.7 | 99.7 | 99.4 | 73.3 | 57.4 | 63.7 |
| 1990[a] | Similkameen | 93.9 | 99.0 | 84.9 | 97.1 | 81.2 | 80.6 | 97.7 | 98.6 | 80.5 |
| 1991[a] | Similkameen | 93.1 | 95.5 | 88.2 | 97.1 | 99.4 | 99.1 | 98.4 | 97.1 | 84.2 |
| 1992[a] | Similkameen | 96.9 | 99.0 | 87.0 | 98.0 | 99.9 | 99.9 | 91.7 | 92.6 | 78.2 |
| 1993[a] | Similkameen | 82.2 | 99.4 | 85.4 | 97.6 | 99.8 | 99.5 | 92.0 | 90.2 | 76.7 |
| 1994 | Similkameen | 96.1 | 90.0 | 86.6 | 100.0 | 98.1 | 97.4 | 73.1 | 89.8 | 63.3 |
| 1995 | Similkameen | 91.9 | 96.2 | 98.2 | 84.1 | 96.5 | 96.2 | 92.7 | 98.2 | 76.6 |
| 1996 | Similkameen | 95.4 | 98.1 | 83.2 | 100.0 | 97.7 | 96.9 | 86.5 | 92.5 | 72.0 |
| 1997 | Similkameen | 91.9 | 94.6 | 86.1 | 98.4 | 98.7 | 98.3 | 98.8 | 99.4 | 83.7 |
| 1998 | Similkameen | 84.0 | 96.2 | 54.1 | 98.0 | 99.4 | 98.9 | 96.6 | 99.6 | 51.2 |
| 1999 | Similkameen | 98.8 | 98.7 | 92.9 | 96.9 | 98.0 | 97.6 | 96.9 | 99.0 | 87.2 |
| 2000 | Similkameen | 90.5 | 96.9 | 89.2 | 98.5 | 98.2 | 98.0 | 93.6 | 97.2 | 82.6 |
| 2001 | Similkameen | 96.2 | 92.3 | 89.1 | 97.6 | 99.7 | 99.5 | 7.4 | 11.9 | 6.4 |
| 2002 | Similkameen | 97.1 | 98.1 | 89.8 | 98.0 | 99.7 | 99.5 | 51.6 | 52.2 | 45.4 |
| 2003 | Similkameen | 96.7 | 97.5 | 86.8 | 97.6 | 99.3 | 98.5 | 98.0 | 98.8 | 83.0 |
| 2004 | Similkameen | 93.6 | 98.2 | 84.0 | 97.6 | 99.6 | 99.3 | 97.8 | 98.8 | 80.2 |
| | Bonaparte | 93.6 | 98.2 | 84.0 | 97.6 | 99.6 | 99.3 | 97.9 | 98.9 | 80.3 |
| 2005 | Similkameen | 97.0 | 89.6 | 88.0 | 99.5 | 99.5 | 99.0 | 93.5 | 94.6 | 81.8 |
| | Bonaparte | 97.0 | 89.6 | 88.0 | 99.5 | 99.5 | 99.0 | 0.0 | 0.0 | 0.0 |
| ***Standard*** | | ***90.0*** | ***85.0*** | ***92.0*** | ***98.0*** | ***97.0*** | ***93.0*** | ***90.0*** | ***95.0*** | ***81.0*** |

[a] Survival rates were calculated from the aggregate population collected at Wells Fish Hatchery volunteer channel and left- and right-ladder traps at Wells Dam.

## 8.3 Disease Monitoring

Rearing of the 2005 brood Okanogan summer Chinook was similar to previous years with fish being held on well water before being transferred for final acclimation on Similkameen or Okanogan river water. The Similkameen population was transferred in late October 2006. Fish were prophylactically treated upon transfer with formalin to control external parasites (*Ich* and *Dermocystidium*) and fungus, which in recent years has led to significant losses in this program. In mid January 2007, the spicule-shaped bacteria responsible for bacterial gill disease (BGD) began to increase in the Similkameen. The use of Chloramine-T was recommended for control of BGD. This group continued to experience exposure to BGD; however, losses continued to remain low. This group was treated with $KMnO_4$ for two days when the river water began to clear up in late March. No additional disease-related problems were noted before release.

The Bonaparte Pond population was transferred and reared on Okanogan River water from early November 2007 until release. Ice formed over the pond in early December and fish were not available for inspection until early February. Given the Similkameen population began breaking with BGD in mid January, it is likely that the Bonaparte population did as well. Upon ice breakup (late

February), BGD was confirmed in all dead fish sampled (significant mortalities were observed). Although no live fish were observed, $KMnO_4$ treatments were applied for three days to ensure that any unseen live fish would not die from BGD.

## 8.4 Spawning Surveys

Surveys for Okanogan/Similkameen summer Chinook redds were conducted from late September to mid-November, 2007, in the Okanogan and Similkameen rivers. Total redd counts (not peak counts) were conducted in the rivers (see Appendix J for more details).

### Redd Counts

A total of 2,008 summer Chinook redds were counted in the Okanogan Basin in 2007 (Table 8.6). This was greater than the 19-year average of 1,608 redds.

**Table 8.6.** Total number of redds counted in the Okanogan Basin, 1989-2007.

| Survey year | Number of summer Chinook redds | | |
|---|---|---|---|
| | Okanogan River | Similkameen River | Total count |
| 1989 | 134* | 370 | 504 |
| 1990 | 47 | 147 | 194 |
| 1991 | 64 | 91 | 155 |
| 1992 | 53 | 57 | 110 |
| 1993 | 162 | 288 | 450 |
| 1994 | 375 | 777 | 1,152 |
| 1995 | 267 | 616 | 883 |
| 1996 | 116 | 419 | 535 |
| 1997 | 158 | 486 | 644 |
| 1998 | 88 | 276 | 364 |
| 1999 | 369 | 1,275 | 1,644 |
| 2000 | 549 | 993 | 1,542 |
| 2001 | 1,108 | 1,540 | 2,648 |
| 2002 | 2,667 | 3,358 | 6,025 |
| 2003 | 1,035 | 378 | 1,413 |
| 2004 | 1,327 | 1,660 | 2,987 |
| 2005 | 1,611 | 1,423 | 3,034 |
| 2006 | 2,592 | 1,666 | 4,258 |
| 2007 | 1,301 | 707 | 2,008 |
| ***Average*** | ***738*** | ***870*** | ***1,608*** |

* Peak count based on an aerial survey.

### Redd Distribution

Summer Chinook redds were not evenly distributed among the survey reaches in the Okanogan Basin. Most redds (87%) were located in the upper Okanogan and lower Similkameen reaches

(reaches upstream of the Riverside Bridge) (Table 8.7; Figure 8.1). Relatively few summer Chinook spawned downstream of the Riverside Bridge on the Okanogan River (Reaches 1-4).

**Table 8.7.** Total number of summer Chinook redds counted in different reaches in the Okanogan Basin during September through mid-November, 2007. Reach codes are described in Table 2.11.

| Survey reach | Total redd count | Percent |
|---|---|---|
| Okanogan 1 | 3 | 0.1 |
| Okanogan 2 | 16 | 0.8 |
| Okanogan 3 | 116 | 5.8 |
| Okanogan 4 | 63 | 3.1 |
| Okanogan 5 | 549 | 27.3 |
| Okanogan 6 | 554 | 27.6 |
| Similkameen 1 | 652 | 32.5 |
| Similkameen 2 | 55 | 2.7 |
| ***Totals*** | ***2,008*** | ***100.0*** |

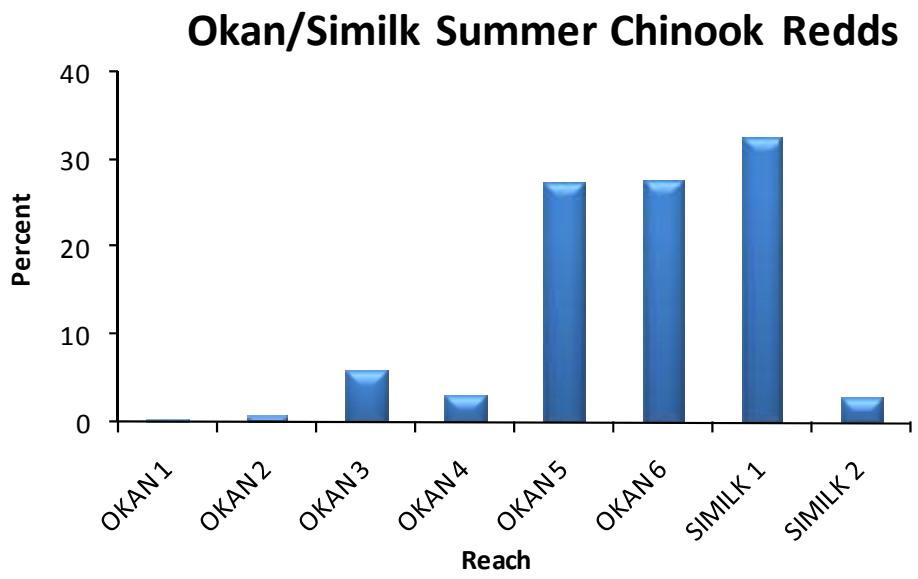


**Figure 8.1.** Percent of the total number of summer Chinook redds counted in different reaches in the Okanogan Basin during September through mid-November, 2007. Reach codes are described in Table 2.11.

### Spawn Timing

Spawning in 2007 began the last week in September in the Similkameen and the first week of October in the Okanogan, and peaked during the second week of October in both rivers (Figure 8.2). Spawning began when stream temperature varied from 12-15°C. The temporal distribution of spawning activity in 2007 was similar to the 16-year average, with the exception of peak spawning in 2007 occurring a week later than the average.

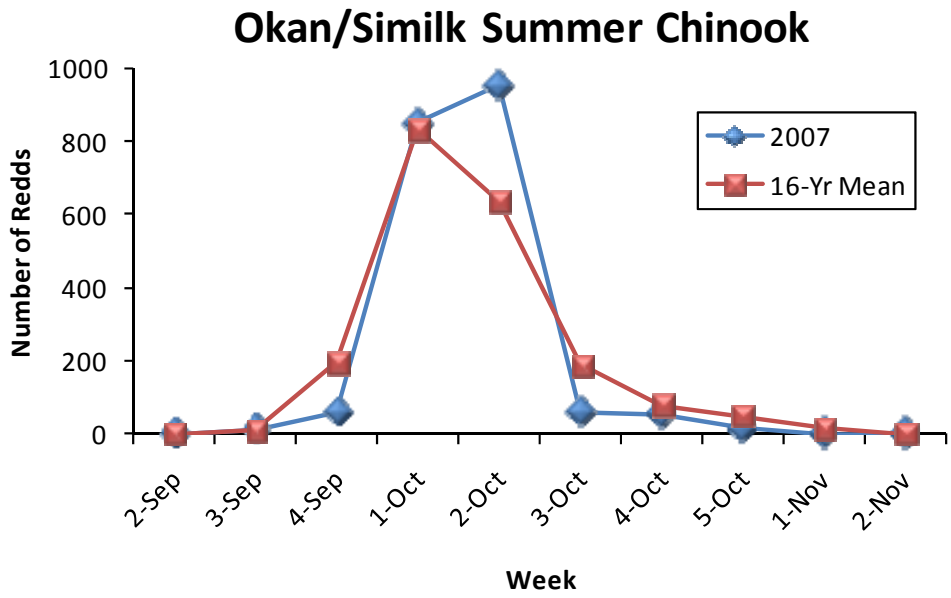


**Figure 8.2.** Comparison of the number of new summer Chinook redds counted during different weeks in the Okanogan Basin, September through mid-November, 2007, to the 16-year average.

### Spawning Escapement

Spawning escapement for Okanogan/Similkameen summer Chinook was calculated as the total number of redds times the fish per redd ratio estimated from fish sampled at Wells Dam. The estimated fish per redd ratio for Okanogan/Similkameen summer Chinook in 2007 was 2.20. Multiplying this ratio by the number of redds counted in the Okanogan and Similkameen rivers resulted in a total spawning escapement of 4,417 summer Chinook (Table 8.8).

**Table 8.8.** Spawning escapements for summer Chinook in the Okanogan and Similkameen rivers for return years 1989-2007.

| Return year | Fish/Redd | Spawning escapement | | |
|---|---|---|---|---|
| | | Okanogan | Similkameen | Total |
| 1989* | 3.30 | 561 | 1,221 | 1,782 |
| 1990* | 3.40 | 381 | 500 | 881 |
| 1991* | 3.70 | 237 | 337 | 574 |
| 1992* | 4.30 | 228 | 245 | 473 |
| 1993* | 3.30 | 535 | 950 | 1,485 |
| 1994* | 3.50 | 1,313 | 2,720 | 4,033 |
| 1995* | 3.40 | 908 | 2,094 | 3,002 |
| 1996* | 3.40 | 394 | 1,425 | 1,819 |
| 1997* | 3.40 | 537 | 1,652 | 2,189 |
| 1998 | 3.00 | 264 | 828 | 1,092 |
| 1999 | 2.20 | 812 | 2,805 | 3,617 |

| Return year | Fish/Redd | Spawning escapement | | |
|---|---|---|---|---|
| | | Okanogan | Similkameen | Total |
| 2000 | 2.40 | 1,318 | 2,383 | 3,701 |
| 2001 | 4.10 | 4,543 | 6,314 | 10,857 |
| 2002 | 2.30 | 6,134 | 7,723 | 13,857 |
| 2003 | 2.42 | 2,505 | 915 | 3,420 |
| 2004 | 2.25 | 2,986 | 3,735 | 6,721 |
| 2005 | 2.93 | 4,720 | 4,169 | 8,889 |
| 2006 | 2.02 | 5,236 | 3,365 | 8,601 |
| 2007 | 2.20 | 2,862 | 1,555 | 4,417 |
| ***Average*** | ***3.03*** | ***1,920*** | ***2,365*** | ***4,285*** |

* Spawning escapement was calculated using the "Modified Meekin Method" (i.e., 3.1 x jack multiplier).

## 8.5 Carcass Surveys

Surveys for summer Chinook carcasses were conducted during late September to mid-November, 2007, in the Okanogan and Similkameen rivers (see Appendix J for more details).

### Number sampled

A total of 1,716 summer Chinook carcasses were sampled during September through mid-November in the Okanogan Basin (Table 8.9). A total of 1,030 were sampled in the Okanogan River and 686 in the Similkameen River.

**Table 8.9**. Numbers of summer Chinook carcasses sampled within each survey reach in the Okanogan Basin, 1993-2007. Reach codes are described in Table 2.11.

| Survey year | Number of summer Chinook carcasses | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Okanogan | | | | | | Similkameen | | Total |
| | O-1 | O-2 | O-3 | O-4 | O-5 | O-6 | S-1 | S-2 | |
| 1993[a] | 0 | 2 | 3 | 0 | 23 | 13 | 73 | 1 | **115** |
| 1994[b] | 0 | 4 | 4 | 0 | 27 | 5 | 318 | 60 | **418** |
| 1995 | 0 | 0 | 2 | 0 | 30 | 0 | 239 | 15 | **286** |
| 1996 | 0 | 0 | 0 | 2 | 5 | 2 | 226 | 0 | **235** |
| 1997 | 0 | 0 | 2 | 0 | 9 | 3 | 225 | 1 | **240** |
| 1998 | 0 | 1 | 8 | 1 | 7 | 7 | 340 | 4 | **368** |
| 1999 | 0 | 0 | 3 | 2 | 23 | 53 | 766 | 48 | **895** |
| 2000 | 0 | 2 | 20 | 15 | 47 | 16 | 727 | 41 | **868** |
| 2001 | 0 | 26 | 75 | 10 | 127 | 112 | 1,141 | 105 | **1,596** |
| 2002 | 10 | 32 | 83 | 35 | 204 | 573 | 1,265 | 259 | **2,461** |
| 2003[c] | 0 | 0 | 26 | 0 | 15 | 208 | 180 | 8 | **437** |
| 2004 | 0 | 4 | 31 | 24 | 146 | 283 | 1,392 | 298 | **2,178** |
| 2005 | 0 | 8 | 93 | 37 | 371 | 431 | 731 | 276 | **1,947** |

| Survey year | Number of summer Chinook carcasses | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Okanogan | | | | | | Similkameen | | Total |
| | O-1 | O-2 | O-3 | O-4 | O-5 | O-6 | S-1 | S-2 | |
| 2006 | 4 | 3 | 31 | 16 | 120 | 291 | 513 | 100 | **1,078** |
| 2007 | 2 | 1 | 48 | 1 | 459 | 519 | 657 | 29 | **1,716** |
| ***Average*** | ***1*** | ***6*** | ***29*** | ***10*** | ***108*** | ***168*** | ***586*** | ***83*** | ***989*** |

[a] 25 additional carcasses were sampled on the Similkameen and 46 on the Okanogan without any reach designation.
[b] One additional carcasses was sampled on the Similkameen without any reach designation.
[c] 793 carcasses were sampled on the Similkameen before initiation of spawning (pre-spawn mortality) and an additional 40 carcasses were sampled on the Okanogan. The cause of the high mortality (*Ichthyophthirius multifilis* and *Flavobacterium columnarae*) was exacerbated by high river temperatures.

### Carcass Distribution and Origin

Summer Chinook carcasses were not evenly distributed among reaches within the Okanogan Basin in 2007 (Table 8.9; Figure 8.3). Most of the carcasses in the basin were found in the upper Okanogan River and lower Similkameen River. The highest percentage of carcasses (38%) was sampled in Reach 1 on the Similkameen River between the Driscoll Channel and Oroville Bridge.

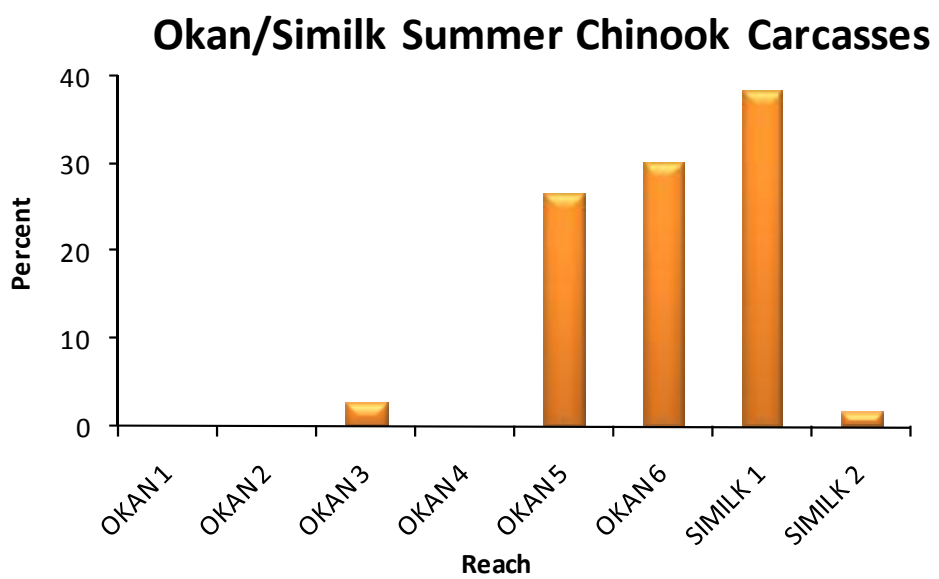


**Figure 8.3.** Percent of summer Chinook carcasses sampled within different reaches in the Okanogan Basin during September through mid-November, 2007. Reach codes are described in Table 2.11.

Numbers of wild and hatchery origin summer Chinook carcasses sampled in 2007 will be available after analysis of CWTs and scales. Based on the available data (1991-2006), most fish, regardless of origin, were found in Reach 1 on the Similkameen River (Driscoll Channel to Oroville Bridge) (Table 8.10). However, a slightly larger percentage of hatchery fish were found in reaches on the Similkameen River than were wild fish (Figure 8.4). In contrast, a larger percentage of wild fish were found in reaches on the Okanogan River.

**Table 8.10.** Numbers of wild and hatchery summer Chinook carcasses sampled within different reaches in the Okanogan Basin, 1993-2006.

| Survey year | Origin | Survey reach | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | O-1 | O-2 | O-3 | O-4 | O-5 | O-6 | S-1 | S-2 | |
| 1993 | Wild | 0 | 0 | 3 | 0 | 13 | 4 | 48 | 1 | **69** |
| | Hatchery | 0 | 2 | 0 | 0 | 10 | 9 | 25 | 0 | **46** |
| 1994 | Wild | 0 | 0 | 1 | 0 | 8 | 1 | 113 | 22 | **145** |
| | Hatchery | 0 | 4 | 3 | 0 | 19 | 4 | 205 | 38 | **273** |
| 1995 | Wild | 0 | 0 | 1 | 0 | 10 | 0 | 66 | 4 | **81** |
| | Hatchery | 0 | 0 | 1 | 0 | 20 | 0 | 173 | 11 | **205** |
| 1996 | Wild | 0 | 0 | 0 | 1 | 3 | 1 | 53 | 0 | **58** |
| | Hatchery | 0 | 0 | 0 | 1 | 2 | 1 | 173 | 0 | **177** |
| 1997 | Wild | 0 | 0 | 1 | 0 | 0 | 2 | 83 | 0 | **86** |
| | Hatchery | 0 | 0 | 1 | 0 | 9 | 0 | 142 | 1 | **153** |
| 1998 | Wild | 0 | 1 | 3 | 1 | 6 | 5 | 162 | 4 | **182** |
| | Hatchery | 0 | 0 | 5 | 0 | 1 | 2 | 178 | 0 | **186** |
| 1999 | Wild | 0 | 0 | 0 | 0 | 9 | 24 | 298 | 10 | **341** |
| | Hatchery | 0 | 0 | 3 | 2 | 14 | 29 | 468 | 38 | **554** |
| 2000 | Wild | 0 | 0 | 8 | 8 | 24 | 11 | 189 | 4 | **244** |
| | Hatchery | 0 | 2 | 12 | 7 | 23 | 5 | 538 | 37 | **624** |
| 2001 | Wild | 0 | 10 | 23 | 5 | 67 | 42 | 390 | 54 | **591** |
| | Hatchery | 0 | 16 | 52 | 5 | 60 | 70 | 751 | 51 | **1,005** |
| 2002 | Wild | 6 | 14 | 20 | 10 | 81 | 212 | 340 | 72 | **755** |
| | Hatchery | 4 | 18 | 63 | 25 | 123 | 360 | 925 | 187 | **1,705** |
| 2003 | Wild | 0 | 0 | 13 | 0 | 12 | 149 | 221 | 116 | **511** |
| | Hatchery | 0 | 0 | 15 | 0 | 5 | 91 | 364 | 257 | **732** |
| 2004 | Wild | 0 | 2 | 19 | 19 | 108 | 225 | 1,126 | 260 | **1,759** |
| | Hatchery | 0 | 2 | 12 | 5 | 38 | 58 | 266 | 38 | **419** |
| 2005 | Wild | 0 | 5 | 51 | 21 | 256 | 364 | 532 | 176 | **1,405** |
| | Hatchery | 0 | 3 | 42 | 16 | 115 | 67 | 199 | 100 | **542** |
| 2006 | Wild | 2 | 2 | 23 | 11 | 110 | 271 | 70 | 78 | **567** |
| | Hatchery | 2 | 1 | 8 | 5 | 10 | 20 | 443 | 22 | **511** |
| ***Average*** | ***Wild*** | ***1*** | ***2*** | ***12*** | ***5*** | ***51*** | ***94*** | ***264*** | ***57*** | ***485*** |
| | ***Hatchery*** | ***0*** | ***3*** | ***16*** | ***5*** | ***32*** | ***51*** | ***346*** | ***56*** | ***509*** |

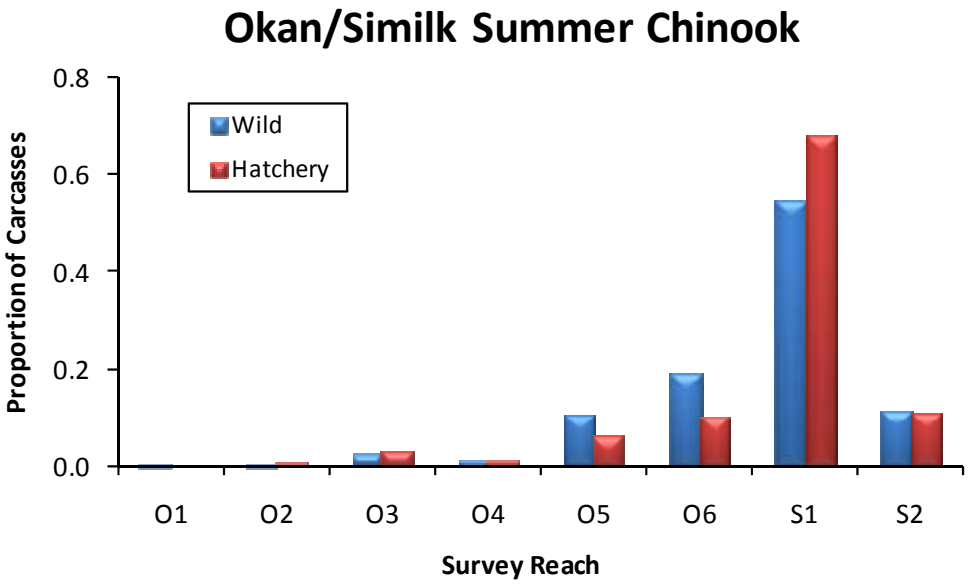


**Figure 8.4.** Distribution of wild and hatchery produced carcasses in different reaches in the Okanogan Basin, 1993-2006. Reach codes are described in Table 2.11.

### Sampling Rate

Overall, 39% of the total spawning escapement of summer Chinook in the Okanogan Basin was sampled in 2007 (Table 8.11). This was above the target of 20%. Sampling rates among survey reaches varied from 1 to 46%.

**Table 8.11.** Number of redds and carcasses, total spawning escapement, and sampling rates for summer Chinook in the Okanogan Basin, 2007.

| Sampling reach | Total number of redds | Total number of carcasses | Total spawning escapement | Sampling rate |
|---|---|---|---|---|
| Okanogan 1 | 3 | 2 | 7 | 0.30 |
| Okanogan 2 | 16 | 1 | 35 | 0.03 |
| Okanogan 3 | 116 | 48 | 255 | 0.19 |
| Okanogan 4 | 63 | 1 | 139 | 0.01 |
| Okanogan 5 | 549 | 459 | 1,208 | 0.38 |
| Okanogan 6 | 554 | 519 | 1,219 | 0.43 |
| Similkameen 1 | 652 | 657 | 1,434 | 0.46 |
| Similkameen 2 | 55 | 29 | 121 | 0.24 |
| ***Total*** | ***2,008*** | ***1,716*** | ***4,417*** | ***0.39*** |

### Length Data

Mean lengths (POH, cm) of male and female summer Chinook carcasses sampled during surveys on the Okanogan and Similkameen rives in 2007 are provided in Table 8.12. The average size of males and females sampled in the Okanogan basin were 64 cm and 76 cm, respectively.

**Table 8.12.** Mean lengths (postorbital-to-hypural length; cm) and standard deviations (in parentheses) of male and female summer Chinook carcasses sampled in different reaches in the Okanogan Basin, 2007.

| Stream/watershed | Mean length (cm) | |
|---|---|---|
| | Male | Female |
| Okanogan 1 | 41.5 (0) | 82.5 (0) |
| Okanogan 2 | 41.0 (0) | - |
| Okanogan 3 | 62.6 (15.6) | 74.1 (3.8) |
| Okanogan 4 | - | 78.5 (0) |
| Okanogan 5 | 64.8 (15.6) | 75.5 (5.4) |
| Okanogan 6 | 62.8 (14.8) | 74.0 (7.1) |
| Similkameen 1 | 66.4 (14.0) | 76.9 (36.7) |
| Similkameen 2 | 78.0 (4.6) | 74.2 (6.0) |
| ***Total*** | ***64.3 (14.9)*** | ***75.8 (25.7)*** |

## *8.6 Life History Monitoring*

Life history characteristics of Okanogan/Similkameen summer Chinook were assessed by examining carcasses on spawning grounds and fish collected or examined at broodstock collection sites, and by reviewing tagging data and fisheries statistics.

### Age at Maturity

Most of the wild and hatchery summer Chinook sampled during the period 1993-2006 in the Okanogan Basin were age-4 and 5 fish (total age) (Table 8.13; Figure 8.5). A higher percentage of age-3 and 4 wild Chinook returned to the basin than did age-3 and 4 hatchery Chinook. In contrast, a higher proportion of age-5 and 6 hatchery fish returned than did age-5 and 6 wild fish. Thus, a higher percentage of hatchery fish returned at an older age than did wild fish.

**Table 8.13.** Proportions of wild and hatchery summer Chinook of different ages (total age) sampled on spawning grounds in the Okanogan Basin, 1993-2006.

| Sample year | Origin | Total age | | | | | | Sample size |
|---|---|---|---|---|---|---|---|---|
| | | 2 | 3 | 4 | 5 | 6 | 7 | |
| 1993 | Wild | 0.00 | 0.00 | 0.76 | 0.24 | 0.00 | 0.00 | 63 |
| | Hatchery | 0.00 | 0.02 | 0.97 | 0.02 | 0.00 | 0.00 | 61 |
| 1994 | Wild | 0.00 | 0.03 | 0.42 | 0.55 | 0.00 | 0.00 | 135 |
| | Hatchery | 0.00 | 0.02 | 0.09 | 0.89 | 0.00 | 0.00 | 292 |
| 1995 | Wild | 0.00 | 0.01 | 0.26 | 0.72 | 0.00 | 0.00 | 68 |
| | Hatchery | 0.00 | 0.01 | 0.16 | 0.35 | 0.48 | 0.00 | 204 |
| 1996 | Wild | 0.00 | 0.14 | 0.50 | 0.36 | 0.00 | 0.00 | 36 |
| | Hatchery | 0.00 | 0.02 | 0.21 | 0.55 | 0.20 | 0.01 | 177 |
| 1997 | Wild | 0.00 | 0.00 | 0.05 | 0.66 | 0.29 | 0.00 | 73 |
| | Hatchery | 0.00 | 0.00 | 0.03 | 0.86 | 0.12 | 0.00 | 153 |
| 1998 | Wild | 0.00 | 0.03 | 0.64 | 0.34 | 0.00 | 0.00 | 151 |
| | Hatchery | 0.01 | 0.05 | 0.50 | 0.23 | 0.22 | 0.00 | 185 |
| 1999 | Wild | 0.00 | 0.00 | 0.33 | 0.66 | 0.00 | 0.00 | 275 |
| | Hatchery | 0.00 | 0.00 | 0.12 | 0.86 | 0.01 | 0.00 | 545 |
| 2000 | Wild | 0.01 | 0.07 | 0.28 | 0.63 | 0.02 | 0.00 | 216 |
| | Hatchery | 0.00 | 0.12 | 0.03 | 0.75 | 0.10 | 0.00 | 545 |
| 2001 | Wild | 0.02 | 0.15 | 0.75 | 0.07 | 0.00 | 0.00 | 531 |
| | Hatchery | 0.00 | 0.05 | 0.88 | 0.02 | 0.05 | 0.00 | 1,005 |
| 2002 | Wild | 0.01 | 0.11 | 0.65 | 0.23 | 0.00 | 0.00 | 692 |
| | Hatchery | 0.00 | 0.01 | 0.21 | 0.78 | 0.00 | 0.00 | 1,681 |
| 2003 | Wild | 0.01 | 0.02 | 0.76 | 0.21 | 0.00 | 0.00 | 478 |
| | Hatchery | 0.00 | 0.03 | 0.06 | 0.79 | 0.12 | 0.00 | 653 |
| 2004 | Wild | 0.00 | 0.12 | 0.11 | 0.76 | 0.01 | 0.00 | 1,529 |
| | Hatchery | 0.00 | 0.01 | 0.32 | 0.46 | 0.21 | 0.00 | 381 |
| 2005 | Wild | 0.00 | 0.08 | 0.76 | 0.14 | 0.02 | 0.00 | 1,282 |
| | Hatchery | 0.00 | 0.03 | 0.13 | 0.69 | 0.14 | 0.00 | 526 |
| 2006 | Wild | 0.00 | 0.01 | 0.47 | 0.51 | 0.01 | 0.00 | 839 |
| | Hatchery | 0.01 | 0.06 | 0.26 | 0.27 | 0.40 | 0.00 | 112 |
| ***Average*** | ***Wild*** | ***0.00*** | ***0.08*** | ***0.49*** | ***0.42*** | ***0.01*** | ***0.00*** | ***6,368*** |
| | ***Hatchery*** | ***0.00*** | ***0.03*** | ***0.27*** | ***0.61*** | ***0.09*** | ***0.00*** | ***6,520*** |

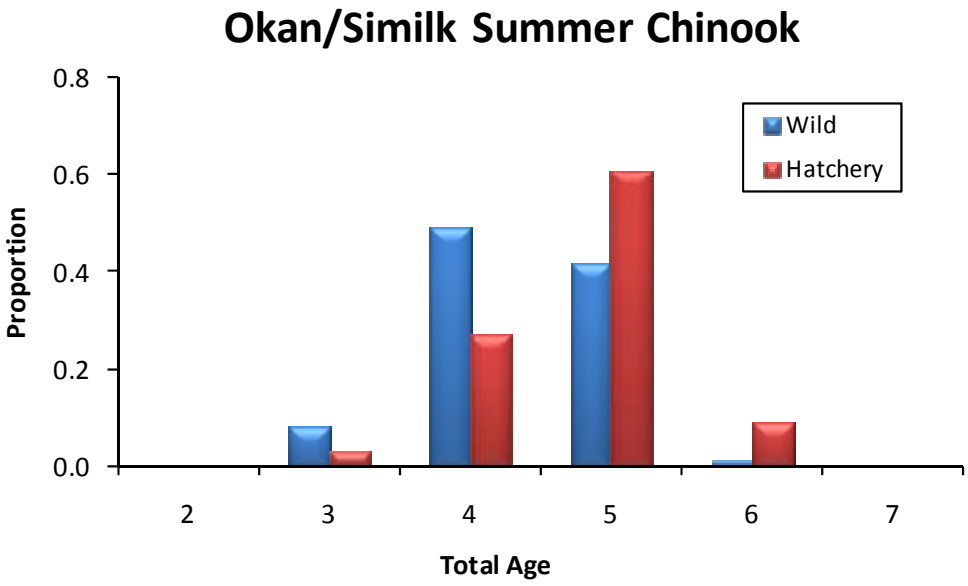


**Figure 8.5.** Proportions of wild and hatchery summer Chinook of different total ages sampled at broodstock collection sites and on spawning grounds in the Okanogan Basin for the combined years 1993-2006.

### Size at Maturity

On average, hatchery summer Chinook were about 1 cm smaller than wild summer Chinook sampled in the Okanogan Basin (Table 8.14). This is interesting given that a slightly higher percentage of hatchery fish returned as age-5 and 6 fish than did wild fish. Future analyses will compare sizes of hatchery and wild fish of the same age groups and gender.

**Table 8.14.** Mean lengths (POH; cm) and variability statistics for wild and hatchery summer Chinook sampled in the Okanogan Basin, 1993-2006; SD = 1 standard deviation.

| Sample year | Origin | Sample size | Summer Chinook length (POH; cm) | | | |
|---|---|---|---|---|---|---|
| | | | Mean | SD | Minimum | Maximum |
| 1993 | Wild | 69 | 73 | 7 | 52 | 90 |
| | Hatchery | 59 | 62 | 6 | 47 | 75 |
| 1994 | Wild | 164 | 71 | 7 | 40 | 86 |
| | Hatchery | 300 | 69 | 8 | 30 | 84 |
| 1995 | Wild | 81 | 75 | 6 | 54 | 87 |
| | Hatchery | 201 | 73 | 8 | 39 | 87 |
| 1996 | Wild | 22 | 68 | 14 | 22 | 85 |
| | Hatchery | 26 | 75 | 8 | 60 | 88 |
| 1997 | Wild | 87 | 71 | 7 | 44 | 85 |
| | Hatchery | 148 | 74 | 6 | 48 | 88 |
| 1998 | Wild | 182 | 70 | 8 | 45 | 94 |
| | Hatchery | 186 | 65 | 12 | 30 | 87 |
| 1999 | Wild | 340 | 73 | 7 | 56 | 91 |

| Sample year | Origin | Sample size | Summer Chinook length (POH; cm) | | | |
|---|---|---|---|---|---|---|
| | | | Mean | SD | Minimum | Maximum |
| | Hatchery | 554 | 71 | 7 | 23 | 84 |
| 2000 | Wild | 241 | 70 | 10 | 32 | 86 |
| | Hatchery | 624 | 69 | 12 | 24 | 92 |
| 2001 | Wild | 579 | 67 | 9 | 26 | 90 |
| | Hatchery | 997 | 61 | 8 | 32 | 90 |
| 2002 | Wild | 755 | 69 | 9 | 28 | 91 |
| | Hatchery | 1,705 | 70 | 8 | 33 | 87 |
| 2003 | Wild | 533 | 68 | 9 | 30 | 93 |
| | Hatchery | 732 | 69 | 10 | 26 | 90 |
| 2004 | Wild | 1,757 | 71 | 10 | 33 | 94 |
| | Hatchery | 416 | 66 | 9 | 41 | 92 |
| 2005 | Wild | 1,407 | 66 | 7 | 41 | 99 |
| | Hatchery | 542 | 68 | 8 | 31 | 85 |
| 2006 | Wild | 940 | 72 | 6 | 31 | 91 |
| | Hatchery | 138 | 70 | 10 | 33 | 86 |
| ***Pooled*** | ***Wild*** | ***7,157*** | ***70*** | ***8*** | ***22*** | ***99*** |
| | ***Hatchery*** | ***6,628*** | ***69*** | ***9*** | ***23*** | ***92*** |

## Contribution to Fisheries

Most of the harvest on Okanogan/Similkameen summer Chinook occurred in the Ocean (Table 8.15). Ocean harvest has made up 69% to 100% of all Okanogan/Similkameen summer Chinook harvested. Brood years 1989 and 1997-2000 provided the largest harvests, while brood year 1996 provided the lowest.

**Table 8.15.** Estimated number and percent (in parentheses) of Okanogan/Similkameen summer Chinook captured in different fisheries, 1989-2000.

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational (sport) | |
| 1989 | 2,325 (79) | 351 (12) | 200 (7) | 79 (3) | 2,955 |
| 1990 | 334 (88) | 27 (7) | 7 (2) | 12 (3) | 380 |
| 1991 | 215 (85) | 37 (15) | 0 (0) | 0 (0) | 252 |
| 1992 | 434 (92) | 24 (5) | 6 (1) | 10 (2) | 474 |
| 1993 | 37 (79) | 10 (21) | 0 (0) | 0 (0) | 47 |
| 1994 | 884 (92) | 41 (4) | 18 (2) | 17 (2) | 960 |
| 1995 | 614 (93) | 3 (0) | 18 (3) | 24 (4) | 659 |
| 1996 | 4 (100) | 0 (0) | 0 (0) | 0 (0) | 4 |
| 1997 | 6,371 (92) | 89 (1) | 80 (1) | 416 (6) | 2,956 |

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational (sport) | |
| 1998 | 4,343 (89) | 8 (0) | 299 (6) | 117 (4) | 4,897 |
| 1999 | 1,322 (69) | 8 (0) | 227 (12) | 371 (19) | 1,928 |
| 2000 | 3,261 (75) | 3 (0) | 443 (10) | 613 (14) | 4,320 |
| 2001 | 178 (72) | 0 (0) | 48 (19) | 21 (9) | 247 |

## Straying

Stray rates were determined by examining CWTs recovered on spawning grounds within and outside the Okanogan Basin. Targets for strays based on return year (recovery year) and brood year should be less than 5%.

Rates of Okanogan summer Chinook straying into basins outside the Okanogan have been very low (Table 8.16). Although a few Okanogan summer Chinook have strayed into other spawning areas, straying, on average, has been less than 5%. The Chelan tailrace has received the largest number of Okanogan strays.

**Table 8.16.** Number and percent of spawning escapements within other non-target basins that consisted of Okanogan summer Chinook, return years 1994-2004. For example, for return year 2002, 1% of the summer Chinook spawning escapement in the Entiat Basin consisted of Okanogan summer Chinook. Percent strays should be less than 5%.

| Return year | Wenatchee | | Methow | | Chelan | | Entiat | | Hanford Reach | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Number | % | Number | % | Number | % | Number | % | Number | % |
| 1994 | 0 | 0.0 | 0 | 0.0 | - | - | - | - | - | - |
| 1995 | 0 | 0.0 | 0 | 0.0 | - | - | - | - | - | - |
| 1996 | 0 | 0.0 | 0 | 0.0 | - | - | - | - | - | - |
| 1997 | 0 | 0.0 | 0 | 0.0 | - | - | - | - | - | - |
| 1998 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1999 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2000 | 0 | 0.0 | 6 | 0.5 | 30 | 4.5 | 0 | 0.0 | 3 | 0.0 |
| 2001 | 12 | 0.1 | 0 | 0.0 | 10 | 1.0 | 0 | 0.0 | 0 | 0.0 |
| 2002 | 0 | 0.0 | 3 | 0.1 | 4 | 0.7 | 5 | 1.0 | 0 | 0.0 |
| 2003 | 0 | 0.0 | 8 | 0.2 | 22 | 5.3 | 0 | 0.0 | 0 | 0.0 |
| 2004 | 0 | 0.0 | 27 | 1.2 | 36 | 8.6 | 0 | 0.0 | 8 | 0.0 |
| ***Total*** | ***12*** | ***0.0*** | ***44*** | ***0.2*** | ***102*** | ***3.1*** | ***5*** | ***0.2*** | ***11*** | ***0.0*** |

On average, less than 1% of the returns have strayed into non-target spawning areas, falling below the target of 5% (Table 8.17). Depending on brood year, percent strays into non-target spawning areas have ranged from 0-4.4%. Few (<2% on average) have strayed into non-target hatchery programs.

**Table 8.17.** Number and percent of Okanogan summer Chinook that homed to target spawning areas and the target hatchery, and number and percent that strayed to non-target spawning areas and non-target hatchery programs, by brood years 1989-2001. Percent stays should be less than 5%.

| Brood year | Homing | | | | Straying | | | |
|---|---|---|---|---|---|---|---|---|
| | Target stream | | Target hatchery | | Non-target streams | | Non-target hatcheries | |
| | Number | % | Number | % | Number | % | Number | % |
| 1989 | 3,132 | 69.7 | 1,328 | 29.6 | 2 | 0.0 | 31 | 0.7 |
| 1990 | 729 | 71.4 | 291 | 28.5 | 0 | 0.0 | 1 | 0.1 |
| 1991 | 1,125 | 71.3 | 453 | 28.7 | 0 | 0.0 | 0 | 0.0 |
| 1992 | 1,264 | 68.5 | 572 | 31.0 | 8 | 0.4 | 1 | 0.1 |
| 1993 | 84 | 61.3 | 51 | 37.2 | 0 | 0.0 | 2 | 1.5 |
| 1994 | 2,174 | 80.8 | 478 | 17.8 | 38 | 1.4 | 2 | 0.1 |
| 1995 | 1,883 | 85.4 | 271 | 12.3 | 50 | 2.3 | 0 | 0.0 |
| 1996 | 27 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1997 | 11,629 | 97.2 | 309 | 2.6 | 27 | 0.2 | 3 | 0.0 |
| 1998 | 2,727 | 95.6 | 99 | 3.5 | 24 | 0.8 | 2 | 0.1 |
| 1999 | 828 | 96.7 | 18 | 2.1 | 10 | 1.2 | 0 | 0.0 |
| 2000 | 1,590 | 93.5 | 20 | 1.2 | 75 | 4.4 | 15 | 0.9 |
| 2001 | 28 | 100.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| ***Total*** | ***27,220*** | ***86.7*** | ***3,890*** | ***12.4*** | ***234*** | ***0.7*** | ***57*** | ***0.2*** |

### Genetics

Tissue (operculum) samples were collected from 144 wild and 144 hatchery summer Chinook in the Okanogan basin in 2006. Results from these samples should be available in 2008.

### Proportion of Natural Influence

Another method for assessing the genetic risk of a supplementation program is to determine the influence of the hatchery and natural environments on the adaptation of the composite population. This is estimated by the proportion of natural origin fish in the hatchery broodstock (pNOB) and the proportion of hatchery origin fish in the natural spawning escapement (pHOS). The ratio pNOB/(pHOS+pNOB) is the Proportion of Natural Influence (PNI). The larger the ratio (PNI), the greater the strength of selection in the natural environment relative to that of the hatchery environment. In order for the natural environment to dominate selection, PNI should be greater than 0.5 (HSRG/WDFW/NWIFC 2004).

For brood years 1989-2005, the PNI was equal to or greater than 0.5 in 8 out of the 17 years (Table 8.18). This indicates that in those years the hatchery environment has had a relatively greater influence on adaptation of Okanogan/Similkameen summer Chinook than has the natural environment.

**Table 8.18.** Proportionate natural influence (PNI) of the Okanogan/Similkameen summer Chinook supplementation program for brood years 1989-2005. PNI was calculated as the proportion of naturally produced Chinook in the hatchery broodstock (pNOB) divided by the proportion of hatchery Chinook on the spawning grounds (pHOS) plus pNOB. NOS = number of natural origin Chinook on the spawning grounds; HOS = number of hatchery origin Chinook on the spawning grounds; NOB = number of natural origin Chinook collected for broodstock; and HOB = number of hatchery origin Chinook included in hatchery broodstock.

| Brood year | Spawners | | | Broodstock | | | PNI |
|---|---|---|---|---|---|---|---|
| | NOS | HOS | pHOS | NOB | HOB | pNOB | |
| 1989 | 1,782 | 0 | 0.00 | 1,297 | 312 | 0.81 | 1.00 |
| 1990 | 881 | 0 | 0.00 | 828 | 206 | 0.80 | 1.00 |
| 1991 | 574 | 0 | 0.00 | 924 | 314 | 0.75 | 1.00 |
| 1992 | 473 | 0 | 0.00 | 297 | 406 | 0.42 | 1.00 |
| 1993 | 731 | 754 | 0.51 | 681 | 388 | 0.64 | 0.56 |
| 1994 | 1,409 | 2,623 | 0.65 | 341 | 244 | 0.58 | 0.47 |
| 1995 | 889 | 2,113 | 0.70 | 173 | 240 | 0.42 | 0.38 |
| 1996 | 579 | 1,240 | 0.68 | 290 | 223 | 0.57 | 0.46 |
| 1997 | 760 | 1,429 | 0.65 | 198 | 264 | 0.43 | 0.40 |
| 1998 | 576 | 516 | 0.47 | 153 | 211 | 0.42 | 0.47 |
| 1999 | 1,426 | 2,190 | 0.61 | 224 | 289 | 0.44 | 0.42 |
| 2000 | 1,273 | 2,428 | 0.66 | 164 | 339 | 0.33 | 0.33 |
| 2001 | 4,614 | 6,242 | 0.57 | 91 | 266 | 0.25 | 0.30 |
| 2002 | 4,149 | 9,709 | 0.70 | 247 | 241 | 0.51 | 0.42 |
| 2003 | 1,971 | 1,449 | 0.42 | 381 | 101 | 0.79 | 0.65 |
| 2004 | 5,262 | 1,518 | 0.22 | 506 | 16 | 0.97 | 0.82 |
| 2005 | 6,464 | 2,426 | 0.27 | 391 | 9 | 0.98 | 0.78 |

### Natural Replacement Rates

Natural replacement rates (NRR) were calculated as the ratio of natural origin recruits (NOR) to the parent spawning population. For brood years 1989-2000, NRR for summer Chinook in the Okanogan Basin averaged 1.08 (range, 0.32-4.00) if harvested fish were not include in the estimate and 2.91 (range, 0.52-13.59) if harvested fish were included in the estimate (Table 8.19). NRRs for more recent brood years will be calculated as soon as all tag recoveries and sampling rates have been loaded into the database.

**Table 8.19.** Spawning escapements, natural origin recruits (NOR), and natural replacement rates (NRR; with and without harvest) for wild summer Chinook in the Okanogan Basin, 1989-2000. *(The numbers in this table may change as the HETT and HC refine the methods for estimating summer Chinook NORs and NRRs.)*

| Brood year | Spawning escapement | Harvest not included | | Harvest included | |
|---|---|---|---|---|---|
| | | NOR | NRR | NOR | NRR |
| 1989 | 1,763 | 2,150 | 1.22 | 3,658 | 2.08 |
| 1990 | 660 | 1,599 | 2.42 | 2,255 | 3.42 |
| 1991 | 574 | 578 | 1.01 | 887 | 1.55 |
| 1992 | 473 | 759 | 1.61 | 1,142 | 2.41 |
| 1993 | 1,485 | 779 | 0.52 | 1,031 | 0.69 |
| 1994 | 4,032 | 1,295 | 0.32 | 2,087 | 0.52 |
| 1995 | 3,002 | 1,993 | 0.66 | 3,861 | 1.29 |
| 1996 | 1,819 | 930 | 0.51 | 2,412 | 1.33 |
| 1997 | 2,190 | 3,822 | 1.75 | 11,565 | 5.28 |
| 1998 | 1,092 | 4,368 | 4.00 | 14,841 | 13.59 |
| 1999 | 3,617 | 6,312 | 1.75 | 21,826 | 6.03 |
| 2000 | 3,701 | 1,746 | 0.47 | 5,575 | 1.51 |
| ***Average*** | ***2,034*** | ***2,194*** | ***1.08*** | ***5,928*** | ***2.91*** |

## Hatchery Replacement Rates

Hatchery replacement rates were estimated as hatchery adult-to-adult returns. These rates should be greater than the NRRs and greater than or equal to 5.30 (the value in BAMP; Murdoch and Peven 2005). HRRs exceeded NRRs in 10 of the 12 years of data, regardless if harvest was or was not included in the estimate (Table 8.20). Hatchery replacement rates (harvest included in the estimate) for Okanogan/Similkameen summer Chinook have exceeded the BAMP target of 5.30 in 8 of the 12 years of data.

**Table 8.20.** Hatchery replacement rates (HRR), NRR, and BAMP target (5.30) for summer Chinook in the Okanogan Basin, 1989-2000. *(The numbers in this table may change as the HETT and HC refine the methods for estimating summer Chinook HRRs and NRRs.)*

| Brood year | Harvest not included | | | Harvest included | | |
|---|---|---|---|---|---|---|
| | HRR | NRR | BAMP | HRR | NRR | BAMP |
| 1989 | 14.78 | 1.22 | 5.30 | 24.50 | 2.08 | 5.30 |
| 1990 | 3.55 | 2.42 | 5.30 | 4.86 | 3.42 | 5.30 |
| 1991 | 4.34 | 1.01 | 5.30 | 5.03 | 1.55 | 5.30 |
| 1992 | 6.07 | 1.61 | 5.30 | 7.63 | 2.41 | 5.30 |
| 1993 | 0.42 | 0.52 | 5.30 | 0.56 | 0.69 | 5.30 |
| 1994 | 8.91 | 0.32 | 5.30 | 12.09 | 0.52 | 5.30 |
| 1995 | 5.72 | 0.66 | 5.30 | 7.44 | 1.29 | 5.30 |
| 1996 | 0.08 | 0.51 | 5.30 | 0.09 | 1.33 | 5.30 |
| 1997 | 38.24 | 1.75 | 5.30 | 60.46 | 5.28 | 5.30 |

| Brood year | Harvest not included | | | Harvest included | | |
|---|---|---|---|---|---|---|
| | HRR | NRR | BAMP | HRR | NRR | BAMP |
| 1998 | 8.10 | 4.00 | 5.30 | 22.01 | 13.59 | 5.30 |
| 1999 | 2.57 | 1.75 | 5.30 | 8.36 | 6.03 | 5.30 |
| 2000 | 5.09 | 0.47 | 5.30 | 18.02 | 1.51 | 5.30 |
| ***Average*** | ***7.97*** | ***1.08*** | ***5.30*** | ***14.02*** | ***2.91*** | ***5.30*** |

### Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adults divided by the number of hatchery smolts released. SARs were based on CWT returns. For the available brood years, SARs have ranged from 0.00006 to 0.03216 for hatchery summer Chinook in the Okanogan Basin (Table 8.21).

**Table 8.21.** Smolt-to-adult ratios (SARs) for Okanogan/Similkameen summer Chinook; NA = not available.

| Brood year | Number of smolts released | Estimated adult captures | SAR |
|---|---|---|---|
| 1989 | 202,125 | 4,287 | 0.02121 |
| 1990 | 367,207 | 958 | 0.00261 |
| 1991 | 360,380 | 975 | 0.00271 |
| 1992 | 537,190 | 2,294 | 0.00427 |
| 1993 | 379,139 | 117 | 0.00031 |
| 1994 | 217,818 | 1,528 | 0.00702 |
| 1995 | 574,197 | 2,813 | 0.00490 |
| 1996 | 487,776 | 30 | 0.00006 |
| 1997 | 572,531 | 18,415 | 0.03216 |
| 1998 | 287,948 | 7,646 | 0.02655 |
| 1999 | 610,868 | 2,715 | 0.00444 |
| 2000 | 528,639 | 5,998 | 0.01135 |
| 2001 | 26,315 | 275 | 0.01045 |
| ***Average*** | ***396,318*** | ***3,696*** | ***0.009326*** |

## *8.7 ESA/HCP Compliance*

### Broodstock Collection

Because summer Chinook adults collected at Wells Dam are used for both the Methow and Okanogan supplementation programs, please refer to Section 7.7 for information on ESA compliance during broodstock collection.

### Hatchery Rearing and Release

The 2005 brood Okanogan/Similkameen summer Chinook reared throughout their juvenile life-stages at Eastbank Fish Hatchery and Similkameen Acclimation ponds without incident; although there was minor mortality associated with bacterial gill disease (see Sections 8.2 and 8.3). The 2005 brood Okanogan/Similkameen summer Chinook transferred and reared at the Bonaparte pond suffered near complete loss because of bacterial gill disease (see Section 8.3).

The 2005 brood smolt release from the Similkameen pond totaled 275,919 summer Chinook, representing 47.9% of the production objective for the Okanogan/Similkameen program and was within the maximum production levels authorized in ESA Section 10 Permit 1347. The shortfall in production was primarily associated with a shortfall in the number a females collected for brood because of a male-skewed sex ratio in the broodstock (Table 7.4). The 2005 brood smolt release from Bonaparte Pond was estimated to be zero and was influenced by sever mortality associated with bacterial gill disease (see Section 8.3).

### Hatchery Effluent Monitoring

Per ESA Permits 1196, 1347, and 1395, permit holders shall monitor and report hatchery effluents in compliance with applicable National Pollution Discharge Elimination Systems (NPDES) (EPA 1999) permit limitations. There were no NPDES violations reported at Chelan PUD Hatchery facilities during the period 1 January 2007 through 31 December 2007. NPDES monitoring and reporting for Chelan PUD Hatchery Programs during 2007 are provided in Appendix E.

### Spawning Surveys

Summer Chinook spawning ground surveys conducted in the Okanogan Basin during 2007 were consistent with ESA Section 10 Permit No. 1347. Because of the difficulty of quantifying the level of take associated with spawning ground surveys, the Permit does not specify a take level associated with these activities, even though it does authorize implementation of spawning ground surveys. Therefore, no take levels are reported. However, to minimize potential impacts to established redds, wading was restricted to the extent practical, and extreme caution was used to avoid established redds when wading was required.

# SECTION 9: TURTLE ROCK SUMMER CHINOOK

## 9.1 Broodstock Sampling

Broodstock for the Turtle Rock programs (yearling and sub-yearling) are collected as part of the Wells summer Chinook volunteer program. Refer to Snow et al. (2003) for information related to adults collected for these programs.

## 9.2 Hatchery Rearing

### Rearing History

#### *Number of eggs taken*

Broodstock for the Turtle Rock summer Chinook are collected at Wells Dam and consist of volunteers to the hatchery. In recent years some naturally produced fish have been incorporated into the brood. Eyed eggs are transferred from Wells FH to Eastbank FH for rearing. As such, the number of green (unfertilized) eggs collected for this program is reported as part of the Wells summer Chinook program.

#### *Disease*

Within the normal and accelerated subyearling program, the primary cause of mortality in the early life stages (swim-up to early ponding) continues to be coagulated yolk as a result of elevated incubation water temperature. Both subyearling groups began exhibiting signs of *Columnaris* shortly before release. As a result of a two week delay in availability of medicated feed, the only solution was to release as soon as possible. The yearling program had no significant health concerns during rearing and no treatments were recommended.

#### *Number of acclimation days*

Rearing of the 2005-brood normal and accelerated subyearling Turtle Rock summer Chinook was similar to previous years with fish being held on well water before being transferred to Turtle Rock for final acclimation in May 2006. Fish were released on 3 and 5 July 2006 after 35 days of acclimation on Columbia River water. One group of yearling Turtle Rock summer Chinook was released on 27 April 2007, after 179 days of acclimation on Columbia River water. The Chelan River net pen group was released on 12 May, after 73 days of acclimation on Chelan River water.

### Release Information

#### *Numbers released*

The 2005 subyearling Turtle Rock summer Chinook program achieved 60.5% of the 810,000 target goal with about 490,074 fish being released (Table 9.1). The 2005 accelerated subyearling summer Chinook program achieved 56.5% of the 810,000 target goal with about 457,340 fish being released (Table 9.2). The 2005 yearling summer Chinook program achieved 102.3% of the 200,000 target goal with about 204,644 fish being released (104,984 from Turtle Rock and 99,660 from the Chelan River net pens) (Table 9.3).

**Table 9.1.** Numbers of Turtle Rock summer Chinook subyearlings released from the hatchery, 1995-2005. The release target for Turtle Rock summer Chinook subyearlings is 810,000 fish.

| Brood year | Release year | Number of smolts |
|---|---|---|
| 1995 | 1996 | 1,074,600 |
| 1996 | 1997 | 385,215 |
| 1997 | 1998 | 508,060 |
| 1998 | 1999 | 301,777 |
| 1999 | 2000 | 369,026 |
| 2000 | 2001 | 604,892 |
| 2001 | 2002 | 214,059 |
| 2002 | 2003 | 656,399 |
| 2003 | 2004 | 491,480 |
| 2004 | 2005 | 411,707 |
| 2005 | 2006 | 490,074 |
| ***Average*** | | ***500,663*** |

**Table 9.2.** Numbers of Turtle Rock summer Chinook accelerated subyearlings released from the hatchery, 1995-2005. The release target for Turtle Rock summer Chinook accelerated subyearlings is 810,000 fish.

| Brood year | Release year | Number of smolts |
|---|---|---|
| 1995 | 1996 | 169,000 |
| 1996 | 1997 | 477,300 |
| 1997 | 1998 | 521,480 |
| 1998 | 1999 | 307,571 |
| 1999 | 2000 | 347,946 |
| 2000 | 2001 | 449,329 |
| 2001 | 2002 | 480,584 |
| 2002 | 2003 | 364,461 |
| 2003 | 2004 | 289,696 |
| 2004 | 2005 | 364,453 |
| 2005 | 2006 | 457,340 |
| ***Average*** | | ***384,469*** |

**Table 9.3.** Numbers of Turtle Rock summer Chinook yearling smolts released from the hatchery, 1995-2005. The release target for Turtle Rock summer Chinook is 200,000 smolts.

| Brood year | Release year | Number of smolts |
|---|---|---|
| 1995 | 1997 | 150,00 |
| 1996 | 1998 | 202,727 |
| 1997 | 1999 | 202,989 |
| 1998 | 2000 | 217,797 |

| Brood year | Release year | Number of smolts |
|---|---|---|
| 1999 | 2001 | 285,707 |
| 2000 | 2002 | 165,935 |
| 2001 | 2003 | 203,279 |
| 2002 | 2004 | 195,851 |
| 2003 | 2005 | 215,366 |
| 2004 | 2006 | 206,734 |
| 2005 | 2007 | 204,644 |
| ***Average*** | | ***210,103*** |

### *Numbers tagged*

About 97.8% of the Turtle Rock accelerated subyearling Chinook and 43.4% of the normal subyearling Chinook were adipose fin-clipped and CWT. The remaining fish were released untagged and unmarked. The yearling Chinook were 98.1% CWT and adipose fin-clipped. No 2005 brood Turtle Rock summer Chinook were PIT tagged.

### *Fish size and condition at release*

Size at release of the normal subyearling Turtle Rock summer Chinook was 89.3% and 109.6% of the target fork length and weight, respectively. This brood year was below the target CV for length by 28% (Table 9.4).

**Table 9.4.** Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Turtle Rock summer Chinook subyearlings released from the hatchery, 1995-2005. Size targets are provided in the last row of the table.

| Brood year | Release year | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| 1995 | 1996 | 102 | 6.3 | 12.6 | 36 |
| 1996 | 1997 | 87 | 8.0 | 7.4 | 62 |
| 1997 | 1998 | 98 | 6.2 | 10.2 | 45 |
| 1998 | 1999 | 96 | 6.3 | 10.7 | 43 |
| 1999 | 2000 | 90 | 9.0 | 9.8 | 46 |
| 2000 | 2001 | 100 | 7.1 | 11.3 | 40 |
| 2001 | 2002 | 104 | 7.2 | 13.4 | 34 |
| 2002 | 2003 | 97 | 7.3 | 11.8 | 39 |
| 2003 | 2004 | 101 | 8.0 | 12.0 | 43 |
| 2004 | 2005 | 100 | 7.8 | 11.4 | 40 |
| 2005 | 2006 | 100 | 6.5 | 12.5 | 36 |
| ***Targets*** | | ***112*** | ***9.0*** | ***11.4*** | ***40*** |

Size at release of the accelerated subyearling Turtle Rock Chinook was 106.3% and 194.7% of the target fork length and weight, respectively. This brood year exceeded the target CV for length by 1% (Table 9.5).

**Table 9.5.** Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Turtle Rock summer Chinook accelerated subyearlings released from the hatchery, 1995-2005. Size targets are provided in the last row of the table.

| Brood year | Release year | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| 1995 | 1996 | 129 | 7.1 | 27.3 | 17 |
| 1996 | 1997 | 107 | 6.5 | 15.6 | 29 |
| 1997 | 1998 | 117 | 6.0 | 18.9 | 24 |
| 1998 | 1999 | 119 | 8.0 | 18.9 | 24 |
| 1999 | 2000 | 114 | 6.7 | 19.0 | 24 |
| 2000 | 2001 | 111 | 7.0 | 16.8 | 27 |
| 2001 | 2002 | 117 | 8.4 | 19.5 | 23 |
| 2002 | 2003 | 116 | 11.3 | 21.2 | 21 |
| 2003 | 2004 | 113 | 14.9 | 17.0 | 30 |
| 2004 | 2005 | 117 | 11.3 | 20.1 | 23 |
| 2005 | 2006 | 119 | 9.1 | 22.2 | 21 |
| ***Targets*** | | ***112*** | ***9.0*** | ***11.4*** | ***40*** |

Size at release of the yearling Turtle Rock summer Chinook was 89.8% and 95.8% of the target fork length and weight, respectively. This brood year exceeded the target CV for length by 122% (Table 9.6).

**Table 9.6.** Mean lengths (FL, mm), weight (g and fish/pound), and coefficient of variation (CV) of Turtle Rock summer Chinook yearlings released from the hatchery, 1995-2005. Size targets are provided in the last row of the table.

| Brood year | Release year | Fork length (mm) | | Mean weight | |
|---|---|---|---|---|---|
| | | Mean | CV | Grams (g) | Fish/pound |
| 1995 | 1997 | - | - | - | - |
| 1996 | 1998 | 166 | 14.2 | 60.9 | 7 |
| 1997 | 1999 | 198 | 4.6 | 91.3 | 5 |
| 1998 | 2000 | 161 | 11.9 | 53.9 | 8 |
| 1999 | 2001 | 164 | 18.6 | 59.0 | 8 |
| 2000 | 2002 | 170 | 15.3 | 59.0 | 8 |
| 2001 | 2003 | 154 | 22.3 | 48.6 | 9 |
| 2002 | 2004 | 157 | 16.7 | 44.0 | 12 |
| 2003 | 2005 | 173 | 13.8 | 54.7 | 8 |
| 2004 | 2006 | 176 | 20.6 | 45.3 | 7 |
| 2005 | 2007 | 158 | 11.0 | 43.5 | 10 |

| | | | | |
|---|---|---|---|---|
| ***Targets*** | ***176.0*** | ***9.0*** | ***45.4*** | ***10.0*** |

## Survival Estimates

### *Normal subyearling releases*

Overall survival of the normal subyearling Turtle Rock summer Chinook program from green egg to release was below the standard set for the program (Table 9.7). Lower than expected survival at ponding and post-ponding (because of coagulated yolk) reduced the overall program performance.

**Table 9.7.** Hatchery life-stage survival rates (%) for Turtle Rock subyearling (zero program) summer Chinook, brood years 2004-2005. Survival standards or targets are provided in the last row of the table.

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 2004 | NA | NA | 93.5 | 74.4 | 93.9 | 91.4 | 90.8 | 99.7 | 63.1 |
| 2005 | NA | NA | 94.4 | 87.9 | 85 | 84.8 | 84.2 | 99.4 | 69.8 |
| ***Standard*** | ***90.0*** | ***85.0*** | ***92.0*** | ***98.0*** | ***97.0*** | ***93.0*** | ***90.0*** | ***95.0*** | ***81.0*** |

### *Accelerated subyearling releases*

Overall survival of the accelerated subyearling Turtle Rock summer Chinook program from green egg to release was below the standard set for the program (Table 9.8). Lower than expected survival at ponding and post-ponding (because of coagulated yolk) reduced the overall program performance.

**Table 9.8.** Hatchery life-stage survival rates (%) for Turtle Rock subyearling (accelerated program) summer Chinook, brood years 2004-2005. Survival standards or targets are provided in the last row of the table.

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 2004 | NA | NA | 92.5 | 98.3 | 93.4 | 92.4 | 90.0 | 97.8 | 81.8 |
| 2005 | NA | NA | 93.8 | 94.6 | 83.7 | 83.4 | 81.7 | 98.8 | 72.5 |
| ***Standard*** | ***90.0*** | ***85.0*** | ***92.0*** | ***98.0*** | ***97.0*** | ***93.0*** | ***90.0*** | ***95.0*** | ***81.0*** |

### *Yearling releases*

Overall survival of the yearling Turtle Rock summer Chinook program from green egg to release was above the standard set for the program (Table 9.9). However, lower than expected survival between fertilization and ponding reduced the overall program performance.

**Table 9.9.** Hatchery life-stage survival rates (%) for Turtle Rock yearling summer Chinook, brood years 2004-2005. Survival standards or targets are provided in the last row of the table.

| Brood year | Collection to spawning | | Unfertilized egg-eyed | Eyed egg-ponding | 30 d after ponding | 100 d after ponding | Ponding to release | Transport to release | Unfertilized egg-release |
|---|---|---|---|---|---|---|---|---|---|
| | Female | Male | | | | | | | |
| 2004 | NA | NA | 92.9 | 97.7 | 96.8 | 96.4 | 95.5 | 99.6 | 86.7 |
| 2005 | NA | NA | 89.1 | 97.5 | 98.1 | 97.8 | 96.6 | 99.1 | 83.9 |
| ***Standard*** | ***90.0*** | ***85.0*** | ***92.0*** | ***98.0*** | ***97.0*** | ***93.0*** | ***90.0*** | ***95.0*** | ***81.0*** |

## 9.3 Life History Monitoring

Life history characteristics of Turtle Rock summer Chinook were assessed by examining carcasses on spawning grounds and by reviewing tagging data and fisheries statistics.

### Contribution to Fisheries

#### *Normal subyearling releases*

Most of the harvest on Turtle Rock summer Chinook (normal subyearling releases) occurred in the Ocean (Table 9.10). Ocean harvest has made up 59% to 100% of all Turtle Rock summer Chinook harvested. Brood year 1995 provided the largest harvest, while brood year 1997 provided the lowest.

**Table 9.10.** Estimated number and percent (in parentheses) of Turtle Rock summer Chinook (normal subyearling releases) captured in different fisheries.

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational (sport) | |
| 1995 | 682 (84) | 5 (1) | 112 (14) | 16 (2) | 815 |
| 1996 | 72 (80) | 0 (0) | 5 (6) | 13 (14) | 90 |
| 1997 | 9 (100) | 0 (0) | 0 (0) | 0 (0) | 9 |
| 1998 | 24 (100) | 0 (0) | 0 (0) | 0 (0) | 24 |
| 1999 | 583 (76) | 7 (1) | 75 (10) | 100 (13) | 765 |
| 2000 | 36 (59) | 0 (0) | 11 (18) | 14 (23) | 61 |
| 2001 | 165 (73) | 0 (0) | 29 (13) | 31 (14) | 225 |

#### *Accelerated subyearling releases*

Most of the harvest on Turtle Rock summer Chinook (accelerated subyearling releases) occurred in the Ocean (Table 9.11). Ocean harvest has made up 62% to 100% of all Turtle Rock summer Chinook harvested. Brood year 2001 provided the largest harvest, while brood years 1995 and 1997 provided the lowest.

**Table 9.11.** Estimated number and percent (in parentheses) of Turtle Rock summer Chinook (accelerated subyearling releases) captured in different fisheries.

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational (sport) | |
| 1995 | 3 (100) | 0 (0) | 0 (0) | 0 (0) | 3 |
| 1996 | 72 (88) | 0 (0) | 10 (12) | 0 (0) | 82 |
| 1997 | 3 (100) | 0 (0) | 0 (0) | 0 (0) | 3 |
| 1998 | 93 (95) | 2 (2) | 3 (3) | 0 (0) | 98 |
| 1999 | 93 (62) | 2 (1) | 14 (9) | 41 (27) | 150 |
| 2000 | 136 (100) | 0 (0) | 0 (0) | 0 (0) | 136 |
| 2001 | 196 (65) | 0 (0) | 32 (11) | 73 (24) | 301 |

#### *Yearling releases*

Most of the harvest on Turtle Rock summer Chinook (yearling releases) occurred in the Ocean (Table 9.12). Ocean harvest has made up 71% to 95% of all Turtle Rock summer Chinook harvested. Brood year 1998 provided the largest harvest, while brood year 1995 provided the lowest.

**Table 9.12.** Estimated number and percent (in parentheses) of Turtle Rock summer Chinook (yearling releases) captured in different fisheries.

| Brood year | Ocean fisheries | Columbia River Fisheries | | | Total |
|---|---|---|---|---|---|
| | | Tribal (Zone 6) | Commercial (Zones 1-5) | Recreational (sport) | |
| 1995 | 428 (74) | 6 (1) | 77 (13) | 70 (12) | 581 |
| 1996 | 725 (95) | 1 (0) | 15 (2) | 21 (3) | 762 |
| 1997 | 2,742 (90) | 29 (1) | 99 (3) | 176 (6) | 3,046 |
| 1998 | 4,251 (90) | 22 (0) | 212 (4) | 229 (5) | 4,714 |
| 1999 | 1,656 (74) | 12 (1) | 207 (9) | 365 (16) | 2,240 |
| 2000 | 1,163 (75) | 1 (0) | 136 (9) | 242 (16) | 1,542 |
| 2001 | 2,456 (71) | 0 (0) | 325 (9) | 694 (20) | 3,475 |

### Straying

#### *Normal subyearling releases*

Rates of Turtle Rock summer Chinook (normal subyearling releases) straying into spawning areas in the upper basin have been low (Table 9.13). Although a few Turtle Rock summer Chinook have strayed into other spawning areas, straying, on average, has been less than 5%. The Chelan tailrace has received the largest number of Turtle Rock strays.

**Table 9.13.** Number (No.) and percent of spawning escapements within other non-target basins that consisted of Turtle Rock summer Chinook (normal subyearling releases), return years 1998-2004. For example, for return year 2003, 0.7% of the summer Chinook spawning escapement in the Methow Basin consisted of Turtle Rock summer Chinook. Percent strays should be less than 5%.

| Return year | Wenatchee | | Methow | | Okanogan | | Chelan | | Entiat | | Hanford Reach | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| 1998 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1999 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2000 | 8 | 0.2 | 3 | 0.3 | 13 | 0.4 | 63 | 9.5 | 0 | 0.0 | 0 | 0.0 |
| 2001 | 0 | 0.0 | 5 | 0.2 | 13 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2002 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2003 | 0 | 0.0 | 26 | 0.7 | 19 | 0.6 | 13 | 3.1 | 0 | 0.0 | 9 | 0.0 |
| 2004 | 5 | 0.1 | 8 | 0.4 | 0 | 0.0 | 8 | 1.9 | 0 | 0.0 | 0 | 0.0 |
| ***Total*** | ***13*** | ***0.0*** | ***42*** | ***0.3*** | ***45*** | ***0.1*** | ***84*** | ***2.6*** | ***0*** | ***0.0*** | ***9*** | ***0.0*** |

On average, about 37% of the returns have strayed into spawning areas in the upper basin (Table 9.14). Depending on brood year, percent strays into spawning areas have ranged from 24-100%. Few (1% on average) have strayed into non-target hatchery programs.

**Table 9.14.** Number and percent of Turtle Rock summer Chinook (normal subyearling releases) that homed to the target hatchery and strayed to non-target spawning areas and non-target hatchery programs, by brood years 1995-2001.

| Brood year | Homing | | | | Straying | | | |
|---|---|---|---|---|---|---|---|---|
| | Target stream | | Target hatchery | | Non-target streams | | Non-target hatcheries | |
| | Number | % | Number | % | Number | % | Number | % |
| 1995 | - | - | 197 | 74.1 | 64 | 24.1 | 5 | 1.9 |
| 1996 | - | - | 54 | 54.5 | 44 | 44.4 | 1 | 1.0 |
| 1997 | - | - | 2 | 28.6 | 5 | 71.4 | 0 | 0.0 |
| 1998 | - | - | 0 | 0.0 | 24 | 100.0 | 0 | 0.0 |
| 1999 | - | - | 79 | 56.8 | 60 | 43.2 | 0 | 0.0 |
| 2000 | - | - | 5 | 50.0 | 5 | 50.0 | 0 | 0.0 |
| 2001 | - | - | 28 | 63.6 | 16 | 36.4 | 0 | 0.0 |
| ***Total*** | ***-*** | ***-*** | ***365*** | ***62.0*** | ***218*** | ***37.0*** | ***6*** | ***1.0*** |

### *Accelerated subyearling releases*

Rates of Turtle Rock summer Chinook (accelerated subyearling releases) straying into spawning areas in the upper basin have been very low (Table 9.15). Although a few Turtle Rock summer Chinook have strayed into other spawning areas, straying, on average, has been less than 1%. The Chelan tailrace, Okanogan Basin, and Methow Basin have received the largest number of Turtle Rock strays.

**Table 9.15.** Number (No.) and percent of spawning escapements within other non-target basins that consisted of Turtle Rock summer Chinook (accelerated subyearling releases), return years 1998-2004. For example, for return year 2001, 0.4% of the summer Chinook spawning escapement in the Methow Basin consisted of Turtle Rock summer Chinook. Percent strays should be less than 5%.

| Return year | Wenatchee | | Methow | | Okanogan | | Chelan | | Entiat | | Hanford Reach | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| 1998 | 3 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1999 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2000 | 7 | 0.2 | 0 | 0.0 | 0 | 0.0 | 24 | 3.6 | 0 | 0.0 | 0 | 0.0 |
| 2001 | 0 | 0.0 | 12 | 0.4 | 31 | 0.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2002 | 0 | 0.0 | 5 | 0.1 | 7 | 0.1 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2003 | 4 | 0.0 | 4 | 0.1 | 0 | 0.0 | 3 | 0.7 | 0 | 0.0 | 0 | 0.0 |
| 2004 | 0 | 0.0 | 0 | 0.0 | 7 | 0.1 | 3 | 0.7 | 0 | 0.0 | 18 | 0.0 |
| ***Total*** | ***14*** | ***0.0*** | ***21*** | ***0.1*** | ***45*** | ***0.1*** | ***30*** | ***0.9*** | ***0*** | ***0.0*** | ***18*** | ***0.0*** |

On average, about 51% of the returns have strayed into spawning areas in the upper basin (Table 9.16). Depending on brood year, percent strays into spawning areas have ranged from 0-83%. None of these fish have strayed into non-target hatchery programs.

**Table 9.16.** Number and percent of Turtle Rock summer Chinook (accelerated subyearling releases) that homed to the target hatchery and strayed to non-target spawning areas and non-target hatchery programs, by brood years 1995-2001.

| Brood year | Homing | | | | Straying | | | |
|---|---|---|---|---|---|---|---|---|
| | Target stream | | Target hatchery | | Non-target streams | | Non-target hatcheries | |
| | Number | % | Number | % | Number | % | Number | % |
| 1995 | - | - | 7 | 70.0 | 3 | 30.0 | 0 | 0.0 |
| 1996 | - | - | 33 | 32.4 | 69 | 67.6 | 0 | 0.0 |
| 1997 | - | - | 6 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| 1998 | - | - | 2 | 16.7 | 10 | 83.3 | 0 | 0.0 |
| 1999 | - | - | 21 | 42.9 | 28 | 57.1 | 0 | 0.0 |
| 2000 | - | - | 12 | 40.0 | 18 | 60.0 | 0 | 0.0 |
| 2001 | - | - | 42 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| ***Total*** | ***-*** | ***-*** | ***123*** | ***49.0*** | ***128*** | ***51.0*** | ***0*** | ***0.0*** |

### *Yearling releases*

Rates of Turtle Rock summer Chinook (yearling releases) straying into spawning areas in the upper basin have varied widely depending on spawning area (Table 9.17). Most of these fish strayed to spawning areas within the Chelan tailrace, Methow Basin, and Entiat Basin. Relatively few, on average, have strayed to spawning areas in the Okanogan Basin, Wenatchee Basin, and Hanford Reach.

**Table 9.17.** Number (No.) and percent of spawning escapements within other non-target basins that consisted of Turtle Rock summer Chinook (yearling releases), return years 1998-2004. For example, for return year 2003, 4.3% of the summer Chinook spawning escapement in the Methow Basin consisted of Turtle Rock summer Chinook. Percent strays should be less than 5%.

| Return year | Wenatchee | | Methow | | Okanogan | | Chelan | | Entiat | | Hanford Reach | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| 1998 | 0 | 0.0 | 2 | 0.3 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 1999 | 3 | 0.1 | 2 | 0.2 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 2000 | 18 | 0.4 | 57 | 4.8 | 167 | 4.5 | 73 | 11.0 | 0 | 0.0 | 10 | 0.0 |
| 2001 | 109 | 1.2 | 523 | 18.9 | 334 | 3.1 | 316 | 32.1 | 0 | 0.0 | 7 | 0.0 |
| 2002 | 92 | 0.7 | 437 | 9.4 | 194 | 1.4 | 191 | 32.8 | 136 | 27.1 | 0 | 0.0 |
| 2003 | 64 | 0.7 | 170 | 4.3 | 14 | 0.4 | 165 | 39.4 | 0 | 0.0 | 9 | 0.0 |
| 2004 | 10 | 0.1 | 55 | 2.5 | 118 | 1.7 | 78 | 18.6 | 0 | 0.0 | 0 | 0.0 |
| ***Total*** | ***296*** | ***0.6*** | ***1,246*** | ***7.6*** | ***827*** | ***1.9*** | ***823*** | ***24.9*** | ***136*** | ***5.9*** | ***26*** | ***0.0*** |

On average, about 75% of the returns have strayed into spawning areas in the upper basin (Table 9.18). Depending on brood year, percent strays into spawning areas have ranged from 46-86%. Few (<1% on average) have strayed into non-target hatchery programs.

**Table 9.18.** Number and percent of Turtle Rock summer Chinook (yearling releases) that homed to the target hatchery and strayed to non-target spawning areas and non-target hatchery programs, by brood years 1995-2001.

| Brood year | Homing | | | | Straying | | | |
|---|---|---|---|---|---|---|---|---|
| | Target stream | | Target hatchery | | Non-target streams | | Non-target hatcheries | |
| | Number | % | Number | % | Number | % | Number | % |
| 1995 | - | - | 180 | 39.3 | 278 | 60.7 | 0 | 0.0 |
| 1996 | - | - | 218 | 27.2 | 583 | 72.8 | 0 | 0.0 |
| 1997 | - | - | 254 | 14.3 | 1,524 | 85.6 | 3 | 0.2 |
| 1998 | - | - | 166 | 19.2 | 698 | 80.7 | 1 | 0.1 |
| 1999 | - | - | 181 | 43.4 | 236 | 56.6 | 0 | 0.0 |
| 2000 | - | - | 96 | 29.4 | 231 | 70.6 | 0 | 0.0 |
| 2001 | - | - | 161 | 54.2 | 136 | 45.8 | 0 | 0.0 |
| ***Total*** | ***-*** | ***-*** | ***1,256*** | ***25.4*** | ***3,686*** | ***74.5*** | ***4*** | ***0.1*** |

### Hatchery Replacement Rates

Hatchery replacement rates were estimated as hatchery adult-to-adult returns. In all years, HRRs for summer Chinook released as yearlings were greater than HRRs for Chinook released as subyearlings (Table 9.19). HRRs based on subyearling releases were consistently less than 5.3, whereas those for yearling releases were consistently greater than 5.3.

**Table 9.19.** Hatchery replacement rates (HRR) for Turtle Rock summer Chinook released as subyearlings or yearlings, 1995-2000. *(The numbers in this table may change as the HETT and HC refine the methods for estimating summer Chinook HRRs.)*

| Brood year | Subyearling releases | | Yearling releases | |
|---|---|---|---|---|
| | HRR (harvest not included) | HRR (harvest included) | HRR (harvest not included) | HRR (harvest included) |
| 1995 | 0.79 | 2.11 | 7.31 | 12.27 |
| 1996 | 0.66 | 1.03 | 8.14 | 14.98 |
| 1997 | 0.03 | 0.08 | 24.79 | 56.48 |
| 1998 | 0.09 | 0.17 | 17.31 | 71.00 |
| 1999 | 0.97 | 3.72 | 1.72 | 9.02 |
| ***Average*** | ***0.51*** | ***1.42*** | ***11.85*** | ***32.75*** |

## Smolt-to-Adult Survivals

Smolt-to-adult survival ratios (SARs) were calculated as the number of hatchery adults divided by the number of hatchery subyearling or yearling Chinook released. SARs were based on CWT returns.

### *Normal subyearling releases*

For the available brood years, SARs for normal subyearling-released Chinook have ranged from 0.000031 to 0.004340 (Table 9.20).

**Table 9.20.** Smolt-to-adult ratios (SARs) for Turtle Rock normal subyearling-released summer Chinook.

| Brood year | Number released | Estimated adult captures | SAR |
|---|---|---|---|
| 1995 | 1,074,600 | 203 | 0.000189 |
| 1996 | 385,215 | 188 | 0.000488 |
| 1997 | 508,060 | 16 | 0.000031 |
| 1998 | 301,777 | 30 | 0.000099 |
| 1999 | 201,615 | 875 | 0.004340 |
| 2000 | 604,892 | 26 | 0.000043 |
| 2001 | 214,059 | 269 | 0.001257 |
| ***Average*** | ***470,031*** | ***230*** | ***0.000488*** |

### *Accelerated subyearling releases*

For the available brood years, SARs for accelerated subyearling-released Chinook have ranged from 0.000006 to 0.000971 (Table 9.21).

**Table 9.21.** Smolt-to-adult ratios (SARs) for Turtle Rock accelerated subyearling-released summer Chinook.

| Brood year | Number released | Estimated adult captures | SAR |
|---|---|---|---|
| 1995 | 169,000 | 13 | 0.000077 |
| 1996 | 477,300 | 77 | 0.000161 |
| 1997 | 521,480 | 3 | 0.000006 |
| 1998 | 307,571 | 66 | 0.000215 |
| 1999 | 202,916 | 197 | 0.000971 |
| 2000 | 449,302 | 71 | 0.000158 |
| 2001 | 480,584 | 141 | 0.000293 |
| ***Average*** | ***372,593*** | ***81*** | ***0.000218*** |

#### *Yearling releases*

For the available brood years, SARs for yearling-released Chinook have ranged from 0.006813 to 0.025580 (Table 9.22).

**Table 9.22.** Smolt-to-adult ratios (SARs) for Turtle Rock yearling-released summer Chinook.

| Brood year | Number released | Estimated adult captures | SAR |
|---|---|---|---|
| 1995 | 150,000 | 1,022 | 0.006813 |
| 1996 | 202,727 | 1,514 | 0.007468 |
| 1997 | 202,989 | 4,757 | 0.023435 |
| 1998 | 217,319 | 5,559 | 0.025580 |
| 1999 | 285,707 | 2,626 | 0.009191 |
| 2000 | 279,969 | 1,868 | 0.006672 |
| 2001 | 314,584 | 3,730 | 0.011857 |
| ***Average*** | ***236,185*** | ***3,011*** | ***0.012748*** |

## *9.4 ESA/HCP Compliance*

### Broodstock Collection

The 2005 brood Turtle Rock summer Chinook program is supported through adult collections at the volunteer trap at Wells Fish Hatchery and in conjunction with the Wells summer Chinook collections. During 2005, broodstock collections at the volunteer trap were consistent with the 2005 Upper Columbia River Salmon and Steelhead Broodstock Objectives and site-based broodstock collection protocols as required in ESA permit 1347. The 2005 collection totaled ?? summer Chinook (combined Wells Fish Hatchery and Turtle Rock Fish Hatchery programs).

### Hatchery Rearing and Release

Brood year 2005 releases totaled 1,152,058 fish, including yearling, regular subyearling, and accelerated subyearling releases (204,644; 490,074 and 457,340 juveniles, respectively). These releases represented ??% and ??% of the Rocky Reach HCP and ESA Section 10 Permit 1347 production for Turtle Rock yearling and subyearling production, respectively.

Consistent with ESA Permit 1347, a total of ?? normal and accelerated subyearling Chinook were adipose fin clipped and coded-wire tagged. The remainder of the subyearling production was released untagged and unmarked. The yearling Chinook were 100% CWT and adipose fin-clipped. No 2005 brood Turtle Rock summer Chinook were PIT tagged. See Section 9.2 for specific rearing, tagging, and release information related to the 2005 brood Turtle Rock summer Chinook program.

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# SECTION 11: APPENDICES

***Appendix A:*** **Abundance and Total Numbers of Chinook Salmon and Trout in the Chiwawa River Basin, Washington, 2007.**

***Appendix B:*** **Fish Trapping at the Chiwawa, Upper Wenatchee, and Lower Wenatchee Smolt Traps during 2007.**

***Appendix C:*** **Summary of ISEMP PIT Tagging Activities in the Wenatchee Basin, 2007.**

***Appendix D:*** **Wenatchee Steelhead Spawning Ground Surveys, 2007.**

***Appendix E:*** **NPDES Hatchery Effluent Monitoring, 2007.**

***Appendix F:*** **Steelhead Stock Assessment at Priest Rapids Dam, 2007.**

***Appendix G:*** **Wenatchee Sockeye and Summer Chinook Spawning Ground Surveys, 2007.**

***Appendix H:*** **Genetic Diversity of Wenatchee Sockeye Salmon, 2007.**

***Appendix I:*** **Genetic Diversity of Natural Chiwawa River Spring Chinook Salmon, 2007.**

***Appendix J:*** **Summer Chinook Spawning Ground Surveys in the Methow and Okanogan Basin, 2007.**

# APPENDIX A

## Abundance and Total Numbers of Chinook Salmon and Trout in the Chiwawa River Basin, Washington, 2007.

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January 31, 2008

TO: HCP Hatchery Committee

FROM: Tracy Hillman

**Subject: Abundance and Total Numbers of Chinook Salmon and Trout in the Chiwawa River Basin, Washington, 2007**

The Chelan County Public Utility District (PUD) hatchery program is operated through a habitat conservation program (HCP) that was incorporated into the PUD's license in 2004. The HCP directed the signatories to develop a monitoring and evaluation plan within one year of the effective date. This study will help the HCP Hatchery Committee determine if it is meeting Objective 7 in the monitoring and evaluation plan (Murdoch and Peven 2005).

***Objective 7:*** *Determine if the proportion of hatchery fish on the spawning grounds affects the freshwater productivity (i.e., number of juveniles per redd) of supplemented streams when compared to non-supplemented streams.*

We estimated densities and total numbers of age-0 spring Chinook salmon *Oncorhynchus tshawytscha,* trout *Oncorhynchus* sp., and char *Salvelinus* sp. in the Chiwawa River basin, Washington, in August 2007. This was the 15th year of an ongoing study to assess the freshwater productivity (juveniles/redd) of Chinook salmon in the Chiwawa Basin. We used landscape classification to stratify streams in the basin that supported juvenile Chinook salmon (Hillman and Miller 2004). Classification "explained" most of the variability in fish numbers caused by geology, land type, valley bottom type, stream state condition, and habitat type. We identified ten reaches on the lower 31 miles (50 km) of the Chiwawa River and one reach in each of Phelps, Rock, Chikamin, Big Meadow, Alder, Brush, Y, and Peven[1] creeks (Figure 1). Each reach consisted of several combinations of state-type and habitat-type strata. We used classification to find reference areas for reaches in the Chiwawa River. We matched Reach 3 and Reach 8 of the Chiwawa River with a moderately-confined section of Nason Creek (RM 0.62-1.70) and an unconfined area of the Little Wenatchee River (RM 4.39-8.55), respectively (Hillman and Miller 2004). Following methods described in Hillman and Miller (2004), we used

[1]Unnamed tributary that drains the eastside of Chiwawa Ridge. Its confluence with the Chiwawa River is about 1 mile (1.6 km) downstream from the mouth of Phelps Creek.

underwater observations to estimate numbers of fish in 189 randomly selected sites.

During sampling in August 2007, discharge in the Chiwawa River averaged 236 cubic feet per second (cfs) and ranged from 157 to 357 cfs (Figure 2). Stream temperatures for the study period ranged from 9.0 to 15.0°C. Fish species observed in the Chiwawa Basin and reference areas during the 1992-2007 survey period[2] included: spring Chinook salmon, coho salmon *O. kisutch*, sockeye salmon *O. nerka* (in the Little Wenatchee River reference area), steelhead/rainbow trout *O. mykiss* (hatchery rainbow were present only in 1992 and 1993), cutthroat trout *O. clarki lewisi*, bull trout *S. confluentus*, brook trout *S. fontinalis*, mountain whitefish *Prosopium williamsoni*, dace *Rhinichthys* sp., suckers *Catostomus* sp., and sculpin *Cottus* sp. The age-0 spring Chinook that we observed in the Chiwawa Basin during the 2007 survey were produced from 297 redds counted in the fall of 2006 (Hillman et al. 2007). Assuming a mean fecundity of 4,324 eggs per female Chinook (from females collected for broodstock), and that no female produced more than one redd, we estimated that the Chiwawa River basin was seeded with 1,284,228 eggs in 2006 (Appendix A).

In 2007, riffles made up the largest fraction of habitat types in reaches of the Chiwawa Basin (47% of the total stream surface area) (Table 1). Pools (17%), glides (7%), and multiple channels (29%) constituted the remaining 53% of the stream surface area. We consistently found woody debris associated with multiple-channel habitat.

**Chinook Salmon Abundance**

Chinook salmon were the most abundant salmonid in the Chiwawa Basin. We estimated, based on surface area, that age-0 Chinook salmon numbered 60,752 (±12.2% of the estimated total) in the Chiwawa River basin in August 2007 (Table 2). Extrapolating based on volume of habitat types, we estimated 62,522 (±11.5%) age-0 Chinook in the Chiwawa Basin.[3] About 11% of the juvenile Chinook were in tributaries to the Chiwawa River. During the 1992-2007 survey period, numbers of age-0 Chinook ranged from 5,815 to 134,874 in the Chiwawa Basin (Figure 3; Appendix B). Most of the difference in juvenile numbers among years resulted from different seeding levels (Figure 4). Numbers of Chinook redds in the Chiwawa Basin during 1992-2007 ranged from 13 to 1,046, resulting in seeding levels of 66,248 to 4,836,704 eggs (Appendix A).

As in most years, age-0 Chinook in 2007 were distributed contagiously among reaches in the Chiwawa River (Table 2). In the Chiwawa River, densities of age-0 Chinook were highest in the upper reaches (Reaches 7-9). The highest densities in the Chiwawa Basin were in tributaries to the Chiwawa River (Table 2), with the highest density in Chikamin Creek (7,387 fish/ha). Age-0 Chinook were most abundant in multiple channels and least abundant in glides. We found the majority of the Chinook associated with woody debris in multiple channels. These sites (multiple channels) made up 29% of the total area of the Chiwawa Basin, but they provided habitat for 40% of all the age-0 Chinook in the basin in 2007 (Appendix C). In contrast, riffles made up

[2] The study period 1992-2007 includes only 15 years of sampling because there was no sampling in 2000.

[3] If the hatchery juvenile Chinook counted in Big Meadow Creek were included, the estimates would increase by 1,818 (based on fish/ha) or 2,195 (based on fish/$m^3$). These fish were from the 12,977 high-ELISA spring Chinook planted in Big Meadow Creek on 22 May 2007.

47% of the total area, but provided habitat for only 12% of all age-0 Chinook in the Chiwawa Basin. Pools made up 17% of the total area and provided habitat for 46% of all age-0 Chinook in the basin. Virtually no Chinook used glides that lacked woody debris.

We assumed that the Chiwawa River was seeded with 1,284,228 Chinook eggs (297 redds times 4,324 eggs/female) in fall, 2006, and that at least 60,752 of those survived to August 2007. This means that the egg-to-parr survival was at least 4.7% (95% confidence bound 4.2-5.3%). During 1992-2007, egg-to-parr survival averaged 6.0% (range 2.7-19.1%) in the Chiwawa Basin (Appendix A). This survival rate comports with those from other streams. For example, Mullan et al. (1992) estimated an egg-to-parr survival rate of 9.8% for spring Chinook salmon in Icicle Creek, a tributary of the Wenatchee River. Using a Beverton and Holt model, Hubble (1993) estimated that egg-to-parr survival of Chinook in the Chewuck River, a tributary to the Methow River, ranged between 13% and 32%, depending on percent seeding level in the basin. Kiefer and Forster (1991) estimated a mean egg-to-parr survival rate of 5.5% (range 5.1-6.7%) for naturally-spawning spring Chinook salmon in the entire upper Salmon River. They also noted that egg-to-parr survival of natural spawners and adult outplants in the headwater streams of the upper Salmon River averaged 24.4% (range 16.1-32.0%). Petrosky (1990) reported an egg-to-parr survival range of 1.2-29.0% for Chinook in the upper Salmon River, Idaho. Konopacky et al. (1986) estimated egg-to-parr survival of Chinook in Bear Valley Creek, Idaho, as 8.1-9.4%. Work by Richards and Cernera (1987) in Bear Valley Creek indicated an egg-to-parr survival of 2.1%.

Mean densities of age-0 Chinook salmon in two reaches of the Chiwawa River were less than those in corresponding reference areas (Figure 5). Within both the Chiwawa River and its reference areas, pools and multiple channels consistently had the highest densities of age-0 Chinook.

We estimated a total of 41 (±48.8% of the estimated total) age-1+ Chinook salmon in the Chiwawa Basin in August 2007 (Table 3). In August 1992-2007, numbers of age-1+ Chinook ranged from 5 to 563 in the Chiwawa River basin (Figure 3; Appendix B). These fish most often occurred downstream from Reach 10. We found relatively few age-1+ Chinook in tributaries. Age-1+ Chinook were most abundant in multiple channels and pools.

**Juvenile Chinook Salmon Productivity (Fish/Redd)**

Freshwater productivity of juvenile Chinook salmon was estimated as the number of parr (age-0 Chinook) per redd in the Chiwawa Basin. Theoretically, the relationship between number of parr and redds can be explained mathematically provided the relationship between the two parameters goes through the origin, increases monotonically at low spawning levels, and shows some level of density dependence at high spawning levels. We identified four alternative hypotheses that may explain the relationship between spawning level (redds) and numbers of age-0 Chinook:

1. The first hypothesis assumed that because of low spawner escapements, the number of juvenile Chinook increases linearly with increasing numbers of redds. This hypothesis assumes that there is no density dependence because of low seeding levels. This hypothesis was modeled with a density-independent function that took the form:

$$J = \alpha R,$$

where $J$ is the number of juvenile (age-0) Chinook, $R$ is the number or redds, and $\alpha$ is the increase in numbers of juveniles with each incremental increase in redds.

2. The second hypothesis assumed that the number of juveniles increases constantly toward an asymptote as the number of redds increases. After the asymptote is reached, the number of juveniles neither increases nor decreases. The asymptote represents the maximum number of juveniles the system can support (i.e., carrying capacity for the system). This hypothesis was modeled with a Beverton-Holt curve that took the form:

$$J = (\alpha R) / (\beta + R),$$

where $J$ and $R$ are as above, $\alpha$ is the maximum number or juveniles produced, and $\beta$ is the number or redds needed to produce (on average) juveniles equal to one-half the maximum number of juveniles.

3. The third hypothesis assumed that the number of juveniles increases to a maximum and then declines as the number or redds increases. In this case, mortality rate of juveniles (or eggs) is proportional to the initial number of redds. Higher mortality rate is associated with density-dependent growth coupled with size-dependent predation. This hypothesis was modeled with a Ricker curve that took the form:

$$J = \alpha R e^{-\beta R},$$

where $J$ and $R$ are as above, $\alpha$ is the number of juveniles per redd at low spawning levels, and $\beta$ describes how quickly the juveniles per redd drop as the number of redds increases.

4. The fourth hypothesis, like the second, assumed that the number of juveniles increases constantly, but unlike the second, the number of juveniles does not reach an asymptote. Rather, the number of juveniles increases indefinitely, but at a slowing rate of increase. This hypothesis was modeled with both a Cushing curve and a Gamma function. The Cushing curve took the form:

$$J = \alpha R^{\gamma},$$

where $J$ and $R$ are as above, $\alpha$ is the number of juveniles per redd at low spawning levels, and $\gamma$ describes the level of density dependence at high spawning levels. The Gamma function is a three-parameter model that has the form:

$$J = \alpha R^{\gamma} e^{-\beta R}.$$

This is an un-normalized gamma function that is similar to the Cushing curve when $\beta = 0$.

We used Akaike's Information Criterion for small sample size ($AIC_c$) to determine which model(s) best explained the productivity of juvenile Chinook in the Chiwawa Basin. $AIC_c$ was estimated as:

$$AIC_c = -2\log(£(\theta|data)) + 2K + [(2K(K + 1))/(n - K - 1)],$$

where $\log(£(\theta|data))$ is the maximum likelihood estimate, $K$ is the number of estimable parameters (structural parameters plus the residual variance parameter), and $n$ is the sample size

(Burnham and Anderson 2002). We used least-squares methods to estimate $\boldsymbol{log(£(\theta|data))}$, which was calculated as $\boldsymbol{log(\sigma^2)}$, where $\boldsymbol{\sigma^2}$ = residual sum of squares divided by the sample size ($\boldsymbol{\sigma^2 = RSS/n}$). $AIC_c$ assesses model fit in relation to model complexity (number of parameters). The model with the smallest $AIC_c$ value represents the "best approximating" model within the model set. Remaining models were ranked relative to the best model using $AIC_c$ difference scores ($\mathbf{\Delta AIC_c}$), Akaike weights ($\boldsymbol{w_i}$), and evidence ratios. Models with $\mathbf{\Delta AIC_c}$ values less than 2 indicate that there is substantial support for these models as being the best-fitting models within the set (Burnham and Anderson 2002). Models with values greater than 2 have less support. Akaike weights are probabilities estimating the strength of the evidence supporting a particular model as being the best model within the model set. Models with small $\boldsymbol{w_i}$ values are less plausible as competing models (Burnham and Anderson 2002). When no single model could be specified as the best model, a "best subset" of competing models was identified using (1) $AIC_c$ differences to indicate the level of empirical support each model had as being the best model, (2) evidence ratios based on Akaike weights to indicate the relative probability that any model is the best model, and (3) coefficients of determination ($R^2$) assessing the explanatory power of each model.

The use of $AIC_c$ indicated that the Cushing model best approximated the information in the juveniles/redd data (Table 4; Figure 6). The estimated structural parameters for this model were:

$$\text{Juveniles} = 9{,}191(\text{Redds})^{0.38},$$

where the estimated standard errors of the two parameters were 4,270 and 0.08, respectively. The adjusted $R^2 = 0.66$. The second-best model was the Beverton-Holt model, which was only 1.7 $AIC_c$ units from the best model (Table 4; Figure 6). The estimated parameters for this model were:

$$\text{Juveniles} = [(115{,}737*\text{Redds}) / (105.5 + \text{Redds})],$$

where the estimated standard errors of the two parameters were 20,839 and 54.6, respectively, and the $R^2 = 0.62$. The $AIC_c$ difference scores, Akaike weights, and evidence ratios indicated that there was substantial support for both the Cushing and Beverton-Holt models (Table 4). There was considerably less support for the remaining models (Gamma[4], Ricker, and Density Independent), which were $\geq 4$ $AIC_c$ units from the best model. This was further supported by the fact that, relative to the best models, the remaining three models had evidence ratios greater than 6.

Although the Cushing and Beverton-Holt models have different biological assumptions, they both indicated a density-dependent relationship between spawning levels (redds) and juvenile Chinook production. This was not only evident in the best approximating models, but there was also a significant negative relationship between juveniles per redd and numbers of redds in the Chiwawa Basin (Figure 7). Although data at high seeding levels are lacking, the Beverton-Holt model would limit the production of juvenile Chinook to less than about 161,000 parr in the

[4] The $\beta$ parameter in the Gamma model was very close to 0, which means that this model is nearly identical to the Cushing model. The reason it did not rank higher is because it contains an extra parameter, which means that it has less bias and greater variance than the Cushing model.

basin (upper 95% CI of $\alpha$ in the Beverton-Holt model). In contrast, the Cushing model, which has no upper limit, indicates that the information in the available data may not support the estimation of a maximum production limit at this time. Additional information is needed to determine maximum juvenile productivity in the Chiwawa Basin.

### Steelhead/Rainbow Abundance

Based on stream surface area, we estimated a total of 14,073 (±10.5% of the estimated total) age-0 steelhead/rainbow (<4 in) in reaches of the Chiwawa Basin in 2007 (Table 5). During the 1992-2007 survey period, numbers of age-0 steelhead/rainbow ranged from 1,410 to 45,727 in the Chiwawa River basin (Figure 8; Appendix B). In 1992-2007, numbers of age-0 steelhead/rainbow varied among reaches, but were typically highest in the lower reaches of the Chiwawa River. In all years they most often used riffle and multiple channel habitats in the Chiwawa River, although we also found them associated with woody debris in pool and glide habitat. In tributaries they were generally most abundant in small pools. Those that we observed in riffles selected stations in quiet water behind small and large boulders or occupied stations in quiet water along the stream margin. In pool and multiple-channel habitats, we found age-0 steelhead/rainbow using the same kinds of habitat as age-0 Chinook salmon.

We estimated that 8,448 (±9.7% of the estimated total) age-1+ steelhead/rainbow (4-8 in) lived in reaches of the Chiwawa Basin in August 2007 (Table 6). During the survey period 1992-2007, numbers of age-1+ steelhead/rainbow ranged from 2,533 to 22,130 (Figure 8; Appendix B). In all years we found these fish in nearly all reaches, but they were typically most numerous in lower reaches of the Chiwawa River. We observed age-1+ steelhead/rainbow mostly in pool, riffle, and multiple-channel habitats. Those that we observed in pools were usually in deeper water than age-0 steelhead/rainbow and Chinook. Like age-0 steelhead/rainbow, age-1+ steelhead/rainbow selected stations in quiet water behind boulders in riffles, but we generally did not find the two age groups together. Age-1+ steelhead/rainbow appeared to use deeper and faster water than did age-0 steelhead/rainbow.

We estimated that steelhead/rainbow larger than 8 inches numbered 77 (±31.2% of the estimated total) in the Chiwawa River in August 2007 (Table 7). During the period 1992-2007, steelhead/rainbow numbers ranged from 8 to 1,869 (Appendix B). Steelhead/rainbow larger than 8 inches were most abundant in the lower Chiwawa River; however, in 1992 and 1993, they were most abundant near campgrounds in Reaches 8, 9, and 10 (these were mostly hatchery fish planted near the campgrounds). We found very few in tributary survey reaches. Most of the steelhead/rainbow larger than 8 inches used deep pools (>5 feet), and occupied stations near the bottom at the upstream end of pools.

### Bull Trout Abundance

We estimated, based on surface area, that at least 95 (±30.5% of the estimated total) juvenile (2-8 in) bull trout lived in reaches of the Chiwawa River basin in 2007 (Table 8). We found most of these fish in the upper-most reaches and in tributaries of the Chiwawa River. During 1992-2007, numbers of juvenile bull trout ranged from 79 to 505 (Figure 9; Appendix B). These estimates and those for adult bull trout are incomplete because we did not sample the entire range of bull trout in all tributaries. Also, we did not extend our survey into the headwaters of the Chiwawa

River because there were no juvenile Chinook there. Areas beyond the distribution of juvenile Chinook salmon are known to support bull trout and cutthroat trout (USFS 1993). In addition, our estimates of bull trout abundance were based on daytime snorkel surveys, which may underestimate the actual abundance of bull trout. Several studies (e.g., Goetz 1994; Thurow and Schill 1996; Hillman and Chapman 1996; Bonar et al. 1997) have found bull trout population estimates based on nighttime snorkeling to be in some cases more accurate than daytime snorkeling, especially for juvenile bull trout. Our estimates of adult bull trout numbers may be more accurate than those for juveniles.

In all years we found most juvenile bull trout in the upstream reaches of the Chiwawa River. Of the reaches we surveyed, they were most numerous in Reaches 8-10 on the Chiwawa River. We found the majority of these fish in multiple channels, pools, and riffles, and few in glides. They consistently occupied stations close to the stream bottom over rubble and small boulder substrate or near woody debris. This is similar to the observation of Pratt (1984) in the upper Flathead River Basin in Montana. She found that juvenile bull trout lay close to instream cover and that they tended to conceal themselves. As a result, she found it difficult to accurately estimate their numbers. Although this implies that we underestimated numbers of juvenile bull trout in the Chiwawa River, the relative distribution of juvenile bull trout is valid if we assume that we saw the same fraction of juveniles in all reaches (i.e., detection probability was the same across survey sites).

We estimated a total of 520 (±14.0% of the estimated total) adult (>8 in) bull trout in reaches of the Chiwawa Basin in 2007 (Table 9). In previous years, numbers ranged from 76 to 900 (Figure 9; Appendix B). As with juvenile bull trout, we found most of the adult bull trout upstream from Reach 6; although they were found in all reaches on the Chiwawa River. We found relatively few adult bull trout in tributaries of the Chiwawa River. Adult bull trout primarily used pools and multiple channel habitat, although most of the smaller adults (<10 in) used riffles. In all years we found few adult bull trout near campgrounds. There also appeared to be an inverse association between numbers of adult bull trout and numbers of age-0 Chinook salmon in pools in Reaches 7-10. That is, where we found large bull trout we generally observed few juvenile Chinook salmon.

### Abundance of Other Salmonids

In 2007 we counted 137 brook trout, an exotic species closely related to the bull trout, in the Chiwawa River, Chikamin Creek, Big Meadow Creek, Minnow Creek, and in the Little Wenatchee River. Brook trout occurred throughout most of the Chiwawa River. In both the Chiwawa and Little Wenatchee rivers, brook trout usually used multiple channels. Few appeared to be bull trout/brook trout hybrids. In Chikamin, Minnow, and Big Meadow creeks, brook trout were most abundant in pools. Brook trout lengths ranged from 2-8 inches.

We counted a total of 61 westslope cutthroat trout in the Chiwawa River, Phelps Creek, and the Little Wenatchee River. These fish most often occurred in pools and multiple channel habitats. They ranged in size from 2-12 inches. Juvenile coho salmon were observed in Nason Creek, but not in the Chiwawa Basin or the Little Wenatchee River.

We observed both juvenile and adult mountain whitefish in the Chiwawa River, Nason Creek,

and the Little Wenatchee River. In sum, we counted 3,543 adult and 887 juvenile whitefish in these streams. We found few whitefish in tributaries to the Chiwawa River.

## Conclusion

This was the 15th year of a study to monitor trends in juvenile spring Chinook production in the Chiwawa River basin. As shown in Figure 3, numbers of juvenile Chinook salmon in the Chiwawa Basin have fluctuated widely over the 15-year period. Numbers of juveniles in 2001 and 2002 were some of the highest recorded, while numbers in the mid-1990s were some of the lowest. Interestingly, the highest spawning escapements (highest redd numbers) resulted in the lowest egg-parr survival rates (Appendix A). This is supported by the fact that the best approximating models clearly demonstrate a density-dependent relationship between seeding levels and juvenile production. Indeed, there is a significant negative relationship between parr per redd and numbers of redds in the Chiwawa Basin. This is an important observation because Objectives 1, 3, 4, and 7 and their associated hypotheses in the monitoring and evaluation plan (Murdoch and Peven 2005) are only valid when the supplemented population is below its carrying capacity.

The presence of density dependence in the early life stages of spring Chinook is not surprising. Rarely does density dependence appear in numbers of adult spring Chinook or on their spawning grounds. The Chiwawa Basin has plenty of spawning habitat, as indicated by the large numbers of spawners and redds widely distributed throughout the basin during 2001 and 2002. However, those large spawning escapements did not translate into large numbers of juveniles or smolts. Thus, density-dependent regulation occurs sometime during the early life stages of the fish. Our observations indicate that it is unlikely that physical habitat (space) currently limits parr production in the basin. Low nutrient levels and its effects on food (macroinvertebrates) production may be the primary limiting factor in the basin. If spawning escapements remain relatively high, marine-derived nutrients should increase in the basin, resulting in more food for juvenile Chinook salmon.

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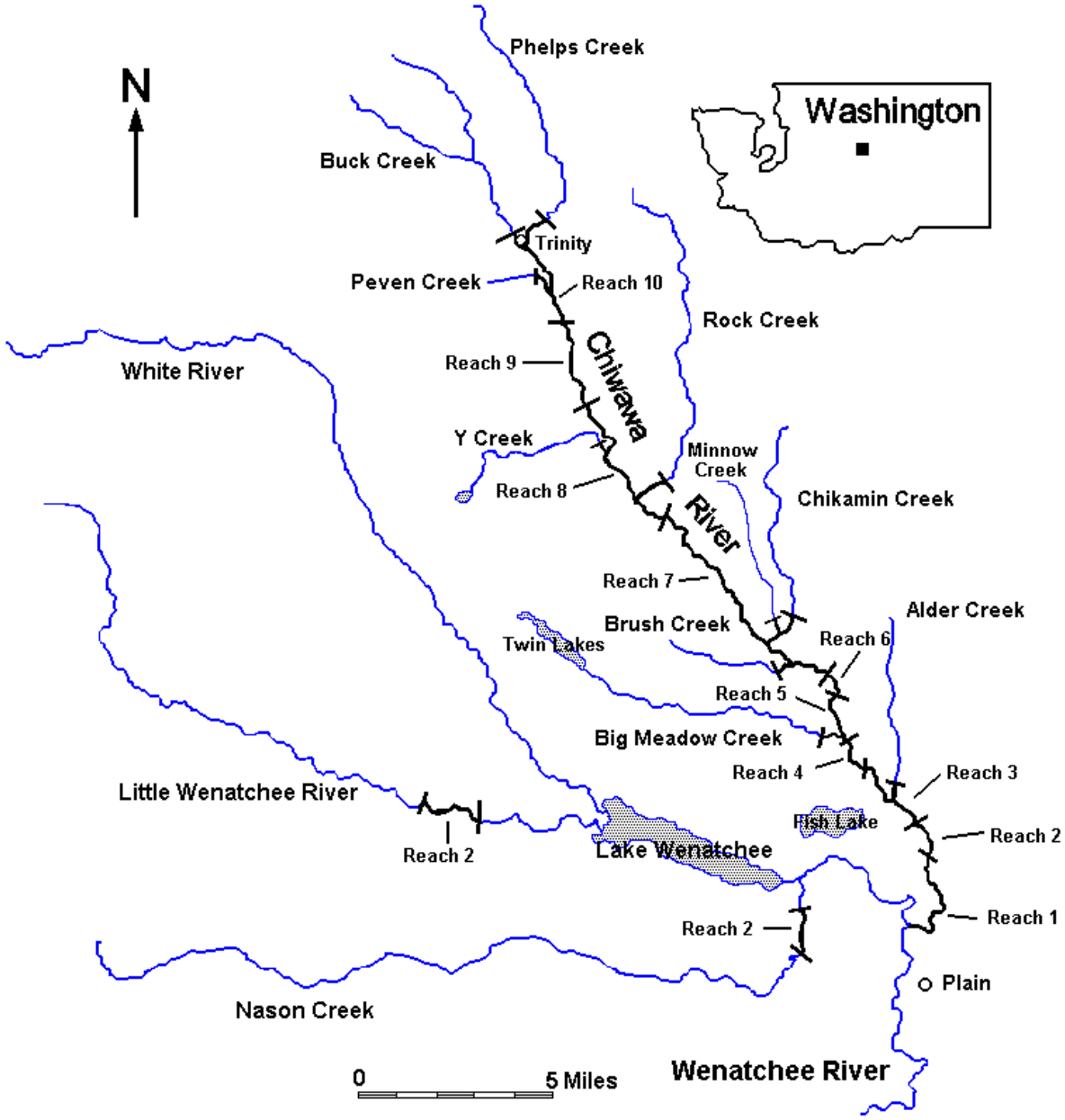



**Figure 1**. Location of study reaches on the Chiwawa River, and Chikamin, Rock, Big Meadow, Peven, Alder, Brush and Phelps creeks, Chelan County, Washington. Reach 2 on Nason Creek and Reach 2 on the Little Wenatchee River were matched with Reaches 3 and 8 on the Chiwawa River, respectively.

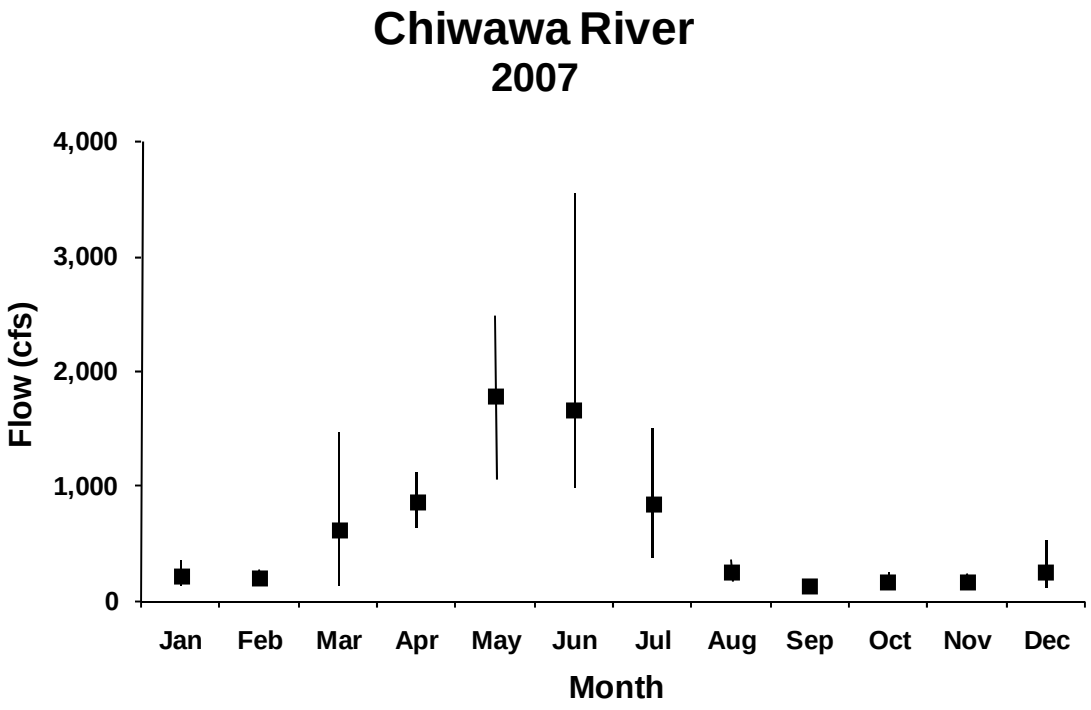



**Figure 2**. Mean, minimum, and maximum monthly flows in the Chiwawa River for 2007.

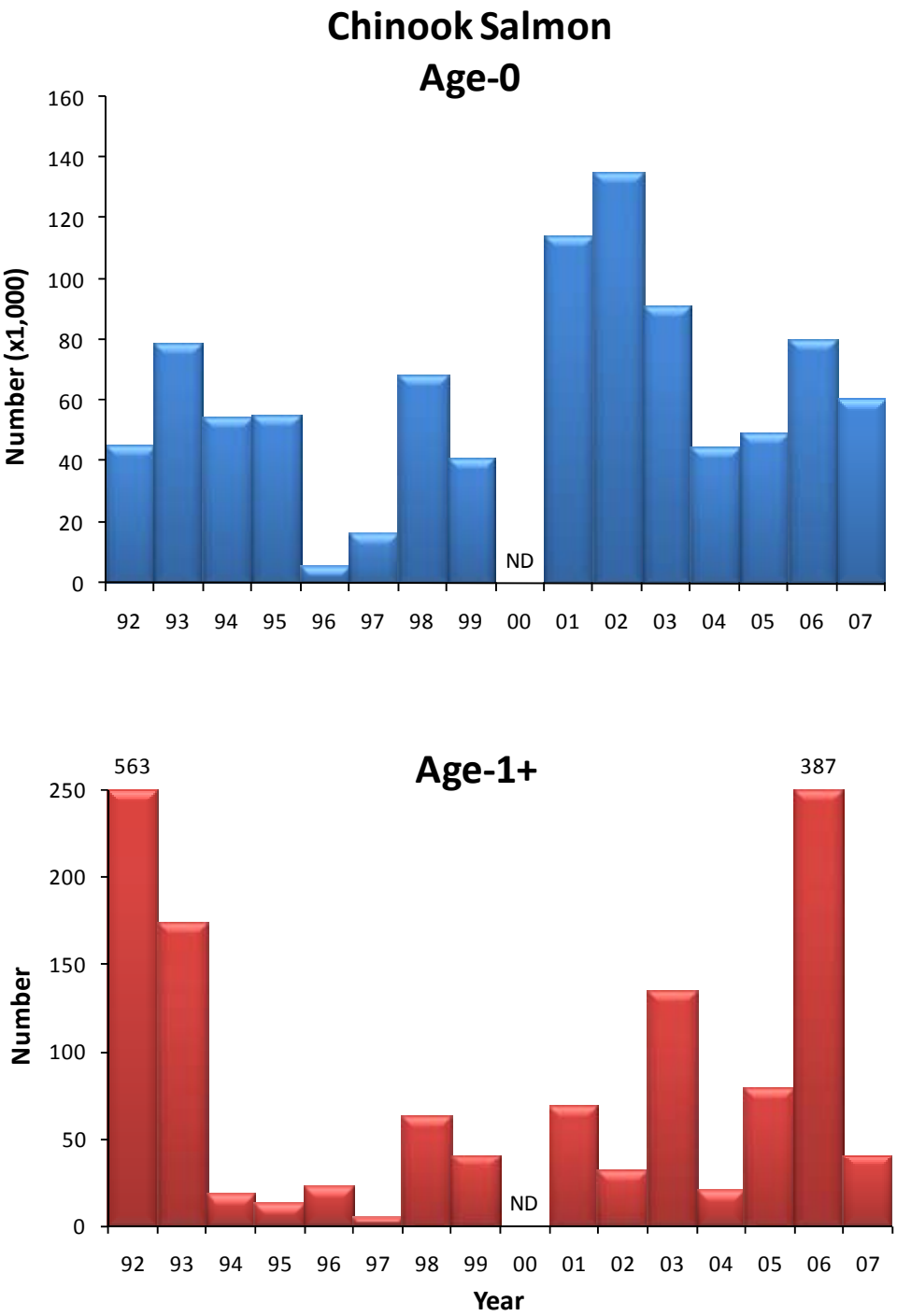



**Figure 3**. Numbers of age-0 and age-1+ Chinook salmon within the Chiwawa River basin in August 1992-2007; ND = no data.

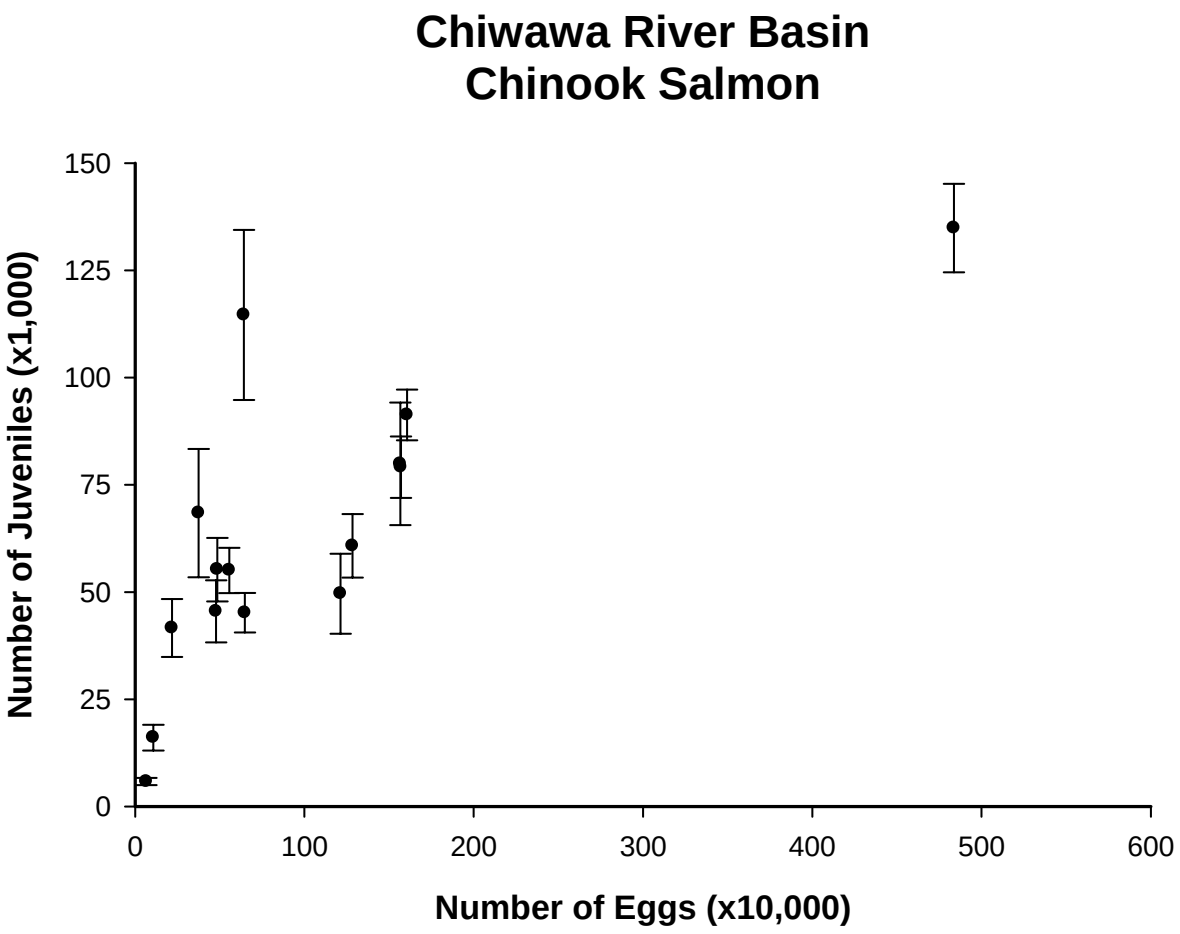



**Figure 4**. Relationship between total numbers of age-0 Chinook salmon (based on fish/ha) and numbers of eggs in the Chiwawa River basin. Vertical bars indicate 95% confidence bounds.

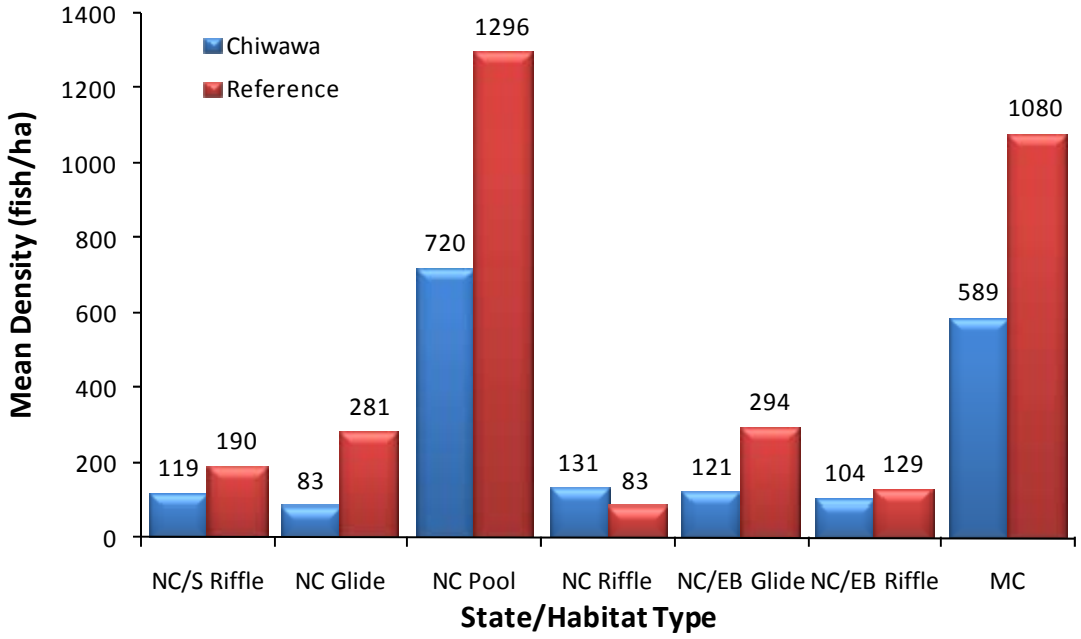
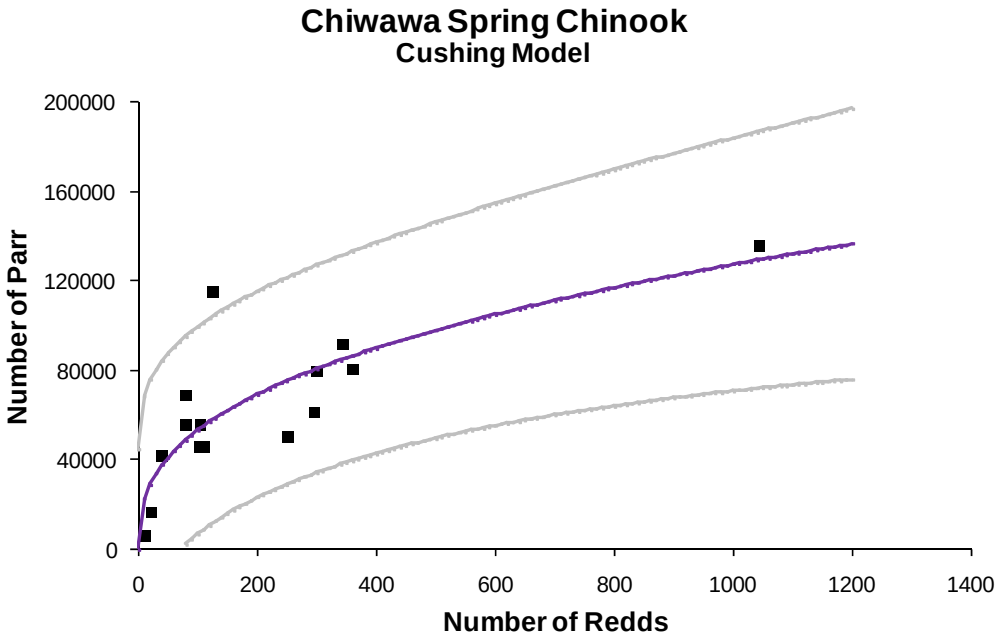



**Figure 5**. Comparison of the 14-year means of age-0 Chinook salmon densities (fish/ha) within state/habitat types in reaches 3 and 8 of the Chiwawa River and their matched reference areas on Nason Creek and the Little Wenatchee River.



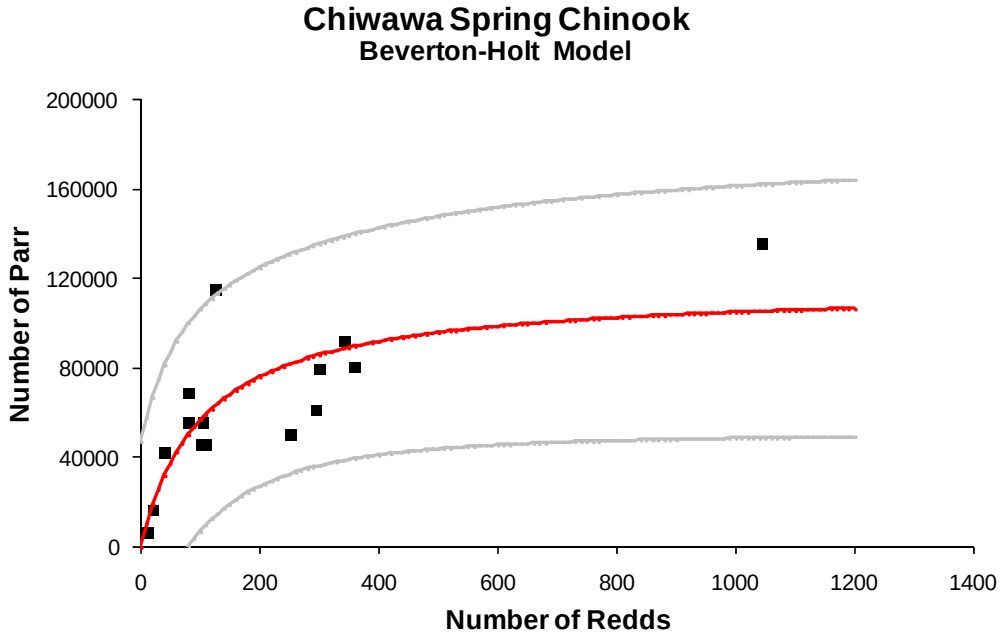




**Figure 6.** Relationship between numbers of juvenile (age-0) Chinook and redds in the Chiwawa Basin, 1992-2007 (no sampling occurred in 2000). Top figure shows the Cushing model fit to the data; bottom figure shows the Beverton-Holt model fit to the data. Gray lines indicate the upper and lower 95% C.B.

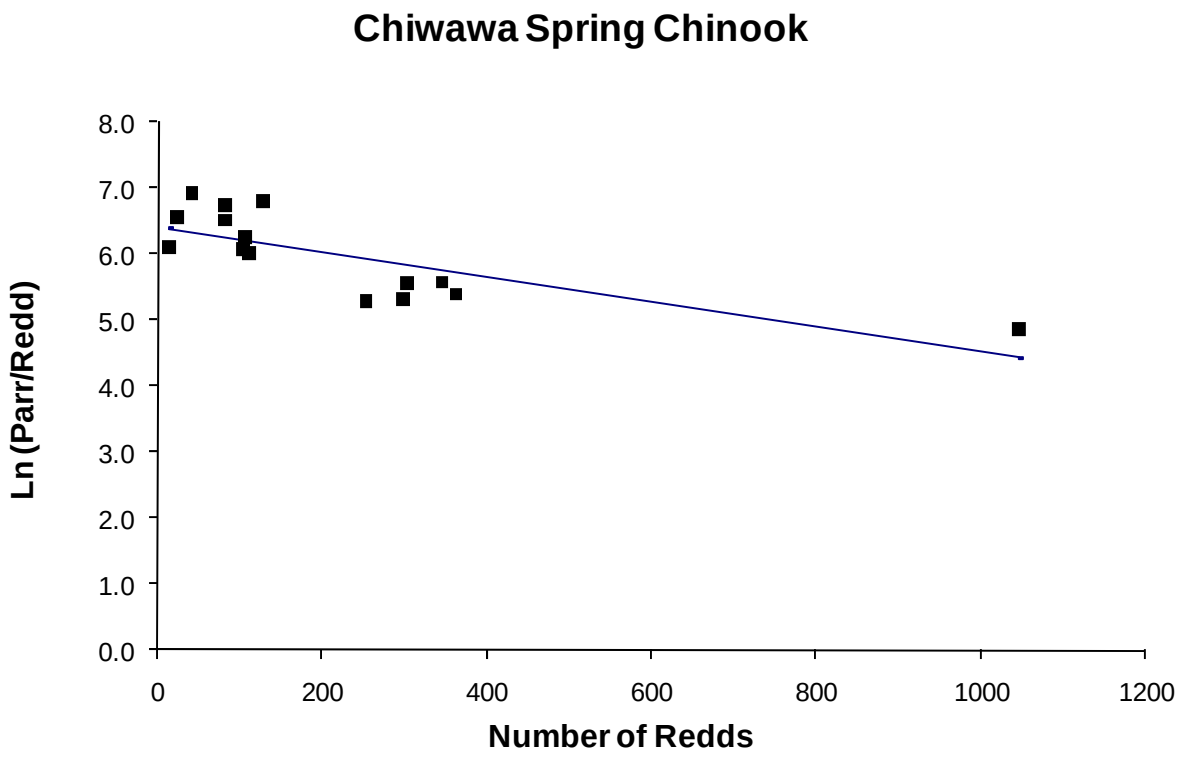



**Figure 7.** Relationship between natural log parr/redd and numbers of redds in the Chiwawa River basin, 1992-2007. No sampling was conducted in 2000. Estimates for 1992-2007 included the Chiwawa River and its tributaries; the 1992 estimate included only the Chiwawa River. The relationship LN(P/R) = 6.42 – 0.002(Redd) was significant with P = 0.001; $R^2$ = 0.59.

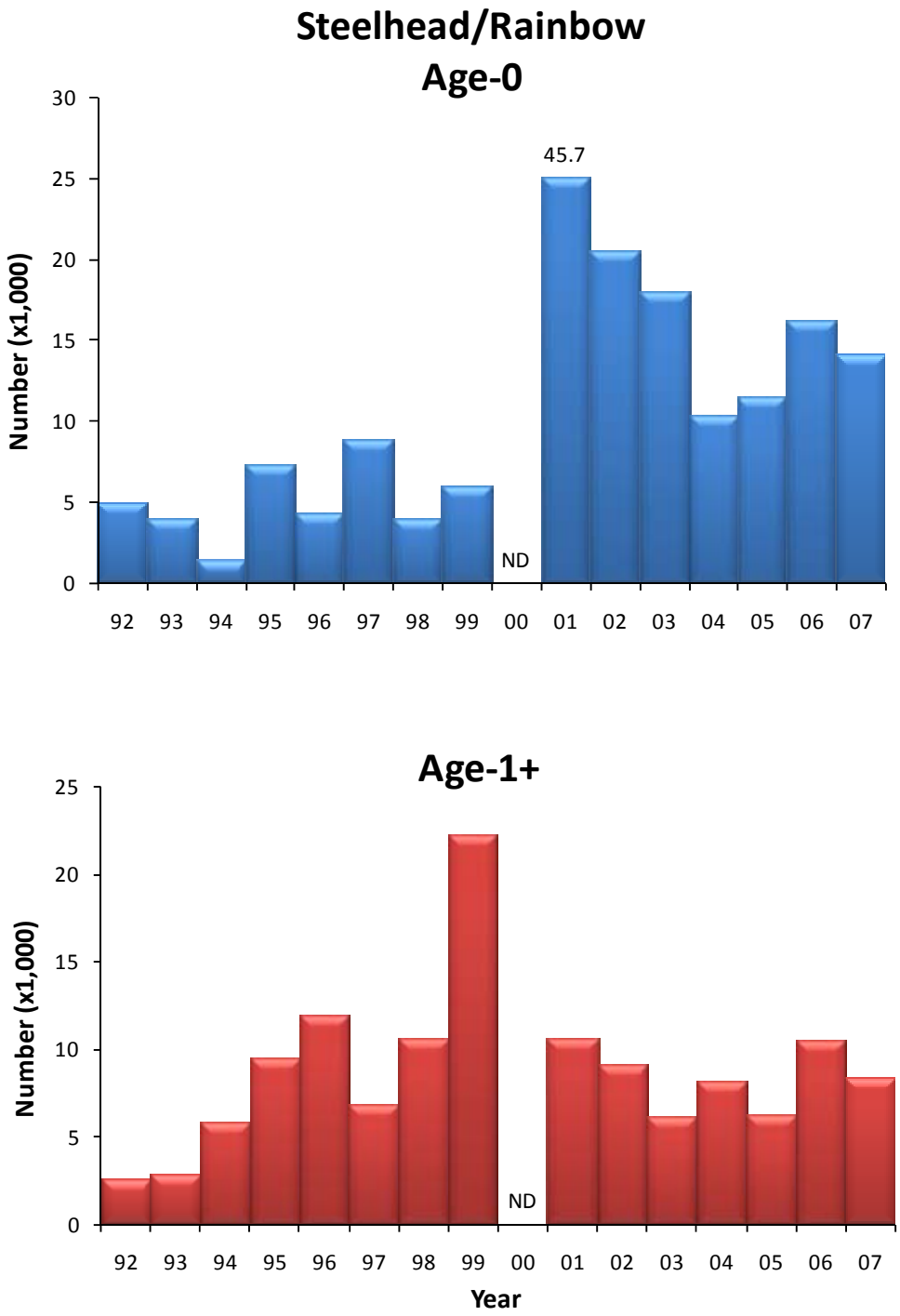



**Figure 8**. Numbers of age-0 (<4 in) and age-1+ (4-8 in) steelhead/rainbow within the Chiwawa River basin in August 1992-2007; ND = no data.

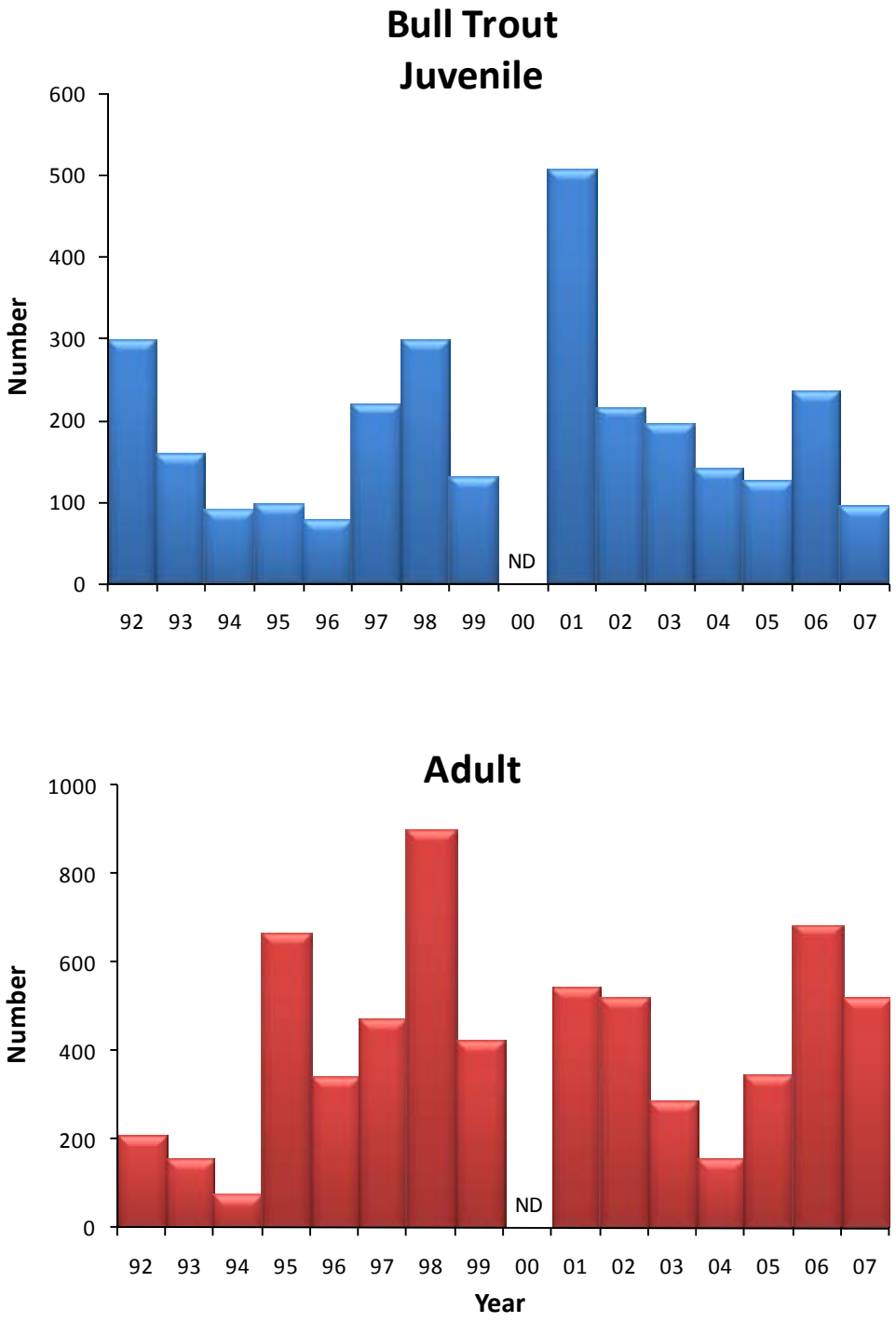



**Figure 9**. Numbers of juvenile (2-8 inches) and adult (>8 inches) bull trout within the Chiwawa River basin in August 1992-2007; ND = no data.

**Table 1**. Description, location (river mile), and area (hectares) of land-class strata (reaches) used by age-0 Chinook salmon in the Chiwawa River basin, 2007. Reaches were classified according to geologic district, landtype association, valley-bottom type, stream state-type, and habitat type within the Cascade Ecoregion; MCV=moderately confined valley, CC=confined canyon, UCV=unconfined valley, G=glide, P= pool, R=riffle, and MC=multiple channel. See Hillman and Miller (2004) for definitions of stream state codes.

| Reach | RM | Gradient | Geologic district | Landtype association | Valley bottom type | Stream state type | Habitat type | Area (ha) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Total | Sample |
| **Chiwawa River** | | | | | | | | | |
| 1 | 0.00-3.77 | 0.007 | Glacial Drift over Chumstick Formation | Glacial Valley | MCV Alluvial | NC/EB | G | 1.23 | 1.23 |
| | | | | | | NC/EB | P | 1.38 | 0.85 |
| | | | | | | NC/EB | R | 14.90 | 2.03 |
| 2 | 3.77-5.51 | 0.010 | Glacial Drift over Chumstick Formation | Glacial Canyon | CC Fluvial | NC/EB | P | 0.52 | 0.28 |
| | | | | | | NC/EB | R | 6.85 | 0.59 |
| 3 | 5.51-7.88 | 0.009 | Glacial Drift over Chumstick Formation | Glacial Valley | MCV Alluvial | NC/S | R | 2.38 | 0.79 |
| | | | | | | NC/EB | G | 0.34 | 0.34 |
| | | | | | | NC/EB | R | 6.25 | 0.80 |
| | | | | | | MC | M | 0.37 | 0.15 |
| 4 | 7.88-8.90 | 0.007 | Glacial Drift over Chumstick Formation | Glacial Canyon | CC Fluvial | NC/EB | P | 0.73 | 0.35 |
| | | | | | | NC/EB | R | 2.91 | 0.72 |
| | | | | | | MC | MC | 0.45 | 0.45 |
| 5 | 8.90-10.83 | 0.011 | Glacial Drift over Chumstick Formation | Glacial Valley | MCV Alluvial | NC/EB | P | 0.18 | 0.18 |
| | | | | | | NC/EB | R | 7.66 | 0.70 |
| 6 | 10.83-11.80 | 0.008 | Glacial Drift over Chumstick Formation | Glacial Canyon | CC Fluvial | NC/EB | G | 0.19 | 0.19 |
| | | | | | | NC/EB | P | 0.14 | 0.14 |
| | | | | | | NC/EB | R | 3.86 | 1.23 |
| | | | | | | MC | MC | 0.53 | 0.53 |
| 7 | 11.80-20.03 | 0.001 | Glacial Drift over Chumstick Formation | Glacial Valley | UCV Alluvial | NC | G | 2.34 | 0.55 |
| | | | | | | NC | P | 5.25 | 1.41 |
| | | | | | | NC | R | 1.49 | 1.01 |
| | | | | | | NC/S | P | 0.79 | 0.39 |
| | | | | | | NC/S | R | 1.46 | 0.43 |
| | | | | | | NC/EB | G | 2.80 | 1.40 |
| | | | | | | NC/EB | P | 6.83 | 1.56 |
| | | | | | | NC/EB | R | 3.23 | 0.52 |
| | | | | | | MC | MC | 4.75 | 2.48 |
| 8 | 20.03-25.42 | 0.003 | Glacial Drift over Swakane Gneiss | Glacial Valley | UCV Alluvial | NC | G | 0.75 | 0.35 |
| | | | | | | NC | P | 1.85 | 0.34 |
| | | | | | | NC | R | 4.47 | 0.79 |
| | | | | | | NC/EB | G | 0.82 | 0.53 |
| | | | | | | NC/EB | P | 3.15 | 0.51 |
| | | | | | | NC/EB | R | 1.27 | 0.51 |
| | | | | | | EB | P | 0.32 | 0.32 |
| | | | | | | EB | R | 0.18 | 0.18 |
| | | | | | | MC | MC | 26.79 | 19.76 |
| 9 | 25.42-28.81 | 0.007 | Glacial Drift over Swakane Gneiss | Glacial Valley | MCV Alluvial | NC | G | 0.61 | 0.61 |
| | | | | | | NC | P | 0.94 | 0.54 |
| | | | | | | NC | R | 3.12 | 0.58 |
| | | | | | | MC | MC | 5.75 | 0.80 |
| 10 | 28.81-31.11 | 0.011 | Pre-upper Jurassic Gneiss | Glacial Valley | MCV Alluvial | NC | P | 0.63 | 0.31 |
| | | | | | | NC | R | 3.47 | 0.38 |
| | | | | | | MC | MC | 2.59 | 0.29 |

**Table 1**. Concluded.

| Reach | RM | Gradient | Geologic district | Landtype association | Valley bottom type | Stream state type | Habitat type | Area (ha) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Total | Sampled |
| **Phelps Creek** | | | | | | | | | |
| 1 | 0.00-0.35 | 0.043 | Pre-upper Jurassic Gneiss | Glacial Valley | MCV Alluvial | NC | P | 0.04 | 0.04 |
| | | | | | | NC | R | 0.13 | 0.13 |
| | | | | | | NC | MC | 0.14 | 0.14 |
| **Chikamin Creek[1]** | | | | | | | | | |
| 1 | 0.00-0.94 | 0.013 | Glacial Drift over Chumstick Formation | Glacial Valley | UCV Alluvial | NC | G | 0.03 | 0.03 |
| | | | | | | NC | P | 0.24 | 0.07 |
| | | | | | | NC | R | 0.35 | 0.06 |
| | | | | | | MC | MC | 0.08 | 0.04 |
| **Rock Creek** | | | | | | | | | |
| 1 | 0.00-0.73 | 0.020 | Glacial Drift over Swakane Gneiss | Glacial Valley | UCV Alluvial | NC | G | 0.01 | 0.01 |
| | | | | | | NC | P | 0.21 | 0.06 |
| | | | | | | NC | R | 0.27 | 0.05 |
| | | | | | | MC | MC | 0.09 | 0.02 |
| **Peven Creek** | | | | | | | | | |
| 1 | 0.00-0.05 | | Pre-upper Jurassic Gneiss | Glacial Valley | MCV Alluvial | NC | P | 0.02 | 0.02 |
| | | | | | | NC | R | 0.02 | 0.02 |
| **Big Meadow Creek** | | | | | | | | | |
| 1 | 0.00-0.35 | 0.025 | Glacial Drift over Chumstick Formation | Glacial Valley | MCV Alluvial | NC | G | 0.01 | 0.01 |
| | | | | | | NC | P | 0.14 | 0.04 |
| | | | | | | NC | R | 0.13 | 0.04 |
| | | | | | | MC | MC | 0.01 | 0.01 |
| **Alder Creek** | | | | | | | | | |
| 1 | 0.00-0.01 | | Glacial Drift over Chumstick Formation | Glacial Valley | MCV Alluvial | NC | P | 0.00 | 0.00 |
| | | | | | | NC | R | 0.01 | 0.01 |
| **Brush Creek** | | | | | | | | | |
| 1 | 0.00-0.01 | | Glacial Drift over Chumstick Formation | Glacial Valley | UCV Alluvial | NC | P | 0.00 | 0.00 |
| | | | | | | NC | R | 0.01 | 0.01 |
| **Y Creek** | | | | | | | | | |
| 1 | 0.00-0.05 | | Glacial Drift over Swakane Gneiss | Glacial Valley | UCV Alluvial | NC | P | 0.00 | 0.00 |
| | | | | | | NC | R | 0.00 | 0.00 |

[1] Includes the lower 0.2 miles of Minnow Creek.

**Table 2**. Estimated mean densities (fish/hectare and fish/m$^3$), total numbers, 95% confidence bounds on total numbers, and percent error of the estimated total number of age-0 Chinook salmon in reaches in the Chiwawa River basin, Washington, August 2007.

| Reach | Mean density | | Surface area (ha) | | | Volume (m$^3$) | | |
|---|---|---|---|---|---|---|---|---|
| | Fish/ha | Fish/m$^3$ | Total No. | 95% C.B. | ± % error | Total No. | 95% C.B. | ± % error |
| **Chiwawa River** | | | | | | | | |
| 1 | 150.9 | 0.043 | 2,643 | ±476 | 18.0 | 2,665 | ±561 | 21.1 |
| 2 | 183.1 | 0.051 | 1,350 | ±317 | 23.5 | 1,477 | ±333 | 22.5 |
| 3 | 89.2 | 0.027 | 833 | ±71 | 8.5 | 988 | ±81 | 8.2 |
| 4 | 684.6 | 0.124 | 2,800 | ±2,059 | 73.5 | 2,560 | ±2,024 | 79.1 |
| 5 | 186.6 | 0.047 | 1,463 | ±72 | 4.9 | 1,465 | ±118 | 8.1 |
| 6 | 327.5 | 0.081 | 1,543 | ±83 | 5.4 | 1,659 | ±129 | 7.8 |
| 7 | 792.1 | 0.132 | 22,919 | ±4,421 | 19.3 | 23,845 | ±4,757 | 19.9 |
| 8 | 362.5 | 0.062 | 14,353 | ±5,272 | 36.7 | 12,420 | ±4,487 | 36.1 |
| 9 | 462.4 | 0.077 | 4,817 | ±1,223 | 25.4 | 3,856 | ±1,609 | 41.7 |
| 10 | 171.0 | 0.049 | 1,142 | ±431 | 37.7 | 1,342 | ±481 | 35.8 |
| **Phelps Creek** | | | | | | | | |
| 1 | 404.4 | 0.161 | 125 | ±0 | 0.0 | 125 | ±0 | 0.0 |
| **Chikamin Creek[1]** | | | | | | | | |
| 1 | 7,386.6 | 5.245 | 5,235 | ±976 | 18.6 | 8,198 | ±1,064 | 12.9 |
| **Rock Creek** | | | | | | | | |
| 1 | 1,500.5 | 0.741 | 870 | ±401 | 46.1 | 1,141 | ±424 | 37.2 |
| **Peven Creek** | | | | | | | | |
| 1 | 1,376.4 | 0.442 | 51 | ±0 | 0.0 | 51 | ±0 | 0.0 |
| **Big Meadow Creek[2]** | | | | | | | | |
| 1 | 1,782.2 | 1.313 | 538 | ±476 | 88.5 | 660 | ±494 | 74.8 |
| **Alder Creek** | | | | | | | | |
| 1 | 2,278.7 | 2.187 | 20 | ±0 | 0.0 | 20 | ±0 | 0.0 |
| **Brush Creek** | | | | | | | | |
| 1 | 3,205.2 | 4.052 | 28 | ±0 | 0.0 | 28 | ±0 | 0.0 |
| **Y Creek** | | | | | | | | |
| 1 | 5,380.4 | 4.579 | 22 | ±0 | 0.0 | 22 | ±0 | 0.0 |
| **Grand Total** | **438.8** | **0.094** | **60,752** | **±7,413** | **12.2** | **62,522** | **±7,190** | **11.5** |

[1] Includes lower 0.2 miles of Minnow Creek.
[2] An additional 1,818 (based on fish/ha) or 2,195 (based on fish/m$^3$) hatchery spring Chinook were counted in Big Meadow Creek in 2007. These were from the 12,977 high-ELISA spring Chinook planted in Big Meadow Creek on 22 May 2007.

**Table 3**. Estimated mean densities (fish/hectare and fish/m$^3$), total numbers, 95% confidence bounds on total numbers, and percent error of the estimated total number of age-1+ Chinook salmon in reaches in the Chiwawa River basin, Washington, August 2007.

| Reach | Mean density | | Surface area (ha) | | | Volume (m$^3$) | | |
|---|---|---|---|---|---|---|---|---|
| | Fish/ha | Fish/m$^3$ | Total No. | 95% C.B. | ± % error | Total No. | 95% C.B. | ± % error |
| **Chiwawa River** | | | | | | | | |
| 1 | 1.2 | 0.001 | 20 | ±14 | 70.0 | 20 | ±15 | 75.0 |
| 2 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 3 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 4 | 3.7 | 0.001 | 15 | ±13 | 86.7 | 13 | ±13 | 100.0 |
| 5 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 6 | 1.2 | 0.001 | 6 | ±0 | 0.0 | 6 | ±0 | 0.0 |
| 7 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 8 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 9 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 10 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Phelps Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Chikamin Creek[1]** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Rock Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Peven Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Big Meadow Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Alder Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Brush Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Y Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Grand Total** | **0.3** | **0.000** | **41** | **±20** | **48.8** | **39** | **±20** | **51.3** |

[1] Includes lower 0.2 miles of Minnow Creek.

**Table 4**. Summary of the five productivity models of juvenile (age-0) Chinook salmon in the Chiwawa Basin. Models are shown, including the number of parameters ($K$), $AIC_c$ values, $AIC_c$ difference scores ($\Delta_i$), the likelihood of the model given the data ($£(g_i|x)$), Akaike weights ($w_i$), and adjusted $R^2$ values. The sample size ($n$) for all models was 15.

| Model | $K^a$ | $AIC_c$ | $\Delta_i$ | $£(g_i\|x)$ | $w_i$ | $R^2$ |
|---|---|---|---|---|---|---|
| Cushing | 3 | 263.30 | 0.00 | 1.00 | 0.63 | 0.66 |
| Beverton-Holt | 3 | 264.98 | 1.68 | 0.43 | 0.27 | 0.62 |
| Gamma[b] | 4 | 267.08 | 3.77 | 0.15 | 0.09 | 0.66 |
| Ricker | 3 | 271.88 | 8.57 | 0.01 | 0.01 | 0.40 |
| Density Independent | 2 | 280.61 | 17.31 | 0.00 | 0.00 | 0.00 |

[a] ***K*** is the number of structural parameters in the model plus 1 for $\sigma^2$.
[b] The $\beta$ parameter in the Gamma model was very close to 0, which means that this model is nearly identical to the Cushing model. The reason it did not rank higher is because it contains an extra parameter, which means that it has less bias and greater variance than the Cushing model (less parsimonious).

**Table 5**. Estimated mean densities (fish/hectare and fish/m$^3$), total numbers, 95% confidence bounds on total numbers, and percent error of the estimated total number of age-0 (<4 in) steelhead/rainbow in reaches in the Chiwawa River basin, Washington, August 2007.

| Reach | Mean density | | Surface area (ha) | | | Volume (m$^3$) | | |
|---|---|---|---|---|---|---|---|---|
| | Fish/ha | Fish/m$^3$ | Total No. | 95% C.B. | ± % error | Total No. | 95% C.B. | ± % error |
| **Chiwawa River** | | | | | | | | |
| 1 | 71.6 | 0.021 | 1,254 | ±132 | 10.5 | 1,309 | ±121 | 9.2 |
| 2 | 187.5 | 0.053 | 1,383 | ±193 | 13.9 | 1,555 | ±245 | 15.8 |
| 3 | 173.2 | 0.056 | 1,617 | ±164 | 10.1 | 2,051 | ±167 | 8.1 |
| 4 | 156.9 | 0.031 | 642 | ±125 | 19.5 | 636 | ±127 | 19.9 |
| 5 | 120.8 | 0.030 | 947 | ±31 | 3.3 | 948 | ±64 | 6.8 |
| 6 | 146.3 | 0.037 | 689 | ±91 | 13.2 | 760 | ±62 | 8.2 |
| 7 | 62.8 | 0.009 | 1,816 | ±515 | 28.4 | 1,613 | ±586 | 36.3 |
| 8 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 9 | 2.1 | 0.001 | 22 | ±45 | 204.5 | 28 | ±45 | 160.7 |
| 10 | 10.8 | 0.003 | 72 | ±21 | 29.2 | 73 | ±12 | 16.4 |
| **Phelps Creek** | | | | | | | | |
| 1 | 173.3 | 0.069 | 53 | ±0 | 0.0 | 53 | ±0 | 0.0 |
| **Chikamin Creek[1]** | | | | | | | | |
| 1 | 3,014.5 | 1.880 | 2,137 | ±425 | 19.9 | 2,939 | ±474 | 16.1 |
| **Rock Creek** | | | | | | | | |
| 1 | 600.9 | 0.298 | 348 | ±129 | 37.1 | 459 | ±134 | 29.2 |
| **Peven Creek** | | | | | | | | |
| 1 | 305.9 | 0.098 | 11 | ±0 | 0.0 | 11 | ±0 | 0.0 |
| **Big Meadow Creek** | | | | | | | | |
| 1 | 9,790.3 | 6.685 | 2,955 | ±1,269 | 42.9 | 3,363 | ±1,412 | 41.9 |
| **Alder Creek** | | | | | | | | |
| 1 | 7,405.7 | 7.109 | 65 | ±0 | 0.0 | 65 | ±0 | 0.0 |
| **Brush Creek** | | | | | | | | |
| 1 | 3,205.2 | 4.052 | 28 | ±0 | 0.0 | 28 | ±0 | 0.0 |
| **Y Creek** | | | | | | | | |
| 1 | 8,070.7 | 6.869 | 34 | ±0 | 0.0 | 34 | ±0 | 0.0 |
| **Grand Total** | **101.7** | **0.024** | **14,073** | **±1,477** | **10.5** | **15,925** | **±1,646** | **10.3** |

[1] Includes lower 0.2 miles of Minnow Creek.

**Table 6**. Estimated mean densities (fish/hectare and fish/m$^3$), total numbers, 95% confidence bounds on total numbers, and percent error of the estimated total number of age-1+ (4-8 in) steelhead/rainbow in reaches in the Chiwawa River basin, Washington, August 2007.

| Reach | Mean density | | Surface area (ha) | | | Volume (m$^3$) | | |
|---|---|---|---|---|---|---|---|---|
| | Fish/ha | Fish/m$^3$ | Total No. | 95% C.B. | ± % error | Total No. | 95% C.B. | ± % error |
| **Chiwawa River** | | | | | | | | |
| 1 | 120.9 | 0.036 | 2,117 | ±427 | 20.2 | 2,203 | ±418 | 18.9 |
| 2 | 142.6 | 0.040 | 1,052 | ±139 | 13.2 | 1,173 | ±180 | 15.3 |
| 3 | 63.4 | 0.020 | 591 | ±34 | 5.8 | 718 | ±37 | 5.2 |
| 4 | 100.7 | 0.019 | 412 | ±144 | 34.9 | 400 | ±141 | 35.3 |
| 5 | 104.9 | 0.026 | 822 | ±56 | 6.8 | 824 | ±77 | 9.3 |
| 6 | 115.5 | 0.029 | 544 | ±82 | 15.1 | 598 | ±64 | 10.7 |
| 7 | 48.7 | 0.007 | 1,409 | ±529 | 37.5 | 1,307 | ±535 | 40.9 |
| 8 | 0.7 | 0.000 | 29 | ±84 | 289.7 | 28 | ±72 | 257.1 |
| 9 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 10 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Phelps Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Chikamin Creek[1]** | | | | | | | | |
| 1 | 1,333.4 | 0.877 | 945 | ±347 | 36.7 | 1,371 | ±319 | 23.3 |
| **Rock Creek** | | | | | | | | |
| 1 | 165.4 | 0.077 | 96 | ±111 | 115.6 | 118 | ±115 | 97.5 |
| **Peven Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Big Meadow Creek** | | | | | | | | |
| 1 | 1,427.9 | 1.014 | 431 | ±120 | 27.8 | 510 | ±128 | 25.1 |
| **Alder Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Brush Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Y Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Grand Total** | **61.0** | **0.014** | **8,448** | **±817** | **9.7** | **9,250** | **±814** | **8.8** |

[1] Includes lower 0.2 miles of Minnow Creek.

**Table 7**. Estimated mean densities (fish/hectare and fish/m$^3$), total numbers, 95% confidence bounds on total numbers, and percent error of the estimated total number of steelhead/rainbow larger than 8 inches in reaches in the Chiwawa River basin, Washington, August 2007.

| Reach | Mean density | | Surface area (ha) | | | Volume (m$^3$) | | |
|---|---|---|---|---|---|---|---|---|
| | Fish/ha | Fish/m$^3$ | Total No. | 95% C.B. | ± % error | Total No. | 95% C.B. | ± % error |
| **Chiwawa River** | | | | | | | | |
| 1 | 0.9 | 0.000 | 16 | ±8 | 50.0 | 16 | ±9 | 56.3 |
| 2 | 2.1 | 0.001 | 15 | ±1 | 6.7 | 14 | ±2 | 14.3 |
| 3 | 0.6 | 0.000 | 6 | ±3 | 50.0 | 6 | ±3 | 50.0 |
| 4 | 1.0 | 0.000 | 4 | ±4 | 100.0 | 4 | ±4 | 100.0 |
| 5 | 0.1 | 0.000 | 1 | ±0 | 0.0 | 1 | ±0 | 0.0 |
| 6 | 0.2 | 0.000 | 1 | ±0 | 0.0 | 1 | ±0 | 0.0 |
| 7 | 0.2 | 0.000 | 6 | ±7 | 116.7 | 5 | ±7 | 140.0 |
| 8 | 0.6 | 0.000 | 25 | ±21 | 84.0 | 26 | ±19 | 73.1 |
| 9 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 10 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Phelps Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Chikamin Creek[1]** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Rock Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Peven Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Big Meadow Creek** | | | | | | | | |
| 1 | 11.5 | 0.009 | 3 | ±5 | 166.7 | 4 | ±5 | 125.0 |
| **Alder Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Brush Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Y Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Grand Total** | **0.6** | **0.000** | **77** | **±24** | **31.2** | **77** | **±23** | **29.9** |

[1] Includes lower 0.2 miles of Minnow Creek.

**Table 8**. Estimated mean densities (fish/hectare and fish/m$^3$), total numbers, 95% confidence bounds on total numbers, and percent error of the estimated total number of juvenile bull trout (2-8 in) in reaches in the Chiwawa River basin, Washington, August 2007.

| Reach | Mean density | | Surface area (ha) | | | Volume (m$^3$) | | |
|---|---|---|---|---|---|---|---|---|
| | Fish/ha | Fish/m$^3$ | Total No. | 95% C.B. | ± % error | Total No. | 95% C.B. | ± % error |
| **Chiwawa River** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 2 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 3 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 4 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 5 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 6 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 7 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| 8 | 0.5 | 0.000 | 19 | ±22 | 115.8 | 19 | ±21 | 110.5 |
| 9 | 0.5 | 0.000 | 5 | ±6 | 120.0 | 7 | ±5 | 71.4 |
| 10 | 4.1 | 0.001 | 27 | ±11 | 40.7 | 25 | ±13 | 52.0 |
| **Phelps Creek** | | | | | | | | |
| 1 | 58.3 | 0.023 | 18 | ±0 | 0.0 | 18 | ±0 | 0.0 |
| **Chikamin Creek[1]** | | | | | | | | |
| 1 | 16.8 | 0.010 | 12 | ±12 | 100.0 | 16 | ±13 | 81.3 |
| **Rock Creek** | | | | | | | | |
| 1 | 23.4 | 0.011 | 14 | ±7 | 50.0 | 17 | ±7 | 41.2 |
| **Peven Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Big Meadow Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Alder Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Brush Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Y Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Grand Total** | **0.7** | **0.000** | **95** | **±29** | **30.5** | **102** | **±29** | **28.4** |

[1] Includes lower 0.2 miles of Minnow Creek.

**Table 9**. Estimated mean densities (fish/hectare and fish/m$^3$), total numbers, 95% confidence bounds on total numbers, and percent error of the estimated total number of adult bull trout (>8 in) in reaches in the Chiwawa River basin, Washington, August 2007.

| Reach | Mean density | | Surface area (ha) | | | Volume (m$^3$) | | |
|---|---|---|---|---|---|---|---|---|
| | Fish/ha | Fish/m$^3$ | Total No. | 95% C.B. | ± % error | Total No. | 95% C.B. | ± % error |
| **Chiwawa River** | | | | | | | | |
| 1 | 0.7 | 0.000 | 11 | ±5 | 45.5 | 11 | ±6 | 54.5 |
| 2 | 1.0 | 0.000 | 8 | ±5 | 62.5 | 7 | ±4 | 57.1 |
| 3 | 0.3 | 0.000 | 3 | ±1 | 33.3 | 3 | ±1 | 33.3 |
| 4 | 2.0 | 0.000 | 8 | ±6 | 75.0 | 8 | ±6 | 75.0 |
| 5 | 0.6 | 0.000 | 5 | ±0 | 0.0 | 5 | ±0 | 0.0 |
| 6 | 0.4 | 0.000 | 2 | ±0 | 0.0 | 2 | ±0 | 0.0 |
| 7 | 4.7 | 0.001 | 136 | ±39 | 28.7 | 133 | ±40 | 30.1 |
| 8 | 4.2 | 0.001 | 167 | ±49 | 29.3 | 161 | ±47 | 29.2 |
| 9 | 7.2 | 0.001 | 75 | ±35 | 46.7 | 67 | ±32 | 47.8 |
| 10 | 15.8 | 0.004 | 105 | ±13 | 12.4 | 120 | ±14 | 11.7 |
| **Phelps Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Chikamin Creek[1]** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Rock Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Peven Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Big Meadow Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Alder Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Brush Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Y Creek** | | | | | | | | |
| 1 | 0.0 | 0.000 | 0 | ±0 | 0.0 | 0 | ±0 | 0.0 |
| **Grand Total** | **3.8** | **0.001** | **520** | **±73** | **14.0** | **517** | **±72** | **13.9** |

[1] Includes lower 0.2 miles of Minnow Creek.

**APPENDIX A**. Numbers of redds, eggs, age-0 Chinook salmon, parr per redd, and percent egg-to-parr survival in the Chiwawa River basin, brood years 1991-2006. Numbers of eggs were calculated as the number of redds times the mean fecundity of females collected for broodstock.

| Brood Year | Chinook Salmon | | | Parr/Redd | Egg-to-parr survival (%) |
|---|---|---|---|---|---|
| | Redds | Eggs | Age-0 (parr) | | |
| 1991 | 104 | 478,400 | 45,483 | 437 | 9.5 |
| 1992 | 302 | 1,570,098 | 79,113 | 262 | 5.0 |
| 1993 | 106 | 556,394 | 55,056 | 519 | 9.9 |
| 1994 | 82 | 485,686 | 55,240 | 674 | 11.4 |
| 1995 | 13 | 66,248 | 5,815 | 447 | 8.8 |
| 1996 | 23 | 106,835 | 16,066 | 699 | 15.0 |
| 1997 | 82 | 374,740 | 68,415 | 834 | 18.3 |
| 1998 | 41 | 218,325 | 41,629 | 1,015 | 19.1 |
| 1999 | 34 | 166,090 | NS | NS | NS |
| 2000 | 128 | 642,944 | 114,617 | 895 | 17.8 |
| 2001 | 1,078 | 4,984,672 | 134,874 | 125 | 2.7 |
| 2002 | 345 | 1,605,630 | 91,278 | 265 | 5.7 |
| 2003 | 111 | 648,684 | 45,177 | 407 | 7.0 |
| 2004 | 241 | 1,156,559 | 49,631 | 206 | 4.3 |
| 2005 | 332 | 1,436,564 | 79,902 | 241 | 5.6 |
| 2006 | 297 | 1,284,228 | 60,752 | 205 | 4.7 |
| **Average** | **207** | **986,381** | **62,870** | **284** | **6.0** |

**APPENDIX B**. Estimated numbers of salmonids (based on fish/ha) in the Chiwawa River basin, Washington, 1992-2007; NS = not sampled.

| Sample year | Chinook salmon | | Steelhead/Rainbow | | | Bull trout | |
|---|---|---|---|---|---|---|---|
| | Age-0 | Age-1+ | Age-0 | Age-1+ | >8 in[1] | 2-8 in | >8 in |
| 1992[2] | 45,483 | 563 | 4,927 | 2,533 | 1,869 | 299 | 208 |
| 1993 | 79,113 | 174 | 4,004 | 2,860 | 768 | 158 | 156 |
| 1994 | 55,056 | 18 | 1,410 | 5,856 | 67 | 90 | 76 |
| 1995 | 55,241 | 13 | 7,357 | 9,517 | 140 | 97 | 664 |
| 1996 | 5,815 | 22 | 4,245 | 11,849 | 78 | 79 | 343 |
| 1997 | 16,066 | 5 | 8,823 | 6,905 | 48 | 220 | 472 |
| 1998 | 68,415 | 63 | 3,921 | 10,585 | 78 | 300 | 900 |
| 1999 | 41,629 | 41 | 5,838 | 22,130 | 33 | 130 | 423 |
| 2000 | NS | NS | NS | NS | NS | NS | NS |
| 2001 | 114,617 | 69 | 45,727 | 10,623 | 420 | 505 | 542 |
| 2002 | 134,874 | 32 | 20,521 | 9,090 | 181 | 217 | 521 |
| 2003 | 91,278 | 134 | 18,020 | 6,179 | 49 | 196 | 282 |
| 2004 | 45,177 | 21 | 10,380 | 8,190 | 8 | 140 | 157 |
| 2005 | 49,631 | 79 | 11,463 | 6,188 | 48 | 125 | 346 |
| 2006 | 79,902 | 388 | 16,245 | 10,533 | 50 | 238 | 686 |
| 2007 | 60,752 | 41 | 14,073 | 8,448 | 77 | 95 | 520 |

[1]During 1992-1993, numbers included both hatchery and wild rainbow trout. Thereafter only wild trout were observed.
[2]Only the Chiwawa River was sampled in 1992. No tributaries were sampled.

**APPENDIX C.** Proportion of total habitat available, fraction of all age-0 Chinook within each habitat type, and densities (fish/ha) and numbers of age-0 Chinook within each habitat type in the Chiwawa River basin, survey years 1992-2007.

| Habitat | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Proportion of total habitat available** | | | | | | | | | | | | | | | | | |
| Glide | 0.10 | 0.09 | 0.10 | 0.10 | 0.10 | 0.09 | 0.09 | 0.09 | NS | 0.07 | 0.08 | 0.07 | 0.07 | 0.08 | 0.08 | 0.07 | **0.08** |
| Pool | 0.19 | 0.19 | 0.21 | 0.18 | 0.18 | 0.17 | 0.16 | 0.17 | NS | 0.15 | 0.16 | 0.17 | 0.16 | 0.16 | 0.16 | 0.17 | **0.17** |
| Riffle | 0.61 | 0.61 | 0.57 | 0.59 | 0.57 | 0.57 | 0.58 | 0.55 | NS | 0.49 | 0.48 | 0.49 | 0.50 | 0.47 | 0.47 | 0.47 | **0.53** |
| M. Chan | 0.10 | 0.11 | 0.12 | 0.14 | 0.14 | 0.17 | 0.17 | 0.19 | NS | 0.29 | 0.28 | 0.26 | 0.27 | 0.29 | 0.30 | 0.29 | **0.21** |
| **Fraction of all age-0 Chinook within habitat types** | | | | | | | | | | | | | | | | | |
| Glide | 0.07 | 0.03 | 0.02 | 0.01 | 0.02 | 0.01 | 0.01 | 0.01 | NS | 0.03 | 0.01 | 0.02 | 0.01 | 0.01 | 0.03 | 0.02 | **0.02** |
| Pool | 0.30 | 0.28 | 0.22 | 0.21 | 0.30 | 0.16 | 0.17 | 0.14 | NS | 0.23 | 0.24 | 0.23 | 0.07 | 0.19 | 0.31 | 0.46 | **0.24** |
| Riffle | 0.19 | 0.16 | 0.12 | 0.11 | 0.43 | 0.23 | 0.08 | 0.11 | NS | 0.18 | 0.15 | 0.15 | 0.14 | 0.07 | 0.12 | 0.12 | **0.14** |
| M. Chan | 0.45 | 0.53 | 0.64 | 0.67 | 0.24 | 0.60 | 0.74 | 0.74 | NS | 0.57 | 0.60 | 0.60 | 0.77 | 0.73 | 0.54 | 0.40 | **0.60** |
| **Densities of age-0 Chinook within habitat types (fish/ha)** | | | | | | | | | | | | | | | | | |
| Glide | 254 | 251 | 93 | 55 | 11 | 12 | 78 | 13 | NS | 351 | 187 | 200 | 58 | 49 | 237 | 113 | **127** |
| Pool | 584 | 1,049 | 619 | 541 | 82 | 122 | 607 | 257 | NS | 1,392 | 1,468 | 951 | 155 | 492 | 1,240 | 1,211 | **720** |
| Riffle | 116 | 188 | 124 | 91 | 38 | 52 | 79 | 62 | NS | 336 | 300 | 216 | 101 | 60 | 166 | 118 | **135** |
| M. Chan | 1,710 | 3,408 | 2,985 | 2,328 | 84 | 449 | 2,620 | 1,201 | NS | 1,820 | 2,069 | 1,626 | 1,008 | 1,057 | 1,147 | 603 | **1,445** |
| **Number of age-0 Chinook within habitat types** | | | | | | | | | | | | | | | | | |
| Glide | 2,967 | 2,458 | 857 | 623 | 137 | 130 | 837 | 157 | NS | 3,231 | 1,931 | 1,884 | 540 | 442 | 2,498 | 1,120 | **1,321** |
| Pool | 13,468 | 21,814 | 12,131 | 11,294 | 1,755 | 2,553 | 11,454 | 5,933 | NS | 25,890 | 32,612 | 21,091 | 3,183 | 9,626 | 26,754 | 28,851 | **15,227** |
| Riffle | 8,531 | 12,616 | 6,698 | 6,197 | 2,525 | 3,699 | 5,392 | 4,626 | NS | 20,629 | 19,754 | 13,783 | 6,501 | 3,367 | 10,753 | 7,809 | **8,859** |
| M. Chan | 20,517 | 42,225 | 35,370 | 36,965 | 1,396 | 9,682 | 50,728 | 30,912 | NS | 64,866 | 80,576 | 54,519 | 34,952 | 36,196 | 46,580 | 25,409 | **38,060** |

# APPENDIX B

## Fish Trapping at the Chiwawa, Upper Wenatchee, and Lower Wenatchee Smolt Traps during 2007.

# STATE OF WASHINGTON
# DEPARTMENT OF FISH AND WILDLIFE
## FISH PROGRAM -SCIENCE DIVISION
## SUPPLEMENTATION RESEARCH TEAM
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February 13, 2008

To: HCP Hatchery Committee

From: Todd Miller

Cc: Distribution List

**Subject: 2007 Chiwawa and Wenatchee River Smolt Estimates**

Smolt monitoring programs in the Wenatchee Basin were intended to estimate the number of naturally produced migrating smolts at either the subbasin (i.e., Wenatchee) or watershed scale (i.e., Chiwawa) depending on the target stock (Table 1). In addition, population estimates of hatchery sockeye emigrating from Lake Wenatchee were used to calculate post release survival (i.e., subyearling parr to yearling smolt). The size of smolt traps operated was determined by water depth and river discharge at each of the locations. The number of smolt traps operated was determined by the expected trap efficiency. Smolt traps were located downstream from all (i.e., Chiwawa spring Chinook, Wenatchee spring Chinook, and Wenatchee sockeye), or the majority (i.e., Wenatchee summer Chinook and Wenatchee steelhead) of the spawning areas (Figure 1).

Table 1. Target stocks and corresponding smolt trapping locations used in 2007.

| Stock | Smolt trap location | Smolt trap | |
|---|---|---|---|
| | | Number | Diameter (m) |
| Chiwawa spring Chinook | Chiwawa | 1 | 2.6 |
| Wenatchee sockeye | Lake Wenatchee | 2 | 1.5 |
| Wenatchee spring Chinook | Monitor (Lower Wenatchee) | 2 | 2.6 |
| Wenatchee summer Chinook | Monitor (Lower Wenatchee) | 2 | 2.6 |
| Wenatchee steelhead | Monitor (Lower Wenatchee) | 2 | 2.6 |

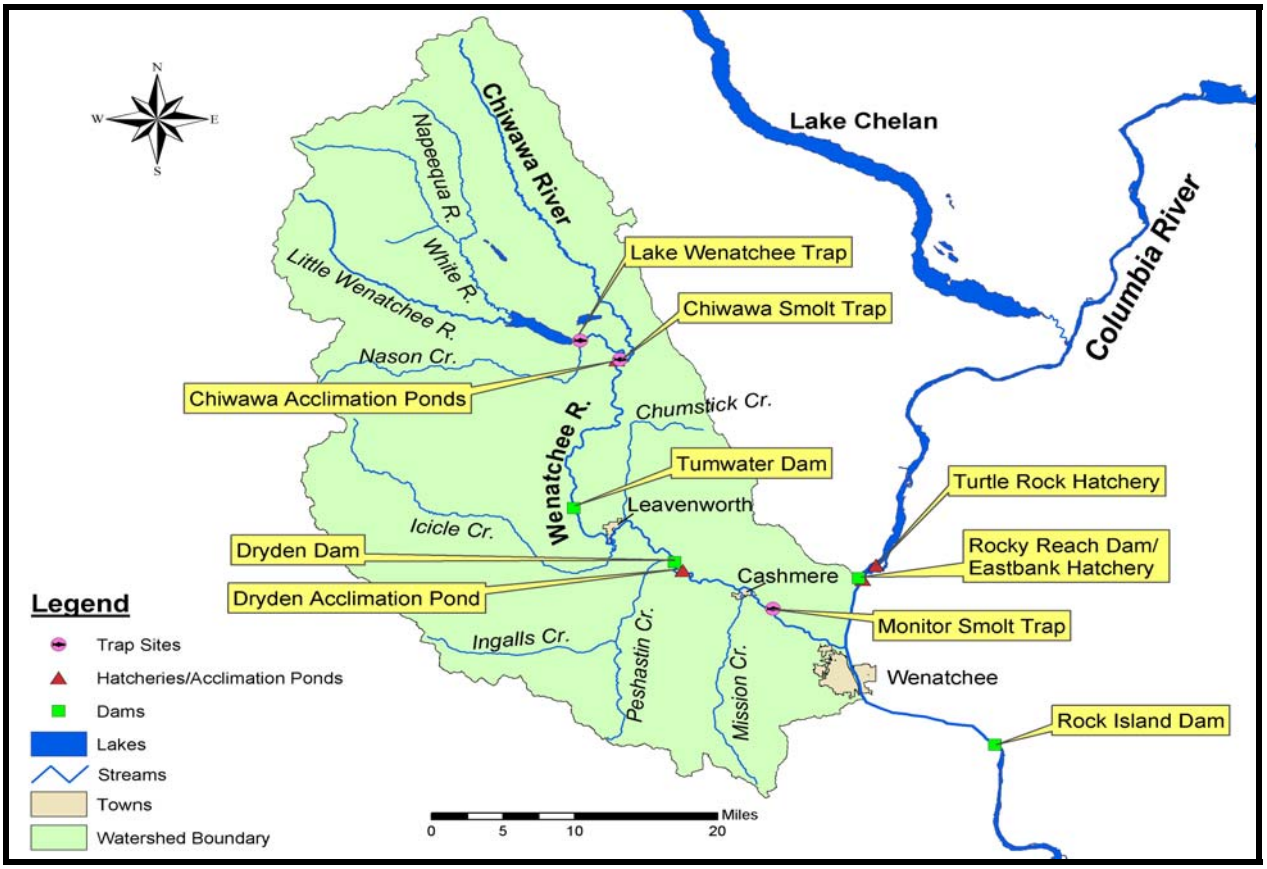


Figure 1. Locations of the upper Wenatchee (Lake Wenatchee Trap), Chiwawa, and lower Wenatchee River (Monitor Smolt Trap) smolt traps.

## Methods

Fish were removed from the trap at a minimum every morning and placed in an anesthetic solution of MS-222. Fish were identified to species and counted. Non-target species were allowed to fully recover in fresh water prior to being released in an area of calm water downstream from the smolt trap. Target species were held in separate live boxes when needed for mark/recapture efficiency trials conducted in the evening.

Fork length was measured to the nearest millimeter and weight to the nearest 0.1 g. A Fulton type condition factor ($WH10^5/FL^3$) was calculated for all target species. The degree of smoltification (parr, transitional, or smolt) was assessed by visual examination. Juvenile spring Chinook and steelhead were classified as parr if parr marks were distinct, transitional if parr marks were not distinct, and smolts if parr marks were not visible and the fish exhibited a silvery appearance.

Mark/recapture efficiency trials were conducted throughout the trapping season. The frequency of mark/recapture trials was dependent on the number of fish captured (i.e., no less than 100) and the river discharge. These trials were conducted over the widest range of discharge possible (interval depends on trap location). Fish utilized for mark/recapture trials were marked by clipping the tip of either the upper or lower lobe of the caudal fin or were PIT tagged by Chelan

County PUD personnel. Chinook fry (i.e., FL < 50 mm) used in mark/recapture trials were dyed using a Bismark brown solution. Marked fish were distributed evenly on both sides of the river in pools or in calm pockets of water around boulders. In the case of the upper Wenatchee River trap, marked fish were transported and released into Lake Wenatchee. Marked fish were released between 1800 h and 2000 h. All recaptures of marked fish typically occurred within 48 h after each trial. Emigration estimates were calculated using estimated daily trap efficiency derived from the regression formula using trap efficiency (dependent variable) and discharge (independent variable).

Trap efficiency was calculated using the following formula:

$$\text{Trap efficiency} = E_i = R / Mi,$$

where $E_i$ is the trap efficiency during time period $i$; $M_i$ is the number of marked fish released during time period $i$; and $R_i$ is the number of marked fish recaptured during time period $i$. The number of fish captured was expanded by the estimated daily trap efficiency ($e$) to estimate the daily number of fish migrating past the trap ($N_i$) using the following formula:

$$\text{Estimated daily migration} = \hat{N}_i = C_i / \hat{e}_i$$

where $N_i$ is the estimated number of fish passing the trap during time period $i$; $C_i$ is the number of unmarked fish captured during time period $i$; and $e_i$ is the estimated trap efficiency for time period $i$ based on the regression equation.

The variance for the total daily number of fish migrating past the trap will be calculated using the following formulas:

$$\text{Variance of daily migration estimate} = \text{var}\left[\hat{N}_i\right] = \hat{N}_i^2 \frac{\text{MSE}\left(1 + \frac{1}{n} + \frac{\left(X_i - \overline{X}\right)^2}{\left(n-1\right)s_X^2}\right)}{\hat{e}_i^2}$$

where $X_i$ is the discharge for time period $i$, and $n$ is the sample size. If a relationship between discharge and trap efficiency was not present (i.e., $P < 0.05$; $r^2 \sim 0.5$), a pooled trap efficiency was used to estimate daily emigration:

$$\text{Pooled trap efficiency} = e_p = \sum R / \sum M$$

The daily emigration estimate was calculated using the formula:

$$\text{Daily emigration estimate} = \hat{N}_i = C_i / e_p$$

The variance for daily emigration estimates using the pooled trap efficiency was calculated using the formula:

Variance for daily emigration estimate = $\mathrm{var}\left[\hat{N}_i\right] = \hat{N}_i^2 \dfrac{e_p(1-e_p)/\sum M}{e_p^2}$

The total emigration estimate and confidence interval was calculated using the following formulas:

$$\text{Total emigration estimate} = \sum \hat{N}_i$$

$$\text{95\% confidence interval} = 1.96 \times \sqrt{\sum \mathrm{var}\left[\hat{N}_i\right]}$$

## Results

### Chiwawa River Smolt Trap

*2005 Brood Year*

The Chiwawa River smolt trap was located approximately 1 km upstream from the confluence with the Wenatchee River. The smolt trap operated between 27 February and 27 November. During that time period the trap was inoperable for 23 days as a result of high river flows, debris, snow/ice, or mechanical failure. During breaks in operation, the estimated number of Chinook captured was calculated from the mean of number of fish captured two days prior and two days after the break in operation. The trap was operated in two positions dependent on river discharge (i.e., lower > 12 $m^3/s$ and upper < 12 $m^3/s$). Daily trap efficiencies were estimated from two regression models (independent variable = discharge) depending on trap position and age class (i.e., subyearling and yearling Chinook).

Wild yearling spring Chinook (2005 brood) were primarily captured between 1 March and 29 June (Figure 2). We captured 4,433 yearling Chinook (Appendix A) and estimated 4,569 yearling Chinook would have been captured if the trap had operated without interruption. Mortality for the season totaled 9 yearling spring Chinook (0.2 %). Eleven mark/recapture efficiency trials were conducted in the lower position with a mean (SD) trap efficiency of 12.4 (9.0 ) %. In 2007, mark/recapture trials could not be conducted at all required discharge levels due to low catch rates. Therefore, efficiency trials were combined with historical trials (2002 – 2007) in order to expand the population model's utility over a greater range of river discharge. The 2007 regression model for the lower position ($r^2 = 0.82$, $P < 0.001$) was used to estimate yearling Chinook. The estimated number (95% C.I.) of yearling Chinook that emigrated from the Chiwawa River in 2007 was 69,064 (±35,747). The large confidence interval was due to the number of fish captured at very high discharge (i.e., low trap efficiency). Fish captured during the months of May and June account for only 22% of the estimated population, but 30% of the total variance. More simply, low trap efficiency (~ 2.5%) during this period was responsible for the large reported variance.

*2006 Brood Year*

Wild subyearling spring Chinook were captured between 8 June and 27 November. We captured 16,250 subyearling Chinook and estimated 16,902 subyearling Chinook would have been captured if the trap had operated without interruption (Figure 2). Mortality for the season totaled 130 subyearling spring Chinook (0.8%). Fifteen mark/recapture efficiency trials were conducted with a mean (SD) trap efficiency of 31.1 (16.8) %. The 2007 subyearling regression model (i.e., upper trap position) also included data from previous years (2002-2004, 2006-2007; $r^2 = 0.74$, $P < 0.01$) increasing the utility of the model over a greater range of river discharge. However, subyearling Chinook were also captured while the trap was operated in the lower position. Hence, a separate regression model was used for that time period ($r^2 = 0.82$, $P < 0.01$). In 2007, the estimated number (95% C.I.) of subyearling spring Chinook (including fry) that moved downstream of the Chiwawa River smolt trap during the sampling period was 70,202 (± 16,147). The estimate should be considered conservative because several days during peak emigration river discharge exceeded the range of the regression model. Hence, the estimated trap efficiency for those days was actually lower than that estimated using the regression model.

The proportion of the subyearling Chinook that were captured and classified as fry was less in 2007 (4%) than in 2006 (10%). Typically the number of fry captured comprises less than 3% of the total number of Chinook captured for any given brood year. The large proportion of fry captured in 2002, 2003, 2004, and 2005 was attributed to a combination of large escapement, proximity of redds to the trapping location, and high water velocity and discharge during the emergence period. We have been unable to determine if fry captured in the smolt trap migrate upstream at a later date and rear in the Chiwawa River or reside downstream of the smolt trap until the following spring and emigrate as yearling smolts. Hillman and Miller (2002) reported large numbers of subyearling chinook in tributaries of the Chiwawa River where no spawning had been reported. These data suggest considerable movement during the summer rearing period. Due to the high likelihood that fry do migrate upstream and reside in the Chiwawa River, fry have not been included in our emigrant production estimates. Excluding the fry from the estimate, the number of subyearling spring Chinook that emigrated from the Chiwawa River was 62,922 (± 13,424).

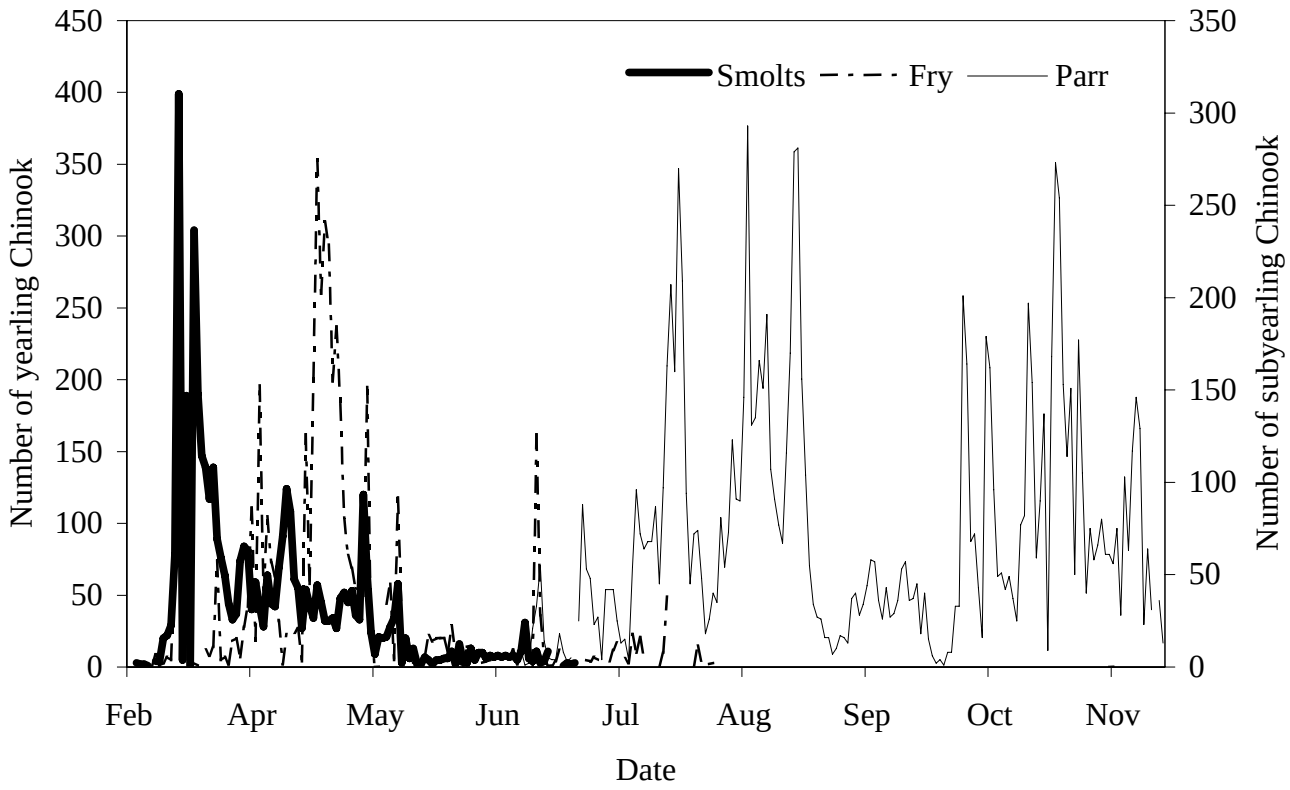


Figure 2. Daily number of Chiwawa River spring Chinook smolts, parr, and fry captured in 2007.

*Emigrant Survival*

The estimated total egg deposition was calculated by multiplying the mean fecundity of the 2005 brood spawners (M. Tonseth, WDFW, personal communication) by the total number of redds found during surveys in the Chiwawa River basin in 2005 (Murdoch et al. 2005). Egg-to-emigrant survival was calculated by dividing the estimated egg deposition by the total number of subyearling (excluding fry) that emigrated in 2006 and yearling spring Chinook that emigrated in 2007. The estimated egg-to-emigrant survival for the 2005 brood Chiwawa spring Chinook was 12.4% (Table 2).

*Length and Weight*

Individual length and weight measurements were recorded from a sample of the daily catch. The mean fork length (SD) of yearling and subyearling Chinook (fry excluded) captured was 91.3 (7.8) mm and 72.1 (11.5) mm, respectively (Table 3). The mean fork length of subyearling Chinook fry was 38.1 (3.8) mm.

Table 2. Estimated egg deposition (# of redds x mean broodstock fecundity) and egg-to-emigrant survival rates for Chiwawa River spring Chinook salmon.

| Brood year | Number of redds | Estimated egg deposition | Estimated number | | | Egg-to-emigrant survival (%) |
|---|---|---|---|---|---|---|
| | | | Subyearling | Yearling | Total emigrants | |
| 1992 | 302 | 1,570,098 | 25,818 | 39,723 | 65,541 | 4.2 |
| 1993 | 106 | 556,394 | 14,036 | 8,662 | 22,698 | 4.1 |
| 1994 | 82 | 485,686 | 8,595 | 16,472 | 25,067 | 5.2 |
| 1995 | 13 | 66,248 | 2,121 | 3,830 | 5,951 | 9.0 |
| 1996 | 23 | 106,835 | 3,708 | 15,475 | 19,183 | 18.0 |
| 1997 | 82 | 374,740 | 16,228 | 28,334 | 44,562 | 11.9 |
| 1998 | 39 | 207,675 | 2,855 | 23,068 | 25,923 | 12.5 |
| 1999 | 34 | 166,090 | 4,988 | 10,661 | 15,649 | 9.4 |
| 2000 | 128 | 642,944 | 14,854 | 40,831 | 55,685 | 8.7 |
| 2001 | 1,046 | 4,836,704 | 459,784 | 86,482 | 546,266 | 11.3 |
| 2002 | 345 | 1,605,630 | 93,331 | 90,948 | 184,279 | 11.5 |
| 2003 | 111 | 648,684 | 16,881 | 16,755 | 33,637 | 5.2 |
| 2004 | 241 | 1,156,559 | 44,079 | 72,080 | 116,158 | 10.0 |
| 2005 | 362 | 1,436,564 | 108,595 | 69,064 | 177,659 | 12.4 |
| 2006 | 297 | 1,284,228 | 62,922 | -- | -- | -- |

Table 3. Mean fork lengths (mm), weights (g), and body condition factor of spring Chinook salmon captured in the Chiwawa River smolt trap during 2007.

| | Yearling | | | Subyearling | | |
|---|---|---|---|---|---|---|
| | Mean | SD | *N* | Mean | SD | *N* |
| Fork length | 91.3 | 7.8 | 2,250 | 72.1 | 11.5 | 1,773 |
| Weight | 8.6 | 2.5 | 2,245 | 4.5 | 2.1 | 1,718 |
| K factor | 1.10 | 0.09 | 2,245 | 1.13 | 0.16 | 1,718 |

*Nontarget Salmonids*

During the trapping period, 152 steelhead smolts and 1,056 steelhead/rainbow trout parr were also captured. Mortality for the season totaled 4 steelhead juveniles (0.3%). The mean fork length (SD) of steelhead parr and smolts captured was 91.4 (30.0) mm and 151.8 (27.7) mm, respectively (Table 4). Bull trout also comprised a large proportion of incidental species captured. During the trapping period, 29 adult (>300mm) and 250 juvenile bull trout were

captured (Table 5). Low numbers of fish captured prevented us from estimating the total number of steelhead and bull trout that emigrated from the Chiwawa River during the sampling period. The monthly totals of all fish captured are listed in Appendix A.

Table 4. Mean fork lengths (mm), weights (g), and body condition factor of juvenile steelhead captured in the Chiwawa River smolt trap during 2007.

| | Parr | | | Smolts | | |
|---|---|---|---|---|---|---|
| | Mean | SD | *N* | Mean | SD | *N* |
| Fork length | 91.4 | 30.0 | 968 | 151.8 | 27.7 | 150 |
| Weight | 11.3 | 18.2 | 965 | 39.2 | 19.0 | 149 |
| K factor | 1.07 | 0.22 | 965 | 1.02 | 0.11 | 149 |

Table 5. Mean fork lengths (mm), weights (g), and body condition factor of bull trout captured in the Chiwawa River smolt trap during 2007.

| | Juvenile | | | Adult | | |
|---|---|---|---|---|---|---|
| | Mean | SD | *N* | Mean | SD | *N* |
| Fork length | 176.3 | 42.2 | 156 | 422.5 | 38.9 | 2 |
| Weight | 60.9 | 40.3 | 156 | 529.5 | 2.1 | 2 |
| K factor | 1.00 | 0.39 | 156 | 0.72 | .20 | 2 |

**Upper Wenatchee River Smolt Trap**

The upper Wenatchee River smolt traps were located approximately 0.5 km below the outlet of Lake Wenatchee. The trap operated nightly between 4 March and 23 July. We captured 38,628 wild and 2,387 hatchery sockeye smolts during the sampling period (Figure 3). Mortality during the season totaled 769 wild sockeye (> 2.0%). Of those mortalities, 736 were from a single day and associated heavy debris in the trap. We also captured 1,597 wild spring Chinook smolts and 80 juvenile steelhead. Mortality of wild spring Chinook during trapping was 14 (0.9%). There was no mortality of juvenile steelhead or bull trout captured during the sampling period. The monthly totals of all fish captured are listed in Appendix B.

A total of 14 mark/recapture efficiency trials (9 wild and 5 hatchery) were conducted during the sampling period. During which, 8,600 wild and 516 hatchery sockeye were marked (i.e., caudal fin clip) and released into Lake Wenatchee. Wild and hatchery sockeye recaptures totaled 119 and 7, respectively. A delay in migration and subsequent recapture of the marked fish from Lake Wenatchee negatively affected the relationship between discharge and trap efficiency (i.e., unequal probability of recapture). Both the hatchery and wild sockeye smolt production estimate was calculated using a wild and hatchery pooled daily trap efficiency (wild = 1.4%; hatchery = 1.4%).

The estimated smolt production (95% C.I.) for wild sockeye was 2,797,313 (±131,973). Age classes of wild sockeye were determined from scales collected randomly from the run (Table 6). Egg deposition was calculated based on the spawning escapement determined at Tumwater Dam and the sex ratio and fecundity of the broodstock (M. Tonseth, WDFW, personal communication). Historical egg-to-smolt survival rates for wild Wenatchee sockeye have ranged between 1.18% and 21.17% (Table 7).

The estimated number (95% CI) of hatchery sockeye that emigrated from Lake Wenatchee was 183,475 (±36,799). This was the first brood year in which all hatchery sockeye parr were released at a similar size and time since 1999 and the third brood year that hatchery smolt estimates for the late release group were greater than the number of fish released. Because the number of hatchery smolts was greater than the number of parr released we assumed that survival was 100% and adjusted our smolt estimates accordingly (Table 8). Overestimates of hatchery sockeye salmon smolts may be the result of some hatchery fish outmigrating at age-2 or an underestimate of the actual trap efficiency. We suggest the later because coded wire tag recovered from outmigrating smolt between 2001 and 2005 indicated that all hatchery smolts emigrate as at age-1 the spring following release. Predator abundance in Lake Wenatchee may have increased since smolt trapping began in 1997. Additional studies are needed to determine the source of error in trap efficiency estimates and possible alternatives.

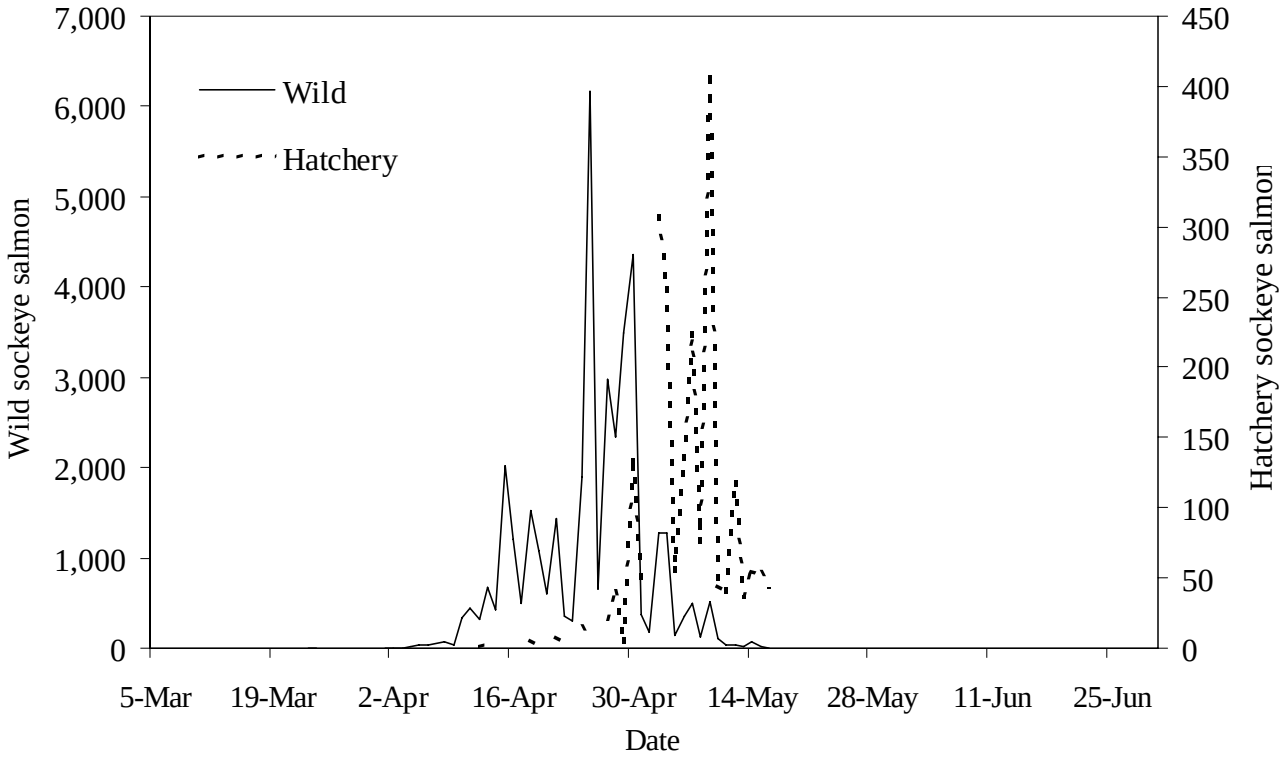


Figure 3. Number of wild and hatchery sockeye captured at the upper Wenatchee smolt trap, 2007.

Table 6. Age composition and estimated number of wild sockeye smolts emigrating from Lake Wenatchee derived from scale samples.

| Run year | Proportion of wild smolts | | | Total emigrants |
|---|---|---|---|---|
| | Age 1+ | Age 2+ | Age 3+ | |
| 1997 | 0.075 | 0.906 | 0.019 | 55,359 |
| 1998 | 0.955 | 0.037 | 0.008 | 1,447,259 |
| 1999 | 0.619 | 0.381 | 0.000 | 1,944,966 |
| 2000 | 0.599 | 0.400 | 0.001 | 985,490 |
| 2001 | 0.943 | 0.051 | 0.006 | 39,353 |
| 2002 | 0.961 | 0.039 | 0.000 | 729,716 |
| 2003 | 0.740 | 0.026 | 0.000 | 5,303,056 |
| 2004 | 0.929 | 0.071 | 0.000 | 5,771,187 |
| 2005 | 0.230 | 0.748 | 0.022 | 723,413 |
| 2006 | 0.994 | 0.006 | 0.000 | 1,266,971 |
| 2007 | 0.959 | 0.038 | 0.003 | 2,797,313 |

Table 7. Estimated egg deposition (mean fecundity x estimated # of females) and egg-to-emigrant survival rates for Lake Wenatchee sockeye salmon.

| Brood year | Estimated egg deposition | Estimated number of wild smolts | | | | Egg-to-smolt survival (%) |
|---|---|---|---|---|---|---|
| | | Age 1+ | Age 2+ | Age 3+ | Total | |
| 1995 | 4,902,120 | 4,174 | 53,549 | 0 | 57,723 | 1.18 |
| 1996 | 10,035,288 | 1,382,133 | 741,032 | 985 | 2,124,150 | 21.17 |
| 1997 | 11,796,932 | 1,203,934 | 394,196 | 236 | 1,598,366 | 13.55 |
| 1998 | 5,505,944 | 590,309 | 2,007 | 0 | 592,316 | 10.76 |
| 1999 | 1,188,488 | 37,110 | 28,459 | 0 | 65,569 | 5.52 |
| 2000 | 30,506,949 | 701,257 | 1,378,795 | 0 | 2,080,052 | 6.82 |
| 2001 | 64,100,860 | 4,024,884 | 409,754 | 90,427 | 4,525,065 | 7.06 |
| 2002 | 49,197,456 | 5,361,433 | 511,453 | 0 | 5,872,886 | 12.00 |
| 2003 | 7,576,738 | 166,385 | 7,602 | 8,392 | 182,379 | 2.41 |
| 2004[a] | 38,332,182 | 1,259,369 | 106,298 | -- | 1,365,667 | 3.56 |
| 2005[a] | 14,667,500 | 2,682,623 | -- | -- | 2,682,623 | -- |

[a] Incomplete brood year

Table 8. Release-to-smolt survival rates for Lake Wenatchee hatchery sockeye.

| Brood year | Release year | Run year | Number of fish released | Fork length (mm) at release (SD) | Date of release | Number of fish captured | Estimated number of smolts | Release to smolt survival |
|---|---|---|---|---|---|---|---|---|
| 1995 | 1996 | 1997 | 150,808 | 106.0(6.2) | 25 Oct | 130 | 28,828 | 19.12% |
| 1996 | 1997 | 1998 | 284,630 | 106.5(7.4) | 22 Oct | 279 | 55,985 | 19.67% |
| 1997 | 1998 | 1999 | 197,195 | 122.1(7.4) | 09 Nov | 586 | 112,524 | 57.06% |
| 1998 | 1999 | 2000 | 121,344 | 112.3(7.6) | 27 Oct | 66 | 24,684 | 20.34% |
| 1999 | 2000 | 2001 | 84,466 | 94.4(8.9) | 28 Aug | 319 | 30,326 | 35.90% |
| 1999 | 2000 | 2001 | 83,489 | 134.3(15.4) | 01 Nov | 548 | 63,720 | 76.32% |
| 2000 | 2001 | 2002 | 92,055 | 122.6(7.9) | 27 Aug | 142 | 30,918 | 33.59% |
| 2000 | 2001 | 2002 | 98,119 | 146.3(12.2) | 27 Sept | 416 | 90,593 | 92.33% |
| 2001 | 2002 | 2003 | 96,486 | 117.9(8.7) | 28 Aug | 162 | 36,484 | 37.81% |
| 2001 | 2002 | 2003 | 104,452 | 134.8(8.7) | 23 Sept | 465 | 103,838 | 99.41% |
| 2002 | 2003 | 2004 | 98,509 | 72.7(5.0) | 16 Jun | 31 | 5,192 | 4.41% |
| 2002 | 2003 | 2004 | 104,855 | 118.1(9.1) | 25 Aug | 376 | 98,412 | 85.88% |
| 2002 | 2003 | 2004 | 112,419 | 145.4(13.7) | 22 Oct | 292 | 112,419 | 100.0% |
| 2003 | 2004 | 2005 | 32,755 | 78.7(3.6) | 15 Jun | 0 | 0 | 0.00% |
| 2003 | 2004 | 2005 | 104,879 | 118.4(7.0) | 25 Aug | 229 | 19,574 | 18.66% |
| 2003 | 2004 | 2005 | 102,825 | 158.2(12.8) | 03 Nov | 1,185 | 102,825 | 100.0% |
| 2004 | 2005 | 2006 | 81,428 | 115.8(6.7) | 29 Aug | 1,500 | 159,500 | 92.2% |
| 2004 | 2005 | 2006 | 91,495 | 150.7(7.0) | 02 Nov | | | |
| 2005 | 2006 | 2007 | 140,542 | 148.9(14.0) | 30 Oct | 516 | 140,542 | 100.0% |

**Lower Wenatchee River Smolt Trap**

The lower Wenatchee River smolt traps were located at the West Monitor Bridge (rkm 9.6). The traps operated nightly between 1 February and 5 August. However, due to heavy debris and/or high flow, both traps was not operational for 14 days (i.e., 3 February through 4 February, 12 March through 14 March, 26 March through 27 March, 2 June through 7 June, and 21 June), and one trap was not operational for 68 days (i.e., 3 February through 4 February, 12 March through 31 March, 10 April through 11 April, 8 May through 16 June, and 22 June through 25 June). We captured 1,906 wild and 45,467 hatchery yearling Chinook during the trapping period, respectively (Figure 4). A total of 86,142 subyearling Chinook were also captured comprising 64.5% of the total number of juvenile Chinook captured in 2007. Mortality during the season

totaled 5 wild yearling Chinook (0.3%) and 245 wild subyearling Chinook (0.3%). The number of wild and hatchery steelhead smolts captured was 433 and 2,697, respectively (Figure 5). The number of steelhead fry captured totaled 203. Mortality during the season totaled 3 wild juvenile steelhead smolts (0.7%) and 1 steelhead fry (0.5%). We also captured 6,340 wild and 248 hatchery sockeye (Figure 6). Only two bull trout were captured in 2007. The monthly totals of all fish captured are listed in Appendix C. Smolt production estimates for salmon and steelhead were calculated using efficiency trials conducted with subyearling Chinook, yearling hatchery Chinook, and yearling hatchery coho. Mark/recapture trials were conducted when river discharge changed between 14 and 28 $m^3/s$ or the trap position had changed. Low abundance of other target species precluded their use in mark/recapture trials.

Smolt production estimates were calculated using separate regression models (independent variable = river discharge) for each trap position and species. However, when too few trials for a given position or species were conducted, efficiency trials from previous years are incorporated into the regression model. Until the relative abundance of wild yearling Chinook and steelhead increases, or trap efficiency significantly increases such that an adequate number of the target species are captured, surrogates must be used in trap efficiency trials. Estimates for yearling Chinook and steelhead incorporated regression models developed with hatchery coho and hatchery Chinook for both the trap positions ($r^2 = 0.70$, $P = 0.04$; $r^2 = 0.76$, $P < 0.01$). Subyearling Chinook were captured in sufficient numbers such that regression models were developed using only subyearling Chinook when the trap was operated in both operating positions ($r^2 = 0.37$, $P < 0.01$; $r^2 = 0.83$, $P = 0.03$). The smolt production estimate (95% CI) for wild yearling and subyearling Chinook was 311,699 (± 293,886) and 9,590,569 (± 1,859,554), respectively. The 2005 brood egg-to-smolt survival for Wenatchee spring Chinook was 8.69% (Table 9). The smolt production estimate for Wenatchee steelhead was 85,443 (± 94,717) and the 2003 brood emigration, completed in 2007, had an egg-to-smolt survival of 1.19% (Table 10).

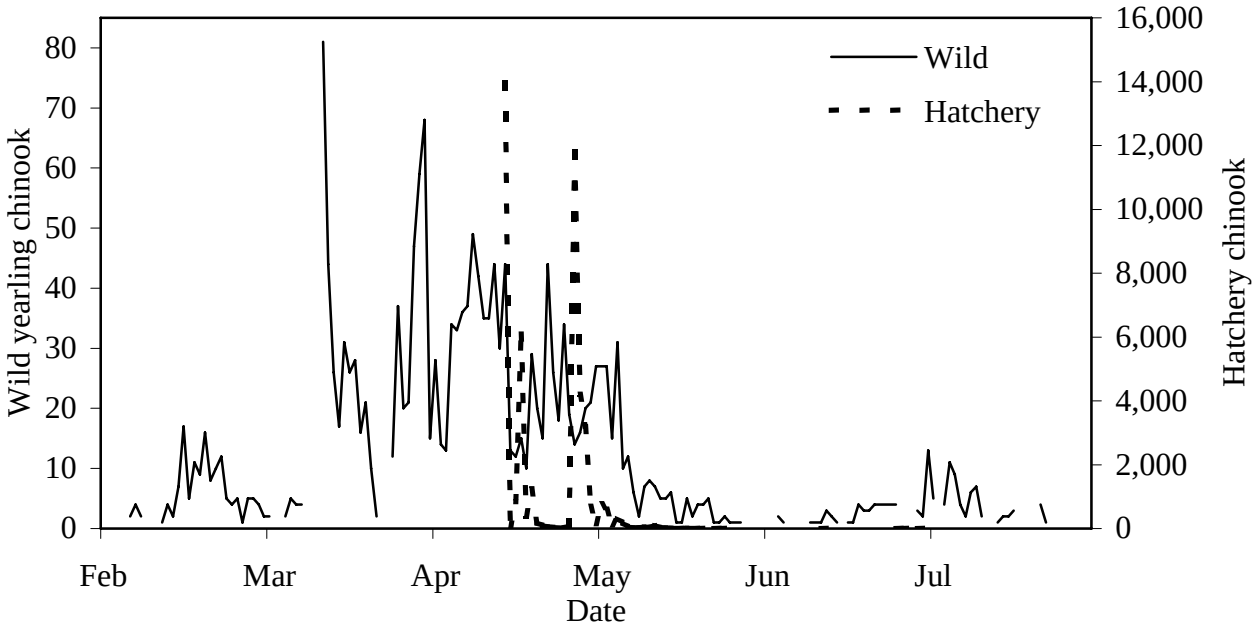


Figure 4. Number of yearling wild Chinook and yearling hatchery Chinook captured at the lower Wenatchee River trap in 2007.

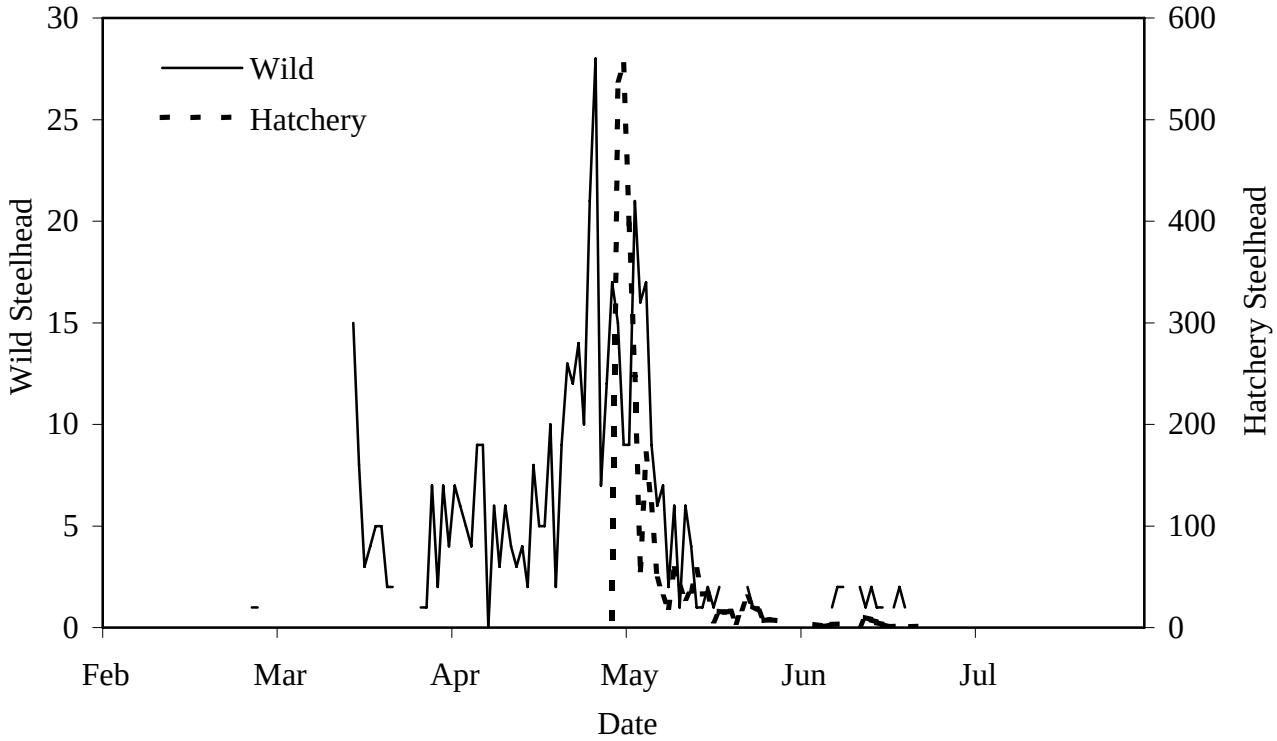


Figure 5. Number of wild and hatchery steelhead captured at the lower Wenatchee River trap in 2007.

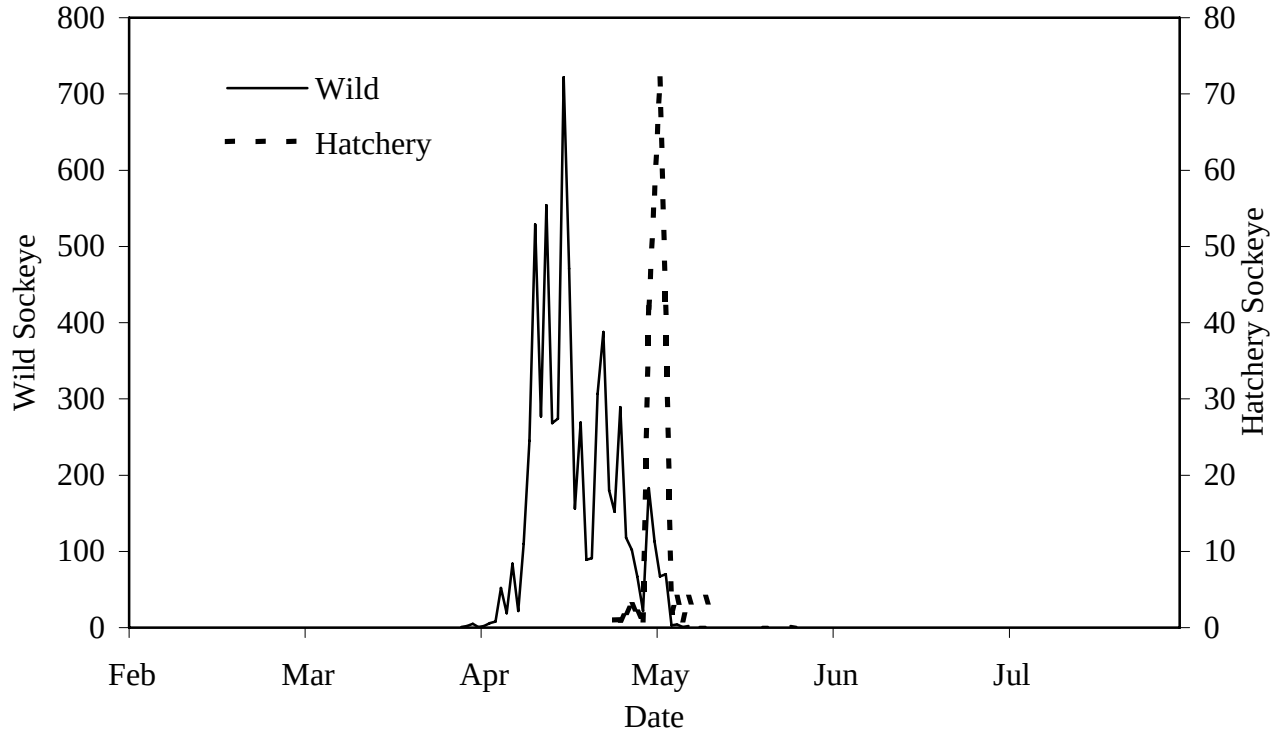


Figure 6. Number of wild and hatchery sockeye captured at the lower Wenatchee River trap in 2007.

Table 9. Estimated egg deposition (# of redds x mean broodstock fecundity) and egg-to-smolt survival rates for Wenatchee Basin spring Chinook salmon.

| Brood year | Number of redds | Estimated egg deposition | Estimated number | |
|---|---|---|---|---|
| | | | Total emigrants | Egg-to-smolt survival (%) |
| 2000 | 350 | 1,758,050 | 76,643 | 4.36 |
| 2001 | 1,876 | 8,674,624 | 243,516 | 2.81 |
| 2002 | 1,139 | 5,300,906 | 165,116 | 3.11 |
| 2003 | 323 | 1,887,612 | 70,738 | 3.75 |
| 2004 | 555 | 2,663,445 | 55,619 | 2.09 |
| 2005 | 829 | 3,587,083 | 311,669 | 8.69 |

Table 10. Estimated egg deposition (mean fecundity x estimated # of females) and egg-to-emigrant survival rates for Wenatchee Basin Steelhead.

| Brood year | Estimated egg deposition | Estimated number of wild smolts | | | | Egg-to-smolt survival (%) |
|---|---|---|---|---|---|---|
| | | Age 1+ | Age 2+ | Age 3+ | Total | |
| 1997[a] | | | | | | |
| 1998[a] | | 16,628 | 14,799 | 4,293 | 35,720 | |
| 1999[a] | | 5,691 | 24,528 | 4,203 | 34,422 | |
| 2000[a] | | 7,972 | 26,462 | 5,857 | 40,292 | |
| 2001[b] | 858,990 | 1,930 | 21,522 | 8,142 | 31,593 | 3.68 |
| 2002 | 2,674,250 | 4,712 | 28,153 | 1,708 | 34,574 | 1.29 |
| 2003 | 2,919,420 | 4,887 | 6,828 | 23,267 | 34,976 | 1.19 |
| 2004[c] | 1,933,560 | 8,963 | 36,563 | -- | -- | -- |
| 2005[c] | 5,620,120 | 25,613 | -- | -- | -- | -- |

[a] No redd counts
[b] Partial basin redd counts
[c] Incomplete brood year

## Discussion

A delay in migration and subsequent recapture of the marked fish from Lake Wenatchee negatively affected the relationship between discharge and trap efficiency (i.e., unequal probability of recapture). Therefore, the pooled trap efficiency (1.4%) was used to calculate sockeye smolt production estimates. Sockeye egg-to-smolt survival rates were based on the

estimated number of females passing Tumwater Dam. This methodology does not take into account prespawn mortality and likely underestimates survival. In the future, redd based egg deposition estimates provided by Chelan PUD should provide more accurate estimates. Hatchery survival rates were consistent with previous estimates for late releases, but underestimates of trap efficiency have been recognized as a concern. Continuation of this release methodology should result in greater parr-to-adult survival rates of hatchery sockeye, however, an alternate methodology to estimate smolt production (hatchery and wild) may be required.

An increase in the capture of wild spring Chinook at the upper Wenatchee trap was notable in 2007. Assuming that hatchery fish released into the White River and Lake Wenatchee were not 100% coded wire tagged (CWT), fish could be misidentified as wild spring Chinook. Alternatively, higher than average egg-to-smolt survival from Nason, White, Little Wenatchee, and Wenatchee rivers upstream of the trap may have increased the abundance of Chinook smolts outmigrating in 2007. One previously PIT tagged spring Chinook was captured in 2007 that was tagged in November 2006 at Nason Creek smolt trap by Yakama Nation (YN) personnel. It is assumed that Nason Creek fish do influence capture rates in the Upper Wenatchee smolt trap. If captures of wild spring Chinook continue to increase at the trap, individual mark/recapture trials will be conducted in the future using wild spring Chinook.

Low abundance of spring Chinook and steelhead precluded their use for mark/recapture trials at the lower Wenatchee smolt trap. Hatchery Chinook and coho were used as surrogates for mark/recaptures trials, which were conducted at various levels of river discharge or if the trap position had changed. Smolt production estimates were calculated using separate regression models (independent variable = river discharge; dependent variable = trap efficiency) for each of the two trap positions. In some cases, efficiency trials from previous years (i.e., 2001-2006) were used in the regression model to increase the sample size used in the model. Hatchery Chinook and coho will continue to be used as surrogates in trap efficiency trials until the relative abundance of wild spring Chinook and steelhead increases sufficiently to allow species-specific efficiency trials.

The precision (confidence intervals) of wild spring Chinook and steelhead estimates for the Wenatchee Basin was low due to high variability in discharge and low trap efficiency. The majority of trapping occurred when river discharge was outside the calculated regression range (i.e., too high or too low). Efficiency trials were not performed at low discharge because fish numbers were insufficient and trials at high discharge were not performed because the trap was not operated due to fish health concerns. As a result, the extremely low estimated trap efficiencies resulted in high confidence intervals. Variance formulas produce higher estimates as trap efficiency decreases. More simply, a greater degree of confidence in the smolt estimate is assumed as trap efficiency increases. Hence, when trap efficiency is low, the confidence interval of the estimate is high. While the confidence intervals were large as a result of low trap efficiency, we suggest smolt production estimates, based on estimated trap efficiencies, are accurate because the regression models used to estimate trap efficiency was significant and had a high coefficient of determination ($r^2 = 0.76$, $P < 0.001$; $r^2 = 0.70$, $P < 0.05$).

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Appendix A. Yearly and monthly total juvenile capture information for the Chiwawa River trap.

| | 2007 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species/Origin | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 2,415 | 1,622 | 294 | 100 | 2 | 0 | 0 | 0 | 0 | -- | 4,433 |
| *Wild subyearling* | 339 | 3,396 | 571 | 687 | 2,541 | 3,365 | 871 | 2,980 | 1,500 | -- | 16,250 |
| *Hatchery yearling* | 0 | 6,041 | 11,570 | 0 | 2 | 9 | 11 | 1 | 0 | -- | |
| Steelhead | | | | | | | | | | | |
| *Wild* | 228 | 164 | 127 | 465 | 35 | 94 | 54 | 43 | 1 | -- | 1,211 |
| *Smolt* | 60 | 65 | 12 | 5 | 4 | 6 | 0 | 0 | 0 | -- | 152 |
| *Parr* | 165 | 99 | 115 | 460 | 31 | 88 | 54 | 43 | 1 | -- | 1,056 |
| *Hatchery* | 1 | 0 | 1,932 | 21 | 2 | 1 | 5 | 2 | 0 | -- | 1,964 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 |
| *Wild subyearling* | 0 | 0 | 1 | 10 | 1 | 0 | 0 | 0 | 0 | -- | 12 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 |
| Bull trout | | | | | | | | | | | |
| *Juvenile* | 33 | 11 | 2 | 22 | 12 | 26 | 72 | 64 | 8 | -- | 250 |
| *Adult* | 0 | 0 | 0 | 0 | 1 | 4 | 15 | 8 | 1 | -- | 29 |
| Cutthroat | 0 | 3 | 0 | 12 | 1 | 16 | 8 | 0 | 0 | -- | 40 |
| Eastern brook | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | -- | 3 |
| White fish | 51 | 18 | 8 | 6 | 68 | 1,041 | 818 | 169 | 7 | -- | 2,186 |
| Northern pikeminnow | 0 | 0 | 0 | 0 | 6 | 8 | 1 | 0 | 0 | -- | 15 |
| Longnose dace | 21 | 96 | 352 | 304 | 133 | 48 | 1,087 | 292 | 16 | -- | 2,349 |
| Sucker spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | -- | 1 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 |
| Yellow perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 |
| Sculpin spp. | 7 | 4 | 7 | 2 | 8 | 14 | 21 | 10 | 0 | -- | 73 |

| | 2006 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species/Origin | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 1,013 | 3,810 | 121 | 26 | 2 | 0 | 2 | 0 | 0 | -- | 4,974 |
| *Wild subyearling* | 65 | 665 | 70 | 323 | 4,066 | 3,094 | 1,182 | 1,445 | 3,624 | -- | 14,542 |
| *Hatchery yearling* | 0 | 5,889 | 3,899 | 3 | 1 | 0 | 3 | 1 | 0 | -- | 9,796 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 37 | 346 | 269 | 173 | 30 | 54 | 112 | 10 | 758 | -- | 1,789 |
| *Smolt* | 1 | 26 | 7 | 6 | 3 | 0 | 9 | 1 | 0 | -- | 53 |
| *Parr* | 36 | 320 | 262 | 167 | 27 | 54 | 103 | 9 | 758 | -- | 1,736 |
| *Hatchery* | 5 | 0 | 1,354 | 16 | 0 | 2 | 4 | 2 | 1 | -- | 1,384 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 3 |
| *Wild subyearling* | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | -- | 2 |
| *Hatchery yearling* | 86 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 126 |
| Bull trout | | | | | | | | | | | |
| *Juvenile* | 12 | 1 | 1 | 7 | 1 | 4 | 31 | 19 | 49 | -- | 125 |
| *Adult* | 5 | 0 | 0 | 0 | 0 | 4 | 19 | 6 | 5 | -- | 39 |
| Cutthroat | 0 | 0 | 0 | 0 | 2 | 5 | 45 | 1 | 3 | -- | 56 |
| Eastern brook | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 3 | -- | 4 |
| White fish | 42 | 13 | 0 | 2 | 272 | 1,097 | 720 | 62 | 59 | -- | 2,267 |
| Northern pikeminnow | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 |
| Longnose dace | 36 | 59 | 160 | 100 | 51 | 29 | 1,226 | 254 | 36 | -- | 1,951 |
| Sucker spp. | 0 | 1 | 2 | 0 | 0 | 0 | 4 | 1 | 0 | -- | 8 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | -- | 1 |
| Yellow perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 |
| Sculpin spp. | 3 | 0 | 5 | 4 | 34 | 11 | 8 | 27 | 12 | -- | 104 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2005 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 355 | 2,327 | 138 | 54 | 0 | 0 | 0 | 0 | 0 | -- | 2,874 |
| *Wild subyearling* | 803 | 1,024 | 12 | 2,453 | 2,324 | 951 | 505 | 1,561 | 1,416 | -- | 11,049 |
| *Hatchery yearling* | 0 | 1,811 | 2,134 | 1 | 2 | 7 | 9 | 1 | 0 | -- | 3,965 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 13 | 170 | 173 | 88 | 68 | 626 | 129 | 381 | 24 | -- | 1,672 |
| *Smolt* | 0 | 25 | 7 | 3 | 10 | 0 | 0 | 0 | 0 | -- | 45 |
| *Parr* | 13 | 145 | 166 | 85 | 58 | 626 | 129 | 381 | 24 | -- | 1,627 |
| *Hatchery* | 0 | 0 | 2,069 | 30 | 1 | 2 | 2 | 0 | 0 | -- | 2,104 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 4 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 |
| *Hatchery yearling* | 0 | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 8 |
| Bull trout | | | | | | | | | | | |
| *Juvenile* | 2 | 1 | 1 | 5 | 1 | 7 | 67 | 73 | 18 | -- | 175 |
| *Adult* | 0 | 0 | 0 | 0 | 2 | 1 | 15 | 21 | 2 | -- | 41 |
| Cutthroat | 0 | 1 | 6 | 11 | 2 | 12 | 8 | 3 | 1 | -- | 44 |
| Eastern brook | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | -- | 4 |
| White fish | 17 | 58 | 10 | 97 | 679 | 2,213 | 579 | 18 | 1 | -- | 3,672 |
| Northern pikeminnow | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 |
| Longnose dace | 8 | 117 | 242 | 382 | 86 | 675 | 1,500 | 82 | 41 | -- | 3,133 |
| Sucker spp. | 0 | 0 | 0 | 0 | 0 | 2 | 5 | 3 | 0 | -- | 10 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | -- | 2 |
| Yellow perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | 0 |
| Sculpin spp. | 1 | 0 | 0 | 0 | 3 | 5 | 11 | 3 | 0 | -- | 23 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2004 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 1,429 | 2,446 | 287 | 152 | 4 | 3 | 5 | 0 | 0 | 0 | 4,326 |
| *Wild subyearling* | 871 | 332 | 44 | 632 | 415 | 595 | 510 | 677 | 1,145 | 45 | 5,266 |
| *Hatchery yearling* | 0 | 4,766 | 2,769 | 1 | 7 | 14 | 0 | 0 | 0 | 0 | 7,557 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 41 | 236 | 186 | 307 | 108 | 1,373 | 116 | 33 | 39 | 2 | 2,441 |
| *Smolt* | 2 | 19 | 1 | 1 | 18 | 239 | 0 | 0 | 0 | 0 | 280 |
| *Parr* | 39 | 217 | 185 | 306 | 90 | 1,134 | 116 | 33 | 39 | 2 | 2,161 |
| *Hatchery* | 1 | 4,917 | 4,709 | 12 | 2 | 18 | 17 | 2 | 0 | 0 | 9,678 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bull trout | 9 | 18 | 11 | 9 | 5 | 24 | 97 | 45 | 32 | 0 | 250 |
| *Juvenile* | 9 | 18 | 11 | 9 | 5 | 20 | 92 | 42 | 32 | 0 | 238 |
| *Adult* | 0 | 0 | 0 | 0 | 0 | 4 | 5 | 3 | 0 | 0 | 12 |
| Cutthroat | 0 | 0 | 1 | 11 | 3 | 20 | 10 | 0 | 0 | 0 | 45 |
| Eastern brook | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| White fish | 6 | 1 | 2 | 10 | 563 | 809 | 2,244 | 27 | 7 | 0 | 3,669 |
| Northern pikeminnow | 0 | 1 | 0 | 0 | 10 | 2 | 0 | 0 | 0 | 0 | 13 |
| Longnose dace | 0 | 44 | 325 | 589 | 190 | 1,175 | 387 | 421 | 31 | 0 | 3,162 |
| Sucker spp. | 2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 5 |
| Redside shiner | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| Yellow perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sculpin spp. | 1 | 2 | 5 | 1 | 10 | 0 | 0 | 9 | 6 | 0 | 34 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2003 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 2,429 | 4,293 | 1,184 | 52 | 24 | 11 | 19 | 0 | 0 | - | 8,012 |
| *Wild subyearling* | 1,029 | 4,661 | 1,894 | 1,060 | 4,751 | 5,588 | 1,209 | 4,064 | 840 | - | 25,096 |
| *Hatchery yearling* | 0 | 2,706 | 3,183 | 1 | 3 | 0 | 0 | 0 | 0 | - | 5,893 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 18 | 148 | 125 | 274 | 90 | 399 | 157 | 427 | 24 | - | 1,662 |
| *smolt* | 2 | 22 | 5 | 3 | 0 | 0 | 0 | 0 | 0 | - | 32 |
| *parr* | 16 | 126 | 120 | 271 | 90 | 399 | 157 | 427 | 24 | - | 1,630 |
| *Hatchery* | 0 | 1,457 | 4,396 | 23 | 2 | 4 | 2 | 2 | 0 | - | 5,886 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Bull trout | 14 | 11 | 19 | 40 | 20 | 36 | 122 | 153 | 29 | - | 444 |
| *Juvenile* | 14 | 11 | 19 | 40 | 19 | 33 | 120 | 153 | 29 | - | 438 |
| *Adult* | 0 | 0 | 0 | 0 | 1 | 3 | 2 | 0 | 0 | - | 6 |
| Cutthroat | 0 | 0 | 0 | 5 | 3 | 10 | 6 | 0 | 4 | - | 28 |
| Eastern brook | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 1 | 0 | - | 6 |
| White fish | 28 | 2 | 1 | 65 | 42 | 889 | 167 | 13 | 5 | - | 1,212 |
| Northern pikeminnow | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | - | 1 |
| Longnose dace | 3 | 0 | 0 | 266 | 306 | 92 | 425 | 461 | 4 | - | 1,557 |
| Sucker spp. | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | - | 4 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | - | 1 |
| Yellow perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Sculpin spp. | 0 | 4 | 0 | 2 | 1 | 0 | 3 | 3 | 0 | - | 13 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2002 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 21 | 1,398 | 1 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 1,423 |
| *Wild subyearling* | 461 | 7,610 | 7,694 | 316 | 15,235 | 12,890 | 3,470 | 2,797 | 3,003 | 196 | 53,672 |
| *Hatchery yearling* | 479 | 2,142 | 291 | 1 | 3 | 5 | 5 | 0 | 0 | 0 | 2,926 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 7 | 153 | 118 | 65 | 65 | 95 | 210 | 28 | 36 | 1 | 778 |
| *Smolt* | 0 | 9 | 11 | 6 | 12 | 37 | 8 | 2 | 1 | 0 | 86 |
| *Parr* | 7 | 144 | 107 | 59 | 53 | 58 | 202 | 26 | 35 | 1 | 692 |
| *Hatchery* | 0 | 0 | 2,687 | 0 | 1 | 5 | 23 | 4 | 0 | 0 | 2,720 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 1 | 4 | 2 | 0 | 0 | 0 | 0 |
| Bull trout | 15 | 13 | 4 | 9 | 15 | 43 | 86 | 45 | 107 | 10 | 347 |
| *Juvenile* | 15 | 13 | 4 | 9 | 15 | 42 | 80 | 44 | 107 | 10 | 339 |
| *Adult* | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 1 | 0 | 0 | 8 |
| Cutthroat | 1 | 0 | 2 | 1 | 3 | 17 | 13 | 0 | 0 | 0 | 37 |
| Eastern brook | 0 | 0 | 2 | 0 | 0 | 1 | 0 | 4 | 0 | 0 | 7 |
| White fish | 10 | 13 | 8 | 1 | 40 | 414 | 228 | 133 | 24 | 0 | 871 |
| Northern pikeminnow | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 3 |
| Longnose dace | 13 | 33 | 41 | 77 | 36 | 92 | 281 | 31 | 0 | 0 | 604 |
| Sucker spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yellow perch | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sculpin spp. | 1 | 0 | 1 | 0 | 0 | 9 | 37 | 6 | 1 | 3 | 58 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2001 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 998 | 1,650 | 76 | 36 | 0 | 1 | 2 | 0 | 0 | 0 | 2,763 |
| *Wild subyearling* | 18 | 17 | 1 | 32 | 192 | 796 | 236 | 1,860 | 1,872 | 153 | 5,177 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 18 | 167 | 137 | 73 | 9 | 449 | 49 | 79 | 95 | 15 | 1,091 |
| *smolt* | 0 | 34 | 4 | 5 | 3 | 4 | 7 | 6 | 0 | 0 | 63 |
| *parr* | 18 | 133 | 133 | 68 | 6 | 445 | 42 | 73 | 95 | 15 | 1,028 |
| *Hatchery* | 0 | 2 | 69 | 11 | 5 | 24 | 18 | 5 | 0 | 0 | 134 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 2 |
| Bull trout | 36 | 21 | 26 | 31 | 4 | 6 | 48 | 50 | 51 | 16 | 289 |
| *Juvenile* | 35 | 21 | 26 | 31 | 4 | 6 | 32 | 42 | 51 | 16 | 264 |
| *Adult* | 1 | 0 | 0 | 0 | 0 | 0 | 16 | 8 | 0 | 0 | 25 |
| Cutthroat | 4 | 4 | 5 | 54 | 6 | 16 | 9 | 35 | 50 | 0 | 183 |
| Eastern brook | 1 | 0 | 0 | 6 | 0 | 0 | 0 | 15 | 3 | 0 | 25 |
| White fish | 15 | 36 | 0 | 0 | 34 | 1,432 | 248 | 39 | 21 | 0 | 1,825 |
| Northern pikeminnow | 0 | 0 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 0 | 14 |
| Longnose dace | 15 | 15 | 12 | 411 | 92 | 247 | 251 | 172 | 2 | 0 | 1,217 |
| Sucker spp. | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 0 | 0 | 6 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yellow perch | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 | 0 | 2 | 14 |
| Sculpin spp. | 4 | 2 | 1 | 0 | 23 | 12 | 9 | 17 | 9 | 0 | 77 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2000 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 334 | 1,135 | 308 | 12 | 0 | 1 | 1 | 0 | 0 | - | 1,791 |
| *Wild subyearling* | 7 | 0 | 0 | 8 | 112 | 286 | 229 | 679 | 162 | - | 1,483 |
| *Hatchery yearling* | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | - | 6 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 1 | 102 | 40 | 7 | 11 | 82 | 47 | 32 | 4 | - | 326 |
| *smolt* | 0 | 74 | 20 | 2 | 3 | 36 | 31 | 11 | 4 | - | 181 |
| *parr* | 1 | 28 | 20 | 5 | 8 | 46 | 16 | 21 | 0 | - | 145 |
| *Hatchery* | 0 | 4 | 7 | 7 | 2 | 13 | 9 | 0 | 3 | - | 45 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Bull trout | 8 | 66 | 71 | 27 | 18 | 19 | 70 | 112 | 49 | - | 440 |
| *Juvenile* | 4 | 65 | 71 | 26 | 18 | 18 | 64 | 106 | 49 | - | 421 |
| *Adult* | 4 | 1 | 0 | 1 | 0 | 1 | 6 | 6 | 0 | - | 19 |
| Cutthroat | 0 | 1 | 3 | 0 | 1 | 11 | 4 | 2 | 0 | - | 22 |
| Eastern brook | 0 | 1 | 4 | 1 | 0 | 0 | 1 | 3 | 0 | - | 10 |
| White fish | 5 | 2 | 1 | 2 | 6 | 669 | 58 | 60 | 34 | - | 837 |
| Northern pikeminnow | 0 | 0 | 0 | 0 | 5 | 7 | 0 | 0 | 0 | - | 12 |
| Longnose dace | 1 | 22 | 256 | 486 | 185 | 141 | 165 | 194 | 6 | - | 1,456 |
| Sucker spp. | 0 | 0 | 36 | 0 | 0 | 3 | 0 | 1 | 0 | - | 40 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Yellow perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Sculpin spp. | 1 | 2 | 9 | 7 | 3 | 16 | 9 | 8 | 1 | - | 56 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1999 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 600 | 2,618 | 684 | 8 | 1 | 1 | 5 | 0 | 0 | 0 | 3,917 |
| *Wild subyearling* | 0 | 4 | 2 | 1 | 10 | 108 | 42 | 127 | 252 | 11 | 557 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | 4 | 51 | 4 | 1 | 0 | 60 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 1 | 108 | 63 | 19 | 17 | 16 | 19 | 7 | 3 | 0 | 253 |
| *smolt* | 0 | 60 | 24 | 9 | 8 | 10 | 18 | 4 | 0 | 0 | 133 |
| *parr* | 1 | 48 | 39 | 10 | 9 | 6 | 1 | 3 | 3 | 0 | 120 |
| *Hatchery* | 1 | 2 | 25 | 14 | 9 | 8 | 8 | 4 | 6 | 1 | 78 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bull trout | 10 | 25 | 35 | 9 | 21 | 16 | 30 | 37 | 64 | 3 | 250 |
| *Juvenile* | 10 | 24 | 35 | 9 | 21 | 16 | 21 | 31 | 64 | 3 | 234 |
| *Adult* | 0 | 1 | 0 | 0 | 0 | 0 | 9 | 6 | 0 | 0 | 16 |
| Cutthroat | 0 | 0 | 0 | 0 | 2 | 3 | 7 | 0 | 1 | 0 | 13 |
| Eastern brook | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 4 | 3 | 0 | 9 |
| White fish | 27 | 76 | 3 | 0 | 2 | 15 | 112 | 49 | 32 | 1 | 317 |
| Northern pikeminnow | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| Longnose dace | 9 | 38 | 34 | 29 | 18 | 0 | 0 | 2 | 0 | 0 | 130 |
| Sucker spp. | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 3 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yellow perch | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sculpin spp. | 0 | 5 | 4 | 0 | 1 | 1 | 7 | 5 | 1 | 0 | 24 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1998 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 1,619 | 1,679 | 110 | 32 | 0 | 9 | 11 | 0 | 0 | 0 | 3,460 |
| *Wild subyearling* | 0 | 13 | 1 | 3 | 439 | 316 | 183 | 297 | 2,567 | 24 | 3,843 |
| *Hatchery yearling* | 0 | 77 | 0 | 0 | 0 | 16 | 4 | 0 | 0 | 0 | 97 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 22 | 168 | 165 | 71 | 51 | 86 | 19 | 6 | 34 | 0 | 622 |
| *Smolt* | 2 | 69 | 26 | 8 | 5 | 47 | 3 | 0 | 0 | 0 | 160 |
| *Parr* | 20 | 99 | 139 | 63 | 46 | 39 | 16 | 6 | 34 | 0 | 462 |
| *Hatchery* | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 3 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bull trout | 34 | 53 | 95 | 66 | 20 | 15 | 94 | 71 | 213 | 1 | 662 |
| *Juvenile* | 34 | 53 | 95 | 66 | 20 | 13 | 41 | 69 | 213 | 1 | 605 |
| *Adult* | 0 | 0 | 0 | 0 | 0 | 2 | 53 | 2 | 0 | 0 | 57 |
| Cutthroat | 0 | 1 | 5 | 6 | 2 | 18 | 1 | 0 | 1 | 0 | 34 |
| Eastern brook | 0 | 0 | 4 | 2 | 0 | 0 | 1 | 0 | 10 | 0 | 17 |
| White fish | 31 | 28 | 2 | 5 | 132 | 1,103 | 180 | 39 | 45 | 0 | 1,565 |
| Northern pikeminnow | 0 | 0 | 0 | 0 | 9 | 38 | 7 | 0 | 0 | 0 | 54 |
| Longnose dace | 8 | 148 | 293 | 746 | 259 | 2 | 5 | 12 | 8 | 0 | 1,481 |
| Sucker spp. | 0 | 0 | 0 | 0 | 0 | 1 | 5 | 4 | 1 | 0 | 11 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yellow perch | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 4 |
| Sculpin spp. | 3 | 10 | 2 | 1 | 40 | 14 | 20 | 19 | 10 | 0 | 119 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1997 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 336 | 484 | 59 | 1 | 0 | 0 | 0 | 0 | 0 | - | 880 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 6 | 87 | 70 | 373 | 208 | - | 744 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 32 | 56 | 32 | 21 | 22 | 31 | 35 | 26 | 5 | - | 260 |
| *smolt* | 1 | 40 | 27 | 3 | 4 | 14 | 9 | 6 | 1 | - | 105 |
| *parr* | 31 | 16 | 5 | 18 | 18 | 17 | 26 | 20 | 4 | - | 155 |
| *Hatchery* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Bull trout | 22 | 23 | 17 | 9 | 22 | 28 | 64 | 55 | 16 | - | 256 |
| *Juvenile* | 22 | 23 | 17 | 9 | 22 | 27 | 50 | 48 | 15 | - | 233 |
| *Adult* | 0 | 0 | 0 | 0 | 0 | 1 | 14 | 7 | 1 | - | 23 |
| Cutthroat | 0 | 2 | 3 | 1 | 1 | 7 | 8 | 0 | 0 | - | 22 |
| Eastern brook | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 16 | 5 | - | 24 |
| White fish | 15 | 21 | 1 | 0 | 7 | 298 | 108 | 58 | 17 | - | 525 |
| Northern pikeminnow | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | - | 3 |
| Longnose dace | 6 | 43 | 31 | 87 | 116 | 74 | 174 | 46 | 2 | - | 579 |
| Sucker spp. | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Redside shiner | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Yellow perch | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | - | 0 |
| Sculpin spp. | 1 | 5 | 0 | 0 | 1 | 18 | 10 | 5 | 2 | - | 42 |

Appendix B. Yearly and monthly total juvenile capture information for the Lake River trap.

| | 2007 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species/Origin | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 174 | 760 | 595 | 39 | 29 | -- | -- | -- | -- | -- | 1,597 |
| *Wild subyearling* | 20 | 130 | 41 | 16 | 6 | -- | -- | -- | -- | -- | 213 |
| *Hatchery yearling* | 0 | 0 | 694 | 55 | 1 | -- | -- | -- | -- | -- | 750 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 15 | 28 | 16 | 16 | 5 | -- | -- | -- | -- | -- | 80 |
| *Smolt* | 3 | 3 | 5 | 1 | 3 | -- | -- | -- | -- | -- | 15 |
| *Parr* | 12 | 25 | 11 | 15 | 2 | -- | -- | -- | -- | -- | 65 |
| *Hatchery* | 0 | 0 | 177 | 1 | 0 | -- | -- | -- | -- | -- | 178 |
| Sockeye | | | | | | | | | | | |
| *Wild* | 3 | 33,388 | 5,217 | 20 | 0 | -- | -- | -- | -- | -- | 38,628 |
| *Hatchery* | 0 | 252 | 2,116 | 19 | 0 | -- | -- | -- | -- | -- | 2,387 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 2 | 1 | 0 | 0 | -- | -- | -- | -- | -- | 3 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| *Hatchery yearling* | 17 | 9 | 270 | 15 | 0 | -- | -- | -- | -- | -- | 311 |
| Bull trout | | | | | | | | | | | |
| *Juvenile* | 0 | 0 | 5 | 0 | 0 | -- | -- | -- | -- | -- | 5 |
| *Adult* | 0 | 2 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 2 |
| Cutthroat | 0 | 0 | 1 | 0 | 0 | -- | -- | -- | -- | -- | 1 |
| White fish | 1 | 31 | 8 | 4 | 5 | -- | -- | -- | -- | -- | 49 |
| Northern pikeminnow | 0 | 24 | 59 | 21 | 9 | -- | -- | -- | -- | -- | 113 |
| Longnose dace | 0 | 2 | 0 | 4 | 18 | -- | -- | -- | -- | -- | 24 |
| Sucker spp. | 0 | 0 | 4 | 7 | 7 | -- | -- | -- | -- | -- | 18 |
| Redside shiner | 0 | 7 | 12 | 7 | 11 | -- | -- | -- | -- | -- | 37 |
| Yellow perch | 1 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 1 |
| Sculpin spp. | 14 | 47 | 57 | 67 | 16 | -- | -- | -- | -- | -- | 201 |

| | 2006 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Species/Origin | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 18 | 68 | 52 | -- | -- | -- | -- | -- | -- | -- | 138 |
| *Wild subyearling* | 636 | 1,375 | 1 | -- | -- | -- | -- | -- | -- | -- | 2,012 |
| *Hatchery yearling* | 0 | 9 | 1 | -- | -- | -- | -- | -- | -- | -- | 10 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 5 | 30 | 7 | -- | -- | -- | -- | -- | -- | -- | 42 |
| *Smolt* | 0 | 5 | 5 | -- | -- | -- | -- | -- | -- | -- | 10 |
| *Parr* | 5 | 25 | 2 | -- | -- | -- | -- | -- | -- | -- | 32 |
| *Hatchery* | 0 | 0 | 160 | -- | -- | -- | -- | -- | -- | -- | 160 |
| Sockeye | | | | | | | | | | | 0 |
| *Wild* | 1 | 13,875 | 6,433 | -- | -- | -- | -- | -- | -- | -- | 20,309 |
| *Hatchery* | 0 | 434 | 1,066 | -- | -- | -- | -- | -- | -- | -- | 1,500 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 5 | 0 | 5 | -- | -- | -- | -- | -- | -- | -- | 10 |
| *Wild subyearling* | 0 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- | 0 |
| *Hatchery yearling* | 14 | 88 | 23 | -- | -- | -- | -- | -- | -- | -- | 125 |
| Bull trout | | | | | | | | | | | |
| *Juvenile* | 0 | 1 | 0 | -- | -- | -- | -- | -- | -- | -- | 1 |
| *Adult* | 0 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- | 0 |
| Cutthroat | 0 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- | 0 |
| White fish | 2 | 1 | 0 | -- | -- | -- | -- | -- | -- | -- | 3 |
| Northern pikeminnow | 0 | 24 | 22 | -- | -- | -- | -- | -- | -- | -- | 46 |
| Longnose dace | 1 | 1 | 0 | -- | -- | -- | -- | -- | -- | -- | 2 |
| Sucker spp. | 0 | 2 | 0 | -- | -- | -- | -- | -- | -- | -- | 2 |
| Redside shiner | 0 | 16 | 5 | -- | -- | -- | -- | -- | -- | -- | 21 |
| Yellow perch | 0 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- | 0 |
| Sculpin spp. | 6 | 28 | 1 | -- | -- | -- | -- | -- | -- | -- | 35 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2005 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 10 | 19 | 31 | 1 | -- | -- | -- | -- | -- | -- | 61 |
| *Wild subyearling* | 224 | 1,412 | 769 | 136 | -- | -- | -- | -- | -- | -- | 2,541 |
| *Hatchery yearling* | 0 | 0 | 6 | 0 | -- | -- | -- | -- | -- | -- | 6 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 3 | 8 | 16 | 9 | -- | -- | -- | -- | -- | -- | 36 |
| *Smolt* | 0 | 0 | 1 | 0 | -- | -- | -- | -- | -- | -- | 1 |
| *Parr* | 3 | 8 | 15 | 9 | -- | -- | -- | -- | -- | -- | 35 |
| *Hatchery* | 0 | 0 | 354 | 0 | -- | -- | -- | -- | -- | -- | 354 |
| Sockeye | | | | | | | | | | | |
| *Wild* | 4 | 5,898 | 677 | 1 | -- | -- | -- | -- | -- | -- | 6,580 |
| *Hatchery* | 0 | 833 | 576 | 7 | -- | -- | -- | -- | -- | -- | 1,416 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 2 | 0 | 0 | -- | -- | -- | -- | -- | -- | 2 |
| *Wild subyearling* | 0 | 0 | 5 | 0 | -- | -- | -- | -- | -- | -- | 5 |
| *Hatchery yearling* | 18 | 17 | 302 | 3 | -- | -- | -- | -- | -- | -- | 340 |
| Bull trout | | | | | | | | | | | |
| *Juvenile* | 2 | 1 | 2 | 0 | -- | -- | -- | -- | -- | -- | 5 |
| *Adult* | 0 | 2 | 0 | 1 | -- | -- | -- | -- | -- | -- | 3 |
| Cutthroat | 0 | 0 | 1 | 0 | -- | -- | -- | -- | -- | -- | 1 |
| White fish | 5 | 19 | 2 | 0 | -- | -- | -- | -- | -- | -- | 26 |
| Northern pikeminnow | 0 | 5 | 8 | 4 | -- | -- | -- | -- | -- | -- | 17 |
| Longnose dace | 1 | 0 | 4 | 48 | -- | -- | -- | -- | -- | -- | 53 |
| Sucker spp. | 1 | 1 | 6 | 20 | -- | -- | -- | -- | -- | -- | 28 |
| Redside shiner | 2 | 8 | 8 | 29 | -- | -- | -- | -- | -- | -- | 47 |
| Sculpin spp. | 11 | 2 | 10 | 62 | -- | -- | -- | -- | -- | -- | 85 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2004 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 35 | 127 | 186 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 355 |
| *Wild subyearling* | 0 | 2 | 2 | 21 | 4 | 7 | 2 | 1 | 100 | 0 | 139 |
| *Hatchery yearling* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 1 | 4 | 6 | 13 | 5 | 10 | 6 | 1 | 9 | 0 | 55 |
| *Smolt* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Parr* | 1 | 3 | 6 | 13 | 5 | 10 | 6 | 1 | 9 | 0 | 54 |
| *Hatchery* | 0 | 15 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 27 |
| Sockeye | | | | | | | | | | | |
| *Wild* | 198 | 35,154 | 2,552 | 47 | 1 | 0 | 0 | 0 | 1 | 0 | 37,953 |
| *Hatchery* | 10 | 1,005 | 765 | 51 | 14 | 7 | 5 | 0 | 9 | 0 | 1,866 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Hatchery yearling* | 0 | 6 | 74 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 81 |
| Bull trout | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Juvenile* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| *Adult* | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Cutthroat | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| White fish | 2 | 2 | 3 | 0 | 4 | 5 | 2 | 0 | 1 | 0 | 19 |
| Northern pikeminnow | 6 | 3 | 12 | 2 | 10 | 11 | 0 | 2 | 0 | 0 | 46 |
| Longnose dace | 0 | 1 | 2 | 3 | 14 | 20 | 3 | 11 | 4 | 0 | 58 |
| Sucker spp. | 0 | 1 | 2 | 11 | 23 | 10 | 0 | 0 | 0 | 0 | 47 |
| Redside shiner | 3 | 1 | 2 | 10 | 13 | 25 | 5 | 2 | 1 | 0 | 62 |
| Sculpin spp. | 6 | 8 | 11 | 25 | 8 | 5 | 1 | 2 | 2 | 0 | 68 |

| | | | | | 2003 | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 25 | 117 | 85 | 30 | 0 | - | - | - | - | - | 257 |
| *Wild subyearling* | 2 | 30 | 1 | 0 | 7 | - | - | - | - | - | 40 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - | 0 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 2 | 1 | 2 | 8 | 1 | - | - | - | - | - | 14 |
| *smolt* | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - | 0 |
| *parr* | 2 | 1 | 2 | 8 | 1 | - | - | - | - | - | 14 |
| *Hatchery* | 0 | 0 | 43 | 0 | 0 | - | - | - | - | - | 43 |
| Sockeye | | | | | | | | | | | |
| *Wild* | 14 | 22,293 | 2,849 | 9 | 0 | - | - | - | - | - | 25,165 |
| *Hatchery* | 1 | 466 | 182 | 13 | 6 | - | - | - | - | - | 668 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - | 0 |
| *Hatchery yearling* | 0 | 0 | 98 | 0 | 0 | - | - | - | - | - | 98 |
| Bull trout | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - | 0 |
| *Juvenile* | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - | 0 |
| *Adult* | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - | 0 |
| Cutthroat | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - | 0 |
| White fish | 0 | 6 | 0 | 0 | 0 | - | - | - | - | - | 6 |
| Northern pikeminnow | 1 | 2 | 20 | 0 | 0 | - | - | - | - | - | 23 |
| Longnose dace | 0 | 0 | 0 | 0 | 0 | - | - | - | - | - | 0 |
| Sucker spp. | 0 | 0 | 5 | 2 | 5 | - | - | - | - | - | 12 |
| Redside shiner | 3 | 0 | 7 | 1 | 3 | - | - | - | - | - | 14 |
| Sculpin spp. | 6 | 4 | 8 | 12 | 4 | - | - | - | - | - | 34 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2002 | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | - | 15 | 19 | - | - | - | - | - | - | - | 34 |
| *Wild subyearling* | - | 3 | 2 | - | - | - | - | - | - | - | 5 |
| *Hatchery yearling* | - | 0 | 0 | - | - | - | - | - | - | - | 0 |
| Steelhead | | | | | | | | | | | |
| *Wild* | - | 1 | 1 | - | - | - | - | - | - | - | 2 |
| *Smolt* | - | 1 | 1 | - | - | - | - | - | - | - | 2 |
| *Parr* | - | 0 | 0 | - | - | - | - | - | - | - | 0 |
| *Hatchery* | - | 4 | 37 | - | - | - | - | - | - | - | 41 |
| Sockeye | | | | | | | | | | | |
| *Wild* | - | 2,450 | 849 | - | - | - | - | - | - | - | 3,299 |
| *Hatchery* | - | 290 | 268 | - | - | - | - | - | - | - | 558 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | - | 0 | 0 | - | - | - | - | - | - | - | 0 |
| *Wild subyearling* | - | 0 | 0 | - | - | - | - | - | - | - | 0 |
| *Hatchery yearling* | - | 0 | 27 | - | - | - | - | - | - | - | 27 |
| Bull trout | - | 0 | 1 | - | - | - | - | - | - | - | 1 |
| *Juvenile* | - | 0 | 1 | - | - | - | - | - | - | - | 1 |
| *Adult* | - | 0 | 0 | - | - | - | - | - | - | - | 0 |
| Cutthroat | - | 0 | 0 | - | - | - | - | - | - | - | 0 |
| White fish | - | 3 | 1 | - | - | - | - | - | - | - | 4 |
| Northern pikeminnow | - | 0 | 5 | - | - | - | - | - | - | - | 5 |
| Longnose dace | - | 0 | 0 | - | - | - | - | - | - | - | 0 |
| Sucker spp. | - | 0 | 0 | - | - | - | - | - | - | - | 0 |
| Redside shiner | - | 0 | 0 | - | - | - | - | - | - | - | 0 |
| Sculpin spp. | - | 2 | 10 | - | - | - | - | - | - | - | 12 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2001 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 0 | 23 | 37 | 2 | - | - | - | - | - | - | 62 |
| *Wild subyearling* | 8 | 65 | 28 | 17 | - | - | - | - | - | - | 118 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 1 | 9 | 20 | 7 | - | - | - | - | - | - | 37 |
| *Smolt* | 1 | 1 | 1 | 1 | - | - | - | - | - | - | 4 |
| *Parr* | 0 | 8 | 19 | 6 | - | - | - | - | - | - | 33 |
| *Hatchery* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Sockeye | | | | | | | | | | | |
| *Wild* | 2 | 648 | 195 | 3 | - | - | - | - | - | - | 848 |
| *Hatchery* | 0 | 449 | 1,128 | 4 | - | - | - | - | - | - | 1,581 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Hatchery yearling* | 0 | 2 | 94 | 23 | - | - | - | - | - | - | 119 |
| Bull trout | 0 | 2 | 2 | 1 | - | - | - | - | - | - | 5 |
| *Juvenile* | 0 | 2 | 0 | 1 | - | - | - | - | - | - | 3 |
| *Adult* | 0 | 0 | 2 | 0 | - | - | - | - | - | - | 2 |
| Cutthroat | 0 | 3 | 3 | 6 | - | - | - | - | - | - | 12 |
| White fish | 0 | 14 | 2 | 0 | - | - | - | - | - | - | 16 |
| Northern pikeminnow | 0 | 6 | 21 | 1 | - | - | - | - | - | - | 28 |
| Longnose dace | 0 | 0 | 4 | 16 | - | - | - | - | - | - | 20 |
| Sucker spp. | 1 | 4 | 12 | 6 | - | - | - | - | - | - | 23 |
| Redside shiner | 0 | 9 | 10 | 2 | - | - | - | - | - | - | 21 |
| Sculpin spp. | 4 | 24 | 39 | 29 | - | - | - | - | - | - | 96 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 2000 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | - | 35 | 14 | 0 | - | - | - | - | - | - | 49 |
| *Wild subyearling* | - | 2 | 7 | 1 | - | - | - | - | - | - | 10 |
| *Hatchery yearling* | - | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Steelhead | | | | | | | | | | | |
| *Wild* | - | 0 | 1 | 0 | - | - | - | - | - | - | 1 |
| *Smolt* | - | 0 | 1 | 0 | - | - | - | - | - | - | 1 |
| *Parr* | - | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Hatchery* | - | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Sockeye | | | | | | | | | | | |
| *Wild* | - | 2,354 | 281 | 0 | - | - | - | - | - | - | 2,635 |
| *Hatchery* | - | 7 | 59 | 0 | - | - | - | - | - | - | 66 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | - | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Wild subyearling* | - | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Hatchery yearling* | - | 0 | 11 | 0 | - | - | - | - | - | - | 11 |
| Bull trout | - | 2 | 4 | 0 | - | - | - | - | - | - | 6 |
| *Juvenile* | - | 2 | 4 | 0 | - | - | - | - | - | - | 6 |
| *Adult* | - | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Cutthroat | - | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| White fish | - | 3 | 1 | 0 | - | - | - | - | - | - | 4 |
| Northern pikeminnow | - | 10 | 14 | 2 | - | - | - | - | - | - | 26 |
| Longnose dace | - | 0 | 3 | 0 | - | - | - | - | - | - | 3 |
| Sucker spp. | - | 3 | 2 | 0 | - | - | - | - | - | - | 5 |
| Redside shiner | - | 13 | 2 | 0 | - | - | - | - | - | - | 15 |
| Sculpin spp. | - | 19 | 16 | 11 | - | - | - | - | - | - | 46 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1999 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 4 | 135 | 83 | 6 | - | - | - | - | - | - | 228 |
| *Wild subyearling* | 0 | 73 | 10 | 1 | - | - | - | - | - | - | 84 |
| *Hatchery yearling* | 0 | 1 | 4 | 0 | - | - | - | - | - | - | 5 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 0 | 6 | 3 | 0 | - | - | - | - | - | - | 9 |
| *Smolt* | 0 | 1 | 0 | 0 | - | - | - | - | - | - | 1 |
| *Parr* | 0 | 5 | 3 | 0 | - | - | - | - | - | - | 8 |
| *Hatchery* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Sockeye | | | | | | | | | | | |
| *Wild* | 0 | 6,428 | 3,458 | 1 | - | - | - | - | - | - | 9,887 |
| *Hatchery* | 0 | 43 | 506 | 23 | - | - | - | - | - | - | 572 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Hatchery yearling* | 0 | 4 | 6 | 0 | - | - | - | - | - | - | 10 |
| Bull trout | 0 | 1 | 1 | 2 | - | - | - | - | - | - | 4 |
| *Juvenile* | 0 | 1 | 1 | 2 | - | - | - | - | - | - | 4 |
| *Adult* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Cutthroat | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| White fish | 1 | 12 | 3 | 0 | - | - | - | - | - | - | 16 |
| Northern pikeminnow | 0 | 41 | 2 | 0 | - | - | - | - | - | - | 43 |
| Longnose dace | 0 | 4 | 1 | 1 | - | - | - | - | - | - | 6 |
| Sucker spp. | 0 | 2 | 18 | 5 | - | - | - | - | - | - | 25 |
| Redside shiner | 1 | 18 | 3 | 1 | - | - | - | - | - | - | 23 |
| Sculpin spp. | 0 | 20 | 34 | 13 | - | - | - | - | - | - | 67 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1998 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 7 | 51 | 31 | 1 | - | - | - | - | - | - | 90 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 0 | 2 | 2 | 0 | - | - | - | - | - | - | 4 |
| *Smolt* | 0 | 1 | 2 | 0 | - | - | - | - | - | - | 3 |
| *Parr* | 0 | 1 | 0 | 0 | - | - | - | - | - | - | 1 |
| *Hatchery* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Sockeye | | | | | | | | | | | |
| *Wild* | 0 | 6,758 | 168 | 0 | - | - | - | - | - | - | 6,926 |
| *Hatchery* | 0 | 173 | 94 | 1 | - | - | - | - | - | - | 268 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Bull trout | 0 | 0 | 1 | 0 | - | - | - | - | - | - | 1 |
| *Juvenile* | 0 | 0 | 1 | 0 | - | - | - | - | - | - | 1 |
| *Adult* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Cutthroat | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Eastern brook | 0 | 0 | 0 | 1 | - | - | - | - | - | - | 1 |
| White fish | 0 | 0 | 10 | 0 | - | - | - | - | - | - | 10 |
| Northern pikeminnow | 0 | 0 | 22 | 11 | - | - | - | - | - | - | 33 |
| Longnose dace | 0 | 1 | 1 | 0 | - | - | - | - | - | - | 2 |
| Sucker spp. | 0 | 0 | 3 | 3 | - | - | - | - | - | - | 6 |
| Redside shiner | 0 | 0 | 5 | 7 | - | - | - | - | - | - | 12 |
| Sculpin spp. | 0 | 3 | 14 | 42 | - | - | - | - | - | - | 59 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1997 | | | | | | |
| Chinook | | | | | | | | | | | |
| *Wild yearling* | 0 | 7 | 3 | 2 | - | - | - | - | - | - | 12 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Steelhead | | | | | | | | | | | |
| *Wild* | 0 | 4 | 3 | 0 | - | - | - | - | - | - | 7 |
| *Smolt* | 0 | 1 | 0 | 0 | - | - | - | - | - | - | 1 |
| *Parr* | 0 | 3 | 3 | 0 | - | - | - | - | - | - | 6 |
| *Hatchery* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Sockeye | | | | | | | | | | | |
| *Wild* | 0 | 0 | 206 | 59 | - | - | - | - | - | - | 265 |
| *Hatchery* | 0 | 53 | 85 | 0 | - | - | - | - | - | - | 138 |
| Coho | | | | | | | | | | | |
| *Wild yearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Wild subyearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| *Hatchery yearling* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Bull trout | 1 | 1 | 1 | 0 | - | - | - | - | - | - | 3 |
| *Juvenile* | 1 | 1 | 1 | 0 | - | - | - | - | - | - | 3 |
| *Adult* | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Cutthroat | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Eastern brook | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| White fish | 0 | 11 | 9 | 0 | - | - | - | - | - | - | 20 |
| Northern pikeminnow | 1 | 47 | 77 | 0 | - | - | - | - | - | - | 125 |
| Longnose dace | 0 | 0 | 0 | 0 | - | - | - | - | - | - | 0 |
| Sucker spp. | 0 | 2 | 3 | 0 | - | - | - | - | - | - | 5 |
| Redside shiner | 2 | 11 | 19 | 2 | - | - | - | - | - | - | 34 |
| Sculpin spp. | 8 | 22 | 21 | 7 | - | - | - | - | - | - | 58 |

Appendix C. Yearly and monthly total juvenile capture information for the Lower Wenatchee River trap.

| | 2007 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species/Origin | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
| Chinook | | | | | | | | | | | | |
| *Wild yearling* | 138 | 426 | 918 | 294 | 46 | 84 | 0 | -- | -- | -- | -- | 1,906 |
| *Wild subyearling* | 135 | 997 | 6,769 | 43,053 | 28,446 | 6,711 | 31 | -- | -- | -- | -- | 86,142 |
| *Hatchery yearling* | 3 | 2 | 23,032 | 22,416 | 9 | 5 | 0 | -- | -- | -- | -- | 45,467 |
| Steelhead | | | | | | | | | | | | |
| *Wild* | 4 | 58 | 225 | 177 | 21 | 10 | 0 | -- | -- | -- | -- | 495 |
| *Smolt* | 2 | 49 | 192 | 173 | 13 | 4 | 0 | -- | -- | -- | -- | 433 |
| *Parr* | 2 | 9 | 33 | 4 | 8 | 6 | 0 | -- | -- | -- | -- | 62 |
| *Hatchery* | 0 | 0 | 2 | 2,641 | 53 | 1 | 0 | -- | -- | -- | -- | 2,697 |
| Sockeye | | | | | | | | | | | | |
| *Wild* | 2 | 1 | 5,691 | 643 | 3 | 0 | 0 | -- | -- | -- | -- | 6,340 |
| *Hatchery* | 0 | 0 | 8 | 240 | 0 | 0 | 0 | -- | -- | -- | -- | 248 |
| Coho | | | | | | | | | | | | |
| *Wild yearling* | 0 | 62 | 111 | 82 | 14 | 23 | 0 | -- | -- | -- | -- | 292 |
| *Wild subyearling* | 2 | 80 | 84 | 30 | 153 | 81 | 1 | -- | -- | -- | -- | 431 |
| *Hatchery yearling* | 0 | 241 | 26,233 | 2,775 | 55 | 1 | 0 | -- | -- | -- | -- | 29,305 |
| Bull trout | | | | | | | | | | | | |
| *Juvenile* | 0 | 2 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 2 |
| *Adult* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Cutthroat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| White fish | 0 | 2 | 1 | 0 | 15 | 5 | 0 | -- | -- | -- | -- | 23 |
| Northern pikeminnow | 0 | 57 | 6 | 46 | 14 | 12 | 0 | -- | -- | -- | -- | 135 |
| Longnose dace | 52 | 1,099 | 310 | 201 | 78 | 78 | 2 | -- | -- | -- | -- | 1,820 |
| Speckled dace | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Umatilla dace | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Sucker spp. | 4 | 217 | 9 | 40 | 50 | 17 | 2 | -- | -- | -- | -- | 339 |
| Peamouth | 0 | 0 | 0 | 1 | 0 | 0 | 0 | -- | -- | -- | -- | 1 |
| Chiselmouth | 0 | 0 | 0 | 0 | 1 | 0 | 0 | -- | -- | -- | -- | 1 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Redside shiner | 2 | 27 | 1 | 5 | 13 | 35 | 1 | -- | -- | -- | -- | 84 |
| Yellow bullhead | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Pacific lamprey | 181 | 947 | 819 | 351 | 416 | 162 | 0 | -- | -- | -- | -- | 2,876 |
| River lamprey | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Sculpin spp. | 7 | 20 | 19 | 5 | 9 | 4 | 0 | -- | -- | -- | -- | 64 |
| Stickleback (3 spined) | 0 | 0 | 0 | 1 | 7 | 31 | 0 | -- | -- | -- | -- | 39 |

| | 2006 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species/Origin | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Total |
| Chinook | | | | | | | | | | | | |
| *Wild yearling* | 18 | 12 | 583 | 37 | 2 | 0 | 0 | -- | -- | -- | -- | 652 |
| *Wild subyearling* | 126 | 429 | 6,467 | 40,376 | 9,722 | 6,416 | 44 | -- | -- | -- | -- | 63,580 |
| *Hatchery yearling* | 0 | 0 | 32,792 | 2,467 | 1 | 1 | 0 | -- | -- | -- | -- | 35,261 |
| Steelhead | | | | | | | | | | | | |
| *Wild* | 1 | 2 | 87 | 51 | 6 | 4 | 0 | -- | -- | -- | -- | 151 |
| *Smolt* | 0 | 0 | 60 | 42 | 2 | 1 | 0 | -- | -- | -- | -- | 105 |
| *Parr* | 1 | 2 | 26 | 9 | 4 | 3 | 0 | -- | -- | -- | -- | 45 |
| *Hatchery* | 0 | 0 | 1 | 3,736 | 32 | 0 | 0 | -- | -- | -- | -- | 3,769 |
| Sockeye | | | | | | | | | | | | |
| *Wild* | 1 | 29 | 4,990 | 180 | 4 | 0 | 0 | -- | -- | -- | -- | 5,204 |
| *Hatchery* | 0 | 0 | 40 | 28 | 0 | 0 | 0 | -- | -- | -- | -- | 68 |
| Coho | | | | | | | | | | | | |
| *Wild yearling* | 12 | 0 | 37 | 41 | 13 | 0 | 0 | -- | -- | -- | -- | 103 |
| *Wild subyearling* | 0 | 1 | 74 | 271 | 166 | 945 | 3 | -- | -- | -- | -- | 1,460 |
| *Hatchery yearling* | 0 | 0 | 10,480 | 3,076 | 70 | 1 | 0 | -- | -- | -- | -- | 13,627 |
| Bull trout | | | | | | | | | | | | |
| *Juvenile* | 0 | 0 | 0 | 1 | 0 | 0 | 0 | -- | -- | -- | -- | 1 |
| *Adult* | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Cutthroat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| White fish | 0 | 0 | 18 | 11 | 0 | 58 | 0 | -- | -- | -- | -- | 118 |
| Northern pikeminnow | 20 | 9 | 48 | 142 | 214 | 41 | 1 | -- | -- | -- | -- | 475 |
| Longnose dace | 7 | 39 | 313 | 219 | 170 | 52 | 1 | -- | -- | -- | -- | 801 |
| Speckled dace | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Umatilla dace | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Sucker spp. | 21 | 86 | 1,151 | 1,525 | 484 | 153 | 0 | -- | -- | -- | -- | 3,420 |
| Peamouth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Chiselmouth | 4 | 2 | 2 | 2 | 9 | 13 | 0 | -- | -- | -- | -- | 32 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Redside shiner | 1 | 1 | 109 | 255 | 435 | 148 | 3 | -- | -- | -- | -- | 952 |
| Yellow bullhead | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Pacific lamprey | 22 | 133 | 582 | 475 | 503 | 218 | 0 | -- | -- | -- | -- | 1,933 |
| River lamprey | 0 | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Sculpin spp. | 4 | 31 | 29 | 18 | 13 | 23 | 0 | -- | -- | -- | -- | 118 |
| Stickleback (3 spined) | 1 | 1 | 0 | 14 | 25 | 37 | 0 | -- | -- | -- | -- | 78 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2005 | | | | | | |
| Chinook | | | | | | | | | | | | |
| *Wild yearling* | 43 | 64 | 156 | 61 | 9 | 0 | -- | -- | -- | -- | -- | 333 |
| *Wild subyearling* | 227 | 1,642 | 42,294 | 149,126 | 29,624 | 1,945 | -- | -- | -- | -- | -- | 224,858 |
| *Hatchery yearling* | 1 | 3 | 17,328 | 6,375 | 2 | 0 | -- | -- | -- | -- | -- | 23,709 |
| Steelhead | | | | | | | | | | | | |
| *Wild* | 5 | 2 | 63 | 167 | 8 | 1 | -- | -- | -- | -- | -- | 246 |
| *Smolt* | 0 | 0 | 47 | 155 | 8 | 0 | -- | -- | -- | -- | -- | 210 |
| *Parr* | 5 | 2 | 16 | 12 | 0 | 1 | -- | -- | -- | -- | -- | 36 |
| *Hatchery* | 0 | 1 | 1 | 1,964 | 47 | 0 | -- | -- | -- | -- | -- | 2,013 |
| Sockeye | | | | | | | | | | | | |
| *Wild* | 0 | 8 | 112 | 82 | 0 | 0 | -- | -- | -- | -- | -- | 202 |
| *Hatchery* | 0 | 0 | 17 | 62 | 0 | 0 | -- | -- | -- | -- | -- | 79 |
| Coho | | | | | | | | | | | | |
| *Wild yearling* | 14 | 18 | 97 | 57 | 3 | 0 | -- | -- | -- | -- | -- | 189 |
| *Wild subyearling* | 2 | 30 | 214 | 1,091 | 453 | 56 | -- | -- | -- | -- | -- | 1,846 |
| *Hatchery yearling* | 0 | 1 | 3,476 | 8,347 | 119 | 0 | -- | -- | -- | -- | -- | 11,943 |
| Bull trout | | | | | | | | | | | | |
| *Juvenile* | 0 | 0 | 1 | 2 | 0 | 0 | -- | -- | -- | -- | -- | 3 |
| *Adult* | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Cutthroat | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| White fish | 0 | 0 | 1 | 7 | 1 | 0 | -- | -- | -- | -- | -- | 9 |
| Northern pikeminnow | 0 | 1 | 28 | 45 | 16 | 0 | -- | -- | -- | -- | -- | 90 |
| Longnose dace | 3 | 14 | 87 | 399 | 126 | 30 | -- | -- | -- | -- | -- | 659 |
| Speckled dace | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Umatilla dace | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Sucker spp. | 6 | 12 | 63 | 102 | 20 | 0 | -- | -- | -- | -- | -- | 203 |
| Peamouth | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Chiselmouth | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Redside shiner | 0 | 1 | 11 | 47 | 89 | 18 | -- | -- | -- | -- | -- | 166 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yellow bullhead | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Pacific lamprey | 13 | 37 | 156 | 320 | 157 | 2 | -- | -- | -- | -- | -- | 685 |
| River lamprey | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Sculpin spp. | 14 | 35 | 29 | 65 | 23 | 5 | -- | -- | -- | -- | -- | 171 |
| Stickleback (3 spined) | 1 | 3 | 2 | 34 | 10 | 1 | -- | -- | -- | -- | -- | 51 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2004 | | | | | | |
| Chinook | | | | | | | | | | | | |
| *Wild yearling* | 11 | 237 | 554 | 241 | 18 | 0 | -- | -- | -- | -- | -- | 1,061 |
| *Wild subyearling* | 129 | 1,001 | 4,895 | 149,570 | 63,410 | 6,544 | -- | -- | -- | -- | -- | 225,549 |
| *Hatchery yearling* | 0 | 36 | 9,693 | 2,108 | 8 | 1 | -- | -- | -- | -- | -- | 11,846 |
| Steelhead | | | | | | | | | | | | |
| *Wild* | 1 | 12 | 117 | 205 | 23 | 2 | -- | -- | -- | -- | -- | 360 |
| *Smolt* | 0 | 2 | 94 | 187 | 15 | 1 | -- | -- | -- | -- | -- | 299 |
| *Parr* | 1 | 10 | 23 | 18 | 8 | 1 | -- | -- | -- | -- | -- | 61 |
| *Hatchery* | 0 | 0 | 519 | 2,690 | 256 | 0 | -- | -- | -- | -- | -- | 3,465 |
| Sockeye | | | | | | | | | | | | |
| *Wild* | 0 | 48 | 3,047 | 106 | 23 | 0 | -- | -- | -- | -- | -- | 3,224 |
| *Hatchery* | 0 | 3 | 139 | 128 | 52 | 13 | -- | -- | -- | -- | -- | 335 |
| Coho | | | | | | | | | | | | |
| *Wild yearling* | 0 | 1 | 12 | 13 | 25 | 7 | -- | -- | -- | -- | -- | 58 |
| *Wild subyearling* | 0 | 5 | 27 | 572 | 233 | 90 | -- | -- | -- | -- | -- | 927 |
| *Hatchery yearling* | 0 | 40 | 2,285 | 12,216 | 914 | 0 | -- | -- | -- | -- | -- | 15,455 |
| Bull trout | 0 | 0 | 1 | 1 | 0 | 0 | -- | -- | -- | -- | -- | 2 |
| *Juvenile* | 0 | 0 | 1 | 1 | 0 | 0 | -- | -- | -- | -- | -- | 2 |
| *Adult* | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Cutthroat | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| White fish | 0 | 2 | 1 | 12 | 15 | 4 | -- | -- | -- | -- | -- | 34 |
| Northern pikeminnow | 0 | 0 | 3 | 25 | 14 | 33 | -- | -- | -- | -- | -- | 75 |
| Longnose dace | 5 | 66 | 498 | 1,444 | 241 | 120 | -- | -- | -- | -- | -- | 2,374 |
| Speckled dace | 0 | 4 | 0 | 0 | 0 | 1 | -- | -- | -- | -- | -- | 5 |
| Umatilla dace | 1 | 0 | 0 | 1 | 0 | 0 | -- | -- | -- | -- | -- | 2 |
| Sucker spp. | 0 | 7 | 13 | 67 | 95 | 26 | -- | -- | -- | -- | -- | 208 |
| Peamouth | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Chiselmouth | 0 | 0 | 0 | 0 | 4 | 3 | -- | -- | -- | -- | -- | 7 |
| Redside shiner | 0 | 0 | 2 | 46 | 34 | 18 | -- | -- | -- | -- | -- | 100 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yellow bullhead | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Pacific lamprey | 2 | 69 | 147 | 221 | 201 | 10 | -- | -- | -- | -- | -- | 650 |
| River lamprey | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Sculpin spp. | 1 | 5 | 17 | 30 | 19 | 14 | -- | -- | -- | -- | -- | 86 |
| Stickleback (3 spined) | 0 | 0 | 0 | 6 | 9 | 70 | -- | -- | -- | -- | -- | 85 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2003 | | | | | | |
| Chinook | | | | | | | | | | | | |
| *Wild yearling* | 21 | 321 | 664 | 538 | 75 | 0 | -- | -- | -- | -- | -- | 1,619 |
| *Wild subyearling* | 90 | 1,423 | 10,039 | 67,378 | 25,014 | 6,584 | -- | -- | -- | -- | -- | 110,528 |
| *Hatchery yearling* | 0 | 0 | 19,952 | 984 | 3 | 0 | -- | -- | -- | -- | -- | 20,939 |
| Steelhead | | | | | | | | | | | | |
| *Wild* | 5 | 15 | 81 | 273 | 38 | 1 | -- | -- | -- | -- | -- | 413 |
| *Smolt* | 0 | 2 | 52 | 269 | 19 | 1 | -- | -- | -- | -- | -- | 343 |
| *Parr* | 5 | 13 | 29 | 4 | 19 | 0 | -- | -- | -- | -- | -- | 70 |
| *Hatchery* | 0 | 0 | 3 | 2,098 | 66 | 8 | -- | -- | -- | -- | -- | 2,175 |
| Sockeye | | | | | | | | | | | | |
| *Wild* | 0 | 14 | 6,747 | 782 | 1 | 0 | -- | -- | -- | -- | -- | 7,544 |
| *Hatchery* | 0 | 0 | 150 | 72 | 27 | 22 | -- | -- | -- | -- | -- | 271 |
| Coho | | | | | | | | | | | | |
| *Wild yearling* | 6 | 59 | 56 | 75 | 3 | 0 | -- | -- | -- | -- | -- | 199 |
| *Wild subyearling* | 2 | 0 | 1 | 12 | 9 | 5 | -- | -- | -- | -- | -- | 29 |
| *Hatchery yearling* | 0 | 109 | 582 | 7,036 | 304 | 3 | -- | -- | -- | -- | -- | 8,034 |
| Bull trout | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| *Juvenile* | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| *Adult* | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Cutthroat | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| White fish | 0 | 2 | 5 | 65 | 15 | 28 | -- | -- | -- | -- | -- | 115 |
| Northern pikeminnow | 1 | 2 | 4 | 12 | 2 | 0 | -- | -- | -- | -- | -- | 21 |
| Longnose dace | 1 | 44 | 104 | 124 | 126 | 89 | -- | -- | -- | -- | -- | 488 |
| Speckled dace | 1 | 2 | 1 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 4 |
| Umatilla dace | 0 | 0 | 0 | 0 | 0 | 1 | -- | -- | -- | -- | -- | 1 |
| Sucker spp. | 1 | 17 | 59 | 53 | 30 | 12 | -- | -- | -- | -- | -- | 172 |
| Peamouth | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Chiselmouth | 0 | 0 | 0 | 0 | 0 | 2 | -- | -- | -- | -- | -- | 2 |
| Redside shiner | 0 | 0 | 4 | 0 | 3 | 7 | -- | -- | -- | -- | -- | 14 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yellow bullhead | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Pacific lamprey | 6 | 67 | 257 | 168 | 390 | 34 | -- | -- | -- | -- | -- | 922 |
| River lamprey | 0 | 0 | 0 | 1 | 0 | 0 | -- | -- | -- | -- | -- | 1 |
| Sculpin spp. | 0 | 10 | 17 | 17 | 12 | 15 | -- | -- | -- | -- | -- | 71 |
| Stickleback (3 spined) | 0 | 0 | 2 | 6 | 6 | 4 | -- | -- | -- | -- | -- | 18 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2002 | | | | | | |
| Chinook | | | | | | | | | | | | |
| *Wild yearling* | -- | 51 | 170 | 111 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 336 |
| *Wild subyearling* | -- | 401 | 1,422 | 17,679 | 7,682 | 11,666 | 556 | 20 | 100 | 133 | 55 | 39,714 |
| *Hatchery yearling* | -- | 6 | 797 | 2,610 | 5 | 0 | 0 | 0 | 0 | 3 | 0 | 3,421 |
| Steelhead | | | | | | | | | | | | |
| *Wild* | -- | 0 | 85 | 137 | 3 | 9 | 3 | 0 | 7 | 8 | 0 | 252 |
| *Smolt* | -- | 0 | 52 | 129 | 2 | 3 | 1 | 0 | 0 | 0 | 0 | 187 |
| *Parr* | -- | 0 | 33 | 8 | 1 | 6 | 2 | 0 | 7 | 8 | 11 | 76 |
| *Hatchery* | -- | 0 | 37 | 2,207 | 16 | 0 | 0 | 0 | 0 | 0 | 0 | 2,260 |
| Sockeye | | | | | | | | | | | | |
| *Wild* | -- | 0 | 4,711 | 327 | 1 | 0 | 3 | 0 | 0 | 0 | 0 | 5,042 |
| *Hatchery* | -- | 0 | 216 | 65 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 281 |
| Coho | | | | | | | | | | | | |
| *Wild yearling* | -- | 9 | 17 | 44 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 72 |
| *Wild subyearling* | -- | 20 | 33 | 186 | 108 | 1,021 | 48 | 1 | 8 | 18 | 0 | 1,443 |
| *Hatchery yearling* | -- | 1 | 1,502 | 10,680 | 134 | 46 | 0 | 0 | 0 | 0 | 0 | 12,363 |
| Bull trout | -- | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Juvenile* | -- | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| *Adult* | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cutthroat | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| White fish | -- | 0 | 3 | 2 | 3 | 21 | 0 | 0 | 1 | 1 | 0 | 31 |
| Northern pikeminnow | -- | 1 | 8 | 37 | 6 | 37 | 0 | 0 | 3 | 0 | 10 | 93 |
| Longnose dace | -- | 29 | 170 | 240 | 43 | 88 | 9 | 1 | 5 | 6 | 20 | 593 |
| Speckled dace | -- | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 3 |
| Umatilla dace | -- | 0 | 0 | 3 | 2 | 5 | 2 | 0 | 0 | 0 | 0 | 012 |
| Sucker spp. | -- | 7 | 44 | 49 | 8 | 54 | 3 | 0 | 1 | 2 | 1 | 169 |
| Peamouth | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chiselmouth | -- | 0 | 0 | 1 | 0 | 6 | 0 | 1 | 0 | 0 | 0 | 7 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Redside shiner | -- | 1 | 0 | 0 | 1 | 34 | 9 | 0 | 1 | 1 | 0 | 47 |
| Yellow bullhead | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Pacific lamprey | -- | 15 | 212 | 384 | 95 | 256 | 2 | 0 | 0 | 8 | 6 | 978 |
| River lamprey | -- | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sculpin spp. | -- | 9 | 38 | 27 | 4 | 15 | 2 | 0 | 0 | 2 | 0 | 97 |
| Stickleback (3 spined) | -- | 9 | 17 | 8 | 5 | 7 | 2 | 0 | 0 | 0 | 0 | 48 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2001 | | | | | | |
| Chinook | | | | | | | | | | | | |
| *Wild yearling* | -- | 27 | 83 | 73 | 23 | 0 | -- | -- | -- | -- | -- | 206 |
| *Wild subyearling* | -- | 95 | 1,183 | 34,156 | 31,098 | 4,420 | -- | -- | -- | -- | -- | 70,952 |
| *Hatchery yearling* | -- | 0 | 8,446 | 294 | 17 | 1 | -- | -- | -- | -- | -- | 8,758 |
| Steelhead | | | | | | | | | | | | |
| *Wild* | -- | 29 | 123 | 163 | 25 | 1 | -- | -- | -- | -- | -- | 341 |
| *smolt* | -- | 5 | 93 | 154 | 21 | 0 | -- | -- | -- | -- | -- | 273 |
| *parr* | -- | 24 | 30 | 9 | 4 | 1 | -- | -- | -- | -- | -- | 68 |
| *Hatchery* | -- | 0 | 169 | 1,376 | 162 | 4 | -- | -- | -- | -- | -- | 1,711 |
| Sockeye | | | | | | | | | | | | |
| *Wild* | -- | 0 | 31 | 26 | 0 | 1 | -- | -- | -- | -- | -- | 58 |
| *Hatchery* | -- | 0 | 45 | 85 | 1 | 0 | -- | -- | -- | -- | -- | 131 |
| Coho | | | | | | | | | | | | |
| *Wild yearling* | -- | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| *Wild subyearling* | -- | 0 | 26 | 105 | 43 | 17 | -- | -- | -- | -- | -- | 191 |
| *Hatchery yearling* | -- | 8 | 4,210 | 6,193 | 847 | 7 | -- | -- | -- | -- | -- | 11,265 |
| Bull trout | -- | 0 | 1 | 1 | 0 | 0 | -- | -- | -- | -- | -- | 1 |
| *Juvenile* | -- | 0 | 1 | 1 | 0 | 0 | -- | -- | -- | -- | -- | 1 |
| *Adult* | -- | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Cutthroat | -- | 0 | 0 | 2 | 0 | 0 | -- | -- | -- | -- | -- | 2 |
| White fish | -- | 0 | 5 | 33 | 30 | 10 | -- | -- | -- | -- | -- | 78 |
| Northern pikeminnow | -- | 0 | 0 | 6 | 1 | 3 | -- | -- | -- | -- | -- | 10 |
| Longnose dace | -- | 11 | 21 | 175 | 73 | 165 | -- | -- | -- | -- | -- | 445 |
| Speckled dace | -- | 0 | 0 | 4 | 3 | 0 | -- | -- | -- | -- | -- | 7 |
| Umatilla dace | -- | 0 | 1 | 0 | 14 | 21 | -- | -- | -- | -- | -- | 36 |
| Sucker spp. | -- | 5 | 36 | 108 | 34 | 18 | -- | -- | -- | -- | -- | 201 |
| Peamouth | -- | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Chiselmouth | -- | 0 | 0 | 0 | 0 | 1 | -- | -- | -- | -- | -- | 1 |
| Redside shiner | -- | 0 | 5 | 8 | 7 | 27 | -- | -- | -- | -- | -- | 47 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yellow bullhead | -- | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | -- | 0 |
| Pacific lamprey | -- | 12 | 466 | 521 | 240 | 28 | -- | -- | -- | -- | -- | 1,267 |
| River lamprey | -- | 0 | 12 | 6 | 0 | 0 | -- | -- | -- | -- | -- | 18 |
| Sculpin spp. | -- | 2 | 6 | 15 | 9 | 23 | -- | -- | -- | -- | -- | 55 |
| Stickleback (3 spined) | -- | 0 | 0 | 0 | 0 | 246 | -- | -- | -- | -- | -- | 246 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | 2000 | | | | | | |
| Chinook | | | | | | | | | | | | |
| *Wild yearling* | -- | 8 | 192 | 67 | 8 | 9 | 0 | -- | -- | -- | -- | 284 |
| *Wild subyearling* | -- | 162 | 3,737 | 41,790 | 21,618 | 4,627 | 310 | -- | -- | -- | -- | 72,244 |
| *Hatchery yearling* | -- | 0 | 2,471 | 270 | 8 | 2 | 2 | -- | -- | -- | -- | 2,753 |
| Steelhead | | | | | | | | | | | | |
| *Wild* | -- | 1 | 171 | 254 | 4 | 16 | 22 | -- | -- | -- | -- | 468 |
| *Smolt* | -- | 0 | 164 | 254 | 3 | 3 | 2 | -- | -- | -- | -- | 426 |
| *Parr* | -- | 1 | 7 | 0 | 1 | 13 | 20 | -- | -- | -- | -- | 42 |
| *Hatchery* | -- | 0 | 208 | 1,952 | 59 | 0 | 0 | -- | -- | -- | -- | 2,219 |
| Sockeye | | | | | | | | | | | | |
| *Wild* | -- | 3 | 1,041 | 70 | 0 | 0 | 0 | -- | -- | -- | -- | 1,114 |
| *Hatchery* | -- | 0 | 6 | 5 | 0 | 0 | 1 | -- | -- | -- | -- | 12 |
| Coho | | | | | | | | | | | | |
| *Wild yearling* | -- | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| *Wild subyearling* | -- | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| *Hatchery yearling* | -- | 82 | 2,724 | 8,769 | 726 | 4 | 0 | -- | -- | -- | -- | 12,305 |
| Bull trout | -- | 0 | 2 | 1 | 0 | 1 | 0 | -- | -- | -- | -- | 4 |
| *Juvenile* | -- | 0 | 2 | 1 | 0 | 1 | 0 | -- | -- | -- | -- | 4 |
| *Adult* | -- | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| Cutthroat | -- | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |
| White fish | -- | 1 | 9 | 5 | 12 | 41 | 5 | -- | -- | -- | -- | 73 |
| Northern pikeminnow | -- | 0 | 2 | 2 | 2 | 2 | 1 | -- | -- | -- | -- | 9 |
| Longnose dace | -- | 1 | 45 | 35 | 128 | 92 | 18 | -- | -- | -- | -- | 319 |
| Speckled dace | -- | 0 | 3 | 0 | 10 | 4 | 0 | -- | -- | -- | -- | 17 |
| Umatilla dace | -- | 0 | 0 | 0 | 6 | 7 | 4 | -- | -- | -- | -- | 17 |
| Sucker spp. | -- | 0 | 21 | 70 | 13 | 15 | 2 | -- | -- | -- | -- | 121 |
| Peamouth | -- | 0 | 0 | 0 | 11 | 0 | 0 | -- | -- | -- | -- | 11 |
| Chiselmouth | -- | 0 | 0 | 0 | 2 | 4 | 0 | -- | -- | -- | -- | 6 |
| Redside shiner | -- | 0 | 0 | 1 | 1 | 5 | 1 | -- | -- | -- | -- | 8 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yellow bullhead | -- | 0 | 0 | 0 | 1 | 0 | 0 | -- | -- | -- | -- | 1 |
| Pacific lamprey | -- | 3 | 610 | 268 | 243 | 265 | 4 | -- | -- | -- | -- | 1,393 |
| River lamprey | -- | 0 | 1 | 0 | 9 | 10 | 0 | -- | -- | -- | -- | 20 |
| Sculpin spp. | -- | 1 | 16 | 15 | 22 | 17 | 5 | -- | -- | -- | -- | 76 |
| Stickleback (3 spined) | -- | 0 | 0 | 0 | 0 | 0 | 0 | -- | -- | -- | -- | 0 |

# APPENDIX C

## Summary of ISEMP PIT Tagging Activities in the Wenatchee Basin, 2007.

**Appendix C.** Numbers of fish captured, PIT tagged, lost, and released in the Wenatchee Basin during February through November, 2007.

| Sampling location | Species and life stage | Number captured | Number tagged | Number that died | Number of shed tags | Number released |
|---|---|---|---|---|---|---|
| Chiwawa Trap | Wild subyearling Chinook | 6,676 | 6,155 | 17 | 1 | 6,137 |
| | Wild yearling Chinook | 4,798 | 4,689 | 30 | 0 | 4,659 |
| | Wild Steelhead/Rainbow | 885 | 840 | 8 | 0 | 832 |
| | Hatchery Steelhead/Rainbow | 4 | 3 | 0 | 0 | 3 |
| Chiwawa River (upstream from trap) | Wild subyearling Chinook | 23 | 21 | 1 | 0 | 20 |
| | Wild yearling Chinook | 1 | 0 | 0 | 0 | 0 |
| | Wild Steelhead/Rainbow | 179 | 167 | 0 | 0 | 167 |
| | Hatchery Steelhead/Rainbow | 52 | 47 | 0 | 0 | 47 |
| Upper Wenatchee Trap | Wild subyearling Chinook | 21 | 20 | 5 | 0 | 15 |
| | Wild yearling Chinook | 1,493 | 1,456 | 21 | 1 | 1,434 |
| | Wild Steelhead/Rainbow | 41 | 38 | 1 | 0 | 37 |
| | Hatchery Steelhead/Rainbow | 0 | 0 | 0 | 0 | 0 |
| Upper Wenatchee River (from Tumwater to Lake) | Wild subyearling Chinook | 68 | 61 | 0 | 0 | 61 |
| | Wild yearling Chinook | 0 | 0 | 0 | 0 | 0 |
| | Wild Steelhead/Rainbow | 1,020 | 1,001 | 0 | 0 | 1,001 |
| | Hatchery Steelhead/Rainbow | 69 | 64 | 0 | 0 | 64 |
| Nason Creek (upstream from trap)[1] | Wild subyearling Chinook | 7 | 7 | 1 | 0 | 6 |
| | Wild yearling Chinook | 7 | 7 | 0 | 0 | 7 |
| | Wild Steelhead/Rainbow | 483 | 453 | 1 | 0 | 452 |
| | Hatchery Steelhead/Rainbow | 116 | 75 | 0 | 0 | 75 |
| Lower Wenatchee Trap | Wild subyearling Chinook | 0 | 0 | 0 | 0 | 0 |
| | Wild yearling Chinook | 1,690 | 1,646 | 5 | 0 | 1,641 |
| | Wild Steelhead/Rainbow | 473 | 462 | 1 | 0 | 461 |
| | Hatchery Steelhead/Rainbow | 0 | 0 | 0 | 0 | 0 |
| **Totals** | **Wild subyearling Chinook** | **6,795** | **6,264** | **24** | **1** | **6,239** |
| | **Wild yearling Chinook** | **7,989** | **7,798** | **56** | **1** | **7,741** |
| | **Wild Steelhead/Rainbow** | **3,081** | **2,961** | **11** | **0** | **2,950** |
| | **Hatchery Steelhead/Rainbow** | **241** | **189** | **0** | **0** | **189** |

[1] An additional 489 wild subyearling Chinook, 582 wild yearling Chinook, and 1,312 wild steelhead/rainbow were tagged and released by the Yakama Nation at the Nason Creek smolt trap.

# APPENDIX D

## Wenatchee Steelhead Spawning Ground Surveys, 2007

# STATE OF WASHINGTON
# DEPARTMENT OF FISH AND WILDLIFE
## FISH PROGRAM – SCIENCE DIVISION
## SUPPLEMENTATION RESEARCH TEAM

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6 February 2008

To: Distribution List

From: Michael Tonseth

**Subject: 2007 Wenatchee River Basin Steelhead Spawning Ground Surveys**

Summer steelhead migrate to their spawning grounds as earlier as nine months prior to spawning. Run escapement estimates of summer steelhead counted at Columbia River dams or Tumwater Dam in the Wenatchee River do not accurately reflect the size of the spawning population due to prespawn mortality. Redd counts may be used to calculate a more accurate estimate of the spawning population, but requires knowledge concerning the number of redds per female and the number of fish per redd. An estimate of the spawning population coupled with other population specific information (i.e., ratio of hatchery and wild spawners and age composition) are critical data needed to assess the productivity of the population (i.e., recruits per spawner).

Our objectives in conducting steelhead spawning ground surveys were to 1) determine spawn timing of naturally spawning steelhead (both hatchery and wild origin) and 2) estimate the abundance of redds and naturally spawning steelhead within selected tributaries. We also examined the relationship between run escapement upstream of Tumwater Dam (i.e., female and total) and redd counts as a method of assessing the precision of our estimates.

## Methods

Survey efforts were primarily concentrated in the upper Wenatchee basin because all hatchery fish were released upstream of Tumwater Dam. Peshastin Creek was included in our surveys because it was identified as a potential reference stream (i.e., no hatchery releases since 1998) for the Wenatchee Basin. Survey methodology involved surveying non-random index areas, defined as major spawning area(s) for each stream, as frequently as once a week. Redds were either individually flagged or in the case of localized spawning, mapped and numbered sequentially. All redds were also geo-referenced using handheld global positioning devices. Between 2000 and 2003, the number of index areas has increased as more information became available. Beginning in 2004, survey

methodology has remained similar. Hence, direct comparisons of redd counts to years before 2004 may not be appropriate.

Index area spawning ground surveys were conducted by foot or raft using the on the Wenatchee River and most major tributaries (Appendix A). For each index area, the same surveyor(s) conducted all weekly surveys. However, when the end of spawning within an index area was thought to be nearly complete, a different observer (i.e., naïve) surveyed the index area to determine the number of redds still visible at the end of spawning. At approximately the same time, non-index areas within a reach or stream were also surveyed. The total number of redds in non-index areas was estimated by dividing the number of redds found in non-index areas by the proportion of redds still visible inside the index area. The reach total redd count was calculated by combining the number of redds in the index area and the estimated number of redds in the non-index. Murdoch and Peven (2005) provide a more detailed description of the methodology (Appendix F, Task 7-3).

Secondary sexual characteristics were used to calculate sex ratios for the entire run at Tumwater Dam. The sex ratio of the run was subsequently used as the value for the number fish per redd (i.e., assuming each female constructed one redd and male spawned with one female). Spawning escapement was estimated by multiplying the estimated total number of redds by the number of fish per redd. Linear regression analysis was used to examine the relationship between run escapement, index redd counts, and total redd counts upstream of Tumwater Dam.

## Results

The number of steelhead migrating upstream of Tumwater Dam decreased 38% between 2006 and 2007 and was 64% below the 5-year average of 1,820 fish (Table 1). A greater proportion of female than male steelhead were observed at Tumwater Dam resulting in a fish per redd value of 1.94. The origin of fish over Tumwater Dam could not be determined because most returning hatchery steelhead were not adipose fin clipped. However, based upon steelhead run composition sampling conducted at Dryden Dam in 2006 (i.e., 2007 spawners), the proportion of naturally produced fish, based on scale samples was estimated at 37% (WDFW, unpublished data). We estimated that the number of hatchery and naturally produced steelhead migrating upstream of Tumwater Dam was 414 and 243, respectively. Because the majority of hatchery releases occur upstream of Tumwater Dam, the proportion of hatchery fish estimated at Dryden Dam should adequately represent the origin composition upstream of Tumwater Dam.

In 2007, river conditions were similar to that observed in 2003 and 2006. High snow pack and warm weather conditions in March and May kept water conditions fluctuating considerably during each of those months. Steelhead began spawning during the second week of April in the Wenatchee River and Nason Creek and progressed upstream as water temperatures increased. Spawning was observed in water temperatures ranging from 3.2–6.9 $^{o}$C. Based on preliminary data, most spawning activity appeared to begin once a mean daily stream temperature reached ~4.2$^{o}$C. Peak spawning in the Wenatchee

River occurred the fourth week of April. Steelhead spawning also peaked in Nason and Peshastin Creek the fourth week of April (Appendix B). Spawning ground surveys were limited beyond the fourth week of May due to poor river conditions. However, one survey was conducted the second week of June to determine if any late spawning could be detected. The high water through much of May resulted in all previously constructed redds being erased with no new redds being located.

Table 1. Total number, gender, and sex ratio of steelhead migrating upstream of Tumwater Dam between 2001 and 2007. Sex ratio in 2001 was determined by the number of fish passed and collected during broodstock collection at Tumwater and Dryden dams. For 2002-2007, gender was determined using Tumwater Dam video data.

| Year | Number of steelhead above Tumwater Dam | | | Male to female ratio | Number of fish per redd |
|---|---|---|---|---|---|
| | Total | Female | Male | | |
| 2001 | 820 | 394 | 426 | 1.08 | 2.08 |
| 2002 | 1,720 | 642 | 1,078 | 1.68 | 2.68 |
| 2003 | 1,810 | 1,133 | 677 | 0.60 | 1.60 |
| 2004 | 1,869 | 846 | 1,023 | 1.21 | 2.21 |
| 2005 | 2,650 | 1,644 | 1,006 | 0.61 | 1.61 |
| 2006 | 1,053 | 513 | 540 | 1.05 | 2.05 |
| 2007 | 657 | 339 | 318 | 0.94 | 1.94 |

The estimated number of redds in the Wenatchee Basin decreased 60% between 2006 ($N$ = 395) and 2007 ($N$ =159) and is 75% below the 3-year average of 644 redds (Table 2). High river discharge occurring before, during, and following the peak of spawning decreased observer efficiency and may have resulted in an underestimate of redd abundance. For the above Tumwater Dam spawning aggregate, the decrease in the proportion of redds (59%) was well below the observed decrease in the estimated number of spawners (44%) between 2006 and 2007. The proportion of redds in tributaries upstream of Tumwater Dam generally increased and decreased in tributaries downstream of Tumwater Dam as well as in the Wenatchee River. The decline in redd abundance in spawning areas below Tumwater Dam was likely the function of poor survey conditions.

In 2007, the proportion of redds in Nason Creek (49%) was greater than the 3-year mean (32%; Table 2). This large increase was likely due to good survey conditions (i.e., water clarity) even during higher flow periods compared to other streams in the Wenatchee Basin. While the overall number of redds in Nason Creek was lower than previous years, spawning continues to be primarily occurring in the middle two reaches (77%; Appendix D1). Steelhead redds observed in the Chiwawa River were also found in locations consistent with previous years (Appendix D2). The proportion of redds found in all streams upstream of Tumwater Dam increased from 57% in 2006 to 96% in 2007 (Appendix D3). While Peshastin Creek experienced only a slight decrease in the proportion of redds, the overall abundance of redds in 2007 was 75% lower than 2006

(Appendix D4). The number of steelhead redds in Icicle Creek, another major spawning tributary downstream of Tumwater Dam, was only 85% of that observed in 2007.

Table 2. Comparison of the number and distribution of steelhead redds in 2007 and the three year mean (2004-2006).

| Stream | 2007 | | Mean (2004-2006) | |
|---|---|---|---|---|
| | Number of redds | Distribution (%) | Number of redds | Distribution (%) |
| Nason Creek | 78 | 49.1 | 205 | 31.8 |
| Chiwawa River | 11 | 6.9 | 81 | 12.6 |
| White River | 1 | 0.6 | 1 | 0.2 |
| L. Wenatchee River | 0 | 0.0 | 0 | 0.0 |
| Peshastin Creek | 17 | 10.7 | 66 | 10.2 |
| Icicle Creek | 6 | 3.8 | 24 | 3.7 |
| Wenatchee River | 46 | 28.9 | 267 | 41.5 |
| Above Tumwater | 44 | 95.7 | 227 | 85.0 |
| Below Tumwater | 2 | 4.3 | 40 | 15.0 |
| Total | 159 | | 644 | |

As a result of poor survey conditions throughout much of the spawning period (particularly in those indexes downstream of the Chiwawa and Icicle rivers), observer efficiency was likely reduced, resulting in fewer visible redds and subsequent lower expansions. The proportion of redds found within index areas upstream of Tumwater Dam (78%) was slightly lower than the 3-year average of 82% (2004-2006, Table 3).

Table 3. Comparison of the number of redds found within index areas and the estimated number of redds in non-index areas upstream of Tumwater Dam between 2001 and 2007.

| Year | Index area | Non-index area | Estimated total | Within index area (%) |
|---|---|---|---|---|
| 2001 | 118 | 19 | 137 | 86 |
| 2002 | 296 | 179 | 475 | 62 |
| 2003 | 353 | 88 | 441 | 80 |
| 2004 | 277 | 92 | 369 | 75 |
| 2005 | 828 | 136 | 964 | 86 |
| 2006 | 192 | 34 | 226 | 85 |
| 2007 | 105 | 29 | 134 | 78 |

Total run escapement explained a slightly greater proportion of the variation in the estimated total number of redds than the number of female steelhead (Figure 1). While, total run escapement explained a greater proportion of the variation in total redd counts

than index redd counts, suggesting that expanded redd counts are a better predictor of the spawning population than index counts (Figure 2).

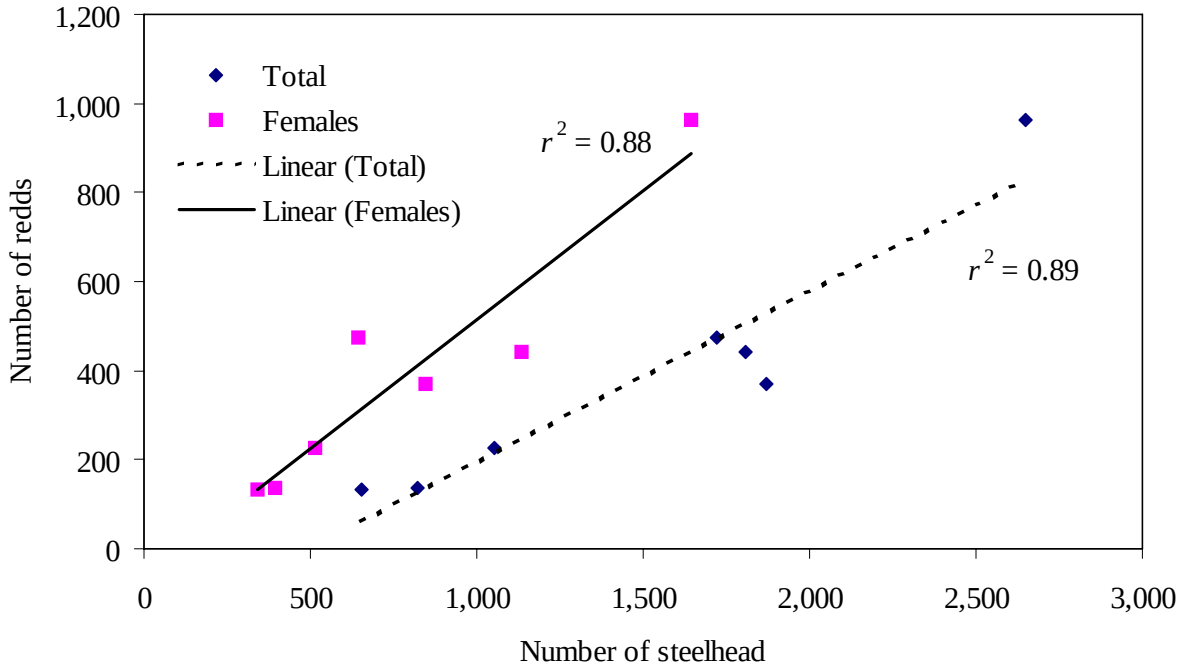



Figure 1. Relationship between steelhead run escapement (total and female) upstream of Tumwater Dam and total redd counts.

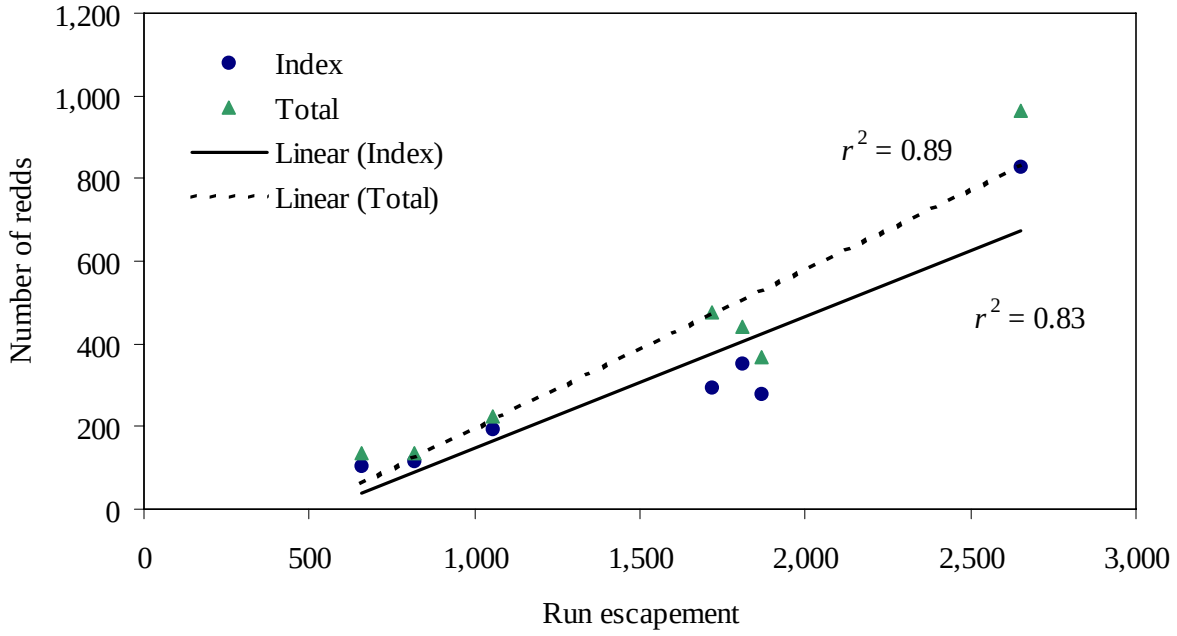



Figure 2. Relationship between steelhead run escapement upstream of Tumwater Dam and total and index area redd counts.

In 2007, only 40% of the steelhead migrating above Tumwater Dam were accounted for on spawning ground surveys compared to the 3-year average (2004-2006) of 49% (Table 4). Difficult survey conditions (i.e., numerous freshets) likely resulted in lower observer efficiency. Other factors that may have influenced spawning escapement (i.e., fall back and prespawn mortality) are unknown.

Table 4. Comparison of run and estimated spawning escapement for steelhead upstream of Tumwater Dam between 2001 and 2007.

| Year | Run Escapement (A) | Number of redds (B) | Number of fish per redd (C) | Estimated spawning escapement (D = B x C) | Proportion of run escapement (E = D/A) |
|---|---|---|---|---|---|
| 2001 | 820 | 137 | 2.08 | 285 | 0.35 |
| 2002 | 1,720 | 475 | 2.68 | 1,273 | 0.74 |
| 2003 | 1,810 | 441 | 1.60 | 706 | 0.39 |
| 2004 | 1,869 | 369 | 2.21 | 815 | 0.44 |
| 2005 | 2,650 | 964 | 1.61 | 1,552 | 0.59 |
| 2006 | 1,053 | 226 | 2.05 | 463 | 0.44 |
| 2007 | 657 | 134 | 1.94 | 260 | 0.40 |

## Discussion

The high correlation between the expanded total redd counts and run escapement ($r$ = 0.94) suggest that the methodology used to estimate the number of steelhead can be very robust in estimating spawning escapement. It also suggests that factors responsible for the observed difference in run and estimated spawning escapement are relatively constant with respect to escapement levels and time. Given the large differences between run and spawn escapement upstream of Tumwater Dam, it is evident that there are multiple contributing factors that are influencing the disparity between the two estimates including:

- Fallback or “wandering” rates of summer steelhead are unknown.
- Prespawn survival rates of summer steelhead are unknown.
- Assumption of one redd per female is invalid.
- Unknown error in the number of fish per redd value.
- Observer efficiency is less than 100% in index areas.
- Spawning occurs in areas not surveyed (i.e., missed redds)

Tumwater Dam offers a unique opportunity to examine all the possible factors that may influence the size of the spawning population. Furthermore, it is not unreasonable to apply results of studies designed to answer these critical uncertainties to all populations in the upper Columbia River Basin. In the following section, we discuss each factor in more detail.

Fallback rates over Tumwater Dam are unknown and would inflate run escapement estimates if not accounted for. Radio telemetry studies on adult steelhead migration between Priest Rapids and Wells dams reported fallback rates ranging from 4.3% to 7.8% (English et. al., 2001). It is unknown if fallback rates in the Columbia River are similar to those in spawning tributaries. Naturally produced steelhead PIT tagged at Tumwater Dam have been detected at Roza Dam in the upper Yakima River approximately one month after tagging (M. Johnston, YN, personal communication). Installation of a PIT tag detector at Tumwater Dam and instream PIT tag antennae arrays throughout the upper Columbia Basin may provide estimates of "wandering" for both hatchery and naturally produced steelhead, but will require that a sufficient number of adult steelhead are PIT tagged. Radio tags would also be an appropriate technique to estimate "wandering" rates, but a large number of tags may be required if rates are low.

Prespawn mortality for adult steelhead is likely greater than the 5% assumed in the management of Upper Columbia Basin steelhead fisheries (Kirk Truscott, WDFW, personal communication). Summer steelhead are iteroparous and as a species have evolved survival traits (i.e., disease resistance) to overcome the extreme rigors of holding in freshwater as much as eleven months in duration before spawning. PIT tags may be used to infer prespawn mortality rates, but radio tags programmed with a motion sensor would likely be required.

In some populations, female steelhead were reported to construct multiple redds. If steelhead in the Wenatchee do construct multiple redds, differences in run and escapement estimates would increase as a result of a lower spawning escapement estimate. A tagging study, internal or external, would be required to test this assumption. Surveys would also need to be conducted on daily basis.

The number of fish per redd is based on the sex ratio of the population. Error associated with observer accuracy (i.e., gender misassignment) could be corrected using portable ultrasound devices. However, if the sex ratio does not accurately reflect the number of fish per redd, additional studies would need to be designed and implemented.

Observer efficiency error in counting redds can be estimated by using multiple surveyors for each index reach. However, studies would also need to be designed to determine the actual number of redds in a given reach in order to determine observer efficiency.

Of all the factors that are contributing to the difference between run and spawning escapement estimates, redds constructed in streams not included in the survey area have the potential to account for a significant portion of the difference. The reported number of redds upstream of Tumwater Dam underestimate the total number of redds because all available spawning habitat (i.e., low order streams) is not surveyed. Studies have been ongoing in the Wenatchee Basin designed to estimate the number of redds in areas not covered under the current survey design. Data from these studies (ISEMP) must be analyzed and incorporated into spawning escapement estimates. Only after these data are included will the magnitude of the other factors be understood. Researchers could then

prioritize which factors likely explain the greatest proportion of the observed difference and studies can be designed and implemented.

The timing and distribution of natural spawning hatchery and naturally produced steelhead in the Wenatchee River is unknown. Differences in spawn timing have been observed in Wenatchee summer steelhead broodstock, but fish are held in a controlled environment on well water. Based on the differences observed in the hatchery, it is possible that a considerable portion of hatchery origin steelhead spawn prior to initiation of spawning ground surveys. Spawning ground surveys start in early March and typically no redds have been found until April suggesting that hatchery steelhead are spawning within the current survey period. However, bi-modal spawning distribution has not been detectable under the current survey protocols, but may be masked by the large proportion of hatchery fish on the spawning grounds. The inability to discern hatchery and naturally produced fish on the spawning grounds precludes determining the spawning distribution and timing of hatchery steelhead relative to naturally produced steelhead. Studies developed and implemented to examine the factors previously discussed, should incorporate as many objectives as possible, to include the temporal and spatial distribution of hatchery and wild steelhead in the Wenatchee Basin.

## References

Murdoch, A. R. and C. M. Peven. 2005. Conceptual approach to monitoring and evaluating the Chelan county Public Utility District hatchery programs. Chelan County PUD, Wenatchee, WA.

English, K. K., C. Sliwinski, B. Nass, and J. R. Stevenson. 2001. Assessment of adult steelhead migration through the Mid-Columbia River using radio-telemetry techniques, 1999-2000. Report prepared by LGL Limited for Public Utility District No.2 of Grant County, Public Utility District No. 1 of Chelan County, and Public Utility District No. 1 of Douglas County. 48 p. + appendices.

Appendix A. Wenatchee River Basin survey reach and index/reference areas – surveys conducted weekly from March through June.

| Reach | Index/reference area |
|---|---|
| *Wenatchee River* | |
| Sleepy Hollow Br. to Lower Cashmere Br. (W2) | Monitor boat ramp to Cashmere boat ramp |
| Leavenworth Bridge to Icicle Road Bridge (W6) | Leavenworth boat ramp to Icicle River |
| Tumwater Dam to Tumwater Bridge (W8) | Swiftwater boat ramp to Tumwater Bridge |
| Tumwater Bridge to Plain (W9) | Tumwater Bridge to Plain |
| Plain to Lake Wenatchee (W10) | Chiwawa pump station to Lake Wenatchee |
| *Peshastin Creek* | |
| Mouth to Camas Creek (P1) | Kings Bridge to Camas Creek |
| Camas Creek to mouth of Scotty Creek (P2A) | Ingalls Creek to Ruby Creek |
| Camas Creek to mouth of Scotty Creek (P2) | FR7320 to mouth of Shaser Cr. |
| *Ingalls Creek* | |
| Mouth to Trailhead rm 1.0 (D1) | Mouth to Trailhead rm 1.0 |
| Trailhead to Wilderness Boundary rm 1.5 (D2) | Trailhead to Wilderness Boundary rm 1.5 |
| *Chiwawa River* | |
| Mouth to Grouse Creek (C1) | Mouth to Road 62 Bridge rm 6.4 |
| Grouse Creek to Rock Creek (C2) | Chikamin Creek to Log jam |
| *Clear Creek* | |
| Mouth to HWY 22 (V1) | Mouth to HWY 22 |
| HWY 22 to Lower culvert rm 2.0 (V2) | HWY 22 to Lower culvert |
| *Nason Creek* | |
| Mouth to Kahler Creek Bridge (N1) | Mouth to Swamp Creek |
| HWY 2 Bridge to Lower R.R. Bridge (N3) | Highway 2 Bridge to Merrit Bridge |
| Lower R.R. Bridge to Whitepine Creek (N4) | Rayrock to Church camp |
| *Icicle River* | |
| Mouth to Hatchery (I1) | Mouth to Hatchery |
| *Little Wenatchee River* | |
| Mouth to Lost Creek (L2) | Fish Weir to Lost Creek |
| Lost Creek to Rainy Creek Bridge (L3) | Lost Creek to Rainy Creek Bridge |
| *White River* | |
| Sears Cr. Bridge to Napeequa River (H2) | Riprap bank to Napeequa River |
| Napeequa River to mouth of Panther Creek (H3) | Napeequa River to Grasshopper Meadows. |
| *Napeequa River* | |
| Mouth to rm 1.0 (Q1) | Mouth to rm 1.0 |

Appendix B. Summary of steelhead spawning ground index surveys in the Wenatchee River basin in 2007.

| Reach | Survey Week of Index Area | | | | | | | | | | | | | | | Reach Total | Expanded #of redds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 Mar | 11 Mar | 18 Mar | 25 Mar | 1 Apr | 8 Apr | 15 Apr | 22 Apr | 29 Apr | 6 May | 13 May | 20 May | 27 May | 3 June | 10 June | | |
| *Wenatchee River* | | | | | | | | | | | | | | | | | |
| W1 | | | | | | | | | | | | | | | | | |
| W2 | 0 | | | | 0 | | 0 | 0 | 0 | | | | | | | 0 | 0 |
| W3 | | | | | | | | | | | | | | | | | |
| W4 | | | | | | | | | | | | | | | | | |
| W5 | | | | | | | | | | | | | | | | | |
| W6 | | | 0 | 0 | | | 1 | 1 | | | | | | | | 2 | 2 |
| W7 | | | | | | | | | | | | | | | | | |
| W8 | 0 | | 0 | | 0 | 0 | 0 | 0 | 0 | 0 | | | | | | 0 | 0 |
| W9 | 0 | | 0 | | 0 | 0 | 3 | 2 | 5 | | | | | | | 10 | 10 |
| W10 | 0 | | 0 | | 0 | 5 | 9 | 7 | 6 | | | 7 | | | | 34 | 34 |
| Total | 0 | | 0 | 0 | 0 | 5 | 13 | 10 | 11 | 0 | | 7 | | | | 46 | 46 |
| *Peshastin Creek* | | | | | | | | | | | | | | | | | |
| P1 | | | | | 0 | | 2 | 3 | 1 | | | | | | | 6 | 6 |
| P2 | | | | | 0 | | 2 | 2 | 1 | | | 6 | | | | 11 | 11 |
| Total | | | | | 0 | | 4 | 5 | 2 | | | 6 | | | | 17 | 17 |
| *Chiwawa River* | | | | | | | | | | | | | | | | | |
| C1 | | | | | 0 | 0 | 1 | 2 | 0 | | | | | | | 3 | 3 |
| C2 | | | | | | | | | | | | | | | | | |
| Total | | | | | 0 | 0 | 1 | 2 | 0 | | | | | | | 3 | 3 |

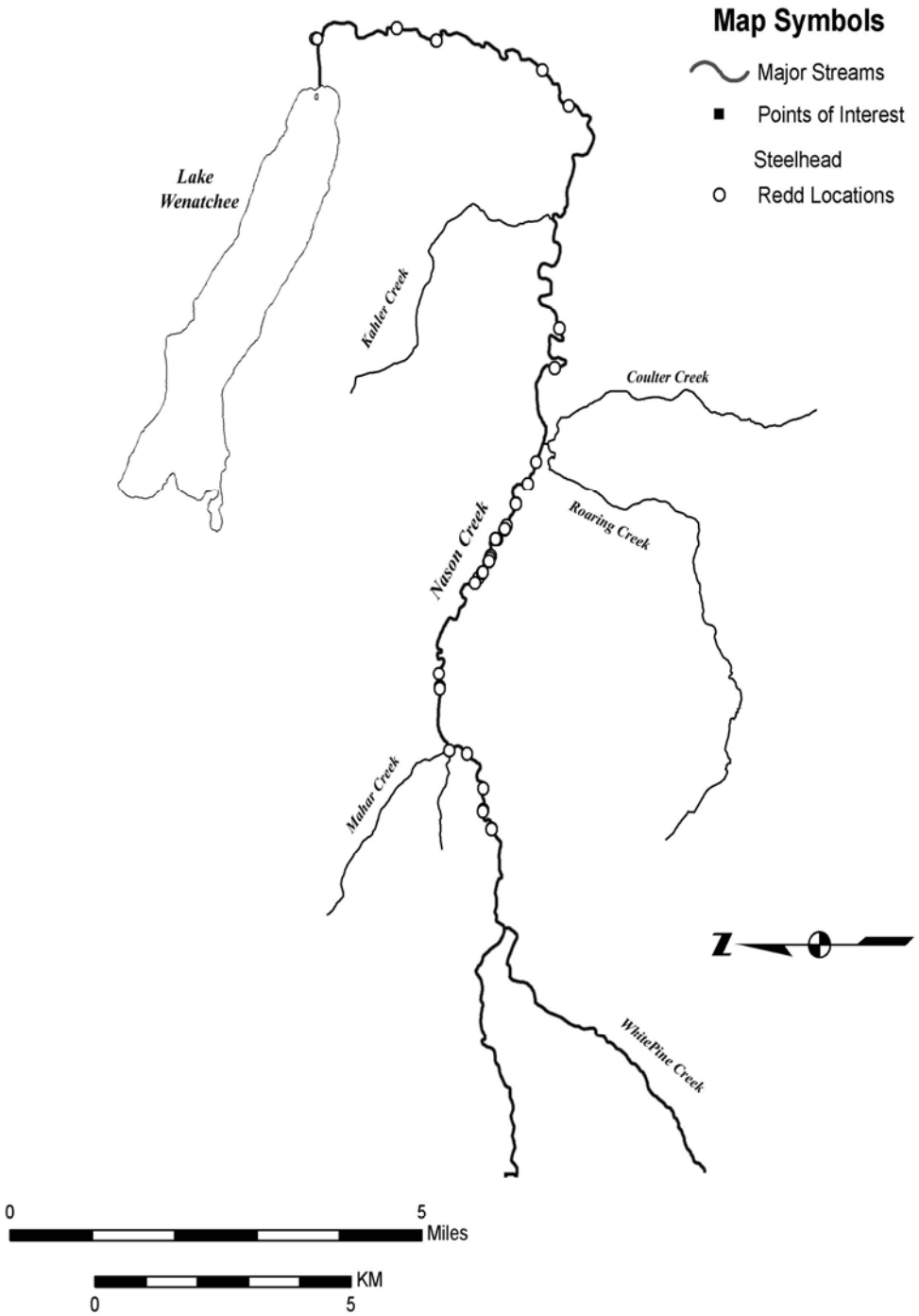
Appendix B. Continued.

| Reach | Survey Week of Index Area | | | | | | | | | | | | | | | Reach Total | Expanded #of redds |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 4 Mar | 11 Mar | 18 Mar | 25 Mar | 1 Apr | 8 Apr | 15 Apr | 22 Apr | 29 Apr | 6 May | 13 May | 20 May | 27 May | 3 June | 10 June | | |
| *Clear Creek* | | | | | | | | | | | | | | | | | |
| V1 | 0 | | 0 | | 0 | 0 | 0 | 0 | 0 | 8 | | 0 | | | 0 | 8 | 8 |
| V2 | | | | | | | | | | 0 | | 0 | | | 0 | 0 | 0 |
| Total | 0 | | 0 | | 0 | 0 | 0 | 0 | 0 | 8 | | 0 | | | 0 | 8 | 8 |
| *Nason Creek* | | | | | | | | | | | | | | | | | |
| N1 | 0 | 0 | | | 0 | 0 | 7 | 1 | 0 | 2 | | 0 | | | 0 | 10 | 11 |
| N2 | | | | | | | | | | 10 | | | | | | 10 | 25 |
| N3 | 0 | 0 | | | 0 | 1 | 4 | 4 | 5 | 8 | | 2 | | | 0 | 24 | 35 |
| N4 | 0 | 0 | | | 0 | 2 | 1 | 1 | 0 | 1 | | 0 | | | 0 | 5 | 7 |
| Total | 0 | 0 | | | 0 | 3 | 12 | 6 | 5 | 21 | | 2 | | | 0 | 49 | 78 |
| *Icicle River* | | | | | | | | | | | | | | | | | |
| Total | | | 0 | 0 | 0 | | 4 | 1 | 1 | | | | | | | 6 | 6 |
| *White River* | | | | | | | | | | | | | | | | | |
| H2 | | | | | 0 | | 0 | 0 | 0 | | | | | | | 0 | 0 |
| H3 | | | | | 0 | | 0 | 1 | 0 | | | | | | | 1 | 1 |
| Total | | | | | 0 | | 0 | 1 | 0 | | | | | | | 1 | 1 |
| *Little Wenatchee River* | | | | | | | | | | | | | | | | | |
| L2 | | | | | | | | | | | | | | | 0 | 0 | 0 |
| L3 | | | | | | | | 0 | | | | | | | 0 | 0 | 0 |
| Total | | | | | | | | 0 | | | | | | | 0 | 0 | 0 |
| *Wenatchee River Basin* | | | | | | | | | | | | | | | | | |
| Total | 0 | 0 | 0 | 0 | 0 | 8 | 34 | 25 | 19 | 29 | | 15 | | | 0 | 130 | 159 |

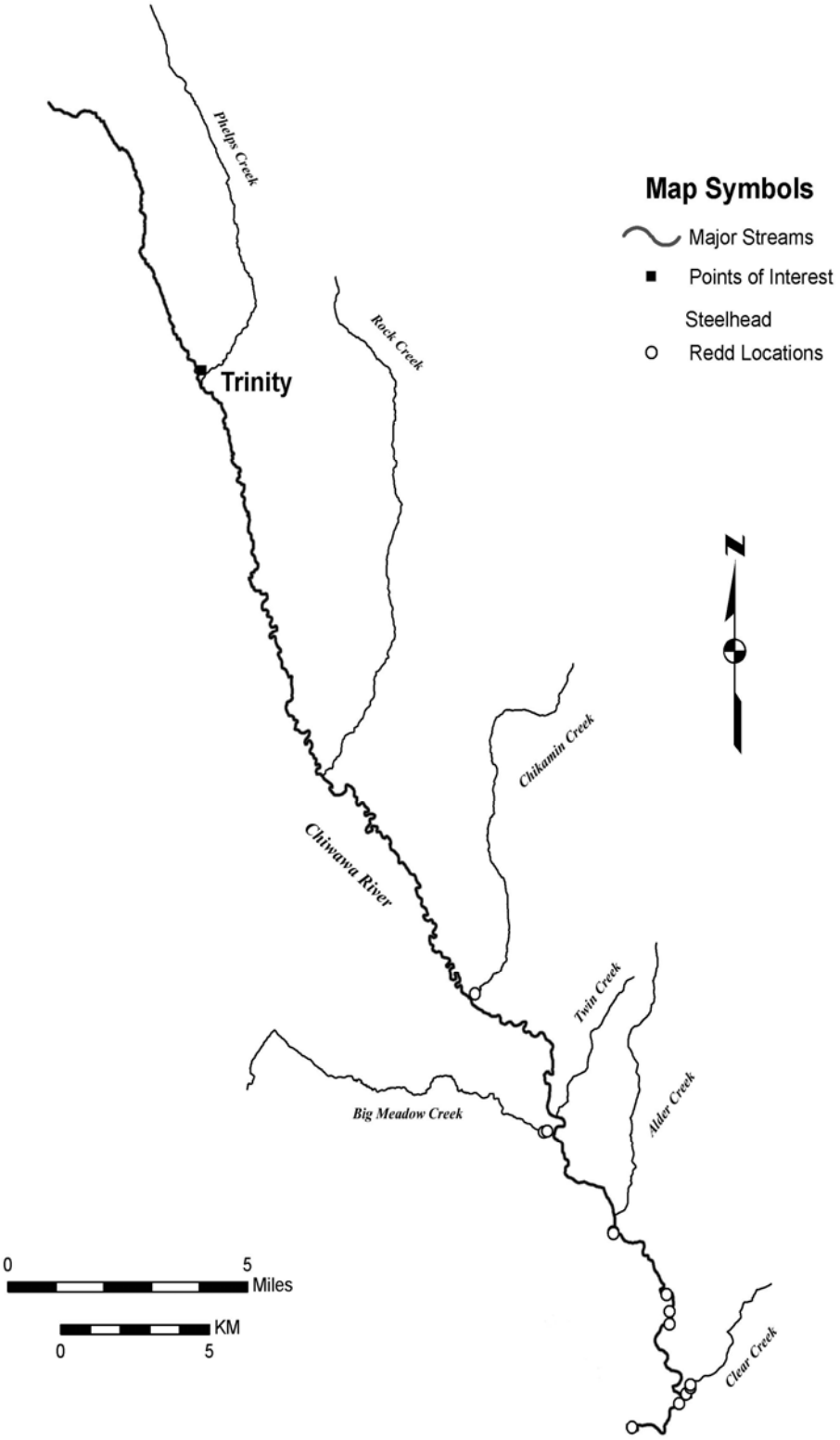
Appendix C. Steelhead spawning surveys in the Wenatchee River basin, 2001 – 2007. Redd counts are expanded values derived from sample rates within index areas.

| Basin/subbasin | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 |
|---|---|---|---|---|---|---|---|
| | | | *Chiwawa River Basin* | | | | |
| Chiwawa River | 25 | 27 | 26 | 17 | 118 | 8 | 3 |
| Rock Creek | -- | 1 | 0 | 0 | 0 | 0 | -- |
| Chikamin creek | -- | 0 | 0 | 1 | 2 | 1 | 0 |
| Meadow Creek | -- | 5 | 1 | 5 | 16 | 3 | 0 |
| Twin Creek | -- | 4 | 0 | -- | 0 | -- | -- |
| Goose Creek | -- | 0 | -- | -- | -- | -- | -- |
| Alder Creek | -- | 0 | 5 | 2 | 14 | 0 | 0 |
| Deep Creek | -- | 0 | -- | -- | -- | -- | -- |
| Clear Creek | -- | 43 | 32 | 37 | 12 | 7 | 8 |
| Subtotal | 25 | 80 | 64 | 62 | 162 | 19 | 11 |
| | | | *Nason Creek Basin* | | | | |
| Nason Creek | 27 | 80 | 121 | 124 | 410 | 74 | 78 |
| White Pine Creek | -- | -- | -- | 0 | 0 | 0 | 0 |
| Un-named Creek | -- | -- | -- | 3 | 0 | 3 | 0 |
| Roaring Creek | -- | -- | -- | -- | 2 | 0 | 0 |
| Subtotal | 27 | 80 | 121 | 127 | 412 | 77 | 78 |
| | | | *White River Basin* | | | | |
| White River | -- | 0 | 1 | 0 | 2 | 0 | 1 |
| Panther Creek | -- | -- | 0 | 0 | 0 | 0 | 0 |
| Napeequa River | -- | 0 | 2 | 0 | 0 | 0 | 0 |
| Subtotal | | 0 | 3 | 0 | 2 | 0 | 1 |
| | | | *Little Wenatchee River* | | | | |
| Mainstem | -- | 1 | 5 | 0 | 0 | -- | 0 |
| | | | *Icicle Creek* | | | | |
| Mainstem | 19 | 27 | 16 | 23 | 8 | 41 | 6 |
| | | | *Peshastin Creek Basin* | | | | |
| Peshastin Creek | -- | -- | 15 | 32 | 91 | 67 | 17 |
| Mill Creek | -- | -- | -- | -- | 1 | 0 | 0 |
| Ingalls Creek | -- | -- | 0 | 0 | 0 | 0 | -- |
| Ruby Creek | -- | -- | 0 | 0 | 0 | -- | -- |
| Tronsen Creek | -- | -- | 0 | 2 | 5 | 0 | 0 |
| Scotty Creek | -- | -- | 0 | 0 | 0 | 0 | 0 |
| Shaser Creek | -- | -- | 0 | 0 | 0 | 0 | 0 |
| Schafer Creek | -- | -- | -- | 0 | 0 | 0 | 0 |
| Subtotal | -- | -- | 15 | 34 | 97 | 67 | 17 |
| | | | *Wenatchee River* | | | | |
| Mainstem | 116 | 315 | 248 | 136 | 456 | 191 | 46 |
| Beaver Creek | -- | 0 | 0 | * 15 | 3 | 0 | 0 |
| Chiwaukum Creek | -- | -- | 0 | -- | 0 | 0 | -- |
| Subtotal | 116 | 315 | 248 | 151 | 459 | 191 | 46 |
| **Wenatchee Basin Total** | **187** | **503** | **472** | **397** | **1,140** | **395** | **159** |

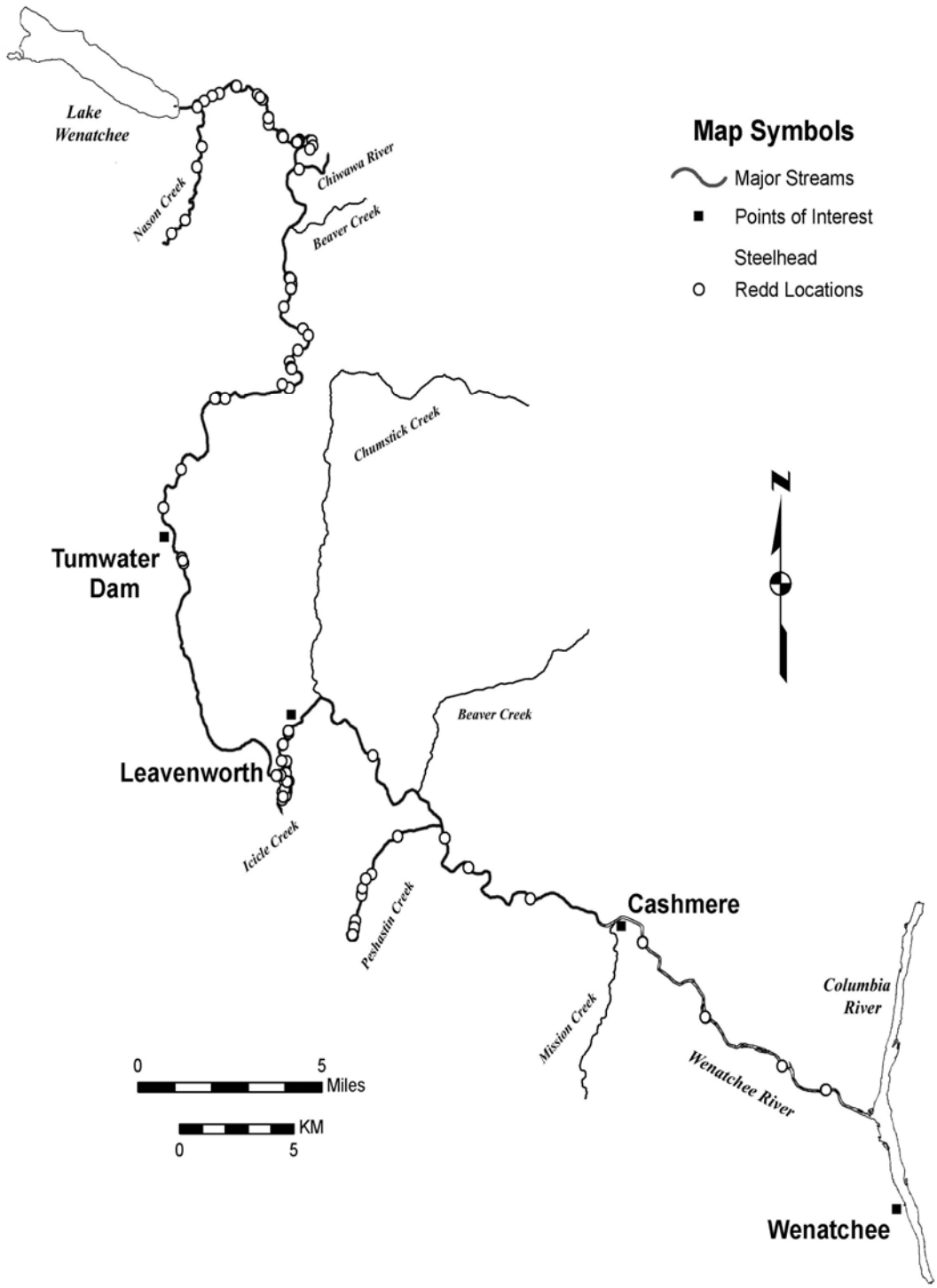
*Redds were enumerated by USFS



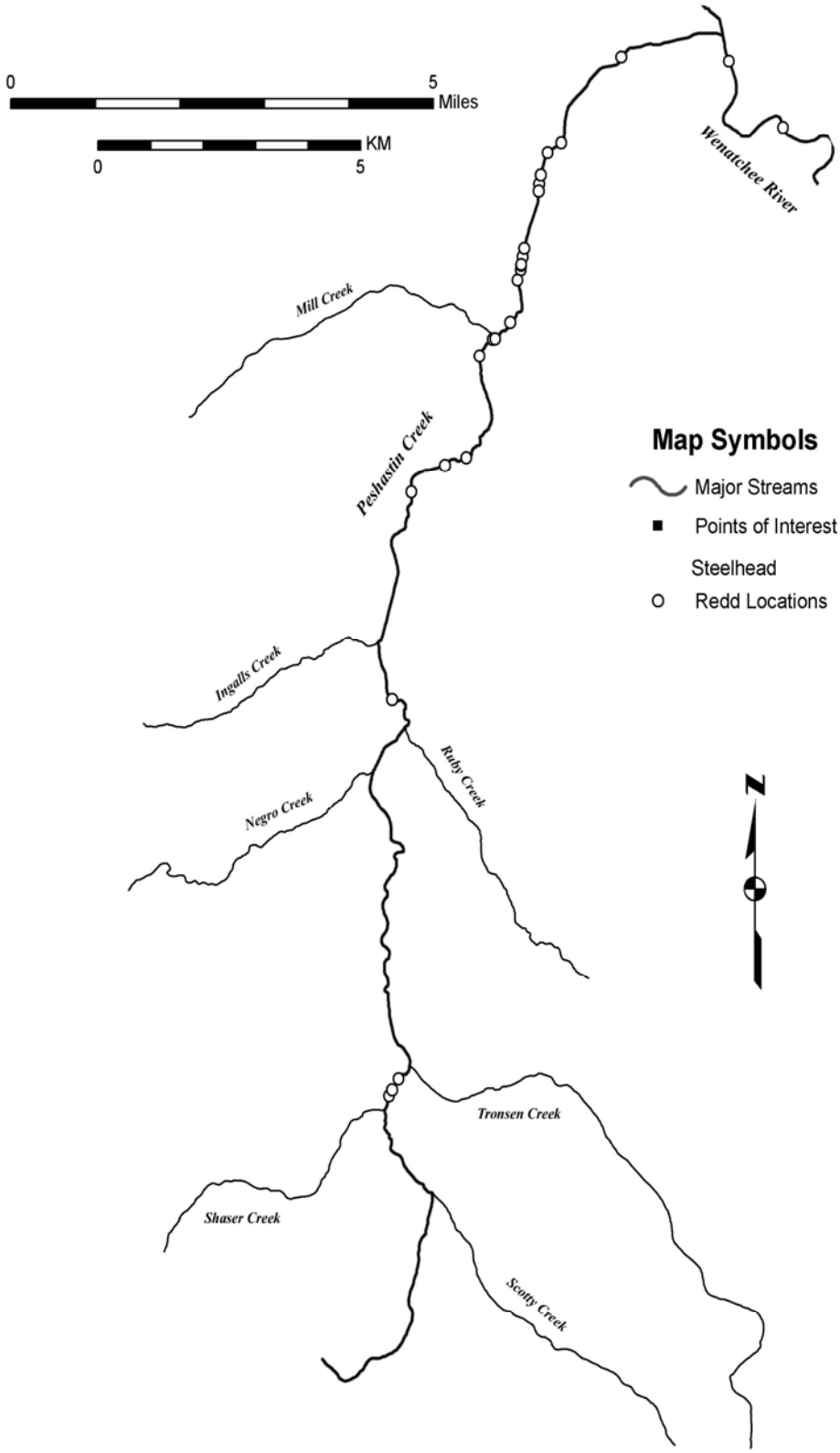

Appendix D1. Steelhead spawning distribution in the Nason Creek Basin in 2007.




Appendix D2. Steelhead spawning distribution in the Chiwawa River Basin in 2007.




Appendix D3. Steelhead spawning distribution in the Wenatchee River in 2007.




Appendix D4. Steelhead spawning distribution in the Peshastin Creek Basin in 2007.

# APPENDIX E

## NPDES Hatchery Effluent Monitoring, 2007

**National Pollutant Discharge Elimination System (NPDES) Effluent Summary**
for the period of January 1, 2007 through December 31, 2007
as reported on the Discharge Monitoring Reports (DMRs)
submitted to the Washington State Department of Ecology

**Eastbank Hatchery**
**NPDES Permit Number WAG13-5011**

| YEAR | MONTH | FLOW | SS EFF | TSS COMP | TSS MAX | FLOW PA | SS PA | SS % | TSS PA | TSS % | Lbs of Fish | Lbs of Feed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | JAN | 30.4 | 0 | 0.2 | 0.2 | 15000 | 0.1 | | 6.8 | | 77439 | 10969 |
| | FEB | 30.4 | 0 | 0.9 | 1.2 | 15000 | 0.1 | | 28 | | 78836 | 17615 |
| | MAR | 30.4 | 0 | 0 | 0 | 12000 | 0.1 | | 26.3 | | 65978 | 18649 |
| | APR | 22.62 | 0 | 0.2 | 0.2 | 15000 | 0.1 | | 16.2 | | 7835 | 3066 |
| | MAY | 22.62 | | | | 3500 | 0.1 | | 16.6 | | 13018 | 3755 |
| | JUN | 26.18 | | | | 7000 | 0.1 | | 19.7 | | 10633 | 3851 |
| | JUL | 30.4 | 0 | 0.4 | 0.4 | 15000 | 0.1 | | 10.8 | | 17355 | 4684 |
| | AUG | 30.4 | 0 | 0 | 0 | 3500 | 0.1 | | 10.4 | | 28058 | 14396 |
| | SEP | 31.7 | 0 | 0.2 | 0.2 | 7000 | 0.1 | | 20.8 | | 43604 | 15144 |
| | OCT | 30.4 | 0 | 0 | 0 | 15000 | 0 | | 11 | | 17341 | 10742 |
| | NOV | 30.4 | 0 | 1 | 1 | 3500 | 0 | | 15 | | 19000 | 14920 |
| | DEC | 31.7 | 0 | 0.4 | 0.4 | 7000 | 0.1 | | 13 | | 25817 | 64036 |

**Turtle Rock**
**NPDES Permit Number WAG13-5004**

| YEAR | MONTH | FLOW | SS EFF | TSS COMP | TSS MAX | Lbs of Fish | Lbs of Feed | SS DD | TSS DD |
|---|---|---|---|---|---|---|---|---|---|
| 2007 | JAN | 14.4 | 0 | 0.6 | 0.6 | 21030 | 3564 | | |
| | FEB | 14.4 | 0 | 1 | 1 | 33457 | 3840 | | |
| | MAR | 14.4 | 0 | -0.3 | -0.2 | 42021 | 4117 | | |
| | APR | 14.4 | 0 | 0.2 | 0.2 | 54715 | 8976 | | |
| | MAY | 14.4 | 0 | 1.8 | 1.8 | 7428 | 1732 | 0.1 | 2.75 |
| | JUN | 14.4 | 0 | 1.4 | 1.4 | 18409 | 10736 | | |
| | JUL | 0 | 0 | 1.2 | 1.2 | 26473 | 0 | 0.05 | 0.9 |
| | AUG | No Monitoring | | | | 0 | 0 | | |
| | SEP | | | | | 1949 | 660 | | |
| | OCT | | | | | 4380 | 1804 | | |
| | NOV | 3.6 | 0 | -0.2 | -0.2 | 6570 | 2024 | | |
| | DEC | 7.2 | 0 | 0.2 | 0.6 | 19200 | 3784 | | |

**Wells Hatchery**
**NPDES Permit Number WAG13-5009**

| YEAR | MONTH | FLOW | SS EFF | TSS COMP | TSS MAX | FLOW PA | SS PA | SS % | TSS PA | TSS % | Lbs of Fish | Lbs of Feed | SS DD | TSS DD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | JAN | 19.5 | 0 | 1.6 | 1.6 | 895 | 0 | | 0.6 | | 47000 | 11345 | | |
| | FEB | 20.7 | 0 | 0.4 | 0.4 | 895 | 0 | | 0.6 | | 48000 | 11038 | | |
| | MAR | 23.4 | 0 | -0.4 | -0.2 | 895 | 0 | | 1.6 | | 55000 | 12550 | | |
| | APR | 23.8 | 0 | -0.2 | -0.2 | 895 | 0 | | 3 | | 51824 | 18960 | | |
| | MAY | 23.4 | 0 | 0.4 | 0.4 | 880 | 0 | | 1 | | 52205 | 5144 | 0.25 | 6.55 |
| | JUN | 4 | 0 | 0.2 | 0.2 | 802 | 0 | | 1 | | 13888 | 4154 | | |
| | JUL | 7 | 0 | -0.4 | -0.4 | 895 | 0 | | 1.6 | | 11000 | 3255 | | |
| | AUG | 10 | 0 | 0.5 | 0.6 | 895 | 0 | | 0.8 | | 14054 | 4706 | | |
| | SEP | 10.7 | 0 | 1.2 | 1.2 | 895 | 0 | | 1.2 | | 16675 | 5193 | | |
| | OCT | 10.4 | 0 | 0 | 0 | 895 | 0 | | 24.2 | | 28563 | 6392 | | |
| | NOV | 10.4 | 0 | 0.4 | 0.4 | 895 | 0 | | 1 | | 31924 | 9060 | | |
| | DEC | 11.4 | 0 | 0 | 0 | 895 | 0 | | 1.4 | | 64246 | 11896 | | |

**Chiwawa Ponds**
**NPDES Permit Number WAG13-5015**

| YEAR | MONTH | FLOW | SS EFF | TSS COMP | TSS MAX | Lbs of Fish | Lbs of Feed | SS DD | TSS DD |
|---|---|---|---|---|---|---|---|---|---|
| 2007 | JAN | 9.07 | 0.03 | 0 | 0 | 21000 | 175 | | |
| | FEB | 9.07 | 0.03 | 0 | 0 | 20634 | 1650 | | |
| | MAR | 9.07 | 0.03 | 0 | 0 | 24470 | 4025 | | |
| | APR | 9.07 | 0.03 | 0.4 | 0.4 | 26000 | 4651 | | |
| | MAY | 4.5 | | | | 7300 | 0 | 0.04 | 49.5 |
| | JUN | No Monitoring | | | | 0 | 0 | | |
| | JUL | No Monitoring | | | | 0 | 0 | | |
| | AUG | No Monitoring | | | | 0 | 0 | | |
| | SEP | 9.07 | 0 | 0 | 0 | 24337 | 245 | | |
| | OCT | 8.87 | 0 | -0.2 | -0.2 | 25263 | 2815 | | |
| | NOV | 6.47 | 0 | 1.2 | 1.6 | 26744 | 1178 | | |
| | DEC | 4.54 | 0 | 0.4 | 0.4 | 26975 | 616 | | |

**Carlton Acclimation Pond**
**NPDES Permit Number WAG13-5013**

| YEAR | MONTH | FLOW | SS EFF | TSS COMP | TSS MAX | Lbs of Fish | Lbs of Feed | SS DD | TSS DD |
|---|---|---|---|---|---|---|---|---|---|
| 2007 | JAN | No Monitoring | | | | 0 | 0 | | |
| | FEB | No Monitoring | | | | 0 | 0 | | |
| | MAR | 10.08 | -0.4 | -1.8 | -1.8 | 21295 | 425 | | |
| | APR | 10.08 | -0.25 | -0.2 | 0.4 | 17500 | 1280 | | |
| | MAY | No Monitoring | | | | 0 | 0 | 0.5 | 46.6 |
| | JUN | No Monitoring | | | | 0 | 0 | | |
| | JUL | No Monitoring | | | | 0 | 0 | | |
| | AUG | No Monitoring | | | | 0 | 0 | | |
| | SEP | No Monitoring | | | | 0 | 0 | | |
| | OCT | No Monitoring | | | | 0 | 0 | | |
| | NOV | No Monitoring | | | | 0 | 0 | | |
| | DEC | No Monitoring | | | | 0 | 0 | | |

**Methow Hatchery**
**NPDES Permit Number WAG13-5000**

| YEAR | MONTH | FLOW | SS EFF | TSS COMP | TSS MAX | FLOW PA | SS PA | SS % | TSS PA | TSS % | Lbs of Fish | Lbs of Feed | SS DD | TSS DD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | JAN | 10.8 | -0.03 | -0.2 | -0.2 | 14400 | 0.07 | | 8 | | 23130 | 3700 | | |
| | FEB | 10.8 | -0.03 | 0 | 0 | 14400 | 0.1 | | 42.2 | | 25000 | 3700 | | |
| | MAR | 10.2 | 0 | -1.4 | -1.4 | 14400 | 0.07 | | 19.8 | | 12000 | 2320 | | |
| | APR | 5.47 | 0.05 | 0.2 | 0.2 | 14400 | 0.05 | | 0.6 | | 11479 | 2250 | | |
| | MAY | 5.47 | | | | 14400 | 0.05 | | 7.8 | | 2720 | 762 | 0.07 | 20 |
| | JUN | 5.47 | | | | 14400 | 0.05 | | 15.6 | | 4758 | 1465 | | |
| | JUL | 5.26 | | | | 14400 | 0.07 | | 1 | | 6261 | 2995 | | |
| | AUG | 5.47 | | | | 14400 | 0.05 | | 0.8 | | 8599 | 2665 | | |
| | SEP | 6.48 | | | | 14400 | 0.05 | | 3.8 | | 13137 | 2443 | | |
| | OCT | 6.48 | | | | 14400 | 0.5 | | 41.2 | | 16212 | 2585 | | |
| | NOV | 9.5 | 0.05 | -1.2 | -1 | 14400 | 0.5 | | 0.6 | | 18444 | 2412 | | |
| | DEC | 9.5 | 0.05 | -0.2 | -0.2 | 14400 | 0.5 | | 4.6 | | 20000 | 2310 | | |

**Similkameen Hatchery**
**NPDES Permit Number WAG13-5007**

| YEAR | MONTH | FLOW | SS EFF | TSS COMP | TSS MAX | FLOW PA | SS IW* | TSS IW* | Lbs of Fish | Lbs of Feed | SS DD | TSS DD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | JAN | 6.5 | 0 | 1.2 | 1.2 | 14895 | 0.2 | 229.2 | 12244 | 0 | | |
| | FEB | 6.5 | 0 | 2.8 | 2.8 | 9360 | 0.1 | 66 | 12634 | 352 | | |
| | MAR | 6.5 | 0 | -0.6 | -0.6 | 45491 | 0.5 | 683.2 | 13743 | 1320 | | |
| | APR | 6.5 | 0 | -0.4 | -0.4 | 43050 | 7.5 | 303.4 | 14970 | 4160 | | |
| | MAY | 6.5 | | | | | | | 15078 | 0 | 0.1 | 40 |
| | JUN | No Monitoring | | | | | | | 0 | 0 | | |
| | JUL | No Monitoring | | | | | | | 0 | 0 | | |
| | AUG | No Monitoring | | | | | | | 0 | 0 | | |
| | SEP | No Monitoring | | | | | | | 0 | 0 | | |
| | OCT | 9.77 | 0 | -0.6 | -0.6 | 18519 | | 576 | 16310 | 1936 | | |
| | NOV | 5.9 | 0 | 0.4 | 0.6 | 16640 | | 59.6 | 19740 | 1056 | | |
| | DEC | 5.9 | 0 | 1.2 | 1.2 | | | 30.4 | 18750 | 0 | | |

* IW- influent waste

**Chelan Hatchery**
**NPDES Permit Number WAG13-5006**

| YEAR | MONTH | FLOW | SS EFF | TSS COMP | TSS MAX | FLOW PA | SS PA | SS % | TSS PA | TSS % | Lbs of Fish | Lbs of Feed |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | JAN | 8.86 | 0.04 | 2.2 | 2.2 | 132173 | 0.05 | | 4.4 | | 28680 | 11708 |
| | FEB | 8.76 | 0.04 | -0.4 | -0.4 | 110775 | 0.05 | | 12.6 | | 41573 | 9828 |
| | MAR | 9.01 | 0.05 | 0 | 0 | 113030 | 0.05 | | 6.8 | | 49687 | 14425 |
| | APR | 8.86 | 0.04 | 1.4 | 1.4 | 132173 | 0.22 | | 9.2 | | 18485 | 14249 |
| | MAY | 8.76 | 0.04 | 0.3 | 0.4 | 110775 | 0.05 | | 9.8 | | 4390 | 4001 |
| | JUN | 9.01 | 0.05 | 0.2 | 0.2 | 113030 | 0.05 | | 9.8 | | 6560 | 2271 |
| | JUL | 9.02 | 0.05 | 1 | 1 | 145161 | 0.05 | | 0.1 | | 10452 | 4955 |
| | AUG | 9.72 | 0.05 | 1.6 | 1.6 | 155566 | 0.05 | | 1.2 | | 21185 | 11045 |
| | SEP | 9.16 | 0.05 | 1.2 | 1.2 | 146673 | 0.05 | | 1.4 | | 20731 | 9212 |
| | OCT | 8.38 | ** | -4.4 | 1.8 | 131112 | ** | | 16.8 | | 17187 | 8830 |
| | NOV | 8.43 | ** | 2.4 | 2.4 | 135666 | ** | | 2.2 | | 22500 | 10047 |
| | DEC | 8.74 | ** | 2.4 | 2.4 | 140714 | ** | | 9.4 | | 20000 | 7668 |

**Samples not taken by hatchery employee.

**Dryden Acclimation Pond**
**NPDES Permit Number WAG13-5014**

| YEAR | MONTH | FLOW | SS EFF | TSS COMP | TSS MAX | Lbs of Fish | Lbs of Feed | SS DD | TSS DD |
|---|---|---|---|---|---|---|---|---|---|
| 2007 | JAN | No Monitoring | | | | 0 | 0 | | |
| | FEB | No Monitoring | | | | 0 | 0 | | |
| | MAR | 20.8 | -0.02 | -0.2 | -0.2 | 49866 | 1804 | | |
| | APR | 20.8 | -0.008 | 0.6 | 0.6 | 55094 | 7920 | 0.03 | 4.6 |
| | MAY | No Monitoring | | | | 0 | 0 | | |
| | JUN | No Monitoring | | | | 0 | 0 | | |
| | JUL | No Monitoring | | | | 0 | 0 | | |
| | AUG | No Monitoring | | | | 0 | 0 | | |
| | SEP | No Monitoring | | | | 0 | 0 | | |
| | OCT | No Monitoring | | | | 0 | 0 | | |
| | NOV | No Monitoring | | | | 0 | 0 | | |
| | DEC | No Monitoring | | | | 0 | 0 | | |

**National Pollutant Discharge Elimination System (NPDES) Effluent Summary**
for the period of January 1, 2006 through December 31, 2007
as reported on the Discharge Monitoring Reports (DMRs)
submitted to the Washington State Department of Ecology

**Priest Rapids**
**NPDES Permit Number WAG13-7013**

| YEAR | MONTH | FLOW | SS EFF | TSS COMP | TSS MAX | Lbs of Fish | Lbs of Feed | SS DD | TSS DD |
|---|---|---|---|---|---|---|---|---|---|
| 2006 | JAN | 11.9 | 0 | | | 0 | 0 | | |
| | FEB | 11.2 | 0 | 0.8 | 0.8 | 7437 | 1671 | | |
| | MAR | 30.3 | 0 | -0.4 | -0.4 | 25344 | 13197 | | |
| | APR | 33.5 | 0 | -0.8 | -0.8 | 53999 | 25737 | | |
| | MAY | 45 | 0 | 0.6 | 0.6 | 118648 | 55000 | | |
| | JUN | 48.2 | 0 | 1 | 1 | 144666 | 32725 | 0 | 4.2 |
| | JUL | 7.95 | 0 | | | 12 | 7 | | |
| | AUG | 1.3 | | | | 13 | 8 | | |
| | SEP | 65 | 0 | 0 | 0 | 12800 | 0 | | |
| | OCT | 65.5 | 0 | 0.8 | 0.8 | 37290 | 0 | | |
| | NOV | 67.5 | 0 | -0.5 | -0.4 | 2860 | 0 | | |
| | DEC | 61.1 | 0 | | | 0 | 0 | | |
| | | | | | | | | | |
| 2007 | JAN | 61.4 | 0 | | | 0 | 0 | | |
| | FEB | 62.8 | 0 | 0.6 | 0.6 | 9128 | 1273 | | |
| | MAR | 68.6 | 0 | 0.2 | 0.2 | 26114 | 8470 | | |
| | APR | 68.1 | 0 | -0.2 | 0.2 | 66212 | 20936 | | |
| | MAY | 67.7 | 0 | 0 | 0 | 127589 | 43802 | | |
| | JUN | 68.3 | 0 | 0.2 | 0.2 | 137533 | 12188 | 0 | 3.4 |
| | JUL | 1.2 | 0 | | | 0 | 0 | | |
| | AUG | 1.2 | 0 | | | 0 | 0 | | |
| | SEP | 59.5 | 0 | 3.1 | 3.4 | 1280 | 0 | | |
| | OCT | 63.1 | 0 | 3.2 | 3.2 | 8755 | 0 | | |
| | NOV | 67.7 | 0 | -0.8 | -0.8 | 2320 | 0 | | |
| | DEC | 64.3 | 0 | | | 0 | 0 | | |

# APPENDIX F

## Steelhead Stock Assessment at Priest Rapids Dam, 2007

**Priest Rapids Dam Upper Columbia River Steelhead Stock Assessment Sampling Report, 2006**

This report will be available in June 2008.

# APPENDIX G

## Wenatchee Sockeye and Summer Chinook Spawning Ground Surveys, 2007

# PUBLIC UTILITY DISTRICT NUMBER 1 OF CHELAN COUNTY

**Fish and Wildlife Department**

*327 N. Wenatchee Ave., Wenatchee WA 98801 (509) 663-8121*


**January, 2008**

To: HCP Hatchery Committee

From: Chuck Peven

**Subject: 2007 Wenatchee River Basin Summer Chinook and Sockeye Salmon Spawning Ground Surveys**

## Introduction

The Chelan County Public Utility District (District) has conducted or funded others to conduct intensive spawning ground surveys of spring and summer/fall (late run)[1] Chinook salmon *Oncorhyncus tshawytscha* and sockeye salmon (*O. nerka*) in river basins of the Columbia River upstream of Rock Island Dam. Summer/fall Chinook spawn in the entire mainstem of the Wenatchee River, from the mouth to the lake (Figure 1; Table 1). Sockeye spawn in the White and Little Wenatchee River basins (Figure 2).

The spawning surveys are performed yearly to assist in evaluating the effectiveness of the District's hatchery program. The purpose of this document is to report the results of the 2007 Chinook and sockeye salmon spawning ground surveys in the Wenatchee River basin. Information included in this document describes abundance, distribution, and timing of spawning activity.

### Study Area

The Wenatchee River originates from Lake Wenatchee and flows 54 miles south/southeast to its confluence with the Columbia River near the city of Wenatchee (Figures 1 and 2). The river drains an area approximately 1,301 square miles (United States Geological Survey (USGS) 2006). From its origin at the lake to river mile (RM) 22, it passes through heavily forested mountains. Below RM 22, the river enters a broad valley predominantly planted with fruit orchards. The mean annual flow at Monitor gage station is 3,255 $ft^3/s$ (1963-2004; USGS 2006), with a mean gradient ranging from 0.21-1.3% (Peven 1990). Primary tributaries of the Wenatchee River include the Little Wenatchee and White rivers, which flow into Lake Wenatchee, and Nason Creek, Chiwawa River, Icicle and Peshastin creeks (Figures 1 and 2).

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[1] The majority of chinook that ascend the mid-Columbia River as adults after July spawn between October and November in the mainstem of the Columbia, Wenatchee, Methow, Similkameen and Okanogan rivers. These fish have been called "summer" and "fall" chinook based on their migration timing past the dams. Their life histories are identical (Mullan 1987), and should be termed "late-run" to separate them from earlier running "spring" chinook which have a different life history. For consistency with previous year's reports, only the earlier segment of the late-run (those that ascend Rock Island Dam between June 24 and September 1; "summers") will be focused on in this report.

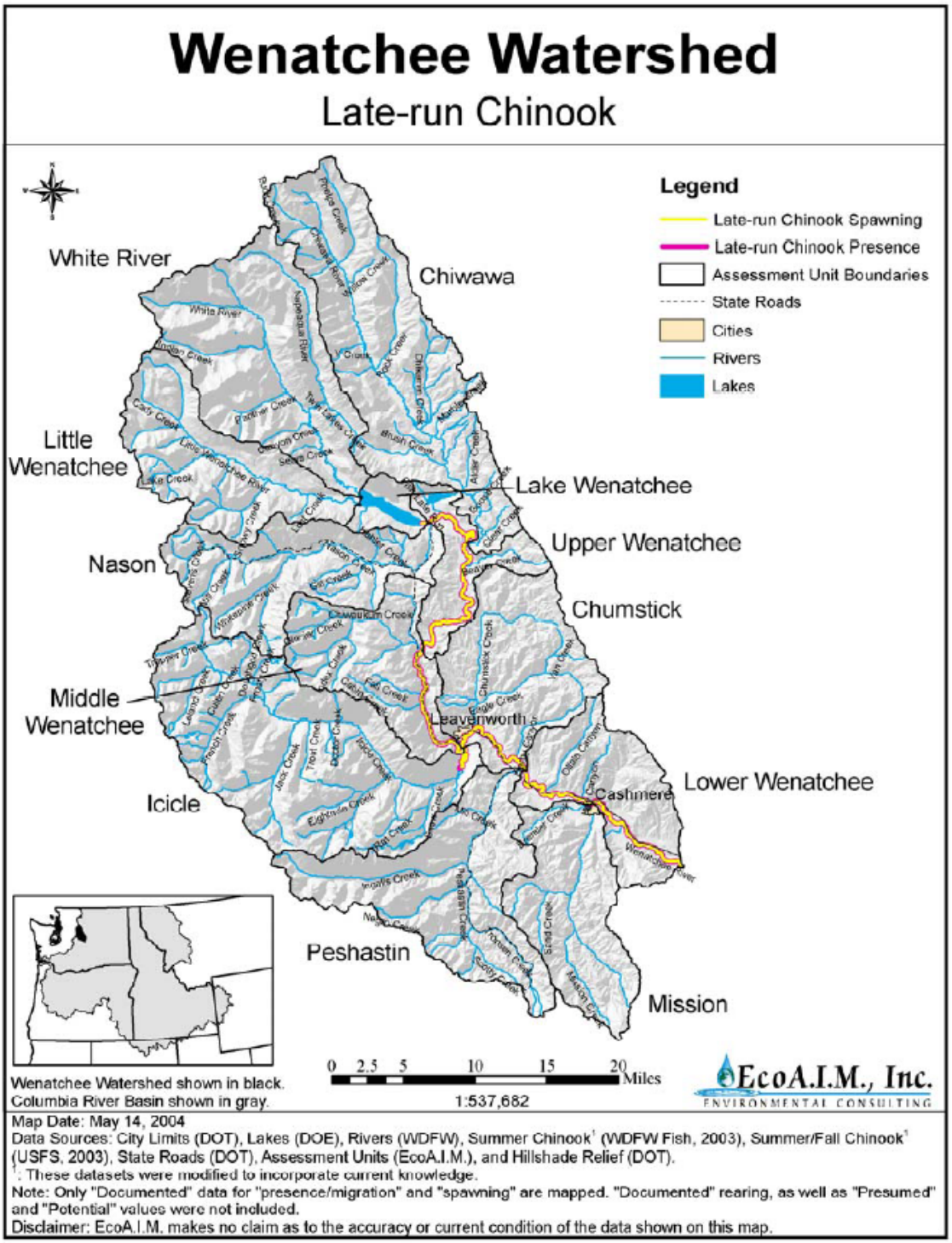


Figure 1. Map of the Wenatchee River Basin with spawning and migrational areas of late-run (summer/fall Chinook) areas highlighted (copied from the Wenatchee Subbasin Plan, NWPCC 2004).

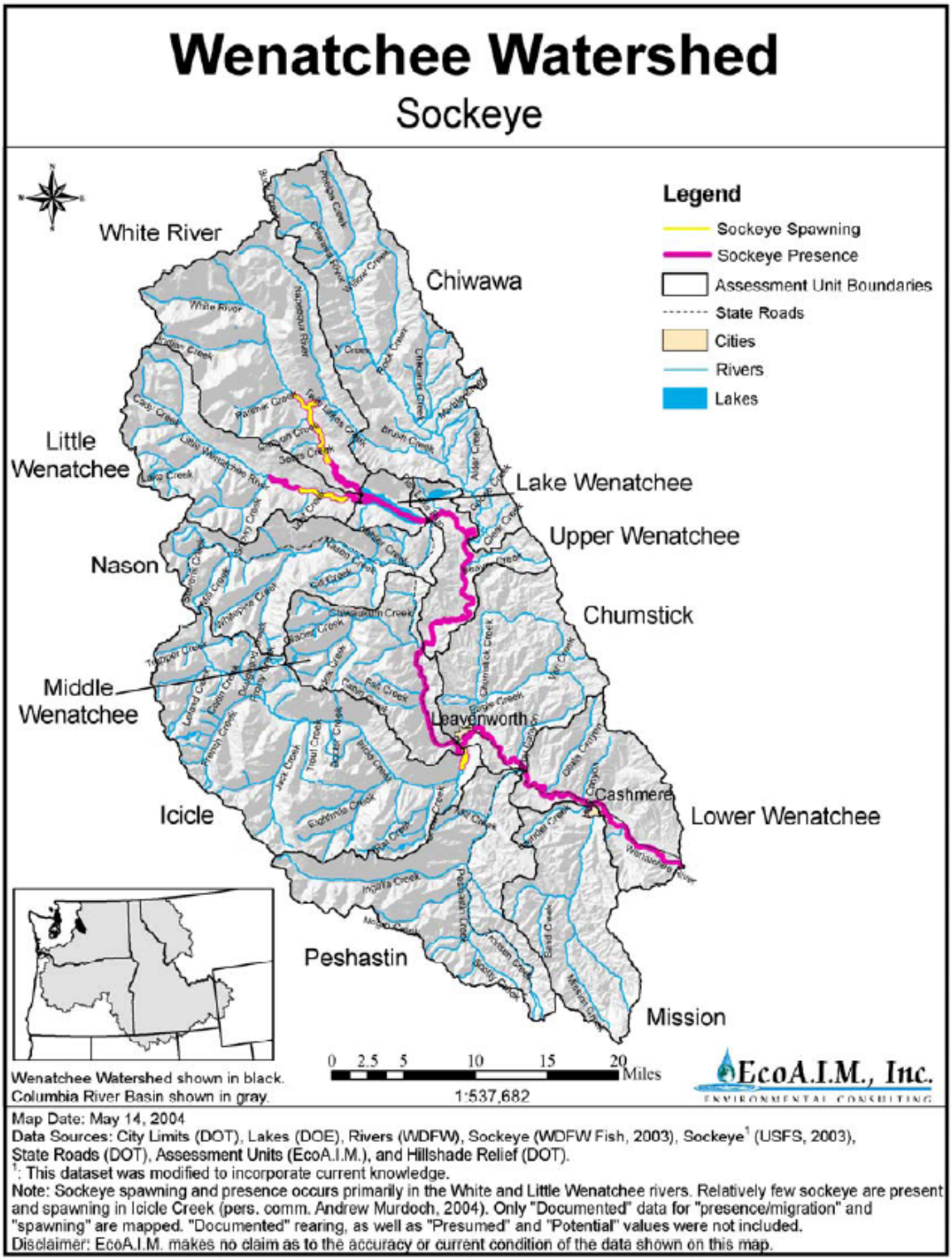


Figure 2. Map of the Wenatchee River Basin with spawning and migrational areas for sockeye highlighted (copied from the Wenatchee Subbasin Plan, NWPCC 2004).

# Methods

***Chinook Spawning Ground Surveys***

Chinook spawning ground surveys are conducted by foot, raft, or canoe. The most appropriate survey method is chosen for a given stream reach based on stream size, flow, and density of spawners. Because of the broad stream width and high spawner densities, individual summer Chinook redds are not flagged. Each reach is surveyed approximately once per week.

In 2007, summer Chinook spawning ground surveys occurred from October 2 to November 15.

***Table 1: Designated survey reaches for spawning ground areas on the Wenatchee, Little Wenatchee, White, and Nepeequa rivers for all species.***

| **Wenatchee River** | |
|---|---|
| **Survey Section** | **River Mile** |
| Mouth to Sleepy Hollow Bridge | 0 – 3.5 |
| Sleepy Hollow Bridge to Lower Cashmere Bridge | 3.5 – 9.5 |
| Lower Cashmere Bridge to Dryden Dam | 9.5 - 17.5 |
| Dryden Dam to Peshastin Bridge | 17.5 – 20.0 |
| Peshastin Bridge to Leavenworth Bridge | 20.0 – 23.9 |
| Leavenworth Bridge to Icicle Road Bridge | 23.9 – 26.4 |
| Icicle Road Bridge to Tumwater Dam | 26.4 – 30.9 |
| Tumwater Dam to Tumwater Bridge | 30.9 – 35.6 |
| Tumwater Bridge to Chiwawa River | 35.6 – 48.4 |
| Chiwawa River to Lake Wenatchee | 48.4 – 54.2 |
| **Little Wenatchee River** | |
| Mouth to Old Fish Weir | 0 – 2.7 |
| Old Fish Weir to Lost Creek | 2.7 – 5.2 |
| Lost Creek to Rainey Creek | 5.2 – 9.2 |
| Rainey Creek to End | 9.2 – End |
| **White River** | |
| Mouth to Sears Creek Bridge | 0 – 6.4 |
| Sears Creek Bridge to Napeequa River | 6.4 – 11.0 |
| Napeequa River to Grasshopper Meadows | 11.0 – 12.9 |
| Grasshopper Meadows to Falls | 12.9 – 14.3 |
| **Napeequa River** | |
| Mouth to End | 0 - End |

Peak and total redd count methodologies were used during the summer Chinook surveys in 2007 (see Appendix F of Murdoch and Peven (2005) for more detail). A peak count is conducted by counting all visible redds (new and old) observed within a reach on each survey. The objective of the peak redd count methodology is to capture the apex of spawning activity over an entire spawning season. This apex occurs at different times

between reaches during the season, i.e. spawning begins sooner in the upstream reaches compared to the downstream reaches. The sum of all of the apex counts for the entire river is the peak redd count for the year. Peak counts provide an index of spawning and have been used historically (Appendix 1).

Two different approaches were used to estimate the total number of redds within the Wenatchee River. The first method used map counts to expand peak counts. Under this approach, a total redd count is conducted by counting or mapping only new or recently constructed redds within an area. Each new redd is mapped on aerial photos and enumerated. The objective of the total redd count methodology is to capture 1) "early" redds that may fade over time due to siltation or algae growth, and 2) redds that become disfigured by superimposition (when new redds are constructed on top of previously existing redds).

Since it is not feasible to map all new redds within the entire river, an expansion is used to estimate total count for the entire Wenatchee River. To account for the different spawning substrate types in the main stem Wenatchee River, the river was delineated into six distinct reaches in consultation with WDFW (Table 2). Within each of these reaches, index areas have been identified as being representative areas of spawning activity. Peak counts are performed within each total reach (referred to as non-index areas), while mapping new redds only occurs within the index areas. An expansion is developed based on the ratio of mapped to peak counts for each reach (i.e., each reach has its own expansion factor), and the sum of the expanded counts is the estimate of the total redd counts. Additional details of how total redd counts are calculated is provided below.

a. Calculate an index peak expansion factor (*IP*) by dividing the peak number of redds in the index by the total number of redds (map count) in the index area.

$$IP = n_{peak} / n_{total}$$

b. Expand the non-index area peak redd counts by the *IP* to estimate the total number of redds in the entire reach (reach total; *RT*).

$$RT = n_{peak} / IP$$

c. Estimate the total number of redds (total redds; *TR*) by summing the reach totals.

$$TR = \sum RT$$

The second approach relied on a "naïve" count to expand redd numbers in reaches that did not have map counts. As noted above, the reaches with map counts are referred to as index reaches and those that were not mapped are called non-index reaches. Near the end

of the spawning period (early November), one team of observers counts all visible redds within all non-index reaches. A separate, independent team counts all visible redds within the index reaches (these are the naïve counts). Surveys within the index and non-index areas should occur within one day of each other near the end of the spawning period. The naïve counts are divided by the total map count to estimate an index expansion factor. This factor is then applied to the total visible count in the non-index areas to estimate the total number of redds within each reach. The sum of the expanded counts is the estimate of the total redd count for the river. Additional details of how total numbers of redds are estimated using this approach is provided below.

a. Calculate an index expansion factor (*IF*) by dividing the number of visible redds in the index by the total number of redds (map counts) in the index area.

$$IF = n_{visible} / n_{total}$$

b. Expand the non-index area redd counts by the proportion of visible redds in the index to estimate the total number of redds in the entire reach (reach total; *RT*).

$$RT = n_{non-index} / IF$$

c. Estimate the total number of redds (total redds; *TR*) by summing the reach totals.

$$TR = \sum RT$$

The total redd count methods are believed to provide a more accurate indication of total spawning than the peak redd count methodology, because the peak count methodology only accounts for visible redds each week during the survey season. For example, summer Chinook redds that were visible during the first week of spawning may not be visible during the third week; those redds would be missed in the third and subsequent weeks' redd counts. Using the total count methodology, the redds in the first week would be mapped and accounted for in subsequent weeks, even though they may fade at some point during the future surveys.

***Table 2: Index (Mapping) Areas on the Wenatchee River.***

| Wenatchee River | | |
|---|---|---|
| **River Reach** | **Check Points (sections)** | **Mapping Index Area** |
| 1 | Mouth to Sleepy Hollow Bridge | Monitor Bridge to Lower Cashmere Bridge |
| | Sleepy Hollow Bridge to Lower Cashmere Bridge | |
| | Lower Cashmere Bridge to Dryden Dam | |
| 2 | Dryden Dam to Peshastin Bridge | Dryden Dam to Peshastin Bridge |
| | Peshastin Bridge to Leavenworth Bridge | |
| 3 | Leavenworth Bridge to Icicle Road Bridge | Icicle Mouth to Takeout |
| 4 | Icicle Road Bridge to Tumwater Dam | Swiftwater Campground to Tumwater Bridge |
| | Tumwater Dam to Tumwater Bridge | |
| 5 | Tumwater Bridge to Chiwawa River | Swing Pool to Railroad Tunnel |
| 6 | Chiwawa River to Lake Wenatchee | Swamp to Bridge |

***Sockeye Spawning Ground Surveys***

In 2007, we employed one survey method; area-under-the-curve (AUC). Sockeye spawning ground surveys began August 30 and ended October 19. Spawning areas in the Little Wenatchee, White, and Napeequa rivers (Table 1) were surveyed at least once per week. Both the Little Wenatchee and White rivers have blocking falls, and spawning is only known to occur within the first few miles of the Napeequa River.

*Area-under-the-curve*

The AUC method is based on the number of live spawners counted. Using AUC, the number of fish observed in a survey is plotted against the day of the year and the number of fish-days is estimated using an algorithm. The number of fish spawning is then estimated by dividing the cumulative fish-days by the estimated mean number of days that the average spawner is alive in the survey area (survey- or stream-life). This is then multiplied by a correction factor for fish visibility (observer efficiency; Hillborn et al. 1999).

Hillborn et al. (1999) outlined what they termed as the most commonly used form of AUC, *trapezoidal approximation*:

$$\mathrm{AUC} = \sum_{i=2}^{n} (t_i - t_{i-1}) \frac{(x_i + x_{i-1})}{2}$$

where $t_i$ is the day of the year and $x_i$ is the number of salmon observed for the *i*th survey. Attempts are often made to initiate surveys prior to the presence of fish; however when

the first or last survey is not zero, then the above algorithm is not valid and Hillborn et al. (1999) recommend using the "rules" that the Alaska Department of Fish and Game use:

$$AUC_{first} = \frac{x_i s}{2}$$

where *s* is the survey life. Attempts should also be made until all salmon die, but when this is not possible, then the final survey should be calculated:

$$AUC_{last} = \frac{x_{last} s}{2}$$

Then total escapement (*E*) is estimated:

$$\hat{E} = \frac{AUC}{s} v$$

where v is a correction for observer efficiency. In 2008, the District will be estimating both observer efficiency and survey life. However, since survey life has not been empirically estimated for the Wenatchee system yet, we used 11 days based on the following:

Perrin and Irvine (1990) reviewed literature and conducted surveys to determine stream life for five species of Pacific salmon. For sockeye, the mean stream-life was 13.2 days (range: 7-26.5). Hyatt et al. (2006) used a stream-life of 11 days because of the Okanogan sockeye's similarity to Early Stuart sockeye.

# Results

***Summer Chinook***

Peak Counts (non-index areas)

A peak redd count of 1,857 summer Chinook redds was estimated in 2007 based on ground surveys along the Wenatchee River (Table 3). Spawning activity began the last week of September and peaked during the second week of October.

Density of redds was greatest near the confluence of the Icicle and Wenatchee rivers (W6). From the mouth of the Chiwawa River to Lake Wenatchee was the next highest area (W10; Figure 3).

Table 3. Summary of summer Chinook redd counts in the Wenatchee River, 2007.

| Survey Section | River Section | Peak Counts | Total Counts | |
|---|---|---|---|---|
| | | | IP | IF |
| Mouth to Sleepy Hollow Bridge | W-1 | 7 | 6 | 0 |
| Sleepy Hollow Bridge to Lower Cashmere Bridge | W-2 | 61 | 49 | 28 |
| Lower Cashmere Bridge to Dryden Dam | W-3 | 172 | 138 | 77 |
| Dryden Dam to Peshastin Bridge | W-4 | 34 | 39 | 39 |
| Peshastin Bridge to Leavenworth Bridge | W-5 | 45 | 52 | 78 |
| Leavenworth Bridge to Icicle Road Bridge | W-6 | 873 | 933 | 550 |
| Icicle Road Bridge to Tumwater Dam | W-7 | 107 | 144 | 102 |
| Tumwater Dam to Tumwater Bridge | W-8 | 61 | 82 | 64 |
| Tumwater Bridge to Chiwawa River | W-9 | 280 | 306 | 288 |
| Chiwawa River to Lake Wenatchee | W-10 | 217 | 208 | 176 |
| **Totals** | | **1,857** | **1,957** | **1,402** |

Total Counts

The total number of redds in the Wenatchee River varied depending on the expansion method used. Using the peak expansion method (*IP*), a total of 1,957 summer Chinook redds were estimated in 2007 (Table 3). Based on the naïve expansion factor (*IF*), a total of 1,402 summer Chinook redds were estimated in the Wenatchee River (Table 3). This later estimate is not very reliable because the naïve counts were not well coordinated with counts in the non-index areas. In some cases the counts in index and non-index areas were more than five days apart.

Historical Summer Chinook Spawning Ground Survey Data

The historical summer Chinook survey estimates (1996-2007) for the Wenatchee River basin are presented in Appendix A. The estimated summer Chinook redd count for the 2007 season was the lowest count since the mid 1990s (Figure 4).

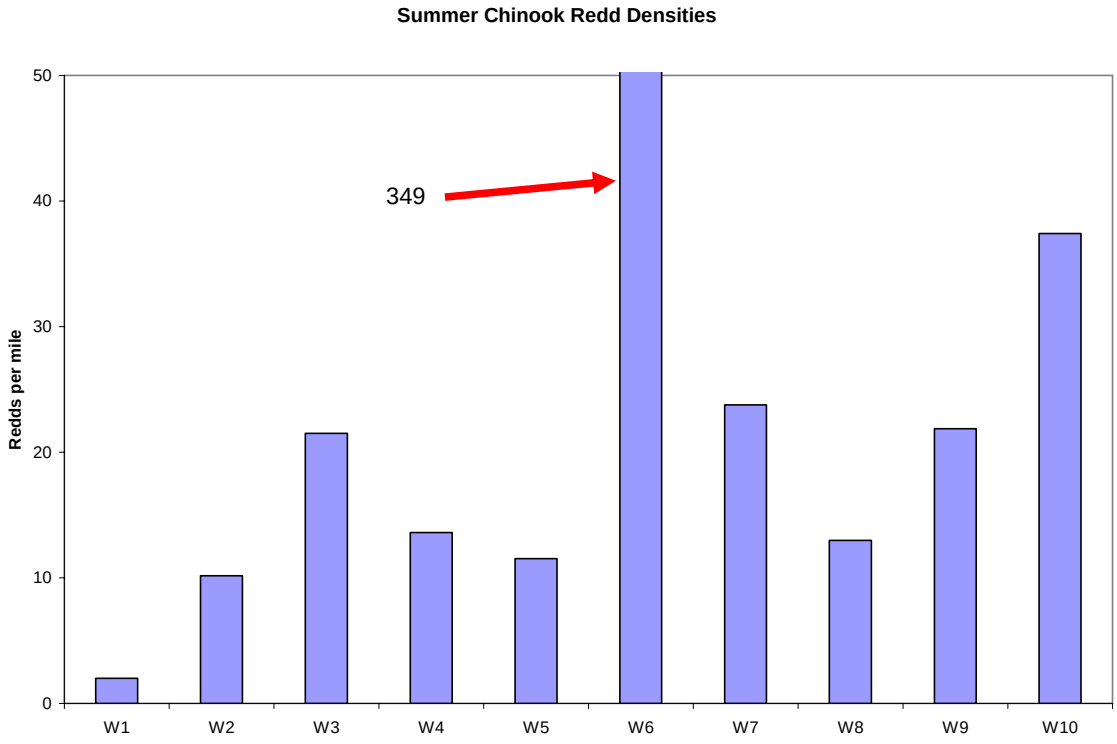


Figure 3. The density of summer Chinook redds in the Wenatchee River, 2007.

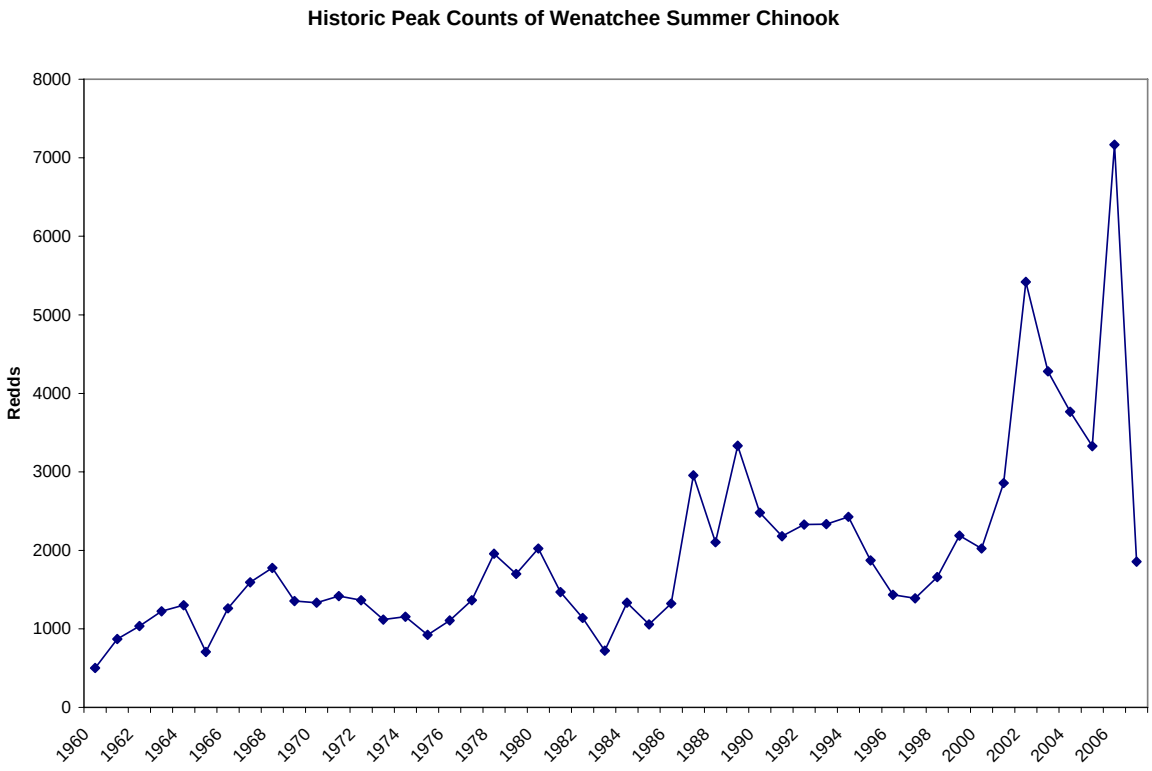


Figure 4. Historic summer/fall Chinook redd counts in the Wenatchee River Basin (see Appendix A for more information).

## *Sockeye*

Live fish counts

Fish counts were conducted for sockeye from August 28 through October 19. Peak spawning occurred in the White River basin (1,183) and Little Wenatchee (102) during the third-fourth week of September (Figure 5; Table 4).

Escapement

The estimated escapement of sockeye in 2007 was 1,870, (Table 5).

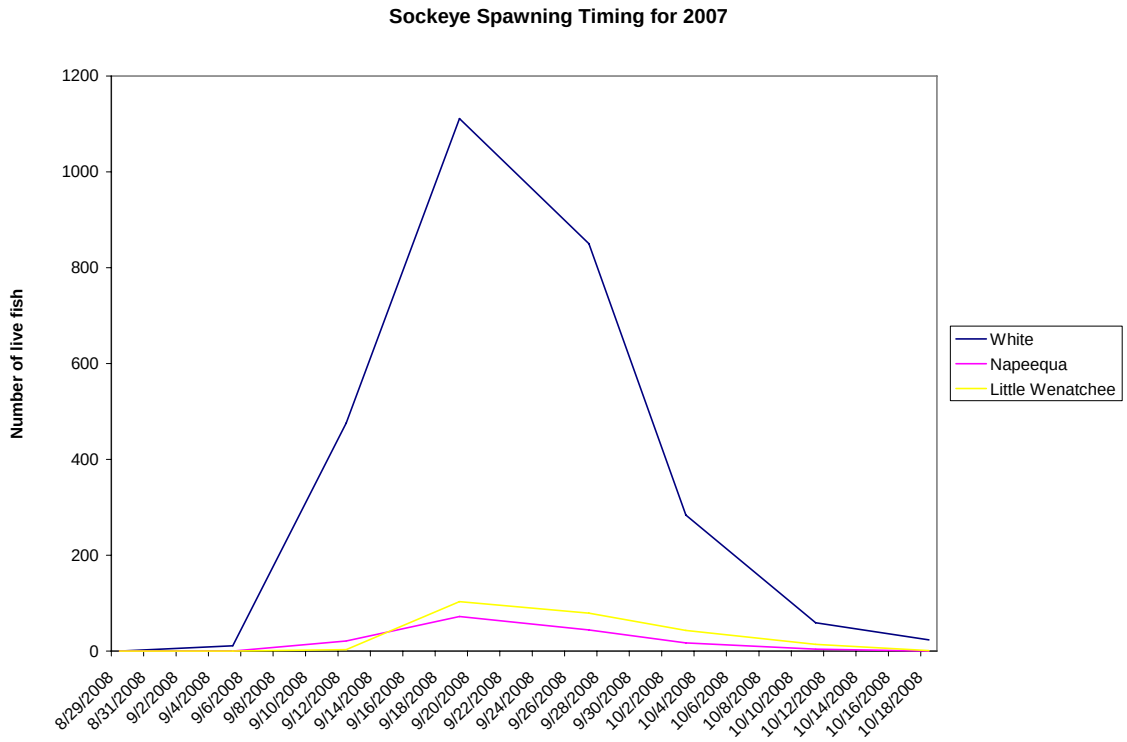


Figure 4. Approximate live counts and survey dates for sockeye salmon in the Wenatchee River Basin, 2007.

Table 5**.** Number of live fish and total spawning escapement estimates for sockeye salmon in the Wenatchee Basin, August through October, 2007.

| Sampling area | Peak number of live fish | Escapement |
|---|---|---|
| Little Wenatchee | 102 | 150 |
| White R Basin | 1,183 | 1,720 |
| **Total** | **1,285** | **1,870** |

## Summary

District crews conducted extensive redd counts in the Wenatchee River basin in 2007 for summer Chinook and sockeye salmon. These surveys were conducted from late August to mid-November.

District crews counted 1,857 summer/fall Chinook redds (peak counts), and 1,402-1,957 (total counts) in 2007. Discrepancies between naïve and other survey methodologies may cause the total count estimate to be suspect. This discrepancy will be corrected prior to the 2008 survey season.

Between late August and mid-October, 1,285 live sockeye were counted, and escapement was estimated at 1,870 using the AUC method.

**Recommendations**

For estimating total summer/fall Chinook redd counts, all 10 mainstem Wenatchee River reaches should have index areas that are mapped so that expansions can be reach-specific. Protocols between those doing the naïve surveys and other summer Chinook surveys need to be better coordinated.

Perform studies to investigate whether observer efficiency and spawner residency time can be estimated.

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# Appendix A.

Historic peak redd counts in the Wenatchee River for summer/fall Chinook salmon. Prior to 1995, all counts based on highest count of multiple agencies surveys, which were usually aerial counts from fixed-wing aircraft. Since 1995, counts are ground counts based on Chelan PUD surveys.

| Year | Highest Count | Year | Highest Count | Year | Highest Count |
|---|---|---|---|---|---|
| 1960 | 502 | 1970 | 1333 | 1980 | 2024 |
| 1961 | 872 | 1971 | 1419 | 1981 | 1469 |
| 1962 | 1035 | 1972 | 1364 | 1982 | 1140 |
| 1963 | 1223 | 1973 | 1119 | 1983 | 723 |
| 1964 | 1300 | 1974 | 1155 | 1984 | 1332 |
| 1965 | 706 | 1975 | 925 | 1985 | 1058 |
| 1966 | 1260 | 1976 | 1106 | 1986 | 1322 |
| 1967 | 1593 | 1977 | 1365 | 1987 | 2955 |
| 1968 | 1776 | 1978 | 1956 | 1988 | 2102 |
| 1969 | 1354 | 1979 | 1698 | 1989 | 3331 |
| 1990 | 2479 | 2000 | 2022 | | |
| 1991 | 2180 | 2001 | 2857 | | |
| 1992 | 2328 | 2002 | 5419 | | |
| 1993 | 2334 | 2003 | 4281 | | |
| 1994 | 2426 | 2004 | 3764 | | |
| 1995 | 1872 | 2005 | 3327 | | |
| 1996 | 1435 | 2006 | 7165 | | |
| 1997 | 1388 | 2007 | 1857 | | |
| 1998 | 1660 | | | | |
| 1999 | 2188 | | | | |

# APPENDIX H

## Genetic Diversity of Wenatchee Sockeye Salmon, 2007.

# Assessing the Genetic Diversity of Lake Wenatchee Sockeye Salmon And Evaluating The Effectiveness Of Its Supportive Hatchery Supplementation Program

Developed for

Chelan County PUD

and the

Habitat Conservation Plan's Hatchery Committee

Developed by
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**March 2008**

## Executive Summary

Nine spawning populations of sockeye (*Oncorhynchus nerka*) salmon have been identified in Washington, including stocks in the Lake Wenatchee basin (SaSI 5800) (Washington Department of Fisheries et al. 1993). Lake Wenatchee sockeye are classified as an Evolutionary Significant Unit (ESU), and consists of sockeye salmon that spawn primarily in tributaries above Lake Wenatchee (the White River, Napeequa River, and Little Wenatchee Rivers). Since 1990, the Wenatchee Sockeye Program has released juveniles into Lake Wenatchee to supplement natural production of sockeye salmon in the basin. The program's broodstock are predominantly natural-origin sockeye adults returning to the Wenatchee River captured at Tumwater Dam (Rkm 52.0), where a net-pen system is used to house both maturing adults and juveniles prior to release into Lake Wenatchee to over-winter.

Previous genetic studies have generally found a lack of concordance between population genetic relationships and their geographic distributions. These studies indicate that the nearest geographic neighbors of sockeye salmon populations are not necessarily the most genetically similar. Specifically for the Columbia River Basin, sockeye from Lake Wenatchee, Okanogan River, and Redfish Lake may be more closely related to a population from outside the Columbia River (depending on marker used) then to each other.

In this study we investigated the temporal and spatial genetic structure of Lake Wenatchee sockeye collections, without regard to sockeye populations outside of the Lake Wenatchee area. Our primary objective here was to determine if the Wenatchee Sockeye Program affected the natural Lake Wenatchee sockeye population. More specifically, we were tasked to determine if the genetic composition of Lake Wenatchee sockeye population had been altered by a supplementation program that was based on the artificial propagation of a small subset of that population. Using microsatellite DNA allele frequencies, we investigated population differentiation between temporally replicated collections of natural-origin Lake Wenatchee sockeye and program broodstock. We analyzed thirteen collections of Lake Wenatchee sockeye (Table 1), eight temporally replicated collections of natural-origin Lake Wenatchee sockeye (N=786) and five temporally replicated collections of Wenatchee Sockeye Program broodstock (N=248). Paired natural – broodstock collections were available from years 2000, 2001, 2004, 2006, and 2007.

*Conclusions*

We observed that allele frequency distributions were consistent over time, irrespective of collection origin, resulting in small and statistically insignificant measures of genetic differentiation among collections. We interpreted these results to indicate no year-to-year differences in allele frequencies among natural-origin or broodstock collections. Furthermore, there were no observed difference between pre- and post-supplementation collections. Therefore, we accepted our null hypothesis that the allele frequencies of the broodstock collections equaled the allele frequencies of the natural collections, which

equaled the allele frequency of the donor population. Given the small differences in genetic composition among collections, the genetic model for estimating $N_e$ produced estimates with extremely large variances, preventing the observation of any trend in $N_e$.

## Introduction

A report titled "Conceptual Approach to Monitoring and Evaluating the Chelan County Public Utility District Hatchery Programs" was prepared July 2005 by Andrew Murdoch and Chuck Peven for the Chelan PUD Habitat Conservation Plan's Hatchery Committee. This report outlined 10 objectives to be applied to various species assessing the impact (positive or negative) of hatchery operations mitigating the operation of Rock Island Dam. This current study pertains only to Lake Wenatchee sockeye and objective 3:

> *Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program. Additionally, determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.*

In order to evaluate cause and effect of hatchery supplementation, WDFW Molecular Genetics Lab surveyed genetic variation of Lake Wenatchee sockeye. The conceptual approach for this project follows that of a parallel study regarding the Wenatchee River spring Chinook supplementation program (Blankenship et al. 2007). We determined the genetic diversity present in the Lake Wenatchee sockeye population by analyzing temporally replicated collections spanning 1989 – 2007, which included collections from before and following the inception of the Wenatchee Sockeye Program. Documenting the genetic composition of the Lake Wenatchee sockeye population is necessary to assess the effect of the hatchery program on the Lake Wenatchee population. In addition, this work provides a genetic baseline for future projects requiring genetic data. See study objectives below for specific details about how this project addresses Murdoch and Peven (2005) objective 3.

*Lake Wenatchee Sockeye Salmon*

Nine spawning populations of sockeye (*Oncorhynchus nerka*) salmon have been identified in Washington (Washington Department of Fisheries et al. 1993): 1) Baker

River, 2) Ozette Lake, 3) Lake Pleasant, 4) Quinault Lake, and 5) Okanogan River (classified as native stock); 6) Cedar River (classified as non-native stock); 7) Lake Wenatchee, classified as mixed stock); 8) Lake Washington/Lake Sammamish tributaries; and 9) Lake Washington beach spawners (classified as unknown origin). Chapman et al. (1995) listed four additional spawning aggregations of sockeye salmon that appear consistently in Columbia River tributaries: the Methow, Entiat, and Similkameen Rivers; and Icicle Creek in the Wenatchee River drainage.

Located in north central Washington, the Wenatchee River basin drains a portion of the eastern slope of the Cascade Mountains, including high mountainous regions of the Cascade crest. The headwater area of the Wenatchee River is Lake Wenatchee, a typical low productivity oligotrophic or ultra-oligotrophic sockeye salmon nursery lake (Allen and Meekin 1980, Mullan 1986, Chapman et al. 1995). Sockeye salmon bound for Lake Wenatchee enter the Columbia River in April and May and arrive at Lake Wenatchee in late July to early August (Chapman et al. 1995; Washington Department of Fisheries et al. 1993). The run timing of Lake Wenatchee sockeye salmon, classified as an Evolutionary Significant Unit (ESU), appears to have become earlier by 6 - 30 days during the past 70 years (Chapman et al. 1995; Quinn and Adams 1996). Additionally, scale pattern analysis suggests Wenatchee sockeye migrate past Bonneville Dam earlier than the sockeye bound for the Okanogan River (Fryer and Schwartzberg 1994). The Wenatchee population spawns from mid-September through October in the Little Wenatchee, White, and Napeequa Rivers above Lake Wenatchee (Washington Department of Fisheries et al. 1993), peaking in late September (Chapman et al. 1995). Limited beach spawning is believed to occur in Lake Wenatchee (L. Lavoy pers. com.; Mullan 1986), although Gangmark and Fulton (1952) reported two lakeshore seepage areas in Lake Wenatchee that were used by spawning sockeye salmon. Sockeye salmon fry enter Lake Wenatchee between March and May (Dawson et al. 1973), and typically rear in the lake for one year before leaving as smolts (Gustafson et al. 1997; Peven 1987).

Both the physical properties of the habitat and ecological/biological factors of the sockeye populations differ between the Lake Wenatchee ESU and the geographically

proximate Okanogan ESU. For example: 1) Different limnology is encountered by sockeye salmon in Lakes Wenatchee and Osoyoos; 2) Lake Wenatchee sockeye predominantly return at ages four and five (a near absence of 3-year-olds), where a large percentage of 3-year-olds return to the Okanogan population; and 3) the apparent one month separation in juvenile outmigration-timing between Okanogan- and Wenatchee-origin fish (Gustafson et al. 1997 and references therein).

*Sockeye Artificial Propagation In Lake Wenatchee*

The construction of Grand Coulee Dam completely blocked fish passage to the upper Columbia River, and 85% of sockeye salmon passing Rock Island Dam between 1935 and 1936 were estimated to be from natural stocks bound for areas up-river to Grand Coulee Dam (Mullan 1986; Washington Department of Fisheries et al. 1938). To compensate for loss of habitat resulting from Grand Coulee Dam, the federal government initiated the Grand Coulee Fish-Maintenance Project (GCFMP) in 1939 to maintain fish runs in the Columbia River above Rock Island Dam. Between 1939 and 1943, all sockeye salmon entering the mid-Columbia River were trapped at Rock Island Dam, and over 32,000 mixed Lake Wenatchee, Okanogan River, and Arrow Lake adult sockeye salmon were released into Lake Wenatchee (Gustafson et al. 1997 Appendix Table D-2). In addition to adult relocation, between 1941 and 1969 over 52.8 million fry descended from original spawners collected at Rock Island and Bonneville Dams, were released into Lake Wenatchee (Gustafson et al. 1997 Appendix Table D-2).

No releases of artificially-reared sockeye salmon occurred in the Wenatchee watershed during the years 1970 to 1989 (Gustafson et al. 1997 Appendix Table D-2). Since 1990, the Wenatchee Sockeye Program has released juveniles into Lake Wenatchee to supplement natural production of sockeye salmon in the basin. Sockeye adults returning to the Wenatchee River are captured at Tumwater Dam (Rkm 52.0) and transferred to Lake Wenatchee net pens until mature. The Wenatchee Sockeye Program goals are 260 adults with an equal sex ratio, <10% hatchery-origin returns (identified by coded wire tags), and the adults removed for broodstock account for <10% of the run size. Fish are spawned at Lake Wenatchee and their gametes are taken to Rock Island Fish Hatchery

Complex (i.e., Eastbank) for fertilization and incubation. Fry are returned to the Lake Wenatchee net -pens after they are large enough to be coded wire tagged, and are housed in the pens until fall (one year after spawning), when they are liberated into the lake to over-winter. For brood years 1991 – 2004 an average of 218,683 (std. dev. = 71,090) pen-reared Lake Wenatchee-origin juvenile sockeye salmon have been released yearly into Lake Wenatchee.

*Previous Genetic Studies*

**Protein (allozyme) variation** – Surveying genetic variation at 12 allozyme loci, Utter et al. (1984) reported moderate population structure among 16 sockeye collections from southeast Alaska through the Columbia River Basin, including Okanogan and Wenatchee stocks, with an apparent genetic association between upper Fraser River and Columbia River sockeye salmon. Winans et al. (1996) surveyed variation at 55 allozyme loci for 25 sockeye salmon and two kokanee collections from 21 sites in Washington, Idaho, and British Columbia, and reported the lowest level of allozyme variability of any species of Pacific salmon and a highest level of inter-population differentiation. Furthermore, these authors reported that there was no clear relationship between geographic and genetic differentiation among the populations within there study. Other studies corroborate the results of Winans et al. (1996), finding a lack of discernible geographic patterning for sockeye salmon populations in British Columbia, Alaska, and Kamchatka (Varnavskaya et al. 1994, Wood et al. 1994, Wood 1995). These studies indicate that the nearest geographic neighbors of sockeye salmon populations are not necessarily the most genetically similar, which contrasts with the other Pacific salmon species that exhibit concordance between geographic and genetic differentiation (Utter et al. 1989, Winans et al. 1994, Shaklee et al. 1991). As part of the comprehensive status review of west coast sockeye salmon (Gustafson et al. 1997), NMFS biologists collected new allozyme genetic information for 17 sockeye salmon populations and one kokanee population in Washington and combined these data for analysis with the existing Pacific Northwest sockeye salmon and kokanee data from Winans et al. (1996). Results of the updated study were consistent with Winans et al. (1996), with no clear concordance between geographic and genetic distances. Sockeye salmon from Lake Wenatchee, Redfish Lake,

Ozette Lake, and Lake Pleasant are very distinct from other collections in the study, and Columbia River populations were not necessarily most closely related to each other. Gustafson et al. (1997) also examined between-year variability within a collection location and found low levels of statistical significance among the five Lake Wenatchee collections included in the study (For 10 pair-wise comparisons using sum-G test, five were statistically significant). Lake Wenatchee brood year 1987 accounted for three of the significant comparisons, which were driven by unusually high frequencies of two allozyme alleles (ALAT*95 and ALAT*108) (Winans et al. 1996). Nevertheless, Gustafson et al. (1997) conclude that, in general, temporal variation at a locale was considerably less than between-locale variation.

**Nucleic acid variation** - Beacham et al. (1995) reported levels of variation in nuclear DNA of *O. nerka* using minisatellite probes. They analyzed 10 collections, including a sample from Lake Wenatchee. Cluster analysis showed the Lake Wenatchee sample was different from all the other collections, including those from the Columbia River. Using a similar molecular technique, Thorgaard et al. (1995) examined the use of multi-locus DNA fingerprinting (i.e., banding patterns) to discriminate among 14 sockeye salmon and kokanee populations. Dendrograms based on analysis of banding patterns produced different genetic affinity groups depending on the probes used. While none of the five DNA probes showed a close relationship between Lake Wenatchee and Okanogan River sockeye salmon, if information from all probes were combined, *O. nerka* from Redfish Lake, Wenatchee, and Okanogan were separate from kokanee of Oregon and Idaho and a sockeye salmon sample from the mid-Fraser River.

*Study Objective*

We documented temporal variation in genetic diversity (i.e., heterozygosity and allelic diversity), and investigated population differentiation between temporally replicated collections of natural-origin Lake Wenatchee sockeye and program broodstock, using microsatellite DNA allele frequencies. Temporally replicated collections from the same location can also be used to estimate effective population size ($N_e$). If populations are "ideal", the census size of a population is equal to the "genetic size" of the population.

Yet, numerous factors lower the "genetic size" below census, such as, non-equal sex ratios, changes in population size, and variance in the numbers of offspring produced from parent pairs. $N_e$ is thought to be between 0.10 and 0.33 of the estimated census size (Bartley et al. 1992; RS Waples pers. comm.), although numerous observations differ from this general rule. $N_e$ can be calculated directly from demographic data, or inferred from observed differences in genetic variance over time. Essentially, when calculated from genetic data, $N_e$ is the estimated size of an "ideal" population that accounts for the genetic diversity changes observed, irrespective of abundance.

We will address the hypotheses associated with Objective 3 in Murdock and Peven (2005) using the following four specific tasks:

**Task 1 -** Document the observed genetic diversity.

**Task 2 -** Test for population differentiation among Lake Wenatchee collections and the associated supplementation program.

Task 2 was designed to address two hypotheses listed as part of Objective 3 in Murdoch and Peven (2005):

- Ho: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop}}$.
- Ho: Genetic distance between subpopulations $_{\text{Year x}}$ = Genetic distance between subpopulations $_{\text{Year y}}$

Murdoch and Peven (2005) proposed these two hypotheses to help evaluate supplementation programs through a "Conceptual Process" (Figure 5 in Murdoch and Peven 2005). There are two components to the first hypothesis, which must be considered separately for Lake Wenatchee sockeye. The first component involves comparisons between natural-origin populations from Lake Wenatchee to determine if there have been changes in allele frequencies through time starting with the donor population. Documenting a change does not necessarily indicate that the supplementation program has directly affected the natural-origin fish, as additional tests would be necessary to support that hypothesis. The intent of the second component is to determine if the hatchery produced populations have the same genetic composition as the naturally produced populations.

**Task 3 -** Calculate $N_e$ using the temporal method for multiple samples from the same location to document trend.

**Task 4 -** Compare $N_e$ estimates with trend in census size for Lake Wenatchee sockeye.

## Methods and Materials

*Sampling*

Thirteen collections of Lake Wenatchee sockeye were analyzed, eight temporally replicated collections of natural Lake Wenatchee sockeye (N=786) and five temporally replicated collections of Wenatchee Sockeye Program broodstock (N=248) (Table 1). Paired natural – broodstock collections were available from years 2000, 2001, 2004, 2006, and 2007 (Table 1). All collections were made at Tumwater Dam on the Wenatchee River. Note that collections classified as broodstock were predominantly natural-origin sockeye. A majority of the genetic samples were from dried scales. The tissue collections from 2006 and 2007 were fin clips stored immediately in ethanol after collection. DNA was extracted from stored tissue using Nucleospin 96 Tissue following the manufacturer's standard protocol (Macherey-Nagel, Easton, PA, U.S.A.).

*Laboratory Analysis*

Polymerase chain reaction (PCR) amplification was performed using 17 fluorescently end-labeled microsatellite marker loci, *One* 2 (Scribner et al 1996) *One* 100, 101, 102, 105, 108, 110, 114, and 115 (Olsen et al. 2000), *Omm* 1130, 1135, 1139, 1142, 1070, and 1085 (Rexroad et al. 2001), *Ots* 3M (Banks et al. 1999) and *Ots* 103 (Small et al. 1998). PCR reaction volumes were 10 μL, with the reaction variables being 2 μL 5x PCR buffer (Promega), 0.6 μL $MgCl_2$ (1.5 mM) (Promega), 0.2 μL 10 mM dNTP mix (Promega), and 0.1 μL *Go Taq* DNA polymerase (Promega). Loci were amplified as part of multiplexed sets, so primer molarities and annealing temperatures varied. Multiplex one had an annealing temperature of 55°C, and used 0.09 Molar (M) *One* 108, 0.06 M *One* 110, and 0.11 M *One* 100. Multiplex two had an annealing temperature of 53°C, and used 0.08 M *One* 102, 0.1 M *One* 114, and 0.05 M *One* 115. Multiplex three had an annealing temperature of 55°C, and used 0.08 M *One* 105 and 0.07 M *Ots* 103. Multiplex four had

an annealing temperature of 53°C, and used 0.09 M *Omm* 1135 and 0.08 M *Omm* 1139. Multiplex five had an annealing temperature of 60°C, and used 0.2 M *Omm* 1085, 0.09 M *Omm* 1070, and 0.05 M *Ots* 3M. Multiplex six had an annealing temperature of 48°C, and used 0.06 M *One* 2, 0.08 M *Omm* 1142, and 0.08 M *Omm* 1130. *One* 101 was run in isolation with a primer molarity of 0.06. Thermal cycling was conducted on either PTC200 (MJ Research) or GeneAmp 9700 thermal cyclers as follows: 94°C (2 min); 30 cycles of 94°C for 15 sec., 30 sec. annealing, and 72°C for 1 min.; a final 72°C extension and then a 10°C hold. PCR products were visualized by denaturing polyacrylamide gel electrophoresis on an ABI 3730 automated capillary analyzer (Applied Biosystems). Fragment analysis was completed using GeneMapper 3.7 (Applied Biosystems).

*Genetic data analysis*

**Assessing within collection genetic diversity** - Heterozygosity measurements were reported using Nei's (1987) unbiased gene diversity formula (i.e., expected heterozygosity) and Hedrick's (1983) formula for observed heterozygosity. Both tests were implemented using the microsatellite toolkit (Park 2001). For each locus and collection FSTAT version 2.9.3.2 (Goudet 1995) was used to assess Hardy-Weinberg equilibrium, where deviations from the neutral expectation of random associations among alleles were calculated using a randomization procedure. Alleles were randomized among individuals within collections (4160 randomizations for this dataset) and the $F_{IS}$ (Weir and Cockerham 1984) calculated for the randomized datasets were compared to the observed $F_{IS}$ to obtain an unbiased estimation of the probability that the null hypothesis was true. The 5% nominal level of statistical significance was adjusted for multiple tests (Rice 1989). Genotypic linkage disequilibrium was calculated following Weir (1979) using GENETIX version 4.05 (Belkhir et al. 1996). Statistical significance of linkage disequilibrium results was assessed using a permutation procedure implemented in GENETIX for each locus by locus combination within each collection.

**Assessing among collection genetic differentiation** - The temporal stability of allele frequencies was assessed by the randomization chi-square test implemented in FSTAT version 2.9.3.2 (Goudet 1995). Multi-locus genotypes were randomized between

collections. The G-statistic for observed data was compared to G-statistic distributions from randomized datasets (i.e., null distribution of no differentiation between collections). Population differentiation was also investigated using pairwise estimates of $F_{ST}$. Multi-locus estimates of pairwise $F_{ST}$, estimated by a "weighted" analysis of variance (Weir and Cockerham, 1984), were calculated using GENETIX version 4.05 (Belkhir et al.1996). $F_{ST}$ was used to quantify population structure, the deviation from statistical expectations (i.e., excess homozygosity) due to non-random mating between populations. To determine if the observed $F_{ST}$ estimate was consistent with statistically expectations of no population structure, a permutation test was implemented in GENETIX (1000 permutations).

**Effective population size ($N_e$)** – Estimates of the effective population size were obtained using a multi-collection temporal method (Waples 1990a). The temporal method assumes that cohorts are used, but we did not decompose the collection year samples into their respective cohorts using age data. Therefore, $N_e$ estimates that pertain to individual year classes of breeders are not valid; however the harmonic mean over all samples will estimate an $N_e$ that pertains to the time period from which the collections are derived. Comparing samples from years *i* and *j*, Waples' (1990a) temporal method estimates the effective number of breeders ($\hat{N}_{b(i,j)}$) according to:

$$\hat{N}_{b(i,j)} = \frac{b}{2(\hat{F} - 1/\tilde{S}_{i,j})}$$

The standardized variance in allele frequency ($\hat{F}$) is calculated according to Pollack (1983). The parameter b is calculated analytically from age structure information and the number of years between samples (Tajima 1992). The age-at-maturity information required to calculate b was obtained from ecological data (Hillman et al. 2007). The harmonic mean of sample sizes from years *i* and *j* is $\tilde{S}_{i,j}$. The harmonic mean over all pairwise estimates of $\hat{N}_{b(i,j)}$ is $\tilde{N}_b$. SALMONNb (Waples et al. 2007) was used to calculate $\tilde{N}_b$.

## Results and Discussion

In this section we combine our presentation and interpretations of the genetic analyses. Additionally, this section is organized based on the task list presented in the study plan.

**Task 1 -** Document the observed genetic diversity.

Substantial genetic diversity was observed over all Lake Wenatchee sockeye collections analyzed (Table 1), with heterozygosity estimates over all loci having a mean of 0.79. Genetic diversity was consistent with expected Hardy-Weinberg random mating genotypic proportions for all collections. The $F_{IS}$ observed for each collection was not statistically significant given the distribution of $F_{IS}$ generated using a randomization procedure. Additionally, there were no statistically significant associations observed between alleles across loci (i.e., linkage equilibrium) (data not shown). We concluded from these results that the genetic data from each collection was consistent with statistical expectations for random association of alleles within and between loci. In other words, each collection represents samples from a single gene pool (i.e., populations), and the genetic diversity observed has no detectable technical artifacts or evidence of natural selection.

**Task 2 -** Test for differentiation among Lake Wenatchee collections and the associated supplementation program.

We explicitly tested the hypothesis of no significant differentiation within natural-origin or broodstock collections from Lake Wenatchee using a randomization chi-square test. The null hypothesis for these tests was that the allele frequencies from two different populations were drawn from the same underlying distribution. We show the results for the pairwise comparisons among eight temporally replicated natural-origin collections from Lake Wenatchee (28 pairwise tests), and report all tests were non-significant (Table 2A). Similarly, for five temporally replicated broodstock collections, 10 of 10 pairwise tests were non-significant (Table 2B). We also tested if natural-origin and broodstock

collections were differentiated from each other over time, and report that 40 of 40 tests were non-significant (Table 2C). The nominal level of statistical significance ($\alpha = 0.05$) was adjusted for multiple comparisons using strict Bonferroni correction (Rice 1989). Yet, there are perhaps slight differences between paired natural-broodstock collections. Note that the p-values for comparisons regarding 2006 and 2007 paired collections are lower than for comparisons regarding 2000, 2001, and 2004. The small sample sizes for broodstock collections in 2006 and 2007 may not have been random samples from the Lake Wenatchee sockeye population.

Given the consistencies observed for allele frequency distributions over time, metrics of population structure were expected to be small. This was the case, as the estimated $F_{ST}$ over all thirteen collections was 0.0003. This observed value fell within the distribution of $F_{ST}$ values expected if there were no population structure present (permutation test p-value 0.12). Analysis of the paired natural-broodstock collections corroborated this result. Pairwise estimates of $F_{ST}$ were 0.000 for years 2000, 2001, 2004, and 2007, and 0.002 for 2006. All five estimates were non-significant. Essentially, all 13 sockeye collections could be considered samples from the same population. Given these results, it is valid to combine all collections for statistical analysis. Therefore, we did not calculate genetic distances among any collections, as it is inappropriate to estimate distances that are effectively zero.

*Conclusions*

We interpret these data to indicate that there appears to be no significant year-to-year differences in allele frequencies among natural-origin or broodstock collections, nor are there observed differences between collections pre- and post-supplementation. As a result, we accept the null hypothesis that the allele frequencies of the broodstock collections equal the allele frequencies of the natural collections, which equals the allele frequency of the donor population. Furthermore, the observed genetic variance that can be attributed to among collection differences was negligible.

**Task 3 -** Calculate $N_e$ using the temporal method for multiple samples from the same location to document trend.

The fundamental parameter for inferring $N_e$ using genetic data is the standardized variance in allele frequency ( $\hat{F}$ ) (Pollack 1983). Methods estimate $N_e$ from observed changes in $\hat{F}$ over temporally replicated collections from the same location. Yet, as previously shown, there were no statistically significant differences detected in allele frequencies. The underlying model for estimating $N_e$ produced estimates with extremely large variances, given small temporal differences in $\hat{F}$ , which rendered any trend in $N_e$ unobservable. Table 3 shows $N_e$ estimates calculated using temporally replicated natural collections.

**Task 4 -** Compare $N_e$ estimates with trend in census size for Lake Wenatchee sockeye.

See Task 3

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**Table 1** Lake Wenatchee sockeye collections analyzed. MNA is the mean number of alleles per locus, Hz is unbiased heterozygosity, Obs Hz is observed heterozygosity, and HW is the p-value of the null hypothesis of random association of alleles (i.e., Hardy – Weinberg equilibrium). For reference, the nominal level of statistical significance at $\alpha = 0.05$ is 0.0002 after correction for multiple tests.

| Year | Collection Code | Tissue Type | Source | N | MNA | Hz | Obs Hz | HW |
|---|---|---|---|---|---|---|---|---|
| 1989 | 89[1] | Scales | Natural | 96 | 14.35 | 0.792 | 0.791 | 0.424 |
| 1990 | 90[1] | Scales | Natural | 96 | 13.19 | 0.793 | 0.779 | 0.131 |
| 2000 | 00AAE | Scales | Broodstock | 96 | 12.31 | 0.787 | 0.776 | 0.213 |
| 2000 | 00[1] | Scales | Natural | 96 | 11.76 | 0.801 | 0.826 | 0.868 |
| 2001 | 01AAS | Scales | Broodstock | 53 | 9.47 | 0.788 | 0.793 | 0.392 |
| 2001 | 01[1] | Scales | Natural | 96 | 14.35 | 0.786 | 0.794 | 0.456 |
| 2002 | 02[1] | Scales | Natural | 96 | 14.53 | 0.794 | 0.777 | 0.780 |
| 2004 | 04[1] | Scales | Natural | 96 | 14.65 | 0.798 | 0.803 | 0.704 |
| 2004 | 04AAV | Scales | Broodstock | 43 | 14.35 | 0.796 | 0.795 | 0.051 |
| 2006 | 06CN | Tissue | Broodstock | 38 | 14.59 | 0.793 | 0.785 | 0.688 |
| 2006 | 06CO | Tissue | Natural | 96 | 14.53 | 0.806 | 0.803 | 0.408 |
| 2007 | 07EE | Tissue | Broodstock | 18 | 14.00 | 0.790 | 0.790 | 0.221 |
| 2007 | 07EF | Tissue | Natural | 96 | 14.35 | 0.789 | 0.800 | 0.347 |

[1] Samples taken from scale cards provided by Jeff Fryer (CRITFC)

**Table 2** Allelic differentiation for Lake Wenatchee sockeye collections. A single analysis tested (pairwise) the allelic differentiation between all thirteen collections; however p-values for G-statistics are partitioned in the table by A) natural-origin, B) broodstock, and C) natural versus broodstock. Underlined values are for paired natural-broodstock collections from the same year. For reference, the nominal level of statistical significance at $\alpha = 0.05$ is 0.0006 after correction for multiple tests. No significant values were observed.

A) Natural-Origin Collections

| | 89 | 90 | 00 | 01 | 02 | 04 | 06CO | 07EF |
|---|---|---|---|---|---|---|---|---|
| 89 | | 0.257 | 0.359 | 0.531 | 0.331 | 0.127 | 0.031 | 0.263 |
| 90 | | | 0.953 | 0.148 | 0.753 | 0.903 | 0.077 | 0.283 |
| 00 | | | | 0.328 | 0.527 | 0.607 | 0.604 | 0.400 |
| 01 | | | | | 0.209 | 0.081 | 0.127 | 0.093 |
| 02 | | | | | | 0.085 | 0.707 | 0.235 |
| 04 | | | | | | | 0.312 | 0.577 |
| 06CO | | | | | | | | 0.435 |
| 07EF | | | | | | | | |

B) Broodstock Collections

| | 00AAE | 01AAS | 04AAV | 06CN | 07EE |
|---|---|---|---|---|---|
| 00AAE | | 0.189 | 0.090 | 0.008 | 0.058 |
| 01AAS | | | 0.122 | 0.020 | 0.116 |
| 04AAV | | | | 0.008 | 0.031 |
| 06CN | | | | | 0.326 |
| 07EE | | | | | |

C) Natural vs. Broodstock

| | 89 | 90 | 00 | 01 | 02 | 04 | 06CO | 07EF |
|---|---|---|---|---|---|---|---|---|
| 00AAE | 0.027 | 0.309 | <u>0.572</u> | 0.018 | 0.041 | 0.012 | 0.093 | 0.040 |
| 01AAS | 0.115 | 0.471 | 0.160 | <u>0.219</u> | 0.519 | 0.049 | 0.654 | 0.133 |
| 04AAV | 0.136 | 0.219 | 0.210 | 0.423 | 0.208 | <u>0.328</u> | 0.037 | 0.153 |
| 06CN | 0.029 | 0.004 | 0.053 | 0.007 | 0.022 | 0.004 | <u>0.019</u> | 0.001 |
| 07EE | 0.099 | 0.229 | 0.053 | 0.015 | 0.093 | 0.178 | 0.090 | <u>0.037</u> |

**Table 3** Estimation of $N_e$ for temporally replicated natural-original sockeye collections. Above the diagonal are pairwise estimates of $N_e$, where negative values mean sampling variance can account for genetic variance observed (i.e., genetic drift unnecessary). Below the diagonal are variances for pairwise estimates of $N_e$. Absent variance values (denoted by - ) were too large for SalmonNb to display.

| Collection | 89 | 90 | 00 | 01 | 02 | 04 | 06CO | 07EF |
|---|---|---|---|---|---|---|---|---|
| 89 | | -3936.6 | -1414 | -2636.3 | 671.4 | 1871.1 | 1066.1 | 1951.2 |
| 90 | 2.59E+09 | | -1490.3 | 3649.1 | -31144 | -6808.4 | 817.6 | 93190.2 |
| 00 | 1.40E+09 | 4.45E+09 | | -592.2 | -6842.2 | -667.1 | -1736.9 | -1350.1 |
| 01 | 1.21E+09 | 1.47E+09 | 2.33E+09 | | 977.1 | 6160.4 | 387.8 | 2531.5 |
| 02 | 1.91E+09 | 1.33E+09 | 1.16E+09 | 2.29E+09 | | 1495.6 | -848.5 | 3213.6 |
| 04 | 2.21E+09 | 3.62E+09 | 4.08E+09 | 1.27E+09 | 1.14E+09 | | 896.6 | 2155.3 |
| 06CO | 1.34E+09 | 1.39E+09 | 1.73E+09 | - | 4.51E+09 | 1.2E+09 | | 3278.6 |
| 07EF | 2.15E+09 | 1.51E+09 | 1.18E+09 | 1.68E+09 | - | 1.36E+09 | 2.65E+09 | |

# APPENDIX I

## Genetic Diversity of Natural Chiwawa River Spring Chinook Salmon, 2007.

# Assessing the Genetic Diversity of Natural Chiwawa River Spring Chinook Salmon and Evaluating the Effectiveness of its Supportive Hatchery Supplementation Program

Developed for

Chelan County PUD

and the

Habitat Conservation Plan's Hatchery Committee

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## Executive Summary

The main objective of this study was to determine the potential impacts of the Chiwawa River Supplementation Program on natural spring Chinook in the upper Wenatchee system. We did this by investigating population differentiation between temporally replicated Chiwawa River natural and hatchery samples from the Wenatchee River watershed using microsatellite DNA allele frequencies and the statistical assignment of individual fish to specific populations. Additionally, to assess the genetic effect of the hatchery program, we investigated the relationship between census and effective population sizes using collections obtained before and after the supplementation program. In this summary, we briefly describe the salient results contained within this report; however, each "Task" within the Results/Discussion section below contains extended coverage for each topic along with an expanded interpretation of each result.

Overall, we observed substantial genetic diversity within collections, with heterozygosities equal to roughly 80%, over thirteen microsatellite markers. Microsatellite allele frequencies among temporally replicated collections from the same population (i.e., location) were variable, resulting in significant genetic differentiation among these collections. However, these difference are likely the result of salmon life history in this area, as four-year-old Chinook comprise a majority of returns each year. That is, the genetic tests are detecting the differences of contributing parents from each cohort, rather than a hatchery effect.

*Analysis of Chiwawa River Collections*

To assess the multiple competing hypotheses regarding population differentiation within and among Chiwawa River collections, we found it necessary to organized the Chiwawa genetic data into three data sets: (1) fish origin (hatchery versus natural), (2) spawning location (hatchery broodstock versus in-river (natural) spawners), and (3) four "treatment" groups (1. hatchery-origin hatchery broodstock, 2. hatchery-origin natural spawner, 3. natural-origin natural spawner, and 4. natural-origin hatchery broodstock). We conducted separate analyses using each of the three data sets, with each analysis

touching on some aspect of the components necessary to move through the Conceptual Process outlined by Murdoch and Peven (2005).

**Origin Dataset** – We report that allele frequencies within and between natural- and hatchery-origin collections are significantly different, but there does not appear to be a robust signal indicating that the recent natural-origin collections have diverged greatly from the pre- or early post-supplementation collections. Genetic drift will occur in all populations, but does not appear to be a major factor affecting allele frequencies within the Chiwawa collections.

**Spawning Location Dataset** – There are significant allele frequency differences within and between hatchery broodstock and natural spawner collections. However, in recent years the allele frequency differences between the hatchery broodstock and natural spawner collections have declined. Furthermore, based on linkage disequilibrium, there is a genetic signal that is consistent with increasing homogenization of allele frequencies within hatchery broodstock collections, but a similar homogenization within the natural spawner collection is not apparent. These data suggest that there exists consistent year-to-year variation in allele frequencies among hatchery and natural spawning collections, but there is a trend toward homogenization of the allele frequencies of the natural- and hatchery-origin fish that compose the hatchery broodstock.

**Four Treatment dataset** – Although there are signals of allelic differentiation among Chiwawa River collections, there are no robust signs that these collections are substantially different from each other. We used two different analyses to measure the degree of genetic variation that exists among individuals and collections within the Chiwawa River. First, we conducted a principal component analysis using all Chiwawa samples with complete genotypes (i.e., no missing alleles from any locus). Although the first two principal component axes account for only 10.5% of the total molecular variance, a substantially greater portion of that variance is among individual fish, regardless of their identity, rather than among hatchery and natural collections. The

variances in principal component scores among individuals are 11 and 13 times greater than the variance in scores among collections.

Secondly, using an Analysis of Molecular Variance (AMOVA), we were able to determine how best to group populations, with "best" being defined as that grouping that accounts for the greatest proportion of among group (i.e., population) variance. Furthermore, by partitioning molecular variance into different hierarchical components, we are able to determine what level accounts for the majority of the molecular variance. The AMOVA results clearly show that nearly all molecular variation, no matter how the data are organized, resides within a collection. The percentage of total molecular variance occurring within collections ranged from 99.68% to 99.74%. These results indicate that the significant differences among collections of Chiwawa fish account for less than one percent of the total molecular variance, and these differences cannot be attributed to fish origin or spawning location.

*Effective Population Size ($N_e$)*

The contemporary estimate of $N_e$ calculated using genetic data combined for Chiwawa natural-origin spawners (NOS) and hatchery-origin spawners (HOS) Chinook is $N_e$=386.8, which is slightly larger than the pre-hatchery $N_e$ we estimated using demographic data from 1989 – 1992. Additionally, the $N_e$ /N ratio calculated using 386.8 for $N_e$ and the arithmetic mean yearly census of NOS and HOS Chinook from 1989 – 2005 for N is 0.40. These results suggest the $N_e$ has not declined during the period of Chiwawa Hatchery Supplementation Program operation.

*Analysis Of Upper Wenatchee Tributary Collections*

We compared genetic data for spring Chinook collected from the major spawning aggregates of the Wenatchee River. We observed significant differences in allele frequencies among temporally replicated collections within populations, and among populations within the upper Wenatchee. However, these differences account for a very small portion of the overall molecular variance, and these populations overall are very similar to each other. Of all the populations within the Wenatchee River, the White River

appears to be the most distinct. Yet, this distinction is more a matter of detail than of large significance, as the median $F_{ST}$ between White River collections and all other collections (except the Little Wenatchee collection; see Results/Discussion) is less than 1.5% among population variance. We consider the implications of these results in the Conclusion section that follows the Results/Discussion section. Additionally, there is no evidence that the Chiwawa River Supplementation Program has changed the allele frequencies in the Nason Creek and White River populations, despite the presence of hatchery-origin fish in both these systems.

## Introduction

Murdoch and Peven (2005) outlined 10 objectives to assess the impact (positive or negative) of hatchery operations mitigating the operation of Rock Island Dam. Two objectives relate to monitoring the genetic integrity of populations:

**Objective 3: Determine if genetic diversity, population structure, and effective population size have changed in natural spawning populations as a result of the hatchery program. Additionally, determine if hatchery programs have caused changes in phenotypic characteristics of natural populations.**

**Objective 5: Determine if the stray rate of hatchery fish is below the acceptable levels to maintain genetic variation between stocks.**

This study addresses Objective 3 (above), and documents analyses and results WDFW completed for populations of spring Chinook (*Oncorhynchus tshawytscha*) in the Wenatchee River watershed. This study was not intended to specifically address Objective 5 (above); however, genetic data provide results relevant to Objective 5. The critical component of Objective 3 is to determine if hatchery supplementation has effected change. Furthermore, change in this context means altering census size and/or genetic marker allele frequencies; we did not attempt to measure changes in fitness. Perhaps a more meaningful rewording of Objective 3 is, "Did the hatchery supplementation program succeed at increasing the census size of a target population while leaving genetic integrity intact?" In order to evaluate cause and effect of hatchery supplementation, we surveyed and compared genetic variation in samples collected before and after potential effects from the Chiwawa Hatchery Supplementation Program. Samples were acquired from the primary spawning aggregates in the upper Wenatchee River watershed: Nason Creek, Little Wenatchee River, White River, and Chiwawa River. Hatchery samples were acquired from programs that could potentially affect genetic composition of Wenatchee stocks, the integrated Chiwawa River stock (local stock), Leavenworth National Fish Hatchery spring Chinook (Carson Stock – non local), and Entiat NFH (Carson Stock – non local). Additionally, the genetic markers used were the Genetic Analysis of Pacific Salmonids (GAPS) (Seeb et al. in review) standardized

microsatellites, so all data from the Wenatchee study will be available for inclusion in the GAPS Chinook coastwide microsatellite baseline.

*History of Artificial Propagation*

Artificial propagation in the upper Columbia River began in 1899 when hatcheries were constructed on the Wenatchee and Methow rivers (Mullan 1987). These initial operations were small, with the Tumwater Hatchery on the Wenatchee River releasing several hundred thousand fry, and the Methow River hatchery producing few Chinook salmon before it was closed in 1913 (Craig and Suomela 1941, Nelson and Bodle 1990). The Leavenworth State Hatchery operated in the Wenatchee River Basin between 1913 and 1931 using eggs from non-native stocks (Willamette River spring-run and lower Columbia Chinook hatchery fall-run). These early attempts at hatchery production were largely unsuccessful for spring-run Chinook (WDF 1934). Between 1931 and 1939, no Chinook salmon hatcheries were in operation above Rock Island Dam (Rkm 730).

In 1938, the last salmon was allowed to pass upstream through the uncompleted Grand Coulee Dam (Rkm 959). To mitigate the loss of habitat, adult Chinook salmon were trapped, under the auspices of the Grand Coulee Fish Maintenance Project (GCFMP), at Rock Island Dam beginning in May 1939, and relocated into three of the remaining accessible tributaries to the upper Columbia River: the Wenatchee, Entiat, and Methow Rivers. GCFMP transfers continued through the autumn of 1943. Spring- and summer/fall-run fish were differentiated at Rock Island Dam based on a 9 July cutoff date for Chinook arrivals at Rock Island Dam (Fish and Hanavan 1948). Spring-run adults collected at Rock Island Dam (pre 9 July fish) were either transported to Nason Creek on the Wenatchee River to spawn naturally (1939-43), or to the newly constructed Leavenworth NFH (1940) for holding and subsequent spawning (1940-43). Eggs were incubated on site or transferred to the Entiat NFH (1941) and Winthrop NFH (1941). In 1944 spring-run adults were allowed to freely pass Rock Island Dam. The GCFMP did not differentiate among late-run stocks (post 9 July fish) passing Rock Island Dam. Late-run offspring reared at the Leavenworth NFH, Entiat NFH, and Winthrop NFHs were an

amalgamation of summer and fall upper Columbia River populations (Fish and Hanavan 1948). Late-run fish were transplanted into the upper and lower Wenatchee, Methow, and Entiat Rivers.

After 1943, the Winthrop NFH continued to use local spring-run Chinook for hatchery production, while the other NFHs largely focused on summer-run Chinook salmon. Renewed emphasis on spring run production in the mid-1970s saw the inclusion of local and non-local eggs (Carson NFH stock, Klickitat River stock, and Cowlitz River stock) to the NFHs. In the early 1980s, imports of non-native eggs were reduced significantly, and thereafter the Leavenworth, Entiat, and Winthrop NFHs have relied on adults returning to their facilities for their egg needs (Chapman et al. 1995). Regarding late-run Chinook, due to the variety of methods employed to collect broodstock at dams, hatcheries, or the result of juvenile introductions into various areas, Chinook populations and runs (i.e., summer and fall) have been mixed considerably in the upper Columbia system over the past five decades (reviewed in Chapman et al. 1994).

Washington Department of Fish and Wildlife (WDFW) operates two facilities producing spring-run Chinook, the Methow Fish Hatchery (MFH) owned by Douglas County PUD that began operation in 1992 and Eastbank Fish Hatchery (EFH) owned by Chelan County PUD that began operation in 1989. Both programs were designed to implement supplementation (supportive breeding) programs for naturally spawning populations on the Methow and Wenatchee Rivers, respectively (Chapman et al. 1995). As part of the Rock Island Mitigation Agreement between Chelan County Public Utility District and the fishery management parties (RISPA 1989), a supplementation (supportive breeding) program was initiated in 1989 on the Chiwawa River to mitigate smolt mortality resulting from the operation of Rock Island Hydroelectric Project. EFH uses broodstock collected at a weir on the Chiwawa River, although in recent years hatchery fish have been collected at Tumwater Dam. Similarly, the MFHC uses returning adults collected at weirs on the Methow River and its tributaries, the Twisp and Chewuch Rivers (Chapman et al. 1995; Bugert 1998). Although low run size and trap efficiency has resulted in most broodstock being collected from the hatchery outfall or in some years Wells Dam,

progeny produced from these programs are reared at and released from satellite sites on the tributaries where the adults were collected. Numerous other facilities have reared spring-run Chinook salmon on an intermittent basis.

*Previous Genetic Studies – Population differentiation*

Waples et al. (1991a) examined 21 polymorphic allozyme loci in samples from 44 populations of Chinook salmon in the Columbia River Basin. These authors reported three major clusters of Columbia River Basin Chinook salmon: 1) Snake River spring- and summer-run Chinook salmon, and mid and upper Columbia River spring-run Chinook salmon, 2) Willamette River spring-run Chinook salmon, 3) mid and upper Columbia River fall- and summer-run Chinook salmon, Snake River fall-run Chinook salmon, and lower Columbia River fall- and spring-run Chinook salmon. Utter et al. (1995) examined allele frequency variability at 36 allozyme loci in samples of 16 upper Columbia River Chinook populations. Utter et al. (1995) indicated that spring-run populations were distinct from summer- and fall-run populations, where the average genetic distance between spring-run and late-run Chinook were about eight times the average of genetic distances between samples within each group. Additionally, allele frequency differences among spring-run populations were considerably greater than that among summer- and fall-run populations in the upper Columbia River. Utter et al. (1995) also reported hatchery populations of spring-run Chinook salmon were genetically distinct from natural spring-run populations, but hatchery populations of fall-run Chinook salmon were not genetically distinct from natural fall-run populations.

As part of an evaluation of the relative reproductive success for the Chiwawa River supplementation program, Murdoch et al. (2006), used eleven microsatellite loci to assess population differentiation among spring Chinook salmon population samples in the upper Wenatchee River. Murdoch et al. (2006) reported a >99% accuracy of correctly identifying spring-run and fall-run Chinook from the Wenatchee River. They also reported slight, but significantly different genetic variation among wild spring populations and between wild and hatchery stocks. Yet, since the spring-run populations

are genetically similar, identifying individuals genetically from the upper tributaries of the Wenatchee River was difficult. This result is exemplified in their individual assignment results, where < 8% of spring-run individuals, hatchery or wild, were correctly assigned using their criterion of an LOD (log of odds) score greater than 2. Murdoch et al. (2006) also reported contemporary natural spring Chinook show heterozygote deficit and low linkage disequilibrium (LD), while contemporary hatchery spring Chinook show heterozygote excess and high LD.

Williamson et al. (submitted) have continued the work of Murdoch et al. (2006) by analyzing Chiwawa River demographic data from 1989 – 2005 to estimate the proportions of recruits that were produced by Chinook with hatchery or wild origin. In an "ideal" population, the genetic size (i.e., effective size or $N_e$) and the census size are equal; however various demographic factors such as unequal sex ratios and variance in reproductive success among individuals reduces the genetic size below the census size. It is generally thought that the genetic size is approximately 10-33% the census size (Bartley et al. 1992; RS Waples pers. comm.), although values have been reported outside this range (Araki et al. 2007; Arden and Kapuscinski 2003; Heath et al. 2002). Despite being difficult to estimate, the effective population size in many respects is a more important parameter to know than census size, because $N_e$ determines how genetic diversity is distributed within populations and how the forces of evolution (i.e., forces that change genetic diversity over time) will affect the genetic variation present.

Williamson et al. (submitted) used demographic data to 1) investigate the effect of unequal sex ratio on genetic diversity, 2) investigate the effect of variation in reproductive success on genetic diversity, 3) investigate the effect of fluctuations in population size on genetic diversity, and 4) estimate the effective population size, using the inbreeding method (Ryman and Laikre 1991). Most importantly, they use demographic data from 1989 – 2000 to assess the impact of the Chiwawa Hatchery Supplementation Program on the effective population size of natural-origin Chiwawa River spring Chinook. They estimate that the $N_e$ of naturally spawning Chiwawa Chinook (i.e., both hatchery- and wild-origin fish on the spawning grounds) from 1989 –

1992 was $N_e$ = 2683 and in 1997 – 2000 was $N_e$ = 989. They compare spawning ground $N_e$ to estimates calculated from combined broodstock and naturally spawning Chinook demographic data. The combined inbreeding $N_e$ estimate from 1989 – 1992 was $N_e$ = 147 and in 1997 – 2000 was $N_e$ = 490. Williamson et al. (submitted) argue that since the combined $N_e$ estimate is lower than the naturally spawning estimate, the supplementation program has had a negative impact on the Chiwawa River $N_e$.

Williamson et al. (submitted) also present genetic data for Chinook recovered on spawning grounds in upper Wenatchee River tributaries in 2004 and 2005. These genetic data are derived from the Murdoch et al. (2006) study. They compare samples collected from Chiwawa River (i.e., hatchery and wild), White River, Nason Creek, and Leavenworth Hatchery. Additionally, they include a 1994 Chiwawa River wild smolt sample for comparison with the 2004 brood year. Williamson et al. (submitted) report statistically significant genetic differentiation among Chiwawa River, White River and Nason Creek. Additionally, they report that the 1994 and 2004 Chiwawa River wild samples are not statistically different, but the 2004 Chiwawa wild and hatchery collections are statistically different.

*Study Objectives*

This study investigated within and among population genetic diversity to assess the effect of the Chiwawa Hatchery's supplemental program on the natural Chiwawa River spring Chinook population. Differences among temporal population samples, the census size, heterozygosity, and allelic diversity were documented. We investigated population differentiation between the Chiwawa River natural and hatchery samples, and among all temporally replicated samples from the Wenatchee River watershed using microsatellite DNA allele frequencies and the statistical assignment of individual fish to specific populations. To assess the genetic effect of the hatchery program, correlation between census and effective population sizes were investigated using temporally replicated samples obtained before and after the supplementation program operation. To address the hypotheses associated with Objective 3 in Murdock and Peven (2005) we developed

eleven specific "Tasks" (Blankenship and Murdoch 2006), to which we analyzed specific genetic data. We present the results from these analyses specific to each individual Task.

## Methods and Materials

*Tissue collection and DNA extraction*

We analyzed thirty-two population collections of adult spring Chinook salmon (*Oncorhynchus tshawytscha*) obtained from the Wenatchee River between 1989 and 2006 (Table 1). Nine collections of natural Chinook adults from the Chiwawa River (n=501), and nine collections of Chiwawa Hatchery Chinook (n=595) were collected at a weir located in the lower Chiwawa River. The 1993 and 1994 Chiwawa Hatchery samples are smolt samples from the 1991 and 1992 hatchery brood years, respectively. Additional samples were collected from upper Wenatchee River tributaries, White River, Little Wenatchee River, and Nason Creek. Six collections of natural White River Chinook (n=179), one collection from the Little Wenatchee (n=19), and six collections from Nason Creek (n=268) were obtained. Single collections were obtained for Chinook spawning in the mainstem Wenatchee River and Leavenworth National Fish Hatchery. An additional out-of-basin collection from Entiat River was also included in the analysis. Samples collected in 1992 or earlier are scale samples. All other samples were either fin clips or operculum punches, stored immediately in ethanol after collection. DNA was extracted from stored tissue using Nucleospin 96 Tissue following the manufacturer's standard protocol (Macherey-Nagel, Easton, PA, U.S.A.).

*Laboratory analysis*

We performed polymerase chain reaction (PCR) amplification on each fish sample using the 13 fluorescently end-labeled microsatellite marker loci standardized as part of the GAPS project (Seeb et al. in review). GAPS genetic loci are: *Ogo*2, *Ogo*4 (Olsen et al. 1998); *Oki*100 (unpublished); *Omm*1080 (Rexroad et al. 2001); *Ots*201b (unpublished); *Ots*208b, *Ots*211, *Ots*212, and *Ots*213 (Grieg et al. 2003); *Ots*3M, *Ots*9 (Banks et al.

1999); *Ots*G474 (Williamson et al. 2002); *Ssa*408 (Cairney et al. 2000). PCR reaction volumes were 10 µL, and contained 1 µL 10x PCR buffer (Promega), 1.0 µL MgCl2 (1.5 mM final) (Promega), 0.2 µL 10 mM dNTP mix (Promega), and 0.1 units/mL Taq DNA polymerase (Promega). Loci were amplified as part of multiplexed sets, so primer molarities and annealing temperatures varied. Multiplex one had an annealing temperature of 50°C, and used 0.37 Molar (M) *Oki*100, 0.35 M *Ots*201b, and 0.20 M *Ots*208b, and 0.20 M *Ssa*408. Multiplex two had an annealing temperature of 63°C, and used 0.10 M *Ogo*2, and 0.25 M of a non-GAPS locus (*Ssa* 197). Multiplex three had an annealing temperature of 56°C, and used 0.18 M *Ogo*4, 0.18 M *Ots*213, and 0.16 M *Ots*G474. Multiplex four had an annealing temperature of 53°C, and used 0.26 M *Omm*1080, and 0.12 M *Ots*3M. Multiplex five had an annealing temperature of 60°C, and used 0.30 M *Ots*212, 0.20 M *Ots*211, and 0.10 M *Ots*9. Thermal cycling was conducted on either a PTC200 thermal cycler (MJ Research) or GeneAmp 9700 (Applied Biosystems) as follows: 95°C (2 min); 30 cycles of 95°C for 30 sec., 30 sec. annealing, and 72°C for 30 sec.; a final 72°C extension and then a 10°C hold. PCR products were visualized by electrophoresis on an ABI 3730 automated capillary analyzer (Applied Biosystems). Fragment analysis was completed using GeneMapper 3.7 (Applied Biosystems). Standardization of genetic data to GAPS allele standards was conducted following Seeb et al. (in review).

*Genetic data analysis*

**Assessing within population genetic diversity** - Heterozygosity measurements are reported using Nei's (1987) unbiased gene diversity formula (i.e., expected heterozygosity) and Hedrick's (1983) formula for observed heterozygosity. Both tests are implemented using the microsatellite toolkit (Park 2001). We used GENEPOP version 3.4 (Raymond and Rousset 1995) to assess Hardy-Weinberg equilibrium (HWE), where deviations from the neutral expectation of random associations among alleles are calculated using a Markov chain method (5000 iterations in this study) to obtain unbiased estimates of Fisher's exact test. Global estimates of $F_{IS}$ according to Weir and Cockerham (1984) were calculated using GENEPOP version 3.4. Genotypic linkage disequilibrium was calculated following Weir (1979) using GENEPOP version 3.4.

Linkage results for population collections are reported as the proportion of pairwise (locus by locus) tests that are significant (alpha = 0.01). Linkage disequilibrium is considered statistically significant if more than 5% of the pairwise tests based on permutation are significant for a collection.

**Within- and among-population genetic differentiation –** The temporal stability of allele frequencies within populations, and pairwise differences in allele frequencies among populations were assessed using several different procedures. First, we tested for differences in allele frequencies among populations defined in Table 1 using a randomization chi-square test implemented in GENEPOP version 3.4 (Raymond and Rousset 1995). This procedure tests for differences between pairs of populations where alleles are randomized between the populations (i.e., genic test). The null hypothesis for this test is that the allele frequency distributions between two populations are the same. A low p-value should be interpreted as the allele frequency distributions being compared are unlikely to be samples drawn from the same underlying distribution.

Second, to graphically describe allele frequency differences among populations we conducted a nonmetric multidimensional scaling analysis using allele-sharing distance matrices from two different data sets. Pairwise allele-sharing distances are calculated as 1 – (mean over all loci of the sums of the minima of the relative frequencies of each allele common to a pair of populations). To calculate the allele-sharing distances for each pair of populations we used PowerMarker v3.25 (Liu and Muse 2005). Nonmetric multidimensional scaling is a technique designed to construct an n-dimensional "map" of populations, given a set of pairwise distances between populations (Manly 1986). The output from this analysis is a set of coordinates along n-axes, with the coordinates specific to the number of n-dimensions selected. To simplify our analysis we selected a 2-dimensional analysis to represent the relative positions of each population in a typical bivariate plot. The goodness of fit between the original allele-sharing distances and the pairwise distances between all populations along the 2-dimensional plot is measured by a "stress" statistic. Kruskal (in Rohlf 2002) developed a five-tier guide for evaluating stress levels, ranging from a perfect fit (stress=0) to a poor fit (stress=0.40). We

conducted the nonmetric multidimensional scaling analysis for one data set containing Chiwawa natural- and hatchery-origin collections, and another data set containing Chiwawa broodstock and in-river spawner collections. We used the mdscale module in MATLAB R2006b (The Mathworks 2006) to generate the nonmetric multidimensional scaling coordinates.

We examined the geographic and temporal structure of populations in the upper Wenatchee (Chiwawa River, Nason Creek, and White River, only) using a series of analyses of molecular variance (AMOVAs). Here, we defined an AMOVA as an analysis of variance of allele frequencies, as originally designed by Cockerham (1969), but implemented in Arlequin v2.1 (Schneider et al. 2000). These analyses permit populations to be aggregated into groups, and molecular variance is then partitioned into within collections, among collections, but within groups, and among group components. With this approach, we were able to determine how best to group populations, with "best" being defined as that grouping that accounts for the greatest proportion of among group variance. Furthermore, by partitioning molecular variance into three different hierarchical components, we are able to determine what level accounts for the majority of the molecular variance.

Finally, we explored the partitioning of molecular variance between among-individuals and among-populations using a principal component analysis and multi-locus estimates of pairwise $F_{ST}$, estimated by a "weighted" analysis of variance (Weir and Cockerham, 1984). Principal component analysis is a data-reduction technique whereby the correlation structure among variables can be used to combine variables into a series of multivariate components, with each original variable receiving a weighted value for each component based on its correlation with that component. Here, we used a program written by Warheit in MATLAB R2006b (The Mathworks 2006) that treats each allele for each locus as a single variable (13 loci = 26 alleles or variables), and these 26 "variables" were arranged into 26 components, with each component accounting for a decreasing amount of molecular variance. Estimates of $F_{ST}$ were calculated using GENETIX version 4.05 (Belkhir et al.1996). To determine if the $F_{ST}$ estimates were

statistically different from random (i.e., no structure), 1000 permutations were implemented in GENETIX version 4.05 (Belkhir et al.1996).

**Effective population size ($N_e$)** – Estimates of the effective population size were obtained using two methods, a multi-collection temporal method (Waples 1990), and a single-collection method (Waples 2006) using linkage disequilibrium data. The temporal method assumes that cohorts are used, but we did not decompose the collection year samples into their respective cohorts using age data. Therefore, $N_e$ estimates that pertain to individual year classes of breeders are not valid; however the harmonic mean over all samples will estimate the contemporary $N_e$. Comparing samples from years *i* and *j*, Waples' (1990) temporal method estimates the effective number of breeders ($\hat{N}_{b(i,j)}$) according to:

$$\hat{N}_{b(i,j)} = \frac{b}{2(\hat{F} - 1/\hat{S}_{i,j})}$$

The standardized variance in allele frequency ($\hat{F}$) is calculated according to Pollack (1983). The parameter b is calculated analytically from age structure information and the number of years between samples (Tajima 1992). The age-at-maturity information required to calculate b was obtained from Murdoch et al. (2006) for this analysis. They observed for Chiwawa Hatchery Chinook that 8.6% matured at age 2, 4% at age 3, 87% at age 4, and 0.4% at age 5. For Chiwawa natural Chinook, Murdoch et al. (2006) observed that 1.8% matured at age 3, 81.6% at age 4, and 16.7% at age 5. The harmonic mean of sample sizes from years *i* and *j* is $\tilde{S}_{i,j}$. Over all pairwise comparisons the harmonic mean of all $\hat{N}_{b(i,j)}$ is $\tilde{N}_b$, the contemporary estimate of the effective population size ($N_e$). SALMONNb (Waples et al. 2007) was used to calculate $\tilde{N}_b$. As suggested by authors, alleles with a frequency below 0.05 were excluded from the analysis to reduce potential bias.

The method of Waples (2006) uses linkage disequilibrium (i.e., mean squared correlation of allele frequencies at different gene loci) as a means of estimating effective population size ($N_e$) from a single sample. While this method is biased in some cases where $N_e$ /N

ratio is less the 0.1 and the sample size is less than the true $N_e$, it has been shown to produce comparable results to the temporal method. Burrows' delta method is used to estimate LD, and a bias corrected estimate of $N_e$ is calculated after eliminating alleles with frequency less than 0.05. This test was implemented using $LDN_e$ (Do and Waples unpublished). In age-structured species, $N_e$ estimates based on LD are best interpreted as the effective number of breeders ($N_b$) that produced the sample (Waples 2006). $N_b$ should be multiplied by the mean generation length (i.e., 4 in this case) to obtain an overall estimate of $N_e$ based on an $N_b$ estimate. We analyzed collections categorized by spawning location (i.e., hatchery broodstock or in-river) and did not analyze collections categorized by origin (i.e., hatchery or natural). Waples' (2006) method estimates $N_e$ from observed LD, therefore the corresponding $N_e$ estimates for the hatchery collections would be low and the estimates for the natural collections would be high. Yet, since the supplementation program is integrated, and hatchery fish can spawn naturally, we feel it inappropriate to analyze the hatchery and natural samples as if they were separate, which would essentially partition all the LD into the hatchery samples.

Each collection has an $N_b$ estimate and an associated confidence interval. If the confidence interval includes infinity, it means that sampling error accounts for all the LD observed (i.e., empirical LD is less than expected LD). The usual interpretation is that there is no evidence for any disequilibrium caused by genetic drift in a finite number of parents. Since the LD method estimates the number of breeders that contributed to the sample being analyzed, in order to calculate an $N_e$ /N ratio, the appropriate census size must be used. The census size used to derive a ratio was the estimate four years prior to the collection analyzed using LD, which assumed a strict four-year-old lifecycle, although the observed proportion of four-year-olds was approximately 85% each year. The census numbers (Table 2) used to calculate the ratios for Chiwawa broodstock and in-river spawners were combined NOS (natural-origin spawners) and HOS (hatchery-origin spawners) census estimates.

**Individual assignment** – A population baseline file was constructed containing all 1704 individual Chinook from 34 population collections (Table 1; Chiwawa origin data set

plus all samples from other populations). All individuals in the baseline had geneotypes that included nine or more loci. Individual Chinook were assigned to their most likely population of origin based on the partial Bayesian criteria of Rannala and Mountain (1997), using a "jack-knife" procedure, where each individual to be assigned was removed from the baseline prior to the calculation of population likelihoods. This procedure was implemented in a program written by Warheit in MATLAB R2006b (The Mathworks 2006). Two assignment criteria were used, 1) the population with the largest posterior probability for an individual was the "most-likely" population of origin (i.e., all individuals assigned to a collection), and 2) an assignment was consider valid only if the posterior probability was greater than or equal to 0.9. Please note that while the analysis used 34 population collections to assign Rannala and Mountain likelihoods for each individual, these likelihoods were aggregated based on "population" (i.e., Chiwawa, Nason, White, and so on) and posterior probabilities were calculated for population location, rather than individual collections.

## Results and Discussion

In this section we combine our presentation and interpretations of the genetic analyses. Additionally, this section will be organized based on the task list presented in the study plan. Overall conclusions are provided following this section.

## Task 1: Determine trend in census size for Chiwawa River spring Chinook.

Census data from 1989 – 2005 are provided in Table 2 for the Chiwawa Hatchery broodstock and spring Chinook present in the Chiwawa River. The demographic data for naturally spawning Chinook are based on redd sampling and carcass surveys, while broodstock data are based on Chiwawa hatchery records. As the supplementation program is integrated by design, we also present the proportion of natural-origin broodstock (pNOB) incorporated into the hatchery, in addition to the number of natural-origin (NOS) and hatchery-origin (HOS) spawners present in Chiwawa River. The

census size fluctuated yearly, and a general reduction in census size was observed in the mid to late 1990's. This trend was apparent in both the broodstock and in the river. The arithmetic mean census size from 1989 – 2005 for the Chiwawa Hatchery (i.e., broodstock) was N=87.5 per year. The arithmetic mean census size from 1989 – 2005 for the Chiwawa River (i.e., NOS and HOS combined) was N=961.9 per year. For collection years when adult Chiwawa hatchery-origin fish would have been absent in the Chiwawa River (1989 – 1992), the arithmetic mean of natural Chiwawa Chinook census size is N=962.7. We will use this number as the baseline census size to assess if census size has changed. We used two different values for the contemporary census size in the Chiwawa River, NOS only and NOS + HOS. Additionally, we used collection years 2002 – 2005 for the contemporary NOS and HOS estimates, as these are the most recent data and the number of years included for estimation is the same as the pre-hatchery estimate above (i.e., four years). For NOS only, the arithmetic mean census size from 2002 – 2005 was N=536.0. For total census size (i.e., NOS and HOS combined), the arithmetic mean census size from 2002 – 2005 was N=1324.0. For the demographic data presented here, the contemporary census size is larger than the census estimate derived from the years prior to hatchery operation.

## Task 2: Document the observed genetic diversity.

*Genetic Diversity Categorized By Origin*

For Chiwawa River collections categorized by origin (Table 1A), substantial genetic diversity was observed, with heterozygosity estimates over all loci, having a mean of 0.80. Genetic diversity was consistent with expected Hardy-Weinberg random mating genotypic proportions for ten of the eighteen collections. Eight of the nine Chiwawa natural collections were consistent with HWE, and two of nine Chiwawa Hatchery collections were consistent with HWE. $F_{IS}$ is observed to be slight for all Chiwawa population collections, suggesting individuals within collections do not show excessive homozygosity.

The deviations from HWE observed were generally associated with hatchery collections. The two smolt collections (i.e., 1993 and 1994) showed significant deviations from HWE, which may be a function of non-random hatchery practices involving the contributing natural-origin parental broodstocks (i.e., 1991 and 1992 cohort). Deviations from HWE in the remaining hatchery collections may be the result of few individuals being represented in the broodstock (see below).

Additionally, linkage disequilibrium (LD) was also common for Chiwawa hatchery-origin collections and minimal for Chiwawa natural-origin collections. The random association of alleles between loci (i.e., linkage equilibrium) is expected under ideal conditions. LD is observed when particular genotypes are encountered more than expected by chance. Laboratory artifacts (e.g. null alleles) or physical linkage of loci on the same chromosome can cause LD, but the LD we observed was not associated with certain locus combinations, which you would expect if either artifacts or physical linkage were the cause of LD. LD was observed for seven of the nine hatchery-origin collections. As with the deviations from HWE, the high LD in the 1993 and 1994 hatchery-origin collections may be a result of non-random hatchery practices. The substantial LD observed in the hatchery-origin adult collections (collection years 2000, 2001, 2004, and 2006) might be the result of small parental broodstock sizes contributing to those returning adults. During the mid 1990's, the Chiwawa broodstock size was low, with zero individuals collected in 1995 and 1999; so fewer individuals would be contributing to the hatchery adult returns than the natural. This idea is corroborated by the lower LD observed for the 2005 hatchery-origin collection, which had a contributing parental broodstock size in 2001 (i.e., the major contributing parental generation) approximately eight times as large as the previous few collection years (Table 2). LD reappears in the 2006 Chiwawa hatchery-origin collection, which had a contributing parental broodstock size (i.e., for the most-part, the 2002 hatchery brood year) five times lower (Table 2) than that of the 2005 collection.

While seven of nine hatchery-origin collections showed significant LD, only one natural origin collection showed LD, and for this collection, only 10% of the loci-pairs were in

disequilibrium (Table 1). The fact that LD predominated in the hatchery samples, suggests that variance in reproductive success (i.e., overrepresentation of particular parents) is higher in the hatchery-origin than in natural-origin collections.

*Genetic Diversity Categorized By Spawning Location*

For upper Wenatchee River collections categorized by spawning location (Table 1B), substantial genetic diversity was observed, with heterozygosity estimates over all loci, having a mean of 0.79 and ranging from a low of 0.69 (1993 White River) to 0.85 (1993 Little Wenatchee). Genetic diversity was consistent with HWE for nineteen of twenty-nine population collections. For the collections that departed from HWE, seven were from the Chiwawa River, one was from Leavenworth Hatchery, one was the Wenatchee mainstem collection of hatchery-origin – naturally spawning fish, and one was from the White River. $F_{IS}$ is observed to be slight for all population collections except the 1993 White River collection (10% heterozygote deficit) (Table 1B). Collections deviating with HWE generally correlated with collections having high LD. Twelve population collections showed a proportion of pairwise linkage disequilibrium tests (across all loci) greater than 5% (Table 1B), eight of which were Chiwawa collections.

Starting in 1996, spawning location collections are composed of both natural- and hatchery-origin samples. The LD seen in the later spawning location collections may be caused by an admixing effect (i.e., mixing two populations), where random mating has not had the chance to freely associate alleles into genotypes. Interestingly, there appears to be a trend of reducing LD through time within the broodstock collections (Table 1B), which suggests that a "homogenizing" effect is taking place within the Chiwawa River. This observation is discussed more fully in Task 3 below.

## <u>Task 3:</u> Test for population differentiation among collections within the Chiwawa River and associated supplementation program.

*Introduction*

Task 3 was designed to address two hypotheses listed as part of Objective 3 in Murdoch and Peven (2005):

- Ho: Allele frequency $_{\text{Hatchery}}$ = Allele frequency $_{\text{Naturally produced}}$ = Allele frequency $_{\text{Donor pop}}$.
- Ho: Genetic distance between subpopulations $_{\text{Year x}}$ = Genetic distance between subpopulations $_{\text{Year y}}$

Murdoch and Peven (2005) proposed these two hypotheses to help evaluate the Chiwawa supplementation program through the "Conceptual Process" (Figure 5 in Murdoch and Peven 2005; repeated here as Figure 1). There are two components to the first hypothesis, which must be considered separately. The first component involves comparisons between natural-origin populations in the Chiwawa to determine if there have been changes in allele frequencies or genetic distances, through time starting with the donor population. Documenting a change does not necessarily indicate that the supplementation program has directly affected the natural origin fish, as additional tests would be necessary to support that hypothesis. The intent of the second component is to determine if the hatchery produced populations have the same genetic composition as the naturally produced populations.

Although on the surface these two components and their associated comparisons may appear simple, from a hypothesis-testing perspective the analyses are complicated by the fact that natural-origin fish may have had hatchery-origin parents, and hatchery-origin fish may have had natural-origin parents. As such, we organized the Chiwawa genetic data into three data sets: (1) fish origin (hatchery versus natural), (2) spawning location (hatchery broodstock versus in-river (natural) spawners), and (3) four "treatment" groups (1. hatchery-origin hatchery broodstock, 2. hatchery-origin natural spawner, 3. natural-origin natural spawner, and 4. natural-origin hatchery broodstock). We conducted separate analyses using each of the three data sets, with each analysis touching on some aspect of the components necessary to move through the Conceptual Process (Figure 1).

*Hatchery- Versus Natural-Origin*

We address the following questions with the origin data set:

1. Are there changes in allele frequencies and allele sharing distances in the natural-origin collections from pre-supplementation to today?
2. Are there changes in allele frequencies and allele sharing distances in the hatchery-origin collections from early supplementation to today?
3. Are there significant differences in allele frequencies and large allele sharing distances between hatchery- and natural-origin adults from a collection year, and has this pattern changed through time?

**Genic Differentiation Tests –** We explicitly tested the hypothesis of no significant differentiation within natural- or hatchery-origin collections from the Chiwawa River using a randomization chi-square test. We show the results for the pairwise comparisons among natural-origin collections from the Chiwawa River populations in the first block of the second page of Table 3. Ten of the 36 (28%) pairwise comparisons have highly significant allele frequency differences, while only 12 of the 36 comparisons (33%) showed no significant differences. Eight of these 12 comparisons involved the 1996 collection, which included only eight samples and therefore provided little power to differentiate allele frequencies. If we exclude the 1996 collection, only 14% of the pairwise comparisons showed no significant differences, and here all but one of these comparisons involved the 1989 collection. The 1989 collection appeared to be the least differentiated collection in the natural-origin data set in that all pairwise comparisons were either not significant, or only mildly significant at the nominal critical value. No comparisons involving the 1989 collection were significant using a Bonferroni-corrected critical value, and 1989 is the only natural-origin collection in our data set that can be classified as "pre-supplementation."

We can interpret these results to indicate that although there appears to be significant year-to-year differences in allele frequencies among post-supplementation collections, the allele frequencies between each post-supplementation collection and the 1989 pre-supplementation collection are not greatly different. However, the level of differentiation

does increase from the early post-supplementation years to the more recent years (2001, 2004-2006), although the statistical level of this significance never exceeds the Bonferroni-corrected critical value. Finally, sample sizes were also small for the 1989 collection (n = 36) and we cannot eliminate a reduction in power as a contributing factor for the lack of significance for these tests.

As with the hatchery-origin collections, most pairwise comparisons of allele frequencies between hatchery-origin samples were significant (Table 3, first page, upper block). Out of the 36 pairwise comparisons, all but three are significant at some level, and most comparisons are highly significant. Similar to the natural-origin analysis, the non-significant results were limited to comparisons involving the 1996, which included only eight samples.

As a result of this analysis *we reject the hypothesis that there was no significant differentiation among natural- or hatchery-origin collections from the Chiwawa River*. Furthermore, the allele frequencies of the hatchery-origin collections are significantly different from those of natural-origin collections (Table 3, first page, second block). For those fish collected in the same year, allele frequencies are significantly different between hatchery- and natural-origin collections, although in 2005 the level of significance was below the Bonferroni critical value (Table 3). The next step is to examine the pattern of allelic differentiation to discover first if there is a trend among the data, and second, if this trend suggests that the allele frequency differences among Chiwawa River natural-origin fish collections has been affected by the hatchery-origin fish.

**Allele-sharing and Nonmetric Multidimensional Scaling –** We constructed a pairwise allele-sharing distance matrix for all hatchery- and natural-origin collections from the Chiwawa River and subjected this matrix to a nonmetric multidimensional scaling analysis, restricting the analysis to two dimensions (Figure 2). The stress statistic for this analysis is 0.09, a value Kruskal (in Rohlf 2002) listed as a good to excellent fit between the actual allele-sharing distances and the Euclidean (straight-line) distances in the plot.

In other words, Figure 2 is a good visual representation of the allele sharing distance matrix; collections with a high percentage of alleles shared will be closer to each other than collections with a lower percentage of alleles shared.

With the exception of the two outlier years (1996 and 1998) the Chiwawa natural-origin collections form a tight cluster indicating an overall common set of shared alleles among these collections. Even if we ignore the 1996 and 1998 hatchery-origin collections, there appears to be a greater variance in shared alleles among the Chiwawa hatchery-origin collections than the natural-origin collections (Figure 2). In fact, the median percentage of alleles shared among the Chiwawa natural-origin collections is 76% compared with 69% alleles shared among the Chiwawa hatchery-origin collections.

Also, there appears to be a convergence in allele sharing distances (i.e., a decrease in allele frequency differences) between the hatchery- and natural-origin fish from the late 1980s/early 1990s to 2006. The series of red arrows in Figure 2 represent the progression of change in hatchery-origin allele sharing distances from 1996 (first adult hatchery origin fish in our analysis) to 2006 and this progression is decidedly in the direction of the natural-origin cluster. However, the most recent natural-origin collections (2001, 2004-2006) appear to have pulled closer to the hatchery-origin collections, compared with the 1989 natural-origin collection (note the close proximity of the 2000 and 1989 natural-origin collections). Nevertheless, the cluster of natural-origin collections adjacent to the hatchery-origin collections in Figure 2 also includes the 1993 natural-origin collection. Qualitatively, it appears that the initial hatchery-origin and natural-origin collections were more different from each other in terms of the percentage of shared alleles than are the most recent hatchery- and natural-origin collections. This may have been a result of a non-random sample of natural-origin fish that was used as broodstock in the initial years of the supplementation program (see discussion in Task 2 concerning deviations from HWE and linkage disequilibrium).

That being said, we do need to emphasize that Figure 2 is dominated by five outlier collections (two each from the 1996 and 1998 collections, and the 1994 smolt collection).

The 1996 and 1998 collections are characterized by small samples sizes, and the 1994 smolt collection has nearly all pairs of loci in linkage disequilibrium (Table 1). If we eliminate these five outlier groups, both the hatchery- and natural-origin collections form a relatively tight cluster. Excluding the five outliers, the median percentage of shared alleles among all pairwise combinations of Chiwawa hatchery versus Chiwawa natural collections is 76%. This compares with a median pairwise percentage of 79% among only Chiwawa natural-origin collections. That is, there are nearly as many alleles shared between the hatchery-origin and natural-origin collections as there are among the natural-origin collections themselves. There is also a narrowing of differences between natural- and hatchery-origin fish from the same collection years from 1993 (76% shared alleles) through 2006 (83% shared alleles).

If allelic differentiation among collections is a function of genetic drift, we would expect a positive correlation between the number of years between two collections and the allele sharing distance. That is, if genetic drift is the primary cause of allele frequency differences between two collections, the greater the number of years between the two collections the larger the allele-sharing distance. For both the natural- and hatchery-origin collections we examined the relationship between the number of years between a pair of collections and the collections' allele-sharing distance (Figure 3). Although the relationship between time interval and allele distance appears to be a positive function in the natural collections, the slope of the regression line is 0.0017, and is not significantly different from zero. Furthermore, the correlation coefficient ($r^2$) equals 0.1068, which means that the time interval between collections accounts for only 10% of the pairwise differences in allelic distance. The hatchery-origin collections do show a significantly positive slope (0.0037; $p = 0.0254$) and a regression coefficient nearly three times greater than that for the natural-origin collections. However, the correlation coefficient is still relatively small ($r^2 = 0.3290$), indicating that the time interval between collections accounts for one-third of the pairwise differences in allelic distance. The results suggest that if genetic drift is a factor in allelic differentiation between collections, it is only a minor factor, and appears to have affected the hatchery-origin collections more than the natural-origin collections.

If four-year-old fish dominate each collection year, we would expect a closer relationship among collections that are spaced at intervals of four years. The average percentage of alleles shared between two natural-origin collections that are separated by four years or a multiple of four years is 81%, compared with 78% for natural-origin collections separated by years that are not divisible by four. Likewise, for hatchery-origin collections the average percentage of alleles shared is 80% and 75% for collections separated by years divisible and not divisible by four, respectively. Although the percent differences described above are relatively small, they are consistent with the idea that allelic differences between collections are a function of year-to-year variability among different cohorts of four year-old fish.

**Summary –** The allele frequencies within and between natural- and hatchery-origin collections are significantly different, but there does not appear to be a robust signal indicating that the recent natural-origin collections have diverged greatly from the pre- or early post-supplementation collections. Genetic drift will occur in all populations, but does not appear to be a major factor with the Chiwawa collections. We propose that the differences among collections are a function of differences in allele frequencies among cohorts of the four year-old fish that dominate each collection.

*Hatchery Broodstock Versus Natural (In-River) Spawners*

We address the following questions with the spawner data set:

1. Are there changes in allele frequencies and allele sharing distances in the natural spawning collections from pre-supplementation to today?
2. Are there changes in allele frequencies and allele sharing distances in the hatchery broodstock collections from early supplementation to today?
3. Are there significant differences in allele frequencies and large allele sharing distances between hatchery and natural spawning adults from a collection year, and has this pattern changed through time?

**Genic Differentiation Tests –** For the most part there are significant differences in allele frequencies among collections for both the hatchery broodstock and natural spawners (Table 4), and these differences are consistent with the origin data set (Table 3). There are four collection years with paired samples (2001, 2004-2006) where we can compare allele frequency differences between the hatchery broodstock and natural spawners, within the same year. The 2001 hatchery broodstock and natural spawner collections have significantly different allele frequencies, but the level of significance decreased from 2001 to 2004, and become non-significant in 2005 and 2006 (Table 4). This indicates that by 2005, the hatchery broodstock and natural spawners collections were effectively sampling from the same population of fish. Additionally, the percentage of alleles shared between the hatchery broodstock and the natural spawners increased from 76% in 2001 to 86% in 2006 (allele sharing distance matrix, not shown). From this analysis, we conclude that although there are year-to-year differences in allele frequencies within the natural and hatchery spawner collections, *there appears to be a convergence of allele frequencies within collection-year, between the natural and hatchery spawner populations*.

**Linkage Disequilibrium** – Linkage disequilibrium is the correlation of alleles between two loci, and can occur for several reasons. If two loci are physically linked on the same chromosome, than alleles from each of these loci should be correlated. However, linkage between two loci can occur as a result of population bottlenecks, small population sizes, and natural selection. If any of these conditions had occurred or were occurring within the Chiwawa River system, we would expect to find substantial linkage disequilibrium in many or perhaps all Chiwawa collections. However, many Chiwawa collections, especially the natural-origin collections, do not show linkage disequilibrium (Table 1), and it would appear that the linkage disequilibrium within certain Chiwawa collections is not a function of the processes listed above. Linkage disequilibrium can also result if the collection is composed of an admixture. That is, if two or more reproductively isolated populations are combined into a single collection, the collection will show linkage disequilibrium. Each broodstock and natural spawning collection is composed of natural- and hatchery-origin fish. If these hatchery- and natural-origin fish are drawn from the

same population, the spawning collections should not show substantial linkage disequilibrium. However, if the hatchery- and natural-origin fish are from different populations (i.e., full hatchery – natural integration has not been achieved), the spawning collections should show substantial linkage disequilibrium.

There are only three Chiwawa spawning collections that are not composed of both hatchery- and natural-origin samples: 1989 (natural-origin, natural spawner), 1993 (natural-origin, hatchery broodstock), and 2001 (natural-origin, natural spawner). Of the 10 spawning collections with both hatchery- and natural-origin fish, seven show significant linkage disequilibrium. Two of the three collections that did not show linkage disequilibrium are the 1996 and 1998 hatchery broodstock collections, which are composed of only seven natural- and six hatchery-origin fish, and two natural- and 19 hatchery-origin fish, respectively. Within the hatchery broodstock collections with linkage disequilibrium, the percent of loci pairs showing linkage decreased from 32% in 2000 to 13% in 2001 and 2004, to only 1% and 5% in 2005 and 2006, respectively (Table 1). If the homogenization of allele frequencies of natural- and hatchery-origin fish was increasing from 2000 to 2006, we would expect a decrease in linkage disequilibrium among the broodstock collections. This is what occurred within the hatchery broodstock collections, but did not occur within the natural spawner collections, where the percent of loci pairs showing linkage was 18% in 2004, 6% in 2005, and 10% in 2006 (Table 1). Furthermore, the 2001 natural spawner collection, with no hatchery-origin component showed linkage disequilibrium with 9% of loci pairs.

There is no correlation between percent of loci pairs showing linkage disequilibrium and percent of broodstock composed of hatchery-origin fish ($r^2 = 0.0045$). Furthermore, the natural spawner and hatchery broodstock collections were each composed of roughly the same average percentage of hatchery-origin fish (57% and 53%, respectively). If the decrease in linkage disequilibrium among the hatchery broodstock collections from 2000 to 2006 was a result of a homogenization of allele frequencies of natural- and hatchery-origin fish in the broodstock, the same degree of homogenization did not occur within the

natural spawner collections. This would occur if natural- and hatchery-origin fish spawning within the river remain segregated, either by habitat or by fish behavior.

**Summary –** As with the origin data set, there are significant allele frequency differences within and between hatchery broodstock and natural spawner collections. However, in recent years the allele frequency differences between the hatchery broodstock and natural spawner collections has declined. Furthermore, based on linkage disequilibrium, there is a genetic signal that is consistent with increasing homogenization of allele frequencies within hatchery broodstock collections, but a similar homogenization within the natural spawner collection is not apparent. These data suggest that there exists consistent year-to-year variation in allele frequencies among hatchery and natural spawning collections, but there is a trend toward homogenization of the allele frequencies of the natural- and hatchery-origin fish that compose the hatchery broodstock.

*Four Treatment Groups*

Analyses of genetic differences between hatchery (broodstock) and natural spawner collections is confounded by the fact that each these two groups are composed of fish of natural- and hatchery-origin. To understand the effects of hatchery supplementation on *natural-origin fish that spawn naturally*, we needed to divide the Chiwawa data set into four mutually exclusive groups: (1) hatchery-origin hatchery broodstock, (2) hatchery-origin natural spawner, (3) natural-origin hatchery broodstock, and (4) natural-origin natural spawner, with each group consisting of multiple collection years, for a total of 25 different groups.

**Allele-sharing and Nonmetric Multidimensional Scaling –**As with previous analyses discussed above, we constructed a pairwise allele-sharing distance matrix for all collections from each of these treatment groups and subjected this matrix to a nonmetric multidimensional scaling analysis, restricting the analysis to two dimensions. Figure 4 shows that five outlier groups dominate the allele-sharing distances within this data set. These outlier groups are also present in Figure 2, as discussed above, and Figure 2 and 4 resemble each other because the same fish are included in each analysis. The difference

between Figures 2 and 4 is that in Figure 4 the fish are grouped into collection year and the four treatment groups, rather than collection year and two treatment groups (hatchery- versus natural-origin).

Figure 4 does not provide useful resolution of the groups within the polygon, because the outlier groups dominate the allele sharing distances. We removed the five outlier groups from Figure 4, recalculated the allele sharing distances and subjected this new matrix to a multidimensional scaling analysis (Figure 5). Figure 5 shows separation among the 2001, 2004-2006 collections, but this separation does not necessarily indicate that within-year collections are more similar to each other than any collection is to a collection from another year. For example, the 2006 natural-origin natural spawner and the 2005 natural-origin hatchery broodstock collections share 81% alleles, while the 2006 natural-origin natural spawner and 2006 hatchery-origin hatchery broodstock collections share 75% alleles. There does not appear to be any discernable pattern of change in allele-sharing distance among the collections relevant to pre- or post-supplementation. Although the 1989 pre-supplementation natural-origin collection appears distinct (Figure 5), the 1993 natural-origin hatchery broodstock collection appears quite similar to the 2005 and 2006 natural-origin collections (Figure 5). The 1993 natural-origin hatchery broodstock collection, although not technically pre-supplementation, is composed of fish whose ancestry cannot be traced to any Chiwawa hatchery fish. Therefore, there is no clear pattern of allele sharing change from pre-supplementation to recent collections.

There does appear to be some change in the average percentage of alleles shared within the 2001 to 2006 collections, with an increase from 74% in 2001 and 2004 to 78% and 79% in 2005 and 2006, respectively. The results provided by this analysis are consistent with the results presented in the origin and spawner data sets. That is, there are allele frequency and allele sharing differences among the collections, but analyses do not strongly suggest that these differences are a function of the supplementation program. Furthermore, there is also a weak signal that the hatchery and natural collections within the most recent years are more similar to each other than in the previous years.

**Overall Genetic Variance –** Although there are signals of allelic differentiation among Chiwawa River collections, there are no robust signs that these collections are substantially different from each other. We used two different analyses to measure the degree of genetic variation that exists among individuals and collections within the Chiwawa River. First, we conducted a principal component analysis using all Chiwawa samples with complete genotypes (i.e., no missing alleles from any locus). Although the first two principal component axes account for only 10.5% of the total molecular variance, a substantially greater portion of that variance is among individual fish, regardless of their identity, rather than among hatchery and natural collections (Figure 6). The variances in principal component scores among individuals are 11 and 13 times greater than the variance in scores among collections, along the first and second axes, respectively.

Second, we conducted a series of analyses of molecular variance (AMOVA) to ascertain the percentage of molecular variance that could be attributed to differences among collections. We organized these analyses to test also for differences in the hierarchical structure of the data. That is, we tested for differences among collections using the following framework:

- No organizational structure – all 25 origin-spawner collections considered separately
- Origin-spawner collections organized into 10 collection year groups
- Origin-spawner collections organized into 2 breeding location groups (hatchery versus natural)
- Origin-spawner collections organized into 2 origin groups (hatchery versus natural)
- Origin-spawner collections organized into the 4 origin-spawner groups

It is clear from this analysis that nearly all molecular variation, no matter how the data are organized, resides within a collection (Table 5). The percentage of total molecular variance occurring within collections ranged from 99.68% to 99.74%. The among group variance component was limited to less than 0.26% and in all organizational structures,

except "no structure," the among group percentage was not significantly greater than zero. Furthermore, none of the organizational structures provided better resolution than "no structure" in terms of accounting for molecular variance within the data set. *These results indicate that if there are significant differences among collections of Chiwawa fish, these differences account for less than one percent of the total molecular variance, and these differences cannot be attributed to fish origin or spawning location.*

*Summary and Conclusions*

We reject the null hypothesis that the allele frequencies of the hatchery collections equal the allele frequencies of the natural collections, which equals the allele frequency of the donor population. Furthermore, because the allele-sharing distances are not consistent within and among collections years, we also reject the second stated hypothesis discussed above. However, there is an extremely small amount of genetic variance that can be attributed to among collection differences. The allelic differentiation that does exist among collections does not appear to be a function of fish origin, spawning location, genetic drift, or collection year. Figure 5 and related statistics does suggest that hatchery and natural collections in 2005 and 2006 are more similar to each other than previous years' collections, and this would be expected in a successful integrated hatchery supplementation program.

Since each of these collection years are generally composed of four-year-old fish, the differentiation among these collections for the most part is differentiation among specific cohorts. The slightly greater percentage of alleles shared among collections that are separated in time by multiples of four years, compared with collections that are not separated in time as such, suggests that cohort differences may be the most important factor accounting for differences in allele frequencies among collections.

## <u>Task 4:</u> Develop a model of genetic drift.

See Task 3

## <u>Task 5:</u> Analyze spring Chinook population samples from the Chiwawa River and Chiwawa Hatchery from multiple generations.

See Task 3

## <u>Task 6:</u> Analyze among population differences for upper Wenatchee spring Chinook.

Supplementation of the Chiwawa River spring Chinook population may affect populations within the Wenatchee River watershed other than the Chiwawa River stock. If the stray rate for Chiwawa hatchery-origin fish is greater than that for natural-origin fish, an increase in gene flow from the Chiwawa population into other populations may result. If this gene flow is high enough, Chiwawa River fish may alter the genetic structure of these other populations. Records from field observations indicate that hatchery-origin fish are present in all major spawning aggregates (A.R Murdoch, unpublished data), and these fish are successfully reproducing (Blankenship et al 2006). The intent of this task is to investigate if there have been changes to the genetic structure of the spring Chinook stocks within upper Wenatchee tributaries during the past 15-20 years, and if changes have occurred, are they a function of the Chiwawa River Supplementation Program? Therefore, we ask the following two questions:

1. Are allele frequencies within populations in the upper Wenatchee stable through time? That is, is there significant allelic differentiation among collections within upper Wenatchee populations?
2. Are the recent collections from the upper Wenatchee populations more similar to the Chiwawa population than earlier collections from the same populations?

For this task we analyzed natural spawning collections from the White River (natural-origin), Little Wenatchee River (natural-origin), Nason Creek (natural-origin), and

Wenatchee mainstem (hatchery-origin), and hatchery collections from Leavenworth NFH and Entiat River NFH (Table 1). We also included in the analysis the natural- and hatchery-origin collections from the Chiwawa River. There are no repeated collections from Leavenworth, Entiat, Little Wenatchee, and Wenatchee mainstem (Table 1), so for many of the analyses we have limited our discussion to the Chiwawa River, White River, and Nason Creek collections. Furthermore, genetic structure of the Little Wenatchee collection, which consisted of only 19 samples, was unexpectedly quite different from the other collections. For example, the $F_{ST}$ statistic measures the percent of total molecular variation that can be attributed to differences between populations. The median $F_{ST}$ for all pairwise combinations of collections from all populations, except Little Wenatchee (33 populations, 528 individual $F_{ST}$ statistics) equals 0.010 (1%), with a range of 0.000 to 0.037 (Table 6). The median $F_{ST}$ for the Little Wenatchee paired with all other collections (33 individual $F_{ST}$ statistics) equals 0.106 (10.6%), with a range of 0.074 to 0.121. The ten-fold increase in the $F_{ST}$ statistic indicates that either the Little Wenatchee spring Chinook is unique among the upper Wenatchee River stocks, or this 1993 collection is somehow aberrant. Therefore, we exclude the Little Wenatchee collection from many other analyses.

**Population Differentiation –** Table 3 provides the levels of significance for all pairwise genic differentiation tests. Most between-collection comparisons are highly significant, with no pattern of increasing or decreasing differentiation with time, and no differences when comparisons are made with Chiwawa hatchery- versus Chiwawa natural-origin fish. For example, excluding the outlier 1996 and 1998 Chiwawa hatchery- and natural-origin collections, Nason Creek showed highly significant allele frequency differences between the Chiwawa hatchery- and natural-origin collections at 100% and 86% of the comparisons, respectively. The same comparisons with the White River produced 100% and 93% highly significant allele frequency comparisons, respectively. Allele frequencies between Nason Creek and White River were likewise differentiated from each other.

The collection allele frequencies within the upper Wenatchee system are significantly different, and these differences do not appear to change as a function of time (Table 3). Nason Creek shows greater within-population year-to-year variation in allele frequencies than does the White River, with 47% of the pairwise comparisons showing highly significant differences, compared with only 13% for the White River. However, the 2005 and 2006 collections from the White River appear to be somewhat more differentiated from not only each other, but from the earlier collections from the White River.

Despite the high degree of temporal and spatial structure suggested by the genic differentiation tests, as described above for within-Chiwawa analysis (Task 3), most of the genetic variation within this data set occurs within populations, rather than between populations (Table 6). The $F_{ST}$ values for most population comparisons are between 0.01 and 0.02, indicating 1% to 2% among-population variance, with the remaining 98% to 99% variance occurring within populations. The White River shows the highest median $F_{ST}$ among the natural-origin collections, equal to 0.014, compared with 0.009 for both the Nason Creek and Chiwawa natural-origin collections. The median $F_{ST}$ for the Chiwawa hatchery-origin collections (0.012) was higher than that for the Chiwawa natural-origin collections.

Table 7 summarizes the information from the $F_{ST}$ analyses, under five different temporal and spatial scenarios. Under all scenarios, over 99% of the molecular variance is within populations. There is significantly greater spatial structure among populations ("Origin") in 2005 and 2006 than from 1989 to 1996. That is, there appears to be more spatial structure among the Chiwawa hatchery-origin, Chiwawa natural-origin, White River, and Nason Creek now, than in 1989 to 1996, despite the potential homogenizing and cumulative effect of hatchery strays. However, we stress that the amount of molecular variance associated with the among population differences, despite being significantly greater than 0.00%, is limited to only 0.43%.

**Allele-sharing and Nonmetric Multidimensional Scaling –** As in the Chiwawa River data discussed above, we constructed an allele-sharing distance matrix and then subjected

that matrix to a multidimensional scaling analysis (Figure 7). Consistent with all previously discussed multidimensional scaling analyses, the 1996 and 1998 adult, and the 1994 smolt collections are outliers. There is clear separation between the White River collections and all other natural-origin and Chiwawa hatchery-origin collections, indicating that there are more alleles shared among the Nason Creek and Chiwawa collections, than with the White River collections. Furthermore, there is a slight separation between the Chiwawa natural-origin natural spawner collections and Nason Creek collections, suggesting different groups of shared alleles between these populations. There is more variation in the allele-sharing distances among collections involved with the Chiwawa hatchery (origin or broodstock) than any of the natural-origin collections, even if we exclude the 1994, 1996, and 1998 collections. This suggests that there is more year-to-year variation in the composition of hatchery-origin and hatchery broodstock than within natural-origin populations throughout the upper Wenatchee. All Wenatchee mainstem fish are hatchery-origin, and if these fish are from the Chiwawa Supplementation Program (rather than from Leavenworth), it is not unexpected that this collection would be plotted within the Chiwawa polygon (Figure 7).

**Assignment of Individual to Populations –** Finally, we conducted individual assignment tests whereby we assigned each individual fish to a population, based on a procedure developed by Rannala and Mountain (1997) (Table 8 and 9). Individual fish may be correctly assigned to the population from which they were collected, or incorrectly assigned to a different population. Incorrect assignments may occur if the fish is an actual migrant (i.e., source population different from population where collected), or because the genotype for that fish matches more closely with a population different from its source. If there are many individuals from a population incorrectly assigned to populations other than its source population, that original population is either unreal (i.e., an admixture), or there is considerable gene flow between that population and other populations. Furthermore, in assigning individuals to populations, we can either accept the assignment with the highest probability, regardless of how low that probability may be, or we can establish a more stringent criterion, such as to not accept an assignment unless the posterior probability is equal to or greater than 0.90. This value is roughly

equal to having the likelihood of the most-likely population equal to 10 times that of the second most-likely population.

We provide a summary of the assignments in Tables 8 and 9. On average, nearly 50% of the fish are assigned incorrectly if we accept all assignments (Table 8), but the incorrect assignment rate drops to roughly 10% when we accept only those assignments with probabilities greater than 0.90. However, with this more stringent criterion, nearly 64% of the fish go unassigned. These results indicate that the allele frequency distributions for these populations are very similar, and it would be very difficult to assign an individual fish of unknown origin to the correct population. If all fish are assigned, there is a 50% chance, overall, of a correct assignment. If you accept only those assignment with the 0.90 criterion, nearly two-thirds of the fish would be unassigned, but there is a 90% chance of correctly assigning those fish that are indeed assigned.

Of all the populations in the data set, there are fewer errors associated with assigning fish to the White River. If all fish are assigned (Table 8), 72% of those fish assigned to the White River, are actually from the White River (115 fish out of a total of 159 fish assigned to the White River). This compares to a rate of only 52% and 53% for Nason Creek and Chiwawa natural-origin, respectively, and 60% for the Chiwawa hatchery-origin collections. With the 0.90 criterion (Table 9), 89% of the fish assigned to the White River, are actually from the White River, compared with 70% and 65% for Nason Creek and Chiwawa natural origin, respectively, and 81% for the Chiwawa hatchery origin.

When all fish are assigned, most of the incorrectly assigned fish from Nason Creek and White River are assigned to Chiwawa River, at roughly equal frequencies to the hatchery- and natural-origin populations. Incorrectly assigned fish to other populations occur at a slightly higher rate in Nason Creek than in the White River. However, when only those fish meeting the 0.90 criterion are assigned (Table 9), incorrectly assigned fish from Nason Creek are distributed among White and Chiwawa Rivers, as well as Leavenworth NFH, and the Entiat NFH. Mis-assignment to the Chiwawa hatchery-origin was the

highest among the Nason Creek collections, equal to nearly 14%. This contrasts with the White River where mis-assignments do not exceed 7% anywhere, and there is a roughly even distribution of mis-assignments among Nason Creek and Chiwawa River collections.

**Summary and Conclusions –** There is little geographic or temporal structure among populations within the upper Wenatchee systems. Among population molecular variance is limited to 1% or less. The little variance that can be attributed to among populations indicates that the White River is more differentiated from the Chiwawa and Nason populations than these populations are from each other. Furthermore, although we cannot rule out a hatchery effect on the Nason Creek and White River populations, there is no indication there has been any temporal changes in allele frequencies within these populations that can be attributed directly to the Chiwawa River Supplementation Program. In fact, Table 7 weakly suggests that there is more differentiation among these populations now, than there was before or at the early stages of Chiwawa supplementation.

Therefore, returning to our two original questions, there are significant differences in allele frequencies among collections within populations, and among populations within the upper Wenatchee spring Chinook stocks. However, these differences account for a very small portion of the overall molecular variance, and these populations overall are very similar to each other. There is no evidence that the Chiwawa River Supplementation Program has changed the allele frequencies in the Nason Creek and White River populations, despite the presence of hatchery-origin fish in both these systems. Finally, of all the populations within the Wenatchee River, the White River appears to be the most distinct. Yet, this distinction is more a matter of detail than of large significance, as the median $F_{ST}$ between White River collections and all other collections (except the Little Wenatchee) is less than 1.5% among population variance.

## Task 7: Calculate the inbreeding effective population size using demographic data for each sample year, and document the ratio of census to effective size.

This analysis was completed by Williamson et al. (submitted).

## Task 8: Calculate LD $N_b$ using genetic data for each sample year, and document the ratio of census to effective size.

We report $N_e$ estimated for the Chiwawa River collections based on the bias correction method of Waples (2006) implemented in LDNe (Do and Waples unpublished). $N_e$ estimates based on LD are best interpreted as the effective number of breeders ($N_b$) that produced the sample (Waples 2006).

For collections categorized by spawning location (i.e., hatchery broodstock or natural), estimates of $N_b$ are shown in Table 10. Considering the hatchery broodstock, $N_b$ estimates range from 30.4 (1996) to 274.3 (2005). To obtain $N_e$ /N ratios, the $N_b$ estimate is multiplied by four (i.e., mean generation length) and divided by the total in river (i.e., NOS [natural-origin spawners] plus HOS [hatchery-origin spawners]) census data from four years prior (i.e., major cohort; see Table 2). The observed $N_e$ /N ratios for the broodstock collections range from 11% to 54% of the census estimate, excluding the 2000 collection which is 106%. A ratio greater than one is possible under special circumstances, and certain artificial mating schemes within hatcheries can inflate $N_e$ above N; yet, it is unknown if this is the case for this collection. While no direct comparisons are possible, the $N_b$ estimates reported by Williamson et al. (submitted) for Chiwawa broodstock collections from 2000 – 2003 are similar in magnitude to our estimates. For Chiwawa natural spawner collections, the $N_b$ estimates range from 5.2 (1989) to 231.5 (2005), with observed $N_e$ /N ratios of 22% - 48% of the census estimate.

## <u>Task 9:</u> Calculate $N_b$ using the temporal method for multiple samples from the same location.

Estimates of effective number of breeders ($N_b$) derived from Waples' (1990) temporal method are shown in Tables 11-13. Eight collection years were used for the Chiwawa broodstock collections (Table 11). The harmonic mean of all pairwise estimates of $N_b$ ($\widetilde{N}_b$) was 269.4. This estimate is the contemporary $N_e$ for Chiwawa broodstock collections. For the five collection years of Chiwawa in-river spawners (Table 12), the estimated $\widetilde{N}_b$ = 224.2. This estimate is the contemporary $N_e$ for Chiwawa River natural spawner collections. Since the Chiwawa Supplementation Program is integrated by design, we also performed another estimation of $N_e$ using composite hatchery and natural samples. There are paired samples from 2004-2006. We combined genetic data for hatchery (HOS) and natural (NOS) origin fish from 2004 – 2006 to create a single Chiwawa River natural spawner sample for each year. The three composite samples from 2004 – 2006 were then analyzed using the temporal method (Table 13), resulting in a $\widetilde{N}_b$ = 386.8. This estimate is the contemporary $N_e$ for Chiwawa River.

Williamson et al. (submitted) estimated $N_e$ using Waples' (1990) temporal method for Chinook captured in 2004 and 2005, and used age data to decompose brood years into consecutive cohorts from 2000 – 2003. They report for Chiwawa broodstock a $\widetilde{N}_b$ = 50.4. This estimate is not similar to our Chiwawa broodstock estimate. However, if we analyze the hatchery-origin Chinook only, our estimate is $\widetilde{N}_b$ = 80.1 for collection years 1989 – 2006 (data not shown). Williamson et al. (submitted) report for Chiwawa naturally spawning Chinook a $\widetilde{N}_b$ = 242.7, which is slightly higher than our estimate for in-river spawners from 1989 – 2006, but lower than our estimate from combined NOS and HOS Chinook from 2004 – 2006 collection years.

## <u>Task 10:</u> Use available data and the Ryman-Laikre and Wang-Ryman models to determine the expected change of $N_e$ for natural spring Chinook salmon in the Wenatchee River due to hatchery operation.

$N_e$ is generally thought to be between 0.10 and 0.33 of the estimated census size (Bartley et al. 1992; RS Waples pers. comm.). We used this range to generate an estimate of $N_e$ for Chiwawa natural spawners prior to hatchery operation. For brood years 1989 – 1992, the arithmetic mean census size was N=962.7 (Table 2), resulting in an estimated $N_e$ ranging from 96.3 – 317.7. The contemporary estimate of $N_e$ calculated using genetic data for the Chiwawa in-river spawners is $N_e$=224.2 (Table 12), falling in the middle of the pre-hatchery range. The $N_e$ /N ratio calculated using 224.2 and the arithmetic census of NOS Chinook from 1989 – 2005 is 0.42. A more appropriate contemporary $N_e$ to compare with the pre-hatchery estimate (i.e., 96.3 – 317.7) is the combined NOS and HOS estimate from natural spawners, since the supplementation program is integrated. As discussed above, the contemporary estimate of $N_e$ calculated using genetic data for Chiwawa NOS and HOS Chinook is $N_e$=386.8 (Table 13), which is slightly larger than the pre-hatchery range, suggesting the $N_e$ has not declined during the period of hatchery operation. The $N_e$ /N ratio calculated using 386.8 and the arithmetic census of NOS and HOS Chinook from 1989 – 2005 is 0.40. These results suggest the Chiwawa Hatchery Supplementation Program has not resulted in a smaller $N_e$ for the natural spawners from the Chiwawa River.

Williamson et al. (submitted) argued that since their combined (i.e., broodstock and natural) $N_e$ estimate was lower than the naturally spawning estimate, the supplementation program likely had a negative impact on the Chiwawa River $N_e$. We disagree with this interpretation of these data. Since the natural spawning component is mixed hatchery and natural ancestry, the $N_e$ estimates from natural spawning data are the results that bear on possible hatchery impacts. The census data show the population declined in the mid 1990's and rebounded by 2000 (Table 2). This trend is reflected in the $N_e$ results, as shown above, and Williamson et al. (submitted) clearly show in their Table 4 the $N_e$ was lower in 2000 ($N_e$ = 989) than it was in 1992 ($N_e$ = 2683). Yet, the important comparison

they make in our view was the natural spawning $N_e$ versus the natural only component $N_e$ (i.e., hypothetically excluding hatchery program). Williamson et al. (submitted) report the 1989 – 1992 $N_e$ estimated from naturally spawning Chinook (i.e., NOS and HOS integrated) was essentially the same as the natural only component estimate, 2683 and 2776, respectively. This result is not surprising since no HOS fish were present between 1989 – 1992. They also report that the 1997 – 2000 $N_e$ estimated from naturally spawning Chinook (i.e., NOS and HOS integrated) was $N_e$ =989, while the natural-origin estimate of $N_e$ in 1997 – 2000 was $N_e$ = 629. Since the natural-origin estimate of 629 is lower than 989, the $N_e$ estimate from all in-river spawners, we argue that their analysis of demographic data show the $N_e$ estimated from naturally spawning Chinook (i.e., NOS and HOS integrated) is larger only if the hatchery Chinook in the river are ignored.

## Task 11: Use individual assignment methods to determine the power of self-assignment for upper Wenatchee River tributaries.

See "Assignment of Individual to Populations" in Task 6

## Conclusions

Has the Chiwawa Hatchery Supplementation Program succeeded at increasing the census size of the target population while leaving genetic integrity intact? This is an important question, as hatcheries can impact natural populations by reducing overall genetic diversity (Ryman and Laikre 1991), reducing the fitness of the natural populations through relaxation of selection or inadvertent positive selection of traits advantageous in the hatchery (Ford 2002; Lynch and O'Hely 2001), and by reducing the reproductive success of natural populations (McLean et al. 2003). The census data presented here show that the current natural spawning census size is similar to the pre-supplementation census size. Despite large numbers of hatchery-origin fish on the Chiwawa River spawning grounds, the genetic diversity of the natural-origin collections appear unaffected by the supplementation program; heterozygosities are high, and contemporary $N_e$ is similar (perhaps slightly higher) than pre-supplementation $N_e$. We did find

significant year-to-year differences in allele frequencies in both the origin and spawner datasets, but these differences do not appear to be related to fish origin, spawning area, or genetic drift. However, we do suggest that cohort differences may be the most important factor accounting for differences in allele frequencies among collections.

The main objective of this study was to determine the potential impacts of the hatchery program on natural spring Chinook in the upper Wenatchee system. We did this by analyzing temporally replicated collections from the Chiwawa River, and by comparing genetic diversity prior to the presumed effect of the Chiwawa Hatchery Supplementation Program, with contemporary collections. We report that the genetic diversity present in the Chiwawa River is unchanged (allowing for differences among cohorts) from 1989 – 2006, and the contemporary estimate of the effective population size ($N_e$) using genetic data is approximately the same as the $N_e$ estimate extrapolated from 1989 – 1992 census data (i.e., pre-hatchery collection years). We observed substantial genetic diversity, with heterozygosities ~80% over thirteen microsatellite markers. Yet, temporal variation in allele frequencies was the norm among temporal collections from the same populations (i.e., location). The genetic differentiation of replicated collections from the same population is likely the result of salmon life history in this area, as four-year-old Chinook comprise a majority of returns each year. The genetic tests are detecting the differences of contributing parents for each cohort. An important point related to the temporal variation, is that the hatchery broodstock is composed in part of the natural origin Chinook from the Chiwawa River. When we compared the genetic data (within a collection year) for Chinook brought into the hatchery as broodstock with the Chinook that remained in the river (years 2001, 2004 – 2006), there was a trend of decreasing statistical differences in allele frequencies from 2001 to 2004, and no differences were detected for 2005 and 2006. While the replicated collections may have detectable differences in allele frequencies, those differences reflect actual differences in cohorts, not the result of hatchery operations, and the hatchery broodstock collection method captures the differences in returning Chiwawa River spring adults each year. We conclude from these results that the genetic diversity of natural spring Chiwawa Chinook has been maintained during the Chiwawa Hatchery Supplementation Program.

We observe slight, but statistically significant population differentiation between Chiwawa River, White River, and Nason Creek collections. Murdoch et al (2006) and Williamson et al. (submitted) also observed population differentiation between Chiwawa River, White River, and Nason Creek collections. Yet, 99.3% of the genetic variation observed was within samples, very little variance could be attributed to population differences (i.e., population structure). The AMOVA analysis and poor individual assignment results suggest the occurrence of gene flow among Wenatchee River locations or a very recent divergence of these groups. While Murdoch et al. 2006 did not perform an AMOVA analysis, their $F_{ST}$ results provide comparable data to our among-population results. Murdoch et al. 2006 report $F_{ST}$ ranging from 2%-3% for pairwise comparisons between of Chiwawa, White, and Nason River collections. Since $F_{ST}$ is an estimate of among-sample variance, these results also imply a majority of the genetic variance (i.e., 97%-98%) resides within collections. To provide further context for the magnitude of these variance estimates, we present the among-group data from Murdoch et al. 2006 comparing summer-run and spring-run Chinook from the Wenatchee River. They report that approximately 91% of observed genetic variance is within-collection for comparisons between collections of summer- and spring-run Chinook. Ultimately, the information provided by this and other reports will be incorporated into the management process for Wenatchee River Chinook. However, we would like to emphasize that the application of these genetic data to management is more about the goals related to the distribution of genetic diversity in the future than specific data values reported. If Chinook are collected at Tumwater Dam instead of within the upper Wenatchee River tributaries, a vast majority of the genetic variation present in the basin would be captured, although any differences among tributaries would be mixed. Alternatively, management policies could be crafted to promote and maintain the among-group genetic diversity that genetic studies consistently observe to be non-zero within the Wenatchee River.

We agree with Murdoch et al. (2006) that it appears hatchery Chinook are not contributing to reproduction in proportion to their abundance. Additionally, if the total census size (i.e., NOS and HOS combined) within the Chiwawa River does not continue

to increase, genetic diversity may decline within this system, given the smaller $N_e$ within the hatchery-origin collections compared with the natural-origin collections.

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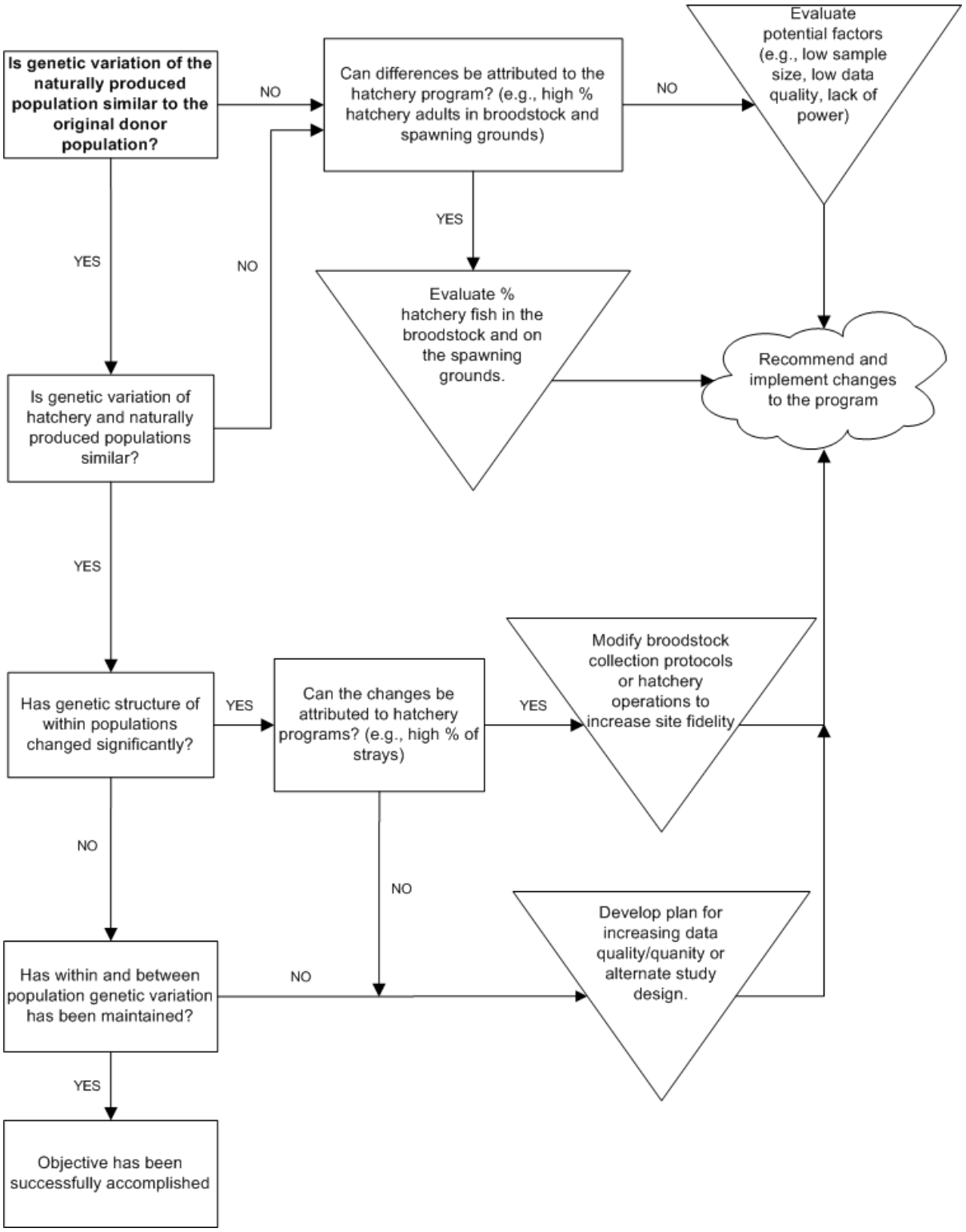


Figure 1. Conceptual process for evaluating potential changes in genetic variation in the Chiwawa naturally produced populations as a result of the supplementation hatchery programs (From Murdoch and Peven 2005).

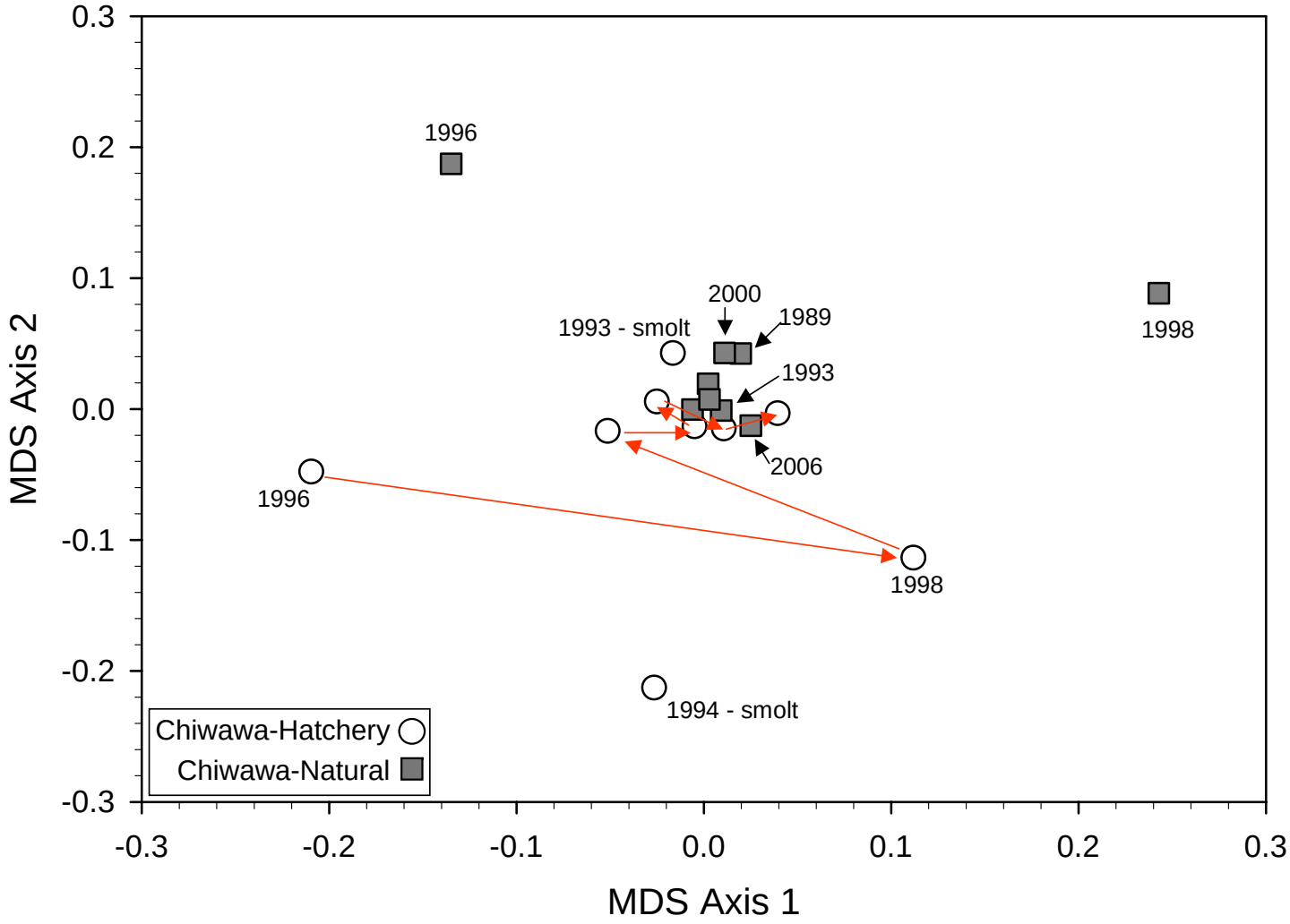


Figure 2. Multidimensional scaling plot from an allele-sharing distance matrix calculated from the Chiwawa data set organized by fish origin (i.e., hatchery versus natural). The red arrows connect consecutive hatchery-origin collections starting with the first adult collection (1996) and ending with the 2006 collection (see Table 1 for collection years).

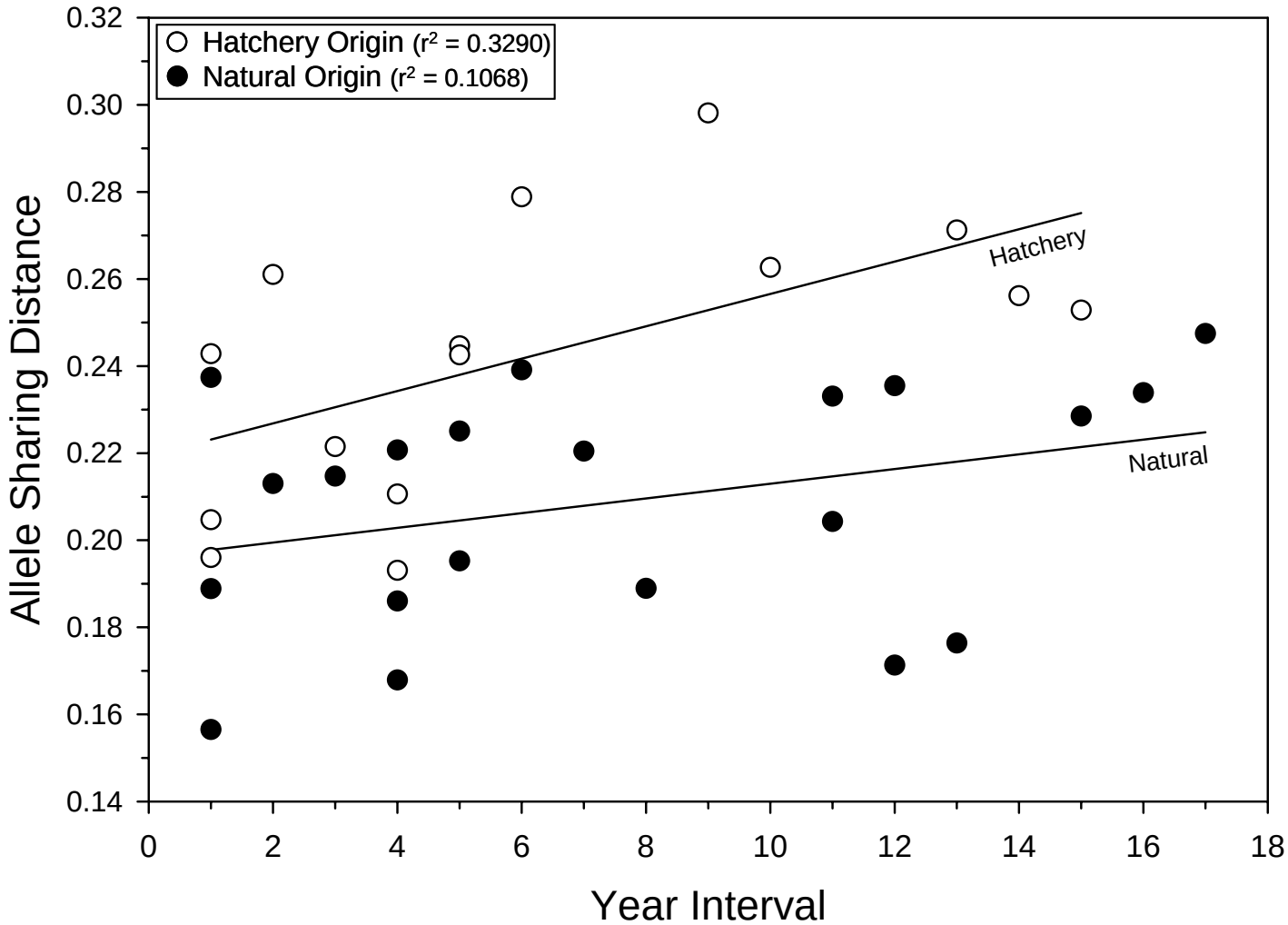


Figure 3. Relationships between the time interval in years and allele sharing distances, with each circle representing the pairwise relationship between two Chiwawa collections. Separate regression lines for the natural- and hatchery-origin collections. The slope for the natural-origin collection is not significantly different from zero (p=0.1483), while the slope for hatchery-origin collection is significantly greater than zero (p=0.0254) indicating a positive relationship between time interval and allele sharing distance.

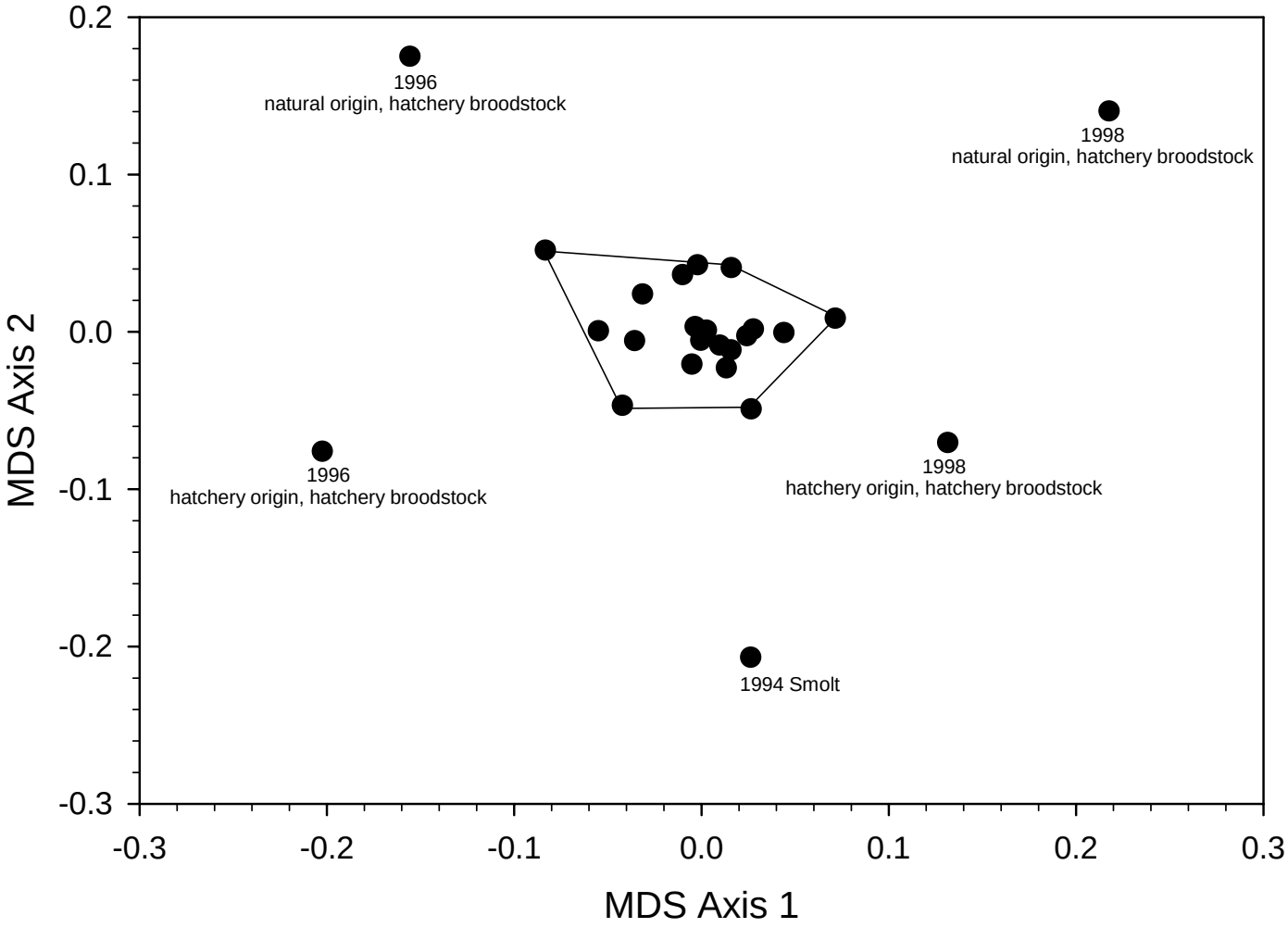


Figure 4. Multidimensional scaling plot from an allele-sharing distance matrix calculated from the Chiwawa data set organized by four treatment groups, as discussed in the text. Each circle represents a single collection within each of the four treatment groups, and the polygon encloses all groups that are not outliers. Each outlier group is specifically labeled.

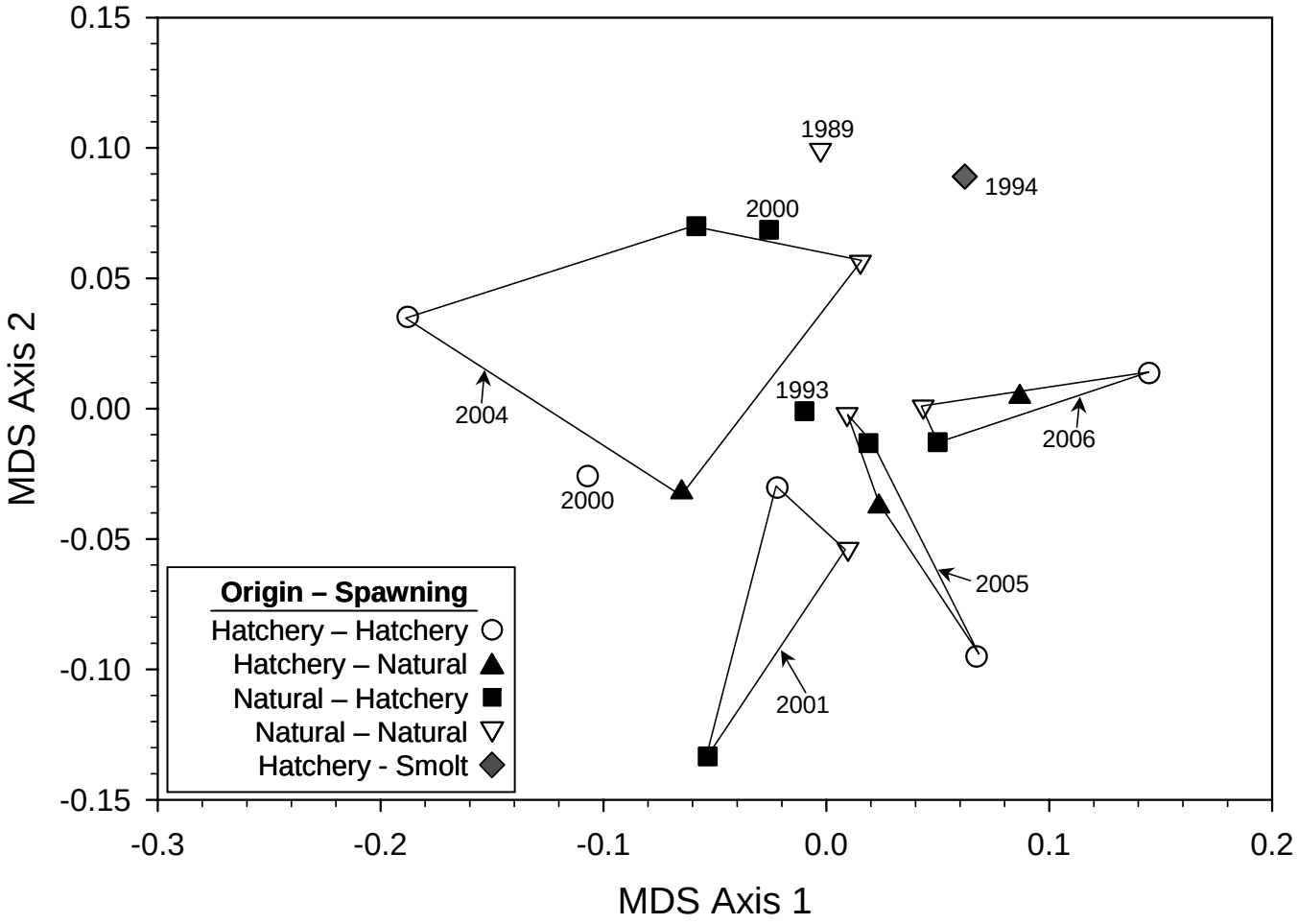


Figure 5. As in Figure 4, but allele-sharing distance matrix recalculated without the five outlier groups shown in Figure 4. Polygons group together treatment groups from the same collection year. Dates associated with symbols also refer to collection year. Collection years 2004-2006 included all four treatment groups, while collection year 2001 did not include a hatchery-origin natural spawner group. Legend is read as follows: Open circles refer to hatchery-origin hatchery spawner group, while filled box refers to natural-origin hatchery spawner group, and so on.

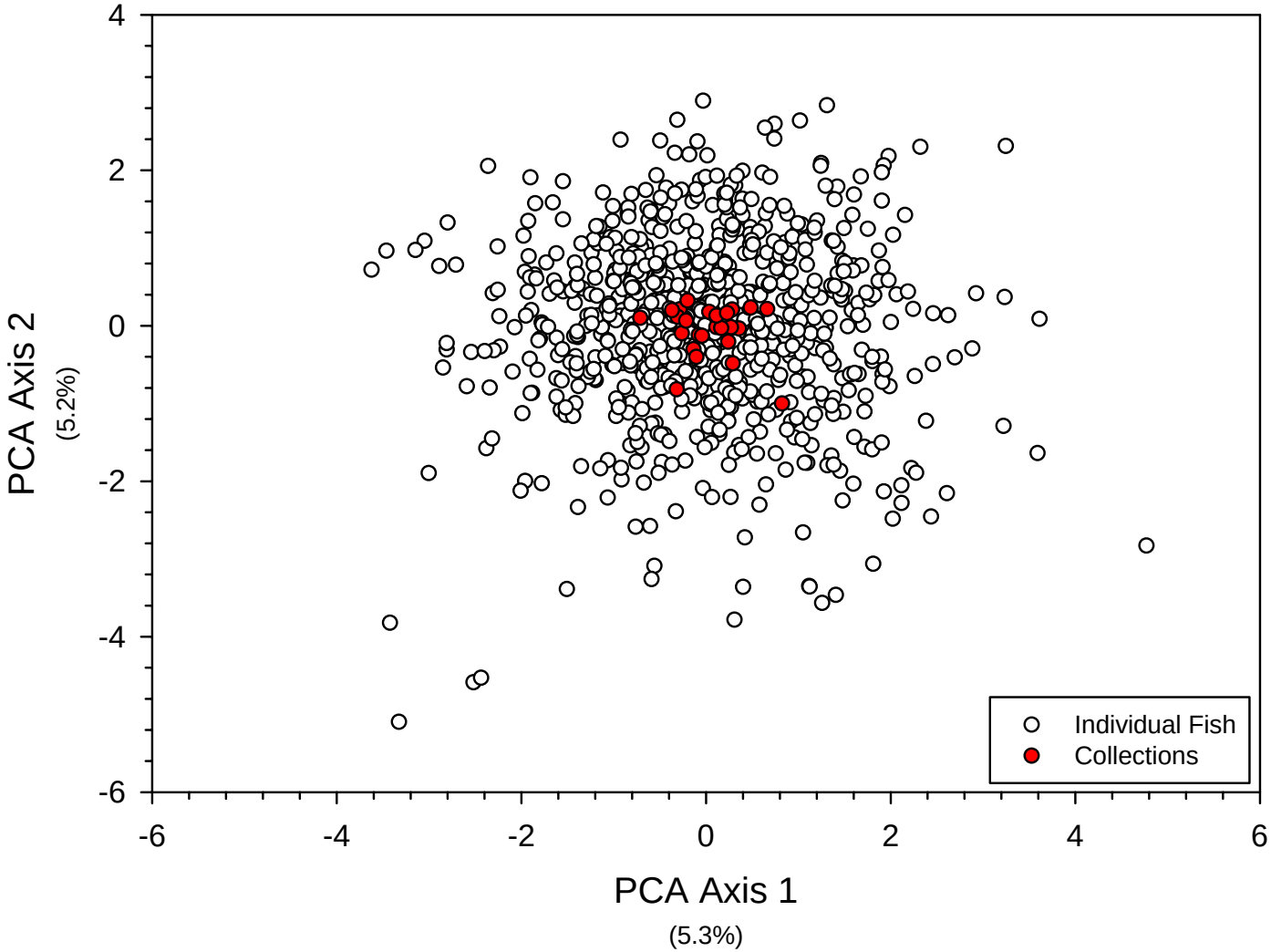


Figure 6. Principal component (PC) analysis of individual fish from the Chiwawa River. Only fish with complete microsatellite genotypes were included in the analysis (n = 757). Open circles are the PC scores for individual fish, and the filled circles are the centroids (bivariate means) for each of the 25 groups discussed in the text. PC axes 1 and 2 account for only 10.5% of the total molecular variance.

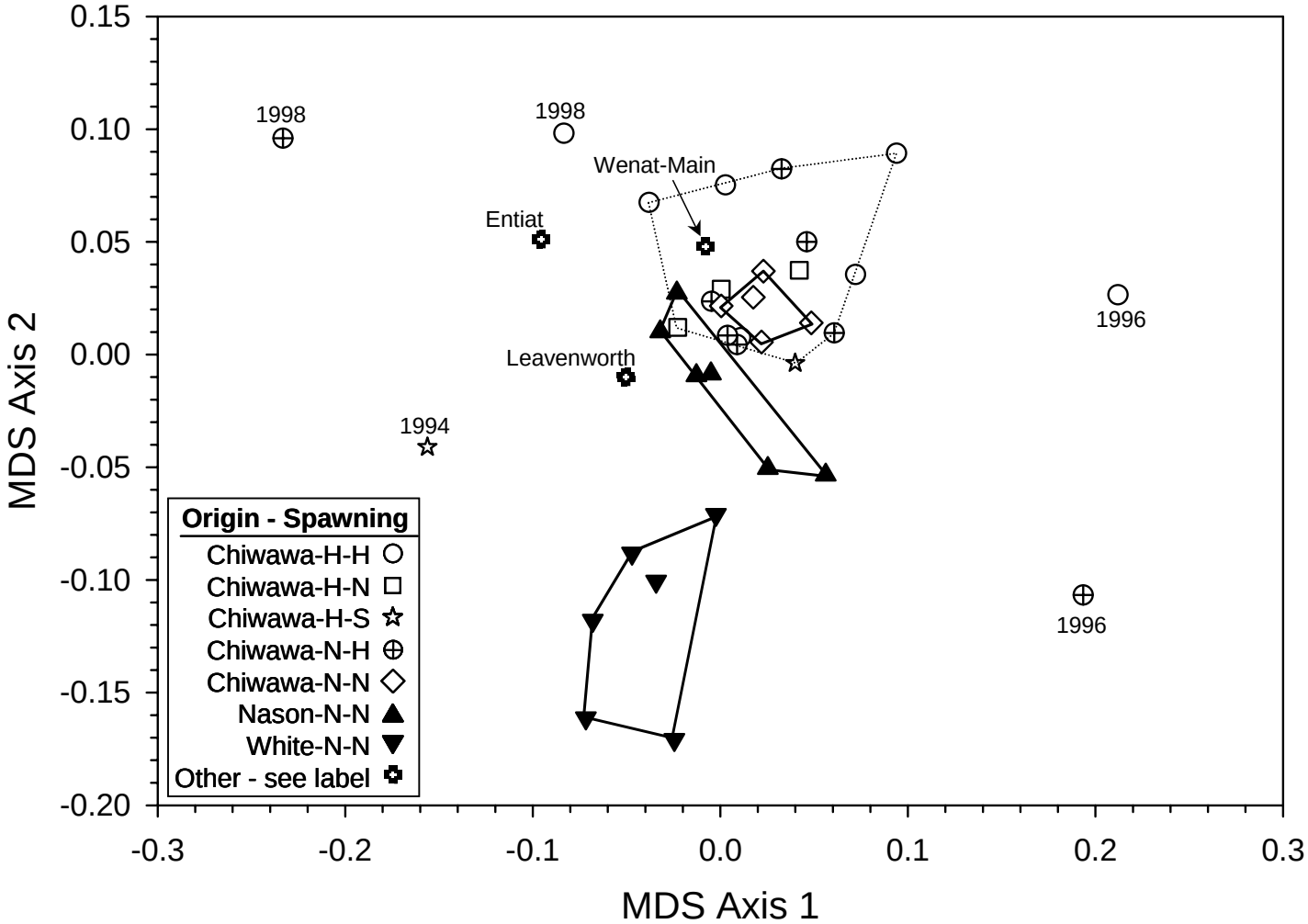


Figure 7. Multidimensional scaling plot from an allele-sharing distance matrix calculated from the Chiwawa origin data set and all other non-Chiwawa collections, except Little Wenatchee River. Legend is read with abbreviations beginning with origin and then spawning location. H=hatchery, N=natural, and S=smolts. Polygons with solid lines enclose the natural-origin natural spawner collections from each population (i.e., river). The polygon with the dotted lines enclose all Chiwawa collections, except for the five outlier collections, as discussed in text.

**Table 1** Summary of within population genetic data. Chiwawa collection data are summarized in A) by origin of the sample (i.e., clipped vs. non-clipped). All collection data are summarized in B) by spawning location (i.e., hatchery broodstock or on spawning grounds). Hz is heterozygosity, HWE is the statistical significance of deviations from Hardy-Weinberg expectations (* = 0.05, ** = 0.01, and *** = 0.001), LD is the proportion of pairwise locus tests (across all populations) exhibiting linkage disequilibrium (bolded values are statistically significant), and the last column is mean number of alleles per locus.

| Collection | Sample size | Gene Diversity | Observed Hz | HWE | $F_{IS}$ | LD | Mean # Alleles |
|---|---|---|---|---|---|---|---|
| A) Origin | | | | | | | |
| 1993 Chiwawa Hatchery | 95 | 0.77 | 0.79 | *** | -0.02 | **0.86** | 14.00 |
| 1994 Chiwawa Hatchery | 95 | 0.76 | 0.77 | *** | -0.01 | **0.91** | 11.38 |
| 1996 Chiwawa Hatchery | 8 | 0.75 | 0.81 | - | -0.01 | 0.00 | 8.23 |
| 1998 Chiwawa Hatchery | 27 | 0.81 | 0.82 | - | 0.00 | 0.04 | 12.62 |
| 2000 Chiwawa Hatchery | 43 | 0.75 | 0.78 | *** | -0.01 | **0.19** | 12.46 |
| 2001 Chiwawa Hatchery | 69 | 0.77 | 0.80 | *** | -0.02 | **0.14** | 15.31 |
| 2004 Chiwawa Hatchery | 72 | 0.77 | 0.77 | *** | 0.01 | **0.45** | 15.92 |
| 2005 Chiwawa Hatchery | 91 | 0.79 | 0.82 | * | -0.03 | **0.05** | 16.15 |
| 2006 Chiwawa Hatchery | 95 | 0.80 | 0.84 | *** | -0.05 | **0.49** | 15.85 |
| 1989 Chiwawa Natural | 36 | 0.76 | 0.78 | - | 0.01 | 0.00 | 12.77 |
| 1993 Chiwawa Natural | 62 | 0.78 | 0.81 | - | -0.02 | 0.04 | 15.85 |
| 1996 Chiwawa Natural | 8 | 0.72 | 0.78 | - | -0.02 | 0.00 | 7.54 |
| 1998 Chiwawa Natural | 10 | 0.78 | 0.84 | - | 0.00 | 0.00 | 8.23 |
| 2000 Chiwawa Natural | 39 | 0.78 | 0.79 | *** | 0.00 | **0.10** | 14.00 |
| 2001 Chiwawa Natural | 75 | 0.78 | 0.80 | - | -0.03 | 0.03 | 15.31 |
| 2004 Chiwawa Natural | 85 | 0.78 | 0.77 | - | 0.02 | 0.01 | 15.77 |
| 2005 Chiwawa Natural | 90 | 0.79 | 0.79 | - | 0.01 | 0.01 | 16.15 |
| 2006 Chiwawa Natural | 96 | 0.80 | 0.81 | - | -0.01 | 0.01 | 16.46 |

**Table 1** Within population genetic data analysis summary continued.

| Collection | Sample size | Gene Diversity | Observed Hz | HW | $F_{IS}$ | LD | Mean # Alleles |
|---|---|---|---|---|---|---|---|
| B) Spawning Location | | | | | | | |
| 1993 Chiwawa Broodstock | 62 | 0.78 | 0.81 | - | -0.02 | 0.00 | 15.85 |
| 1996 Chiwawa Broodstock | 16 | 0.75 | 0.79 | - | -0.02 | 0.00 | 10.92 |
| 1998 Chiwawa Broodstock | 37 | 0.82 | 0.83 | - | 0.00 | 0.01 | 14.38 |
| 2000 Chiwawa Broodstock | 82 | 0.78 | 0.78 | *** | 0.00 | **0.32** | 15.62 |
| 2001 Chiwawa Broodstock | 89 | 0.78 | 0.80 | * | -0.02 | **0.13** | 15.77 |
| 2004 Chiwawa Broodstock | 61 | 0.77 | 0.76 | * | 0.02 | **0.13** | 14.92 |
| 2005 Chiwawa Broodstock | 75 | 0.79 | 0.78 | * | 0.02 | 0.01 | 15.85 |
| 2006 Chiwawa Broodstock | 89 | 0.80 | 0.83 | - | -0.03 | **0.05** | 16.46 |
| 1989 Chiwawa River | 36 | 0.76 | 0.78 | - | 0.01 | 0.00 | 12.77 |
| 2001 Chiwawa River | 55 | 0.78 | 0.80 | - | -0.02 | **0.09** | 14.00 |
| 2004 Chiwawa River | 96 | 0.78 | 0.78 | * | 0.01 | **0.18** | 17.23 |
| 2005 Chiwawa River | 106 | 0.79 | 0.82 | * | -0.02 | **0.06** | 16.69 |
| 2006 Chiwawa River | 102 | 0.80 | 0.83 | *** | -0.03 | **0.10** | 16.77 |
| 1989 White River | 48 | 0.75 | 0.75 | - | 0.01 | 0.01 | 12.85 |
| 1991 White River | 19 | 0.76 | 0.76 | - | 0.03 | 0.00 | 10.92 |
| 1992 White River | 22 | 0.75 | 0.79 | - | -0.02 | 0.01 | 11.00 |
| 1993 White River | 21 | 0.75 | 0.69 | * | 0.10 | 0.00 | 10.15 |
| 2005 White River | 29 | 0.75 | 0.77 | - | -0.01 | 0.03 | 12.23 |
| 2006 White River | 40 | 0.76 | 0.76 | - | 0.01 | 0.04 | 13.38 |

**Table 1** Within population genetic data analysis summary continued.

| Collection | Sample size | Gene Diversity | Observed Hz | HW | $F_{IS}$ | LD | Mean # Alleles |
|---|---|---|---|---|---|---|---|
| 1993 Little Wenatchee R. | 19 | 0.84 | 0.85 | - | 0.02 | 0.00 | 11.23 |
| 1993 Nason Creek | 45 | 0.78 | 0.80 | - | -0.01 | 0.01 | 13.77 |
| 2000 Nason Creek | 51 | 0.76 | 0.78 | - | -0.02 | **0.13** | 13.92 |
| 2001 Nason Creek | 41 | 0.79 | 0.81 | - | -0.01 | **0.08** | 14.23 |
| 2004 Nason Creek | 38 | 0.76 | 0.76 | - | 0.02 | 0.03 | 13.23 |
| 2005 Nason Creek | 45 | 0.78 | 0.82 | - | -0.04 | 0.03 | 14.92 |
| 2006 Nason Creek | 48 | 0.80 | 0.82 | - | -0.01 | 0.00 | 15.77 |
| 2001 Wenatchee River | 32 | 0.79 | 0.80 | * | 0.00 | 0.04 | 12.85 |
| 2000 Leavenworth NFH | 73 | 0.80 | 0.82 | * | -0.02 | **0.15** | 16.23 |
| 1997 Entiat NFH | 37 | 0.81 | 0.83 | - | -0.01 | **0.06** | 14.38 |

**Table 2** Demographic data for Chiwawa Hatchery and Chiwawa natural spring Chinook salmon. BS is census size of hatchery broodstock, pNOB is the proportion of hatchery broodstock of natural origin, NOS is the census size of natural-origin spawners present in Chiwawa River, HOS is the census size of hatchery-origin spawners present in Chiwawa River, Total is NOS and HOS combined, and pNOS is the proportion of spawners present in Chiwawa River of natural origin.

| | Hatchery | | In River | | | |
|---|---|---|---|---|---|---|
| Brood Year | BS | pNOB | NOS | HOS | Total | pNOS |
| 1989 | 28 | 1 | 1392 | 0 | 1392 | 1.00 |
| 1990 | 18 | 1 | 775 | 0 | 775 | 1.00 |
| 1991 | 32 | 1 | 585 | 0 | 585 | 1.00 |
| 1992 | 78 | 1 | 1099 | 0 | 1099 | 1.00 |
| 1993 | 94 | 1 | 677 | 491 | 1168 | 0.58 |
| 1994 | 11 | 0.64 | 190 | 90 | 280 | 0.68 |
| 1995 | 0 | 0 | 8 | 50 | 58 | 0.14 |
| 1996 | 18 | 0.44 | 131 | 51 | 182 | 0.72 |
| 1997 | 111 | 0.29 | 210 | 179 | 389 | 0.54 |
| 1998 | 47 | 0.28 | 134 | 45 | 178 | 0.75 |
| 1999 | 0 | 0 | 119 | 13 | 132 | 0.90 |
| 2000 | 30 | 0.3 | 378 | 310 | 688 | 0.55 |
| 2001 | 371 | 0.3 | 1280 | 2850 | 4130 | 0.31 |
| 2002 | 71 | 0.28 | 694 | 919 | 1613 | 0.43 |
| 2003 | 94 | 0.44 | 380 | 223 | 603 | 0.63 |
| 2004 | 215 | 0.39 | 820 | 788 | 1608 | 0.51 |
| 2005 | 270 | 0.33 | 250 | 1222 | 1472 | 0.17 |

**Table 3** Levels of significance for pairwise tests of genic differentiation among all hatchery- and natural-origin collections used in this analysis. HS = highly significant (P < 0.000095; the Bonferroni corrected p-value for an alpha = 0.05); * = P < 0.05 (nominal critical value for most statistical test); - = P > 0.05 (not significant). A significant result between pairs of populations indicates that the allele frequencies between the pair are significantly different. Results are read by comparing the collections along the rows to collections along columns. The top block for each section is a symmetric matrix, as it compares collections within the same group.

| | | Chiwawa – Hatchery Origin | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **1993** | **1994** | **1996** | **1998** | **2000** | **2001** | **2004** | **2005** | **2006** |
| **Chiwawa – Hat. Origin** | **1993** | | HS | * | HS | HS | HS | HS | HS | HS |
| | **1994** | HS | | HS | HS | HS | HS | HS | HS | HS |
| | **1996** | * | HS | | * | - | * | - | - | * |
| | **1998** | HS | HS | * | | HS | HS | HS | HS | HS |
| | **2000** | HS | HS | - | HS | | HS | * | HS | HS |
| | **2001** | HS | HS | * | HS | HS | | HS | * | HS |
| | **2004** | HS | HS | - | HS | * | HS | | HS | HS |
| | **2005** | HS | HS | - | HS | HS | * | HS | | HS |
| | **2006** | HS | HS | * | HS | HS | HS | HS | HS | |
| **Chiwawa – Natural Origin** | **1989** | HS | HS | - | HS | HS | * | HS | HS | HS |
| | **1993** | HS | HS | - | HS | HS | - | HS | * | HS |
| | **1996** | * | HS | - | * | - | - | - | - | - |
| | **1998** | HS | HS | - | - | HS | * | * | * | - |
| | **2000** | HS | HS | - | HS | HS | HS | * | HS | HS |
| | **2001** | HS | HS | - | HS | HS | HS | HS | * | HS |
| | **2004** | HS | HS | - | HS | HS | HS | HS | HS | HS |
| | **2005** | HS | HS | - | HS | HS | * | HS | * | HS |
| | **2006** | HS | HS | - | * | HS | HS | HS | HS | HS |
| **Nason** | **1996** | HS | HS | - | HS | HS | HS | HS | HS | HS |
| | **2000** | HS | HS | * | HS | HS | HS | HS | HS | HS |
| | **2001** | HS | HS | - | HS | HS | HS | HS | HS | HS |
| | **2004** | HS | HS | - | HS | HS | HS | HS | HS | HS |
| | **2005** | HS | HS | - | HS | HS | HS | HS | HS | HS |
| | **2006** | HS | HS | - | * | HS | HS | HS | HS | HS |
| **White** | **1989** | HS | HS | HS | HS | HS | HS | HS | HS | HS |
| | **1991** | HS | HS | - | HS | HS | HS | HS | HS | HS |
| | **1992** | HS | HS | * | HS | HS | HS | HS | HS | HS |
| | **1993** | HS | HS | * | HS | HS | HS | HS | HS | HS |
| | **2005** | HS | HS | - | HS | HS | HS | HS | HS | HS |
| | **2006** | HS | HS | HS | HS | HS | HS | HS | HS | HS |
| **Other** | **Wen-M** | HS | HS | * | HS | HS | * | * | - | HS |
| | **Leaven** | HS | HS | * | HS | HS | HS | HS | HS | HS |
| | **Entiat** | HS | HS | * | HS | HS | HS | HS | HS | HS |

**Table 3** (con't)

| | | Chiwawa – Natural Origin | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **1989** | **1993** | **1996** | **1998** | **2000** | **2001** | **2004** | **2005** | **2006** |
| **Chiwawa – Natural Origin** | **1989** | | - | - | - | - | * | * | * | * |
| | **1993** | - | | - | * | * | * | HS | * | HS |
| | **1996** | - | - | | - | - | - | - | - | - |
| | **1998** | - | * | - | | * | * | HS | * | * |
| | **2000** | - | * | - | * | | HS | - | HS | HS |
| | **2001** | * | * | - | * | HS | | HS | * | HS |
| | **2004** | * | HS | - | HS | - | HS | | HS | HS |
| | **2005** | * | * | - | * | HS | * | HS | | * |
| | **2006** | * | HS | - | * | HS | HS | HS | * | |
| **Nason** | **1996** | * | * | - | * | * | HS | HS | HS | HS |
| | **2000** | HS | HS | HS | HS | HS | HS | HS | HS | HS |
| | **2001** | HS | * | - | * | HS | HS | HS | HS | HS |
| | **2004** | HS | HS | - | HS | HS | HS | HS | HS | HS |
| | **2005** | * | * | - | * | HS | HS | HS | HS | HS |
| | **2006** | HS | HS | - | - | HS | HS | HS | HS | HS |
| **White** | **1989** | HS | HS | * | HS | HS | HS | HS | HS | HS |
| | **1991** | HS | HS | * | - | HS | HS | HS | HS | HS |
| | **1992** | HS | HS | - | * | HS | HS | HS | HS | HS |
| | **1993** | HS | * | - | * | HS | HS | HS | HS | HS |
| | **2005** | HS | * | * | * | HS | HS | HS | * | HS |
| | **2006** | HS | HS | * | HS | HS | HS | HS | HS | HS |
| **Other** | **Wen-M** | * | - | - | - | * | * | HS | * | * |
| | **Leaven** | HS | HS | * | * | HS | HS | HS | HS | HS |
| | **Entiat** | HS | HS | * | HS | HS | HS | HS | HS | HS |

**Table 3** (con't)

| | | Nason | | | | | |
|---|---|---|---|---|---|---|---|
| | | **1996** | **2000** | **2001** | **2004** | **2005** | **2006** |
| **Nason** | **1996** | | HS | - | HS | - | * |
| | **2000** | HS | | HS | HS | HS | HS |
| | **2001** | - | HS | | * | - | * |
| | **2004** | HS | HS | * | | * | HS |
| | **2005** | - | HS | - | * | | - |
| | **2006** | * | HS | * | HS | - | |
| **White** | **1989** | HS | HS | HS | HS | HS | HS |
| | **1991** | * | HS | HS | HS | * | * |
| | **1992** | HS | HS | HS | HS | HS | HS |
| | **1993** | * | HS | HS | HS | HS | HS |
| | **2005** | * | HS | HS | HS | HS | HS |
| | **2006** | HS | HS | HS | HS | HS | HS |
| **Other** | **Wen-M** | HS | HS | HS | HS | * | HS |
| | **Leaven** | HS | HS | HS | HS | HS | HS |
| | **Entiat** | HS | HS | HS | HS | HS | HS |

**Table 3** (con't)

| | | White | | | | | | Other | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | **1989** | **1991** | **1992** | **1993** | **2005** | **2006** | **Wen-M 2001** | **Leaven 2000** | **Entiat 1997** |
| **White** | **1989** | | - | * | - | HS | HS | HS | HS | HS |
| | **1991** | - | | - | - | * | * | * | HS | HS |
| | **1992** | * | - | | - | * | * | HS | HS | HS |
| | **1993** | - | - | - | | * | * | HS | HS | HS |
| | **2005** | HS | * | * | * | | * | HS | HS | HS |
| | **2006** | HS | * | * | * | * | | HS | HS | HS |
| **Other** | **Wen-M** | HS | * | HS | HS | HS | HS | | HS | HS |
| | **Leaven** | HS | HS | HS | HS | HS | HS | HS | | HS |
| | **Entiat** | HS | HS | HS | HS | HS | HS | HS | HS | |

**Table 4** Probabilities (above diagonal) and levels of significance (below diagonal) for pairwise tests of genic differentiation among all Chiwawa hatchery broodstock and Chiwawa natural spawner collections used in this analysis. HS = highly significant (P < 0.000476; the Bonferroni corrected p-value for an alpha = 0.05); * = P < 0.05 (nominal critical value for most statistical test); - = P > 0.05 (considered not significant). A significant result between pairs of populations indicates that the allele frequencies between the pair are significantly different. Pairwise comparisons between the hatchery broodstock and natural spawner collections from 2001, 2004, 2005, and 2006, respectively, are highlighted.

| | | Smolt | | Hatchery Broodstock | | | | | | | | Natural Spawners | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1993 | 1994 | 1993 | 1996 | 1998 | 2000 | 2001 | 2004 | 2005 | 2006 | 1989 | 2001 | 2004 | 2005 | 2006 |
| Smolt | 1993 | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| | 1994 | HS | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| Hatchery Broodstock | 1993 | HS | HS | | 0.9155 | 0.0000 | 0.0073 | 0.3647 | 0.0003 | 0.0694 | 0.0000 | 0.2220 | 0.0039 | 0.0008 | 0.0095 | 0.0000 |
| | 1996 | HS | HS | - | | 0.0151 | 0.8388 | 0.0452 | 0.4916 | 0.3189 | 0.0716 | 0.5591 | 0.0759 | 0.8101 | 0.2364 | 0.0786 |
| | 1998 | HS | HS | HS | * | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0043 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0005 |
| | 2000 | HS | HS | * | - | HS | | 0.0000 | 0.4720 | 0.0000 | 0.0000 | 0.0036 | 0.0000 | 0.0712 | 0.0000 | 0.0000 |
| | 2001 | HS | HS | - | * | HS | HS | | 0.0000 | 0.0059 | 0.0000 | 0.0003 | 0.0000 | 0.0000 | 0.0126 | 0.0000 |
| | 2004 | HS | HS | * | - | HS | - | HS | | 0.0000 | 0.0000 | 0.0001 | 0.0000 | 0.0012 | 0.0000 | 0.0000 |
| | 2005 | HS | HS | - | - | HS | HS | * | HS | | 0.0005 | 0.0024 | 0.0137 | 0.0025 | 0.7782 | 0.0018 |
| | 2006 | HS | HS | HS | - | * | HS | HS | HS | * | | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.5770 |
| Natural Spawners | 1989 | HS | HS | - | - | HS | * | * | HS | * | HS | | 0.0023 | 0.0317 | 0.0000 | 0.0003 |
| | 2001 | HS | HS | * | - | HS | HS | HS | HS | * | HS | * | | 0.0000 | 0.2641 | 0.0000 |
| | 2004 | HS | HS | * | - | HS | - | HS | * | * | HS | * | HS | | 0.0000 | 0.0000 |
| | 2005 | HS | HS | * | - | HS | HS | * | HS | - | HS | HS | - | HS | | 0.0000 |
| | 2006 | HS | HS | HS | - | * | HS | HS | HS | * | - | * | HS | HS | HS | |

**Table 5** Analysis of molecular variance (AMOVA) for the Chiwawa collections, showing the partition of molecular variance into (1) within collections, (2) among collections but within group, and (3) among group components. Each column in the table represents a separate analysis testing for differences under a different spatial or temporal hypothesis. The different analyses are grouped together in a single table for comparisons. The values within the table are percentages and the parenthetical values are P-values, or probabilities, associated with that percentage. P-values greater than 0.05 indicate that the percentage is not significantly different from zero. For example, when collections are organized by hatchery- versus natural-origin ("Origin" – fourth column), 0.11% of the molecular variance is attributed to among group (i.e., hatchery- versus natural-origin), which is not significantly different from zero. No collections (first column) indicates no organization or grouping among all collections, and the among-group percentage is equal to the $F_{ST}$ for the entire data set.

| | No Structure | Collection Year | Spawning Location | Origin | Origin-Spawning Location |
|---|---|---|---|---|---|
| Among Groups | 0.26 (0.00) | 0.20 (0.43) | 0.05 (0.48) | 0.11 (0.15) | 0.11 (0.06) |
| Among collections - Within groups | - | 0.08 (0.003) | 0.24 (0.00) | 0.21 (0.00) | 0.18 (0.06) |
| Within collections | 99.74 (0.00) | 99.72 (0.00) | 99.71 (0.00) | 99.68 (0.00) | 99.71 (0.00) |

**Table 6** $F_{ST}$ values for all pairwise combinations of populations. Each $F_{ST}$ is the median value for all pairwise combinations of collections within each population (the number of collections within each population is shown parenthetically next to each population name on each row). For example, the $F_{ST}$ for the Chiwawa hatchery versus the White River (0.019) is the median value of 54 pairwise comparisons. The bold values along the center diagonal are the median $F_{ST}$ values within each collection. For those populations with only one collection, the diagonal value was set at 0.000.

| | Chiwawa-Hatchery | Chiwawa-Natural | Entiat | Leaven-worth | Nason | Wenatchee-main | White | Little Wenatchee |
|---|---|---|---|---|---|---|---|---|
| **Chiwawa-Hatchery (9)** | **0.013** | 0.008 | 0.016 | 0.012 | 0.011 | 0.005 | 0.019 | 0.111 |
| **Chiwawa-Natural (9)** | | **0.003** | 0.012 | 0.011 | 0.007 | 0.003 | 0.014 | 0.105 |
| **Entiat (1)** | | | **0.000** | 0.005 | 0.010 | 0.008 | 0.019 | 0.078 |
| **Leavenworth (1)** | | | | **0.000** | 0.007 | 0.008 | 0.014 | 0.092 |
| **Nason (6)** | | | | | **0.006** | 0.008 | 0.015 | 0.099 |
| **Wenatchee-main (1)** | | | | | | **0.000** | 0.012 | 0.098 |
| **White (6)** | | | | | | | **0.005** | 0.113 |
| **Little Wenatchee (1)** | | | | | | | | **0.000** |

**Table 7** As in Table 5, except data includes Chiwawa hatchery- and natural-origin, Nason Creek, and White River collections

| | All Years | All Years | 1989-1996 | 2005-2006 | 2005-2006 |
|---|---|---|---|---|---|
| | No Structure | Origin | Origin | Origin | Collection Year |
| Among Groups | 0.28<br>(0.00) | 0.33<br>(0.00) | -0.07<br>(0.67) | 0.43<br>(0.01) | -0.06<br>(0.57) |
| Among Collections - Within groups | - | 0.04<br>(0.00) | 0.22<br>(0.00) | 0.25<br>(0.00) | 0.64<br>(0.00) |
| Within Collections | 99.72 | 99.63 | 99.85 | 99.32 | 99.41 |

**Table 8** Individual assignment results reported are the numbers of individuals assigned to each population using the partial Bayesian criteria of Rannala and Mountain (1997) and a "jack-knife" procedure (see Methods). The population with the highest posterior probability is considered the stock of origin (i.e., no unassigned individuals). Individuals from each population are assigned to specific populations (along rows). Bold values indicate correct assignment back to population of origin. Individuals assigned to a population are read down columns. For example, of the 595 individuals from Chiwawa hatchery origin, 134 individuals were assigned to Chiwawa natural origin (reading across). Of the 511 individuals assigned to Chiwawa natural origin (reading down), 60 were from Nason Creek.

| **Population** | **Total** | **Unassigned** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1) Chiwawa Hatchery | 595 | 0 | **371** | 134 | 2 | 16 | 0 | 45 | 15 | 12 |
| 2) Chiwawa Natural | 501 | 0 | 156 | **269** | 4 | 5 | 0 | 42 | 9 | 16 |
| 3) Entiat | 37 | 0 | 4 | 5 | **13** | 8 | 0 | 6 | 1 | 0 |
| 4) Leavenworth | 73 | 0 | 9 | 8 | 3 | **33** | 0 | 17 | 0 | 3 |
| 5) Little Wenatchee | 19 | 0 | 0 | 0 | 0 | 0 | **19** | 0 | 0 | 0 |
| 6) Nason | 268 | 0 | 49 | 60 | 5 | 11 | 0 | **131** | 1 | 11 |
| 7) Wenatchee Mainstem | 32 | 0 | 12 | 9 | 0 | 1 | 0 | 2 | **6** | 2 |
| 8) White | 179 | 0 | 22 | 26 | 0 | 2 | 0 | 13 | 1 | **115** |
| TOTAL | 1704 | 0 | 623 | 511 | 27 | 76 | 19 | 256 | 33 | 159 |

**Table 9** As in Table 8, except the posterior probability from the partial Bayesian criteria of Rannala and Mountain (1997) must be 0.90 or greater, to be assigned to a population. Those individuals with posterior probabilities less than 0.90 are unassigned.

| **Aggregate** | **Total** | **Unassigned** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|---|---|
| 1) Chiwawa Hatchery | 595 | 332 | **214** | 31 | 1 | 4 | 0 | 10 | 3 | 0 |
| 2) Chiwawa Natural | 501 | 375 | 30 | **82** | 0 | 1 | 0 | 5 | 2 | 6 |
| 3) Entiat | 37 | 24 | 1 | 1 | **5** | 4 | 0 | 2 | 0 | 0 |
| 4) Leavenworth | 73 | 51 | 0 | 1 | 1 | **19** | 0 | 1 | 0 | 0 |
| 5) Little Wenatchee | 19 | 2 | 0 | 0 | 0 | 0 | **17** | 0 | 0 | 0 |
| 6) Nason | 268 | 188 | 11 | 6 | 2 | 5 | 0 | **53** | 0 | 3 |
| 7) Wenatchee Mainstem | 32 | 23 | 4 | 3 | 0 | 0 | 0 | 0 | **2** | 0 |
| 8) White | 179 | 92 | 4 | 3 | 0 | 1 | 0 | 5 | 1 | **73** |
| TOTAL | 1704 | 1087 | 264 | 127 | 9 | 34 | 17 | 76 | 8 | 82 |

**Table 10** Estimates of $N_e$ based on bias correction method of Waples (2006) implemented in LDNe (Do and Waples unpublished). Collections are categorized by spawning location. Sample size is the harmonic mean of the sample size, 95% CI is the confidence interval calculated using Waples' (2006) equation 12, and Major Cohort assumes that each collection is 100% four-year-olds.

| | Sample size | Estimated $N_b$ | 95% CI | Major Cohort | Census | $N_e/N$ |
|---|---|---|---|---|---|---|
| 1993 Chiwawa Broodstock | 58.4 | 103.1 | 77.0 - 149.7 | 1989 | 1392 | 0.30 |
| 1996 Chiwawa Broodstock | 15.5 | 30.4 | 19.6 - 58.1 | 1992 | 1099 | 0.11 |
| 1998 Chiwawa Broodstock | 33.4 | 37.7 | 29.8 - 49.7 | 1994 | 280 | 0.54 |
| 2000 Chiwawa Broodstock | 77.8 | 48.4 | 41.4 - 57.2 | 1996 | 182 | 1.06 |
| 2001 Chiwawa Broodstock | 80.4 | 49.6 | 42.2 - 59.2 | 1997 | 389 | 0.51 |
| 2004 Chiwawa Broodstock | 56.6 | 48.1 | 39.0 - 60.9 | 2000 | 688 | 0.28 |
| 2005 Chiwawa Broodstock | 73 | 274.3 | 148.9 - 1131.8 | 2001 | 4130 | 0.27 |
| 2006 Chiwawa Broodstock | 88.4 | 198.3 | 136.1 - 340.5 | 2002 | 1613 | 0.49 |
| | | | | | | |
| 1989 Chiwawa River | 26.6 | 5.2 | 3.9 - 6.3 | 1985 | | |
| 2001 Chiwawa River | 46.7 | 38.6 | 31.0 - 49.3 | 1997 | 389 | 0.40 |
| 2004 Chiwawa River | 88.5 | 82.6 | 67.3 - 104.4 | 2000 | 688 | 0.48 |
| 2005 Chiwawa River | 104.2 | 231.5 | 161.8 - 382.7 | 2001 | 4130 | 0.22 |
| 2006 Chiwawa River | 101.1 | 107.3 | 87.2 - 136 | 2002 | 1613 | 0.27 |

**Table 11** Summary of output from program SALMONNb and data for eight Chiwawa broodstock collections from Wenatchee River. For each pairwise comparison of samples *i* and *j*, $\tilde{S}$ is the harmonic mean sample size, *n* is the number of independent alleles used in the comparison, $\hat{N}_{b(i,j)}$ are the pairwise estimates of $N_b$, and Var [ $\hat{N}_{b(i,j)}$ ] is the variance of $\hat{N}_{b(i,j)}$. $\tilde{N}_b$ is the harmonic mean of the $\hat{N}_{b(i,j)}$. Alleles with a frequency below 0.05 were excluded from the analysis to reduce potential bias.

| Year | 1993 | 1996 | 1998 | 2000 | 2001 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|---|---|---|
| Pairwise $\tilde{S}$ (above diagonal) and *n* (below diagonal): | | | | | | | | |
| 1993 | - | 24.5 | 42.5 | 66.4 | 67.2 | 57.2 | 64.6 | 70.3 |
| 1996 | 82 | - | 21.2 | 25.8 | 26.0 | 24.4 | 25.6 | 26.4 |
| 1998 | 80 | 81 | - | 46.7 | 47.2 | 42.0 | 45.8 | 48.4 |
| 2000 | 80 | 82 | 84 | - | 78.6 | 65.2 | 75.1 | 82.7 |
| 2001 | 73 | 77 | 81 | 76 | - | 66.0 | 76.2 | 84.2 |
| 2004 | 77 | 81 | 75 | 76 | 78 | - | 63.5 | 69.0 |
| 2005 | 71 | 75 | 82 | 73 | 73 | 69 | - | 80.0 |
| 2006 | 81 | 80 | 84 | 75 | 74 | 75 | 72 | - |
| Pairwise $\hat{N}_{b(i,j)}$ (above diagonal) and Var [ $\hat{N}_{b(i,j)}$ ] (below diagonal): | | | | | | | | |
| 1993 | - | -742.7 | 406.9 | 1240.8 | -5432.0 | 829.8 | 808.9 | 729.0 |
| 1996 | 22491.2 | - | 110.4 | -1786.5 | 765.9 | 162.8 | 824.7 | 382.7 |
| 1998 | 10910.4 | 67299.1 | - | 101.8 | 237.1 | 69.6 | 307.0 | 140.0 |
| 2000 | 6910.0 | 742895.8 | 19122.7 | - | 490.6 | 1498.2 | 706.9 | 201.6 |
| 2001 | 49318.3 | 21402.8 | 9754.2 | 6126.6 | - | 307.8 | 82.0 | 362.5 |
| 2004 | 8338.4 | 257267.7 | 24283.0 | 145043.4 | 7095.7 | - | 269.7 | 140.1 |
| 2005 | 31511.8 | 22242.5 | 10015.8 | 6596.6 | 114931.1 | 8240.4 | - | 599.6 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2006 | 6223.8 | 43935.2 | 73518.7 | 10152.5 | 5885.3 | 12827.0 | 6370.8 | - |

$\tilde{N}_b = 269.4$

**Table 12** Summary of output from program SALMONNb and data for five Chiwawa in-river spawner collections from Wenatchee River. For each pairwise comparison of samples *i* and *j*, $\tilde{S}$ is the harmonic mean sample size, *n* is the number of independent alleles used in the comparison, $\hat{N}_{b(i,j)}$ are the pairwise estimates of $N_b$, and Var [ $\hat{N}_{b(i,j)}$ ] is the variance of $\hat{N}_{b(i,j)}$. $\tilde{N}_b$ is the harmonic mean of the $\hat{N}_{b(i,j)}$. Alleles with a frequency below 0.05 were excluded from the analysis to reduce potential bias.

| Year | 1989 | 2001 | 2004 | 2005 | 2006 |
|---|---|---|---|---|---|
| Pairwise $\tilde{S}$ (above diagonal) and *n* (below diagonal): | | | | | |
| 1989 | - | 33.3 | 40.2 | 41.7 | 42.2 |
| 2001 | 72 | - | 60.5 | 63.9 | 63.3 |
| 2004 | 72 | 77 | - | 95.3 | 94.0 |
| 2005 | 69 | 72 | 75 | - | 102.5 |
| 2006 | 76 | 76 | 77 | 78 | - |
| Pairwise $\hat{N}_{b(i,j)}$ (above diagonal) and Var [ $\hat{N}_{b(i,j)}$ ] (below diagonal): | | | | | |
| 1989 | - | 118.4 | 299.0 | 143.3 | 165.3 |
| 2001 | 40378.8 | - | 181.7 | -1537.3 | 153.5 |
| 2004 | 10455.2 | 7265.5 | - | 387.1 | 329.4 |
| 2005 | 20923.6 | 68660.6 | 5040.7 | - | 356.8 |
| 2006 | 16227.2 | 8886.9 | 3802.0 | 4522.8 | - |

$\tilde{N}_b = 224.2$

**Table 13** Summary of output from program SALMONNb and data for three brood years that combined Chiwawa natural- and hatchery-origin samples from Wenatchee River. For each pairwise comparison of samples *i* and *j*, $\tilde{S}$ is the harmonic mean sample size, *n* is the number of independent alleles used in the comparison, $\hat{N}_{b(i,j)}$ are the pairwise estimates of $N_b$, and Var [ $\hat{N}_{b(i,j)}$ ] is the variance of $\hat{N}_{b(i,j)}$. $\tilde{N}_b$ is the harmonic mean of the $\hat{N}_{b(i,j)}$. Alleles with a frequency below 0.05 were excluded from the analysis to reduce potential bias.

| Year | 2004 | 2005 | 2006 |
|---|---|---|---|
| Pairwise $\tilde{S}$ (above diagonal) and *n* (below diagonal): | | | |
| 2004 | - | 162 | 164.3 |
| 2005 | 77 | - | 188.2 |
| 2006 | 76 | 75 | - |
| Pairwise $\hat{N}_{b(i,j)}$ (above diagonal) and Var [ $\hat{N}_{b(i,j)}$ ] (below diagonal): | | | |
| 2004 | - | 611.3 | 210.8 |
| 2005 | 9351.5 | - | 727.5 |
| 2006 | 14965.5 | 8673.9 | - |

$\tilde{N}_b$ = 386.8

# APPENDIX J

## Summer Chinook Spawning Ground Surveys in the Methow and Okanogan Basins, 2007

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February 1, 2008

To: HCP Hatchery Committee

From: Mark Miller

Re: 2007 Spawning Ground Surveys in the Okanogan and Methow Basins

The purpose of this memo is to provide information on the hatchery-supplemented natural spawning population of summer Chinook in the Methow and Okanogan basins. This work is part of a larger effort focused on monitoring and evaluating Chelan PUD's hatchery supplementation program. The tasks and objectives associated with implementing Chelan PUD's hatchery M&E plan for 2007 are outlined in several documents (Murdoch and Peven 2005; Peven 2006; Hays et al. 2006). Figures and tables are presented at the end of this memo.

## METHODS

Spawning ground surveys were conducted by foot, raft, and aircraft beginning the last week of September and ending mid-November. During aerial surveys an observer recorded the location and number of redds on topographic maps. We did not use aerial surveys on the Methow River because past work has demonstrated that ground counts were more accurate than aerial surveys (Miller and Hillman 1997). Because of the depth of redds, aerial surveys were the only census method used for the Columbia River downstream from Wells Dam. Ground surveys were used to provide more accurate counts and a complete census of Chinook redds within their spawning distribution. Observers floated through sampling reaches and recorded the location and numbers of redds each week. Observers recorded the date, water temperature, rivermile, and constructed a drawing of the area where redds were located. A different symbol was used each week to record the number of new and incomplete redds.

To maintain consistency, at least one observer surveyed the same stream reach on successive dates. In areas where numerous salmon spawn, we constructed detailed maps of the river and used the cell-area method (Hamilton and Bergersen 1984) to identify the number of redds within each cell. Cells were bound by noticeable landmarks along the banks (e.g., bridges or trees) or at stream habitat boundaries (e.g., transitions between pools and riffles). The number of redds were then recorded in the corresponding grid on the map. When possible, observers estimated the number of redds in a large disturbed area by counting females that defended their redds. We assumed that the area or territory defended by a female was one redd.

During redd surveys, we sampled carcasses of summer Chinook to describe the spawning population. Biological data included collection of scale samples for age analysis, length measurements (POH and FKL), gender, egg voidance, and a check for tags or marks. These data will be used to assess length-at-age, size-at-age, egg voidance, origin (hatchery or naturally produced), and stray rates. DNA samples were not collected on summer Chinook this year.

## RESULTS

### Methow

There were 620 summer Chinook redds counted within seven reaches of the Methow River (Table 1). This was the seventh highest redd count observed in the Methow River (Appendix A). Spawning began the first week of October and peaked the second week of October and ended after the first week of November (Table 1; Figure 1). Stream temperatures in the Methow River, when spawning began, varied from 7-10°C. Peak spawning occurred in most reaches (M2-M5) of the Methow River during the second week of October except the lowest reach (M1), which occurred the following week. Most redds (91%) were located in reaches (M1-M3) downstream from the town of Twisp and in reach M5 between Methow Valley Irrigation Diversion (MVID) and Winthrop Bridge (Table 1). Few summer Chinook spawned upstream from the Winthrop Bridge in reaches M6 and M7. Estimated escapement based on redd counts and the sex-ratio observed at Wells Dam during broodstock collection suggests that 1,364 summer Chinook (620 redds x 2.2 fish/redd) escaped to the Methow River.

There were 456 summer Chinook salmon carcasses sampled within the different reaches of the Methow River (Table 2). Thirty-three percent of the fish returning to the Methow River were sampled based on the estimated escapement of 1,364 summer Chinook. Females made up 57% and males 43% of the carcasses examined. Mean percent egg voidance assessed from 262 female carcasses was 96%. Nine females (3%) died before they spawned (i.e., they retained all their eggs). Ad-clipped hatchery fish made up 41% and naturally produced fish were 59% of the sample collected (Table 2). The distribution of ad-clipped hatchery and naturally produced fish showed that more than half (70%) of the ad-clipped hatchery fish were located in the lower two reaches while naturally produced fish were more evenly distributed (Figure 2).

### Okanogan

There were 1,301 summer Chinook redds counted within six reaches of the Okanogan River (Table 1). This was the fifth highest redd count observed in the Okanogan River (Appendix A). Peak aerial redd counts (1,265 redds) were about 97 percent of redds counted from the ground. Spawning began the first week of October and peaked the following two weeks (Figure 1). Spawning was initiated in the Okanogan River when the stream temperature varied from 12-15°C. Spawning activity ended after the second week of November (Table 1; Figure 1). Peak spawning in the Okanogan River occurred during the second and third week of October. Most redds (85%) were located in the upper reaches (O5 and O6) between Zosel Dam and the town of Riverside (Table 1). Estimated escapement (1,301 redds x 2.2 fish/redd) to the Okanogan River was 2,862 summer Chinook.

There were 1,030 summer Chinook salmon carcasses sampled within 6 reaches of the Okanogan River (Table 2). Thirty-six percent of the fish returning to the Okanogan River were sampled based on the estimated escapement of 2,862 summer Chinook. Females made up 49% and males 51% of the carcasses examined. Mean percent egg voidance from 502 female carcasses was 99%. Five females (1%) died before they spawned. Ad-clipped hatchery fish made up 31% and naturally produced fish 69% of the sample collected (Table 2). Most naturally produced and ad-clipped hatchery fish were collected in the upper reaches (O5 and O6) of the Okanogan River closely following the distribution of redds (Figure 2).

**Similkameen**

There were 707 summer Chinook redds counted within the two reaches of the Similkameen River (Table 1). This was the second highest redd count recorded in the Similkameen River (Appendix A). The peak aerial count (523 redds) was about 74% of redds counted on the ground. Spawning began the last week of September and peaked two weeks later in the middle of October (Figure 5). Spawning was initiated in the Similkameen River when the temperature varied from 13-15°C. Spawning activity ended by the first week of November (Table 1). Most (92%) spawning occurred in the lower reach from the Oroville Bridge downstream to the Driscoll channel on the Similkameen River. Estimated escapement (707 redds x 2.2 fish/redd) to the Similkameen River was 1,555 summer Chinook.

There were 686 summer Chinook salmon carcasses sampled within the two reaches of the Similkameen River (Table 2). Forty-four percent of the fish returning to the Similkameen River were sampled based on the estimated escapement of 1,555 summer Chinook. Females made up 74% and males 26% of the carcasses examined. Mean percent egg voidance was 99% from 508 female carcasses sampled. Five females (1%) died before they spawned. Ad-clipped hatchery fish made up 30% and naturally produced fish 70% of the sample collected (Table 2).

**Chelan and Columbia Rivers**

There were 86 and 52 Chinook redds counted in the Chelan River and in the Columbia River downstream from Wells Dam, respectively (Table 1). No redds were observed during aerial surveys in the Columbia River upstream from Wells Dam. Spawning began the first week of October in the Chelan River and two weeks later in the Columbia River. Peak spawning in both rivers occurred the near the end of October. Estimated escapement (86 redds x 2.2 fish/redd) to the Chelan River was 189 summer Chinook.

There were 107 summer Chinook salmon carcasses sampled within the Chelan River (Table 2). Fifty-seven percent of the fish returning to the Chelan River were sampled based on the estimated escapement of 189 summer Chinook. Females made up 77% and males 23% of the carcasses examined. Ad-clipped hatchery fish made up 58% and naturally produced fish 42% of the sample collected (Table 2). In the Chelan River, mean percent egg voidance was 76% from 84 female carcasses examined. Nineteen females (23%) died before they spawned.

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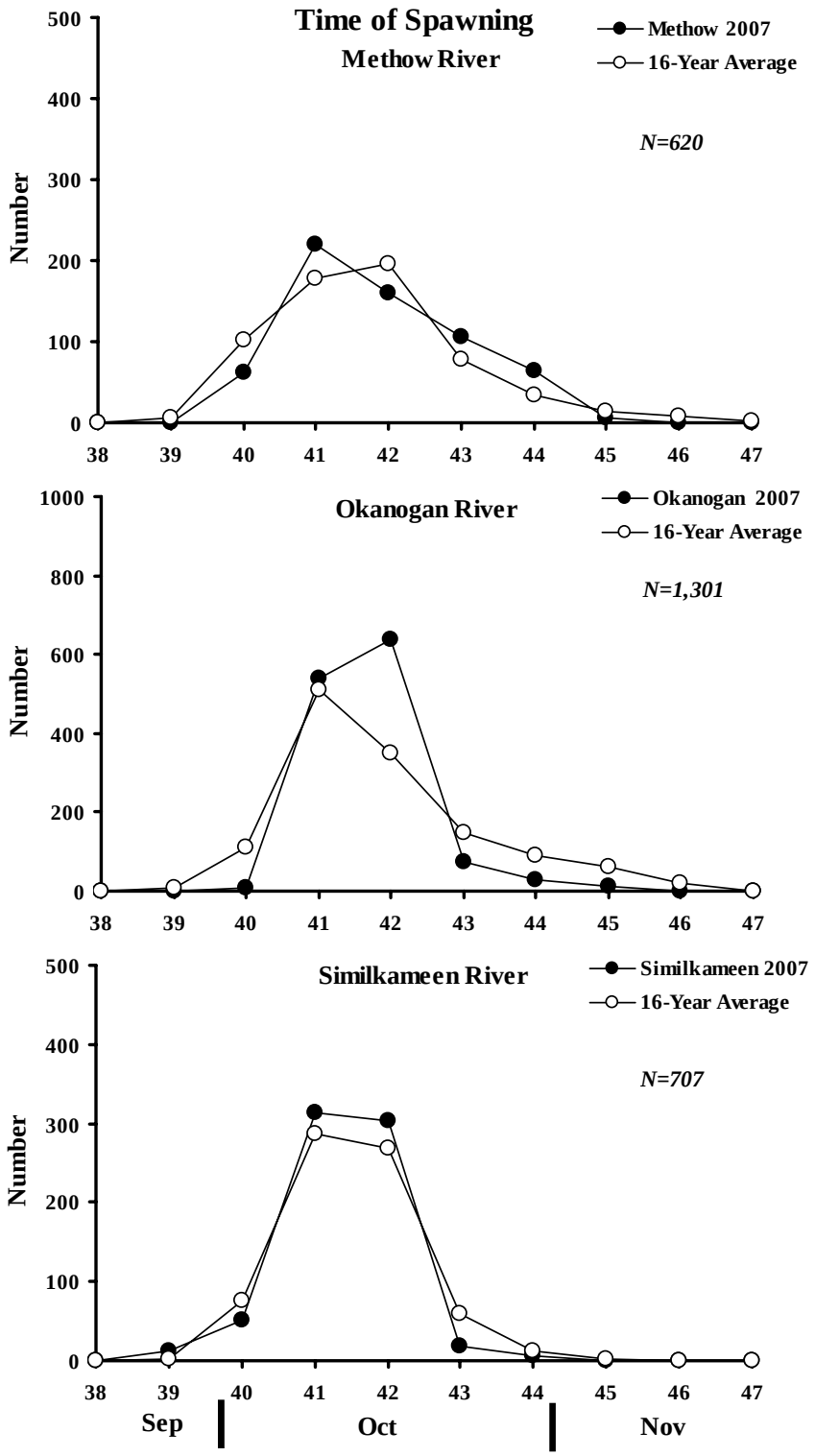


**Figure 1. Number of new redds counted each week from September to mid-November. The figure displays the beginning, peak, and end of spawning for summer Chinook in the Methow, Okanogan, and Similkameen rivers in 2007 compared to a 16-year average (1991-2006).**

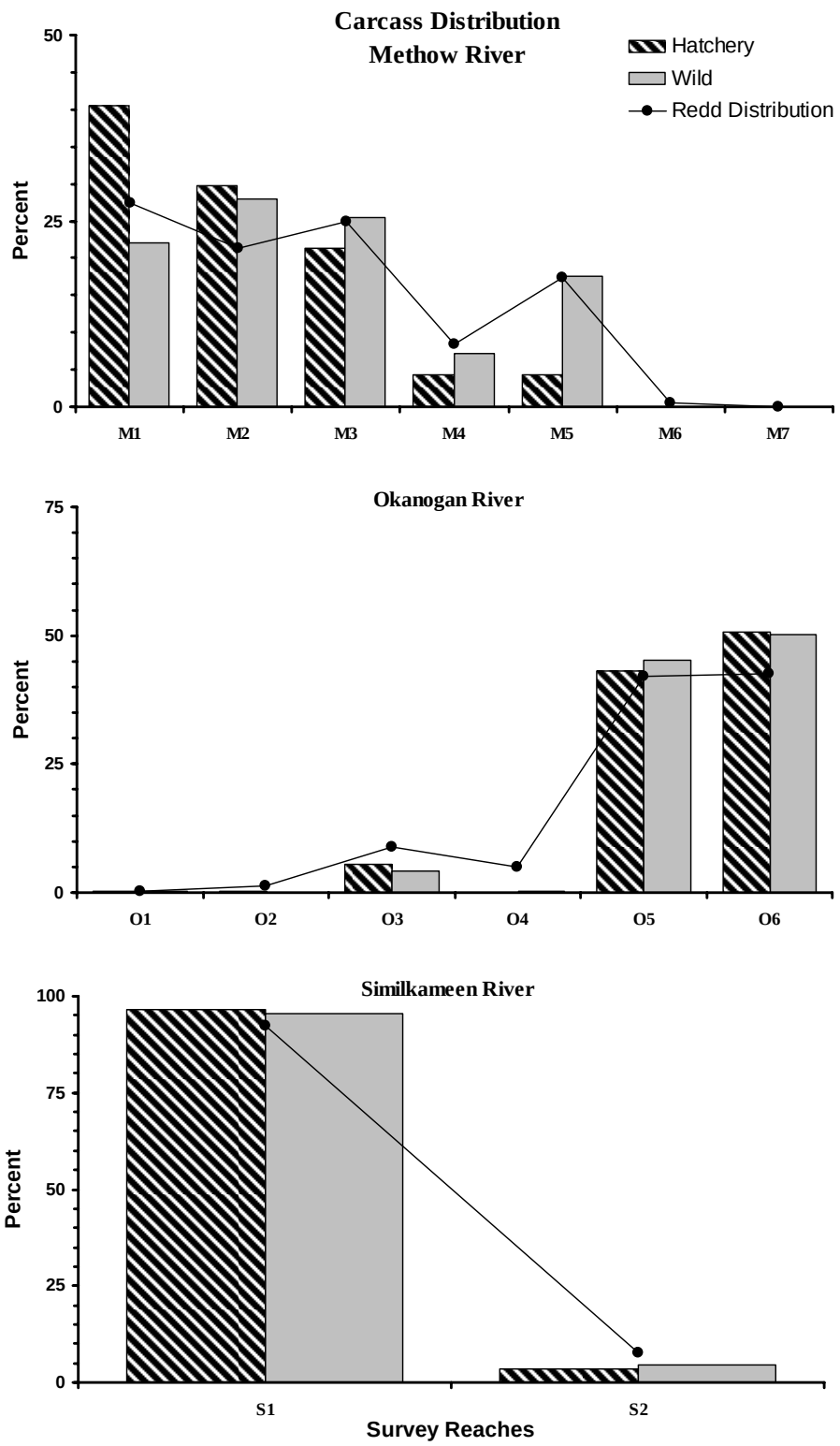


**Figure 2. Percent distribution of ad-clipped hatchery and naturally produced fish plotted against the percent distribution of redds observed in reaches of the Methow, Okanogan, and Similkameen rivers, 2007.**

**Table 1. Number of summer Chinook redds observed each week within reaches of the Methow, Okanogan, Similkameen, and Chelan rivers, 2007.**

| Reach | Location (Rkm) | Sep | | Oct | | | | Nov | | Total | Percent |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 23-29 | 30-6 | 7-13 | 14-20 | 21-27 | 28-3 | 4-10 | 11-17 | | |
| | | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | | |
| **Methow River** | | | | | | | | | | | |
| M1 | 0.0-25.0 | 0 | 3 | 36 | 27 | 59 | 45 | 0 | 0 | **170** | **27.4** |
| M2 | 25.0-45.9 | 0 | 24 | 54 | 19 | 29 | 6 | 0 | 0 | **132** | **21.3** |
| M3 | 45.9-63.6 | 0 | 5 | 65 | 63 | 9 | 7 | 6 | 0 | **155** | **25.0** |
| M4 | 63.6-75.8 | 0 | 5 | 20 | 18 | 3 | 6 | 0 | 0 | **52** | **8.4** |
| M5 | 75.8-84.2 | 0 | 26 | 46 | 32 | 4 | 0 | 0 | 0 | **108** | **17.4** |
| M6 | 84.2-87.2 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | **3** | **0.5** |
| M7 | 87.2-90.2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | **0** | **0.0** |
| | **Total** | **0** | **63** | **221** | **160** | **106** | **64** | **6** | **0** | **620** | **100** |
| **Okanogan River** | | | | | | | | | | | |
| O1 | 0.0-27.2 | 0 | 0 | 0 | 0 | 1 | 0 | 2 | 0 | **3** | **0.2** |
| O2 | 27.2-41.9 | 0 | 0 | 0 | 8 | 2 | 2 | 4 | 0 | **16** | **1.2** |
| O3 | 41.9-49.4 | 0 | 0 | 15 | 64 | 28 | 7 | 2 | 0 | **116** | **8.9** |
| O4 | 49.4-65.4 | 0 | 0 | 0 | 50 | 8 | 2 | 3 | 0 | **63** | **4.8** |
| O5 | 65.4-91.4 | 0 | 5 | 256 | 255 | 23 | 10 | 0 | 0 | **549** | **42.2** |
| O6 | 91.4-129.6 | 0 | 3 | 269 | 261 | 13 | 8 | 0 | 0 | **554** | **42.6** |
| | **Total** | **0** | **8** | **540** | **638** | **75** | **29** | **11** | **0** | **1301** | **100** |
| **Similkameen River** | | | | | | | | | | | |
| S1 | 0.0-2.9 | 13 | 48 | 296 | 272 | 18 | 5 | 0 | 0 | **652** | **92.2** |
| S2 | 2.9-9.1 | 0 | 4 | 17 | 31 | 1 | 2 | 0 | 0 | **55** | **7.8** |
| | **Total** | **13** | **52** | **313** | **303** | **19** | **7** | **0** | **0** | **707** | **100** |
| **Chelan River** | | | | | | | | | | | |
| | 0.0-1.0 | 0 | 1 | 13 | 29 | 33 | 10 | 0 | 0 | **86** | |
| **Columbia River** | | | | | | | | | | | |
| | 953.3-954.3 | 0 | 0 | 0 | 8 | 25 | 0 | 19 | 0 | **52** | |

**Table 2. Number and percent of hatchery (ad-clipped) and naturally produced (not ad-clipped) summer Chinook collected within reaches of the Methow, Okanogan, Similkameen, and Chelan rivers, 2007.**

| Reach | Location (Rkm) | Ad-Clipped Hatchery | | | | Naturally Produced | | | | Reach Total |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Male | Female | Total | Percent | Male | Female | Total | Percent | |
| **Methow River** | | | | | | | | | | |
| **M1** | 0.0-25.0 | 27 | 49 | 76 | 40.4 | 28 | 31 | 59 | 22.0 | **135** |
| **M2** | 25.0-45.9 | 22 | 34 | 56 | 29.8 | 49 | 26 | 75 | 28.0 | **131** |
| **M3** | 45.9-63.6 | 12 | 28 | 40 | 21.3 | 32 | 36 | 68 | 25.4 | **108** |
| **M4** | 63.6-75.8 | 3 | 5 | 8 | 4.3 | 5 | 14 | 19 | 7.1 | **27** |
| **M5** | 75.8-84.2 | 1 | 7 | 8 | 4.3 | 15 | 32 | 47 | 17.5 | **55** |
| **M6** | 84.2-87.2 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | **0** |
| **M7** | 87.2-90.2 | 0 | 0 | 0 | 0.0 | 0 | 0 | 0 | 0.0 | **0** |
| | **Total** | **65** | **123** | **188** | **100** | **129** | **139** | **268** | **100** | **456** |
| **Okanogan River** | | | | | | | | | | |
| **O1** | 0.0-27.2 | 1 | 0 | 1 | 0.3 | 0 | 1 | 1 | 0.1 | **2** |
| **O2** | 27.2-41.9 | 1 | 0 | 1 | 0.3 | 0 | 0 | 0 | 0.0 | **1** |
| **O3** | 41.9-49.4 | 8 | 10 | 18 | 5.6 | 14 | 16 | 30 | 4.2 | **48** |
| **O4** | 49.4-65.4 | 0 | 0 | 0 | 0.0 | 0 | 1 | 1 | 0.1 | **1** |
| **O5** | 65.4-91.4 | 74 | 66 | 140 | 43.2 | 131 | 188 | 319 | 45.2 | **459** |
| **O6** | 91.4-129.6 | 125 | 39 | 164 | 50.6 | 174 | 181 | 355 | 50.3 | **519** |
| | **Total** | **209** | **115** | **324** | **100** | **319** | **387** | **706** | **100** | **1030** |
| **Similkameen River** | | | | | | | | | | |
| **S1** | 0.0-2.9 | 71 | 128 | 199 | 96.6 | 104 | 354 | 458 | 95.4 | **657** |
| **S2** | 2.9-9.1 | 0 | 7 | 7 | 3.4 | 3 | 19 | 22 | 4.6 | **29** |
| | **Total** | **71** | **135** | **206** | **100** | **107** | **373** | **480** | **100** | **686** |
| **Chelan River** | | | | | | | | | | |
| | 0.0-1.0 | 10 | 52 | 62 | 58 | 15 | 30 | 45 | 42 | **107** |

**Appendix A. Historical aerial and ground redd counts of summer Chinook in the Methow, Okanogan, and Similkameen rivers, 1957-2007.**

| | Methow | | Okanogan | | Similkameen | |
|---|---|---|---|---|---|---|
| Year | Aerial | Ground | Aerial | Ground | Aerial | Ground |
| 1956 | 109 | -- | 37 | -- | 30 | -- |
| 1957 | 451 | -- | 53 | -- | 30 | -- |
| 1958 | 335 | -- | 94 | -- | 31 | -- |
| 1959 | 130 | -- | 50 | -- | 23 | -- |
| 1960 | 194 | -- | 29 | -- | -- | -- |
| 1961 | 120 | -- | -- | -- | -- | -- |
| 1962 | 678 | -- | -- | -- | 17 | -- |
| 1963 | 298 | -- | 9 | -- | 51 | -- |
| 1964 | 795 | -- | 112 | -- | 67 | -- |
| 1965 | 562 | -- | 109 | -- | 154 | -- |
| 1966 | 1,275 | -- | 389 | -- | 77 | -- |
| 1967 | 733 | -- | 149 | -- | 107 | -- |
| 1968 | 659 | -- | 232 | -- | 83 | -- |
| 1969 | 329 | -- | 103 | -- | 357 | -- |
| 1970 | 705 | -- | 656 | -- | 210 | -- |
| 1971 | 562 | -- | 310 | -- | 55 | -- |
| 1972 | 325 | -- | 182 | -- | 64 | -- |
| 1973 | 366 | -- | 138 | -- | 130 | -- |
| 1974 | 223 | -- | 112 | -- | 201 | -- |
| 1975 | 432 | -- | 273 | -- | 184 | -- |
| 1976 | 191 | -- | 107 | -- | 139 | -- |
| 1977 | 365 | -- | 276 | -- | 268 | -- |
| 1978 | 507 | -- | 195 | -- | 268 | -- |
| 1979 | 622 | -- | 173 | -- | 138 | -- |
| 1980 | 345 | -- | 118 | -- | 172 | -- |
| 1981 | 195 | -- | 55 | -- | 121 | -- |
| 1982 | 142 | -- | 23 | -- | 56 | -- |
| 1983 | 65 | -- | 36 | -- | 57 | -- |
| 1984 | 162 | -- | 235 | -- | 301 | -- |
| 1985 | 164 | -- | 138 | -- | 309 | -- |
| 1986 | 169 | -- | 197 | -- | 300 | -- |
| 1987 | 211 | -- | 201 | -- | 164 | -- |
| 1988 | 123 | -- | 113 | -- | 191 | -- |
| 1989 | 126 | -- | 134 | -- | 221 | 370 |

**Appendix A. Concluded.**

| | Methow | | Okanogan | | Similkameen | |
|---|---|---|---|---|---|---|
| **Year** | **Aerial** | **Ground** | **Aerial** | **Ground** | **Aerial** | **Ground** |
| 1990 | 229 | -- | 88 | 47 | 94 | 147 |
| 1991 | -- | 153 | 55 | 64 | 68 | 91 |
| 1992 | -- | 107 | 35 | 53 | 48 | 57 |
| 1993 | -- | 154 | 144 | 162 | 152 | 288 |
| 1994 | -- | 310 | 372 | 375 | 463 | 777 |
| 1995 | -- | 357 | 260 | 267 | 337 | 616 |
| 1996 | -- | 181 | 100 | 116 | 252 | 419 |
| 1997 | -- | 205 | 149 | 158 | 297 | 486 |
| 1998 | -- | 225 | 75 | 88 | 238 | 276 |
| 1999 | -- | 448 | 222 | 369 | 903 | 1,275 |
| 2000 | -- | 500 | 384 | 549 | 549 | 993 |
| 2001 | -- | 675 | 883 | 1,108 | 865 | 1,540 |
| 2002 | -- | 2,013 | 1,958 | 2,667 | 2,000[a] | 3,358 |
| 2003 | -- | 1,624 | 1,099 | 1,035 | 103 | 378 |
| 2004 | -- | 973 | 1,310 | 1,327 | 2,127 | 1,660 |
| 2005 | -- | 874 | 1,084 | 1,611 | 1,111 | 1,423 |
| 2006 | -- | 1,353 | 1,857 | 2,592 | 1,337 | 1,666 |
| 2007 | -- | 620 | 1,265 | 1,301 | 523 | 707 |