B O N N E V I L L E   P O W E R   A D M I N I S T R A T I O N

Mid-Columbia Coho Reintroduction Feasibility Study

Monitoring and Evaluation

Annual Report 2003 | March 2006 | DOE/BP-00013747-2

This Document should be cited as follows:

Murdoch, Keely, Cory Kamphaus, Scott Prevatte, "Mid-Columbia Coho Reintroduction Feasibility Study; Monitoring and Evaluation", 2003 Annual Report, Project No. 199604000, 207 electronic pages, (BPA Report DOE/BP-00013747-2)

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

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

MID-COLUMBIA COHO REINTRODUCTION FEASIBLITY STUDY

2003 Monitoring and Evaluation Report

Prepared by:

Keely G. Murdoch
Corydon M. Kamphaus
Scott A. Prevatte

7 June 2005

Prepared for:
Project #1996-040-000
Bonneville Power Administration
Portland, OR

YAKAMA NATION
FISHERIES RESOURCE MANAGEMENT

EXECUTIVE SUMMARY

The long-term vision for the mid-Columbia coho reintroduction project is to reestablish naturally reproducing coho salmon populations in mid-Columbia river basins, with numbers at or near carrying capacity that provide opportunities for significant harvest for tribal and non-tribal fishers. The feasibility of re-establishing coho in mid-Columbia tributaries may initially rely upon the resolution of two central issues: the adaptability of a domesticated lower river coho stock used in the re-introduction efforts and associated survival rates, and the ecological risks to other species associated with coho re-introduction efforts. Research efforts in 2003 focused on addressing these two central issues.

• We investigated predation rates by hatchery and naturally reared coho salmon smolts on spring chinook fry in Nason Creek, and predation by hatchery coho smolts emigrating through Lake Wenatchee on sockeye fry. In Nason Creek, the incidence of predation (percentage of samples that had consumed fish) on spring chinook fry by both hatchery and naturally reared coho was 0.28% and 2.70%, respectively. We found no predation on sockeye fry by hatchery coho migrating through Lake Wenatchee. Sample sizes for of both naturally reared coho in Nason Creek and hatchery coho migrating through Lake Wenatchee were small, potentially increasing error into the estimates.

• We repeated the 2002 investigation into competition for space and food between sub-yearling coho salmon, sub-yearling chinook salmon and yearling steelhead in Nason Creek. We found that juvenile coho, chinook, and steelhead select different microhabitats; at densities tested, juvenile coho did not appear to displace juvenile chinook from preferred microhabitats.

• Through radio-telemetry, we evaluated stray rates and spawning locations for adult coho returning to the Wenatchee and Methow rivers. Adult coho used in the evaluation were trapped and tagged at Priest Rapids and Wells dams on the Columbia River, and at Tumwater Dam on the Wenatchee River. A total of 282 coho were radio-tagged during 2003. Of the 282, 63.9% were tracked to probable spawning locations. Within-basin stray/dropout rates were 19.4% and 27.8% for the Wenatchee and Methow rivers respectively. Median passage time for radio-tagged coho between the release site at Vantage to Rock Island Dam was 8.8 days and 3.8 days from Rock Island Dam to Monitor on the Wenatchee River.

• During spawning ground surveys in the Wenatchee Basin, we observed 507 coho redds in Icicle Creek, 6 redds in Nason Creek, 75 redds in the Wenatchee River and a combined 37 redds in Brender, Mission, and Peshastin creeks, for a total of 625 coho redds. In the Methow Basin we found a total of 28 redds in the Methow River and tributaries.

• Spring 2003 marked the second emigration of naturally produced coho smolts from the Wenatchee River in close to a century. Based on data collected from WDFW's rotary smolt trap located near Monitor on the Wenatchee River (RK 11.4), we estimate that 36,678 naturally produced yearling coho emigrated between March 2nd and June 30th, 2003. From the population estimate we calculated an egg-to-emigrant survival rate of 8.85% (154 coho redds, 2700 eggs/female). This egg-to-emigrant survival rate should be considered a maximum value, any unidentified coho redds would result in an overestimate of egg-to-emigrant survival. However

the egg-to-emigrant survival rates comport well with the rates reported for spring chinook in the Wenatchee Basin (A. Murdoch pers. comm.).

• We estimate that the average smolt-to-adult survival rate for brood year 2001 hatchery coho smolts released in the Wenatchee River basin is 0.41% (4032 adults and 88 jacks) for all release groups. The SARs for lower Columbia River brood coho released from Icicle Creek (0.31%) were significantly lower than first-generation mid-Columbia River brood released from the same acclimation pond (0.53%; $p<0.001$). Using scale analysis for identification, we estimated the SAR for the first return of naturally produced coho to be 0.34%, or 1.4% of the coho return to the Wenatchee Basin. The SARs for hatchery coho returning to the Methow River was between 0.08% and 0.15%.

●We estimate the smolt-to-adult survival rate for brood-year 2001 hatchery coho returning to the Methow River to be between 0.15% and 0.08%, as measured by Wells Dam counts and by collected broodstock plus redd counts (2.2 fish per redd).

• Based on PIT-tag detections, we estimate that 63% mid-Columbia River brood coho survived from release in Icicle Creek to McNary Dam. We estimated that 37% and 20% of mid-Columbia River brood coho released from Nason Creek and the Little Wenatchee River survived to McNary Dam.

TABLE OF CONTENTS

APPENDIX A: COMPARISON OF PREDATION STUDY RESULTS IN THE YAKIMA AND WENATCHEE RIVERS, 1998-2003

APPENDIX B: HYDROACOUSTIC SURVEY OF LAKE WENATCHEE, WASHINGTON

APPENDIX C: NASON CREEK 2003 SNORKEL COUNTS

APPENDIX D: RADIO-TELEMETRY TAGGING DATA

APPENDIX E: RADIO-TELEMETRY FISH TRACKING HISTORY

APPENDIX F: PRIEST RAPIDS FOREBAY DAILY TEMPERATURES, 2001-2003

APPENDIX G: COHO SPAWNING GROUND SURVEY RECORDS, 2003

APPENDIX H: RELEASE-TO-MCNARY DAM SURVIVAL INDICES FOR YEAR 2003 RELEASES INTO THE WENTACHEE AND METHOW RIVERS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

We are thankful to the many people involved in this study. Bonneville Power Administration funded the study. Linda Hermeston administered funding. Jerald Reed, Anne Hudson, Theresa Blodgett, Lana Goudy, Phillip James, Kerby Wallahee, Sam Shavehead, Elroy Shavehead, Ted Martin and Jason Bergeron helped collect the field data. Brock Stables (Shuksan Fisheries Consulting) conducted hydroacoustic surveys on Lake Wenatchee. Doug Neeley (International Statistical Training and Technical Services) provided statistical consultation for survival estimates of PIT-tagged fish. John Sneva, Washington Department of Fish and Wildlife, aged and determined origin (hatchery or wild) based on scale analysis. Todd Miller, Washington Department of Fish and Wildlife provided the population estimate for naturally produced coho emigrating from the Wenatchee River. The Public Utility Districts of Grant, Chelan, and Douglas counties were exceptional in their assistance with the telemetry evaluation. Thanks to Chris Carlson and Grant County PUD for providing the trapping location at Priest Rapids Dam: no other location would have worked so well. Thanks to Thad Mosey at Chelan Count PUD for coordinating the use of the detection systems at Rock Island and Rocky Reach: the data collected from these two locations is vital to the study. Thanks also to Shane Bickford and Douglas County PUD for allowing the use of the ladder trap at Wells Dam. And thanks to the consulting group at BioAnalysts Inc. for setting up and managing a great array of detection sites and sharing data throughout the study. The US Fish and Wildlife Service helped during the telemetry evaluation by sharing telemetry stations and aerial survey data: thanks to David Saint-George and Judy Delavergne. Several employees at WDFW provided assistance during throughout the year, including Janet Eckenberg at the at Priest Rapids Dam Trap, Todd Miller at the Monitor Smolt Trap, and Rick Stillwater and his crew during broodstock collection.

We thank Laurie Weitkamp, NOAA Fisheries, and Jeff Haymes, WDFW for their valuable comments and suggestions on the draft document. The success of Mid-Columbia Coho Reintroduction Feasibility Study would not be possible without the help and cooperation from the many people and agencies working to protect and enhance the fisheries resources of the mid-Columbia River.

GENERAL INTRODUCTION

Wild stocks of coho salmon *Oncorhynchus kisutch* were once widely distributed within the Columbia River Basin (Fulton 1970; Chapman 1986). Since the early 1900s, the native stock of coho has been extirpated from the tributaries of the middle reach of the Columbia River (the Wenatchee, Entiat, and Methow rivers) (Mullan 1983). Efforts to restore coho within the mid and upper Columbia Basin rely upon large releases of hatchery coho. The feasibility of re-establishing coho in the tributaries of the mid-Columbia River may initially depend upon the resolution of two central issues: the adaptability to natural selection by domesticated lower Columbia coho stocks used in the re-introduction efforts and their associated survival rates; and the ecological risk to other species of concern.

Continued downward trends in the abundance of wild spring chinook and steelhead above Priest Rapids Dam caused the National Marine Fisheries Service (NMFS) to list these species as endangered under the Endangered Species Act (ESA). The ecological risk associated with coho re-introduction efforts may be greatest for endangered species or those of critically low abundance. Many types of ecological interactions are theoretically possible between coho and other native fish species. Potential interactions could include predation, competition, or behavioral changes. Priorities can be assigned to different ecological interactions based on their effect on the productivity and viability of impacted populations. Although the impact of predation on an individual prey animal is unambiguous, the impact on a population of prey is not. Depending on the abundance and productivity of the prey population, the impact of predation on the persistence and productivity of the prey population may range from negligible to serious. Indeed, those ecological interactions that influence the survival, growth, or broad-scale distribution of the impacted population would potentially be most serious in nature. Other potential interactions may include competition for space or food in the natal streams, or competition for spawning space and associated redd superimposition by the returning adults.

The mid-Columbia coho re-introduction feasibility study uses early-run stocks of hatchery coho smolts from state and federal facilities. Most of these facilities have a lengthy history of culture activities, which may have the potential to subject these stocks to genetic changes due to selective effects. This term is called domestication selection (Busack et al. 1997). The genetic composition of the endemic and extirpated coho of the mid-Columbia tributaries is unknown; however, it is likely that genotypic differences existed between the lower Columbia River hatchery coho salmon and original endemic mid-Columbia River stocks. It is possible that phenotypic differences between endemic mid-Columbia coho salmon populations and lower Columbia coho populations may have included maturation timing, run timing, stamina, or size of returning adults. Thus the reproductive potential of returning hatchery coho is a critical uncertainty which may ultimately determine if this project successfully re-establishes natural populations of coho.

If coho re-introduction efforts in the mid-Columbia tributaries are to succeed, parent stocks must possess sufficient genetic variability to allow phenotypic plasticity to respond to differing selective pressures between the environments of the lower Columbia River and mid-Columbia tributaries. The mid-Columbia Coho Hatchery and Genetic Management Plan (HGMP 2002) outlines strategies to track the local adaptation process.

We are optimistic that the project will observe positive trends in hatchery coho survival as the program transitions from the exclusive use of lower Columbia River hatchery coho to the exclusive use of in-basin locally adapted broodstock. Therefore it is important to measure hatchery fish performance not only to use as an indicator of project performance but to track potential short- and long-term program benefits from the outlined project strategies. Additionally, if the re-introduction effort is to be successful in the long term, when habitat and hydro impacts might be reduced, adult returns must be sufficient to meet replacement levels.

LITERATURE CITED

Busack, C., B. Watson, T. Pearsons, C. Knudsen, S. Phelps, M.. Johnston. 1997. Yakima fisheries project spring chinook supplementation monitoring plan. Unpublished Yakima/Klickitat Fisheries Project internal report, Toppenish, Washington.

Chapman, D. W. 1986. Salmon and steelhead abundance in the Columbia River in the nineteenth century. Transaction of the American Fisheries Society 115:662-670.

Fulton, L.A. 1970. Spawning areas and abundance of steelhead trout and coho, sockeye, and chum salmon in the Columbia River Basin-past and present. United States Fish and Wildlife Service. Special scientific report-Fisheries Number 618. Washington D.C.

Gross, M.R. 1987. Evolution of diadromy in fishes. American Fisheries Society Symposium 1: 14-25.

HGMP. 2002. Hatchery and genetics management plan: Mid-Columbia coho reintroduction program. Yakama Nation, Washington Department of Fish and Wildlife, Bonneville Power Administration.

Mullan J.W. 1983. Overview of Artificial and Natural Propagation of Coho Salmon (*Oncorhynchus kisutch*) on the mid-Columbia River. Fisheries Assistance Office, U.S. Fish and Wildlife Service, Leavenworth, Washington. December 1983.

CHAPTER 1: PREDATION ON SPRING CHINOOK AND SOCKEYE FRY BY HATCHERY AND NATURALLY REARED COHO SALMON

INTRODUCTION

Predation is generally believed to be a major source of mortality for salmon after emergence from gravel (Healey 1998; Foerster and Ricker 1941; Ruggerone and Rogers 1992). Current known piscivorous predators of salmonids in the Wenatchee River Basin include mountain whitefish *Prosopium williamsoni*, cutthroat trout *Oncorhynchus clarki*, rainbow/steelhead trout *O. mykiss*, bull trout *Salvelinus confluentus,* brook trout *S. fontinalis,* northern pikeminnow *Ptychocheilus oregonensis*, and sculpin *Cottus spp.* (Chapman et al. 1995).

Juvenile coho salmon feed primarily on insects (Sandercock 1998; Mason 1974; Mundie 1969). However, coho salmon have been shown to prey on several species of salmonids, including sockeye salmon fry *O. nerka* (Ricker 1941; Forester and Ricker 1953; Ruggerone and Rogers 1992), pink salmon fry *O. gorbuscha,* chum salmon fry *O. keta* (Hunter 1959), and fall chinook salmon (Thompson 1996). In order to resolve any scientific uncertainty associated with the impact of juvenile hatchery coho salmon predation on ESA-listed spring chinook populations within the Wenatchee River Basin, the Yakama Nation conducted a predation evaluation during the 2003 spring emigration. The 2003 evaluation replicates a predation evaluation conducted in 2001 (Murdoch and Larue 2001). The YN has conducted similar studies in the Yakima River Basin on fall and spring chinook salmon (Dunnigan 1999), and in the Wenatchee River on summer chinook fry (Murdoch and Dunnigan 2002). All previous coho predation evaluations in the Wenatchee and Yakima River Basin have shown very low rates of predation (<1% of the fry population) by hatchery coho smolts on chinook fry (Dunnigan 1999; Murdoch and Dunnigan 2002; Murdoch and LaRue 2002).

During 2003 the YN initiated a predation evaluation with three distinct sub-evaluations: Part 1 evaluated predation by hatchery coho emigrating from Nason Creek on spring chinook fry; Part 2 evaluated predation by naturally reared coho salmon emigrating from Nason Creek on spring chinook fry; and Part 3 examined predation rates by hatchery coho emigrating from the Little Wenatchee River, through Lake Wenatchee, on sockeye fry. Part 1 is a replicate of the predation evaluation completed in 2001 (Murdoch and Larue 2002) while parts 2 and 3 were initiated in 2003.

METHODS

Part 1: Hatchery Coho Predation on Spring Chinook Fry in Nason Creek

In 2003, a total of 261,394 hatchery coho smolts were released from three acclimation sites in Nason Creek: Butcher Creek (RK13.2), Coulter Creek (RK 13.7), and Mahar Creek (RK 20.3) (Figure 1). The total number of coho smolts released from each acclimation site can be found in Table 1.

Acclimation Site	Nason Ck. RM	Start of Volitional Release	Number of coho released
Butcher Creek	8.1		145,409
Coulter Pond	8.5		82,631
Mahar Pond	12.6		33,344

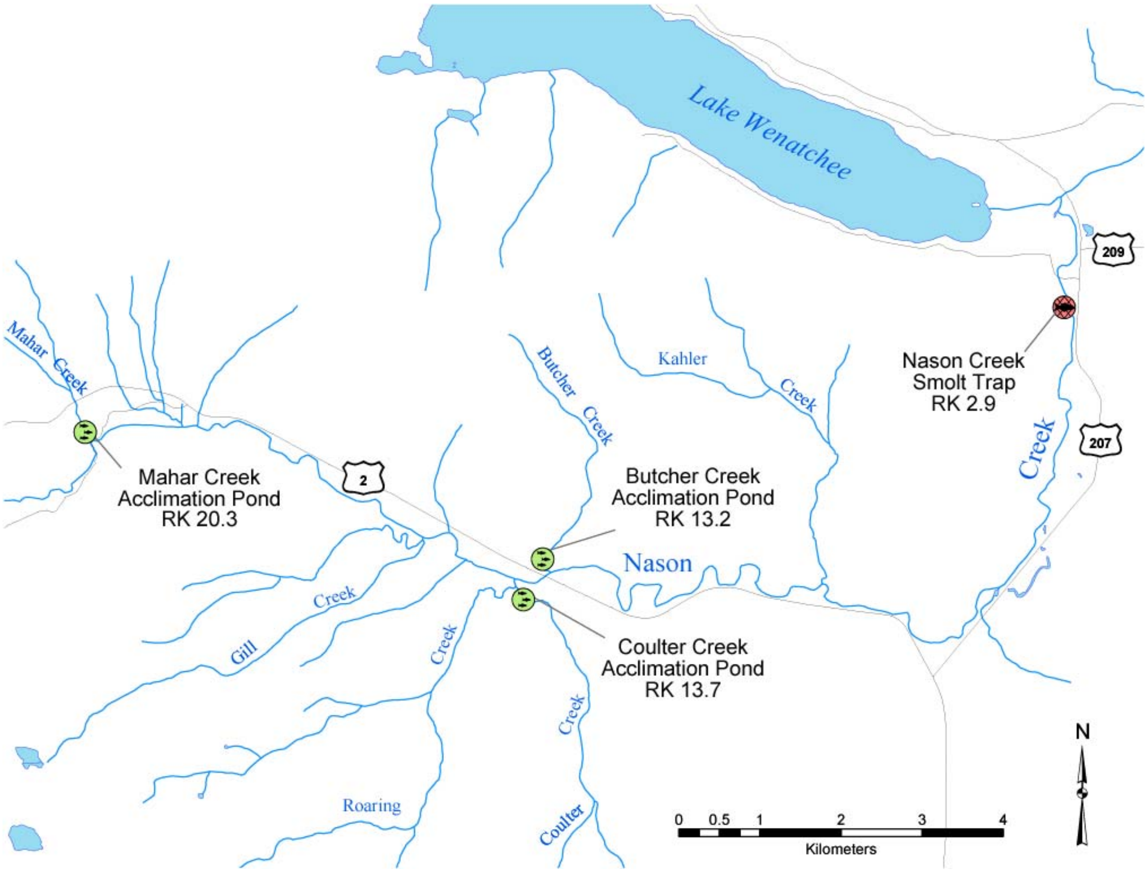


Figure 1. The Nason Creek study area showing the 3 acclimation sites in relation to the smolt trapping location.

During the volitional releases, hatchery coho smolts were recaptured in a 5-foot rotary smolt trap located in the Nason Creek Campground at RK 2.9. All hatchery coho smolts were coded wire tagged (CWT). To evaluate any influence of release location on the incidence of predation, the release sites for coho collected for stomach analysis were determined through CWT recovery. For hatchery coho, residence time was calculated based on PIT tag detection at the outlet of the Butcher Creek acclimation site and recapture at the trap. This method allowed us to calculate a residence time with more accuracy than methods employed in 2001 (Murdoch and LaRue 2002). No PIT tagged fish were released from Coulter pond; because the two ponds were within a ½ river mile of each other it is assumed that the residence (migration) time (pond exit to recapture) was the same at both Coulter and Butcher Creek ponds. Similarly, no PIT tags were released at Mahar Pond; Mahar Pond is located 4.5 river miles upstream of Butcher Creek pond. The extra migration length of 4.5 miles may have resulted in a slightly longer residence (migration) time.

Part 2: Naturally Reared Coho Predation on Spring Chinook Fry in Nason Creek

During July 2002, approximately 33,000 coho parr were scatter-planted in Nason Creek between RK 3.0 and 13.0. Details on scatter-plant location and numbers can be found in Murdoch et. al. (2004). The scatter-planted coho over-wintering in Nason Creek were recaptured in the rotary smolt trap described above. Trap operation began the second week of March and continued until mid-June. The scatter-planted coho were identified by an adipose clip and verified in the lab through coded wire tag (CWT recovery). During the predation evaluation, all naturally reared coho and naturally produced coho were retained for stomach content analysis. The adipose fin of naturally reared coho was clipped allow us to distinguish the naturally reared coho from naturally produced coho. An estimated "predation window" was used in the predation expansion equations described under Data Analysis (this chapter) in lieu of a measured residence time. The predation window was calculated as the time between mean chinook fry emergence, as measured by tracking temperature units and verified by catch at the trap, and mean passage of scatter-planted coho at the trap.

Part 3: Hatchery Coho Predation on Sockeye Fry in Lake Wenatchee

A total of 97,807 hatchery coho smolts were released from an acclimation site on the Little Wenatchee River (Two Rivers acclimation site approx RK 2.5) (Figure 2). Hatchery coho volitionally released emigrated through Lake Wenatchee and were recaptured in a 5-foot rotary smolt trap located at RK 86.24 on the Wenatchee River (1.0 KM downstream from the Lake Wenatchee outlet) (Figure 2). The smolt trap is operated and maintained by WDFW for the purpose of estimating sockeye emigrant populations. During the predation evaluation (April 30th to May 31st, 2003), smolt trap operation was shared by WDFW and YN. The YN operated the trap 4 nights per week and retained all coho collected while checking the trap live-box hourly. WDFW operated the trap 3 nights per week. Residence time was calculated based on PIT tag detection at the outlet of the Two Rivers acclimation site, and recapture at the trap.

The distribution, densities, and numbers of sockeye fry within Lake Wenatchee were measured with hydroacoustics prior to, during, and at the end of the release. These data enabled us to determine the distribution and abundance of sockeye fry during the evaluation. The hydro-acoustics surveys represent the third year of sockeye distribution evaluations (Murdoch and Larue 2002; Murdoch et al 2004). Details on the methods used for the hydroacoustic surveys can be found in Stables 2003 (Appendix B).

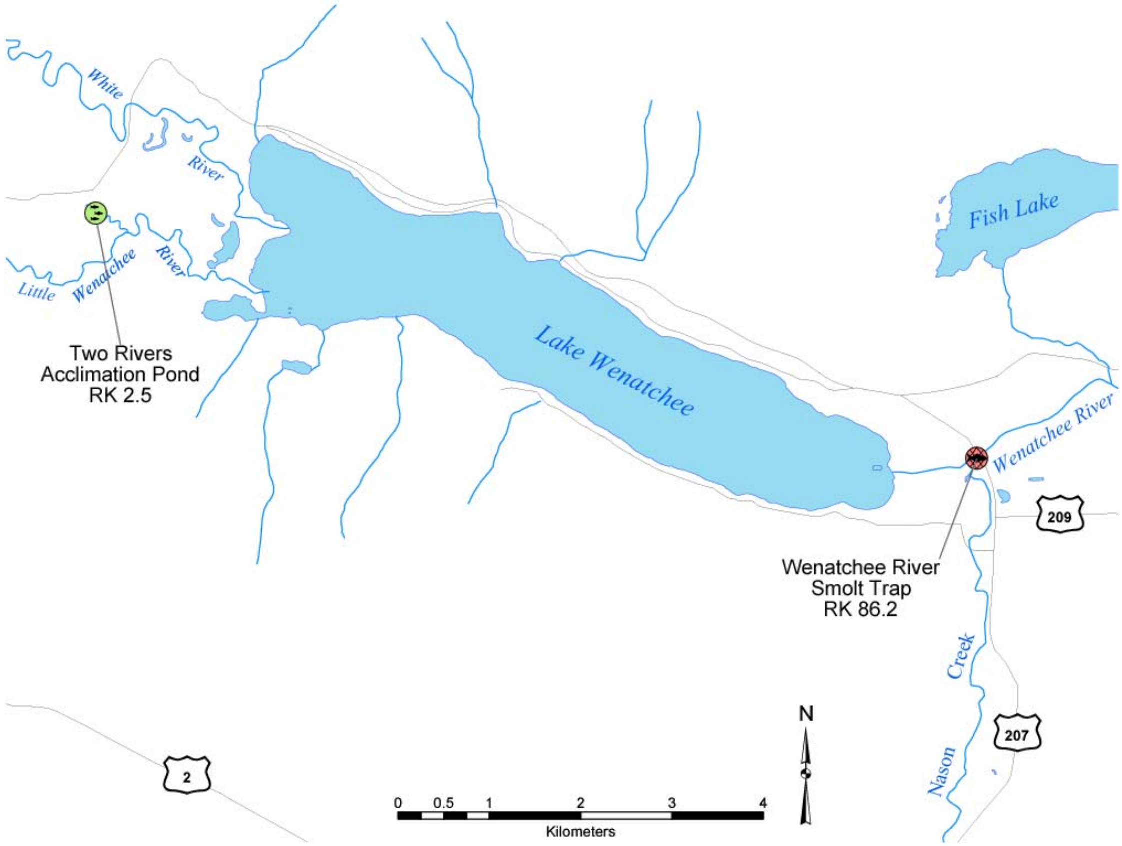


Figure 2. Lake Wenatchee study area showing the Two Rivers acclimation site and the smolt trap location.

Fish Capture and Preservation Methods

Both the Nason Creek and Wenatchee River smolt traps were checked and the live box emptied once an hour. The frequent removal of coho from the trap minimized the opportunity for predation within the live box. Sampled coho were given a lethal dose of MS-222. A small amount of 10% formalin solution was injected into the stomach of each fish to preserve stomach contents. Up to five fish were preserved in individual whirl pack bags with a liberal amount of 10% formalin solution; they were later dissected in the laboratory. Any fish remains that were found in the stomach samples were digested using a digestive enzyme (Taylor and Van Dyke 1985), stained (Caillet et al. 1986), and identified with the use of diagnostic bones (Hansel et al. 1988).

Data Analysis

For hatchery coho, residence time was calculated from PIT-tag detections as fish were exiting the Butcher Creek and Two Rivers acclimation sties, and then recaptured at the Nason Creek and Lake Wenatchee traps. For naturally reared coho, a predation window rather than residence time was calculated as a measure of time between peak chinook fry emergence (based on temperature unit tracking and verified by catch at the trap) and mean passage date for naturally reared coho smolts that passed the trap.

The total number of spring chinook fry available for potential coho predation in Nason Creek was calculated based upon redd counts, mean fecundity, and an empirically derived estimate of egg-to-emergence survival rates (Fast et al. 1986). We did not attempt to estimate the population of chinook fry based on catch at the trap because newly emerged chinook fry typically do not actively migrate during the spring. Population estimates for sockeye fry were calculated from the final hydroacoustic survey (Stables 2003) (Appendix B).

Fork length (mm) and weight (g) were measured from a random sample of spring chinook fry captured in the trap. We recorded river temperatures every 60 minutes during the spring emigration with an "Onset Stowaway" temperature logger to calculate mean daily water temperatures. Lengths and weight of sockeye fry were not taken because no sockeye fry were trapped.

We estimated the incidence of predation by coho smolts on spring chinook and sockeye fry using the following formula:

$$I = \frac{n}{N}$$

where I = the incidence of predation, n = the number of coho samples containing chinook (or sockeye) remains, and N= the total number of coho samples collected.

We calculated 95% confidence intervals for the incidence of predation (Zar 1999). Gastric evacuation rates were estimated using a species generic exponential gastric evacuation model developed by He and Wurtsbaugh (1993). This model was empirically derived from data collected from 22 fish species (He and Wurtsbaugh 1993). Based upon the gastric evacuation model we estimated the total number of chinook consumed using the following formula:

$$NP = \frac{I*COHO*R}{E}$$

where NP = the total number of prey (chinook or sockeye) consumed by coho, I = the incidence of predation, COHO = the number of coho present in the river during the study, R= the coho weighted mean residence time (or predation window) within that reach of the river (days), and E = the mean gastric evacuation rate (hours).

We used the upper and lower bounds of the 95% confidence interval for the incidence of predation to calculate the upper and lower bounds of the total number of chinook consumed for each gastric evacuation model.

To assess the relative impact coho predation had on the chinook and sockeye populations, we expressed the total number of chinook or sockeye consumed by coho as a proportion of the total 2003 chinook and sockeye fry populations in Nason Creek and Lake Wenatchee respectively.

RESULTS

Part 1: Hatchery Coho Predation on Spring Chinook Fry in Nason Creek

Incidence of predation by hatchery coho smolts

Rotary smolt trap operation at RK 2.9 on Nason Creek began on March 10^{th} and continued until June 14^{th}. Throughout this trapping period, 4992 hatchery coho smolts were captured along with 717 spring chinook fry (Figure 3). Trapping efficiency was determined to be 2.23% based on PIT tag recaptures from the Butcher Creek release site.

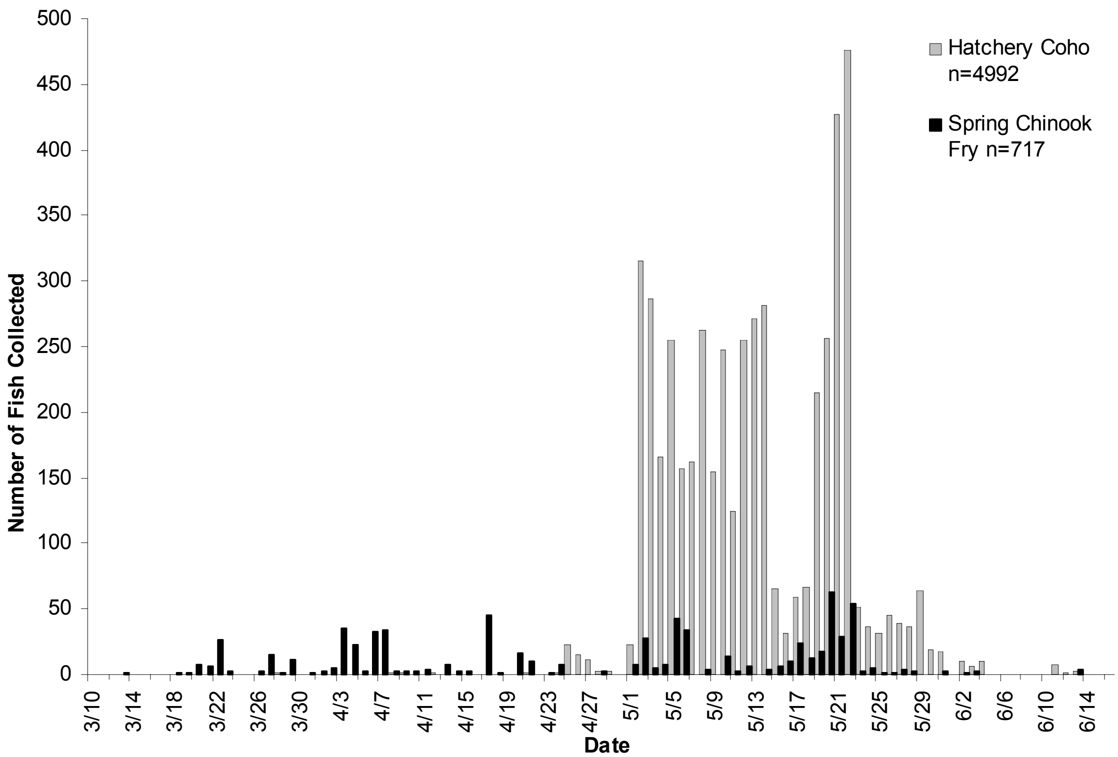


Figure 3. Distribution of hatchery coho smolts and spring chinook fry trapped in Nason Creek during the 2003 predation study.

From the 4992 coho caught in the smolt trap, 1065 coho salmon smolts (mean FL = 133.7 mm; standard deviation = 8.6 mm) were retained for stomach content analysis.

We typically operated the trap 24 hours per day. Only coho captured while the trap was actively operated and checked hourly were retained for stomach sample analysis. Coho predation on fish was uncommon. Of the coho collected for stomach content analysis, 3 were verified to have fish remains in the stomach contents, with one of the 3 having consumed 2 fish (Table 1).

The fish consumed were not positively identified as spring chinook fry. YN biologists, using the only known diagnostic bones key for prey species in the region (Hansel 1988), were unable to adequately identify the prey beyond that of the salmonidea family. However, Hansel's key does not describe all potential salmonid prey species present in Nason Creek, including brook trout and bull trout, and was created based on the diagnostic bones of larger (42-184 mm chinook smolts). Also, two of the four fish consumed were incomplete specimens and did not contain the dentaries and opercales required for analysis. Pending further research and analysis, the data are presented as a "worst case scenario" by assuming that all prey fish collected are confirmed spring chinook.

Table 1. The incidence of predation by hatchery coho smolts collected in Nason Creek during the 2003 study period.

Time period	Number of coho sampled	Number of samples containing fish	Incidence of predation	95% Confidence Interval
May 1 to June 4	1065	3	0.0028	0.0006-0.0082

Diet of hatchery coho

Results of the stomach content analysis indicate that the coho smolts fed primarily on insects (Figure 4). Of all the coho samples collected during the study (n=1065), 540 (50.7%) contained insects, 315 (29.6%) of the samples were empty, 174 (16.4%) contained plant material, 160 (15.0%) were unidentifiable (likely detritus or other digested fish food), and 3 (0.28%) contained fish. Some stomachs contained more than one type of food item.

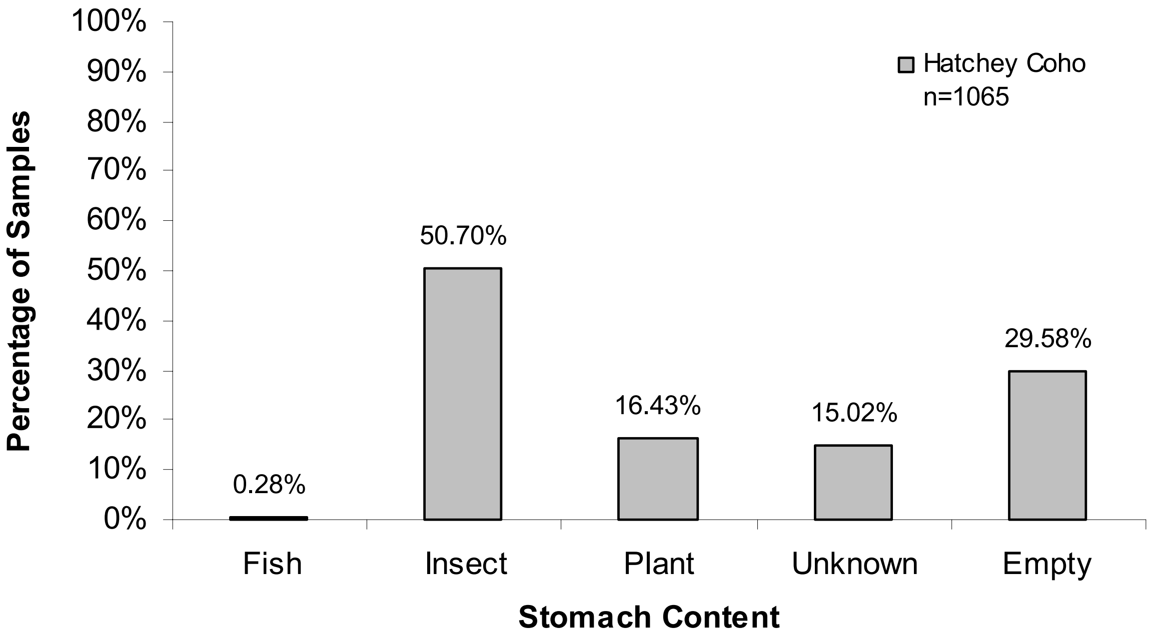


Figure 4. Contents of hatchery coho stomach samples collected in Nason Creek (May 1st to June 4th, 2003)

Estimated number of spring chinook consumed by hatchery coho smolts

The mean daily water temperature during the study was 5.5º C. Based on the recovery of 124 PIT tags, we estimate the mean residence time within the study reach was 1.7 days (40:45; hh:mm).

The gastric evacuation model developed by He and Wurtsbaugh (1993) estimates a 95% gastric evacuation rate of 40.5 hours. An evacuation rate of 40.5 hours allowed us to evaluate the incidence of predation over a diel period. The estimated number of spring chinook fry consumed was calculated by the exponential model presented by He and Wurtsbaugh (1993). We calculated the total number of spring chinook fry consumed to be 1,009 (Table 2). The estimated number of spring chinook fry available for consumption was calculated by multiplying the total number of redds counted in Nason Creek in 2002 (294; Grassell 2003) by the mean fecundity (4200 eggs; WDFW unpublished data) and by a mean egg-to-emergence survival rate of 60% (Fast et al. 1986). The estimated number of spring chinook fry available for consumption during the predation study was 740,880. The estimated percent of the spring chinook fry population consumed was 0.14% (95% CI: 0.028%-0.40%) (Table 2).

Table 2. Estimated number of spring chinook consumed by hatchery coho smolts in Nason Creek during 2003.

Sample Size	Observed Incidence of Predation	95% CI Incidence of Predation	***Total Estimated Number of Prey Consumed***	95% CI for Number of Prey Consumed	Percent of Estimated Summer Chinook Population Consumed	95% CI Estimated Spring Chinook Population Consumed	Residence Time (days)	Evacuation rate (hours)
1065	0.0028	0.00058 - 0.0082	1009	208 – 2942	0.14%	0.028%- 0.40%	1.7	40.5

Part 2: Naturally Reared Coho Predation on Spring Chinook Fry in Nason Creek

Incidence of predation by naturally reared coho smolts

During the study, 37 naturally reared coho smolts were captured in the rotary smolt trap located at RK 2.9 on Nason Creek (Figure 5).

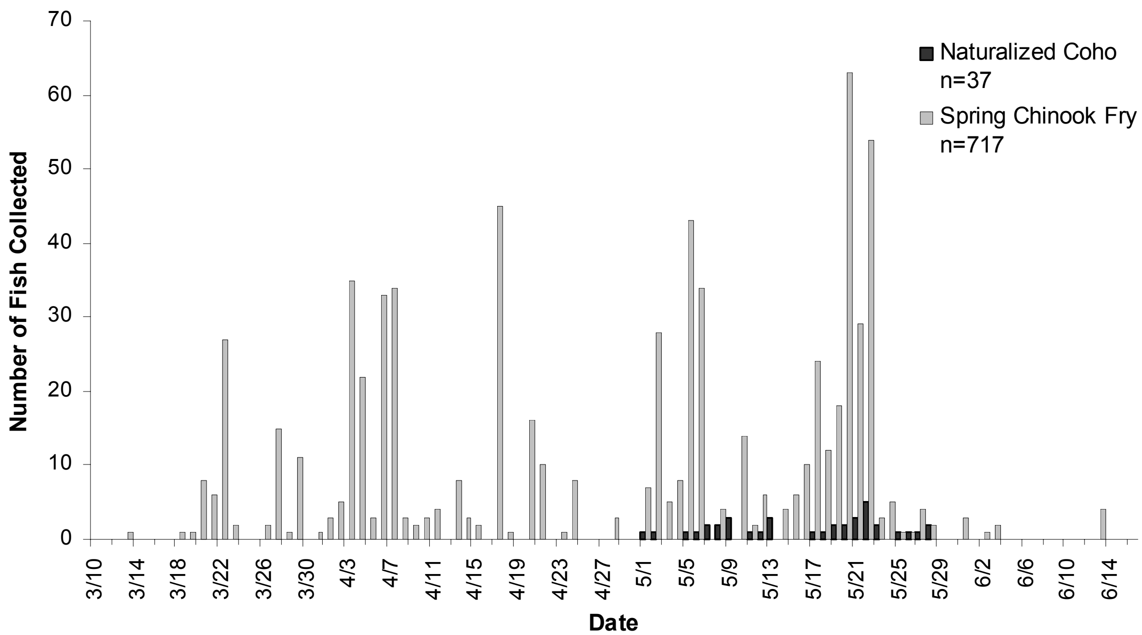


Figure 5. Distribution of naturally reared coho smolts trapped in Nason Creek during the 2003 predation study.

All 37 naturally reared coho caught in the smolt trap, (mean FL = 108.9 mm; standard deviation = 13.9) were retained for stomach content analysis.

We typically operated the trap 24 hours per day. Only naturally reared coho captured while the trap was actively operated and checked hourly were retained for stomach sample analysis. Coho predation on fish was uncommon. Of the naturally reared coho collected for stomach content analysis, one consumed fish (Table 3).

The fish consumed was not positively identified as a spring chinook fry. As stated previously, in Part 1 of this chapter**,** the available identification material does not adequately describe all available prey species present in Nason Creek. Again, the following analysis results is presented as a "worst case scenario" by assuming that the prey fish collected will be confirmed as spring chinook after further research.

Table 3. The incidence of predation by naturally reared coho smolts collected in Nason Creek during the 2003 study period.

Time period	Number of coho sampled	Number of samples containing fish	Incidence of predation	95% Confidence Interval
March 10th to June 14th	37	1	0.027	0.0007-0.1416

Diet of naturally reared coho

Results of the stomach content analysis indicate that the naturally reared coho fed primarily on insects (Figure 6). Of all the naturally reared coho samples collected during the study (n=37), 28 (75.7%) contained insects. Five (13.5%) of the samples were empty, 5 (13.5%) contained plant material, 1 (2.7%) contained fish, and 2 (5.4%) were unidentifiable (likely detritus or other digested fish food).

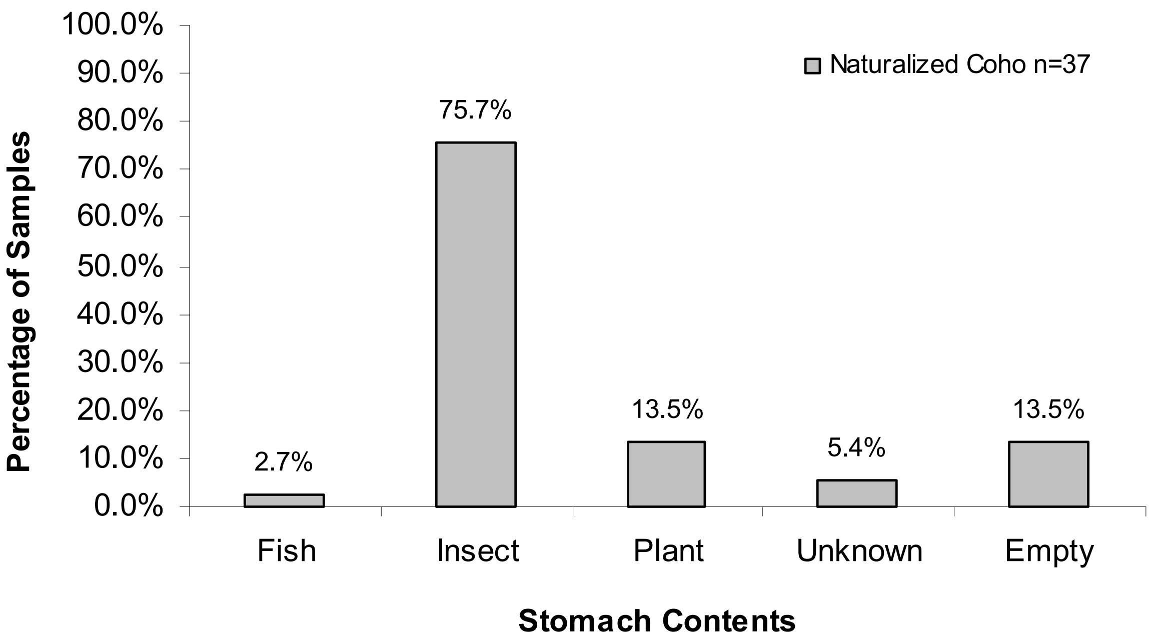


Figure 6. Contents of naturally reared coho stomach samples (May 1st to June 4th, 2003).

Estimated number of spring chinook consumed by naturally reared coho smolts

The mean daily water temperature during the study was 5.5º C. We estimated the predation window to be 52 days based on a mean emergence date of March 23rd and a mean passage date at the trap on May 15th.

The gastric evacuation model developed by He and Wurtsbaugh (1993) estimates a 95% gastric evacuation rate of 40.5 hours. An evacuation rate of 40.5 hours allowed us to evaluate the incidence of predation over a diel period. The estimated number of spring chinook fry consumed was calculated by the exponential model presented by He and Wurtsbaugh (1993). We estimate the total number of spring chinook fry consumed to be 1265 (Table 4). The estimated number of spring chinook fry available for consumption was calculated by multiplying the total number of redds counted in Nason Creek in 2002 (294; Grassell 2003) by the mean fecundity (4200 eggs; WDFW unpublished data) and? by a mean egg to emergence survival rate of 60% (Fast et al. 1986). The estimated number of spring chinook fry available for consumption during the predation study was 740,880. The estimated percent of the spring chinook fry population consumed was 0.17% (95% CI: 0.0043%-0.89%) (Table 4).

Table 4. Estimated number of spring chinook consumed by naturally reared coho smolts.

Sample Size	Observed Incidence of Predation	95% CI Incidence of Predation	***Total Estimated Number of Prey Consumed***	95% CI for Number of Prey Consumed	Percent of Estimated Summer Chinook Population Consumed	95% CI Estimated Spring Chinook Population Consumed	Residence Time (days)	Evacuation rate (hours)
37	0.027	0.00068 - 0.14	1451	37 – 7601	0.20%	0.0050% -1.03%	52.0	40.5

Part 3. Hatchery Coho Predation on Sockeye Fry in Lake Wenatchee

Incidence of sockeye fry predation by hatchery coho smolts by coho smolts

During spring 2003, 102 hatchery coho smolts were captured in the rotary smolt trap located at RK 86.2 (Figure 7). No sockeye fry were captured in the smolt trap. It is uncommon for sockeye fry to emigrate from Lake Wenatchee in the spring (T. Miller pers. comm.), although the presence, distribution, and densities of sockeye fry within Lake Wenatchee during the evaluation was well documented (Stables 2003) (Appendix B).

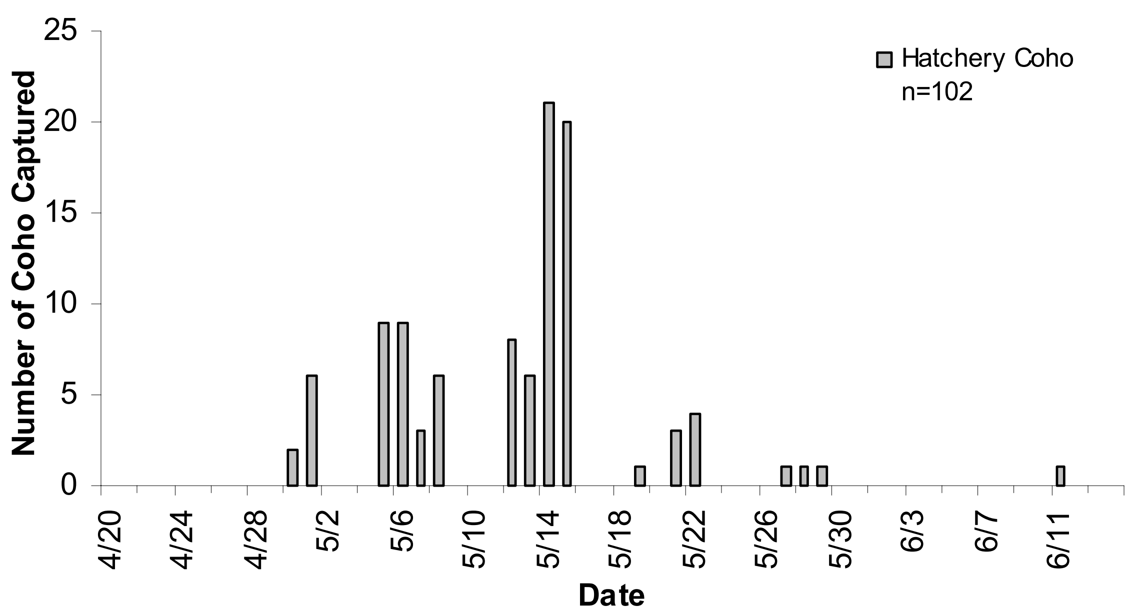


Figure 7. Distribution of hatchery coho smolts trapped during the Lake Wenatchee predation study, 2003.

From 102 coho caught in the smolt trap, 74 coho salmon smolts (mean FL = 133.7 mm; standard deviation = 12.6) were retained for stomach content analysis. Only coho captured while the trap was actively operated and checked hourly were retained for stomach sample analysis. No coho collected for stomach content analysis consumed fish (Table 5). Based on CWT recovery, of the 74 hatchery coho retained for stomach sample analysis, only 37 actually migrated through Lake Wenatchee (Figure 8). The reference to a Nason/Winthrop release site was due to the unexpected discovery of a small number of CWT codes intended for a coho release from the WNFH, but recovered in Nason Creek. The release site from which these fish originated is not known.

Table 5. The incidence of predation by hatchery coho smolts on Lake Wenatchee sockeye during the 2003 study.

Time Period	Number of coho sampled	Number of samples containing fish	Incidence of Predation	95% Confidence Interval (Incidence of predation).
April 30th to June 13th	42	0	0.00	0.00-0.0397

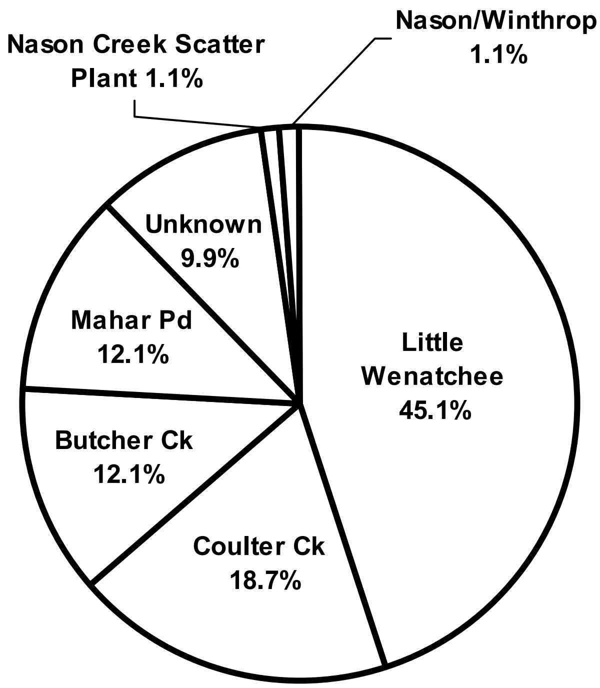


Figure 8. Release locations and proportions of hatchery coho recovered from the smolt trap on the Upper Wenatchee River, 2003.

Diet of hatchery coho

Stomach content analysis results indicate that hatchery coho smolts migrating through Lake Wenatchee fed primarily on insects (Figure 9). Of all the coho samples collected during the study (n=37), 78.6%

contained insects, 19.0% of the samples were empty, 0.0% contained fish, 0.0% contained plant material, and 4.4% were unidentifiable (likely detritus or other digested fish food).

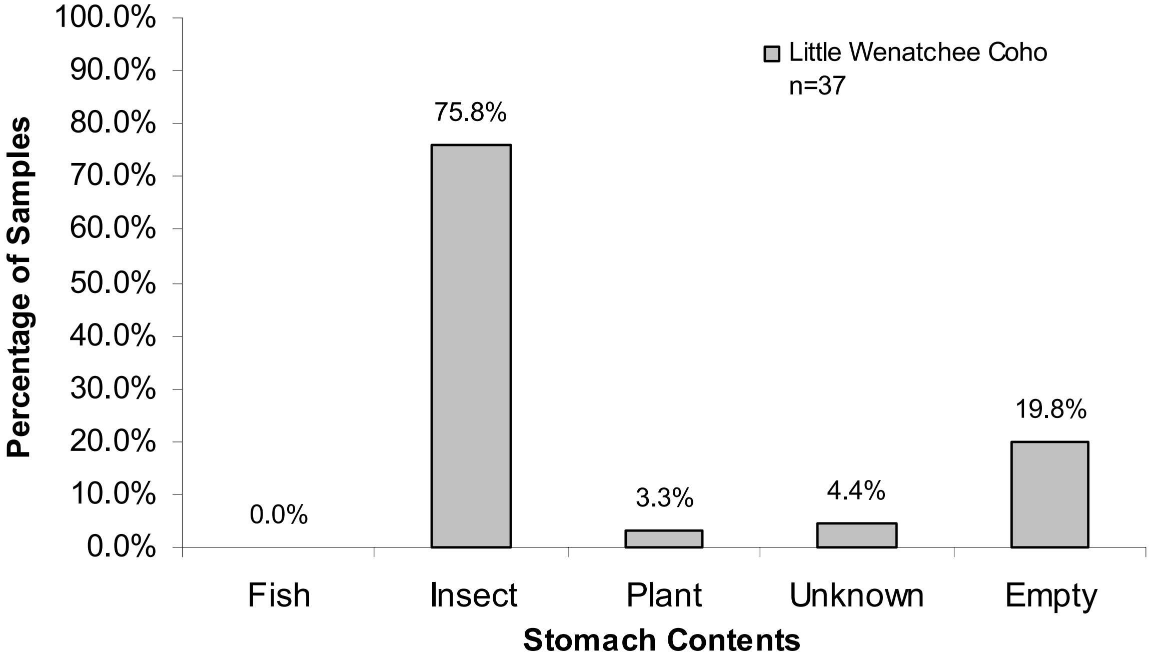


Figure 9. Contents of hatchery coho stomach samples from the Upper Wenatchee River smolt trap (April 30th through June 13th) 2003.

Estimated number of sockeye fry consumed by hatchery coho smolts

Only one PIT tagged coho detected exiting the Two Rivers acclimation site was recovered at the upper Wenatchee River smolt trap. This fish migrated from the acclimation site, through the lake, and was captured in 3.68 days. The mean residence time for hatchery coho, as calculated from the date the volitional release began to the mean passage date for coho captured in the smolt trap, was 12.95 days. Residence time based on mean passage data is less reliable than actual residence time calculated from PIT tags. The mean passage date does not reflect the actual date a smolt emigrated from the acclimation pond during the volitional release; instead, it uses the start date for the volitional release to measure residence time, resulting in a mean residence time which overestimates the true value.

The mean daily water temperature during the study was 6.5º C. The gastric evacuation model developed by He and Wurtsbaugh (1993) estimates a 95% gastric evacuation rate of 36.7 hours. An evacuation rate of 36.7 hours allowed us to evaluate the incidence of predation over a diel time period.

Because we measured an incidence of predation of 0.00 (95% CI = 0.00-0.0397), the estimated total number of sockeye fry consumed is also zero. We calculated the same results with a residence time of 3.68 days and 12.95 days.

DISCUSSION

Nason Creek Predation Evaluations

An accurate determination of mean residence time is essential to calculating the estimated number of spring chinook consumed by coho in Nason Creek. The mean residence time used in the predation evaluation was based upon the passage of PIT-tagged coho at the smolt trap. The volitional release from the Butcher Creek acclimation pond began on May 1st. A detection system at the pond outlet recorded 7,121 dates and times from PIT-tagged fish exiting the pond. The smolt trap located 10.3 RK downstream recaptured 124 of these pit tagged fish. The mean travel time was calculated from these data (Table 6). Peak emigration occurred between May 8th and May 21st, with 76.1% (4992) of the tagged fish leaving the pond. The last detection from the pond occurred on June 25th.

Table 6. Travel time for pit tagged coho exiting Butcher Creek acclimation pond (RK 13.2) and recaptured at the smolt trap in Nason Creek (RK 2.9).

Mean Travel Time	Minimum Travel Time	Maximum Travel Time
1.69 Days	0.09 Days	14.00 Days

The use of PIT tags allowed us to accurately measure residence time, which resulted in a more accurate estimate of predation on spring chinook fry by hatchery coho as compared to the 2001 evaluation (Murdoch and LaRue 2002). The results of the 2001 study overestimated the number of spring chinook fry consumed as a result of a known overestimate of residence time. We conclude, based on the results of both evaluations, that the actual impact of coho predation on spring chinook fry within the study reach represents a negligible proportion of the spring chinook produced in Nason Creek. A comparison of predation study results between sites and years can be found in Appendix A.

We believe this evaluation provides valuable empirical data of predation rates by hatchery coho volitionally released into Nason Creek on spring chinook fry. However, the predation rates obtained from hatchery fish may not apply to naturally produced coho salmon. This study also attempted to measure predation rates by naturally reared coho smolts on spring chinook fry. The incidence of predation we observed by naturally reared coho was a magnitude higher than observed for hatchery coho. However, the small sample size of naturally reared coho may not have resulted in an accurate estimate of predation. The confidence intervals surrounding the incidence of predation by naturally reared coho, encompassed the incidence of predation estimated for hatchery coho, making it difficult to evaluate whether the rate of predation by naturally produced coho is actually higher than the rate for hatchery coho. Results of a z-test for differences in proportions indicate that there is no significant difference in the incidence of predation between naturally reared and hatchery coho salmon ($p=0.31$). Reasons the rate of predation could be higher for naturally produced coho than for hatchery coho include increased residence time (increased opportunity to consume spring chinook fry), and dietary differences as a result of natural rearing. However because naturally produced coho are smaller than hatchery coho, their ability to consume a spring chinook fry may be size limited. An accurate measure of predation by naturally produced coho smolts on newly emerged spring chinook fry may not be possible until increased natural coho production occurs in tributaries which also contain spring chinook.

Spring chinook fry were available for consumption throughout the evaluation period. From the first day of the evaluation, we consistently captured fry in the rotary smolt trap. In 2002, 294 spring chinook redds were counted in Nason Creek, accounting for 25.8% of the spring chinook redds in the Wenatchee Basin (Grassell 2003). One-hundred percent of the spring chinook redds were located upstream of the smolt trap site.

It is not possible to determine whether a prey fish was consumed in the river or in the live box. As a result of artificially high densities and lack of hiding areas, predation within a live box does not reflect predation rates in the river. At both trapping sites (Nason Creek and Lake Wenatchee), we attempted to reduce predation in the live box by removing fish hourly.

The results of this predation evaluation comport well with other studies in the Yakima River. Following the same protocols as this evaluation, Dunnigan (1999) observed the incidence of predation by coho on spring chinook fry in the upper Yakima River of 0.001 and 0.00 in 1998 and 1999 respectively. A comparison of predation evaluation results between years and sites can be found in Appendix A.

Lake Wenatchee Predation Evaluation

Over 6 million sockeye fry were present in Lake Wenatchee during the predation evaluation (Stables 2003) (Appendix B). The sockeye fry were distributed throughout the lake and displayed a diel migration from the pelagic zone during daylight hours to nearshore areas at dark (Stables 2003) (Appendix B).

Our ability to collect hatchery coho migrating through Lake Wenatchee was hindered by very low trap efficiencies (<0.5%, T. Miller, WDFW, pers. comm.). Even though the coho smolt sample size was smaller than desired (42 coho recovered), no sockeye were consumed. However, as in the naturally reared coho predation study discussed above, the small samples size resulted in a large confidence interval (95% CI = 0.00 – 0.0397). We would expect the predation rate by hatchery coho on sockeye fry to be low because the opportunity for coho smolts to prey on sockeye is limited by behavioral differences and differences in habitat use (Appendix B). In lakes, juvenile coho salmon inhabit nearshore habitat and are rarely found in pelagic zones (Swales et al. 1988), while sockeye fry are found primarily in pelagic areas during daylight hours. In 2002, we evaluated the distribution of coho smolts and sockeye fry in Lake Wenatchee and concluded that the predation risk for sockeye salmon fry by hatchery coho smolts was minimal (Murdoch et. al. 2004). The greatest opportunity for hatchery coho to encounter a sockeye fry is at night, when the fry move into nearshore areas (Murdoch et al. 2004). Coho feeding ceases after dark (Sandercock 1998).

Summary

- Through the use of PIT-tagged fish and detection systems at the acclimation site outlet and at the smolt trap recapture site we were able to calculate a more accurate residence time for the hatchery fish in Nason Creek. This provided for a more accurate estimate of the total number of spring chinook fry consumed than in the previous study conducted in 2001.

- Spring chinook fry were abundant in Nason Creek during the time of the study. Fry were trapped throughout the evaluation. We estimated that 740,880 chinook fry were in Nason Creek during the study.

- The traps did not select for non-feeding migrants. Over 80.2% of the samples contained food items.

• The evacuation rate of 40.5 hours allowed us to evaluate diel food consumption.

• Despite the limitations of the predation study, the "worst case scenario" was still less than 0.15% of the Nason Creek spring chinook fry population.

● The 2003 incidence of predation observed for hatchery coho in Nason Creek (0.0028) is similar to the incidence of predation we observed in 2001 (0.0018), however, due to our ability to measure residence time with PIT tags in 2003, our estimate of the total number of spring chinook consumed (1009) and the proportion of the Nason Creek spring chinook population (0.14%) is lower than observed in 2001 (2436, 0.96%; Appendix A).

●Sockeye fry were abundant, present, and distributed throughout Lake Wenatchee during the Lake Wenatchee predation evaluation.

● No fish were found in the stomachs of hatchery coho migrating through Lake Wenatchee; behavioral differences may reduce the vulnerability of sockeye fry to predation.

● Coho smolts migrating through Lake Wenatchee consumed primarily insects.

• Results of this predation evaluation comport well with previous studies of hatchery coho predation rates on spring chinook fry.

LITERATURE CITED

Cailliet, G.M., M.S. Love, and A.W. Ebeling. 1986. Fishes – A field and laboratory manual on their structure, identification, and natural history. Waveland Press, Incorporated. Prospect Heights, Illinois.

Chapman, D., C. Peven, A. Giorgi, T. Hillman, F. Utter, M. Hill, J. Stevenson, and M. Miller. 1995. Status of sockeye salmon in the mid-Columbia region.

Dunnigan, J.L. 1999. Feasibility and risks of coho reintroduction in the mid-Columbia: Monitoring and Evaluation. Prepared for: Bonneville Power Administration. Portland, Oregon.

Fast, D.E., J.D. Hubble, and B.D. Watson. 1986. Yakima River spring chinook enhance-ment study. Project Annual Report. Bonneville Power Administration. Project 82-16.

Foerster, R.E., and W.E. Ricker. 1941. The effect of reduction of predaceous fish on survival of young sockeye salmon at Cultus Lake. Journal of the Fisheries Research Board of Canada. 5(4) 315-336.

Foerster, R.E., and W.E. Ricker. 1953. The coho salmon of Cultus Lake and Sweltzer Creek. Journal of the Fisheries Research Board of Canada 10:293-319.

Grassel, A. 2003. 2002 Wenatchee River Basin spring and summer chinook spawning ground surveys. Public Utility District Number 1 of Chelan County, Wenatchee WA. Technical memo: May 20, 2003.

Hansel, H.C., S.D. Duke, P.T. Lofy, and G.A. Gray. 1988. Use of diagnostic bones to identify and estimate original lengths of ingested prey fishes. Transactions of the American Fisheries Society 117:55-62.

Hartman, G.F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon and steelhead trout. Journal of the Fisheries Research Board of Canada 22:1035-1081.

He, E., and W.A. Wurtsbaugh. 1993. An empirical model of gastric evacuation rates for fish and an analysis of digestion in piscivorous brown trout. Transactions of the American Fisheries Society 122:717-730.

Healy, M.C. 1998. *In:* C. Groot, and L. Margolis, Pacific salmon life histories. UBC Press, University of British Columbia, Vancouver.

Hunter, J.G. 1959. Survival and production of pink and chum salmon in a coastal stream. Journal of the Fisheries Research Board of Canada 16:835-886.

Mason, J.C. 1974. Aspects of the ecology of juvenile coho salmon (*Oncorhynchus kisutch*) in Great Central Lake, B.C. Fisheries Research Board of Canada Technical Report. 438: 7p.

Mundie, J.H. 1969. Ecological implications of the diet of juvenile coho in streams. *In:* T.G. Northcote, editor. Symposium on Salmon and Trout in Streams. H.R. MacMillan Lectures in Fisheries. University of British Columbia, Vancouver B.S.

Murdoch, K.G., and M.L. LaRue. 2002. Feasibility and risks of coho reintroduction in mid-Columbia River tributaries: 2001 Annual Monitoring and Evaluation Report. *Prepared For:* Bonneville Power Administration, Project Number 1996-040-000. Portland, Oregon.

Murdoch, K., C. Kamphaus, S. Prevatte. 2004. Feasibility and risks of coho reintroduction in mid-Columbia River tributaries: 2002 Annual Monitoring and Evaluation Report. *Prepared For:* Bonneville Power Administration, Project Number 1996-040-000. Portland OR.

Ricker, W.E. 1941. Resource partitioning in fish assemblages: A review of field studies. Copeia 1986(2):352-388.

Ruggerone, G.T., and D.E. Rogers. 1992. Predation on sockeye salmon fry by juvenile coho salmon in the Chignik Lakes, Alaska: Implications for salmon management. North American Journal of Fisheries Management 12:87-102.

Sandercock, F.K. 1998. Life history of coho salmon (*Oncorhynchus kisutch*). *In:*C.Groot and L. Margolis, editors: Pacific Salmon Life Histories. University of British Columbia Press, Vancouver, B.C.

Stables, B. 2003. Abundance, spatial distribution, and crepuscular migrations of sockeye salmon fry in Lake Wenatchee, Washington: April and May 2003. *Prepared For:* Yakama Nation, Fisheries Resource Management, Toppenish WA. 34 pgs.

Swales, S., F. Caron, J.R. Irvine, and C.D. Levings. 1988. Overwintering habitats of coho salmon and other salmonids in the Keogh River system, British Columbia. Canadian Journal of Zoology 66:254-261.

Taylor, W.R., and G.C. Van Dyke. 1985. Revised procedures for staining and clearing small fishes and other vertebrates for bone and cartilage study. Cybium 9:107-119.

Thompson, R.B. 1996. Effects of predator avoidance conditioning on the post-survival rate of artificially propagated salmon. Ph.D. dissertation submitted to University of Washington, Seattle.

Zar, J.H. 1999. Biostatistical Analysis, 4th edition. Prentice Hall Publishing. Upper Saddle River New Jersey.

CHAPTER 2: MICROHABITAT USE – COMPETITION FOR SPACE AND FOOD

INTRODUCTION

The long-term vision of the mid-Columbia coho reintroduction program is to re-establish naturally reproducing coho salmon populations in mid-Columbia river basins, with numbers at or near carrying capacity. Interactions between hatchery releases of coho and ESA-listed spring chinook and steelhead in the Wenatchee River Basin are ongoing (Dunnigan 2000, Murdoch and Dunnigan 2002, Murdoch and LaRue 2002; Murdoch et al. 2004)). In 2003 we evaluated the potential for naturally produced coho salmon to negatively impact steelhead and spring chinook salmon through competition for space and food. The microhabitat evaluation described in this report builds on the results of the microhabitat study conducted in 2002 (Murdoch et al. 2004).

Coho salmon, chinook salmon, and rainbow/steelhead trout are reported to be sympatric along the western coast of North America from California to British Columbia (Hartman 1965; Johnston 1967; Frasier 1969; Burns1971; Lister and Genoe 1972; Stein 1972; Shirvell 1994). While, habitat requirements of newly emerged chinook and coho salmon are similar during the first three months of stream life, differences in spawn timing, emergence timing, and size, result in a high degree of spatial segregation (Lister and Genoe 1970). Chinook fry emerge about a month earlier than coho fry, are larger upon emergence, and grow at a faster rate (Lister and Genoe 1970). Coho were shown not to affect chinook or steelhead habitat use and growth in the Wenatchee River (Spaulding et al. 1989). Hartman (1965) concluded that strong habitat selection occurred in the spring and summer as a result of agnostic behaviors that were differentially directed by coho against steelhead in pools and by steelhead against coho in riffle habitats. Shirvell (1994) evaluated the effect of stream flow on microhabitat use by juvenile coho and chinook salmon in a natural stream. Comparisons between species showed that juvenile coho and chinook salmon chose different microhabitats for each of three stream flows tested in Kloiya Creek, British Columbia (Shirvell 1994).

The purpose of this evaluation was to continue investigations into habitat use and growth of spring chinook, steelhead and coho salmon in Nason Creek, Washington, with the specific objective to determine the potential for naturally produced juvenile coho salmon to negatively impact spring chinook salmon and steelhead parr through competition for space and food. In 2002, only one coho redd was identified in Nason Creek during weekly spawning ground surveys (Murdoch et. al. 2004). Due to the low number of coho redds observed, we out-planted hatchery coho parr in Nason Creek for this evaluation. While the scatter-planted coho salmon are of hatchery origin, they served as a surrogate for naturally produced coho, providing valuable information regarding interactions between juvenile coho, chinook and steelhead.

METHODS

Study Area and Scatter Plants

Distribution, macrohabitat preference, microhabitat use, and growth of 0+ spring chinook salmon, yearling steelhead and 0+ coho salmon were examined in Nason Creek in July, August, and September, 2003. Due to the low number of coho redds in Nason Creek in 2002, hatchery coho parr from mid-Columbia River broodstock origin were scatter-planted on July 28, 2003 into two of four study reaches (Table 1; Figure 1). A total of 31,628 coho parr were released into Nason Creek (Table 2; Figure 1). All scatter-planted coho were adipose clipped for future identification.

Table 1. Nason Creek study reaches.

Reach Number	Location	Coho Scatter Plants	River Kilometer
1	Mouth to Kahler Creek Bridge	Yes	0.0 to 6.3
2	Kahler Creek Bridge to Butcher Creek	Yes	6.3 to 13.3
3	Butcher Creek to Merritt Bridge	No	13.3 to 17.9
4	Merritt Bridge to Whitepine Creek	No	17.9 to 24.8

Table 2. Coho scatter-plant release locations, Nason Creek 2003.

River Kilometer	Location	Number Released	Pounds
1.6	Nason Creek Campground	3571	41.05
2.2	Hwy 207 upstream of Campground	1309	15.05
3.25	Blue Grouse Lodge	3054	35.10
4.9	Swamp Creek	4046	46.50
5.2	Hwy 207 downstream of ‘fish pond’	479	5.50
5.9	Scale House	1137	13.07
6.3	Kahler Creek Bridge	1137	13.07
7.3	Hwy 2 upstream of Kahler Ck Bdg	2488	28.60
9.5	High voltage power lines	5237	60.20
11.4	Butcher Creek Rd bridge	4520	51.95
12.1	Rest area	1770	20.35
13.3	Wood bridge @ Butcher Creek	2880	33.1
	Total	**31,628**	**363.54**

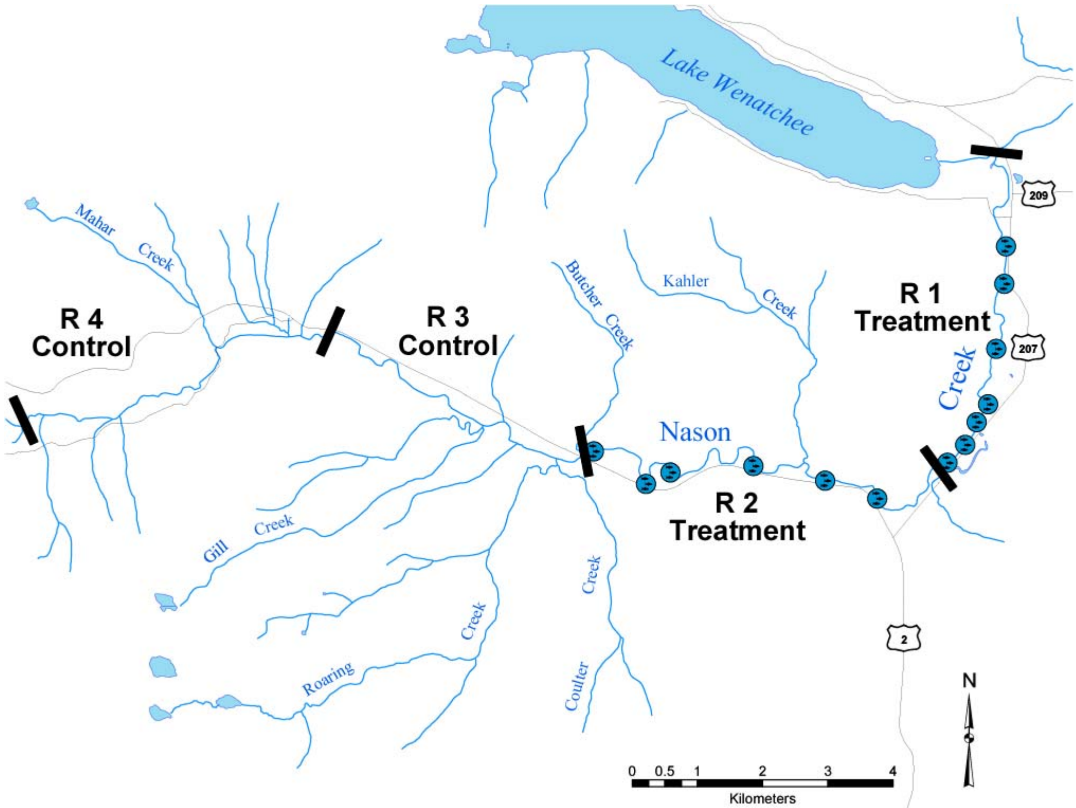


Figure 1. Nason Creek study reaches and coho scatter planting locations, 2003.

We determined the number of coho scatter plants based on an estimate of spring chinook salmon carrying capacity in Nason Creek. The spring chinook carrying capacity in Nason Creek was determined by the National Marine Fisheries Service (NMFS) at 917 spawners (memo from Tim Tynan, NMFS-SFD and Laurie Weitkamp-NWFSC, June 29, 2001). This estimate was provided by Tom Cooney (NMFS-UCR TRT), and was back-calculated from the estimated proportion of the total number of spring chinook salmon late summer parr produced in the Wenatchee River basin attributable to Nason Creek (~21%). In this same memo, it was recommended that the annual adult coho salmon escapement in 2001 and 2002 be limited to no greater than half the estimated spring chinook salmon carrying capacity in Nason Creek (917 spawners), or no greater than the total number of spring chinook salmon adults estimated in-season to have escaped to Nason Creek, whichever is the smaller figure.

The above guidelines allow for a maximum of 459 adult coho spawners. Using a figure of 2.2 fish per redd, 459 spawners could result in a maximum of 209 coho redds in Nason Creek (Table 3). The maximum egg seeding level could reach 564,300 (mean fecundity: 2700). Mean egg-to-late-summer-parr survival for spring chinook salmon during an eight-year study in the Chiwawa River was 10.6% (Hillman and Miller 2000).

Table 3. Determination of Nason Creek coho parr densities and scatter plant numbers.

Chinook Carrying Capacity[1]	Temp. Coho Escapement Cap (max)[2]	Maximum Possible Coho Redds[3]	Mean Fecundity	Max. Egg Seeding Level	Egg to Parr Survival Rate[4]	Est. Coho Parr Population
917 spawners	459 spawners	209	2700	564,300	10.6%	59,816

Nason Creek Available Habitat[5]	Estimated coho parr density	Study Reach Available Habitat[6]	Coho Scatter Planting Numbers[7]
336,102 m^3	0.178coho/m^3	180,248 m^3	32,084

[1]Nason Creek spring chinook carrying capacity as determined by Tom Cooney (NMFS-UCR TRT).
[2]Nason Creek coho salmon suggested temporary escapement limit as recommended by Tim Tynan (NMFS-SFD) and Laurie Weitkamp (NMFS-NWFSC). In 2001 and 2002, the annual adult coho salmon escapement will be limited to no greater than half of the estimated spring chinook salmon carry capacity in Nason Creek, or no greater than the total number of spring chinook salmon adults estimated in-season to have escaped to Nason Creek, whichever is the smaller figure.
[3] Assumes 2.2 adults/redd and a 50:50 male/female ratio. Actual male/female ratios may increase the number of adults/redd and decrease the maximum number of redds.
[4]Hillman T.W., and M.D. Miller Abundance and Total numbers of Chinook Salmon and Trout in the Chiwawa River Basin, Washington, 1999.
[5]Available habitat: river kilometer 24.8 – 0.0, mean depth 0.975 m, mean width 13.9 m. Mean depth and width data provided by Pierre Dawson, USFS.
[6]Study reach extends from the Butcher Creek acclimation site to the confluence (RK 13.3-0.0). Mean depth and width data provided by Pierre Dawson, USFS.
[7]Scatter-planting numbers were calculated by multiplying the estimated density of coho parr (fish/m^3) to the available habitat within the study reach.

Since no data are available for coho salmon in tributaries to the Wenatchee River; the spring chinook egg-to-parr survival rate of 10.6% was used to project coho parr numbers in Nason Creek (Hillman and Miller 2002). An egg-to-parr survival rate of 10.6% and an egg seeding level of 564,300 predicts 57,240 late summer coho parr. Based on the mean width and depth of Nason Creek (data provided by Pierre Dawson, USFS), 57,240 coho parr result in a mean density of 0.1715 fish/m^3. By applying this density to the treatment reaches (RK 13.3 to 0.0), we determined that 32,084 coho parr were required for scatter-planting between the Butcher Creek acclimation site (RK 13.3) and the confluence of Nason Creek (RK 0.0).

Study Design Changes, 2003 vs. 2002

In 2003 we chose a habitat based sampling design, as described in Hankin (1984) and Hankin and Reeves (1988), rather than the stratified random sampling design used in 2002. This sampling method ensuring equal representation of each habitat type (pool, riffle, and glide).

In 2003, the microhabitat study was conducted in reaches one and three (see controls and replication). Reaches one and three contained the largest proportion of brood year 2002 spring chinook redds (21.1%% and 28.6%% respectively) and provided the most habitat diversity (A. Grassell, CPUD, unpublished data. Reaches 2 and 4 are largely characterized by channel confinement, due to highway and railway development, rip-rapped banks, and long riffles with little habitat diversity. During the 2002 study (Murdoch et al 2002) data from reaches 3 and 4 were combined, and data from 1 and 2 were combined for analysis purposes. Due to small samples sizes, or for some surveys, no data, it was not possible to analyze the results of reaches 2 and 4 separately (Murdoch et. al. 2004).

The growth and condition factor sampling and data analysis was unchanged from the methods described in 2002 (Murdoch et al. 2004). All reaches were included in the growth and condition factor portion of the evaluation. Due to the stress and possibility of mortality (immediate and/or latent) associated with electro-fishing, we chose to include four reaches to reduce the chances of shocking the same fish more than once during the three surveys.

Selection of Sampling Units for Micro-Habitat Evaluation

Habitat units (pools, riffles, and glides) were identified and measured (length and width) in reaches one and three (Table 1). Habitat types were defined as described in USFS (1996). Beginning with a random number, every fifth habitat unit of each type (pool, riffle, glide) was selected as a sample unit, following the methodology described by Hankin and Reeves (1988).

Underwater Observation Methods

We snorkeled the selected sample units on clear days between 0900 and 1800 hours, following techniques described by Thurow (1994). Three observers snorkeled in a downstream direction; depth typically did not permit snorkeling in an upstream direction. Observers maintained a prescribed spacing from one another by snorkeling through a predetermined counting lane.

For each species, we grouped fish according their age or size. We divided juvenile chinook into age 0 (<4 inches) and age 1+ or residual chinook (>4 inches). Coho salmon were grouped into the same size categories as spring chinook. Steelhead/rainbow trout were divided into three size/age classes: age 0 (0-3 inches), age 1 (3-6 inches) and those measuring greater than 6 inches. Residual hatchery steelhead were recorded separately and were easily distinguishable from wild steelhead based on their large size, the presence of an elastomer tag, and by eroded fins. Bull trout were grouped into two size classes, juvenile (2-8 inches) and adult (>8 inches).

Controls and Survey Replication

The study was designed with both spatial and temporal controls to detect and evaluate changes in habitat use. For the microhabitat use evaluation, reach three served as a spatial control, or reference reach. The spatial control allowed us to evaluate differences in habitat use between the control and treatment reach. The first survey, completed prior to scatter-planting (see "Survey and Sampling Timeline" section), served as a temporal control, providing a baseline of fish distribution and habitat use in both the treatment and control reaches. Survey 2 occurred one week after scatter-planting and was essentially a "check-in" to observe how the coho were distributing themselves (see "Survey and Sampling Timeline"). Survey 3 occurred a month after scatter planning and provided the final comparison of habitat use.

Microhabitat Use

During the surveys, each observer carried a selection of large washers. The washers were color coded for identification. For example, a red washer was used to identify the location of a 0+ chinook, a yellow washer identified the location of yearling steelhead, and a ½ red/ ½ yellow washer identified the location of 0+ coho. Each washer was placed in the location the observer first saw a fish. If more than one fish was observed in a given location, the observer wrote the number of fish counted on the appropriate washer with a grease pencil. Microhabitat variables were measured after the 100-meter unit was completed and fish locations identified. Water velocity was measured with a Marsh-McBirney flow meter (0.01 ft/s). Depth was measured to the nearest 0.10 ft. Dominant and sub-dominant substrate classes were estimated using a modified Wentworth particle scale (Table 4). The presence of cover and cover type was recorded.

Table 4. Modified Wentworth particle scale.

Code	Classification	Particle Size
1	Detritus	-----
2	Silt	0.09-0.625 mm
3	Sand	0.625-2.0 mm
4	Gravel	2 – 16 mm
5	Pebble	17 – 64 mm
6	Cobble	65 – 255 mm
7	Boulder	> 256 mm

Data Analysis

Macrohabitat availability and selection

The available macrohabitat was measured in terms of the proportion of pools, riffles and glides sampled. The proportion of each habitat type in the control and treatment reaches was compared with a Chi-Square Goodness-of-Fit test to test the null hypothesis that the proportion of pools, riffles and glides were the same in the treatment and control reaches.

To evaluate macrohabitat selection, we used a Chi-Square Goodness-of-Fit test to compare the proportions of chinook, coho, and steelhead found in each of the habitat types to the proportions in which those habitat types were sampled.

Microhabitat use and displacement

A MANOVA was used to examine microhabitat use and overlap in reaches where chinook, steelhead, and coho were sympatric (treatment reach, surveys 2 & 3 only). The dependant variables used in the model were flow velocity (ft/sec), depth (ft), dominant substrate type, and cover use. Independent variables used in the model were species and survey. If the null hypothesis was rejected, we used a Fisher's Least Significant Differences (Fisher's LSD) test to determine where the differences in habitat use occurred (α=0.05).

In order to detect a habitat shift, or displacement of chinook and/or steelhead from preferred habitat in reaches where coho were planted, we used a MANOVA to compare microhabitat use by chinook in the control and treatment reaches. The dependant variables in the model were flow velocity, depth, cover use, and dominant substrate. The independent variables were survey and treatment. If the null hypothesis was rejected, we used a Fisher's LSD test to determine where the differences in habitat use occurred (α=0.05).

Growth and Condition Factors

We measured fish growth and condition factors to indirectly assess competition for space and food. Similar to the microhabitat evaluation, growth and condition factor surveys were conducted prior to scatter-planting (temporal control) and twice after scatter-planting coho parr in both the treatment and control reaches (spatial control) (Table 5; Figure 2). A Fulton-type condition factor was calculated for each fish examined:

$$Kfactor = (w/fl^3)*10^5$$

where Kfactor = condition factor, w = fish weight (g), and fl = fork length (mm).

We believe that if competition for food exists to the extent that the population of juvenile chinook is negatively affected, then condition factors and/or growth should be depressed in areas where all three species occur together (treatment) when compared to reaches where coho are absent (control). Condition factors may also decline if a species is using less suitable habitat where all three species coexist as compared to areas where coho are not present (i.e., habitat displacement).

A temperature probe was placed in the treatment and control reaches, allowing us to evaluate if any differences in Kfactor were the result of temperature.

Fish were collected with a backpack electro-fisher. We attempted to collect 25 fish of each species (coho, chinook, steelhead), in each of the four reaches, during all three sample periods. The first sample period occurred prior to scatter planting coho. The remaining two sample periods occurred one and two months after scatter planting coho parr into the treatment reaches.

Survey and Sampling Timeline

Table 5. Timeline of microhabitat surveys, growth and condition factor sampling and juvenile coho scatter planting in Nason Creek, 2003.

Date	Survey/Sample Number	Activity
July 15 & 16, 2003	N/A	Habitat Pre-survey and Unit Selection
July 18, 21, 22	Baseline	Microhabitat Use
July 22-24	Baseline	Growth and Kfactor
July 28	Scatter Plant Coho	Scatter Plant Coho
August 11-15	Survey 2	Microhabitat Use
August 18-20	Survey 2	Growth and Kfactor
August 25-28	Sample 3	Microhabitat Use
October 1-2	Sample 3	Growth and Kfactor

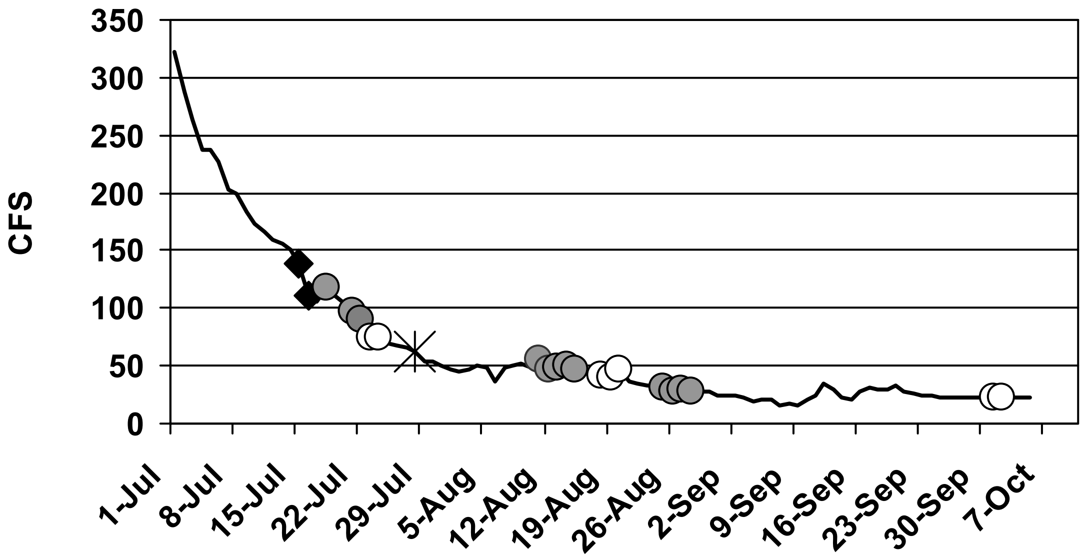


Figure 2. Plot of microhabitat survey, growth and condition factor, and scatter planning timeline vs. CFS in Nason Creek, 2002.
Black Diamond = pre-survey, Grey dots = microhabitat survey, white dots = growth and Kfactor surveys, black star = scatter-planting date.

Data Analysis

To compare the fork length (mm) and Kfactors of chinook, coho and steelhead (fry and yearlings) where all three species coexisted (treatment reaches), we used a MANOVA. Species and survey were the independent variables in the model; fork length and Kfactor were the dependant variables.

We used MANOVA to compare fork length (dependant variable) and Kfactor (dependant variable) between juvenile chinook and yearling steelhead in the control and treatment reaches (independent variable), before and after planting coho (independent variable).

RESULTS

Distribution Of Chinook, Steelhead and Coho in Nason Creek

Baseline distribution

Prior to scatter-planting coho salmon parr into the treatment reaches (reaches 1 & 2,) we completed a baseline distribution survey of Nason Creek (reaches 1-4). During the baseline survey we observed 1 naturally produced coho parr, 1145 juvenile spring chinook salmon, 74 yearling steelhead, 184 steelhead fry, and 37 residual hatchery steelhead (Figure 3). All naturally produced coho were observed in reach 1. Seventy-one percent of the juvenile chinook were observed in reach 1. Most steelhead yearlings and fry were observed in reach one, 90% and 80% respectively, while only 35% of residual hatchery steelhead were observed in reach one (Figure 3). Of all anadromous salmonids observed, residual steelhead were the only species in which the majority were observed in the control reach (R3), rather than the treatment reach (R1) (Figure 3). Sample sizes are also reported in Table 9; Complete species counts can be found in Appendix C.

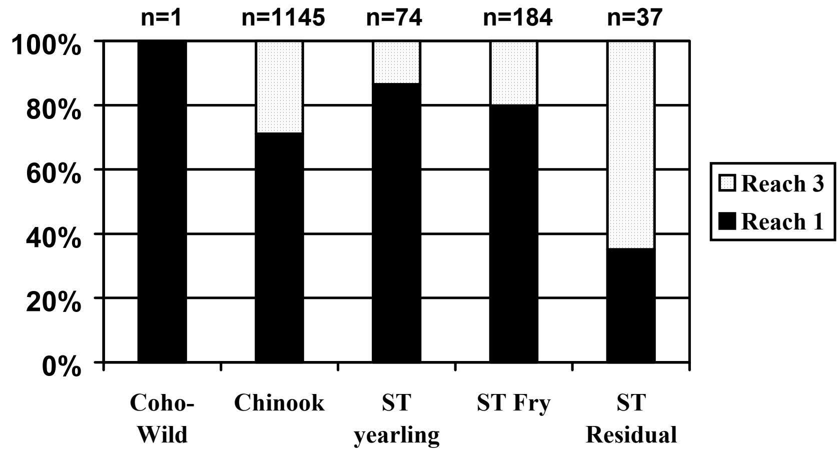


Figure 3. Distribution of juvenile coho salmon, chinook salmon and steelhead trout during the baseline survey (before scatter-planting) in Nason Creek, July 18-22, 2003.

Second survey

The second survey was completed 2 weeks after scatter-planting coho parr into the treatment reaches. The second survey served as a "check-in" to observe how the scatter-planted fish were distributing within the treatment reach. During the second survey we observed no naturally produced coho. We counted 328 scatter-planted coho. Scatter-planted coho were observed in the treatment reach only (R1). We counted 1505 juvenile chinook salmon (Figure 4). Nearly equal proportions of chinook were observed in the treatment (51%) and control (49%) reaches. Approximately 53% of yearling steelhead, 75% of steelhead fry and 65% of hatchery residual steelhead were found in the treatment reach (R1) (Figure 4). Sample sizes can also be found in Table 9; All species counts can be found in Appendix C.

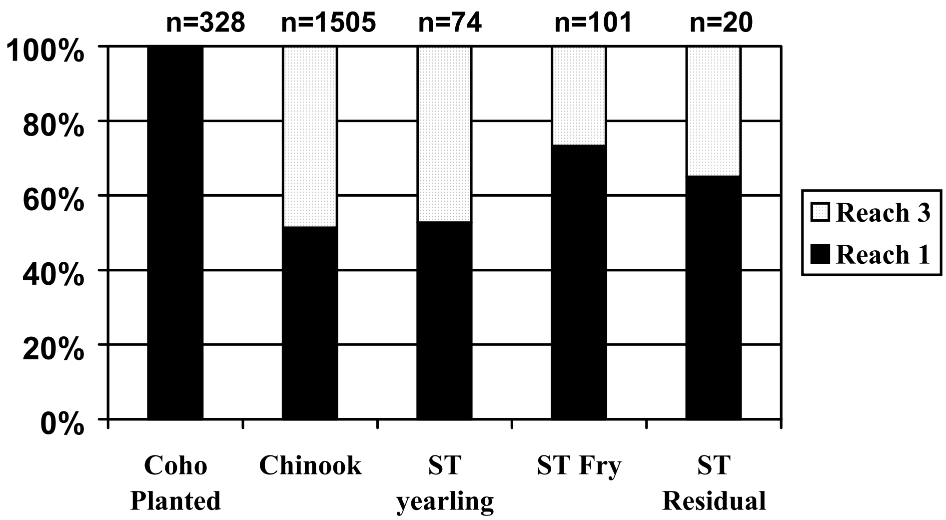


Figure 4. Distribution of coho, chinook and steelhead during the second survey (2 weeks after scatter-planting coho), Nason Creek August 11-15, 2003.

Third survey

The third survey was completed one month after scatter-planting. This survey provided the final comparison of habitat use and distribution of juvenile chinook, coho and steelhead. During the third survey, no naturally produced coho parr were observed. The scatter-planted coho were found only in reach 1 (Figure 5). We counted 1170 juvenile chinook with 48% in Reach 1. Fifty-three percent of the yearling steelhead, and 29% of the steelhead fry were found in reach 1. All hatchery residual steelhead observed on the third survey were found in the control reach (reach 3) (Figure 5). Sample sizes can also be found in Table 9; Complete species counts can be found in Appendix C.

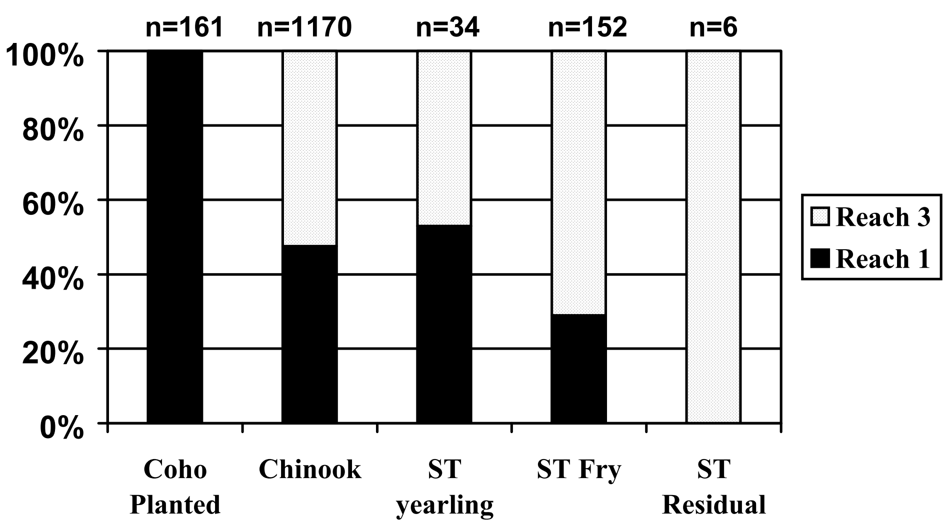


Figure 5. Distribution of coho, chinook and steelhead during the final survey (3-4 weeks after scatter-planting coho) in Nason Creek, August 25-28, 2003.

Observed Fish Densities

The densities reported below are calculated from actual fish counts during the final survey (actual fish counts/m^2 snorkeled units); counts were not expanded for observer efficiency and should be considered a minimum value. In reach 1, we observed a coho density of 0.0006 fish/m^2 for all habitat units combined (Figure 6). Coho densities were highest in pools (0.02 fish/m^2) and lowest in glides (0.004 fish/m^2). Chinook densities were similar in both the control reach (reach 3; 0.020 fish/m^2). Similar to coho, the highest chinook densities were observed in pools. Steelhead densities were the same in both the control and treatment reaches (0.0007 fish/m^2) (Figure 6) with the highest densities of steelhead observed in riffles.

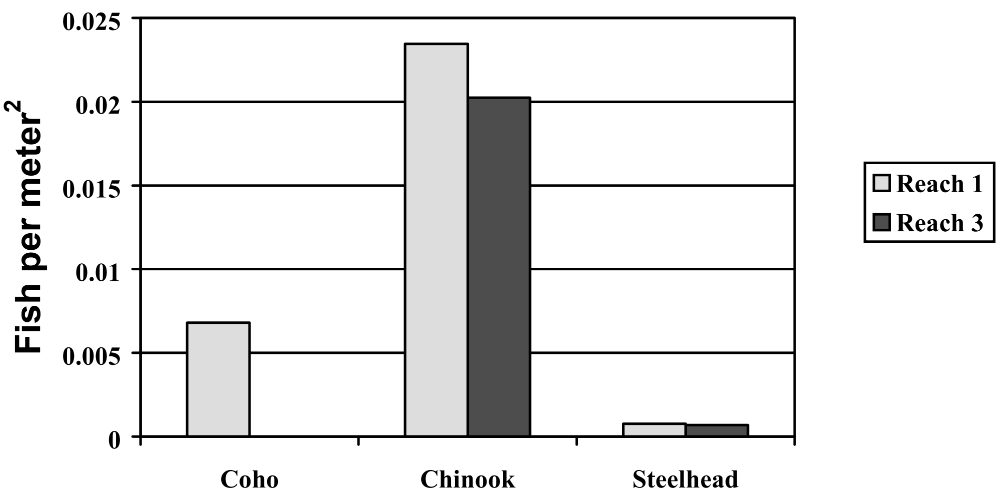


Figure 6. Densities of fish observed during the final survey of Nason Creek, 2003.

Table 6. Results of Chi-Square Goodness of Fit test to evaluate the proportion of macrohabitat types in the treatment and control reaches, Nason Creek, 2002.

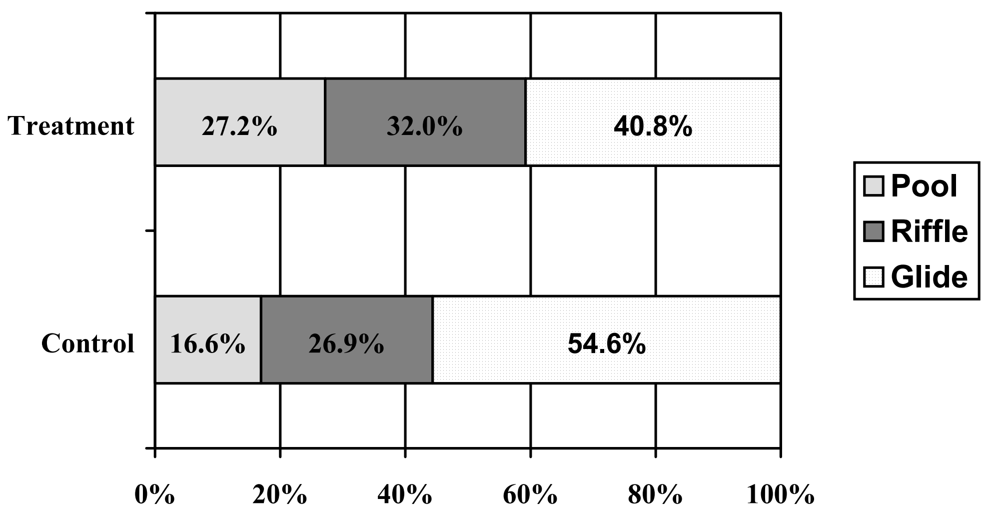
H_o: The proportion of pools, riffles, and glides was the same in the treatment and control reaches				
H_a: The proportion of pools, riffles and glides was not the same in treatment and control reaches				
Statistic	Critical Value	P	H_o	H_a
$\chi^2 = 134.2$	$\chi^2 > 5.991$	P=0.000	Reject	Do not reject
Conclude: The proportion of pools, riffles, and glides in the treatment reach was not the same as the control reach. There were more pools and less glides in the treatment reach. The proportion of riffles sampled was similar.				

Available Macro-Habitat

We used a Chi-Square Goodness-of-Fit test to compare the available macro-habitat in the control and treatment reaches. Results of the Chi-Square Goodness-of-Fit test can be found in Table 6.

We rejected the null hypothesis and concluded that the proportion of each habitat unit type in the treatment reach was not the same as the proportion of each habitat type in the control reach. There were a greater proportion of pools, and less glides in the treatment reach. The proportion of riffle samples was similar.

Figure 7. Available macro-habitat in treatment and control reaches, Nason Creek 2003.



Macro-Habitat Use

Juvenile coho and chinook salmon were observed in pools more frequently than in other habitat types. We observed 38.6% of coho and 45.9% of chinook in pools (Figure 7). Juvenile coho and chinook were observed least often in riffles with 26.5% and 18.5% respectively (Figure 8). Juvenile steelhead were observed most often in riffles, with 48.9% of the steelhead observations (Figure 8).

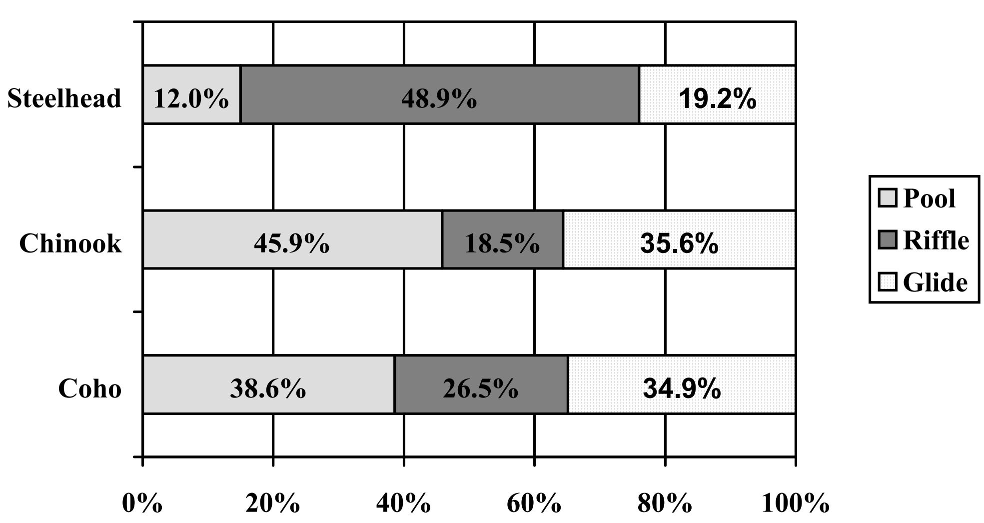


Figure 8. The proportion of juvenile coho, chinook, and steelhead observed in pools, riffles and glides, Nason Creek, 2003.

Macro-Habitat Selection

We compared the proportion of juvenile coho, chinook, and steelhead counted in pools, riffles and glides, with the proportion of pools, riffles, and glides sampled with a Chi-Square Goodness-of-Fit test, providing a measure of habitat selection. If no habitat selection occurred, we would expect to find the proportion of juvenile coho, chinook, and steelhead found in each habitat type in the same proportions as each habitat type was sampled. For chinook and steelhead, we used data collected from all four reaches of Nason Creek in the analysis (Table 7). Microhabitat selection data for coho was analyzed for treatment reaches only (no coho were observed in control reaches) (Table 8).

Table 7. Results of Chi-Square Goodness of Fit test to evaluate macrohabitat selection by juvenile chinook and steelhead (all surveys pooled), Nason Creek, 2003.

H_o: The proportion of chinook and steelhead found in pools, riffles, and glides was the same as the proportion in which pools, riffles and glides were sampled (no selection).				
H_a: The proportion of chinook and steelhead found in pools, riffles, and glides was not the same as the proportion of pools, riffles, and glides sampled (macrohabitat selection).				
Statistic	Critical Value	P	H_o	H_a
$\chi^2 = 1364$	$\chi^2 > 5.991$	$P<0.00$	Reject	Do not reject
Conclude: Juvenile chinook and steelhead were not found in habitat types in the proportions in which they were sampled. Chinook were found less frequently in riffles and glides, selecting pools. Steelhead were found less frequently in glides and were selecting riffles and pools.				

Table 8. Results of Chi-Square Goodness-of-Fit test to evaluate macrohabitat selection by juvenile coho salmon (surveys 2 & 3, treatment reaches only), Nason Creek, 2003.

H_o: The proportion of juvenile coho found in pools, riffles, and glides was the same as the proportion in which pools, riffles and glides were sampled (no selection).				
H_a: The proportion of juvenile coho found in pools, riffles, and glides was not the same as the proportion of pools, riffles, and glides sampled (macrohabitat selection).				
Statistic	Critical Value	P	H_o	H_a
$\chi^2 = 32$	$\chi^2 > 5.991$	$P<0.01$	Reject	Do not reject
Conclude: Juvenile coho salmon were not found in habitat types in the proportions in which they were sampled. Coho were found less frequently in riffles and glides and were selecting pools.				

The results of the Chi-Square analysis indicated that juvenile chinook and coho were selecting pools, and were found less frequently in glides and riffles. Yearling steelhead were selecting riffles and to a lesser degree, pools. Yearling steelhead and were found less frequently in glides.

Further analysis indicated that macrohabitat selection by chinook in the treatment reach was the same as in the control reach. In both reaches chinook were selecting pool habitats. Macrohabitat selection by steelhead in the treatment and control reach was also compared. In the treatment reach, steelhead selected riffles, and were found less frequently in pools and glides. In the control reach coho were found selecting for both pools and riffles. These data, however, were skewed by the presence of 20 juvenile steelhead in pool number 7 during the second survey. This number of steelhead in a single pool was not normally observed and was not typical of steelhead counts within the reach. During the first and third surveys, 0 and 2 steelhead were observed in this same pool (number 7), respectively.

We do not have an explanation for the large number of steelhead observed in the single pool during the second survey. Complete species counts for each snorkeled habitat unit can be found in Appendix C.

Microhabitat Sample Sizes

Sample sizes used in microhabitat analyses can be found in Table 6. Sample sizes of chinook and coho were large during all three surveys. In comparison, sample sizes of steelhead were smaller, resulting in larger confidence intervals (Table 9).

Table 9. Sample sizes of scatter-planted coho, sub-yearling chinook, and yearling steelhead used in microhabitat use and displacement analyses.

Reach	Survey	Coho (N)	Chinook (N)	Steelhead (N)
Treatment	**1**	0	814	64
Control	**1**	0	331	10
Treatment	**2**	328	773	39
Control	**2**	0	732	35
Treatment	**3**	161	556	18
Control	**3**	0	614	16
Total		**489**	**3677**	**182**

Microhabitat Use

We used MANOVA to examine microhabitat use in reaches where chinook, steelhead, and coho were sympatric. To meet these criteria, we used data collected in treatment reaches during surveys 2 and 3 only. The dependant variables in the MANOVA model were flow velocity (ft/sec), depth (ft), dominant substrate type, and cover use. Species and survey were the independent variables. The hypotheses tested and the results of the MANOVA are presented in Table 10.

Table 10. Results of MANOVA comparing microhabitat use between chinook, steelhead, and coho.

<table>
<tr><td colspan="7">H_o: Spring chinook, steelhead, and coho use the same microhabitat when all three species occur together</td></tr>
<tr><td colspan="7">H_a: Spring chinook, steelhead, and coho do not use the same microhabitat when all three species occur together</td></tr>
<tr><td>Effect</td><td>Test</td><td>Value</td><td>F</td><td>Df error</td><td>P</td><td>H_o</td></tr>
<tr><td>Intercept</td><td>Wilks</td><td>0.168</td><td>2315.27</td><td>1868</td><td>0.000</td><td>Reject</td></tr>
<tr><td>Survey</td><td>Wilks</td><td>0.992</td><td>3.76</td><td>1868</td><td>0.004</td><td>Reject</td></tr>
<tr><td>Species</td><td>Wilks</td><td>0.886</td><td>29.26</td><td>3763</td><td>0.000</td><td>Reject</td></tr>
<tr><td>Survey*species</td><td>Wilks</td><td>0.994</td><td>1.51</td><td>3763</td><td>0.14</td><td>Do not reject</td></tr>
<tr><td colspan="7">Conclude: Spring chinook, steelhead, and coho do not use the same microhabitat when all three species occur together. Each species may use the same microhabitat between surveys.</td></tr>
</table>

We rejected the null hypothesis between surveys, and between species. The null hypothesis was not rejected for the interaction between survey and species. Descriptions and comparison of habitat variables and results of Fisher's LSD to determine where differences and similarities in microhabitat use existed are described below.

Flow velocity

In reaches where juvenile spring chinook, steelhead and coho were sympatric (surveys 2 & 3, treatment reaches), coho used significantly slower velocities than chinook and steelhead (Figure 9: Table 11). Steelhead trout were found in the fastest velocities (Figure 9). Chinook used significantly slower velocities during the third survey (Table 8). While flow velocities used by the scatter-planted coho also decreased during the third survey (Figure 9), the difference was not significant (Table 11). We observed yearling steelhead in faster currents that chinook or coho. There was no statistical difference in flow velocities used by steelhead between the second and third surveys (Table 8).

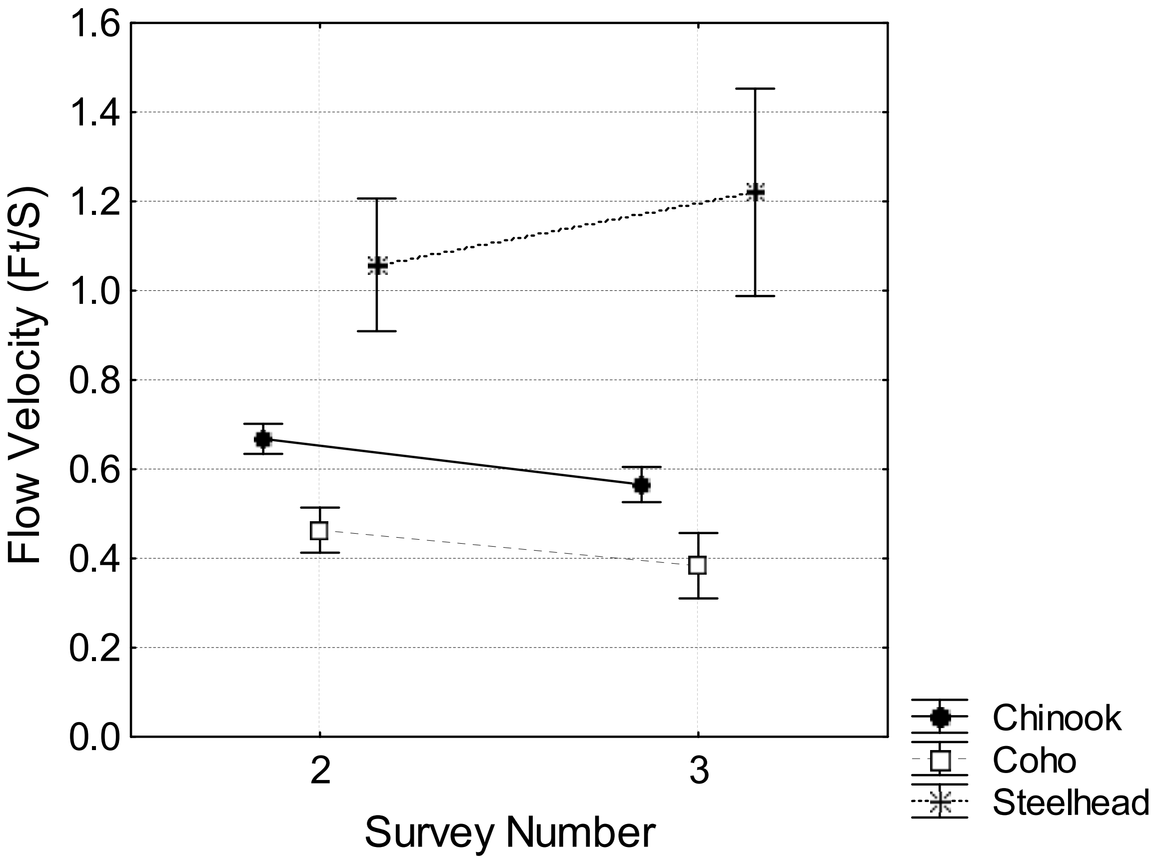


Figure 9. Mean flow velocities used by chinook, coho, and steelhead where they co-occurred (surveys 2 & 3, treatment reaches).
Error bars represent a 95% confidence interval.

Table 11. Fisher's LSD matrix of results for differences in observed velocities used by coho, chinook, and steelhead in Nason Creek, 2002.

Cell No.	Survey	Species	**(1) chinook survey 2**	**(2) coho survey 2**	**(3) steelhead survey 2**	**(4) chinook survey 3**	**(5) coho survey 3**	**(6) steelhead survey 3**
(1)	2	Chinook		S	S	S	S	S
(2)	2	Coho	S		S	S	S	S
(3)	2	Steelhead	S	S		S	S	N
(4)	3	Chinook	S	S	S		S	S
(5)	3	Coho	S	N	N	S		S
(6)	3	Steelhead	S	S	N	N	S	

S = significant differences in mean velocities, N = no statistical difference in observed velocities.

Depth

During both surveys, juvenile chinook were found in statistically greater depths than the scatter-planted coho or yearling steelhead (Figure 10; Table 9). All species were found in deeper depths during the second survey than during the third. The differences in depths between surveys 2 and 3 were significant for juvenile chinook but not for coho or steelhead (Figure 10; Table 12).

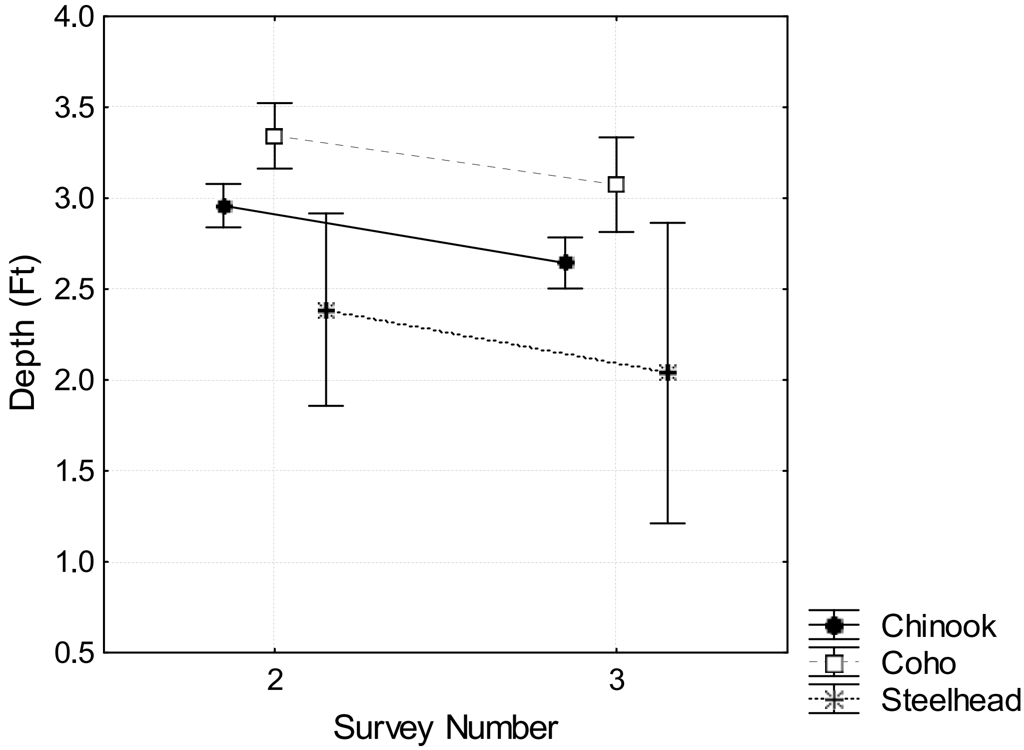


Figure 10. Mean observed depths for juvenile chinook, steelhead, and coho in Nason Creek, 2003. Error bars represent 95% confidence intervals.

Table 12. Fisher's LSD matrix of results for differences in observed depths (ft) used by coho, chinook, and steelhead in Nason Creek, 2002.

Cell No.	Survey	Species	**(1) chinook survey 2**	**(2) coho survey 2**	**(3) steelhead survey 2**	**(4) chinook survey 3**	**(5) coho survey 3**	**(6) steelhead survey 3**
(1)	2	Chinook		S	S	S	N	S
(2)	2	Coho	S		S	S	N	S
(3)	2	Steelhead	S	S		N	S	N
(4)	3	Chinook	S	N	N		S	N
(5)	3	Coho	N	S	S	S		S
(6)	3	Steelhead	S	S	N	N	S	

S = significant differences in mean depth (ft), N = no statistical difference in mean depths (ft).

Cover use

Coho used cover statistically more often than chinook or steelhead during both surveys 2 and 3 (Figures 11 & 12). For all three species the proportion of each found under cover decreased significantly between the second and third surveys (Figures 11 & 12).

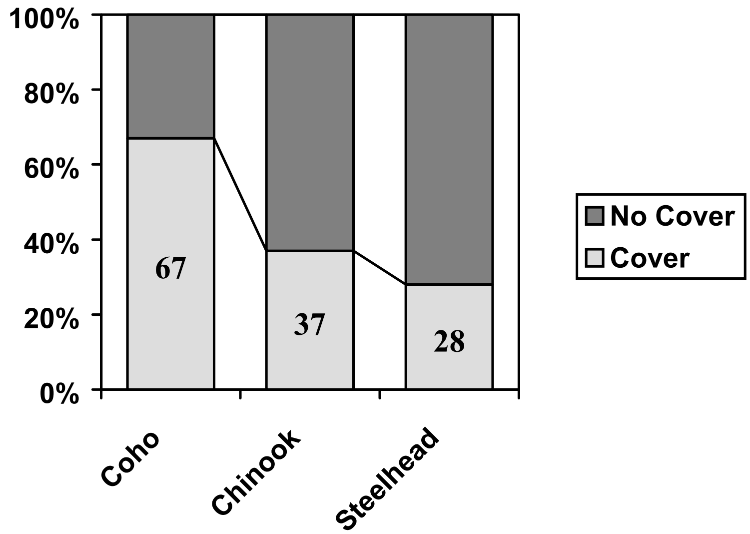


Figure 11. Cover use by juvenile coho, chinook, and steelhead during survey two treatment reach, Nason Creek, 2003.

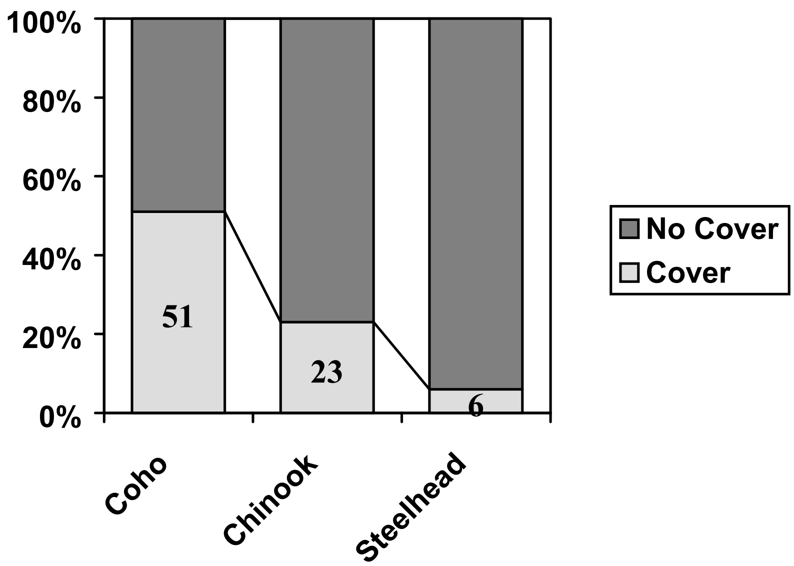


Figure 12. Cover use by juvenile coho, chinook, and steelhead during survey three treatment reach, Nason Creek, 2003.

Dominant substrate types

The dominant substrate type over which juvenile chinook, coho, and steelhead were found is illustrated in Figure 13. Coho were found most frequently over silt or sand, while steelhead were more frequently found over larger substrate types (Figure 13). During survey 2, chinook were found most frequently over silt or sand, moving over larger substrate types during survey 3 (Figure 13).

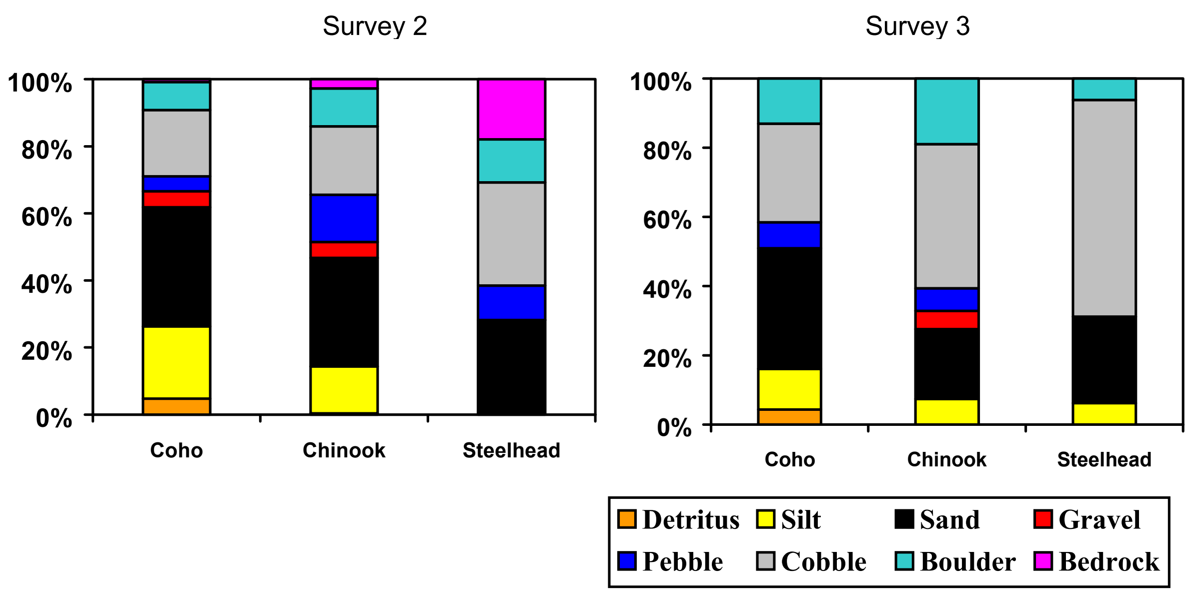


Figure 13. Dominant substrate types where juvenile coho, chinook, and steelhead were observed, Nason Creek., 2003.

Microhabitat Displacement

To determine if spring chinook microhabitat use changed after the introduction of juvenile coho salmon, we use MANOVA (Table 10) to compare microhabitat use by juvenile spring chinook in the control and treatment reaches. The first survey served as a temporal control in all reaches.

We rejected the null hypothesis and concluded that spring chinook and steelhead did not use the same microhabitat in the treatment and control reaches (Table 13). Descriptions and comparison of microhabitat variables, and results of Fisher's LSD to determine where differences in microhabitat use occurred are described below.

Table 13. Results of MANOVA comparing microhabitat use by sub-yearling chinook salmon in treatment and control reaches of Nason Creek, 2003.

H_o: Spring chinook and steelhead used the same microhabitat in treatment and control reaches.						
H_a: Spring chinook and steelhead did not use the same microhabitat in treatment and control reaches.						
Effect	Test	Value	F	Df error	P	H_o
Intercept	Wilks	0.256	2849.9	3943	0.0000	Reject
Reach (T,C)	Wilks	0.985	14.46	3943	0.0000	Reject
Survey	Wilks	0.991	4.169	7886	0.0001	Reject
Species	Wilks	0.971	29.19	3943	0.0000	Reject
Reach*survey	Wilks	0.992	4.08	7886	0.0001	Reject
Reach*species	Wilks	0.995	4.51	3943	0.0012	Reject
Survey*species	Wilks	0.992	4.12	7886	0.0001	Reject
Reach*survey*species	Wilks	0.994	2.76	7886	0.0048	Reject
Conclude: Spring chinook and steelhead did not use the same microhabitat in the control and treatment reaches.						

Flow velocities

Within the treatment reach we found no difference in flow velocities used by juvenile chinook before coho were planted (first survey) and after coho were planted (third survey) (Table 14; Figure 14). Steelhead within the treatment reach used the same flow velocities before and after coho were planted (first and third surveys). During all three surveys (before and after coho scatter-planting), flow velocities used by juvenile chinook were significantly faster in the treatment reach than in the control reach. Similarly, flow velocities used by steelhead were significantly faster in the control than the treatment reach. This discrepancy between flow velocities by juvenile spring chinook maintained itself throughout the evaluation (Table 14; Figure 14). Because both chinook and steelhead were found in faster flow velocities in the treatment reach, and because the differences in flow velocities existed prior to scatter planting coho, we do not believe the difference in observed flow velocities was the result of coho introduction, rather may reflect characteristics of the habitat sampled.

Table 14. Fisher's LSD matrix of results for differences in observed velocities used by sub yearling chinook in Nason Creek, 2002.

Cell No.	Treatment	Survey	Species	(1) Treatment Survey 1 Chinook	(2) Treatment Survey 1 Steelhead	(3) Treatment Survey 2 Chinook	(4) Treatment Survey 2 Steelhead	(5) Treatment Survey 3 Chinook	(6) Treatment Survey 3 Steelhead	(7) Control Survey 1 Chinook	(8) Control Survey 1 Steelhead	(9) Control Survey 2 Chinook	(10) Control Survey 2 Steelhead	(11) Control Survey 3 Chinook	(12) Control Survey 3 Steelhead
(1)*	Trt.*	1	Chin		S	S	S	N	S	S	S	S	N	S	N
(2)*	Trt.*	1	Sthd	S		S	S	S	N	S	N	S	S	S	S
(3)	Trt.	2	Chin	S	S		S	S	S	S	S	S	N	S	N
(4)	Trt.	2	Sthd	S	S	S		S	N	S	N	S	S	S	S
(5)	Trt.	3	Chin	N	S	S	S		S	S	S	S	N	S	N
(6)	Trt.	3	Sthd	S	N	S	N	S		S	N	S	S	S	S
(7)	Cont.	1	Chin	S	S	S	S	S	S		S	S	S	N	S
(8)	Cont.	1	Sthd	S	N	S	N	S	N	S		S	S	S	N
(9)	Cont.	2	Chin	S	S	S	S	S	S	S	S		S	S	N
(10)	Cont.	2	Sthd	N	S	N	S	N	S	S	S	S		S	N
(11)	Cont.	3	Chin	S	S	S	S	S	S	N	S	S	S		S
(12)	Cont.	3	Sthd	N	S	N	S	N	S	S	N	N	N	S	

S = significant differences in flow velocity (ft/s), N = no statistical difference in mean flow velocities (ft/s).
*The first survey in the treatment reach was pre-coho planting and served as a temporal control.

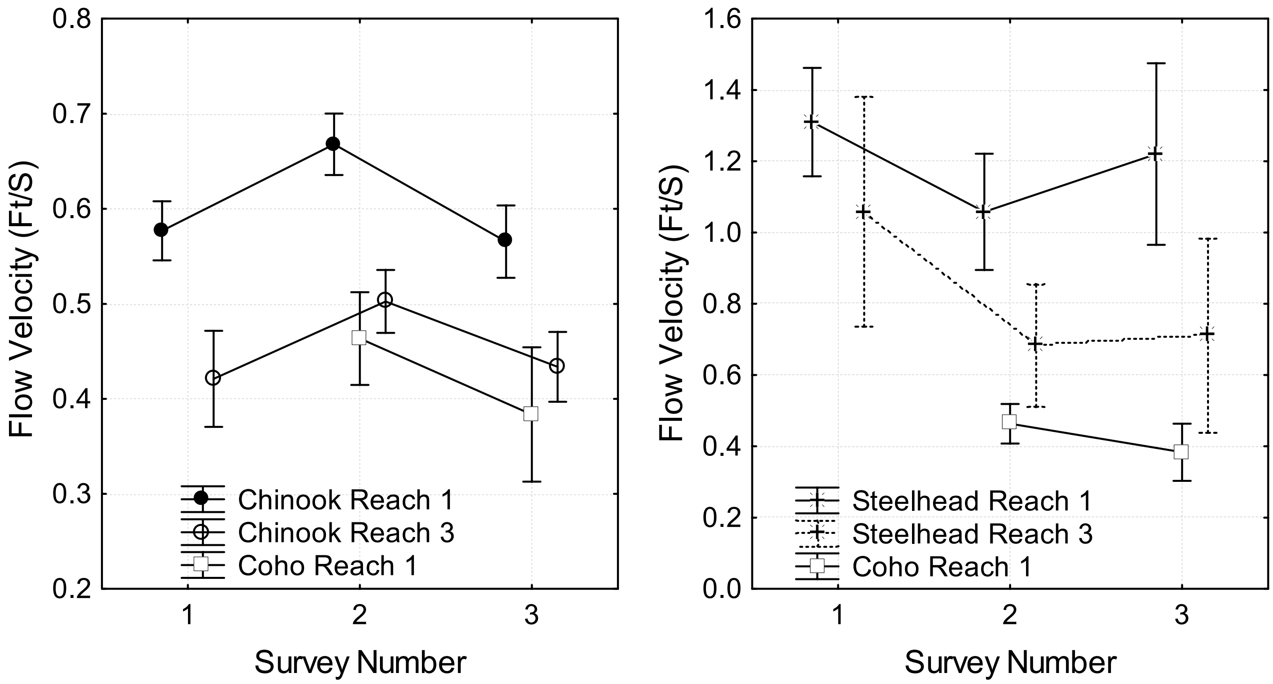


Figure 14. Flow velocities used by juvenile chinook salmon and steelhead in treatment and control reaches, Nason Creek, 2002.
Note: Survey 1, treatment reach, was surveyed prior to planting coho in the reach and served as a temporal control for the treatment reach (R1). .

Depth

Both before and after scatter-planting coho, juvenile chinook were found in deeper areas in the control reach than in the treatment reach (Table 15, Figure 15). Within the treatment and control reaches, there was no significant difference in depths use by juvenile chinook in surveys one and two (Table 15). During survey three, juvenile chinook were found in significantly shallower locations in both the control and treatment reaches (Figure 15).

There was no significant difference in the depths where juvenile steelhead were found in the treatment and control reaches before (survey 1) and after (survey 3) scatter-planting (Table 15). During survey 2, yearling steelhead were found in deeper locations in the control than treatment reach (Figure 15). Within the treatment reach, juvenile steelhead were found in the same depths during all three surveys. Within the control reach, juvenile steelhead used the same depths during surveys 1 and 3; depths used during survey 2 were significantly deeper (Table 15; Figure 15).

Table 15. Fisher's LSD matrix of results for differences in observed depths used by sub-yearling chinook in Nason Creek, 2002.

Cell No.	Treatment	Survey	Species	(1) Treatment Survey 1 Chinook	(2) Treatment Survey 1 Steelhead	(3) Treatment Survey 2 Chinook	(4) Treatment Survey 2 Steelhead	(5) Treatment Survey 3 Chinook	(6) Treatment Survey 3 Steelhead	(7) Control Survey 1 Chinook	(8) Control Survey 1 Steelhead	(9) Control Survey 2 Chinook	(10) Control Survey 2 Steelhead	(11) Control Survey 3 Chinook	(12) Control Survey 3 Steelhead
(1)*	Trt.*	1	Chin		S	N	S	S	S	S	N	S	S	N	N
(2)*	Trt.*	1	Sthd	S		S	N	N	N	S	N	S	S	S	N
(3)	Trt.	2	Chin	N	S		S	S	S	S	N	S	S	N	N
(4)	Trt.	2	Sthd	S	N	S		N	N	S	N	S	S	N	N
(5)	Trt.	3	Chin	S	N	S	N		N	S	N	S	S	S	N
(6)	Trt.	3	Sthd	S	N	S	N	N		S	N	S	S	S	N
(7)	Cont.	1	Chin	S	S	S	S	S	S		S	N	S	S	N
(8)	Cont.	1	Sthd	N	N	N	N	N	N	S		S	S	N	N
(9)	Cont.	2	Chin	S	S	S	S	S	S	N	S		S	S	N
(10)	Cont.	2	Sthd	S	S	S	S	S	S	S	S	S		S	S
(11)	Cont.	3	Chin	N	S	N	N	S	S	S	N	S	S		N
(12)	Cont.	3	Sthd	N	N	N	N	N	N	N	N	N	S	N	

S = significant differences in mean depth (ft), N = no statistical difference in mean depths (ft).
* The first survey in the treatment reach was pre-coho planting and surveyed as a temporal control.

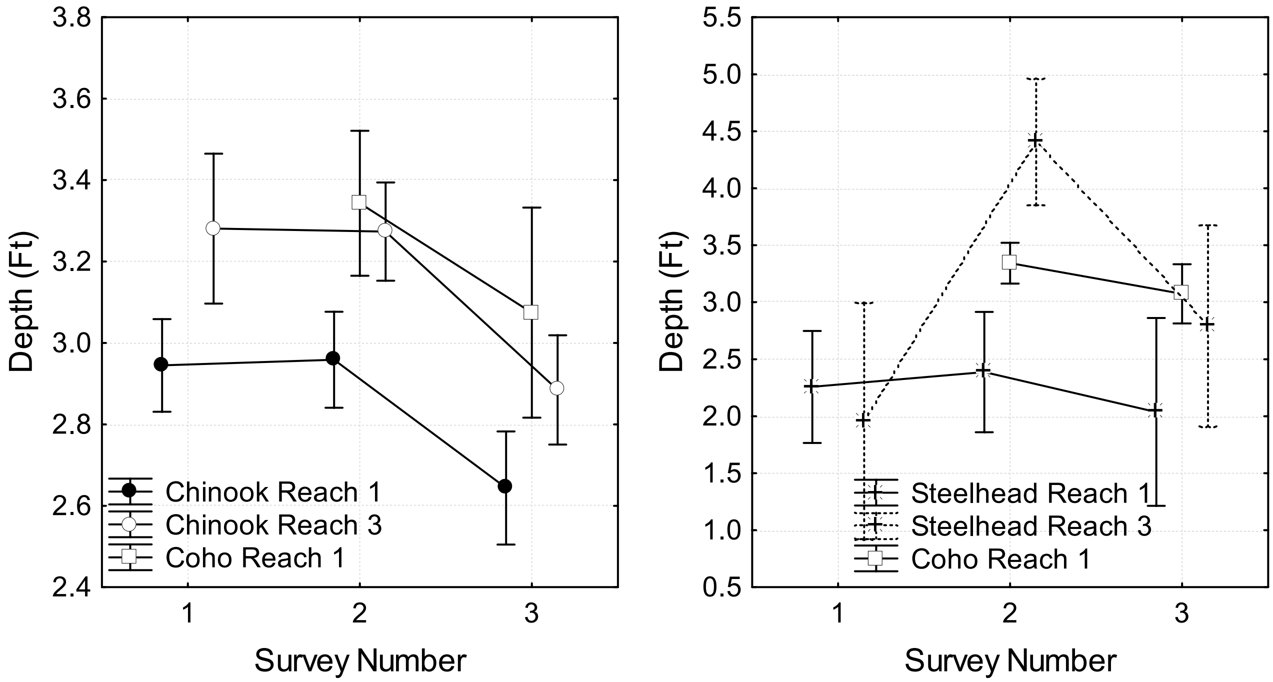


Figure 15. Depths used by juvenile chinook salmon and steelhead in treatment and control reaches during Surveys 1 through 3, Nason Creek, 2003.

Note: Survey 1, treatment reach, was surveyed prior to planting coho in the reach and served as a temporal control for the treatment reach (R1).

Cover use

The proportion of juvenile chinook found under cover (woody debris, overhanging vegetation, or undercut bank) was measured in the treatment and control reaches. Cover use by chinook was similar in the treatment and control reaches, with cover use highest during the first survey and lowest during the third survey (Figure 16). Cover use by steelhead was sporadic in both the control and treatment reaches (Figure 17).

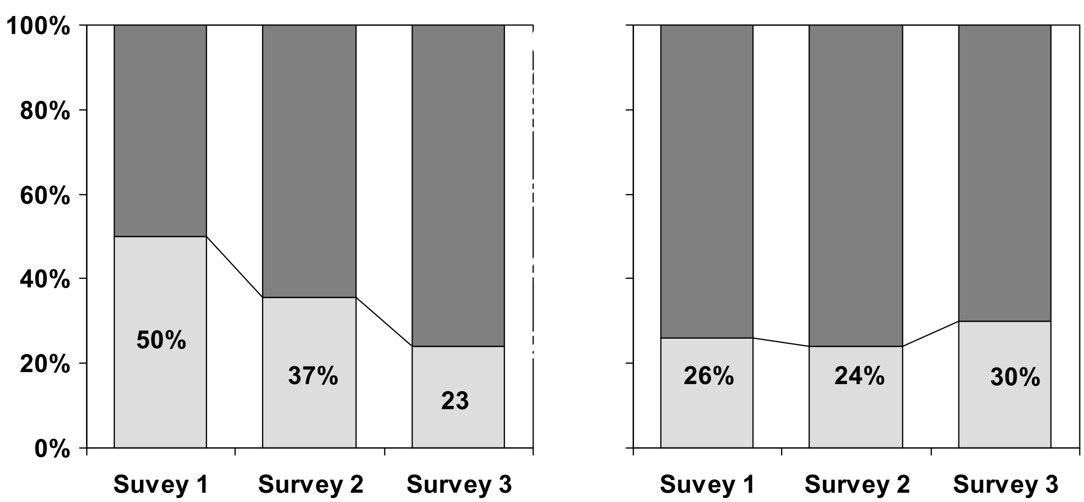


Figure 16. Proportion of juvenile chinook found under cover (woody debris, undercut bank, overhanging vegetation) in the control and treatment reaches, all three surveys, in Nason Creek, 2003.

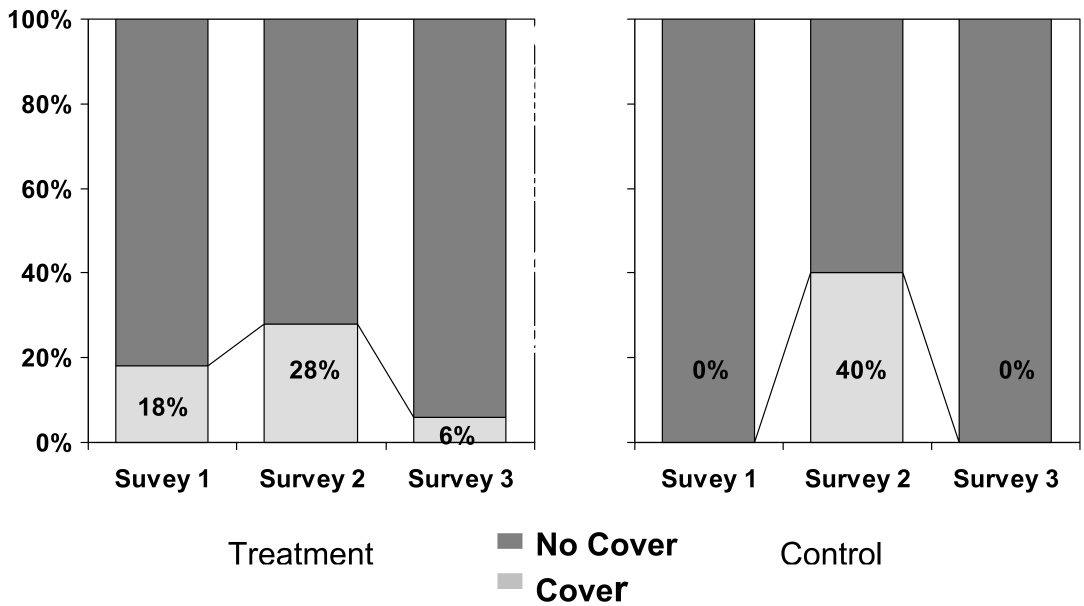


Figure 17. Proportion of yearling steelhead found under cover (woody debris, undercut bank, overhanging vegetation) in the control and treatment reaches, all three surveys, in Nason Creek, 2003.

Growth and Condition Factors of Sympatric Spring Chinook and Coho Salmon

We attempted to collect 25 fish of each species from each of the four identified Nason Creek reaches in July, August, and early October. The first survey (July) was conducted prior to coho planting and served a baseline or temporal control. We were able to collect the desired sample size of juvenile chinook (Table 13) but fell short of the desired sample size for yearling steelhead (Table 16). Because the number of steelhead sampled was low, we pooled data from reaches 1 and 2 to form a larger "treatment" reach, and we pooled data from reaches 3 and 4 to form a larger "control reach". Pooling the data effectively increased sample sizes in the MANOVA model, resulting in steelhead sample sizes large enough to make a comparison between surveys and reaches.

Table 16. Sample sizes of juvenile spring chinook, scatter planted coho, steelhead yearlings, and steelhead fry used in growth and condition factor analysis, Nason Creek, 2003.

Reach	Baseline (C)				Sample 2				Sample 3			
	Sp Ch	Coho Plant	Sthd Year	Sthd Fry	Sp Ch	Coho Plant	Sthd Year	Sthd Fry	Sp Ch	Coho Plant	Sthd Year	Sthd Fry
1 (T)	22	0	1	26	36	34	10	23	37	24	8	51
2 (T)	25	0	12	21	30	49	7	19	27	45	15	45
3 (C)	23	0	14	7	27	0	3	3	35	0	3	14
4 (C)	25	0	2	3	28	0	8	9	24	0	5	21

We used MANOVA to compare fork length and fish condition (Kfactor) of chinook, steelhead, and coho where all three species coexisted (surveys 2 & 3 treatment reach). To test the null hypothesis that sub-yearling spring chinook, yearling steelhead, and scatter-planted coho were the same size and condition in August and October, we used FL and Kfactor as the dependant variable in the MANOVA model, and species and survey the independent variable (Table 17).

Table 17. Results of MANOVA comparing spring chinook, steelhead and coho size and condition where they co-occurred in Nason Creek, 2003.

H_o: Sub-yearling spring chinook, yearling steelhead, and scatter-planted coho were the same size and condition in August and September.							
H_a: Sub-yearling chinook, yearling steelhead, and scatter-planted coho were not the same size and condition during August and September.							
Effect	Test	Value	F	Df error	P	H_o	H_a
Intercept	Wilks	0.0083	26359	442	0.0000		
Survey	Wilks	0.9637	8.32	442	0.0003	Reject	Accept
Species	Wilks	0.2947	186.10	884	0.0000	Reject	Accept
Species x survey	Wilks	0.9966	0.37	884	0.8305	Do not Reject	Reject
Conclude: There was a statistical difference in FL and Kfactor between surveys and between species. The interaction of species and survey was not significant.							

We rejected the null hypothesis between species (coho, chinook) and surveys (Table 17), but did not reject the null hypothesis for the interaction of species and survey (Table 17). To further understand and evaluate these results, we used Fisher's LSD test to determine where the differences in size and fish condition existed.

Fork length - sympatric

During both August and October, the FL (mm) of spring chinook was significantly smaller than the FL (mm) of scatter-planted coho and steelhead (Table 18; Figure 18). The FL of spring chinook in October was statistically longer than the FL of spring chinook in August. There was no significant difference in coho FL (mm), or steelhead FL (mm) between August and October (Table 18; Figure 18).

Table 18. Fisher's LSD matrix of results for differences in fork length (mm) between sub-yearling chinook, and scatter-planted coho where they co-occurred in Nason Creek, 2003.

Cell No.	Survey	Species	**(1) Chinook Aug**	**(2) Steelhead Aug**	**(3) Coho Aug**	**(4) Chinook Oct**	**(5) Steelhead Oct**	**(6) Coho Oct**
(1)	August	Chinook		S	S	S	S	S
(2)	August	Steelhead	S		S	S	N	S
(3)	August	Coho	S	S		S	S	N
(4)	October	Chinook	S	S	S		S	S
(5)	October	Steelhead	S	N	S	S		S
(6)	October	Coho	S	S	N	S	S	

(Treatment reach after scatter planting) S = significant difference in FL, N = no statistical difference in FL.

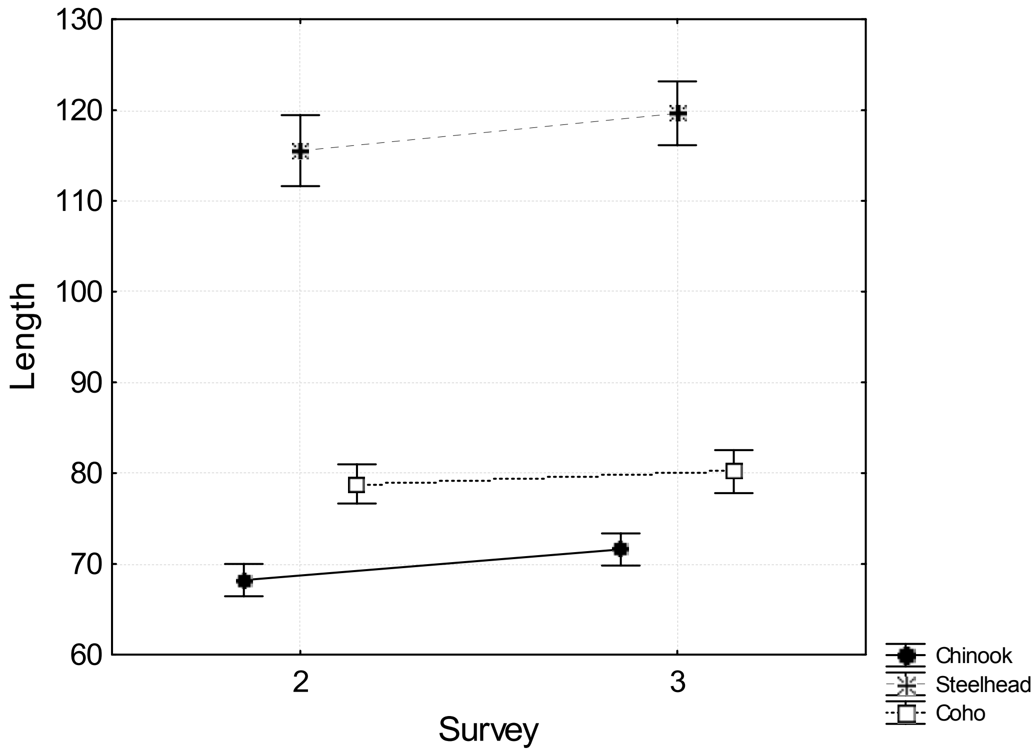


Figure 18. Mean fork length (mm) of sub-yearling spring chinook, yearling steelhead and scatter-planted coho in the treatment reach, Nason Creek, 2003.

Fish condition – sympatric

There was no statistical difference in fish condition (Kfactor) between sub-yearling chinook and scatter-planted coho during August or October (Table 19; Figure 19). Steelhead Kfactors were significantly higher than chinook or coho during both sample periods (Table 19; Figure 19).

Chinook Kfactors increased significantly between the August survey and the October survey, while the mean Kfactor for coho and steelhead remained the same (Table 19; Figure 19).

Table 19. Fisher's LSD matrix of results for differences in condition factor (Kfactor) (between sub-yearling chinook, scatter planted coho, yearling steelhead and steelhead fry where they co-occurred in Nason Creek, 2003. (Treatment reach after scatter planting) S = significant difference in FL, N = no statistical difference in FL.

Cell No.	Survey	Species	**(1) Chinook Aug**	**(2) Steelhead Aug**	**(3) Coho Aug**	**(4) Chinook Oct**	**(5) Steelhead Oct**	**(6) Coho Oct**
(1)	August	Chinook		S	N	S	N	S
(2)	August	Steelhead	S		S	S	N	S
(3)	August	Coho	N	S		N	N	S
(4)	October	Chinook	S	S	N		S	N
(5)	October	Steelhead	N	N	N	S		S
(6)	October	Coho	S	S	N	N	S	

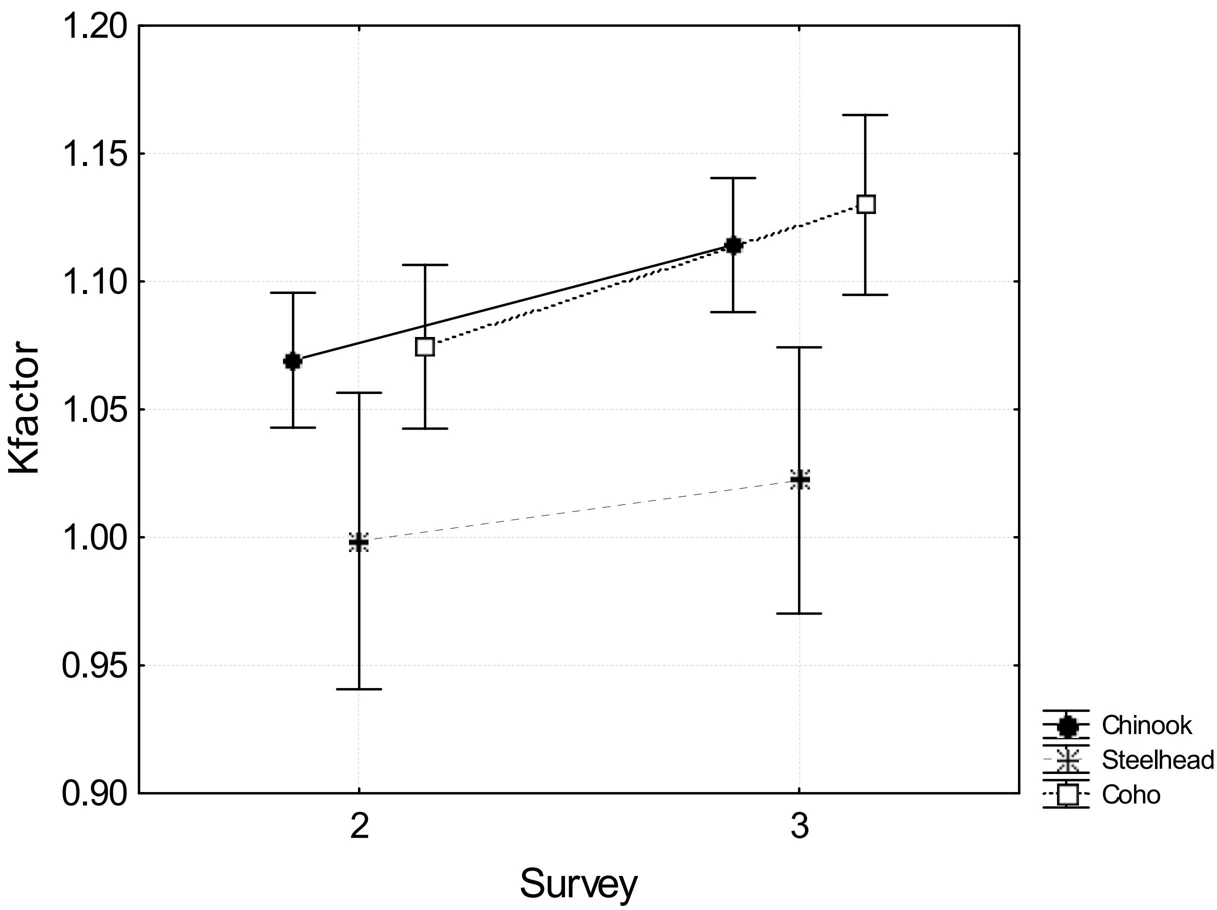


Figure 19. Mean Kfactor of subyearling spring chinook, and scatter planted coho in the treatment reach, Nason Creek, 2003.

Growth and Condition Factors of Juvenile Spring Chinook in Control and Treatment Reaches

We used growth and condition factors of spring chinook and steelhead in control and treatment reaches, before and after scatter-planting juvenile coho salmon to evaluate competition for resources (food and/or space). Theoretically, if competition for resources exists, at coho scatter-planting densities, to such an extent as to negatively affect the population of juvenile chinook salmon, or steelhead trout, we should be able to measure a decline in growth rates and/or fish condition in areas where both species occurred when compared to reaches without coho salmon.

We used MANOVA to compare spring chinook and steelhead FL (mm) and Kfactors in the treatment and control reaches, before and after scatter-planting coho salmon (Table 20). Dependant variables in the model were reach (treatment or control) and survey (July, August, and September). The independent variables were species and survey. The July survey occurred prior to scatter-planting juvenile coho and served as a baseline for comparison, or temporal control.

Table 20. Results of MANOVA comparing spring chinook size and condition in the control and treatment reach, Nason Creek 2003.

H_o: Spring chinook were the same size and condition in control and treatment reaches during each survey.							
H_a: Spring chinook were not the same size and condition in control and treatment reaches during each survey							
Effect	Test	Value	F	Df error	P	H_o	H_a
Intercept	Wilks	0.0150	13369	408	0.0000	Reject	Accept
Reach (T,C)	Wilks	0.9980	0.41	408	0.6646	Do not Reject	Reject
Survey	Wilks	0.8850	12.85	816	0.0000	Reject	Accept
Species	Wilks	0.3322	410.22	408	0.0000	Reject	Accept
Reach*Survey	Wilks	0.9963	0.38	816	0.8260	Do not Reject	Reject
Reach*Species	Wilks	0.9973	0.55	408	0.5781	Do not Reject	Reject
Survey*Species	Wilks	0.9654	3.62	816	0.0061	Reject	Accept
Reach*Survey*Species	Wilks	0.9920	0.82	816	0.5100	Do not Reject	Reject
Conclude: There was no significant difference in FL or fish condition (Kfactor) in the treatment and control reaches, before and after scatter-planting coho.							

The results of the MANOVA indicated no significant difference in spring chinook FL and Kfactor between the treatment and control reaches, or the interaction of reach, species and survey. The interaction between species and survey was significant (Table 20). To further understand and evaluate these results, we used Fisher's LSD test to determine where the differences in size and fish condition existed.

Fork length

For both species (chinook and steelhead) the mean fork length and the change in mean fork length (growth) between surveys in the treatment reach mirrored the control reach (Figure 20). During the evaluation, the mean fork length of chinook and steelhead increased the most between the first and second surveys in both the control and treatment reaches (Figure 21). For both chinook and steelhead, there was no significant difference in FL between the control and treatment reaches during any of the surveys (Table 21). Chinook within the treatment reach grew significantly longer between the first and second survey with no significant difference in FL between the second and third surveys (Table 18). Chinook within the control reach followed the same pattern, growing significantly longer between the first and second survey, with no significant difference in FL between the second and third survey (Table 21). Steelhead grew significantly longer between the first and third surveys in both the control and treatment reaches (Table 21).

Table 21. Results of Fisher's LDS test for significant differences in fork length of spring chinook and steelhead in control and treatment reaches, before and after scatter-planting coho salmon, Nason Creek 2003.

Cell No.	Treatment	Survey	Species	(1) Treatment Survey 1 Chinook	(2) Treatment Survey 1 Steelhead	(3) Treatment Survey 2 Chinook	(4) Treatment Survey 2 Steelhead	(5) Treatment Survey 3 Chinook	(6) Treatment Survey 3 Steelhead	(7) Control Survey 1 Chinook	(8) Control Survey 1 Steelhead	(9) Control Survey 2 Chinook	(10) Control Survey 2 Steelhead	(11) Control Survey 3 Chinook	(12) Control Survey 3 Steelhead
(1)*	Trt.*	1	Chin		S	S	S	S	S	N	S	S	S	S	S
(2)*	Trt.*	1	Sthd	S		S	S	S	S	S	N	S	N	S	S
(3)	Trt.	2	Chin	S	S		S	N	S	S	S	N	S	S	S
(4)	Trt.	2	Sthd	S	S	S		S	N	S	S	S	N	S	N
(5)	Trt.	3	Chin	S	S	N	S		S	S	S	N	S	N	S
(6)	Trt.	3	Sthd	S	S	S	N	S		S	S	S	N	S	N
(7)	Cont.	1	Chin	N	S	S	S	S	S		S	S	S	S	S
(8)	Cont.	1	Sthd	S	N	S	S	S	S	S		S	N	S	S
(9)	Cont.	2	Chin	S	S	N	S	N	S	S1	S		S	N	S
(10)	Cont.	2	Sthd	S	N	S	N	S	N	S	N	S		S	N
(11)	Cont.	3	Chin	S	S	S	S	N	S	S	S	N	S		S
(12)	Cont.	3	Sthd	S	S	S	N	S	N	S	S	S	N	S	

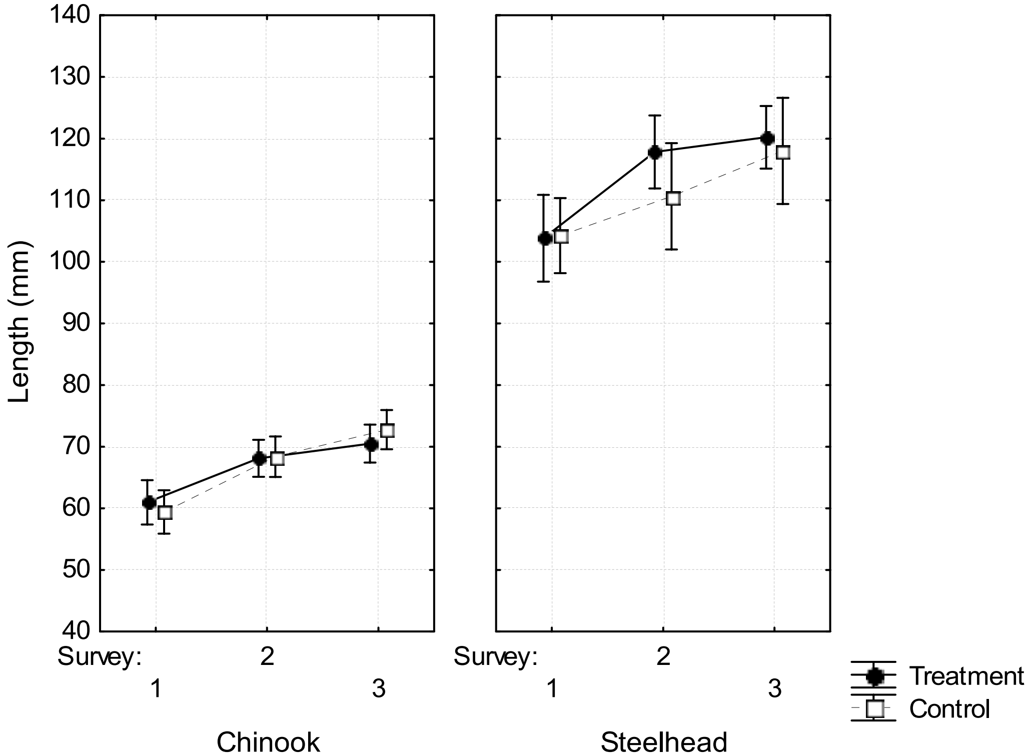


Figure 20. Fork length (mm) and growth of spring chinook and steelhead in treatment and control reaches, Nason Creek, 2003.

Fish condition

There was no significant difference in the mean Kfactor of juvenile spring chinook or steelhead between the control and treatment reaches during any of the surveys (Table 22; Figure 21). Within the control reach, the mean chinook Kfactor did not change significantly during the evaluation (no difference in July, August, or Oct), but chinook Kfactors increased significantly in the treatment reach during the third survey (October; Table 22). The same trend in Kfactor was observed in steelhead. There was no significant change in Kfactor in the control reach, while steelhead Kfactors increased significantly between the first and third survey in the treatment reach (Table 22; Figure 21).

Table 22. Results of Fisher's LDS test for significant differences in kfactor of spring chinook and steelhead in control and treatment reaches, before and after scatter-planting coho salmon, Nason Creek 2003.

Cell No.	Treatment	Survey	Species	(1) Treatment Survey 1 Chinook	(2) Treatment Survey 1 Steelhead	(3) Treatment Survey 2 Chinook	(4) Treatment Survey 2 Steelhead	(5) Treatment Survey 3 Chinook	(6) Treatment Survey 3 Steelhead	(7) Control Survey 1 Chinook	(8) Control Survey 1 Steelhead	(9) Control Survey 2 Chinook	(10) Control Survey 2 Steelhead	(11) Control Survey 3 Chinook	(12) Control Survey 3 Steelhead
(1)*	Trt.*	1	Chin		S	S	N	S	N	N	S	N	N	S	N
(2)*	Trt.*	1	Sthd	S		N	S	N	S	N	N	S	S	N	N
(3)	Trt.	2	Chin	S	N		S	N	N	N	N	N	N	N	N
(4)	Trt.	2	Sthd	N	S	S		S	N	N	N	N	N	S	N
(5)	Trt.	3	Chin	S	N	N	S		S	S	N	S	S	N	N
(6)	Trt.	3	Sthd	N	S	N	N	S		N	N	N	N	S	N
(7)	Cont.	1	Chin	N	N	N	N	S	N		N	N	N	N	N
(8)	Cont.	1	Sthd	S	N	N	N	N	N	N		N	N	N	N
(9)	Cont.	2	Chin	N	S	N	N	S	N	N	N		N	N	N
(10)	Cont.	2	Sthd	N	S	N	N	S	N	N	N	N		N	N
(11)	Cont.	3	Chin	S	N	N	S	N	S	N	N	N	N		N
(12)	Cont.	3	Sthd	N	N	N	N	N	N	N	N	N	N	N	

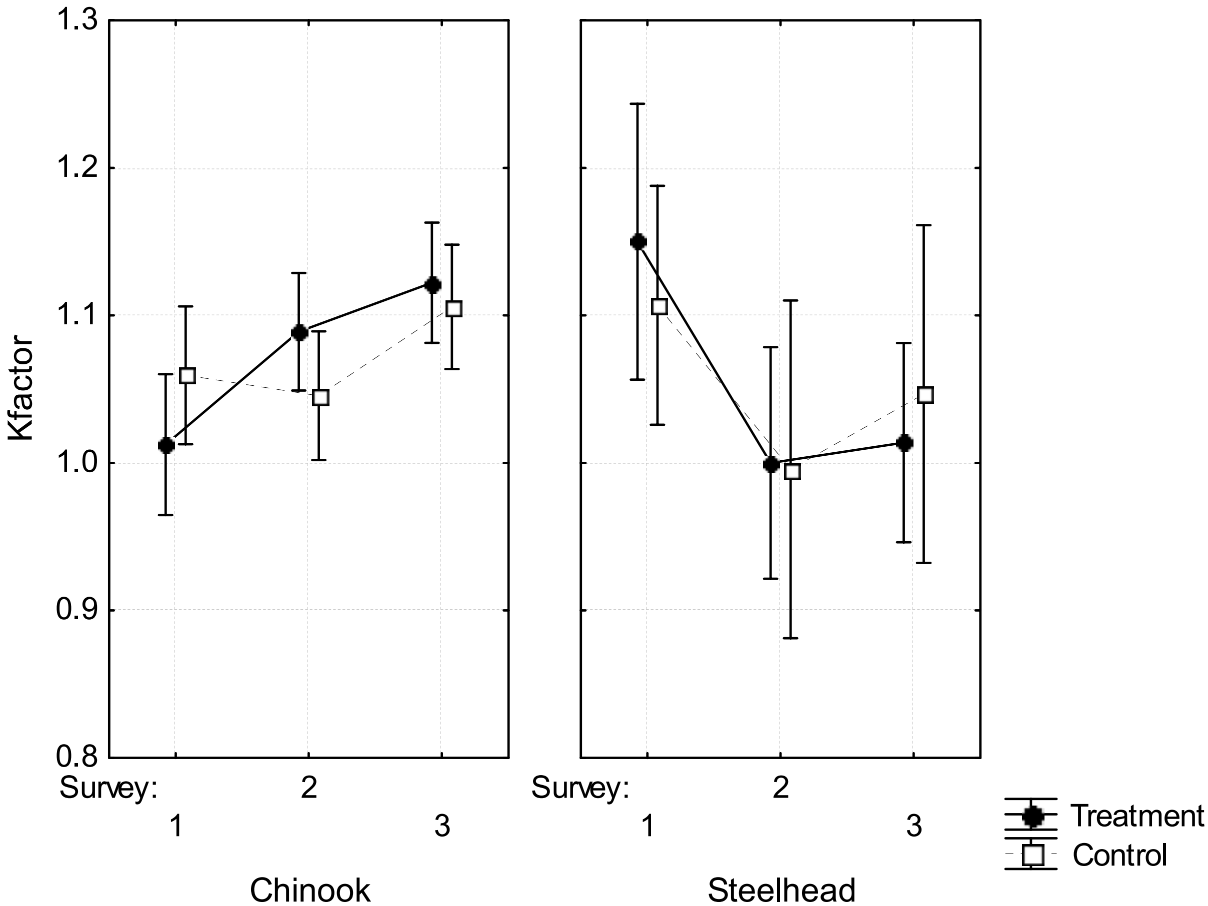


Figure 21. Fish condition (Kfactor) of juvenile spring chinook in treatment and control reaches, Nason Creek, 2003.

DISCUSSION

The results of this evaluation support the results and conclusions of the 2002 evaluation (Murdoch et al. 2004) and indicate that sub-yearling chinook, sub-yearling coho, and yearling steelhead select different habitats within Nason Creek. Yearling steelhead selected riffles, while juvenile coho and chinook both selected pools. The macrohabitat selection we observed in Nason Creek comports well with previously reported habitat use for coho, chinook, and steelhead (Hartman 1965; Lister and Genoe 1970; Allee 1981; Glova 1987; Bisson et al. 1988; Spaulding et al. 1988; Murphy et al. 1989; Bugert and Bjornn 1991; Taylor 1991; Nichelson et al. 1992; Beecher et al. 2002; Hicks and Hall 2003; Murdoch et al. 2004).

Each species is best adapted to only a subset of all the conditions within a stream. The total microhabitat used by a species can be divided into preferred microhabitat and non-preferred microhabitat (Hearn 1987). Two mechanisms contribute to the segregation of salmonid species: interactive segregation is produced by competition-related behavioral interactions, while selective segregation results from the process of natural selection and implies innate differences which lead to species-specific habitat use regardless of whether the other species is present. Innate differences between salmonid species contribute to habitat segregation through such mechanisms as differences in habitat preference and timing of fry emergence and body morphology; these differences have been well documented. Stream dwelling salmonids which have evolved in sympatry have developed mechanisms to promote coexistence and partition the available habitat. Studies with coho salmon and steelhead trout (Hartman 1965; Johnson 1967; Frasier 1969; Allee 1974), chinook salmon and steelhead trout (Everest and Chapman 1972), chinook salmon and coho salmon (Lister and Genoe 1970; Stein et al. 1972; Murphy et al. 1989), coho salmon and cutthroat trout (Bjornn 1971; Bustard and Narver 1975; Sabo and Pauley 1997) and coho salmon and dolly varden (Dolloff and Reeves 1990) all support this statement.

Based on observed the microhabitat use, juvenile chinook, steelhead and introduced coho salmon did not use the same set of habitat conditions. As in the 2002 evaluation, we found coho in significantly slower velocities than both chinook and steelhead. We found coho in significantly deeper areas than chinook or steelhead. These results comport well with other reported habitat use by coho and chinook; Taylor (1991) reported that coho and chinook used different microhabitats in two streams where both coho and chinook were sympatric. Coho used slow water, deep pool areas while chinook were found in faster water (Taylor 1991). Taylor (1991) inferred that the differences in habitat use were the result of species-specific differences in habitat preference and not behavioral interaction because chinook made greater use of faster water and riffle habitats when they were introduced alone or with coho. In an experimental stream, coho were more abundant than steelhead in pools (Allee 1981), but when the stream channel habitat was all riffle, or divided equally into pools and riffles, spatial overlap by coho and steelhead occurred in the stream channel, but simple competitive exclusion in either habitat type was not evidenced (Allee 1981). Within pools, vertical stratification was observed. Coho were distributed near the surface, while steelhead were found near the bottom of pools (Allee 1981). A comparison of flow velocities and depths where coho, chinook, and steelhead were observed in 2002 and 2003 can be found in Figure 22.

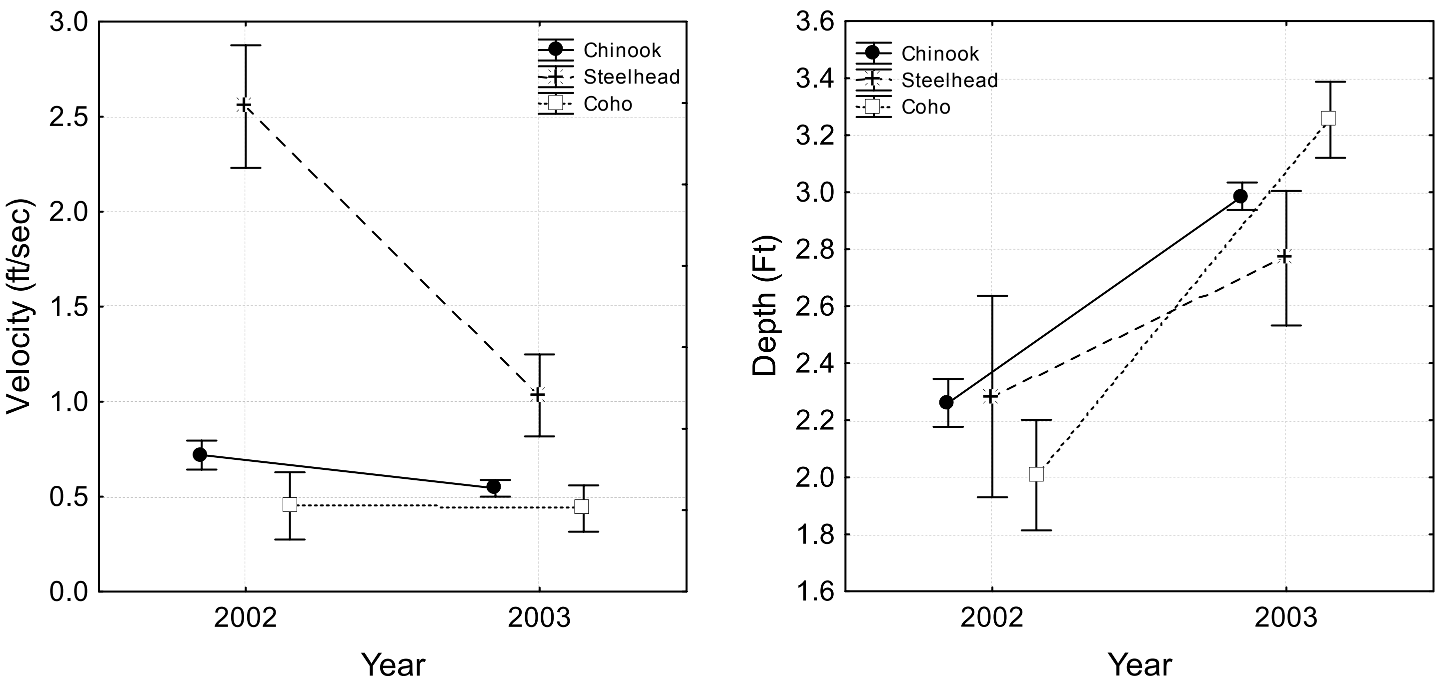


Figure 22. Comparison of mean water velocities and depths where coho, chinook , and steelhead were observed in 2002 and 2003.

We found coho under cover (in-stream and/or overhead) more often than chinook or steelhead. This trend in cover use by juvenile coho, chinook, and steelhead was also seen during our 2002 evaluation (Murdoch et al. 2004) and comports well with previously reported research. Giannco and Healy

(1999) reported that juvenile coho preferred pools with in-stream cover and coho abundance increased as cover complexity increased (McMahon and Hartman 1989).

We found no evidence of chinook habitat displacement with the introduction of coho into the treatment reach. The mean flow velocity used by spring chinook in the treatment reach was the same prior to scatter-planting coho as it was one month after planting coho. While spring chinook used significantly faster velocities in the treatment reach than in the control reach, the difference in flow velocities used remained the same before and after the introduction of coho.

As in the 2002 evaluation, habitat differences observed by coho and chinook in Nason Creek did not appear to be size-related. Due to the use of hatchery coho in this evaluation, the mean coho salmon length was consistently larger than that the mean length of chinook salmon, yet the chinook selected faster water than the coho salmon. Spaulding et al. (1989) used hatchery coho to investigate microhabitat use and competition with chinook (ocean-type) and steelhead in the Wenatchee River and reported this same trend. This differs from Lister and Genoe (1970), who investigated chinook and coho salmon in a British Columbia river, and who document that segregation was maintained by inter-specific size differences, with larger fish occupying faster water. While Lister and Genoe (1970) stated that segregation was based on size, rather than on innate differences in habitat selection, it was still chinook that occupied faster water rather than naturally produced coho, the smaller of the two species.

Three hundred eighty-four spring chinook redds were counted in 2001 (2002 evaluation) and 284 spring chinook redds were counted in Nason Creek in 2002 (2003 evaluation). The 2001 spawning escapement was the highest on record since 1954, and the 2002 evaluation was the 4^{th} highest escapement on record (Grassell 2003). The high spawning escapements in 2001 and 2002 resulted in high densities of juvenile spring chinook, making 2002 and 2003 both ideal years to evaluate interactions between juvenile chinook and coho salmon.

At stocking densities evaluated in 2002 and 2003, we believe that juvenile chinook, coho, and steelhead in Nason Creek are segregating based on habitat preferences (selective segregation) rather than on competitive segregation. In a similar evaluation of microhabitat use, growth and competition between coho, chinook (ocean-type) and steelhead in the Wenatchee River, inter-specific aggression between salmon species did not intensify with increased numbers of coho salmon (Spaulding et al. 1989), implying that habitat segregation was innate, rather than the result of competitive interactions. In faster water, few chinook salmon were found with coho salmon; in pools, no inter-specific clustering was observed (Spaulding et al. 1989). Steelhead did not aggregate with salmon in pool or riffle habitat (Spaulding et al. 1989).

It is possible that with increased densities of coho and/or chinook we could measure a negative interaction to either of the species. However, it is unlikely that the current or proposed release numbers for coho smolts reintroduced into Nason Creek (Kamphaus 2003; Yakama Nation et al. 2001) would result in higher densities of naturally produced coho.

Results of the growth and condition factor analysis support the conclusions of our microhabitat evaluation. While there was no significant difference in mean fork length in the control and treatment reaches for chinook, chinook had a higher condition factor when they co-occurred with coho than when alone in the control reach. If competition for food or space occurred to such an extent as to have a negative effect on the spring chinook population, we would expect condition factors and/or growth rates to decline in reaches where coho were introduced. Similarly, the introduction of coho to a chinook/steelhead community in the Wenatchee River did not affect the growth rates, densities, or emigration rate of juvenile chinook or steelhead fry (Spaulding et al. 1989).

The use of a hatchery coho parr as a surrogate for naturally produced coho may not have provided exactly the same results as if the evaluation were conducted with naturally produced coho; however, we believe that any negative or competitive interactions were maximized by using hatchery coho. Hatchery coho are larger than naturally produced coho and spring chinook. Much existing literature on competition among salmonids suggests that larger fish generally dominate smaller fish in both inter- and intra-specific competition (Griffith 1972; Abbot et al. 1985; Hearn 1987; Chandler and Bjornn 1988; Hughes 1992; Sabo and Pauley 1997). In addition to the possible size advantage, hatchery experience may contribute to aggressive dominance of coho salmon (Spaulding et al. 1989). Hatchery experience provided juvenile Atlantic salmon an aggressive advantage over other wild fish (Fenderson et al. 1968; Dickson and MacCrimmon 1982). Similarly, residual hatchery steelhead have been shown to dominate over wild rainbow trout (McMichael et. al. 1997). Any negative effects of competition to spring chinook should have been exacerbated by the use of hatchery coho as a surrogate for naturally produced coho.

While the coho were introduced to Nason Creek, the juvenile chinook and steelhead were naturally produced, establishing prior residence in the creek. It is possible that prior residence and resulting established territories gave the spring chinook and steelhead a competitive advantage over scatter-planted coho parr. There is limited data specifically pertaining to potential effects of prior residence among salmonids in inter-specific competition evaluations. Allee (1974; 1981) reported that prior residence did not provide either coho or steelhead with exclusive habitat occupancy. Coexistence was always the outcome (Allee 1981). Innate species-specific habitat selection seemed to be the more important determinant of final population structure than prior residence (Allee 1981).

Spring chinook salmon in Nason Creek evolved with coho. On an evolutionary time scale, the extirpation of coho in the Wenatchee basin has been very recent. Introductions that produce sympatry between populations of species that have evolved together elsewhere are less likely to result in intense competition than introductions that bring together species that are not naturally sympatric (Hearn 1987).

Based on the results of this evaluation and our 2002 evaluation, we believe that, at the sub-yearling coho parr densities that may result from the temporary maximum recommended coho spawning escapement numbers (memo from NMFS 6/29/01), coho do not negatively affect sub-yearling chinook and yearling steelhead through the mechanism of competition. Juvenile coho, chinook, and steelhead appear to have innate differences in habitat selection. At the fish densities evaluated, Nason Creek can support the observed differences in habitat selection, resulting in increased biomass and salmonid production.

LITERATURE CITED

Abbott, J. C., R. L. Dunbrack, and C. D. Orr. 1985. The interaction of size and experience in dominance relationships of juvenile steelhead trout (*Salmo gairdneri*). Behavior 92: 241-253.

Allee. B.J. 1974. Spatial requirements and behavioral interactions of juvenile coho salmon and steelhead trout. Doctoral Dissertation, University of Washington, Seattle.

Allee, B.J. 1981. The role of interspecific competition in the distribution of salmonids in streams. Pages 111-122 in E.L. Brannon and E. O. Salo, editors. Proceedings of the salmon and trout migratory behavior symposium. University of Washington Press, Seattle.

Beecher, H.A., B. A. Caldwell, and S. B. DeMond. 2002. Evaluation of depth and velocity preferences of juvenile coho salmon in Washington streams. North American Journal of Fisheries Mgt: 22:785-795.

Bisson, P. A., K. Sullivan, and J.L. Nielsen. 1988. Channel hydraulics, habitat use, and body form of juvenile coho salmon, steelhead and cutthroat trout in streams. Trans. AM. Fish. Soc. 117:262-273.

Bjornn, T. C. 1971. Trout and salmon movements in two Idaho streams as related to temperature, food, stream flow, cover, and population density. Trans. Am. Fish. Soc.: 100:423-438.

Bugert, R. M., and T. C. Bjornn. 1991. Habitat use by steelhead and coho salmon and their responses to predators and cover in laboratory streams. Trans. Am. Fish. Soc. 120(4):486-493.

Burns, J.W. 1971. The carrying capacity for juvenile salmonid in some northern California streams. California Fish and Game 57(1): 44-57.

Bustard, D. R., and D. W. Narver. 1975. Preferences of juvenile coho salmon (Oncorhynchus kisutch) and cutthroat trout (Salmo clarki) relative to simulated alteration of winter habitat. J. Fish. Res. Board Can. 19(6): 1047-1080.

Chandler, G.L., and T.C. Bjornn. 1988. Abundance, growth, and interactions of juvenile steelhead relative to time of emergence. Transactions of the American Fisheries Society 117: 432-443.

Dickson, T.A., and H.R. MacCrimmon. 1982. Influence of hatchery experience on growth and behavior of juvenile Atlantic salmon (Salmon salar) within allopatric and sympatric populations. Can. J. Fish. Aquat. Sci. 39:1453-1458.

Dolloff, C. A., and G. H. Reeves. 1990. Microhabitat partitioning among stream-dwelling juvenile coho salmon, *Oncorhynchus kisutch*, and Dolly Varden, *Salvelinus malma*. Can. J. Fish. Aquat. Sci 47:2297-2306.

Dunnigan, J. 2000. Feasibility and risks of coho reintroduction to mid-Columbia tributaries: 1999 Annual Report. *Prepared for:* Project number 1996-040-00. Bonneville Power Administration, Portland OR.

Everest, F.W. and D. W. Chapman. 1972. Habitat selection and spatial interaction by juvenile chinook salmon and steelhead trout in two Idaho streams. J. Fish. Res. Board Can. 29:91-100.

Fenderson, O.C., W. H. Everhart, and K. M. Muth. 1968. Comparative agnostic and feeding behavior of hatchery-reared and wild salmon in aquaria. J. Fish. Res. Bd. Can. 25(1):1-4.

Frasier, F. J. 1969. Population density effects on survival and growth of juvenile coho salmon and steelhead trout in experimental stream channels. *In*: Symposium on salmon and trout in streams. T. G. Northcote, (ed.). University of British Columbia, Vancouver B. C. pgs 253-266.

Giannico, G. R. and M. C. Healy. 1999. Ideal free distribution theory as a tool to examine juvenile coho salmon (*Oncorhynchus kisutch*) habitat choice under different conditions of food abundance and cover. Can. J. Fish. Aquat. Sci. 26:2362-2373.

Glova, G. J. 1987. Comparison of allopatric cutthroat trout stocks with those sympatric with coho salmon and sculpins in small streams. Environmental Biology of Fishes, 20(4):275-284.

Grassell, A. 2003. 2002 Wenatchee River Basin spring and summer chinook spawning ground surveys. Public Utility District No. 1 of Chelan County, Wenatchee WA. Technical Memo, May 20, 2003. 15pgs.

Griffith, J.S. 1972. Comparative behavior and habitat utilization of brook trout and cutthroat trout in a small stream in northern Idaho. Journal of the Fisheries Resource Board of Canada 29:265-273.

Groot, C. and L. Margolis. 1991. Pacific salmon life histories. UBC Press, University of British Columbia, Vancouver.

Hankin, D.G. and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Canadian Journal of Fisheries and Aquatic Science. Vol. 45: 834-844.

Hankin, D.G. 1984. Multistage sampling designs in fisheries research: applications in small streams. Can. J. Fish. Aquat. Sci. Vol. 41:1575-1591.

Hartman, G.F. 1965. The role of behavior in the ecology and interaction of underyearling coho salmon and steelhead trout. Journal of the Fisheries Research Board of Canada 22:1035-1081.

Hearn, W. E. 1987. Interspecific competition and habitat segregation among stream-dwelling trout and salmon: a review. Fisheries, Vol. 12, No. 5: pgs 24-32.

Hicks, B. J., and J.D. Hall. 2003. Rock type and channel gradient structure salmonid population in the Oregon coast range. Trans. Am. Fish Soc. 132:468-482.

Hillman, T.W., and M.D. Miller. 2002. Abundance and total numbers of chinook salmon and trout in the Chiwawa River Basin, Washington, 2002.

Hughes, N.F. 1992. Ranking of feeding positions by drift-feeding arctic grayling (*Thaymallus arcticus*) in dominance hierarchies. Canadian Journal of Fisheries and Aquatic Sciences 49: 1994-1998.

Jaeger, R. G. 1974. Competitive exclusion: comments on survival and extinction of a species. Bioscience 24:33-39.

Johnston, J.M. 1967. Food and feeding habits of juvenile coho salmon and steelhead trout in Worth Creek, Washington. Masters of Science Thesis, University of Washington, Seattle.

Kamphaus, C.K. 2003. Mid-Columbia coho reintroduction feasibility study: draft 2002 annual broodstock development report. Project Number 1996-040-00. *Prepared for:* Bonneville Power Administration, Portland OR.

Lister, D. B., and H.S. Genoe. 1970. Stream habitat utilization by cohabitating underyearling of chinook and coho salmon I the Big Qualicum River, B. C. J. Fish Res. Board Can. 27:1215-1224.

McMahon, T. E. and G. F. Hartman. 1989. Influence of cover complexity and current velocity on winter habitat use by juvenile coho salmon (*Oncorhynchus kisutch*). Can. J. Fish. Aquat. Sci. 46:1551-1557.

McMichael, G.A., C.S. Sharpe, and T.N. Pearsons. 1997. Effects of residual hatchery-reared steelhead on growth of wild rainbow trout and spring chinook salmon. Trans. Am. Fish. Soc. 126:230-239.

Mosey, T.R., and L.J. Murphy. 2002. Spring and summer chinook spawning ground surveys on the Wenatchee River Basin, 2001. Chelan County Public Utility District, Wenatchee, Washington.

Murdoch, K.G., and J.L. Dunnigan. 2002. Feasibility and risks of coho reintroduction in mid-Columbia river tributaries: 2000 annual report. Project Number 19964000. *Prepared for* Bonneville Power Administration, Portland OR.

Murdoch, K.G. and M.L. LaRue. 2002. Feasibility and risks of coho reintroduction in mid-Columbia river tributaries: 2001 annual report. Project Number 19964000. *Prepared for* Bonneville Power Administration, Portland OR.

Murdoch, K., C. Kamphaus, and S. Prevatte. 2004. Feasibility and risks of coho reintroduction in mid-Columbia river tributaries: 2002 annual report. *Prepared for:* Bonneville Power Administration, Project Number 1996-040-000. Portland OR.

Murphy, M. L., J. Heifetz, J.F. Thedinga, S. W. Johnson, and K. V. Koski. 1989. Habitat utilization by juvenile Pacific salmon in the glacial Taku River, southeast Alaska. Can. J. Fish. Aquat. Sci. 46:1677-1685.

Nickelson, T. E., J.D. Rodgers, S.L. Johnson, and M.F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Oncorhynchus kisutch*) in Oregon coastal streams. Can. J. fish. Aquat. Sci., 49:783-789.

Sabo, J. L., and G. B. Pauley. 1997. Competition between stream-dwelling cutthroat trout (*Oncorhynchus clarki*) and coho salmon (*Oncorhynchus kisutch*): effects of relative size and population origin. Can. J. Fish. Aquat. Sci. (54)2609-2617.

Shirvell, C.S. 1994. Effect of changes in stream flow on the microhabitat use and movements of sympatric juvenile coho salmon and chinook salmon in a natural stream. Canadian Journal of Fisheries and Aquatic Science 51: 1644-1652.

Spaulding, J.S., T.W. Hillman, J.S. Griffith. 1989. Habitat use, growth, and movement of chinook salmon and steelhead in response to introduced coho salmon. Pages 156-208 in Don Chapman Consultants, Inc. Summer and winter ecology of juvenile chinook salmon and steelhead trout in the Wenatchee River, Washington. Chelan County Public Utility District, Washington.

Stein, R.A, P.E. Reimers, and J.D. Hall. 1972. Social interaction between juvenile coho and fall chinook salmon in Sixes River, Oregon. Journal of the Fisheries Research Board of Canada 29: 1737-1748.

Symons, P.E.K., and M. Heland. 1978. Stream habitats and behavioral interactions of underyearling and yearling atlantic salmon. J. Fish. Res. Board Can. 35:175-183.

Taylor, E.B. 1991. Behavioral interaction and habitat use in juvenile chinook, *Oncorhynchus tshawytscha*, and coho, *O. kisutch*, salmon. Anim. Behav. 42: 729-744.

Thurow, R.F. 1994. Underwater methods for study of salmonids in the intermountain west. United States Forest Service, Intermountain Research Station. General Technical Report INT-GTR-307.

USFS. 1996. Nason Creek stream survey report. United States Forest Service, Wenatchee, WA. 41pgs.

CHAPTER 3: COHO RADIO-TELEMTRY: COLUMBIA, WENATCHEE, ENTIAT AND METHOW RIVERS

INTRODUCTION

Coho salmon, reintroduced to mid-Columbia tributaries, have a significantly longer spawning migration (500-600 miles) then the stocks from which they originated (150-200 miles). A goal of the mid-Columbia coho reintroduction feasibility study is to determine whether a local brood can be developed from lower Columbia River stocks. The increased migratory distance likely will result in strong selective pressures during the first generations of broodstock development. With divergence from the founding stocks, we may see a change in migration timing, spawn timing, egg size, or other phenotypic traits as a result of the selective pressures associated with the increased migration length.

Anadromous salmon migrations are energetically expensive (Hinch and Rand 2000). The duration of a migration or travel time is often a critical variable in determining the cost of migration (Zable 2002). Natural selection for greater energy reserves prior to migration is perhaps the most likely mechanism by which migratory costs are ameliorated (Kinneson et al. 2001). Wild salmon with longer freshwater migrations, such as Yukon River chum salmon, can have nearly four times the energy reserves (primarily fat content) found in salmon from coastal populations (Brett 1995).

The trade-off between reproductive investment and migration should be an important factor shaping the evolution of life history traits among populations following their radiation, or introduction, into habitats with different migratory costs (Kinneson et al. 2001). Long-migrating salmon need to conserve energy during their migration to ensure that they can reach the spawning ground and still have enough energy to mature and successfully spawn. However, they may have a limited amount of time to reach spawning areas; migrational delays could have a negative effect on fitness (Hinch and Rand 2000). To reach spawning grounds in the Wenatchee and Methow rivers, salmon must migrate past nine major hydropower facilities. Salmon that migrate long distances are under strong selective pressure to complete spawning early enough to ensure sufficient degree-days for eggs and alevin development, and to reduce chances of over-winter mortality caused by spawning ground freeze-up (MacDonald and Williams 1998). Kinneson et al. (2001) examined the effects of altered migration distance on reproductive investment in chinook salmon and found that the cost of a longer migration appears to come not only as a cost to tissue energy reserves, but also as a cost to ovarian investment, primarily egg size.

The selective pressures described by Brett (1995), Hinch and Rand (2000), and Kinneson et al. (2001) are similar to the selective pressures that may face reintroduced coho salmon returning to mid-Columbia tributaries. Returning coho that do not have enough energy reserves to migrate 500–600 miles will drop out and die, or will stray to closer spawning locations.

Through the broodstock development process, we expect to see selection for traits that support the increased migration distance. These traits may include altered run-timing, egg size, or energy reserves. The expression of these phenotypic traits should result in increased SARs for reintroduced coho and a reduction in dropout and stray rates along the migratory route.

High dropout or stray rates of returning reintroduced coho salmon may be a potential factor that could limit project success. Sufficient numbers of adults must return to mid-Columbia tributaries to be collected for the broodstock development process. Observations made during the previous coho returns to the Wenatchee River basin in 2000, 2001, and 2002 indicated that some coho are spawning in the mainstem of the Wenatchee and Methow rivers as well as in other tributaries along the migratory route, such as the Entiat River (C. Hamstreet, USFWS, personal communication) and Chelan Falls (C. Snow, WDFW, personal communication). The numbers of coho spawning in lower mainstem tributaries of release and other locations is unknown.

In 2003 we initiated a radio-telemetry evaluation to examine stray and dropout rates in adult coho salmon returning to the Wenatchee and Methow rivers to answer questions related to energetics and reintroduction, and to meet the following objectives:

- Objective 1 – To determine the stray rates of coho salmon returning to the Wenatchee and Methow river basins
- Objective 2 – To determine if the development of a local broodstock decreases stray rates of coho salmon returning to mid-Columbia tributaries
- Objective 3- To determine if there is a correlation between run-timing, size, or gender with the ability to return to streams of acclimation
- Objective 4 – To determine the spawning distribution of reintroduced coho salmon.

Study Area

The study area includes 238 river kilometers of the Columbia River from Priest Rapids Dam located at RK 638.9 to Chief Joseph Dam at RK 877.1, and the major tributaries which include the Wenatchee, Entiat, Methow, and Okanogan rivers. This reach of the Columbia River contains Wanapum Dam at RK 638.9, Rock Island Dam at RK 729.5, Rocky Reach Dam at RK 762.2, and Wells Dam at RK 829.6 (Figure 1).

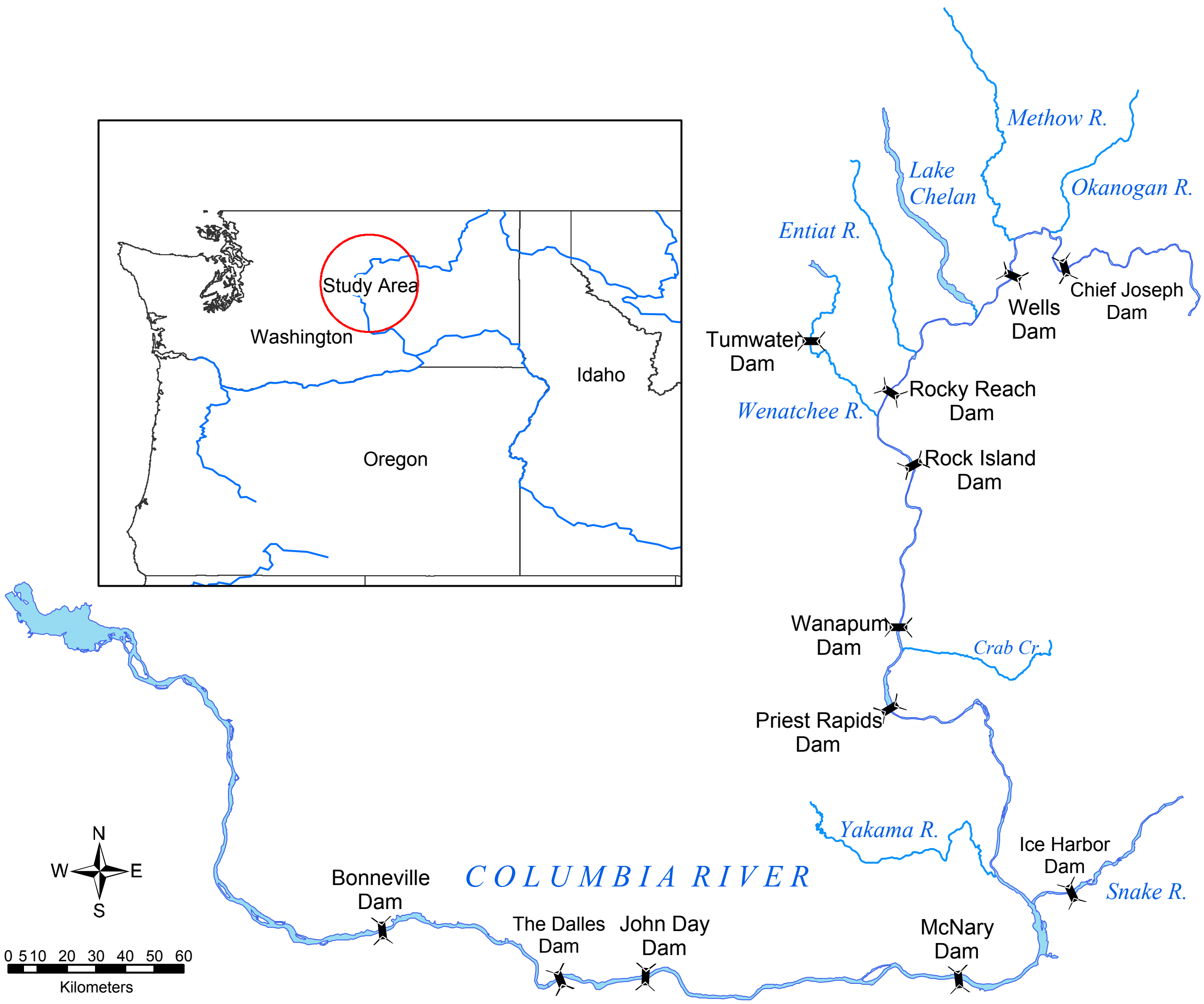


Figure 1. The mid Columbia coho radio telemetry study area extends from Priest Rapids Dam to Chief Joseph Dam in the Columbia River and includes all the major tributaries in this reach with a focus on the Wenatchee and Methow rivers.

METHODS

Study Design

To answer the questions posed in the study objectives, a total of 315 mid-Columbia River coho were scheduled to be radio tagged throughout the migration period (September-November). This sample size would provide an expected tagging rate of 5.25 percent of an estimated 6,000 returning adults.

The movements of radio-tagged coho were monitored with fixed-station receivers and mobile tracking in the mid-Columbia River and its tributaries. Individual fish were then tracked to their possible spawning locations.

Priest Rapids Dam

We attempted to radio-tag 240 coho at Priest Rapids Dam between September 1st and November 14th, 2003. To evaluate the effect of run timing on return, stray, and drop-out rates, the tagging schedule was divided into 3 equally sized tag groups with weekly tagging goals (Table 1).

Table 1. Tag group timing, dates, and tagging goals at Priest Rapids Dam, 2003.

Timing	Dates	Tagging Goal
Early Run	Aug 26 – Sept 19	80 fish at 20 fish/week
Middle Run	Sept 20 – Oct. 17	80 fish at 20 fish/week
Late Run	Oct. 18 – Nov. 14	80 fish at 20 fish/week

Tagging was conducted at the east bank exit trap of Priest Rapids Dam. Trapping at the dam was done in conjunction with WDFW's steelhead stock assessment sampling which typically occurred on Tuesday and Thursday of each week. Beginning at 8:00 a.m., all fish were directed from the ladder into the trap for sorting and sampling. At 4:00 p.m. the denil fishway was turned off and passage through the fish ladder resumed.

During the trapping operations at Priest Rapids Dam, all coho greater than 50 cm were radio-tagged by YN personnel. Other species collected in the trap were sampled by WDFW personnel and retuned to the river.

Radio-tagged coho were held for recovery in a fish transport tank with freshwater recirculation for a period of 1 to 6 hours. Radio-tagged coho were transported 39 river kilometers upstream and released at the Vantage boat ramp. The upstream transport was intended to minimize fallbacks over Wanapum Dam where no telemetry detection equipment was in place.

Tumwater Dam

By increasing the number of radio-tags implanted into coho with a known destination (Nason Creek), the radio-tags used at Tumwater Dam allowed for a more detailed evaluation of spawning areas in the upper Wenatchee basin. Up to 30 coho were scheduled to be tagged at Tumwater Dam in the Wenatchee River basin. A weekly tagging goal of 5 fish was established based on the expected number and timing of returns.

The fish collection system at Tumwater Dam was passively operated three days per week from October 9th through November 29th, 2002. The trap was set in the morning by gating off the fish ladder and turning on the denil fishway, which shunted upstream migrants into a holding area. The trap was checked at least twice daily and the denil was turned off at 4:00 p.m., allowing passage to resume in the fish ladder.

Any coho larger than 50 cm and in generally healthy condition were radio-tagged. Tagged coho were held in a 300 gallon transport tank for a one-hour recovery period, and then transported 0.5 kilometer upstream to the top of Lake Yolanda for release. The upstream transport was intended to prevent fallbacks over Tumwater Dam. All incidentally trapped fish were counted, recorded, and released into the Wenatchee River.

Wells Dam

To provide more data on coho returning to the Methow River, up to 20 radio-tags were available to be used at Wells Dam. The priority during trapping at Wells Dam was the broodstock collection quota; therefore no weekly tagging goals were planned.

Trapping was done at the left bank fish ladder broodstock collection area 3 days per week from September 10th to October 27th. The trap is operated by placing a barrier fence across a pool located about halfway up the ladder. The fish then ascend a denil and enter a sorting chute were they are identified and either diverted into a holding tank or allowed to pass.

After tagging, coho were held in a truck-mounted tank with freshwater circulation and oxygen. After recovery, the fish were transported to the release site located approximately 2 miles upstream of Wells Dam.

Bonneville Dam

In order to explore the option of collecting data throughout the Columbia River system, 15 radio-tags were available for use at this location. Tagging at Bonneville Dam was provided by University of Idaho personnel. Mid-Columbia bound fish were selected in the fish ladder by PIT-tag identification.

Tagging Procedures – All Locations

All trapped coho were anesthetized in a solution of MS-222 at a concentration of 80 mg/L. After the fish was sedated, fork length was measured to the nearest millimeter, sex was determined, and external marks were noted. The coho was placed on its back in a V-shaped trough designed to support the fish, and was either tagged in the water or was kept wet with sprinklers. The radio-tag was activated and checked with a receiver to ensure that it was functioning prior to use. A small rubber O-ring was placed around the radio-tag to help prevent regurgitation. The radio-tag was then inserted gastrically using a plastic pipette as a push-rod. Proper placement of the tag was determined by feel as the tag was inserted. While still anesthetized, the tagged coho was placed in a rubber boot with water and hoisted up or carried to the recovery/transport tank. Prior to release, all fish were examined to confirm tag retention, and release time was noted.

Equipment

Tags

Lotek MCFT-3A coded transmitters (16 x 51mm) were used in the evaluation. Individually coded tags were distributed across 4 frequencies. The transmitters applied in fish at Priest Rapid, Wells, and Bonneville dams were compatible with the digital spectrum processors (DSPs) used at some of the detection sites. The transmitters used at these locations were also equipped with a 27-week kill switch to ensure that the tags were deactivated after the evaluation was complete, thus reducing the chance of interfering with future evaluations in the Columbia River. The same Lotek MCFT-3A coded transmitter was used at Tumwater Dam. The Tumwater Dam radio-tags were not DSP-compatible (could not be detected at some fixed stations) and had a tag life of 685 days (1.9 years). The tag life on the Tumwater tags allowed us to locate and recover the transmitters, manually turn them off, and re-use the tag in future evaluations.

Receivers

Receivers manufactured by Lotek Engineering Inc. of Newmarket, Ontario, were used for all monitoring throughout the study. The Lotek SRX 400 with W16 software was used at the fixed detection sites. The Lotek DSP 500 was used in the fish ladders of Chelan and Douglas County PUD hydropower facilities to provide continuous monitoring. The Lotek SRX 400 with W31 software and GPS interface was used during mobile tracking to provide precise locations of detections. Receivers were either powered with AC where it was available, or with 12-volt batteries and a 50-watt solar panel for continuous charging. During the winter months, when solar energy was low, the batteries were replaced twice a week.

Antennas

Controlled tests done by Johnson in 1996 and 1997 showed that the range of detection for aerial antennas varied from 130 to 300 meters, depending on the depth of a tag in the water column. Radio-tagged fish traveling in the top 3 meters of the water column could be detected from 200 to 300 meters, whereas radio-tagged fish that were traveling deeper than 3 meters could be detected from 130 to 240 meters. Because of the characteristics of underwater signal propagation, the range of detection for underwater antennas was 5–10 meters (Johnson et. al 1999). The detection sites installed at Columbia River dams included both underwater and aerial antenna arrays in or around the fish ladder exits. Tributary river monitoring sites consisted of 2 or more Yagi 6- or 9-element aerial antennas aimed both upstream and downstream at approximately a 45-degree angle, allowing for detections both coming and going. During mobile tracking, 2- or 4-element Yagi antennas were mounted on aircraft wings, in a boat, and on a truck. A small 2-element hand-held antenna was used in a raft and on foot.

Fixed Detection Sites

The movements of radio-tagged coho were monitored through a series of fixed detection sites (Figure 2). Several of these sites were owned by the mid-Columbia PUDs and operated by their consultant, Bioanalysts, while other sites were shared between USFWS and Yakama Nation or owned and operated entirely by YN (Table 2).

Data pertaining to coho from the PUD-administered sites was provided to YN on a bi-weekly basis. Fixed stations owned by YN or the USFWS were downloaded weekly by YN personnel. The YN sorted and processed the raw data files from these stations using Microsoft Excel and Access programs.

Table 2. Fixed-station detection sites location, river kilometer, and ownership during the 2003 mid-Columbia River study.

River of Detection	Site Location	Site Owner/Operator
Columbia River	Rock Island Dam (RK729.5)	Chelan PUD
Wenatchee River	Monitor (RK 8.7)	Chelan PUD
Wenatchee River	Tumwater Dam (RK 49.4)	USFWS/ YN
Wenatchee River	Upper Wenatchee River (RK 93.3)	USFWS/ YN
Nason Creek	Nason Creek Campground (RK 1.6)	YN
Nason Creek	Butcher Creek Wood Bridge (RK 13.2)	YN
Columbia River	Rocky Reach Dam (RK 762.2)	Chelan PUD
Entiat River	Mouth	Chelan PUD
Columbia River	Wells Dam (RK 829.6)	Douglas PUD
Methow River	Mouth (RK 3)	Douglas PUD
Methow River	Carlton Acclimation Ponds (RK 18)	YN
Okanogan River	Mouth	Douglas PUD

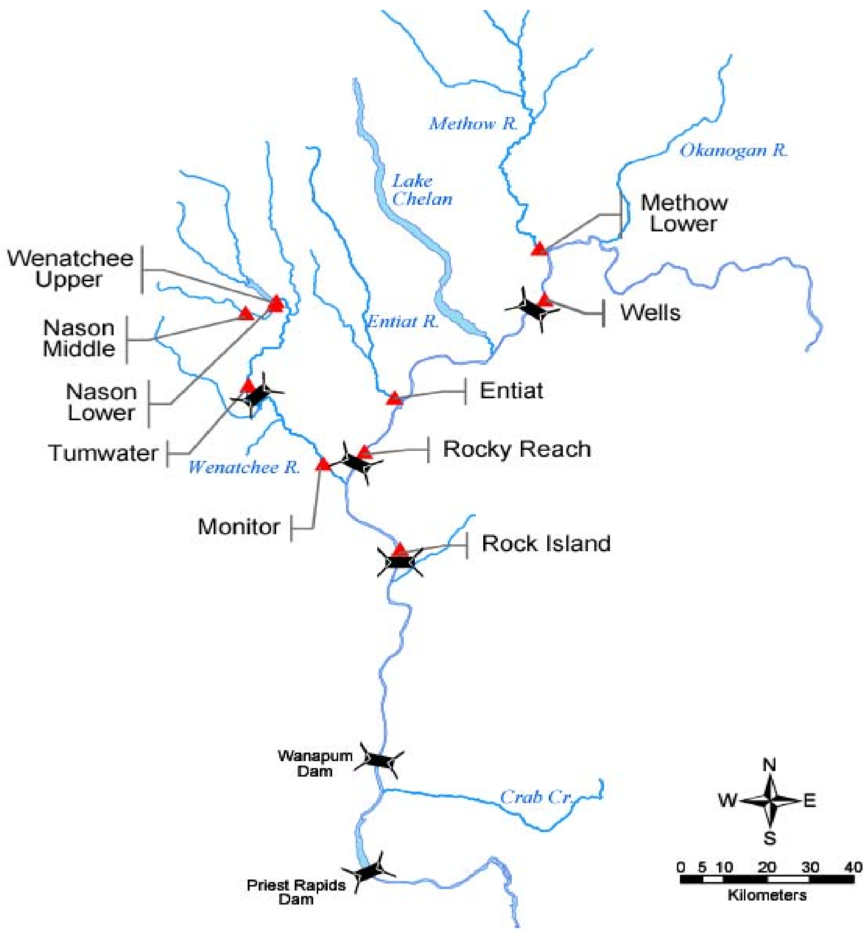


Figure 2. Location of fixed-station detection sites operated in the mid-Columbia River study area during the 2003 coho study.

Mobile Tracking

Mobile tracking was conducted regularly throughout the study area by airplane, truck, raft/boat, and on foot. These data were used to determine the exact holding or spawning locations of radio-tagged coho.

Aerial surveys

A Cessna fixed-wing aircraft was contracted for surveys throughout the migration and spawning period. The plane was able to provide complete coverage of the study area in one day while traveling at a speed between 60 and 100 mph and maintaining an elevation between 300 and 500 feet. Data collection was optimized by operating 2 receivers, one having GPS interface capabilities. Both receivers were set to scan all 4 channels, but the scanning sequence was offset so that a detection logged on the receiver without GPS capability could be matched by time to the nearest coordinate recorded on the other receiver.

Truck surveys

Tracking by road, while traveling to download receivers, was done on the upper Wenatchee River and Nason Creek, and on the Methow River. Tracking by truck in the lower Wenatchee River and along the Columbia River between the Wenatchee River and Priest Rapids Dam was done while driving to the tagging site. Other areas that were tracked by road include Entiat River, Okanogan River, Columbia River between Wenatchee and Chief Joseph Dam, tributaries to the Wenatchee River, Sandhollow Wasteway, and Crab Creek.

Raft/Boat surveys

Mobile tracking by raft was done in Icicle Creek and in the Wenatchee River during spawning ground surveys. Mobile tracking by power boat was done in the Columbia River between Rock Island and Rocky Reach dams.

RESULTS

Tagging

A total of 282 radio-tags were used between all 4 tagging locations (Table 3). The Priest Rapids Dam collection site was the focus of the study with 217 tagged fish; 30 coho were tagged at Tumwater Dam, 20 at Wells Dam, and 15 at Bonneville Dam. No mortality due to handling was observed. Three tags were regurgitated in the transport tank and were recovered and reused. Appendix D shows the individual tagging dates and specific data collected at the time of tagging

Table 3. Total number of coho radio-tagged at each of the 4 tagging locations in 2003.

Tagging Location	Total Tagged
Priest Rapids	217
Tumwater	30
Wells	20
Bonneville	15

The peak migration over Priest Rapids dam occurred between September 11th and October 10th. During this period, 78% of the run passed the dam and 62% of the tags were used (Figure 3). The tagging goal of 250 fish was not met due to the low numbers of coho passing the dam during the late tagging period (Table 1 and Table 3), when only 15% of the run passed the dam.

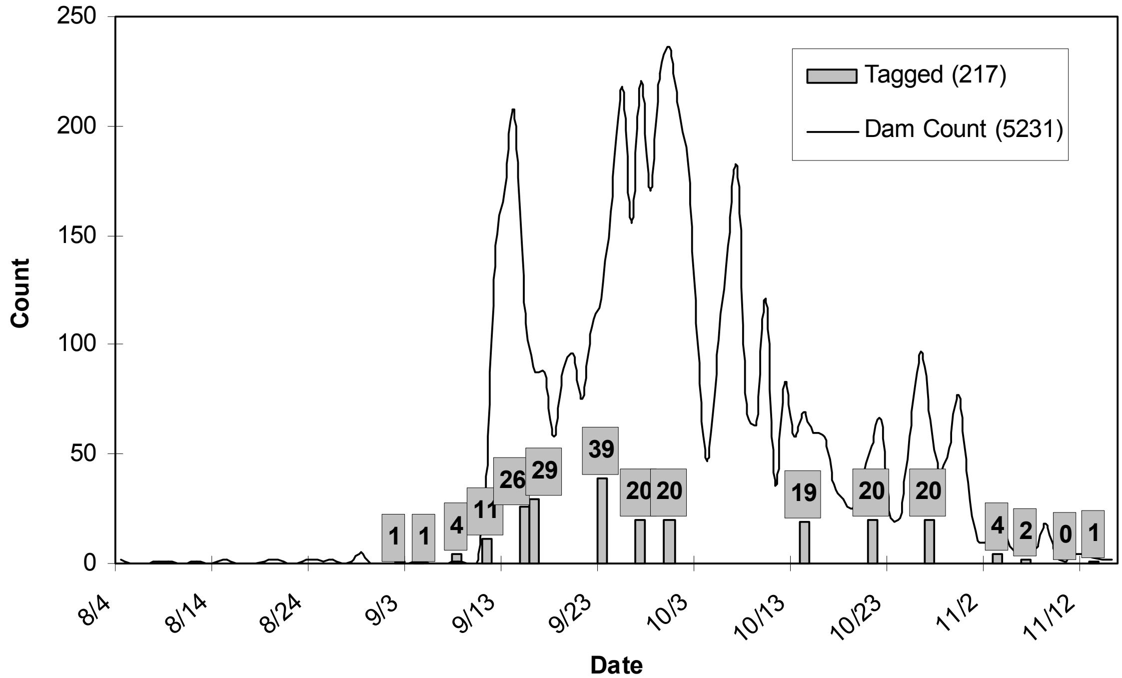


Figure 3. Distribution of adult coho passage counts and number of fish tagged per day at Priest Rapids Dam, 2003.

Overall, 181 male and 101 female coho were radio-tagged (Table 4). The mean fork length was 61.0 cm (SD=6.0 cm) for males and 61.4 cm (SD-5.1) for females. See Appendix D for complete gender and size data.

Table 4. Radio-tagged coho gender and size summary for each tagging location, 2003.

Tagging Location	Males	Females	Mean FL (cm)	Range FL (cm)	St Dev FL (cm)
Priest Rapids Dam	134	83	60.9	48.5 to 76.5	5.6
Tumwater Dam	28	2	62.7	53.5 to 73.0	5.6
Wells Dam	10	10	61.2	51.1 to 73.6	6.0
Bonneville Dam	9	6	62.5	54.0 to 66.5	3.2

Tracking Effort

Of the 282 radio-tagged coho, 179 (63.9%) were tracked at some point during their migration (Table 5). The total number of telemetry records collected from radio-tagged coho during this study was 144,500 (Table 6). Approximately 98% of this data was obtained at the 12 fixed detection sites. Records from fixed-stations and mobile tracking were sorted by date, time and signal strength and then condensed to the first, strongest, and last detections for each day of detection, resulting in approximately 1,100 unique daily locations.

Table 5. The radio-telemetry tracking effort success showing the number and percent of fish tagged and tracked from each tagging location during the 2003 study.

Tagging Location	Combined Total		Priest Rapids		Tumwater		Wells		Bonneville*	
	No.	%	No.	%	No.	%	No.	%	No.	%
No Data	101	35.8	86	39.6	0	0.0	2	10.0	11	73.3
Tracked	179	63.9	129	59.4	30	100.0	18	90.0	2	13.3
Tagged	282		217		30		20		15	

* 2 coho radio-tagged at Bonneville Dam were reported caught by anglers in the lower Columbia River

Table 6. Total radio-telemetry records analyzed throughout the study and the number of overall unique daily locations provided by the different tracking methods.

Tracking Method	Total Detections	Unique Daily Locations
Fixed -station	142,307	442
Aerial survey	665	309
Truck	484	223
Boat/Raft	1,044	21

Fixed-stations

Fixed detection sites were operated 24 hours a day between September 8th and December 21st. Receivers located at Columbia River dams and those at the lower Wenatchee, Entiat, and Methow river sites were downloaded bi-monthly by Bioanalyst. The upper Wenatchee and Methow river sites and the Nason Creek sites were downloaded and maintained weekly by YN. Most of the 142,307 record data set from fixed-station downloads was generated by fish holding in areas near receiver antennas. After sorting, 442 unique locations were determined as radio-tagged fish migrated upstream.

Aerial surveys

Aerial surveys of the entire study area were conducted 5 times between October 2nd and December 18th. Flight contracting and data collection were shared between USFWS and YN. The use of aerial surveys generated 309 unique locations and provided the most complete and precise information of final spawning and holding areas.

Truck surveys

Surveys were done by truck wherever roads followed streams in the study area. The Wenatchee and Methow rives and some of their tributaries have highways along nearly the entire length and were surveyed weekly. The close proximity to the river and shallow water depth provided good results. While traveling to the tagging sites, staff tracked by road along the Columbia River with some success. Deep water and the distance from roads to the river were limiting factors. The truck surveys produced 223 unique radio-tag locations throughout the study period.

Raft/Boat surveys

A raft was used to collect radio-telemetry data on the Wenatchee River and Icicle Creek during weekly spawning ground surveys between October 15th and December 30th. Use of this tracking method identified 21 unique locations. A power boat was used in the Columbia River on one occasion between Rock Island Dam and Rocky Reach Dam. No radio-tags were detected during this survey, likely due to tagged fish exceeding the 10-meter signal frequency receiving depth.

Coho Movement

For analysis and discussions, the mid-Columbia study area has been divided into nine reach segments based on the locations of dams and tributary rivers (Figure 4).

Spawning distribution

One of the objectives of this study was to determine the spawning distribution of reintroduced coho. For this task, the most upstream detection of each fish tracked was used to define the probable spawning location (Figure 5). There were some fish, however, that turned around from their furthest known location and were monitored holding in another area. In a few cases this area was determined to be the most likely spawning location. See Appendix E for final location details.

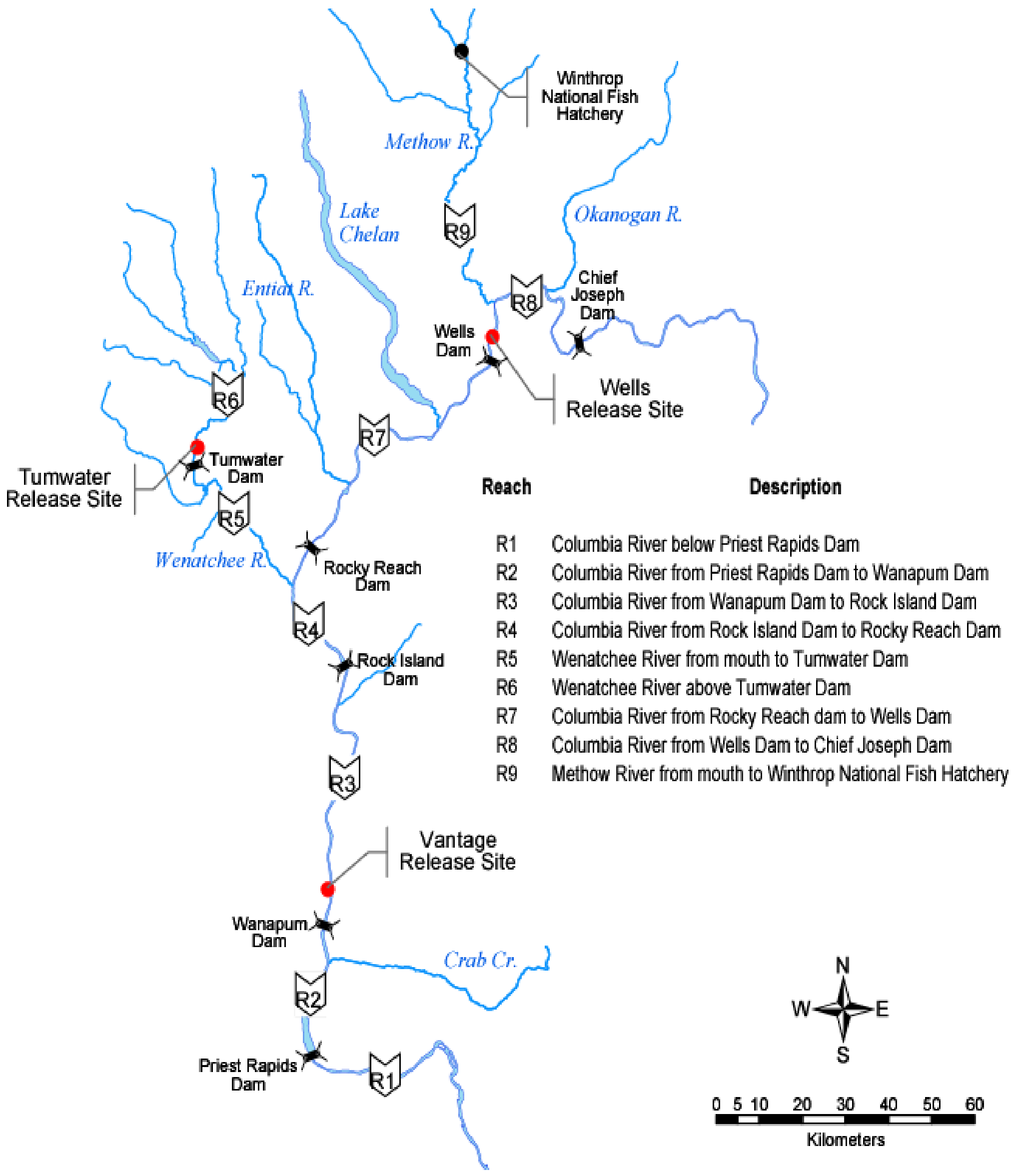


Figure 4. Reach locations and descriptions used during analysis in relation to the three release sites of the 2003 Mid-Columbia coho study.

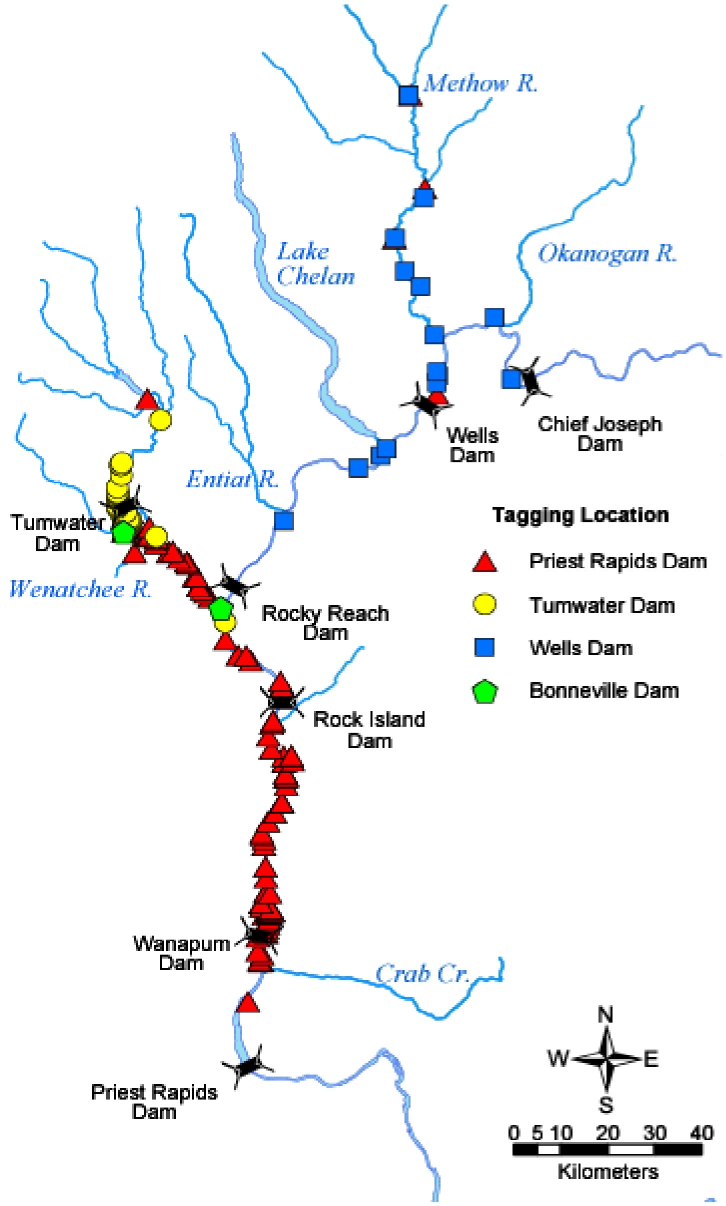


Figure 5. The probable spawning distribution of radio-tagged coho in the mid-Columbia River study area during 2003.

Coho spawning was widely distributed throughout the Mid-Columbia study area as shown by the radio-telemetry study (Table 7). Radio-tagged fish revealed several previously unknown spawning areas. Sandhollow Wasteway, a tributary to the Columbia River between Wanapum Dam and Vantage, attracted 11 radio-tagged coho, and another 6 were detected near the mouth. Peshastin Creek, a tributary to the Wenatchee River, received 5 radio-tagged fish. Chelan Falls, a tributary to the Columbia River, had 2 radio-tagged fish detected.

Table 7. Probable spawning locations of radio-tagged coho by study area reach during 2003.

Reach	Reach Description	Tagging Location				
		Priest Rapids	Tumwater	Wells	Bonneville	Total
R1	Columbia River to Priest Rapids				2	2
R2	Priest Rapids to Wanapum	6				6
R3	Wanapum to Rock Island	60				60
R4	Rock Island to Rocky Reach	14				14
R5	Wenatchee River to Tumwater	45	19		2	66
R6	Wenatchee River above Tumwater	1	11			12
R7	Rocky Reach to Wells			4		4
R8	Wells to Chief Joseph	1		5		6
R9	Methow River to Winthrop NFH	3		9		12

Areas of concentrated spawning occurred in the mainstem of the Wenatchee River— 46 radio-tagged fish were located here. A tributary to the Wenatchee River, Icicle Creek, had 25 radio-tags. The mainstem of the Methow River contained 12 radio-tagged coho, with 5 returning to the Winthrop National Fish Hatchery acclimation site.

Results indicate that many radio-tagged fish remained in the Columbia River within study reach 3 (Figure 4). It is likely that some successful spawning took place at the mouths of the many small tributaries along the west shoreline between Wanapum Dam and Rock Island Dam; 48 tags remained in this reach, including the Sandhollow Wasteway fish. Spawning ground surveys and tag recovery was not attempted in this area, other than at Sandhollow, due its inaccessibility during the winter months.

Stray rates

Combined tracking efforts accounted for the location of 179 of the 282 coho that were radio-tagged (Table 5 and Figure 6). With 2 tagged fish reported as caught in the lower Columbia River taken out of the equation, 63.9% of the tagged fish were tracked. The fate of the remaining 35.8% radio-tagged fish is unknown. It is likely the result of mortality due to handling or regurgitated tags residing at depths greater than the 10-meter receiving capability. Another possibility is fallback below Priest Rapids Dam and movement outside the study area tracking zone; however, no fixed station detection system exists below Rock Island Dam, and no tags were ever detected in the area of Priest Rapids during aerial surveys. The following analysis is based on the results of the 179 fish that were accounted for.

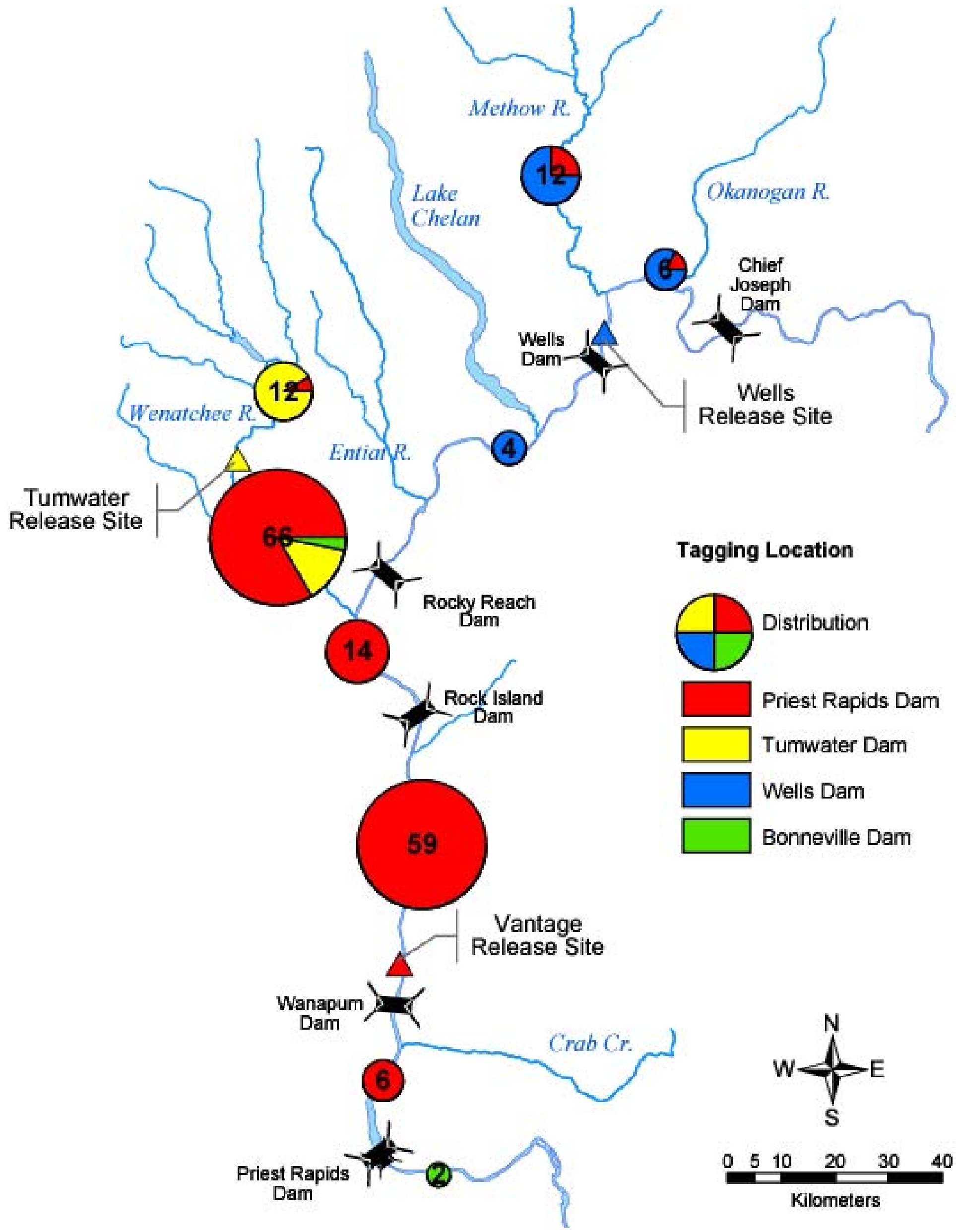


Figure 6. Final locations of radio-tagged coho showing sample size proportions from each tagging location by river reach in the mid-Columbia River study area, 2003.

Fish migration performance was evaluated to answer the question on stray rates posed in Objective 1. Performance categories have been defined for the purpose of this analysis (Table 8). These categories are being used as indicators to discuss coho migration distance and probable spawning locations.

Table 8. Coho migration performance indicator categories and descriptions for the 2003 radio-telemetry study.

Homing Success	Returned the tributary of acclimation and release
Home Basin Stray	Returned to a tributary of the Wenatchee or Methow river
Home Basin Dropout	Returned to the mainstem Wenatchee or Methow river
Dropout	Remained in the Columbia River or other tributary

Twenty six (14.5%) of the radio-tagged coho were determined to be successful in migrating all the way to their original tributary of acclimation (Table 9). The majority, 19 out of 26 fish, returned to Icicle Creek and 4 of these traveled to spawning grounds above the acclimation pond. The Methow River returns produced 5 successful radio-tagged coho migrants that swam into the hatchery outfall at Winthrop. One fish tagged at Tumwater successfully returned to Beaver Creek and went above the acclimation pond. Another successful migrant was tagged at Priest Rapids and tracked to Nason Creek.

Table 9. Radio-tagged coho stray and dropout rates shown by tagging location during the 2003 study.

	Combined		Priest Rapids		Tumwater		Wells		Bonneville	
Performance	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Homing Success	26	14.5	20	15.5	1	3.3	4	22.2	1	50.0
Home Basin Stray	11	6.1	4	3.1	7*	23.3	0	0.0	0	0.0
Home Basin Dropout	53	29.6	25	19.4	22	73.3	5	27.8	1	50.0
Dropout	89	49.7	80	62.0	0	0.0	9	50.0	0	0.0

Six fish tagged at Tumwater Dam fell back and descended to Icicle Creek. It is unknown whether they originated from Icicle Creek or from a Nason Creek acclimation pond and therefore could have been successful at reaching their home stream.

Radio-tagged coho that returned to a tributary of the Wenatchee or Methow rivers are considered as home basin strays; 6.1% of the study fish were in this category. Peshastin Creek in the Wenatchee basin received 5 of the 11 home basin strays. One coho spawning in Peshastin Creek was tagged at Tumwater Dam, while the other 4 were tagged at Priest Rapids Dam. Six fish tagged at Tumwater Dam fell back and descended to Icicle Creek. It is unknown whether they originated from Icicle Creek or from a Nason Creek acclimation pond and therefore could have been successful at reaching their home stream. No radio-tagged coho were detected in tributaries to the Methow River.

Radio-tagged fish that migrated into the Wenatchee or Methow rivers but did not continue on to their tributary of acclimation or stray into another tributary are categorized as home basin dropouts and accounted for 29.6% of the study group. Of the 30 fish tagged at Tumwater Dam, 22 (73.3%), including 19 fallbacks over the dam, remained in the mainstem of the Wenatchee River.

Radio-tagged coho that remained in the Columbia River make up the largest portion of the study group. This 49.7% of the fish that were tracked after tagging are described as dropouts remaining in the Columbia River or its smaller tributaries. The group tagged at Priest Rapids Dam comprised the majority, with 80 out of 217 fish (62.0%). Of the 20 fish tagged at Wells Dam, 9 (50%) remained in the Columbia River including 4 fallbacks over the dam. None of the fish tagged at Tumwater Dam were included in the dropout category.

The returning adult coho were 100% coded wire tagged with unique numbers for each acclimation and release location. The collection of fish snouts during spawning ground surveys and the extraction and reading of the tags provided information on where stray coho originated. In Icicle Creek, 282 snouts with CWTs were recovered, revealing that 2.5% of the Icicle Creek coho that spawned there were released from Nason Creek acclimation ponds. The Sandhollow Wasteway was another area that allowed for carcass recovery; 18 snouts with CWTs were collected. These strays showed 67% (12) originating from Icicle Creek, 28% (5) from Nason Creek, and 6% (1) from the Methow River acclimation site. While the recovery of radio-tagged coho was limited by high water and snowfall in November and December of 2003, 4 tags were recovered. In Icicle Creek, 2 fish with radio-tags and CWTs were found to have been released from the Icicle Creek acclimation pond. The other 2 fish with radio-tags and CWTs were collected from Sandhollow and these had also released from Icicle Creek.

Run timing and migration success

One of the objectives of this study is to determine if there is a correlation between run timing and migration success. The Priest Rapids tag group was used for this analysis because it is the only group of sufficient size on which to base conclusions. The same performance categories defined in Table 8 and the tagging periods from Table 1 were used in the comparison shown in Figure 7. The early run, August 26th to September 19th, had the highest percentage of fish returning to the home basin (47%). The middle run, September 20th to October 17th, showed the most overall success, with 22% of the tag group returning to their stream of acclimation. The late run, October 18th to November 14th, had the most dropouts (60%), the most home basin dropouts (30%), and the fewest successful migrants (10%).

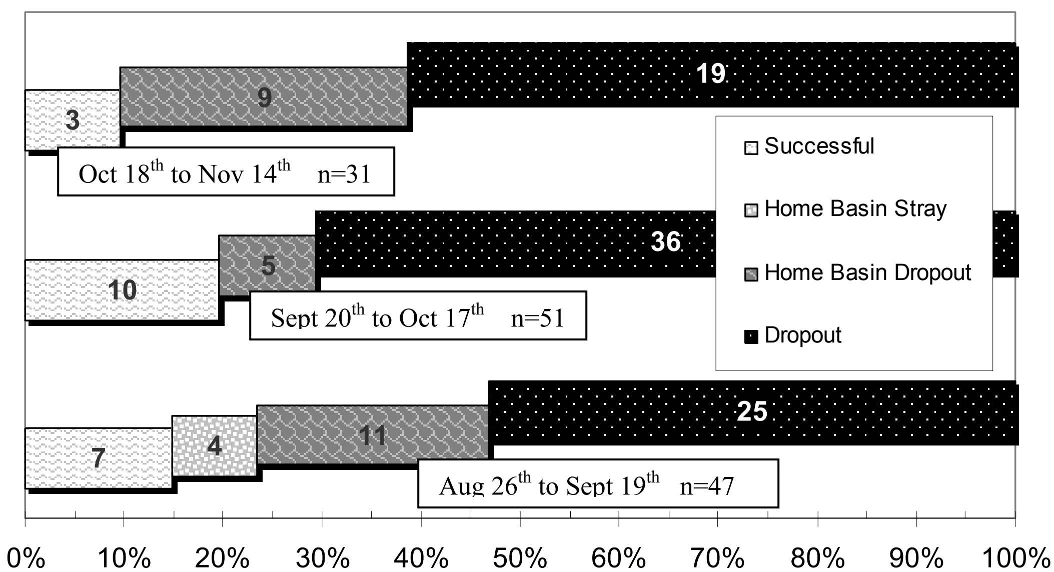


Figure 7. Comparison of migration performance to run timing for coho radio-tagged at Priest Rapids Dam during the 2003 study.

Gender and migration success

The correlation between fish gender and migration success was also analyzed using the Priest Rapids Dam tag group data and previously defined performance criteria (Figure 8). The data show that male fish were more successful in returning all the way to their stream of acclimation (20%) compared to 10% for females, while females had more overall success in making it back to their home basin, with 45% compared to 35%. Males had a 65% overall dropout rate, while females had a lesser 55% dropout.

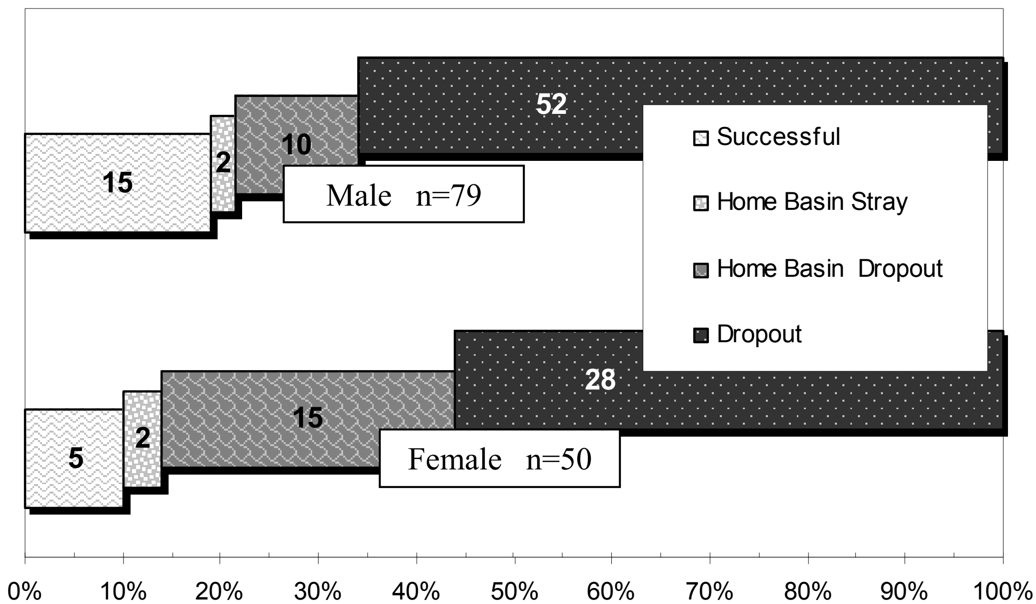


Figure 8. Comparison of migration performance and fish gender for coho radio-tagged at Priest Rapids Dam during the 2003 study.

A comparison was also done between fish gender and distance traveled from the release site at Vantage, Washington (Figure 9). Four males and 3 females traveled downstream approximately 16 RKm and fell over Wanapum Dam. The first spike on the graph includes the 11 dropouts that strayed into Sandhollow Wasteway; 10 of these fish were males. In the Wenatchee River between Monitor and Icicle Creek, the ratio of males to females was nearly equal. In Icicle Creek, however, 13 of the 19 radio–tagged fish from the Priest Rapids tag group were males. The group of 6 fish that descended from the Tumwater Dam tagging site to spawn in Icicle Creek contained 5 males and 1 female. The coho that traveled the farthest was a male that swam into Winthrop National Fish Hatchery.

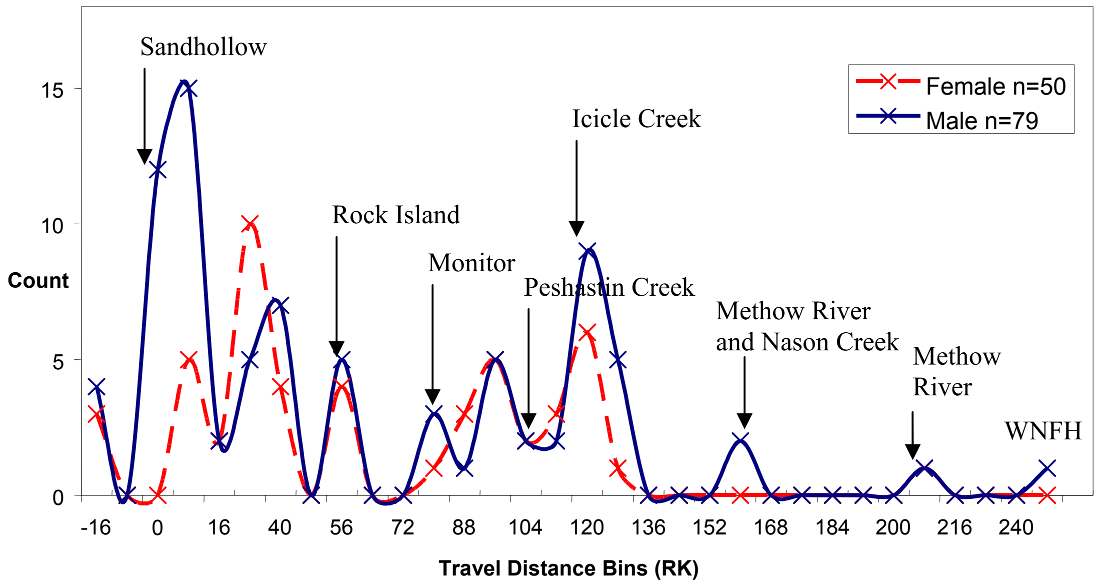


Figure 9. Comparison of migration distance after tagging to fish gender for coho radio-tagged at Priest Rapids Dam during the 2003 study.

Size and migration success

The correlation between coho size and the ability to return to streams of acclimation is compared in Figure 10. The mean fork length of the Priest Rapids Dam tag group was 60.9 cm. The distance traveled by the 22 fish between the lengths of 59.5 and 61.5cm ranged from 216 RKm near Winthrop National Fish Hatchery to 12 RKm downstream of the release site below Wanapum Dam. The smallest fish in the group, a 48.5-cm male, traveled the farthest, 245 RKm, reaching WNFH. The largest fish, a 76.5-cm male, was recovered in Sandhollow Wasteway after traveling 2 RKm downstream from the release site.

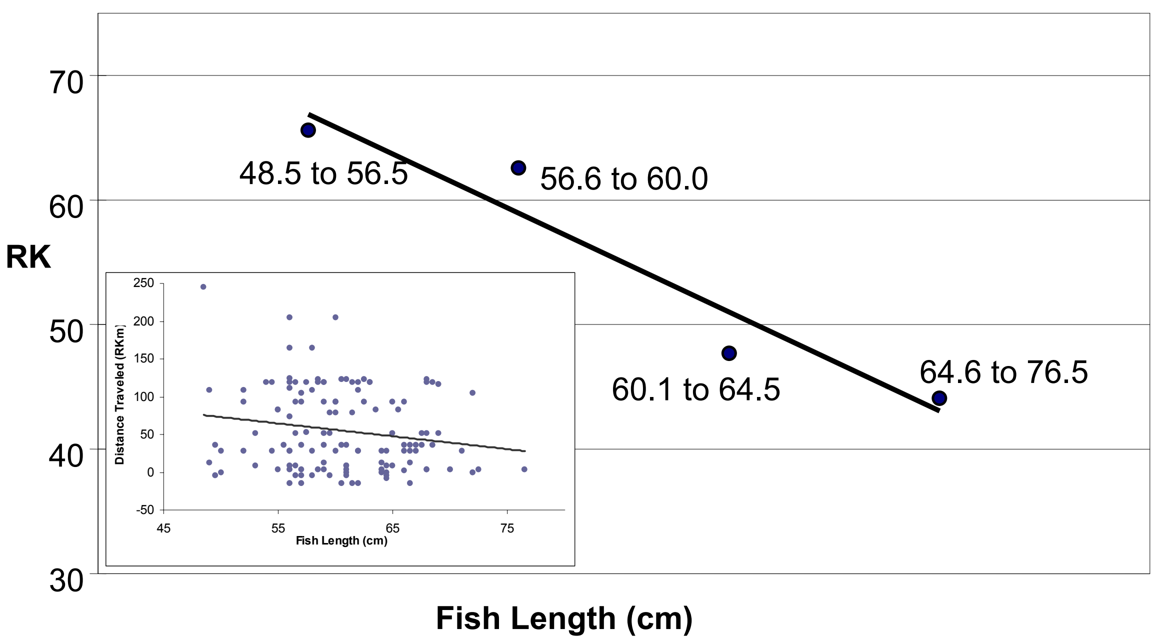


Figure 10. Comparison of migration distance after tagging to fish size quartiles for coho radio-tagged at Priest Rapids Dam during the 2003 study. Inset shows the entire length distribution.

Migration speed

The travel time between fixed detection sites was highly variable among the Priest Rapids Dam tag group (Table 10). Of the 63 radio-tagged coho to pass Rock Island Dam, the mean migration time was 8.8 days, with a range from 2 to 46 days. The mean holding period observed around Rock Island Dam was 1.2 days, with a range of 0 to 19 days. Forty-seven of these fish continued another 30.6 RK to reach the Monitor fixed detection site in the lower Wenatchee River. The mean travel time between Rock Island and Monitor was 3.8 days, with a range between 1 and 12 days.

Table 10. Coho migration travel times and holding times between fixed telemetry detection sites in the mid-Columbia during the 2003 study.

	RK	Mean Days	Range Days	St Dev Days
From Vantage to Rock Island Dam n=63	90.1	8.8	2 to 46	9.85
Rock Island Dam Holding Period n=63		1.2	0 to 19	3.40
From Rock Island Dam to Wenatchee River at Monitor n=47	30.6	3.8	1 to 12	3.06

DISCUSSION

Radio-telemetry has been used as a technique to study migrating salmon in the Columbia River, but this is the first study to analyze coho movement and migration associated with reintroducing a long-migrating stock. This was the second year of the Mid-Columbia Coho Telemetry Study; low smolt-to-adult survival in 2002 (brood year 1999) resulted in an inability to trap and tag enough adult coho to meet the objectives outlined in the "Introduction" section of this chapter or to draw any meaningful conclusions. In 2003 we were able to trap, radio tag, and track a total of 282 adult coho salmon returning to the Wenatchee and Methow rivers. These fish were able to provide us with data regarding the broodstock development process, run timing, straying, and the survival of coho returning to mid-Columbia tributaries.

Coho salmon returning to the mid-Columbia in 2003 were a mixture of both first generation mid-Columbia brood and lower Columbia River brood (57% MCR; 43% LCR based on release numbers). We expect some level of straying and/or dropout during the broodstock development process. It is likely that the proportion of dropouts will be highest for lower Columbia brood coho, and will decrease with each generation of mid-Columbia brood coho as a result of strong selective pressures.

Most fish categorized as "drop-outs" were last detected in the Columbia River between Wanapum Dam and Rock Island Dam. The increase in drop-outs in this reach of the Columbia River may have been exacerbated by the handling stress of the tagging procedure on energetically challenged fish. In 2004, we plan to use PIT tags along with radio-tags to evaluate both handling and tag effect during the telemetry evaluation.

The proportion of drop-outs (fish that do not return to natal tributaries and do not spawn) and strays (fish that do not return to natal tributaries but spawn elsewhere), may be the result of either insufficient energy reserves or run-timing that is unsuitable for the mid-Columbia region. Natural selection should act strongly on traits and behaviors that help accrue energy in preparation for migration and that conserve energy during migration (Crossin et al. 2004).

Fish size may influence the performance of reintroduced coho returning to the mid-Columbia region. A decrease in fish size corresponding with an increase in the length of migration has been well documented in sockeye salmon (Crossin et al. 2004; Hinch and Rand 2000). Long-distance populations tend to be smaller and more streamlined than short distance populations (Crossin et al. 2004); these are mechanical adaptation that may help them conserve energy during their migration (Hinch and Rand 2000). Similarly, reintroduced coho salmon returning to the Methow River are consistently shorter than reintroduced coho returning to the Wenatchee River (Murdoch and Kamphaus 2005; Murdoch and Kamphaus 2004). The results of this evaluation indicated that smaller coho are able to travel further than larger coho, consistent with the limited radio-tag data we collected in 2002 (Murdoch et. al. 2004).

There is also evidence that fecundity and ovarian mass decrease with migration distance (Linley 1993). In females, the increasing ovarian investment may pose a two-fold cost to migration efficiency through a reduction in swimming efficiency, with potential energetic and survival costs as well as a reduction in energy reserves available for the migration itself (Kinneson et al 2001). Ovarian investment and the two-fold cost to migration could explain why radio-tagged male coho were more successful in returning to their stream of acclimation than radio-tagged female coho.

In addition to size and gender, run timing may also affect a fish's ability to return to its stream of acclimation. Long-migrating salmon are under strong selective pressure to complete spawning early enough to ensure sufficient degree days for egg and alevin development, reducing the chance of over-winter mortality caused by spawning ground freeze up (Hinch and Rand 2000). The extended migration distance for coho reintroduced to mid-Columbia tributaries may result in selective pressures which ensure that they reach the spawning grounds with sufficient time and energy to mature and successfully spawn. Radio tagged coho salmon in the "early" group (Table 1) had the highest percentage of fish returning to their basin of origin. The "late" group had the greatest proportion of drop-outs and the least successful migrants.

Water temperature during tagging and transport may also influence fish survival and behavior after release. Cooler water temperatures during fall, winter, and spring steelhead telemetry studies are believed to reduce the effect of handling stress on radio-tagged steelhead and to improve post release survival (LGL et al. 2001). The peak temperature at Priest Rapids Dam typically occurs during the beginning of the coho trapping period, and high temperatures continue into October (Table 11) (Grant County PUD 2003). In 2003, the months of September and October had above-average temperatures; during 42 of the 81-day trapping period, temperatures exceeded 18.0 degrees C. The permitted trap operating threshold is 21 degrees C. This could have been an influencing factor in the large number of undetected fish and the dropouts that remained in the Columbia River. Complete daily temperature data for the Priest Rapids Dam forebay from 2001 to 2003 can be found in Appendix F.

Table 11. Average monthly temperatures in degrees Celsius at Priest Rapids Dam forebay during the permitted coho trapping period of August 26th to November 14th for 2001 to 2003.

Month/Year	2001	2002	2003
August	18.9	20.0	20.0
September	18.7	19.0	19.2
October	15.6	17.0	16.9
November	13.0	N/A	12.2

Low SARs in 2002 (brood year 1999) resulted in an inability to trap and tag enough adult coho to meet the objectives outlined in the Introduction to this chapter or to draw any meaningful conclusions; therefore, the study was repeated. While we were able to meet the objectives of this evaluation during the 2003 study and answer key questions regarding dropout and stray rates, there is more information to be gathered from future radio-telemetry studies with coho. We plan to repeat this evaluation in 2004, with a slightly increased tag group number. Two consecutive years of data should provide a more valid conclusion to the stray and dropout rate questions, while also testing concerns on how fish handling influences survival and behavior.

The 2004 evaluation also will continue to address the four objectives. In particular, Objective two, to determine if stray and dropout rates will decrease through the development of a locally adapted broodstock, cannot be answered with one year of data.

SUMMARY

1. A total of 282 coho destined for the Wenatchee and Methow rivers were radio-tagged at four locations during 2003.

2. Of the 282 radio-tagged coho, 63.9% (179 fish) were tracked from the release site to probable and known spawning areas.

3. Of the 179 radio-tagged coho that were tracked, 14.5% (26 fish) migrated to their stream of origin.

4. Straying rates of the 179 radio-tagged coho that were tracked within tributaries to the Wenatchee River were estimated to be 6.1% (11 fish); no stray coho were located in tributaries to the Methow River.

5. Dropout rates of the 179 radio-tagged coho that were tracked within the Wenatchee River were estimated to be 19.4% (25 fish) for coho tagged at Priest Rapids Dam and 73% (22 fish) for coho tagged at Tumwater Dam. Dropout rate within the Methow River was estimated at 27.8% (5 fish).

6. Dropout rates of the 179 radio-tagged coho that were tracked in the Columbia River were estimated at 62.0% (80 fish) for coho tagged at Priest Rapids Dam and 50.0% (9 fish) for coho tagged at Wells Dam.

7. Fallback rates of the 179 radio-tagged coho that were tracked varied by release site and were estimated at 2.8% (6 fish) for coho released above Wanapum Dam, 20% (4 fish) for coho released above Wells Dam, and 63.3% (19 fish) for coho released above Tumwater Dam.

8. Of the 29 radio-tagged fish recognized as fallbacks, 37.9% (11 fish) were tracked to known spawning areas including Icicle Creek below Tumwater Dam and Chelan Falls below Wells Dam.

9. The median passage time for radio-tagged coho between the release site at Vantage to Rock Island was 8.8 days (n=63 fish) and 3.8 days (n=47 fish) from Rock Island to Monitor on the Wenatchee River.

LITERATURE CITED

Bernatchez, L., and Dodson, J.J. 1987. Relationship between bioenergetics and behavior in anadromous fish migrations. Can. J. Fish. Aquat. Sci. 44:399-407.

Brett, J.R. 1995. Energetics. In Physiological ecology of pacific salmon. Edited by C. Groot, L. Margolis, and W. C. Clarke. University of British Columbia Press, Vancouver.

Crossin, G. T., S. G Hinch, A. P. Farrell, D. A. Higgs, A.G. Lotto, J.D. Oakes, and M.C. Healy. 2004. Energetics and morphology of sockeye salmon: effects of upriver migratory distance and elevation. Journal of Fish Biology 65, 788-810.

Hinch, S. G. and J. Bratty. 2000. Effects of swim speed and activity pattern on success of adult sockeye salmon migration through an area of difficult passage. N. Am. J. Fish. Mgt. 129:604-612.

Hinch, S.G. and P.S. Rand. 1998. Swim speeds and energy use of upriver-migrating sockeye salmon (Oncorhynchus nerka): role of local environment and fish characteristics. Can J. Fish. Aquat. Sci. 55:1821-1831.

Hinch, S. G., and P. S. Rand. 2000. Optimal swimming speeds and forward-assisted propulsion: energy-conserving behaviours of upriver-migrating adult salmon. Can. J. Fish. Aquat. Sci. 57:2470-2478.

Johnson, G. E. 1999. Evaluation of the Prototype Surface Bypass for Salmonid Smolts in Spring 1996 and 1997 at Lower Granite Dam on the Snake River, Washington. Transactions of the American Fisheries Society 129(2): 381–397.

Kinnison, M.T., M.J. Unwin, A.P. Hendry, and T. P. Quinn. 2001. Migratory costs and the evolution of egg size and number in introduced and indigenous salmon populations. Evolution 55(8): 1656-1667.

Macdonald, J.S., and I.V. Williams. 1998. Effects of environmental conditions on salmon stocks: the 1997 run of early Stuart sockeye salmon. In: Speaking for Salmon Workshop Proceedings. Editied by P. Gallaugher and L. Wood. Institute of Fisheries Analysis, Simon Fraser University, Burnaby, B.C. pp 46-51.

Zabel, R. W. 2002. Using "travel time" data to characterize the behavior of migrating animals. The American Naturalist 159(4): 372-387.

English, K. K., C. Slilwinsky. B. Nass, and J. R. Stevenson. 2001. Assessment of adult steelhead migration through the Mid-Columbia River using radio-telemetry techniques, 1999-2000. p 39.

CHAPTER 4: COHO SPAWNING GROUND SURVEYS

INTRODUCTION

The long-term vision of the mid-Columbia coho reintroduction project is to re-establish a naturally reproducing coho salmon population in mid-Columbia tributaries, with numbers at or near carrying capacity (HGMP 2002). A short-term goal for the project's feasibility phase is to initiate natural production in areas of low risk to listed species and in areas where interactions between naturally reproducing coho salmon and ESA-listed species can be evaluated. Although, the current project focus is broodstock development, quantifying natural production in the Wenatchee River basin is an important performance indicator.

The information presented in this chapter represents the fourth year of adult returns to the Wenatchee and Methow river basins, and the first year the majority of the adult returns are mid-Columbia brood coho. Our efforts described below are fundamental to measuring spawn timing and quantifying natural production. As the reintroduced coho become locally adapted, it is possible that we will see changes in spawn or run timing. Redd counts will allow us to evaluate egg-to-smolt survival rates, and eventually develop a spawner-recruitment curve for naturally produced coho salmon in the natural environment. The HGMP (2002) outlines the future monitoring plan to assess the reproductive success of returning coho.

METHODS

In the Wenatchee Basin, we focused our efforts in Nason Creek, Icicle Creek, and the Wenatchee River. In the Methow basin, our efforts were focused on the mainstem Methow River. In both basins, we expanded the surveys to include several smaller tributaries.

In the Wenatchee Basin, we surveyed Nason, and Icicle creeks weekly. Frequent surveys allowed us to measure spawn timing as well as the number of redds. In the mainstem Wenatchee River and in the smaller tributaries surveyed (Beaver, Brender, Chiwaukum, Chumstick, Peshastin, and Mission creeks) we surveyed as often as possible, but at a minimum twice following peak spawn. Infrequent surveys after peak spawn allowed us to evaluate the distribution and number of naturally spawning coho in each basin, but did not allow us to evaluate spawn timing. In the Methow Basin, Beaver Creek was surveyed on a weekly basis. The Methow River was surveyed as often as possible, with the entire river being surveyed at least twice during the spawning season. Other tributaries were surveyed as time allowed. Survey reaches for both basins are identified in Table 1. All surveys in the Wenatchee and Methow river basins were completed between mid-October and the end of December.

We conducted the spawning ground surveys by either foot or raft, depending upon the size of the river and the terrain. Surveys were completed by one- or two-person teams. Individual redds were marked and cataloged to get precise redd counts and timing. Coho redds were flagged with surveyor's tape tied to nearby shrubbery. Each flag was marked with the date, approximate redd location, and redd number. The number of new redds, live and dead fish, time required to complete the survey, and the stream temperature were recorded. Surveyors checked all flags from previous surveys as they searched for new redds. Global positioning (GPS) was used to record the exact location of individual redds on all surveys.

During the surveys, we recovered coho carcasses. From the carcasses we measured fork length (FL) and post-orbital hypural length (POH) to the nearest centimeter. Snouts were collected from all carcasses. The snouts were scanned for the presence of coded wire tags (CWT) in the laboratory; all snouts containing CWTs were dissected and the CWTs recovered. Carcass gender was recorded.

Female carcasses were checked for egg retention by visual estimation of the number of eggs voided. The caudal fin was removed from sampled carcasses to prevent re-sampling during later surveys.

Table 1. Spawning ground reaches for the Wenatchee and Methow river basins, 2003.

Reach Designation	Reach Description	Reach Location (RK)
	Icicle Creek	
I1	Mouth to E. Leavenworth Br.	0.0-3.7
I2	E. Leavenworth Br. to Hatchery	3.7-4.5
I3	Hatchery to Dam 5	4.5-4.7
	Nason Creek	
N1	Mouth to Kahler Cr. Br.	0.0-6.3
N2	Kahler Cr. Br. to High Voltage Lines	6.3-10.3
N3	High Voltage Lines to Old Wood Br.	10.3-13.3
N4	Old Wood Br. to Rayrock	13.3-20.9
N5	Rayrock to Whitepine Cr.	20.9-25.4
	Chiwaukum Creek	
CH1	Highway 2 Bridge to Mouth	0.0-0.8
	Chumstick Creek	
CS1	Mouth to North Rd culvert	0.0-1.6
	Peshastin Creek	
P1	Mouth to RM 4.0	0.0-6.4
	Mission Creek	
M1	Mouth to Brender Creek	0.0-0.8
M2	Brender Creek to RM 2.0	0.8-3.2
	Brender Creek	
BR1	Mouth to Mill Rd.	0.0-0.3
	Beaver Creek (WEN)	
BW1	Mouth to Acclimation Pond	0.0-2.4
	Wenatchee River	
W1	Mouth to Sleepy Hollow Br.	0.0-5.6
W2	Sleepy Hollow Br. to Monitor Br.	5.6-9.3
W3	Monitor Br. to lower Cashmere Br.	9.3-15.3
W4	Lower Cashmere Br. to Dryden Dam	15.3-28.2
W5	Dryden Dam to Leavenworth Br.	28.2-38.5
W6	Leavenworth Br. to Icicle Rd. Br.	38.5-42.5
W7	Icicle Rd. Br. to Tumwater Br.	42.5-57.3
W8	Tumwater Br. to Lake Wenatchee	57.3-86.3
	Wolf Creek	
WF1	Mouth to RM 1.6	0.0-2.6
	Beaver Creek (MET)	
BM1	Mouth to RM 1.6	0.0-2.6
	Libby Creek	
L1	Mouth to RM 1.0	0.0-1.6
	Gold Creek	
G1	Mouth to RM 1.5	0.0-2.4

Chewuch River		
CR1	Mouth to RM 1.0	0.0-1.6
Twisp River		
T1	Mouth to RM 2.0	0.0-3.2
Spring Creek		
S1	Mouth to WNFH	0.0-0.4
Methow River		
M1	Mouth to Steel Br.	0.0-8.1
M2	Steel Br. to Methow	8.1-23.8
M3	Methow to Lower Gold Cr. Br.	23.8-34.3
M4	Lower Gold Cr. Br. to Carlton	34.3-44.4
M5	Carlton to Twisp	44.4-63.7
M6	Twisp to Winthrop	63.7-80.2
M7	Winthrop to Wolf Cr.	80.2-85.0

RESULTS

Icicle Creek

We conducted spawning ground surveys in Icicle Creek between October 15th and December 17th. Five-hundred and seven coho redds were counted and recorded in 2003 (Figure 1; Table 2). The first redd was found on October 15th, which coincided with the first observations of live coho. Peak spawn occurred during the first week of November; two weeks earlier than the mean peak spawn for the 2000-2002 broods (Figure 2). Three hundred and sixty-nine coho carcasses were recovered and sampled by YN personnel: 157 females, 203 males, and 9 unknown. The unknown carcasses lacked distinguishable features, both external and internal, used for sex identification purposes. Three hundred and sixteen snouts were collected for CWT analysis, while 53 carcasses lacked snouts, primarily due to aviary and mammalian predation. An additional 22 coho carcasses were recovered by WDFW during summer chinook spawning ground surveys. Mean POH for both male and female coho was 51.1 cm (SD = 5.4) and 53.4 cm (SD = 4.5), respectively. All females were examined for the presence of eggs within the body cavity. Mean egg voidance was 86.3% and ranged between 0% and 100% (n=157). Coded wire tag analysis determined that 89.9% of the tags recovered originated from Icicle Creek. Butcher Creek and Beaver Creek releases that were found in the Icicle comprised only 2.3% of the total. The remaining 7.9% (*n=25*) of snouts collected had either a lost tag or no tag (Table 2). The no-tag fish are important to note considering this was the first return of naturally produced coho to the Wenatchee River basin. Scale analysis is ongoing and will help determine the origin of these un-tagged coho adults. The majority of redds (*n=325*; 64.1%) were located between the East Leavenworth Road bridge and the mouth of Icicle Creek (Reach 1; I1). Eighty-one percent of the coho redds found in the Wenatchee River basin were located in Icicle Creek (Table 3). Complete survey records can be found in AppendixG.

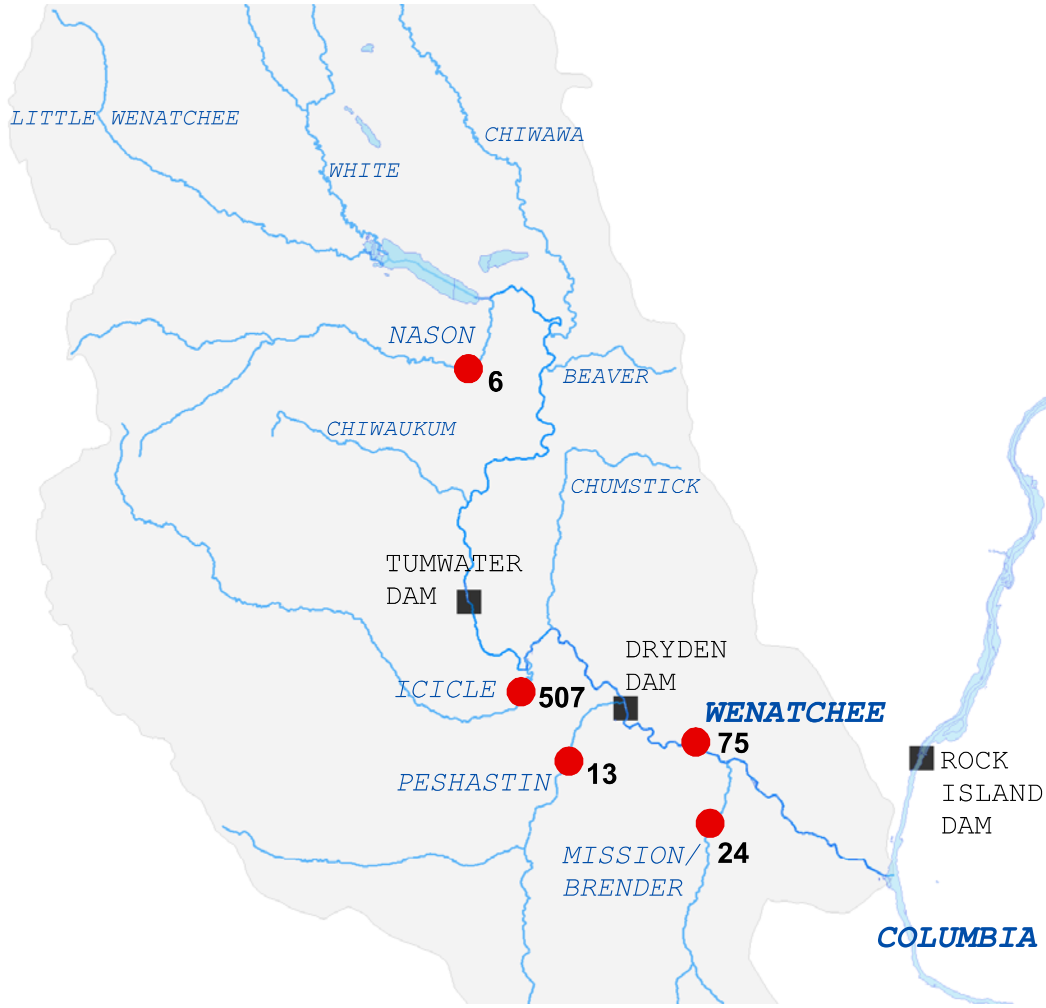


Figure 1. Spatial distribution and number of coho redds in the Wenatchee River basin, 2003.

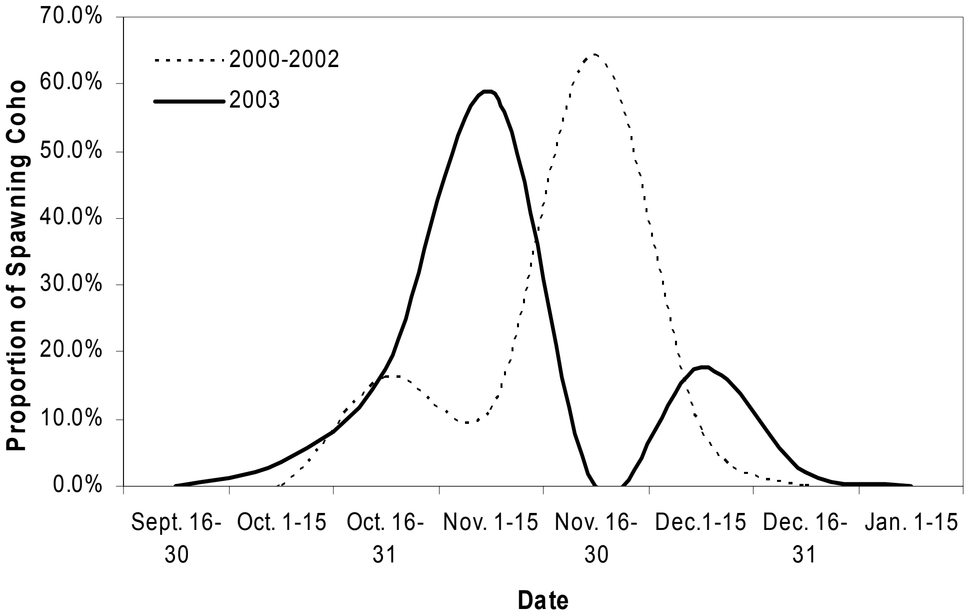


Figure 2. Coho spawn timing in Icicle Creek, 2003.

Table 2. Coded-wire tag (CWT) analysis from carcasses recovered on Icicle Creek, 2003.

Tagcode	**Release origin**	**Number of recoveries (%)**
050577 050581 054532 055012	Icicle Creek	284 (89.9%)
050578	Butcher Creek	4 (1.3%)
050582	Beaver Creek	3 (1.0%)
Lost Tag	Unknown Hatchery	11 (3.5%)
No Tag	Unknown Origin	14 (4.4%)
Total		**316 (100%)**

Table 3. Summary of coho redds counted in the Wenatchee River basin and the percentage of redds within each waterway, 2003.

River	No. of Redds	% Of Redds
Icicle Creek	507	81.1%
Nason Creek	6	1.0%
Peshastin Creek	13	2.1%
Mission Creek	23	3.6%
Brender Creek	1	0.2%
Wenatchee River upstream of Dryden Dam	44	7.0%
Wenatchee River downstream of Dryden Dam	31	5.0%
Total	**625**	**100%**

Nason Creek

Spawning ground surveys were conducted on Nason Creek between October 16th and December 11th (Appendix F). Nason Creek survey reaches can be found in Table 1. Six redds were identified in Nason Creek, with peak spawning occurring December 1st (*n=3*). Four carcasses were recovered in Nason Creek, two males and two females. One female originated from a fish transplant on October 30th. We relocated 12 females and 7 males collected at Dryden Dam/Icicle Creek traps to the uppermost reach of Nason Creek in an attempt to supplement ongoing natural spawning. Mean POH for both males and females was 51.5 cm (SD=2.1) and 48.0 cm (SD=0), respectively. The only female examined for egg voidance was a pre-spawn mortality from the Dryden/Icicle fish transplant. Fifty percent of the redds (*n=3*) identified in Nason Creek were located in the lowest reach (N1). CWT analysis indicated that two (50.0%) of the coho recovered originated from the 2002 Butcher Creek release. Of the other two carcasses recovered, one originated from the 2002 Icicle Creek release while the other did not have a tag. Nason Creek redds represented 1.0% of the coho redds in the Wenatchee River basin.

Wenatchee River

Wenatchee River surveys were conducted to determine distribution and number of redds rather than spawn timing. Wenatchee River reaches surveyed can be found in Table 1. A total of 75 redds were identified in the Wenatchee River (Table 2). The majority of spawning (69.3%) occurred in reaches W2 and W5 (*n=22* and *n=30*). YN personnel found eight carcasses on the Wenatchee River, four females and four males. Mean POH for both males and females was 59.0 cm (SD=8.2) and 50.0 cm (SD=0), respectively. Mean egg voidance was 100% (*n=1*). Of the eight carcasses recovered, only two had retrievable snouts. One fish originated from the 2002 Icicle Creek release while the other had no tag. Snouts were unobtainable from remaining six coho carcasses. An additional 79 coho carcasses were recovered in the Wenatchee River by WDFW personnel during summer chinook spawning ground/carcass surveys. Scale analysis determined that all of the carcasses recovered by WDFW were hatchery origin, three-year-old coho. Redds located on the Wenatchee River accounted for 12.0% of the observed coho redds in the Wenatchee Basin (Table 2).

Other Tributaries

On small tributaries associated with the Wenatchee River, we surveyed to determine spawning distribution and counts rather than spawn timing. Survey areas included the lower reach of Beaver

Creek, Brender Creek, Chiwawa River (lower), Chiwaukum Creek, Chumstick Creek, Peshastin Creek and Mission Creek (Table 2). No redds were located in Beaver Creek, Chiwawa River (lower), Chiwaukum Creek, or Chumstick Creek. A total of 37 redds were found in Brender, Mission, and Peshastin creeks (Table 3).

Mission Creek/Brender Creek

Mission Creek survey reaches can be found in Table 1. Twenty-three coho redds were identified in Mission Creek. One redd was located in Brender Creek approximately 10 meters upstream from the confluence with Mission Creek. All 23 redds identified in Mission Creek were in the lowermost reach, with 15 redds located below Brender Creek (M1). We recovered 9 carcasses—4 females, 4 males, and 1 unknown. We were unable to collect snouts for CWT analysis on seven of the nine carcasses. Mean POH for both males and females was 55.5 cm (SD=9.2) and 56.0 cm (SD=0), respectively. Mean egg voidance was 100% (*n=1*). CWT recovery and analysis demonstrated that two tags were recovered from the carcasses. One CWT originated from the 2002 Icicle Creek release while the other came from the 2002 Butcher Creek release. Redds located in Mission and Brender creeks represented 3.8% of the coho redds in the Wenatchee River basin.

Peshastin Creek

Peshastin Creek was divided into three reaches for spawning ground surveys (Table 1). Thirteen coho redds were identified between November 1st and December 30th. Eighteen carcasses were recovered—13 females and 5 males. Mean POH for both male and female coho was 49.2 cm (SD = 4.1) and 50.5 cm (SD = 6.2), respectively. Mean egg voidance was 52.7%. Five of the 13 females examined for egg voidance were pre-spawn mortalities. Coded wire tag analysis determined 14 of the 18 carcasses recovered had tags and originated from the 2002 Icicle Creek release. Of the four carcasses without CWTs, three did not have tags, and one carcass did not have a retrievable snout. Further scale analysis will help determine the origin of the unknown carcasses. Redds located in Peshastin Creek represented 2.1% of the coho redds in the Wenatchee River basin.

Methow River

Methow River surveys were conducted in 2003 to determine distribution rather than spawn timing. These surveys were divided into seven reaches (Table 1). A total of 13 redds were identified in the Methow River (Table 4). YN personnel found 3 carcasses in the Methow River, 2 females and 1 male. Mean POH for both male and female coho was 53.5 cm (SD=0.0) and 59.0 cm (SD=7.1), respectively. Egg voidance was not determined due to the decomposed condition of the recovered carcasses.

Other tributaries

Spawning ground surveys were expanded in 2003 to include many tributaries associated with the Methow River. Survey areas included the lower reaches of Beaver Creek, Chewuch River, Gold Creek, Libby Creek, Spring Creek, Twisp River, and Wolf Creek (Table 1). No redds were found in Chewuch River, Libby Creek, Twisp River, or Wolf Creek. A total of 15 redds were found in Beaver, Gold, and Spring creeks (Table 3).

Beaver Creek

Beaver Creek surveys were conducted as one reach (Table 1). Five coho redds were identified in Beaver Creek. All identified redds were in the lower 200 meters of Beaver Creek. We recovered 4 carcasses—2 females and 2 males. Mean POH for both males and females was 52.1 cm (SD=2.8) and 55.1 cm (SD=0.8), respectively. Mean egg voidance was 96.3% (*n=2*). Coded wire tag analysis determined that 3 tags were recovered that originated from the 2002 WNFH release. The fourth carcass recovered did not have a tag, but scale analysis will help determine origin. Beaver Creek redds represented 17.9% of the total coho redds located in the Methow River basin (Table 4).

Gold Creek
Gold Creek was also surveyed as one reach in 2003 (Table 1). Three coho redds were identified on November 3rd in the lower 300 meters of the creek. One female coho carcass was recovered with a POH of 59.2 cm (SD = 0.0). Egg voidance was 93.9%. The coho sampled originated from the 2002 WNFH release. Redds identified in Gold Creek represented 10.7% of the coho redds in the Methow River basin (Table 4).

Spring Creek
Spring Creek, also known as the WNFH outfall, is approximately 300 meters in length and was surveyed as one reach in 2003 (Table 1). Seven coho redds were identified between November 3rd and December 1st. One male coho carcass was recovered with a POH of 50.7 cm (SD = 0.0). Redds located in Spring Creek accounted for 25.0% of the coho redds in the Methow River basin (Table 4).

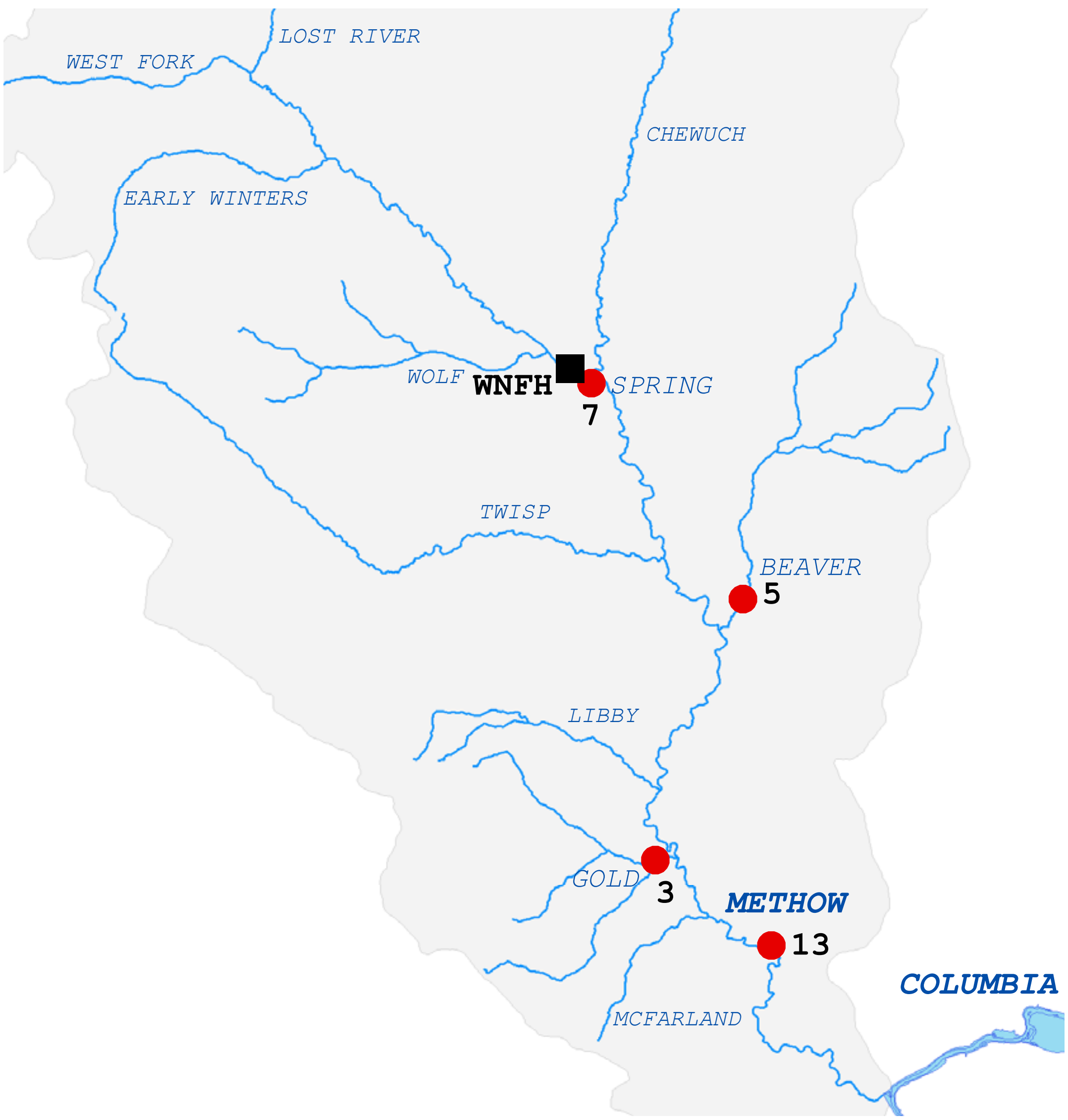


Figure 3. Spatial distribution and number of coho redds in the Methow River basin, 2003.

Table 4. Summary of coho redds counted in the Methow River basin and the percentage of redds within each waterway, 2003.

River Reach	No. of Redds	% Of Redds
Methow River	13	46.4%
Beaver Creek	5	17.9%
Chewuch River	0	0.0%
Gold Creek	3	10.7%
Libby Creek	0	0.0%
Spring Creek	7	25.0%
Wolf Creek	0	0.0%
Total	**28**	**100%**

DISCUSSION

The 2003 adult coho returns to the Wenatchee River were the highest observed since coho recovery efforts in mid-Columbia tributaries began, and may in part be the result of broodstock development (Murdoch et.al. 2005). We estimate that 4,133 coho returned to the Wenatchee River basin, as measured by Dryden Dam trap counts expanded for non-trapping days plus redd counts below Dryden Dam (Chapter 6). Of the returning coho we trapped, 1,706 were collected for broodstock (Kamphaus 2005), leaving a minimum spawning escapement of 2,427 coho. From the 2,427 coho estimated to have escaped to the Wenatchee Basin, we found 625 redds (3.9 fish per redd). The sex ratio observed at Dryden Dam predicts 2.4 fish per redd. A discrepancy in fish-per-redd estimates could result if not all redds were found or if some level of pre-spawn mortality is occurring. Locating coho redds on the Wenatchee River can be difficult. Coho spawn timing overlaps with summer chinook. Coho redds in heavily used summer chinook spawning areas cannot be positively identified without seeing fish on these redds.

Most of the coho passing over Tumwater Dam were unaccounted for during spawning ground surveys. A total of 260 coho were counted passing over Tumwater Dam in 2004. It was likely that the video count is inflated due to fallback and possible re-ascent by individual fish. The fallback rate for coho salmon at Tumwater Dam, as measured during the radio-telemetry study during 2003, was 56.7% (Chapter 3). Several of the radio-tagged coho tagged at Tumwater Dam spawned in Icicle Creek or other downstream locations (Chapter 3). If the fall back rate observed in radio-tagged fish is representative of the population of non-radio-tagged fish, we estimate that 113 coho continued to migrate upstream, destined for the upper basin. The sex ratio of coho passing over Tumwater Dam was 1F:14M, predicts 15 fish per redd upstream of the dam. Twenty females potentially spawned in the upper basin (Nason Creek and Beaver Creek returning adults plus transplanted coho). Six redds were found upstream of Tumwater Dam, all in Nason Creek. Based on carcass recovery, at least one of the six redds was created by a female transported to Nason Creek and was not included in the estimate of females migrating above the dam. Based on the results of the telemetry evaluation (Chapter 3), and on observations during trapping, we believe that females are dropping out earlier than males or are otherwise unable to navigate though Tumwater Canyon, possibly due to the maturation of gametes. Our observations at Dryden Dam indicate that some coho may be ascending the Wenatchee River in a ripe condition and must spawn prior to reaching their tributary of release or suitable habitat.

Historically, Nason Creek may have been the largest producer of coho in the Wenatchee basin (Mullan et al. 1992). We are optimistic that the development of a local broodstock will result in increased returns and natural production in coho habitat. Through the broodstock development process, natural selection should eliminate some of the deleterious traits that could affect successful reproduction (run timing, spawn timing etc).

As the broodstock development process continues, we plan to continue spawning ground surveys, supplemented by radio-telemetry evaluations, to track the distribution of coho spawners.

SUMMARY

• During spawning ground surveys in Icicle Creek, we observed 507 coho redds and recovered 369 coho carcasses. The mean egg voidance was of 86.3% (n=157).

• During spawning ground surveys in Nason Creek, we counted six coho redds and recovered 4 carcasses. The mean egg voidance was 0.0% (n=1).

• We found 75 coho redds in the mainstem Wenatchee River and a combined 37 redds in Brender, Mission, and Peshastin creeks. In Mission and Peshastin creeks, 9 and 18 carcasses were recovered and mean egg voidance was 100.0% (n=1) and 52.7% (n=13), respectively.

• A total of twenty-eight redds were identified in the Methow River and associated tributaries in 2003. Nine carcasses were recovered with a mean egg voidance of 95.5% (n=3) in the Methow River basin.

LITERATURE CITED

Dunnigan, J.L. 2001. Yakima coho monitoring and evaluation 2000 annual report. *In*: Monitoring and evaluation, Yakima/Klickitat Fisheries Project. Final Report 2000. Bonneville Power Administration Project Number 95-063-25. Portland, OR.

HGMP. 1999. Hatchery and Genetics Management Plan: Mid-Columbia Coho Reintroduction Program. Bonneville Power Administration, Portland OR.

Kamphaus, C. K. 2003. Mid-Columbia coho reintroduction feasibility study: Draft 2002 annual broodstock development report. *Prepared for*: Bonneville Power Administration, Portland OR.

Mosey, T.R., and L.J. Murphy. 2002. Spring and summer chinook spawning ground surveys on the Wenatchee River Basin, 2001. Chelan County Public Utility District, Wenatchee, WA.

Mullan, J.W., K.R. Williams, G. Rhodus, T.W. Hillman, and J.D. McIntyre. 1992. Production and habitat of salmonids in mid-Columbia river tributary streams. Monograph I. U.S. Fish and Wildlife Service, Leavenworth, WA.

Murdoch, K.G., and M.L. LaRue. 2002. Feasibility and Risks of Coho Reintroduction in Mid-Columbia River Tributaries, 2001. Draft Report 2001. Bonneville Power Administration Project Number 1996-040-00. Portland, OR.

CHAPTER 5: POPULATION ESTIMATE OF NATURALLY PRODUCED COHO SALMON SMOLTS *ONCORHYNCHUS KISUTCH* IN THE WENATCHEE RIVER BASIN

INTRODUCTION

Efforts to restore naturally producing coho to tributaries of the mid-Columbia River depend largely upon the ability of adult coho to spawn successfully in the natural environment. Estimating the number of naturally produced smolts that emigrate from the basin is essential to measuring smolt-to-adult survival rates, establishing recovery goals, and for the development of coho stock-recruitment curves in the mid-Columbia (Symons 1979; Chadwick 1982; Gardiner and Shackley, 1991; Kennedy and Crozier 1993; Ward and Slaney 1993).

The Washington Department of Fish and Wildlife (WDFW) currently operates a rotary smolt trap in the lower Wenatchee River above the town of Monitor (RK 10.9). This smolt trap is designed to collect data from all emigrating salmonids in the basin, including data from coho emigrants.

The 2003 smolt emigration included the second naturally produced coho smolts in the Wenatchee River in close to a century. Our efforts described below mark an important step in evaluating the potential for reintroduced hatchery coho salmon to reproduce successfully in mid-Columbia tributaries.

METHODS

To collect data on the emigration of naturally produced and hatchery coho in the Wenatchee River, YN personnel worked with WDFW personnel on the Monitor rotary smolt trap between April 25th and May 25th. The trap crews operated the smolt trap each night from dusk until dawn. The trap was not operated during daylight hours because salmon smolts migrate primarily at night (Sandercock 1991; Roper and Scarnecchia 1999). Biological information recorded nightly on both hatchery and natural coho emigrants helped define length-at-migration and run timing. On nights when the trap was inoperable due to high river discharge or mechanical problems, the number of trapped coho was estimated from the mean number of coho salmon smolts captured two days before and two days after the break in operation. WDFW personnel conducted mark/recapture trap efficiency trials. Trap efficiency was used to calculate population estimates for naturally produced coho salmon. The efficiency trial and emigration estimate methods described below were provided by T. Miller, WDFW.

Efficiency Trials

Hatchery coho smolts were collected for mark/recapture efficiency trials throughout the smolt emigration. A minimum of 100 fish were used in each mark group. Fish used in the efficiency trials were held in floating live boxes located at the rear of the trap. The holding time required to collect a sufficient sample typically did not exceed 24 hours. A fin clip was applied to either the top or the bottom lobe of the caudal fin to mark fish used in the efficiency trials. A small caudal clip, whether on the upper or lower lobe, has no significant effects on capture efficiency (Petersen et al. 1995). Marked fish were then transported upstream to Dryden Dam (RK 28.2) and released in equal proportions on both sides of the river.

Data Analysis and Emigration Estimate

Trap efficiency trials were conducted at various river discharges and three trap operation positions. Efficiency trials from multiple years (2001-2003) were used to calculate trap efficiency. The efficiency estimates were stratified by flow and three trap positions. Emigration estimates were calculated by Todd Miller, WDFW, using an estimated daily trap efficiency derived from a regression formula using trap efficiency (dependant variable) and river discharge (independent variable; Seiler et. al. 2004). The coho production estimate was calculated using separate regression models for each trap position (Seiler et. al. 2004). Data analysis details can be found in Seiler et. al. (2004).

RESULTS

Coho Run Timing

Naturally produced coho smolts were seen emigrating between March 2nd and June 30th. Peak migration occurred between April 25th and May 12th (Figure 1). Hatchery coho were observed emigrating between March 14th and July 10th (volitional releases began on April 23rd), with a peak emigration between May 11th and 24th (Figure 1). The emigration of naturally produced coho was prolonged over the run timing of volitionally released hatchery coho. Emigration trends of both hatchery and natural coho appeared related to the river discharge (Figure 1); We observed an increase in migration of natural smolts as flow peaked, while hatchery smolts appeared to migrate just prior to peak river discharge.

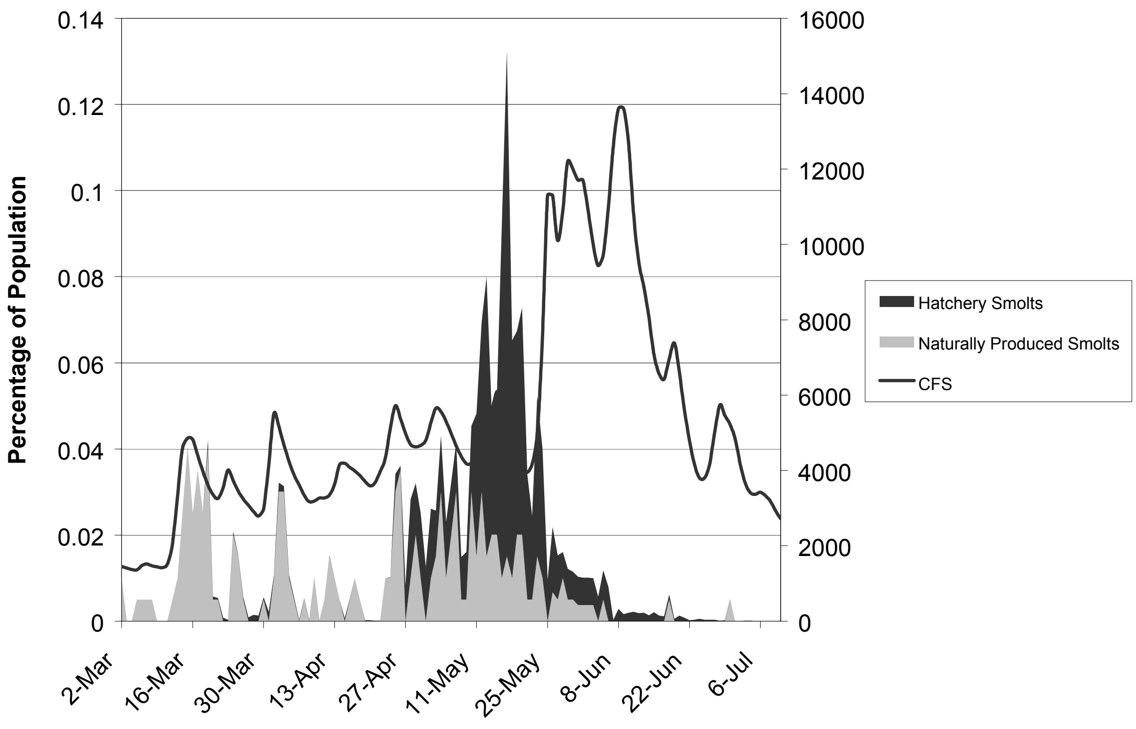


Figure 1. Run timing of natural and hatchery coho emigrating from the Wenatchee River, 2003.

Emigration Expansion

A total of 199 naturally produced coho smolts (brood year 2001) were trapped during 2003. Due to low numbers of wild coho available for efficiency trials, hatchery coho and wild sockeye were used as surrogates for wild coho smolts (Seiler et al. 2004). The relationship between efficiency and river discharge found for surrogates is thought to be similar for wild coho smolts (Seiler et al. 2004). A total of 36 efficiency trials groups were released at Dryden Dam. The number of fish released in each group ranged from 146 to 1,201 (Seiler et. al. 2004). Yearling recapture rates averaged 0.79% and trials ranged from 0.00% to 3.02% (Seiler et al. 2004). Wenatchee River flows used to stratify the efficiency trials ranged from 84.8 cms to 267.6 cms (Seiler et. al. 2004).

Based on the efficiency estimates, river flow, and trap position, approximately 36,678 naturally produced coho smolts emigrated from the Wenatchee River in 2003 (T. Miller, WDFW, unpublished data). This estimate is dependent on the ability to differentiate between hatchery coho among wild coho. All hatchery coho were CWT marked but not adipose fin clipped. At the trap, each coho caught in the trap was scanned for tags by WDFW or YN personnel and separated. Any coho with no CWT was visually scanned for "hatchery fins' and for morphological traits to identify the coho as wild or hatchery. A scale sample was taken from coho of questionable origin to ensure greater accuracy. Scale samples were taken from a total of 135 coho of which 134 were considered wild yearlings (Seiler et al. 2004).

Egg-to-Emigrant Survival

We assume the Wenatchee River basin was seeded with 415,800 coho salmon eggs in 2001 (154 redds times 2700 eggs/female) (Murdoch and LaRue 2002). Using naturally produced coho emigration point estimates provided by T. Miller (WDFW unpublished data), we calculate an egg-to-emigrant survival rate of 8.82%. This estimate of egg-to-emigrant survival should be viewed as a maximum; It is possible that not all coho redds were located in the Wenatchee basin because surveys were only conducted in tributaries of acclimation and release (Nason Creek and Icicle Creek); the mainstem Wenatchee River was not surveyed in 2001. Unaccounted for redds would artificially inflate the egg-to-emigrant survival rate. To account for unobserved redds, we also calculated a minimum egg-to-smolt survival rate based upon an alternate estimate of spawning escapement using expanded trap counts at Dryden Dam, and redds observed downstream from Dryden Dam (Murdoch and LaRue 2002). Because expanding Dryden Dam counts resulted in a larger estimated adult return in 2001 than redd counts alone, this method may account for any unobserved redds. Using this method (estimated spawning escapement = 554 coho, pre-spawn mortality rate =0.10, fish per redd = 2.2, fecundity = 2700) we estimate a minimum egg-to-emigrant survival of 5.9%.

DISCUSSION

Trap efficiencies at WDFW's rotary smolt trap located near Monitor on the Wenatchee River are extremely low due to the large size of the Wenatchee River during spring run-off. Because of the low trap efficiency, efficiency trials from multiple years were used in the development of a population estimate model (T. Miller, WDFW, pers comm.). Due to the high variability in trap efficiencies, even when stratified for river discharge and trap operation position, only a point estimate could be calculated. As more efficiency trials are conducted in future years, a reanalysis of 2003 data may provide a population estimate with a 95% confidence interval.

The egg-to-emigrant survival rate (8.82%) observed for the first generation of naturally produced coho provides an optimistic outlook for the future of naturally producing coho salmon in the Wenatchee basin. The observed egg-to-emigrant survival rate comports well with egg-to-emigrant survival rates observed for spring chinook in the Chiwawa River between 1994 and 2003 (4.7% to 18.1%) (Murdoch et al. 2001; A. Murdoch, WDFW, pers. comm.).

The 2003 migration of naturally produced coho smolts demonstrates that successful natural production of reintroduced hatchery coho occurred. Successful reproduction, even on a small scale, can provide valuable insight on the feasibility of introduction. With each generation of coho returns to the Wenatchee River, a locally adapted coho stock should evolve in mid-Columbia tributaries. We expect local adaptation to result in increased natural production and improved survival rates.

LITERATURE CITED

Chadwick, E.M.P. 1982. Stock-recruitment relationship for Atlantic salmon in Newfoundland rivers. Canadian Journal of Fisheries and Aquatic Sciences 39:1496-1501.

Gardiner, R. and P. Shackley. 1991. Stock and recruitment and inversely density-dependent growth of salmon, *Salmo salar* L., in a Scottish stream. Journal of Fish Biology 38:691-696.

Kennedy, G.J.A. and W.W. Crozier. 1993. Juvenile Atlantic salmon production and predation. Pgs. 179-187 in R.J. Gibson and R.E. Cutting Production of juvenile Atlantic salmon in natural waters. Canadian Special Publication of the Fisheries and Aquatic Sciences 118.

Miller, T. In Prep. 2003 Chiwawa River, Lake Wenatchee, and Wenatchee River smolt trap estimates. Washington Department of Fish and Wildlife, Wenatchee WA.

Miller, T. 2003. 2002 Chiwawa and upper Wenatchee River smolt estimates. Washington Department of Fish and Wildlife, Wenatchee, WA.

Murdoch, K.G., and J. Dunnigan. 2002. Feasibility and risks of coho reintroduction in mid-Columbia Tributaries. 2000 annual monitoring and evaluation report. *Prepared for:* Project number 1996-040-000, Bonneville Power Administration. Portland, OR.

Murdoch, K.G., and M. LaRue. 2002. Feasibility and risks of coho reintroduction in mid-Columbia Tributaries: 2001 annual monitoring and evaluation report. *Prepared for:* Project number 1996-040-000, Bonneville Power Administration, Portland OR.

Murdoch, A., K. Petersen, T. Miller, M. Tonseth, and T. Randolph. 2001. Freshwater production and emigration of juvenile spring chinook from the Chiwawa River in 2000. *Prepared for:* Public Utility District Number 1 of Chelan County, Wenatchee WA.

Petersen, K., R. Eltrich, A. Mikkelsen, and M. Tonseth. 1995. Downstream movement and emigration of chinook salmon from the Chiwawa River in 1994. Report No. H95-09. Washington Department of Fish and Wildlife, Olympia, WA.

Roper, B.B., and D.L. Scarnecchia. 1999. Emigration of age-0 chinook salmon (*Onchorynchus tshawytscha*) smolts from the upper South Umpqua River basin, Oregon, U.S.A. Can. J. Fish. Aquat. Sci. 56:939-946.

Sandercock, F.K. 1991. Life history of coho salmon. *In:* C. Groot and L. Margolis, editors, Pacific Salmon Life Histories. UBC Press, Vancouver B.C.

Seiler, D., G. Bolkhardt, P. Topping, L. Fleischer, T. Miller, S. Schonning, D. Rawding, M. Gresbeck, R. Woodard, S. Hawkins, WDFW Fish Management Division. 2004. Juvenile Salmonid Production Evaluation Report 2003: Green River, Wenatchee River, Cedar Creek. Washington Department of Fish and Wildlife, Olympia WA.

Symons, P.E.K. 1979. Estimated escapement of Atlantic salmon for maximum smolt production in rivers of different productivity. Journal of the fisheries Research Board of Canada 36:132-140.

Ward, B.R. and P.A. Slaney. 1993. Egg-to-smolt survival and fry-to-smolt density dependence of Keogh River steelhead trout. Pgs. 209-217 *In*: R.J. Gibson and R.E. Cutting. Production of juvenile Atlantic salmon in natural waters. Canadian Special Publication of the Fisheries and Aquatic Sciences 118.

CHAPTER 6: SURVIVAL OF HATCHERY AND NATURALLY PRODUCED COHO

INTRODUCTION

Project success requires sufficient numbers of adult coho to return to the basin from which they were released in order to spawn naturally or to be spawned in a hatchery. The mid-Columbia Hatchery and Genetics Management Plan (HGMP 2002) identifies several project performance indicators. The performance indicator of highest interest in the short term may be smolt-to-adult survival. The HGMP speculates that to develop a local broodstock, sufficient adults must return to the Wenatchee and Methow rivers in order to meet broodstock requirements. Thus, a monitoring program that tracks smolt-to-adult survival rates through time is essential to track the project's long-term performance.

The project is also interested in juvenile survival in order to parse out that portion of the smolt-to-adult mortality that is occurring in the freshwater life stages. Juvenile coho released in the Wenatchee and Methow rivers must migrate past 7 and 9 hydropower dams on the mainstem Columbia River before reaching the Pacific Ocean. These dams have increased the total cross-sectional area of the Columbia River, resulting in decreased water velocity and turbidity, which in turn has increased smolt travel time and generally subjected smolts to greater exposure to predators and other factors influencing survival (Raymond 1979, 1988; Williams 1989). Physical changes in the Columbia River environment attributable to hydro-projects may require salmonids to migrate under a different set of environmental conditions than the conditions in which they evolved.

Juvenile and adult coho survival in the Columbia River mainstem may be further depressed by the source of hatchery broodstock. Lower Columbia River stocks of coho may not be well adapted to migrate the long distances required for them to reach the ocean and return. A baseline monitoring program that tracks both juvenile survival and smolt-to-adult survival rates will be important to determine if survival benefits are achieved through the development of a locally adapted broodstock.

METHODS

Wenatchee River Basin: Downstream Smolt Survival

The YN acclimated and released an estimated 911,422 yearling coho smolts into Wenatchee River tributaries in 2003. Release sites and the estimated numbers of fish released from each site (after attributing for known mortalities), and the number of PIT tags in each release group can be found in Table 1.

Table 1. Number of coho released from Wenatchee basin acclimation sites, 2003.

Basin	Tributary	Acc. Site	Broodstock Origin	Est. No. Released[1]	No. of PIT tags	CWT
Wenatchee	Icicle Ck.	Dam 5	Lower Col.	36,911	N/A	100%
		Dam 5	Mid. Col.	445,917	7989	100%
	Nason Ck.	Butcher Ck. Pd.	Mid. Col.	144,335	7986	100%
		Coulter Pd	Mid. Col.	82,631	N/A	100%
		Mahar Pd.	Mid-Col.	33,344	N/A	100%
	Little Wenatchee River	Two Rivers	Mid-Col.	97,807	8994	100%
	Beaver Ck.	Beaver Ck. Pd.	Mid. Col.	75043	N/A	100%
Methow	Methow R.	WNFH	Lower. Col.	182,415	N/A	100%
	Methow R	WNFH	Lower. Col.	59,940[3]	N/A	100%

[1]Estimated number of smolts released is based on the number of fish transported minus the estimated number of mortalities. Estimated mortality numbers are 2 x the known mortality (Kamphaus 2003).
[2]Coho released from Early Pond shared a PIT code with one of five tag groups released in from Dam 5.
[3]Coho released directly into hatchery outfall, no on-station acclimation

PIT-tagged fish released from the Dam 5, Butcher Creek Pond, and Two Rivers acclimation site (Table 1) were detected at McNary, John Day and Bonneville dams and allowed estimates of release-to-McNary survival to be calculated.

Statistical analysis

To obtain a McNary passage index of PIT-tagged fish released into the Wenatchee and Methow basins, the number of McNary Dam PIT tag detections were expanded by dividing by an estimate of the McNary detection-rate (efficiency). McNary's detection rate is the proportion of total PIT-tagged fish passing the dam that are detected by the dam's PIT tag detectors. McNary's detection rate is calculated by summing the number of PIT-tagged fish detected at McNary and at a downstream dam and dividing by the total number detected at the downstream dam. An index of survival to McNary is the McNary passage index divided by the number of PIT-tagged fish released.

For the 2003 survival rates, detection-rate estimates were calculated for the Leavenworth and Winthrop releases separately, based on John Day Dam and Bonneville Dam Powerhouse 2 detections. All detection-rate estimates were statistically tested for comparison using a z-test for binomial proportions, and if the detection-rate estimates were not different, the estimates were pooled. Neeley (2004) (Appendix H) describes the methods used to estimate coho smolt survival to McNary Dam in detail.

Methow and Wenatchee River Basin Smolt-Adult Survival

The third return of adult coho to the Wenatchee, and the third year of trapping adult coho in the Methow River occurred in 2003. The Yakama Nation acclimated and released 186,053 coho smolts into the Methow River Basin in 2002 (Murdoch and Kamphaus 2003). Smolt-to-adult survival was calculated based on two methods of enumerating adult coho in the Methow River: 1) broodstock (WNFH swim-ins and Wells trapping) and redd counts, and 2) Wells Dam fish counts. CWTs and scale samples for non-CWT fish were used to distinguish naturally produced fish from hatchery fish.

The Yakama Nation acclimated and released 1,002,323 coho smolts into the Wenatchee River basin in 2002 (Kamphaus and Murdoch 2004). The smolts were released from four acclimation sites within the

Wenatchee River basin: 143,314 coho smolts were released from the Butcher Creek acclimation site on Nason Creek, 19,001 from the Early Pond acclimation site on Nason Creek, 72,676 from the Beaver Creek acclimation site, and 767,332 coho smolts were released from the Dam 5 acclimation site behind the LNFH on Icicle creek. We calculated smolt-to-adult survival for 2002 adult returns using three equations to estimate the number of adults that returned:

1) Dryden Dam counts expanded by linear regression for non-trapping days, plus redd counts downstream from Dryden Dam;
2) Broodstock collected at Dryden Dam plus all redd counts;
3) Mainstem dam counts (Rock Island Dam – Rocky Reach Dam).

Method one may underestimate the total number of coho returning to the basin if the trapping efficiency of Dryden Dam is low (due to high Wenatchee River flows) or may overestimate the number of coho returning if fallback rates of fish not collected in the broodstock is high. Method two may also underestimate the number of coho to return to the Wenatchee River because it does not take non-spawning fish, or pre-spawn mortalities into account. Additionally, if not all redds are located, we may underestimate the spawning escapement to the Wenatchee River. Method three is an overestimate, as it assumes no fallbacks or dropouts occurred between Rock Island and Rocky Reach Dams. Due to low flows and warm river temperatures in 2001, it is possible that the dropout rate was high. SARs calculated from methods one and two have been very similar in previous years. We believe that method one may provide the most accurate count of coho returning to the Wenatchee River.

RESULTS

Wenatchee River: Smolt Survival, Release to McNary Dam

A pooled daily McNary detection-rate estimate over releases and downstream dams was used to calculate the survival index for Wenatchee basin releases. The methods of estimation of daily passages and detection rates and the identification of detection-rate strata are described in Neeley 2004 (Appendix H). All PIT-tagged fish represent first generation mid-Columbia brood coho. The calculated survival index for the 2003 Icicle Creek, Nason Creek, and Little Wenatchee River releases was 0.63, 0.37, and 0.20 respectively (Table 2).

Table 2. Tagging-to-McNary Survival-Index and Release-to-McNary mean travel time for the 2003 coho release sites in the Wenatchee Basin.

Tributary of Release	Acclimation Site	Release RKm (from Mouth of Wenatchee River)	Release Date	Number PIT-tagged coho released	Tagging-to-McNary-Detection Survival Index (proportion of release	Release-to-McNary Travel Time (in days)
Little Wenatchee	Two Rivers	96.7	April 30	8984	0.2039	38.3
Nason Creek	Butcher Creek	99.4	May 1	7966	0.3719	42.9
Dam 5	Icicle River	45.7	April 23	7981	0.6282	40.4

Source: Neeley 2004 (Appendix G).

The passage of PIT-tagged coho released on April 23th, 2003 from the acclimation site behind the LNFH peaked at McNary Dam on May 30st, with 102 PIT-tagged fish per day (Figure 1). The mean detection date for coho released on Icicle Creek was June 4th; we estimate that a total of 5012 (62.8%) PIT-tagged coho released from Dam 5 on Icicle Creek passed McNary Dam between May 15th and July 28th.

Detection at McNary Dam of PIT-tagged mid-Columbia brood coho released from Nason Creek peaked on June 11th with 85 detections per day. The mean detection date for PIT-tagged MCR brood coho from Nason Creek was June 16th, 2002. We estimate that a total of 2960 (37.2%) PIT-tagged coho released from the Butcher Creek acclimation site passed McNary Dam between May 22nd and August 8th.

Detection at McNary Dam of PIT-tagged mid-Columbia brood coho released from the Two Rivers acclimation site on the Little Wenatchee River peaked on June 5th with 41 detections per day. The mean detection date for PIT-tagged MCR brood coho from Nason Creek was June 9th, 2002. We estimate that a total of 1831 (20.4%) PIT-tagged coho released from the Two Rivers acclimation site passed McNary Dam between May 15th and July 29th.

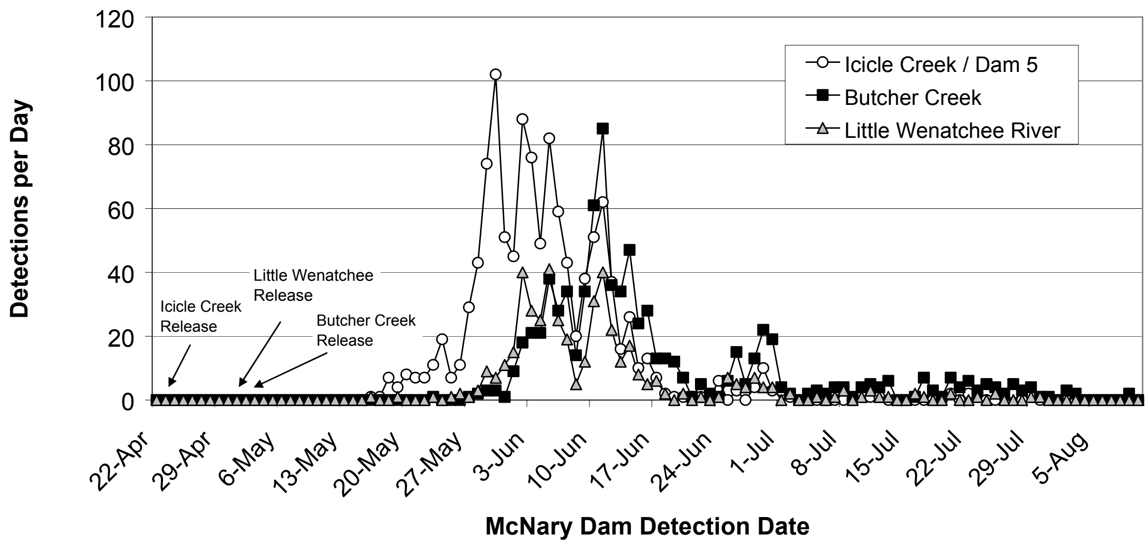


Figure 1. Daily PIT-tag detections at McNary Dam for hatchery coho released into Icicle and Nason Creeks, and the Little Wenatchee, Wenatchee River Basin, 2003.

Methow River Basin Smolt-to-Adult Survival

Based on coho enumeration method one (broodstock and redd counts), we estimate that 207 adults (BY 2000) and 1 coho jack (BY 2001) returned to the Methow River in 2003. An additional 23 jacks (BY 2000) were estimated to have returned in 2002. Using method one for BY 2000 returns, we estimate the SAR for coho returning to the Methow River to be 0.15% (Table 3). Based on Wells Dam counts (method two), an estimated 107 coho adults (BY 2000) and 11 coho jacks (BY 2001) returned to the Methow River, with an additional 36 jack coho in 2002 (BY 2000), resulting in a SAR of 0.08%. We believe that method one is the more accurate estimate because the number of coho collected for broodstock exceeds the number of coho counted at Wells Dam.

Table 3. Smolt-to-Adult survival rates for brood year 2000 returns to the Methow River, 2003.

Method	2003 return estimate (BY 1999 & 2000)	2002 Jack Estimate (BY 1999)	SAR
1) Broodstock and redd counts	267 adult & 1 jack	23 jack	0.15%
2) Wells Dam Counts*	107 adult & 11 jack	36 jack	0.08%

* A discrepancy in Wells Dam counts exists between reporting web sites. The University of Washington's D.A.R.T. web site reports 118 coho at Wells Dam while the Fish Passage Center reports 168 coho.

Wenatchee River Smolt-to-Adult Survival

Coho counts at Dryden Dam, expanded with linear regression for non-trapping days, plus redd counts (method one), predict that 4090 coho adults and 43 coho jacks returned to the Wenatchee basin in 2003. Based on scale analysis, we predict that 1.6% of the adult coho returning to the Wenatchee River were naturally produced, resulting in a hatchery origin return of 4025 adults, and 65 natural origin adults. An additional 88 jacks from BY 2000 were estimated to have passed Dryden Dam in 2002. Using coho enumeration method one, the smolt-to-adult survival rate (BY 1999) for the Wenatchee River basin was 0.41%. Using coho enumeration method two (trapped broodstock and redd counts), we estimate that 3145 hatchery origin adults, 51 natural origin adults, and 33 jacks returned to the Wenatchee River in 2003. An additional 74 jacks (BY 2000) returned in 2002, resulting in an SAR of 0.32%. We present both methods because the difference between spawning escapement based solely on redd counts, and escapement based upon expanded Dryden Dam counts may reflect upon our ability to accurately find and identify coho redds as presented in Chapter 4. Based on the difference in counts of coho at Rock Island Dam and Rocky Reach Dam (method 3), 4825 (4748 hatchery origin and 77 natural origin) adult coho and 51 jacks returned to the Wenatchee River in 2003; an additional 323 jack coho returned in 2002, resulting in an SAR for 0.51% for BY 2000 (Table 4). Mainstem dam counts used in calculations of SARs for Wenatchee and Methow river returning coho can be found in Figure 2. Fish counters at Rock Island, Rocky Reach and Wells dams did not differentiate between adult and jack coho. Counts from Priest Rapids and McNary dams included both adults and jacks. We estimated the number of jacks passing over Rock Island, Rocky Reach, and Wells dams based upon the proportion of jacks observed in-basin (Kamphaus and Murdoch 2005).

Table 4. Brood year 2000 hatchery coho smolt-to-adult survival in the Wenatchee River basin.

Method	2003 return estimate (BY 2000 & 2001)*	2002 Jack Estimate (BY 2000)	Smolt-to-Adult Survival
1) Dryden Dam counts expanded for non-trapping days plus redd counts downstream from Dryden Dam	4025 hatchery origin adults & 43 jacks	88 jack	0.41%
2) Broodstock collected at Dryden Dam and redd counts	3145 hatchery origin adult & 33 jack	74 jack	0.32%
3) Rock Island Dam Count minus Rocky Reach Dam counts	4748 hatchery origin & 51 jack	323 jack	0.51%

* Fish counts reflect returns of hatchery origin coho only. An estimated 1.6% of the run was natural origin based on interpretation of coho scales collected at spawning (J. Sneva pers. comm.).

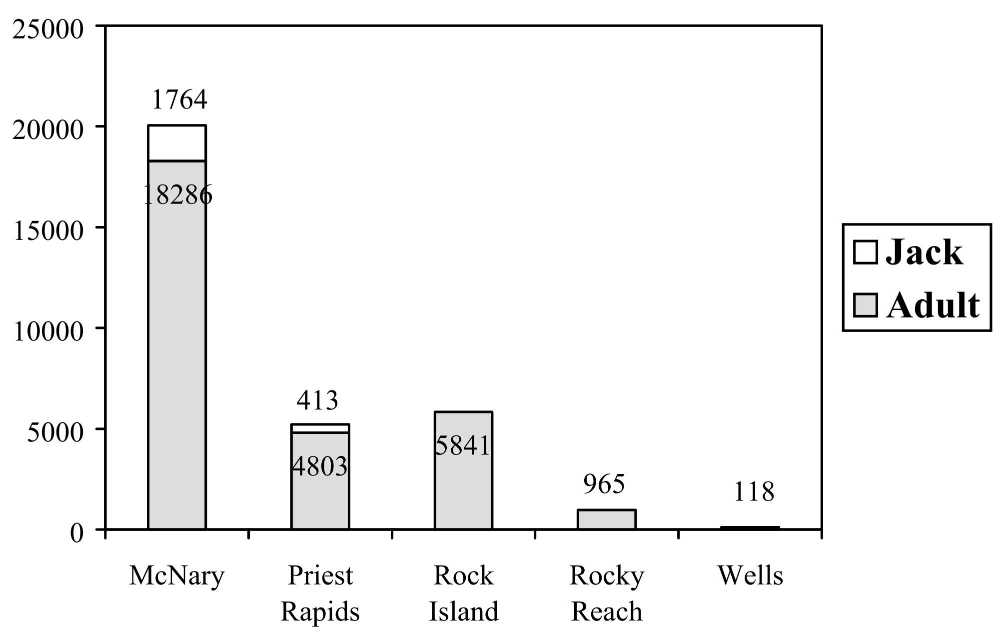


Figure 2. Mid-Columbia River dam counts of adult and jack coho, 2003.

In addition to calculating SARs for the sum of all hatchery coho returning to the Wenatchee River, we calculated SARs for each release site based on the recovery of CWTs. The SAR for natural-origin returns was based on scale analysis of adult returns, and a smolt emigration was estimated based on data collected at a rotary smolt trap located on the Wenatchee River near Monitor (See Chapter 5) (BY 2000 emigration estimate: 17,054). The SARs for the Butcher Creek release site, Icicle Creek (Dam 5) and Beaver Creek are found in Figure 3. Within the Dam 5 release site, results of a z-test for differences in proportions indicated that SARs for mid-Columbia brood coho (0.53%) were significantly higher than SARs for lower Columbia River brood coho (0.31%; $p<0.0001$). SARs from Butcher Creek and Beaver Creek both measured 41%. Mid-Columbia brood coho were released from both Beaver and Butcher creeks, and both acclimation ponds are located upstream of Tumwater Canyon.

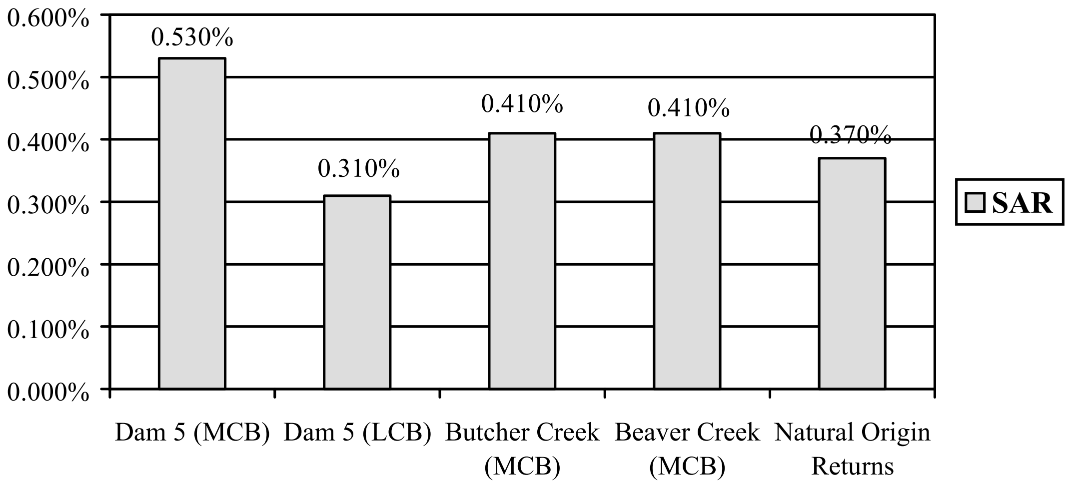


Figure 3. Wenatchee Basin acclimation /release site, and naturally produced coho in the Wenatchee River Basin, 2003.

DISCUSSION

The downstream hatchery coho smolt survival index from release in Icicle Creek to McNary Dam (62%) was substantially higher than the downstream smolt survival estimates for hatchery coho released into Nason Creek from the Butcher Creek acclimation site (37%) or the Little Wenatchee River release (20%). This difference in downstream survival rates between Icicle Creek and Nason Creek was also observed in 2002. Differences in the survival indices could be the result of differing predation rates in the acclimation sites, or differing migration routes. Fish released from both upper basin releases sites (Nason Creek and Little Wenatchee River) must migrate approximately 18 km farther and navigate Tumwater Canyon and Tumwater Dam. Fish migrating through Lake Wenatchee (Little Wenatchee River) may be exposed to increased predation within the lake (bull trout *S. confluentus* and northern pikeminnow *P. oregonensis*). We plan to direct investigations in 2004 to begin to identify sources of mortality for hatchery coho migrating from the upper basin.

The survival rate from release in Icicle Creek to detection at McNary Dam is typical of previous releases (Range 21.6% - 87.4%; Table 5).

Table 5. Comparison of smolt-smolt survival, smolt travel time, and smolt-adult survival rates for mid-Columbia coho releases, 1999-2003.

Release Year	Methow River Smolt Travel Time (km/day)*	Methow R. Smolt Survival *	Methow R. Smolt-Adult Survival	Icicle Creek Smolt Travel Time (km/day)*	Upper Wenatchee Smolt Travel Time (km/day)	Icicle Creek Smolt Survival*	Nason Creek Smolt Survival*	Wenatchee R. Smolt-Adult Survival
1999	N/A	N/A	N/A	11.4	N/A	53.9%	N/A	0.21% - 0.38%
2000	9.8	33.3%	0.17% - 0.27%	8.1	N/A	63.0%	N/A	0.17% - 0.86%
2001	9.6	9.9%	0.03%	7.9	N/A	21.6%	N/A	0.03%- .13%
2002	N/A	N/A	0.15%	15.4**- 14.0***	14.7+***	87.4%** 78.5%***	39.3%***	0.32%- 0.51%
2003	N/A	N/A		13.3	13.5+ 15.3++	62.8%	37.2%+ 20.4%++	

*Release to McNary Dam based on PIT tag detections
** Lower-Columbia brood smolts
***Mid-Columbia brood smolts
+Butcher Creek Acclimation Site
++Two Rivers Acclimation Site

The smolt-to-adult survival rate in the Wenatchee was higher than in the Methow, as would be predicted by the increased migration distance and two additional hydropower dams encountered by coho returning to the Methow River, although the difference in SARs of the magnitude observed in 2003 has not been seen in previous years. We believe the difference in survival is, at least in part, the result of the high proportion of mid-Columbia brood returning to the Wenatchee River. We observed significantly higher SARs for mid-Columbia brood than for reprogrammed lower Columbia River brood returning to the same acclimation site, an indicator that local adaptation is occurring. We expect to see continued survival benefits as the broodstock development process continues.

The discrepancy between the three smolt-to-adult survival rates may be due to high dropout rates, or to stray rates in the Columbia River and lower Wenatchee River. The smolt-to-adult survival rate calculated from Wenatchee River counts (i.e., trapped broodstock plus redd counts) was very close to the smolt-to-adult survival rate calculated from Dryden Dam passage counts plus redd counts below Dryden Dam. With both of these methods, uncounted redds or pre-spawn mortalities may result in an underestimate of the total number of returning adults. Both in-basin estimates were lower than the SAR calculated from the difference between Rock Island Dam counts and Rocky Reach counts.

LITERATURE CITED

HGMP. 1999. Hatchery and Genetics Management Plan: Mid-Columbia Coho Reintroduction Program. Bonneville Power Administration, Portland OR.

Murdoch, K.G. 2001. Mid-Columbia Coho Reintroduction Feasibility Project: 2000 Annual Acclimation Report. *Prepared for*: Bonneville Power Administration. Project Number 199604000. Portland, OR.

Murdoch, K.G., and J.L. Dunnigan. 2002. Feasibility and Risks of Coho Reintroduction in Mid-Columbia Tributaries: 2000 Annual Monitoring and Evaluation Report. *Prepared for:* Bonneville Power Administration. Project Number 199604000. Portland, OR.

Neeley, D. 2002. Annual Report: Outmigration year 2000. Yakama Nation, unpublished data. Toppenish, WA.

Raymond, H.L. 1979. Effects of dams and impoundments on migrations of juvenile chinook salmon and steelhead from the Snake River, 1966-1975. Transactions of the American Fisheries Society 108:505-529.

Raymond, H.L. 1988. Effects of hydroelectric development and fisheries enhancement on spring and summer chinook salmon and steelhead in the Columbia River Basin. North American Journal of Fisheries Management 8:1-24.

Williams, J.G. 1989. Snake River spring and summer chinook salmon: can they be saved? Regulated Rivers; Research and Management 4:17-26.

Appendix A: Comparison of Predation Study Results
In the Yakima and Wenatchee Rivers, 1998-2003

Appendix A: Comparison of Predation Study Results in the Yakima and Wenatchee Rivers, 1998-2003.

	Location	Year	Coho Origin	Prey Item	Coho Sample Size	Observed Incidence of Predation	Total Estimated Number of Prey Consumed*	% of Estimated Prey Population Consumed*
Yakima River	Yakima River (RM 203)	1998	Volitional Hatchery Release	Spring Chinook Fry	981	0.001	93	**0.005-0.14%**
	Yakima River (RM 203)	1999	Volitional Hatchery Release	Spring Chinook Fry	1757	0.00	0.00	**0.00%**
Wenatchee	Wenatchee River (RM 7.1)	2000	Volitional Hatchery Release	Summer Chinook Fry	663	0.006	134,125	**1.31%**
	Nason Creek	2001	Volitional Hatchery Release	Spring Chinook Fry	1094	0.0018	2436	**0.96%**
	Nason Creek	2003	Volitional Hatchery Release	Spring Chinook Fry	1065	0.0028	1009	**0.14%**
	Nason Creek	2003	Naturally Reared	Spring Chinook Fry	37	0.027	1451	**0.20%**
	Lake Wenatchee	2003	Volitional Hatchery Release	Sockeye Fry	42	0.00	0.00	**0.00%**

[1] Residence time estimated from the date the volitional release began to the mean catch of coho at the sampling location.
[2] Residence time estimated from PIT tag detection as fish volitionally left the acclimation pond to PIT tag recovery at the sampling location.
[3] A 'predation window' based upon peak chinook fry emergence and mean passage date at the trap for naturally reared coho was used instead of an estimate of residence time.

Appendix B: Hydroacoustic survey of Lake Wenatchee, Washington

ABUNDANCE, SPATIAL DISTRIBUTION, & CREPUSCULAR MIGRATIONS OF SOCKEYE SALMON FRY IN LAKE WENATCHEE, WASHINGTON APRIL AND MAY 2003

Prepared for
The Yakama Nation
Fisheries Resource Management Program
P.O. Box 151
Toppenish, WA 98948

Prepared by

Brock Stables
Shuksan Fisheries Consulting
PO Box 485
Sumas, WA 98295
(360) 988-5411
brockstables@cs.com

June 2003

INTRODUCTION

A recent initiative to re-introduce coho salmon to the Wenatchee River watershed requires consideration of the ecological risk posed by this action to juvenile sockeye salmon in Lake Wenatchee (Murdoch 2001). To this end, the Yakama Nation conducted studies during spring 2001-2003 to assess the interaction between out-migrant coho and sockeye fry in the lake, and to develop effective sampling methods for this task.

In 2001 and 2002, juvenile salmonids were sampled in pelagic areas with small tow-nets and in littoral areas by snorkeling surveys (Murdoch 2003). Radio telemetry was also used to track movements of tagged coho smolts throughout the lake in 2002 (Murdoch 2003). A one-night mobile hydroacoustic survey was conducted in May 2002 to estimate the abundance and distribution of fish in the lake and to examine how this method might complement other sampling activities (Stables 2002).

In 2003, trawling and telemetry were curtailed and PIT tags were instead used to assess migrations of coho fry through the system. Three two-night acoustics surveys were performed to estimate sockeye fry abundance and distribution patterns that affect their vulnerability to predation. Snorkeling was conducted on one occasion to support acoustic sampling. Findings of the 2003 acoustic surveys are the subject of this report.

Objectives for 2003 acoustic surveys were:
1) to measure the horizontal and vertical distribution of sockeye fry and other fish throughout the lake during hours of darkness on each survey date, including pelagic and nearshore (but not littoral) areas;
2) to estimate the total numbers of sockeye fry and other fish in the lake and their 95% confidence intervals on each survey date; and
3) to characterize vertical and horizontal crepuscular migrations of sockeye fry at selected locations where predation by coho smolts was considered likely.

METHODS

Data Collection

Acoustic surveys were conducted on April 16-18, April 29 to May 1, and May 20-22, 2003. Sampling equipment and methods were very similar to those of May 2002 (Stables 2002). A BioSonics 120 kHz, DT6000, split-beam echo sounder with a 7.4º transducer was used to collect data from a powerboat moving at 1.5-2.0 meters/second. For most sampling, the transducer was deployed from a pipe attached to the side of the boat, aimed vertically toward the lake bottom, effectively sampling fish that were at least 2 m beneath the lake surface. On April 29, the transducer was deployed at the same depth from a "towed body" for dusk and whole-lake sampling. This method proved less stable than the pipe mount for maneuvering on zigzag and crepuscular transects near shore, and its use was discontinued. The echo sounder was operated by a computer, which allowed monitoring of data quality on echograms at the time of collection and served as a data logger. Latitude and longitude were added to acoustic data files during collection from a differential GPS (JRC model 200 or Garmin model 182). Additional data collection details and equipment settings appear in Table 1.

Sampling for population estimates was performed along ten pre-determined transects spaced about 650 meters apart, perpendicular to the long axis of the lake (Figure 1). These transects were the same as those used on acoustic surveys in the 1970s (Dawson et al. 1973). Half the segments between transect endpoints were also sampled while running between transects to increase coverage of near shore areas out to a depth of about 40 meters (Figure 1). Generally, transects were terminated when the depth was less than 2 m, so littoral shallows were not sampled. Population estimate and nearshore transects were sampled during darkness, between 2130 and 0200 hours.

Crepuscular sampling was performed at two locations (Figure 1). On the first evening of each survey, two transects on the southeast shore were run repeatedly from daylight to darkness (dusk). On the second night, two transects on the southeast shore were run repeatedly from daylight to darkness (dusk) and from darkness to daylight (dawn). Dusk and dawn sampling occurred between 2000 and 2230 hours and 0400 and 0730 hours, respectively. Transects encompassed depths ranging from about 4-45 m at the east end and 2-45 m at the west end of the lake.

Data Analysis

Fish density (fish per m^3 or per m^2) was determined according to standard echo-trace counting methods (Thorne 1983, MacLennan and Simmonds 1992). Computer files were processed in the office using Echoview© v2.25 software to extract fish traces, to measure target strength (TS), and to determine sampling volumes. Fish traces were recognized on echograms by their shape, cohesiveness, and number of echoes (Figure 2). Traces from occasional columns of bubbles were recognized by their pattern of association and slope, and excluded from fish abundance estimates. TS was determined by the split-beam method. Accuracy of acoustic measurements was assured by shop and field calibration tests. The echo sounder was calibrated at BioSonics prior to the survey, and in-situ TS measurements of a standard sphere were within 0.9 dB of the expected value (-41.1 dB) on average.

Lengths of individual fish were estimated from TS using Love's (1977) equation for fish insonified dorsally:

$$\text{length (mm)} = 10 * 10^{((TS + 0.9 \log (kHz) + 62) / 19.1)}$$

Because TS is affected by factors other than fish size (MacLennan and Simmonds 1992) and Love's (1977) equation is a generalization from many fish species and sizes, this equation provides an estimate of fish length less precise than hands-on physical measurements.

Depth intervals for data analysis were 0-5 m, 5-10m, 10-15 m, and so forth to 75 m. Fish densities were summarized as fish per m^3 within depth intervals of transects for the population estimate, and as fish per m^2 in 50 m long segments along transects for spatial analysis. For each spatial cell of interest, fish density was calculated as the total number of fish counted divided by the volume sampled. The volume sampled in each spatial cell was calculated from the acoustic beam angle and distance transected corrected for bottom intrusion, using the wedge model (Kieser and Mulligan 1984) for all depth intervals. Processing settings were a -65 dB counting threshold and an 8º full beam angle. A complete list of data analysis settings appears in Table 1.

For the population estimate, each transect provided one replicate of each depth interval that it included (shallow transects did not contain all intervals). For each depth stratum, mean fish density was expanded in proportion to stratum volume, and resulting abundance estimates were summed to obtain the total population estimate. Variance and 95% confidence intervals of this estimate were calculated as for a stratified random sample with depth intervals the only stratification (Cochran 1977). For descriptive purposes, the lake was also divided into east, middle, and west sections, as shown in Figure 1.

Volumes of 5 m thick depth strata from 0 m to 75 m were derived from values for 10 m thick depth intervals from 10 m to 70 m in Dawson et al. (1973) using the equations:

volume = area x interval thickness
area = $(-0.0412 * \text{depth}^{1.69} + 50.9180)^{1/1.69}$ $R^2 = 0.9979$
where area = surface area (million m^2) of a slice at the depth interval midpoint

Acoustic estimates were apportioned among groups of fish based on findings of lake-wide townetting and snorkeling in 2001 and 2002 (Murdoch 2003), TS measurements in 2002 (Stables 2002) and 2003, and snorkeling in the west end of the lake on May 21, 2003 (Appendix A), all of which indicated that most small fish in the lake were sockeye, and that potentially confounding species such as stickleback or peamouth chub were absent. Therefore, echoes from the smallest size group in TS frequency distributions were considered to be sockeye fry, and were the basis of abundance estimates and spatial patterns of sockeye fry in this report. As described in detail below, the cutoff point between fry and larger fish was –50 dB.

Depth ranges and distances from shore inhabited by coho smolts in Lake Wenatchee are not known and cannot be determined from recent studies (K. Murdoch, Yakama Nation Fisheries Resource Management Program, personal communication), however, other information suggests that coho likely remain close to the lake shore most of the time. Juvenile coho co-existing with sockeye in Chilliwack Lake, British Columbia occur almost exclusively in the littoral zone (J. Hume, Department of Fisheries and Oceans, personal communication). In Chignik Lake, Alaska, where juvenile coho preyed on sockeye fry, Ruggerone and Rogers (1992) found that nearly all coho occurred in the upper 15 meters of the water column and within 25 meters of shore. Therefore, as a measure of potential overlap with coho smolts in Lake Wenatchee, sockeye fry density (number/m^3 of fish with TS<-50 dB) was calculated for the portion of each crepuscular transect that extended from the littoral limit to the 15 m depth contour. This region extended about 50 m from shore at the eastern crepuscular site, and about 100 m out from the 2 m depth contour at the western site. For convenience, this region is referred to as the coho zone in this report.

RESULTS

General Spatial Patterns Throughout the Lake for Fish of All Sizes

During Survey 1, areal fish density (fish/m^2) was highest in the eastern lake section, and was lower within about 100 m of shore than further offshore throughout the lake (Figure 3). Volumetric fish densities (fish/m^3) within each depth layer of each transect ranged from 0.0 to 0.017 fish/m^3, with highest values in the 35-45 m range, and fairly uniform densities within the upper 55 m of the water column where most fish were found (Table 2).

During Survey 2, areal fish density was similar in all lake sections, with high and low density patches scattered throughout, including nearshore and offshore areas (Figure 3). Volumetric fish densities within each depth layer of each transect ranged from 0.0 to 0.063 fish/m^3, with highest values in the 0-15 m range, and another high density layer from 35-45 m (Table 2).

During Survey 3, areal fish density was highest in the western lake section, with high density patches in nearshore and offshore areas (Figure 3). Fish densities were higher along the north shore than the south shore in the west and east lake sections, but were higher along the south shore in the eastern section. Densities within each depth layer of each transect ranged from 0.0 to 0.080 fish/m^3. Highest values occurred in the upper 20 m of the water column in western and middle sections, while relatively high densities occurred to 30 m in the eastern section (Table 2).

Size of Fish Estimated from Acoustic Data

Frequency distributions of target strength (TS) indicated the predominance of two size groups of fish during all surveys of spring 2003 (Figure 4). The small fish were found on all transects during all surveys and were relatively abundant on the final survey (Appendix B, Figure 4). The larger fish were present mainly on transects that crossed deep water (3-8), and were relatively abundant on the first two surveys (Appendix B, Figure 4). The mode of the small fish ranged from –57 dB to –54 dB with a slight decrease over time, whereas the mode of the larger fish ranged from –48 dB to –46 dB with a slight increase over time. The minimum between the two peaks was consistently about –50 dB. These TS values were very similar to those of the previous year (Stables 2002). Fish lengths estimated from TS ranged from 10-634 mm for survey 1, from 10-662 mm for survey 2, and from 10-759 mm for survey 3. Major modes were at 30.5 and 67.5 mm for survey 1, 17.5 and 67.5 mm for survey 2, and 17.5 and 67.5 for survey 3, with the same trends in relative abundance among size groups as were described for TS (Figure 4). In townet catches from 2002, fork length averaged 27 mm ± 1 SD (n = 47) for sockeye fry, 82 mm ± 7.8 SD (n = 3) for wild yearling sockeye, and 121 mm for one yearling hatchery sockeye that was captured (Murdoch 2003). Preliminary smolt trapping results suggests that yearling sockeye may be smaller in 2003 than in 2002 (C. Kamphaus, Yakama Nation Fisheries Resource Management Program, personal communication). Based on a comparison of acoustic results to these other data, the two major TS groups were concluded to be wild sockeye fry and yearlings.

Spatial Distribution of Sockeye Fry

Areal densities of sockeye fry (number/m^2 of fish with TS<-50 dB) and larger fish were plotted to describe changing horizontal distribution patterns of fish throughout the lake during the surveys. A minimum TS of –48 dB was used for larger fish (rather than –50 dB) so more abundant fry would not obscure their abundance patterns. On survey 1, fry density was highest in the eastern lake section, and was lower within about 100 m of shore than further offshore throughout the lake (Figure 5). The distribution of larger fish around the lake was similar, except that they were concentrated more strongly away from the shoreline (Figure 6). On survey 2, fry density was similar in all lake sections, with high and low density patches scattered throughout both nearshore and offshore areas (Figure 5). It also tended to be higher along the south shore than the north shore, except at the east and west ends of the lake. Highest densities of larger fish occurred in the middle and eastern lake sections during survey 2 (Figure 6). They were less abundant than on survey 1, and were even less numerous near the lake edges. On survey 3, sockeye fry were markedly more abundant than before, approaching densities of 1.8 fish/m^2, compared to maximum values less than 0.8 fish/m^2 on previous surveys (Figure 5). Fry density was highest in the western section of the lake, and was generally higher along the south shore than the north shore, except in the east end of the lake. In contrast, larger fish density had declined further and continued to be highest in the middle and eastern lake sections (Figure 6).

Plots of volumetric density of sockeye fry (number/m^3 of fish with TS<-50 dB) on three representative transects showed that fry were scattered throughout the water column during survey 1 (Figure 7). Relatively high densities occurred near the surface and shore in the east and west lake sections, but densities in the middle section were low except in the midwater pelagic zone. Fry were more surface oriented during survey 2, especially in the west section of the lake, and were again most shore oriented in the east and west lake sections (Figure 8). During survey 3, maximum fry density was much higher than previously on all transects (Figure 9). High densities occurred throughout the water column and at the north and south shores in the east lake section. Fry were concentrated in the upper 15 m of the water column in the middle section of the lake, where they were dense in the south half of the lake all the way to the shore. In the west lake section, fry tended to be densest in the southern half of the lake above 20 m, and were very dense at the south shore in the upper 10 m.

Population Estimates

During survey 1 (April 16), there were an estimated 1.7 million fish of all sizes in Lake Wenatchee, of which 1.2 million were sockeye fry (Table 4, Appendix C). The 95% confidence intervals (95% CI) of these estimates were +/- 12% and 11%, respectively. By survey 2 (April 29), the total population had increased to 2.2 million fish, including 1.7 million sockeye fry (95% CI +/- 28% and 35%, respectively). By survey 3 (May 20), the total population estimate had risen to 5.0 million fish, of which 4.8 million were sockeye fry (95% CI +/- 23% and 24%, respectively). The proportion of fry in the upper water column increased as the season progressed; the 0-15 m range contained 25% of fry on April 16, 64% on April 29, and 69% on May 20 (Appendix C).

Crepuscular Surveys

Eight crepuscular surveys, five dusk and three dawn, were performed in spring 2003. An additional dusk survey planned for April 30 was missed due to boat problems. Resulting echograms show a movement of fish upward and toward shore at dusk (Figures 10-12). The migration began in deep water (>30 m) at least as soon as the sun dropped below the horizon, and proceeded rapidly until full darkness, about two hours after astronomical sunset (sunset for local latitude and longitude without effects of topography). This pattern was observed at eastern and western stations, but was least pronounced on survey 1 (April 16), especially at the eastern site. Fish abundance was relatively low in the lake and fish density was especially low near shore at that time (Figure 3). At dawn, an opposite migration – downward and away from shore - took place, commencing more than an hour before astronomical sunrise (Figures 10-12). Most of these movements were below surface waters, and fish were nearly absent from the upper 15 meters except at night.

During the eight crepuscular surveys, fry density in the coho zone (defined as fish/m^3 with TS<-50 dB, approximately between 2 m and 15 m depth contours) ranged from 0-0.08 fry/m^3 (Figure 13). During survey 1, fry abundance was low (<0.015 fish/m^3) and erratic over the sampling period during dusk sampling at the eastern site and dawn sampling at the western site. In contrast, fry density increased fairly regularly as darkness fell throughout dusk sampling at the western site during survey 1, reaching about 0.025 fry/m^3 after dark. Temporal patterns were more sharply defined during surveys 2 and 3. During survey 2, fry were present in the coho zone from about one hour after sunset until about one hour before sunrise. Density rapidly increased from 0 to 0.03 fry/m^3 in about half an hour during the dusk survey at the eastern station. Nighttime fry density at the west end station was also about 0.03 fry/m^3, declining to zero about one hour before sunrise. During survey 3, fry were again present in the coho zone from about one hour after sunset until about one hour before sunrise, with maximum densities at the western station exceeding 0.08 fry/m^3 about 2 hours after sunset. Densities declined slightly after the post-dusk peak at both the eastern and western stations. During the dawn survey, densities declined rapidly from 0.03 to 0.0 fry/m^3within the space of half an hour.

DISCUSSION

Fish abundance in Lake Wenatchee changed considerably from survey to survey in spring 2003. The total population estimate (all fish) increased from 1.7 million fish in mid April to 5.0 million fish in mid May, while corresponding values for sockeye fry were 1.2 million and 4.8 million fish. The rapid increase in fry abundance over this period is in agreement with sockeye fry emergence timing estimated from spawning dates and temperature units during incubation (Murdoch 2003). The declining abundance of fish larger than fry is consistent with emigration of sockeye smolts from the lake over the study period. The May 2003 population estimates of all fish and fry were higher than those of May 2002 (4.2 million total fish and 3.9 million fry, Stables 2002). The May 2003 estimate of 5.0 million total fish was also slightly higher than any of the May or June estimates for 1973-1975 (range 2.3-4.9 million fish, Dawson et al. 1973, Dawson and Thorne 1974, Dawson and Thorne 1975).

Nighttime fish distribution patterns changed among this year's surveys as well. Fry were sparse near shore throughout the lake during survey 1, possibly due to bright conditions from a full moon. By survey 3 they were abundant in many places near shore, especially in the west end and along the south side. The proportion of fry in the west end of the lake also increased over time. The horizontal distribution of fry observed this year in mid May was very similar to that of last year at the same time (Stables 2002). Fry became more concentrated in the upper reaches of the water column as the season progressed. The upper 0-15 meter range contained 25% of fry on April 16, 64% on April 29, and 69% on May 20. The vertical distribution in May this year was similar to that of the same time last year, when 71% of fry were in the upper 15 meters. Depth distributions of fish were markedly different in the 1970s, when peak nighttime densities occurred at 20-30 m with very few fish in the upper water column (Dawson et al. 1973, Dawson and Thorne 1974, Dawson and Thorne 1975).

The high concentrations of fry near the surface in the west end of the lake in mid-May 2003 suggest that risk of predation from coho was greatest there and then. Coho smolts and sockeye fry were both observed in the littoral zone during night snorkeling surveys at that time, so their use of this habitat overlapped then. No coho were seen in the pelagic area at that time, but the amount of snorkeling there was too limited to be conclusive. Despite whatever habitat overlap does occur, sockeye fry reduce predation risk by avoiding the coho zone during daylight, although they reached high densities there at night. These patterns are generally consistent with juvenile sockeye behavior described in published literature. Sockeye fry are typically littoral and bottom oriented both day and night in the spring, becoming more pelagic as the season progresses (Burgner 1991). By late spring and summer when they have become mainly pelagic, fry usually remain below the level of light penetration during the day in lakes with significant predation risk (Levy 1989). Older age groups are typically highly pelagic and (except larger kokanee) also migrate vertically where there is predation risk. The effectiveness of this strategy for avoiding coho predation could be determined in the future by capture of coho and examination of stomach contents (Ruggerone and Rogers 1992), or, alternatively, by modeling predation rates using acoustic data as a primary input supported by some fish capture data (e.g., Beauchamp et al. 1999).

Nighttime light levels varied considerably during the three surveys due to differences in cloud cover and phase of the moon. Conditions were bright for survey 1, with a full moon with clear skies. Survey 2 with no moon was very dark. With a new moon for survey 3, conditions were very dark for the whole-lake survey, but the moon was up and the night was bright when the dawn crepuscular survey began. The effect of nighttime light levels on fish distributions was not clear. For example, fish were generally deeper during survey 1 with a full moon than on survey 2 with no moon. However, during survey 1 fish were observed near the surface when the dawn crepuscular survey began (Figures 10 & 11).

The lack of other fish sampling to complement this year's acoustic surveys leaves some uncertainty about the identity of acoustic targets. Fish lengths estimated from TS are model estimates without corroboration from actual measurements of fish. Consistency with last years TS results, which were supported by trawling and snorkeling, lends confidence to this year's findings, and apportionment among fry and larger fish using a –50 dB breakpoint appears valid. Exploratory examination of other TS groups was suggestive, but finer apportionment, such as between yearling sockeye and coho smolts, would be speculative and potentially misleading without confirmation through capture of fish. The addition of even limited complementary sampling on a regular basis would greatly increase the information obtainable from future acoustic surveys in the lake.

As dictated by the survey plan, the 0-2 m depth range of the water column was not sampled. The shallow depth distribution of fish observed in 2002 and 2003 surveys suggests that attention to these depths may be merited in the future work. In pelagic areas, this layer could be sampled efficiently with an upward looking transducer. In littoral areas, mobile acoustic surveys are of limited value and other methods such as snorkeling or beach seining are usually more effective. Nighttime snorkeling in May 2003 was especially promising. Fish of six species were observed in the littoral and pelagic zones within a short time. In contrast, almost no fish were seen during daylight snorkeling a short time earlier when fish were observed feeding at the surface in the area sampled. Avoidance of the snorkeler during daylight was suspected. Acoustics using fixed location transducers is another option for sampling littoral areas to describe patterns of fish movement between shallow and deep water habitats on a daily or hourly time scale (Stables and Thomas 1992).

In summary, the spring 2003 acoustic surveys spanned a period when the fish community of Lake Wenatchee was experiencing large and rapid seasonal changes. Newly hatched sockeye fry were entering the lake as sockeye smolts were leaving. Releases of coho smolts into the system began on May 1 and continued throughout the study period. Spatial distributions of these and other fish in the lake changed as they interacted with each other and with their environment. Acoustic surveys quantified resulting changes in distribution and abundance of fish in the lake, thereby providing an important part of the information necessary to evaluate the risk of coho predation on sockeye fry.

References

Beauchamp, D. A., C. M. Baldwin, J. L. Vogel, and C. P. Gubala. 1999. Estimating diel, depth-specific foraging opportunities with a visual encounter rate model for pelagic piscivores. Canadian Journal of Fisheries and Aquatic Sciences 56:1-12.

Burgner, R.L. 1991. Life history of sockeye salmon. Pages 1-118 in Pacific Salmon Life Histories, C Groot and L. Margolis (eds.), UBC Press, Vancouver.

Dawson, J. D., R. E. Thorne, and J. J. Traynor. 1973. Acoustic surveys of Lake Wenatchee and Lake Osoyoos in 1973. FRI UW Final Report, Service Contract 526.

Dawson, J. D., R. E. Thorne. 1974. Acoustic surveys of Lake Wenatchee and Lake Osoyoos in 1974. FRI UW Final Report, Service Contract 575.

Dawson, J. D., R. E. Thorne. 1975. Acoustic surveys of Lake Wenatchee 1975. FRI UW Final Report, Service Contract 634.

Kieser, R. & T. J. Mulligan. 1984. Analysis of echo counting data: A model.. Canadian Journal of Fisheries and Aquatic Sciences 41:451-458.

Levy, D.A. 1989. The selective advantage of diel vertical migration behavior in juvenile sockeye salmon and kokanee. PhD dissertation, Univ of British Columbia, 123 pages.

Love, R. H. 1977. Target strength of an individual fish at any aspect. Journal of the Acoustical Society of America 62:1397-1403.

MacLennan, D. N., and E. J. Simmonds. 1992. Fisheries Acoustics. Chapman and Hall, London.

Murdoch, K. G. 2001. Sockeye/coho interaction study: Lake Wenatchee, spring 2001. Study plan for 2001 sampling by Yakima Indian Nation, 8 pages.

Murdoch, K. G. 2003. Lake Wenatchee sockeye fry and coho interaction evaluation. Yakama Indian Nation, Toppenish, WA.

Ruggerone, G. T., and D. E. Rogers. 1992. Predation on sockeye salmon fry by Juvenile coho salmon in the Chignik Lakes, Alaska: Implications for salmon management. North American Journal of Fisheries Management 12:87-102.

Stables, T. B., and G. L. Thomas. 1992. Acoustic measurement of trout distributions in Spada Lake, Washington, using stationary transducers. Journal of Fish Biology 40:191-203.

Stables, T. B. 2002. Hydroacoustic survey of Lake Wenatchee, Washington, conducted May 16-17 2002, with emphasis on sockeye salmon fry spatial distribution. Report to Yakama Indian Nation.

Thorne, R. E. 1983. Hydroacoustics. In Fisheries Techniques (Nielsen, L. and Johnson, D. eds.), pp. 239-260. Bethesda, American Fisheries Society.

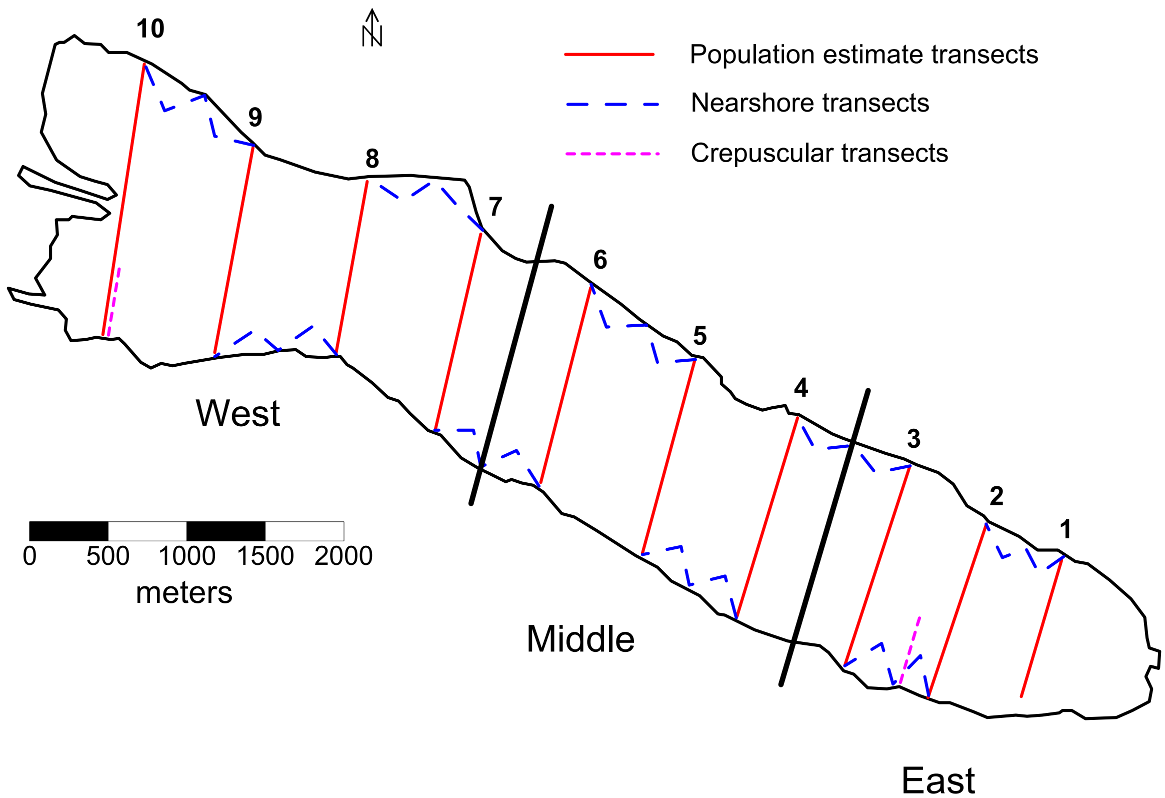


Figure 1. Map of Lake Wenatchee, showing transects for spring 2003 acoustic surveys.

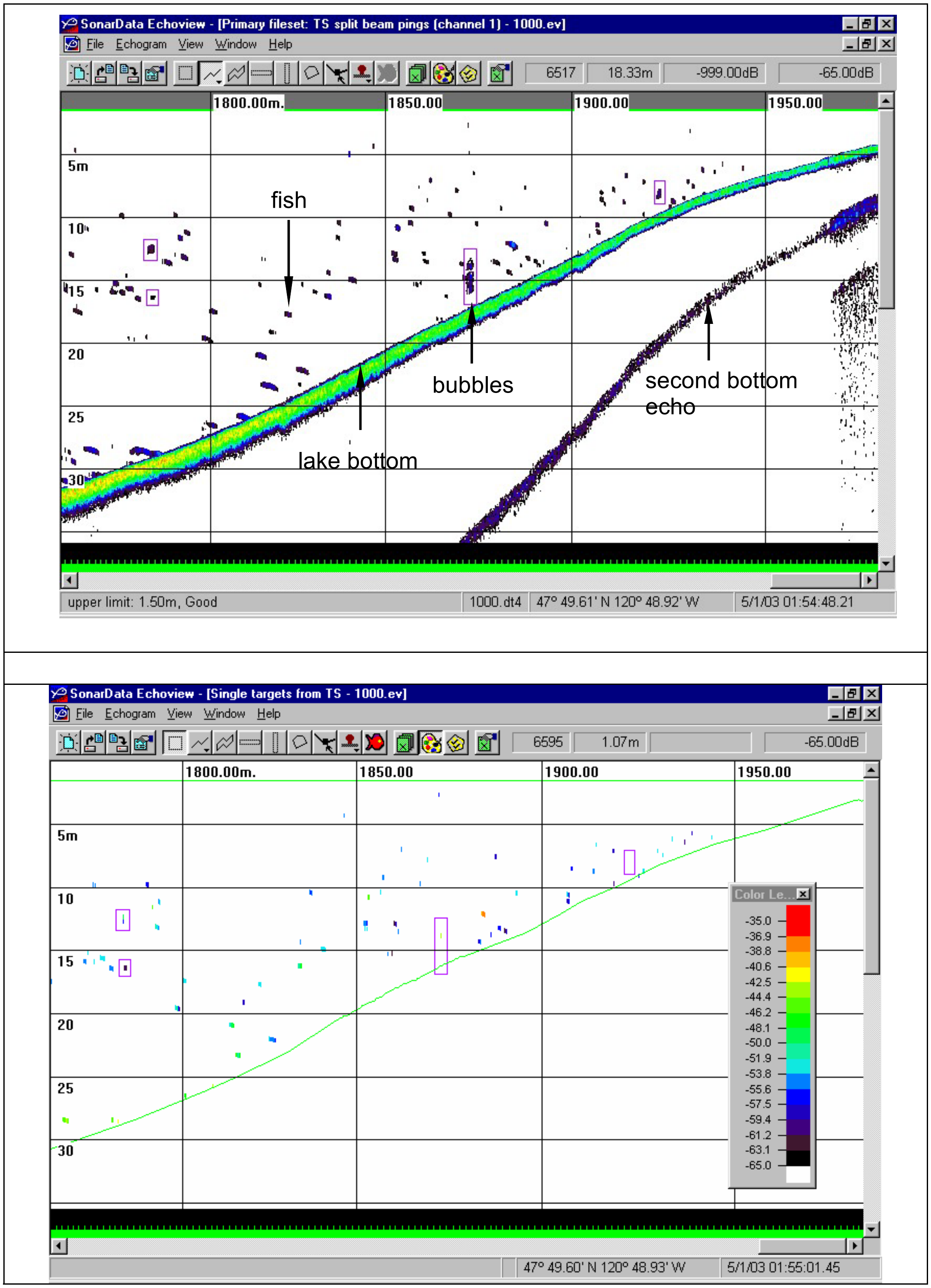


Figure 2. Typical echograms from Lake Wenatchee during spring 2003. The upper raw echogram shows all echoes detected within the acoustic beam. The lower one shows only echoes within 4 degrees of the beam's center (the subset from which counts and TS measurements were made), and is color-coded by TS. Plots are from the south end of Transect 10 on May 1, 2003.

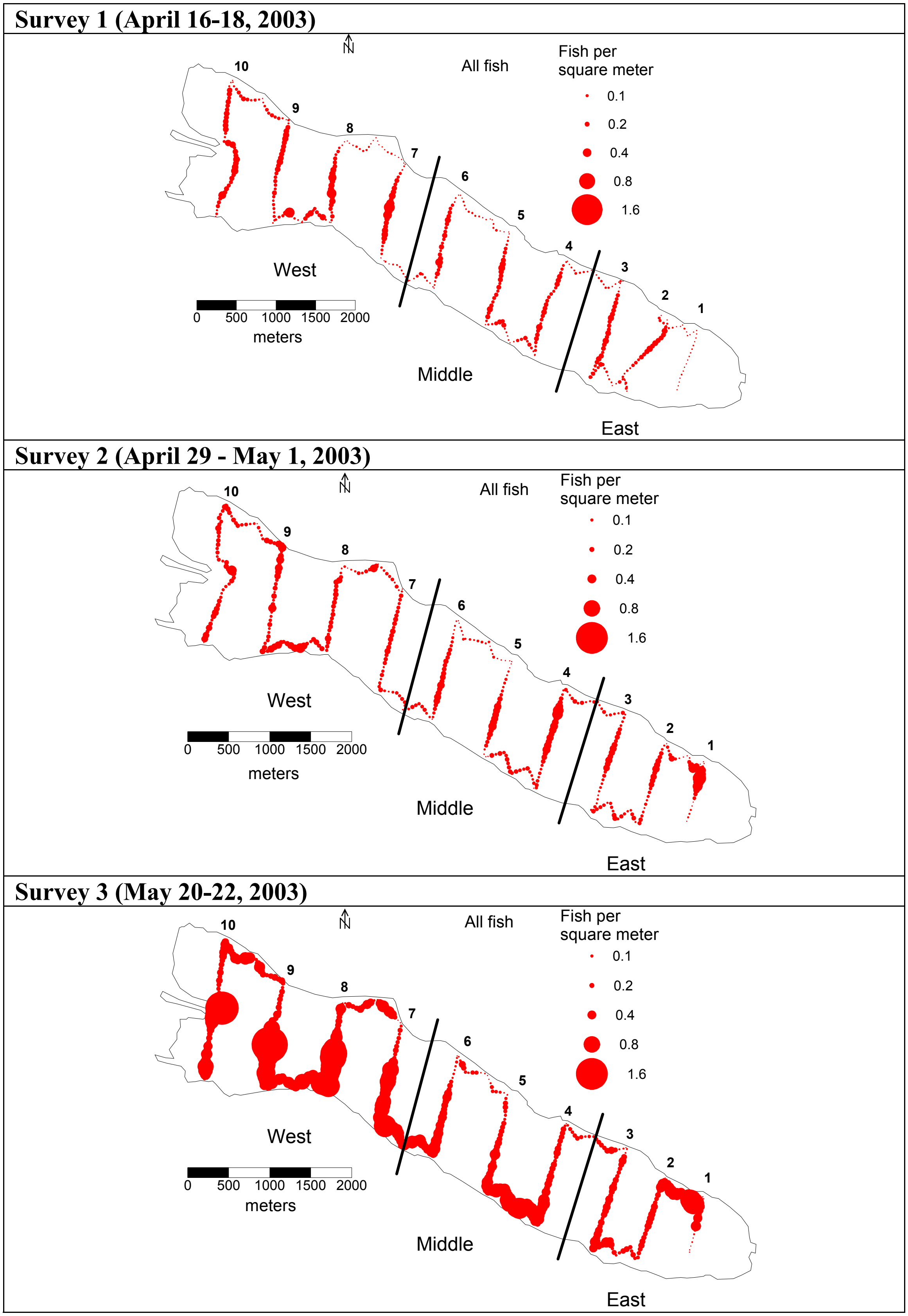


Figure 3. Fish density (fish/m^2) for fish of all sizes along acoustic transects of Lake Wenatchee during spring 2003 surveys.

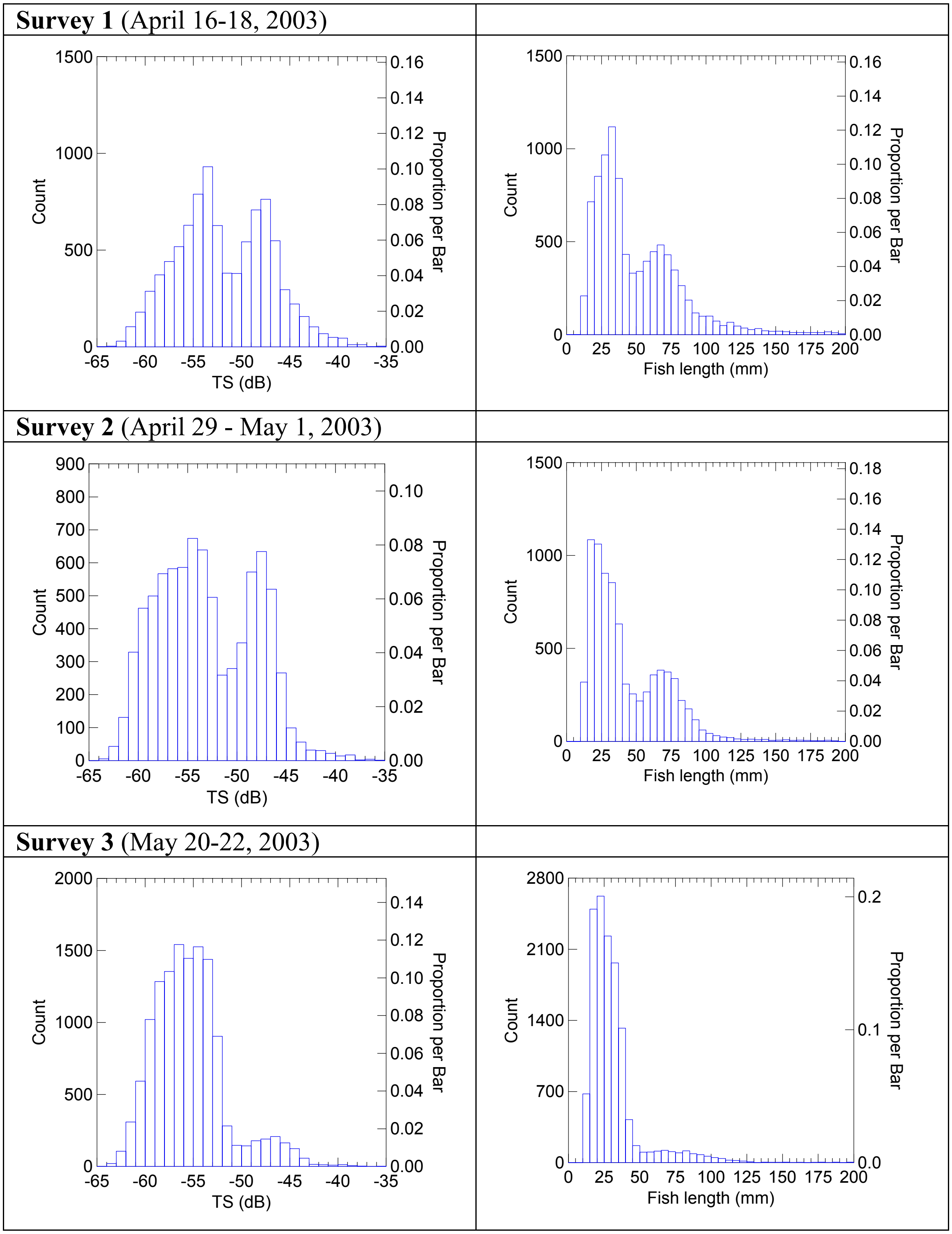


Figure 4. Frequency distribution of TS (left plot) and estimated fish length (right plot) during spring 2003 surveys of Lake Wenatchee. Fish length was estimated using TS Love's (1977) relationship for fish insonified dorsally. Data are from all transects and depths combined.

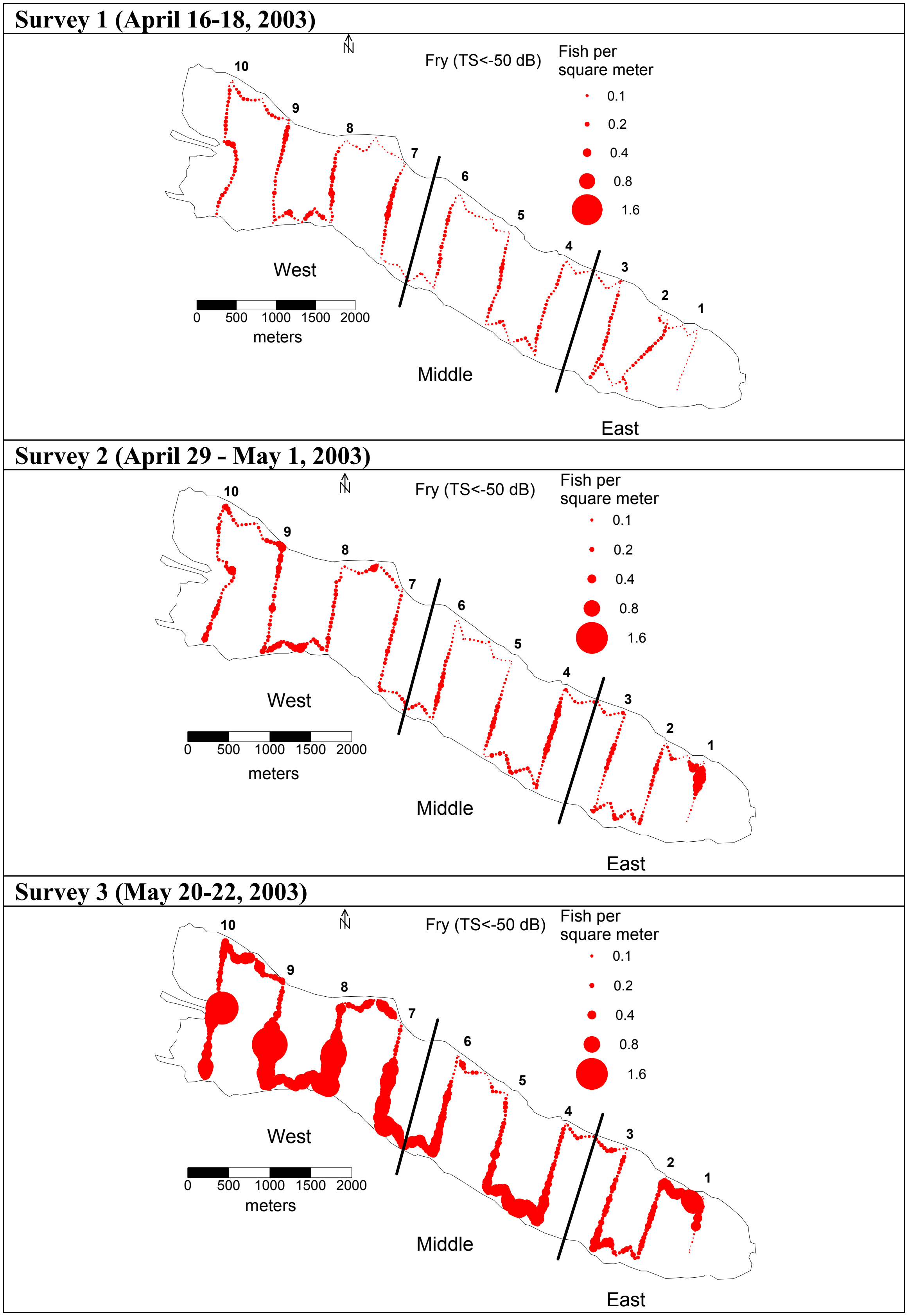


Figure 5. Density (fish/m^2) of sockeye fry (TS<-50dB) along acoustic transects during spring 2003 surveys of Lake Wenatchee.

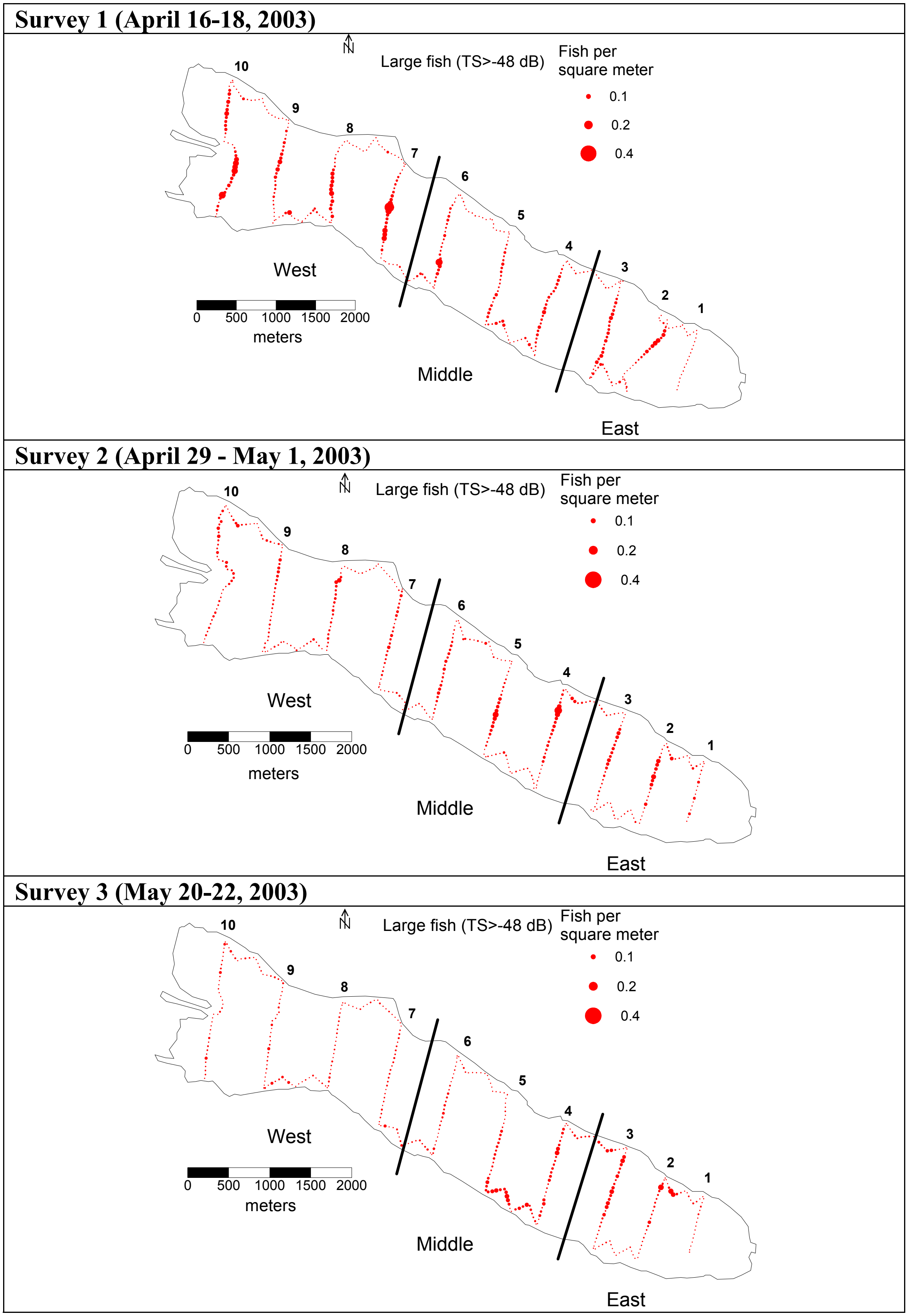


Figure 6. Density (fish/m^2) of fish larger than sockeye fry (TS>-48 dB)along acoustic transects during spring 2003 surveys of Lake Wenatchee.

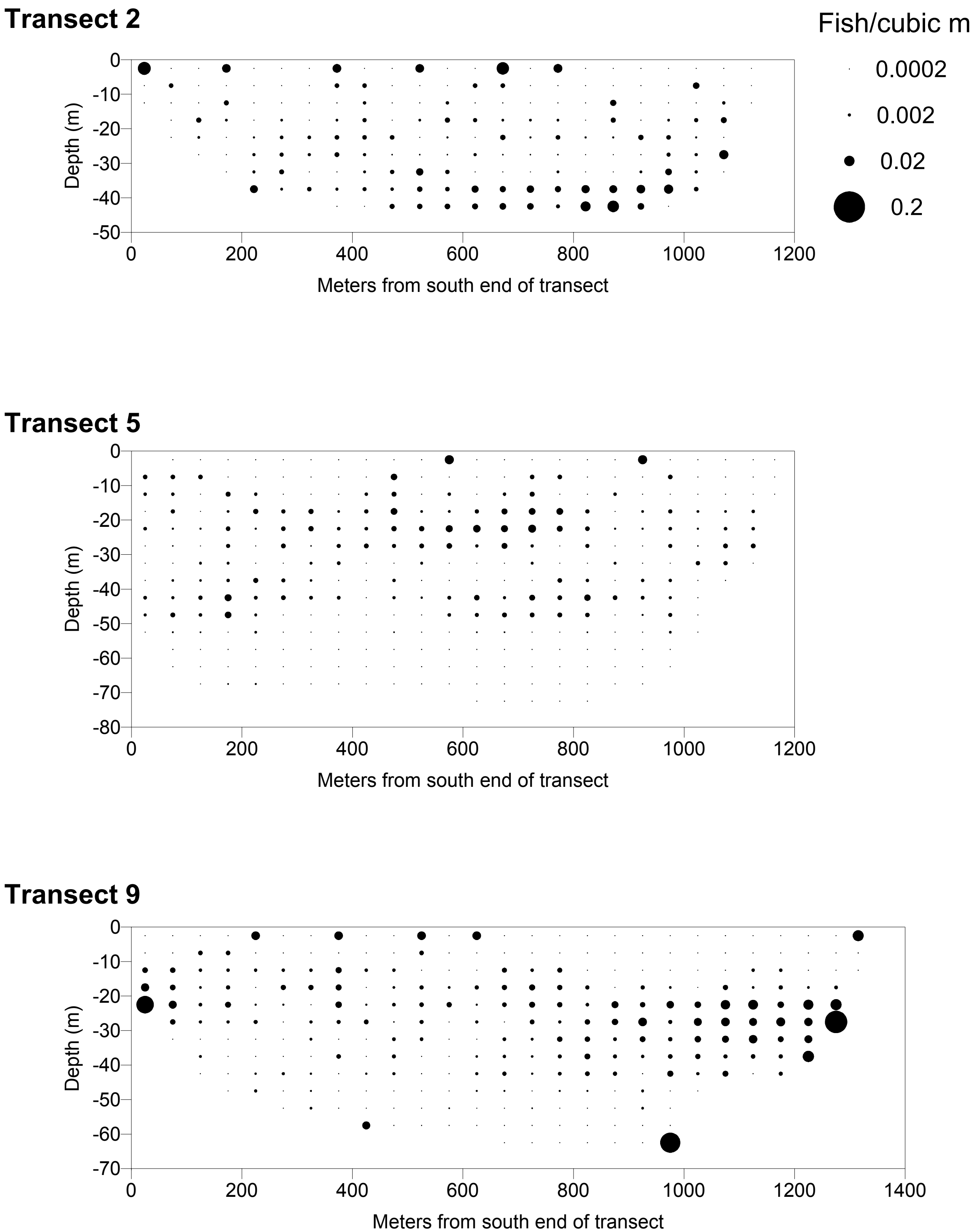
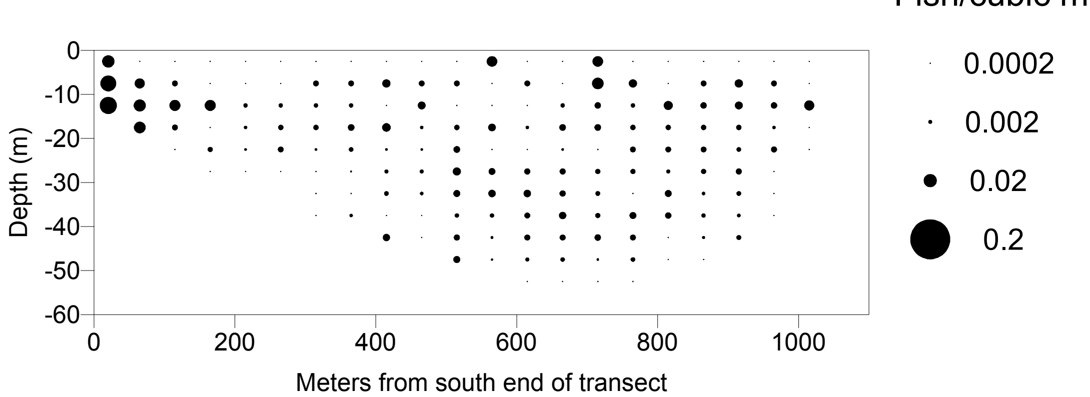
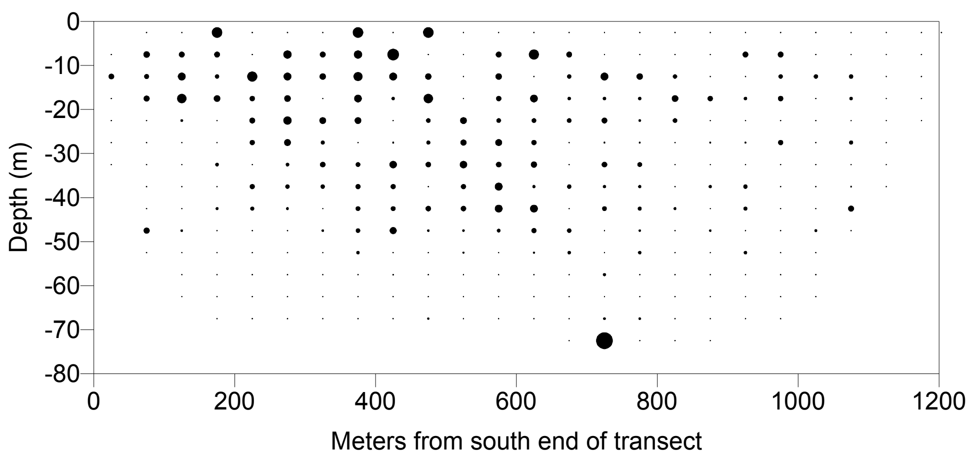


Figure 7. Density of sockeye fry (fish/m^3 from traces with TS<-50dB) by depth and distance from south end of transect during Survey 1 of Lake Wenatchee (2145-0200 hours of April 16-17, 2003). Data are from transects 2 (east section), 5 (mid lake), and 9 (west section). Lengths were estimated from TS using Love's (1977) dorsal aspect relationship.

Transect 2



Transect 5



Transect 9

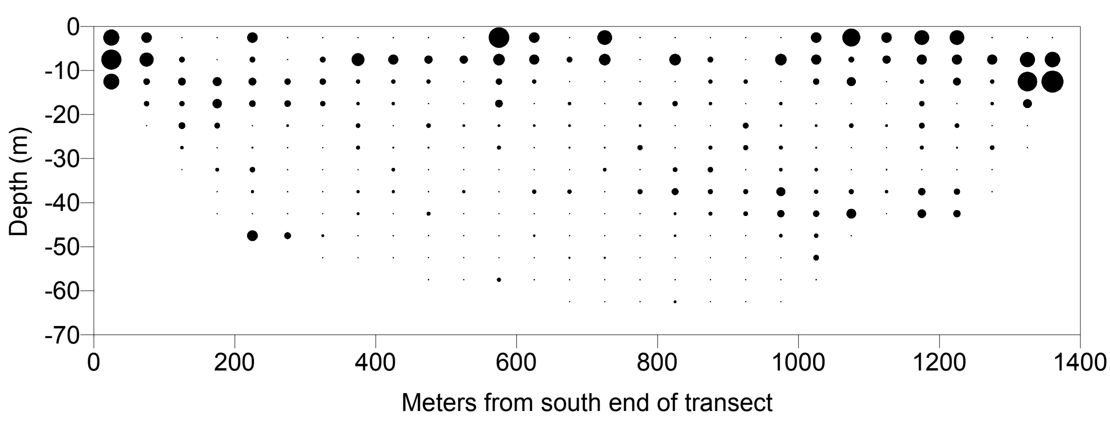


Figure 8. Density of sockeye fry (fish/m^3 from traces with TS<-50dB) by depth and distance from south end of transect during Survey 2 of Lake Wenatchee (April 29 - May 1, 2003). Data are from transects 2 (east section), 5 (mid lake), and 9 (west section). Lengths were estimated from TS using Love's (1977) dorsal aspect relationship.

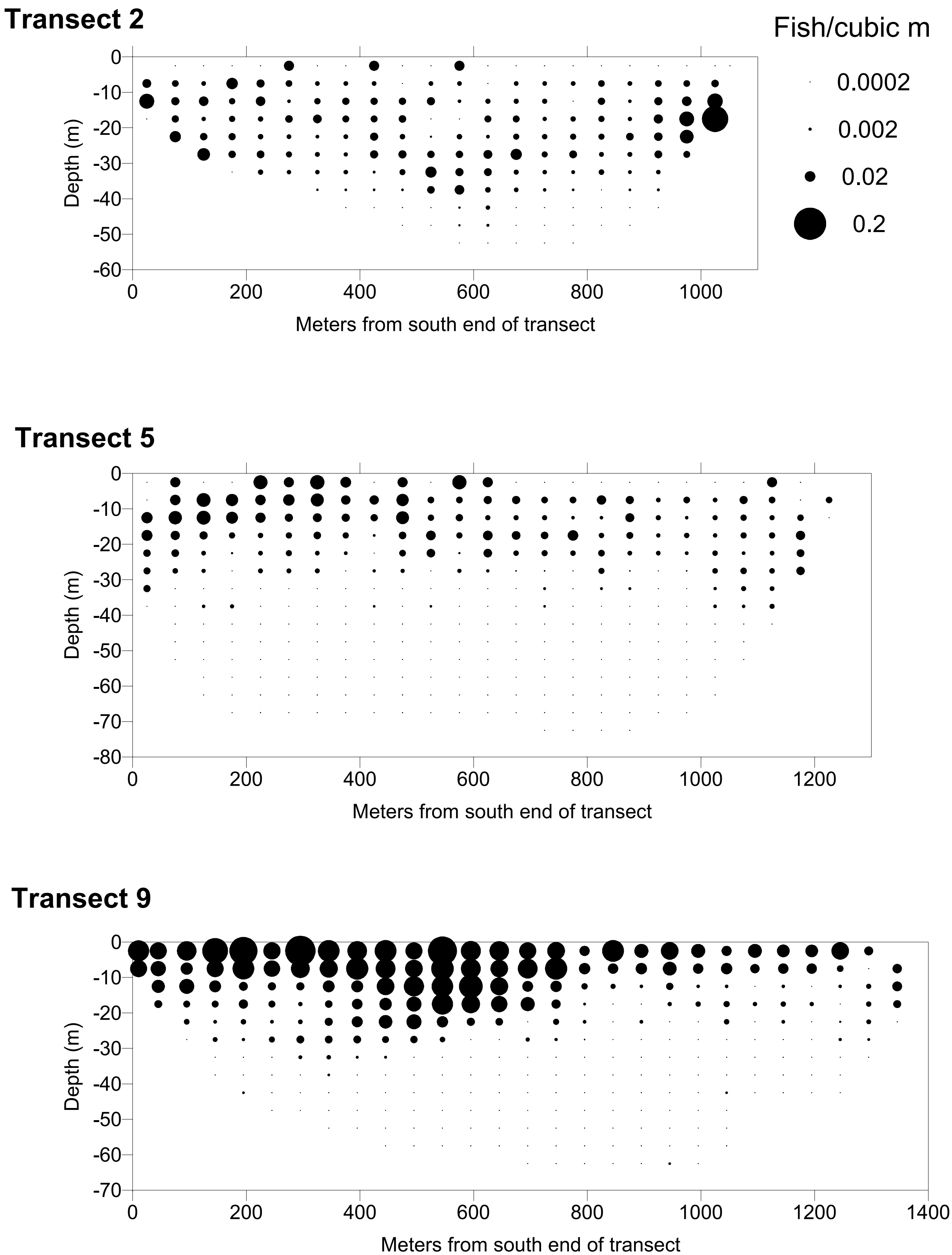


Figure 9. Density of sockeye fry (fish/m^3 from traces with TS<-50dB) by depth and distance from south end of transect during Survey 3 of Lake Wenatchee (April 29 - May 1, 2003). Data are from transects 2 (east section), 5 (mid lake), and 9 (west section). Lengths were estimated from TS using Love's (1977) dorsal aspect relationship.

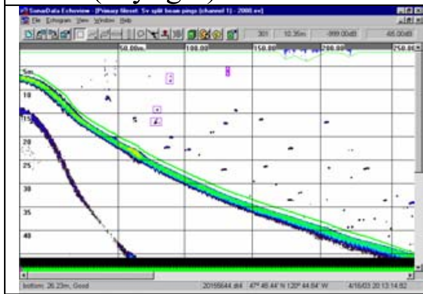
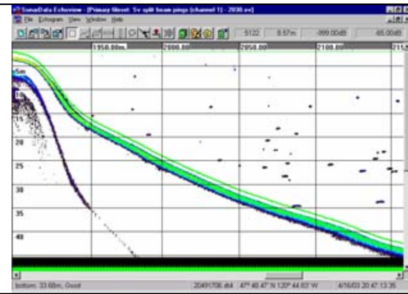
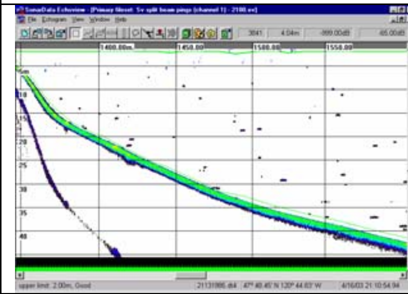
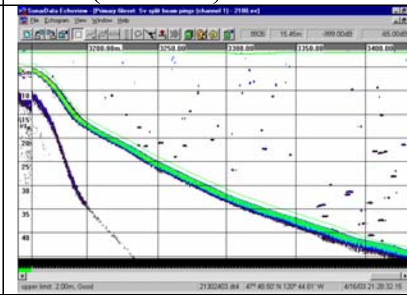
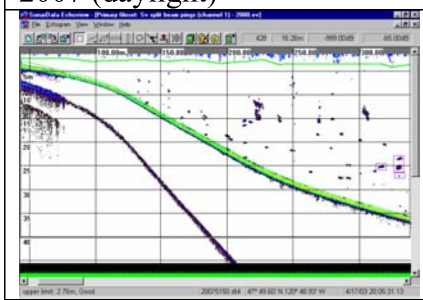
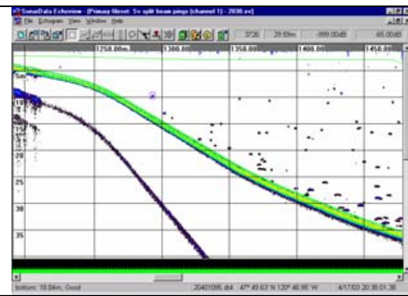
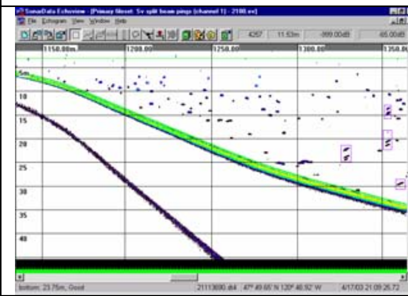
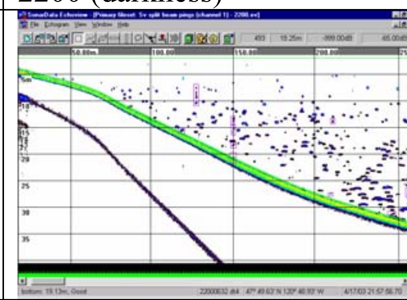
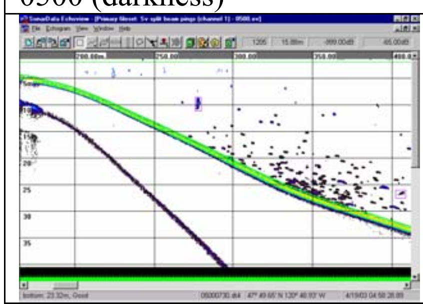
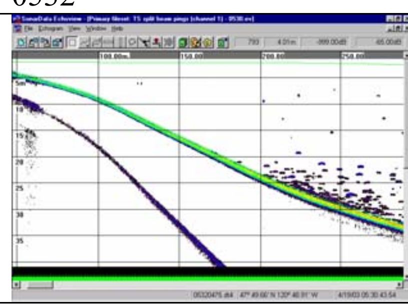
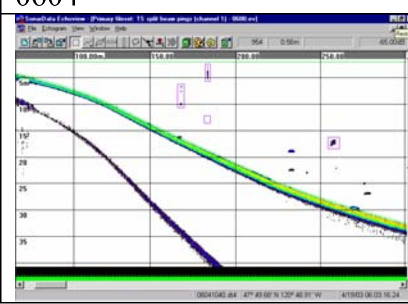
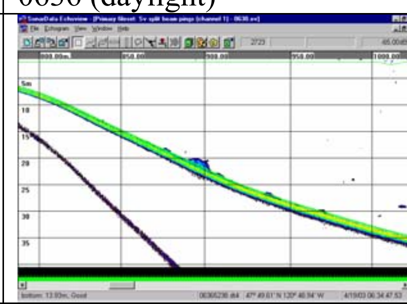
4/16 dusk, east end of lake Sunset at 1952 hours			
2015 (daylight)	2049	2113	2130 (darkness)
			
4/17 dusk, west end of lake Sunset at 1952 hours			
2007 (daylight)	2040	2111	2200 (darkness)
			
4/18 dawn, west end of lake Sunrise at 0613 hours			
0500 (darkness)	0532	0604	0636 (daylight)
			

Figure 10. Echograms from April 16-18 crepuscular surveys of Lake Wenatchee, showing changing fish distribution patterns at dusk and dawn in the east and west ends of the lake. Vertical and horizontal spacing of grid is 5 and 50 m, respectively. Purple boxes mark columns of bubbles that were excluded from analysis.

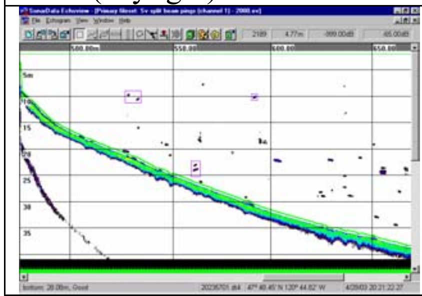
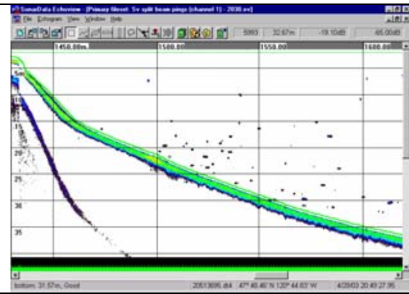
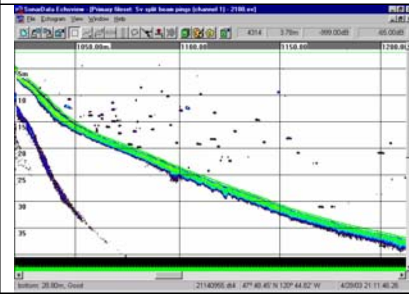
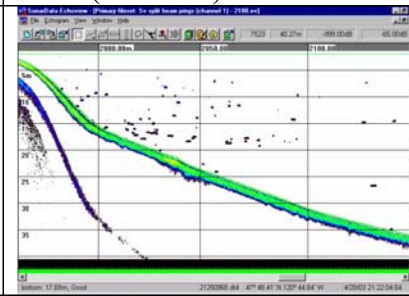
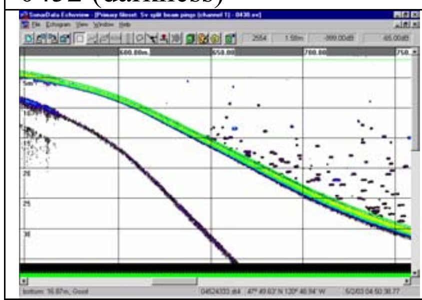
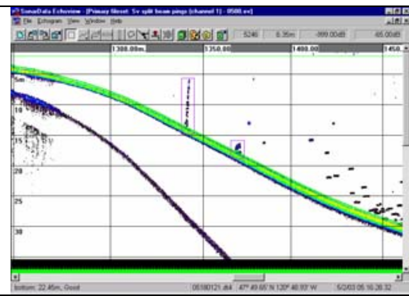
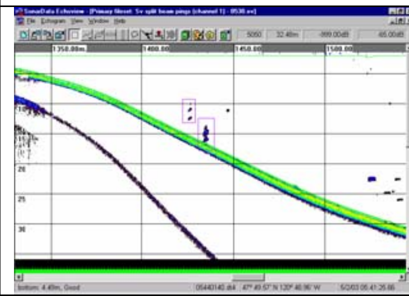
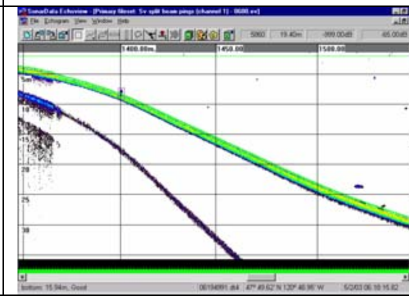
4/29 dusk, east end of lake Sunset at 2011 hours			
2023 (daylight)	2051	2114	2125 (darkness)
			
5/1 dawn, west end of lake Sunrise at 0548 hours			
0452 (darkness)	0518	0540	0619
			

Figure 11. Echograms from April 29 and May 1 crepuscular surveys of Lake Wenatchee, showing changing fish distribution patterns at dusk and dawn in the east and west ends of the lake. Vertical and horizontal spacing of grid is 5 and 50 m, respectively. Purple boxes mark columns of bubbles that were excluded from analysis.

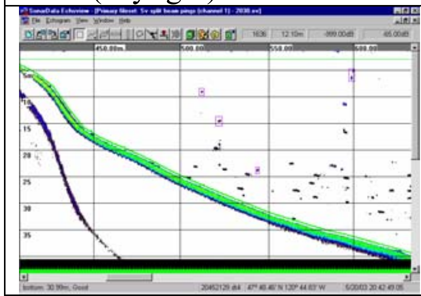
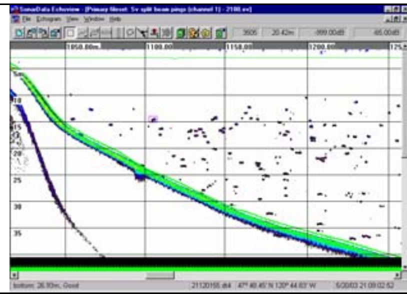
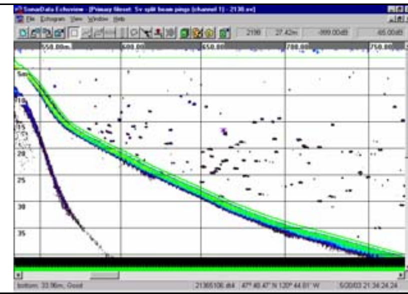
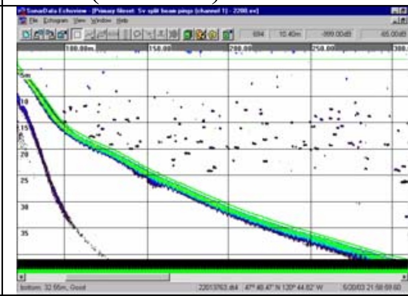
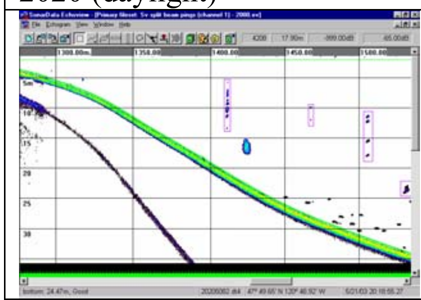
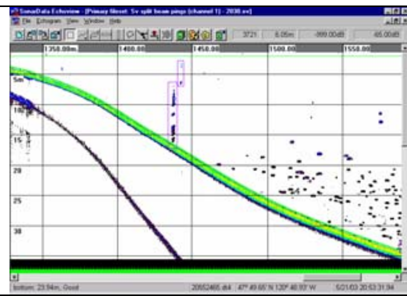
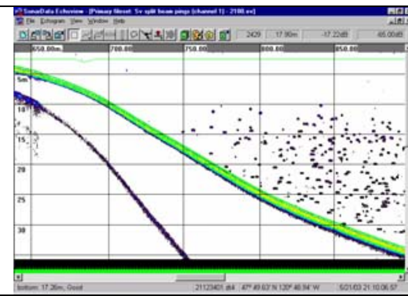
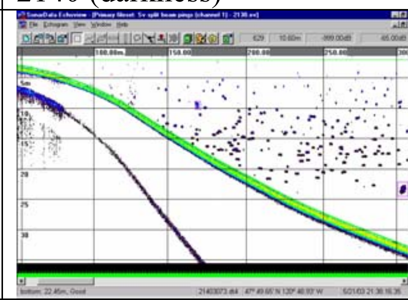
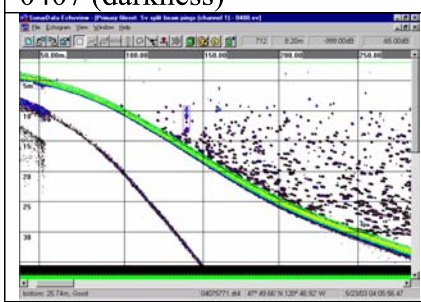
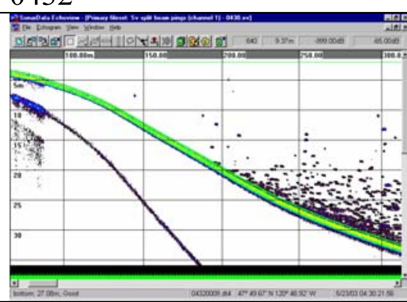
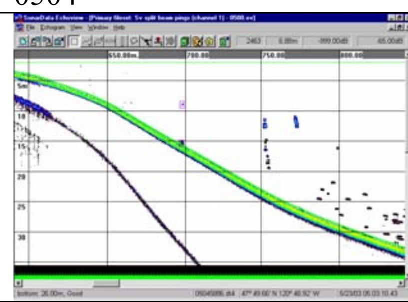
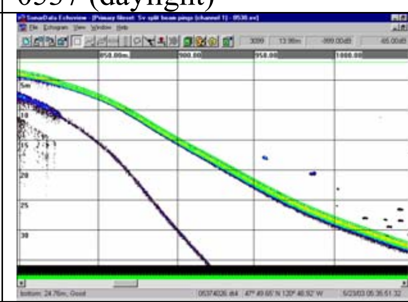
5/20 dusk, east end of lake Sunset at 2038 hours			
2045 (daylight)	2112	2136	2201 (darkness)
			
5/21 dusk, west end of lake Sunset at 2038 hours			
2020 (daylight)	2055	2112	2140 (darkness)
			
5/22 dawn, west end of lake Sunrise at 0520 hours			
0407 (darkness)	0432	0504	0537 (daylight)
			

Figure 12. Echograms from May 20-22 crepuscular surveys of Lake Wenatchee, showing changing fish distribution patterns at dusk and dawn in the east and west ends of the lake. Vertical and horizontal spacing of grid is 5 and 50 m, respectively Purple boxes mark columns of bubbles that were excluded from analysis.

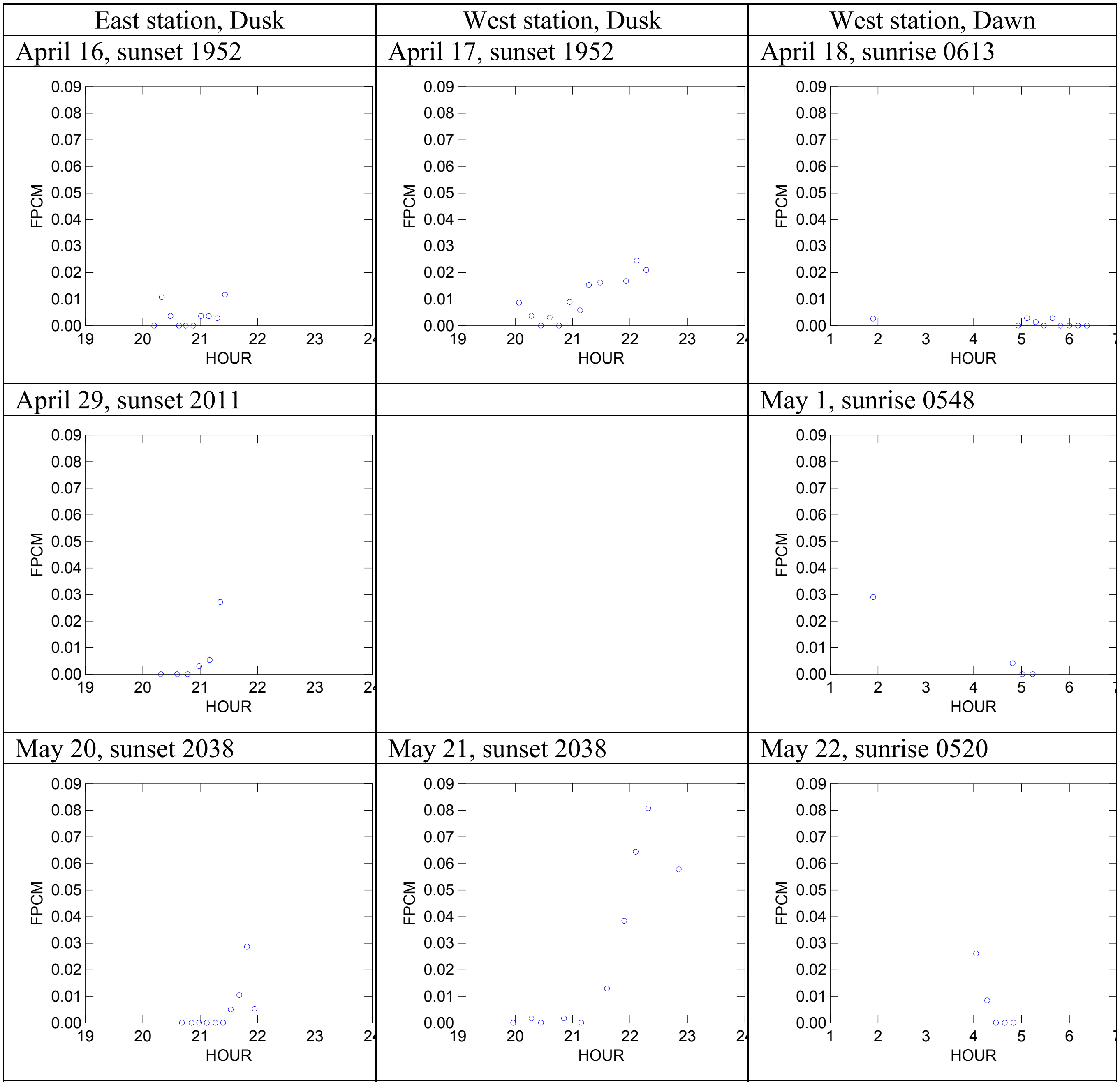


Figure 13. Volumetric density of sockeye fry (TS<-50 dB) in the nearshore zone reputedly favored by juvenile coho (bottom depth <15 m) at the east and west ends of Lake Wenatchee, from April and May 2003 crepuscular acoustic surveys. FPCM is fry/m^3.

Table 1. Sampling details and equipment settings for acoustic surveys of Lake Wenatchee during April and May 2003.

Project Phase	Category	Parameter	All transects
Data collection	transducer	type	split beam
		sound frequency	120 kHz
		nominal beam angle	7.4 x 17 deg
		pulse width	0.4 msec
		data collection threshold	-69 dB
		Time Varied Threshold	40 log R
		Transecting speed	1.5-2.0 m/sec
		ping rate	6pps
	GPS	type	differential
		coordinate system	NAD83
Data Analysis		Time Varied Gain	40 log R
		processing threshold	-65dB
		calibration offset	0.9dB
		beam full angle	8 degrees
		Single target filters:	0.8-1.5 @ -6dB
	Fish tracking parameters:		
		minimum hits	1
		max change in range	0.2m
		max ping gap	2-4

Table 2. Volumetric density (fish/m3) for fish of all sizes in Lake Wenatchee by depth and transect during the three acoustic surveys of spring 2003. Shoreline areas with depth < 2 m and the upper 2 m of the water column were not sampled.

Survey 1(April 16-18, 2003)

Depth interval	Upper limit (m)	Lower limit (m)	Fish density by transect 1	2	3	4	5	6	7	8	9	10	Total n	Mean	Var
1	0	5	0.0000	0.0048	0.0027	0.0024	0.0020	0.0011	0.0082	0.0012	0.0031	0.0067	10	0.00322	0.000007
2	5	10	0.0013	0.0012	0.0023	0.0010	0.0017	0.0066	0.0080	0.0048	0.0009	0.0029	10	0.00308	0.000006
3	10	15	0.0015	0.0010	0.0015	0.0017	0.0013	0.0013	0.0018	0.0011	0.0019	0.0019	10	0.00150	0.000000
4	15	20		0.0022	0.0025	0.0029	0.0033	0.0024	0.0035	0.0047	0.0032	0.0031	9	0.00308	0.000001
5	20	25		0.0025	0.0020	0.0025	0.0044	0.0037	0.0033	0.0070	0.0069	0.0042	9	0.00403	0.000003
6	25	30		0.0021	0.0018	0.0010	0.0024	0.0020	0.0028	0.0047	0.0057	0.0068	9	0.00325	0.000004
7	30	35		0.0042	0.0020	0.0013	0.0014	0.0012	0.0029	0.0028	0.0047	0.0093	9	0.00330	0.000007
8	35	40		0.0130	0.0040	0.0038	0.0029	0.0025	0.0065	0.0056	0.0058	0.0131	9	0.00634	0.000016
9	40	45		0.0167	0.0066	0.0079	0.0069	0.0041	0.0068	0.0061	0.0055	0.0082	9	0.00764	0.000013
10	45	50			0.0096	0.0064	0.0054	0.0041	0.0036	0.0045	0.0025	0.0032	8	0.00491	0.000005
11	50	55			0.0043	0.0030	0.0026	0.0014	0.0016	0.0028	0.0013	0.0000	8	0.00211	0.000002
12	55	60			0.0007	0.0011	0.0008	0.0006	0.0005	0.0010	0.0003		7	0.00071	0.000000
13	60	65			0.0005	0.0004	0.0007	0.0003	0.0002	0.0003	0.0006		7	0.00043	0.000000
14	65	70				0.0002	0.0003	0.0002	0.0002				4	0.00021	0.000000
15	70	75					0.0000	0.0000					2	0.00000	0.000000
		Mean	0.0009	0.0053	0.0031	0.0025	0.0024	0.0021	0.0036	0.0036	0.0032	0.0054			

Survey 2 (April 29 - May 1, 2003)

Depth interval	Upper limit (m)	Lower limit (m)	Fish density by transect 1	2	3	4	5	6	7	8	9	10	Total n	Mean	Var
1	0	5	0.0076	0.0024	0.0005	0.0021	0.0016	0.0032	0.0037	0.0024	0.0093	0.0077	10	0.00405	0.000009
2	5	10	0.0294	0.0058	0.0029	0.0072	0.0033	0.0058	0.0057	0.0074	0.0108	0.0084	10	0.00867	0.000058
3	10	15	0.0629	0.0059	0.0045	0.0053	0.0042	0.0054	0.0059	0.0043	0.0052	0.0074	10	0.01110	0.000332
4	15	20	0.0000	0.0041	0.0026	0.0042	0.0038	0.0038	0.0024	0.0038	0.0028	0.0048	10	0.00323	0.000002
5	20	25		0.0028	0.0032	0.0030	0.0024	0.0027	0.0011	0.0022	0.0018	0.0021	9	0.00237	0.000000
6	25	30		0.0039	0.0022	0.0031	0.0027	0.0022	0.0019	0.0019	0.0015	0.0018	9	0.00237	0.000001
7	30	35		0.0051	0.0032	0.0034	0.0041	0.0031	0.0022	0.0031	0.0016	0.0020	9	0.00310	0.000001
8	35	40		0.0060	0.0055	0.0062	0.0052	0.0041	0.0043	0.0054	0.0050	0.0041	9	0.00509	0.000001
9	40	45		0.0046	0.0048	0.0070	0.0043	0.0028	0.0037	0.0053	0.0035	0.0059	9	0.00467	0.000002
10	45	50		0.0035	0.0035	0.0049	0.0025	0.0015	0.0015	0.0019	0.0019	0.0017	9	0.00255	0.000001
11	50	55		0.0000	0.0015	0.0021	0.0013	0.0006	0.0010	0.0010	0.0010		8	0.00108	0.000000
12	55	60			0.0007	0.0011	0.0005	0.0004	0.0004	0.0008	0.0007		7	0.00068	0.000000
13	60	65			0.0003	0.0018	0.0002	0.0002	0.0000	0.0017	0.0004		7	0.00067	0.000001
14	65	70				0.0017	0.0007	0.0004	0.0005				4	0.00082	0.000000
15	70	75					0.0028	0.0000	0.0000				3	0.00094	0.000003
		Mean	0.0250	0.0040	0.0027	0.0038	0.0026	0.0024	0.0023	0.0032	0.0035	0.0046			

Survey 3 (May 20-22, 2003)

Depth interval	Upper limit (m)	Lower limit (m)	Fish density by transect 1	2	3	4	5	6	7	8	9	10	Total n	Mean	Var
1	0	5	0.0035	0.0027	0.0057	0.0065	0.0095	0.0096	0.0248	0.0325	0.0669	0.0475	10	0.02092	0.000479
2	5	10	0.0115	0.0064	0.0101	0.0121	0.0139	0.0193	0.0310	0.0473	0.0455	0.0380	10	0.02351	0.000241
3	10	15	0.0626	0.0096	0.0084	0.0130	0.0133	0.0182	0.0239	0.0374	0.0258	0.0142	10	0.02264	0.000275
4	15	20	0.0797	0.0102	0.0127	0.0152	0.0123	0.0102	0.0138	0.0257	0.0178	0.0064	10	0.02038	0.000462
5	20	25		0.0103	0.0114	0.0114	0.0066	0.0057	0.0079	0.0151	0.0081	0.0030	9	0.00884	0.000013
6	25	30		0.0105	0.0068	0.0055	0.0035	0.0028	0.0032	0.0050	0.0034	0.0008	9	0.00462	0.000008
7	30	35		0.0065	0.0042	0.0026	0.0013	0.0011	0.0013	0.0021	0.0008	0.0004	9	0.00226	0.000004
8	35	40		0.0047	0.0012	0.0008	0.0009	0.0003	0.0006	0.0007	0.0002	0.0003	9	0.00109	0.000002
9	40	45		0.0009	0.0002	0.0002	0.0002	0.0001	0.0002	0.0001	0.0002	0.0002	9	0.00027	0.000000
10	45	50		0.0006	0.0000	0.0001	0.0000	0.0001	0.0000	0.0001	0.0001	0.0000	9	0.00011	0.000000
11	50	55		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	9	0.00002	0.000000
12	55	60			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001		7	0.00002	0.000000
13	60	65			0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0009		7	0.00016	0.000000
14	65	70				0.0000	0.0000	0.0000	0.0001				4	0.00003	0.000000
15	70	75					0.0000	0.0000					2	0.00000	0.000000
		Mean	0.0393	0.0057	0.0047	0.0048	0.0041	0.0045	0.0076	0.0128	0.0131	0.0101			

Table 3. Volumetric density of sockeye fry (fish/m^3 using fish with TS<-50 dB) in Lake Wenatchee by depth and transect during the three acoustic surveys of spring 2003. Shoreline areas with depth < 2 m and the upper 2 m of the water column were not sampled.

Survey 1(April 16-18, 2003)

Depth	Upper	Lower	Fish density by transect										Total		
interval	limit (m)	limit (m)	1	2	3	4	5	6	7	8	9	10	n	Mean	Var
1	0	5	0.0000	0.0048	0.0027	0.0024	0.0014	0.0011	0.0033	0.0006	0.0026	0.0044	10	0.00232	0.000003
2	5	10	0.0013	0.0012	0.0015	0.0009	0.0013	0.0039	0.0055	0.0021	0.0004	0.0027	10	0.00208	0.000002
3	10	15	0.0015	0.0009	0.0014	0.0017	0.0013	0.0013	0.0015	0.0011	0.0019	0.0017	10	0.00143	0.000000
4	15	20		0.0021	0.0024	0.0028	0.0033	0.0024	0.0035	0.0046	0.0032	0.0030	9	0.00303	0.000001
5	20	25		0.0023	0.0019	0.0023	0.0042	0.0036	0.0033	0.0069	0.0067	0.0041	9	0.00391	0.000003
6	25	30		0.0016	0.0017	0.0008	0.0024	0.0018	0.0027	0.0044	0.0053	0.0057	9	0.00293	0.000003
7	30	35		0.0026	0.0014	0.0008	0.0010	0.0010	0.0019	0.0020	0.0036	0.0049	9	0.00212	0.000002
8	35	40		0.0075	0.0018	0.0019	0.0015	0.0017	0.0032	0.0028	0.0024	0.0053	9	0.00312	0.000004
9	40	45		0.0069	0.0038	0.0037	0.0034	0.0020	0.0027	0.0026	0.0021	0.0025	9	0.00330	0.000002
10	45	50			0.0039	0.0032	0.0023	0.0019	0.0015	0.0015	0.0008	0.0015	8	0.00207	0.000001
11	50	55			0.0016	0.0012	0.0007	0.0005	0.0008	0.0011	0.0004	0.0000	8	0.00079	0.000000
12	55	60			0.0003	0.0002	0.0002	0.0002	0.0002	0.0004	0.0001		7	0.00022	0.000000
13	60	65			0.0002	0.0001	0.0002	0.0001	0.0001	0.0003	0.0006		7	0.00023	0.000000
14	65	70				0.0001	0.0002	0.0000	0.0001				4	0.00009	0.000000
15	70	75					0.0000	0.0000					2	0.00000	0.000000
		Mean	0.0009	0.0033	0.0019	0.0016	0.0016	0.0014	0.0022	0.0023	0.0023	0.0033			

Survey 2 (April 29 - May 1, 2003)

Depth	Upper	Lower	Fish density by transect										Total		
interval	limit (m)	limit (m)	1	2	3	4	5	6	7	8	9	10	n	Mean	Var
1	0	5	0.0042	0.0018	0.0005	0.0021	0.0016	0.0032	0.0037	0.0024	0.0093	0.0074	10	0.00362	0.000008
2	5	10	0.0289	0.0045	0.0027	0.0072	0.0031	0.0050	0.0050	0.0065	0.0106	0.0083	10	0.00819	0.000059
3	10	15	0.0624	0.0054	0.0044	0.0050	0.0038	0.0048	0.0055	0.0038	0.0051	0.0067	10	0.01067	0.000331
4	15	20	0.0000	0.0037	0.0026	0.0039	0.0033	0.0036	0.0021	0.0034	0.0023	0.0042	10	0.00292	0.000002
5	20	25		0.0023	0.0029	0.0028	0.0021	0.0023	0.0009	0.0017	0.0016	0.0013	9	0.00199	0.000000
6	25	30		0.0030	0.0019	0.0025	0.0016	0.0014	0.0011	0.0014	0.0012	0.0011	9	0.00168	0.000000
7	30	35		0.0032	0.0016	0.0022	0.0021	0.0013	0.0012	0.0022	0.0011	0.0012	9	0.00179	0.000000
8	35	40		0.0029	0.0026	0.0025	0.0019	0.0019	0.0020	0.0028	0.0025	0.0021	9	0.00236	0.000000
9	40	45		0.0029	0.0022	0.0031	0.0021	0.0012	0.0021	0.0026	0.0020	0.0027	9	0.00232	0.000000
10	45	50		0.0018	0.0015	0.0023	0.0014	0.0005	0.0007	0.0011	0.0010	0.0009	9	0.00124	0.000000
11	50	55		0.0000	0.0007	0.0007	0.0006	0.0003	0.0007	0.0004	0.0004		8	0.00048	0.000000
12	55	60			0.0003	0.0005	0.0003	0.0003	0.0003	0.0005	0.0002		7	0.00033	0.000000
13	60	65			0.0002	0.0012	0.0001	0.0000	0.0000	0.0010	0.0002		7	0.00040	0.000000
14	65	70				0.0013	0.0004	0.0003	0.0004				4	0.00061	0.000000
15	70	75					0.0028	0.0000	0.0000				3	0.00094	0.000003
		Mean	0.0239	0.0029	0.0019	0.0027	0.0018	0.0017	0.0017	0.0023	0.0029	0.0036			

Survey 3 (May 20-22, 2003)

Depth	Upper	Lower	Fish density by transect										Total		
interval	limit (m)	limit (m)	1	2	3	4	5	6	7	8	9	10	n	Mean	Var
1	0	5	0.0035	0.0027	0.0057	0.0065	0.0095	0.0096	0.0248	0.0325	0.0669	0.0464	10	0.02080	0.000472
2	5	10	0.0107	0.0064	0.0098	0.0118	0.0136	0.0192	0.0308	0.0466	0.0455	0.0376	10	0.02319	0.000241
3	10	15	0.0622	0.0096	0.0077	0.0119	0.0119	0.0168	0.0234	0.0371	0.0250	0.0138	10	0.02194	0.000279
4	15	20	0.0725	0.0086	0.0093	0.0116	0.0093	0.0087	0.0128	0.0251	0.0168	0.0057	10	0.01803	0.000396
5	20	25		0.0074	0.0075	0.0090	0.0053	0.0052	0.0075	0.0140	0.0079	0.0027	9	0.00739	0.000010
6	25	30		0.0094	0.0050	0.0045	0.0029	0.0026	0.0027	0.0048	0.0032	0.0007	9	0.00398	0.000006
7	30	35		0.0062	0.0036	0.0025	0.0012	0.0010	0.0010	0.0016	0.0006	0.0003	9	0.00201	0.000004
8	35	40		0.0039	0.0011	0.0008	0.0009	0.0001	0.0003	0.0004	0.0001	0.0001	9	0.00087	0.000001
9	40	45		0.0006	0.0002	0.0002	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	9	0.00017	0.000000
10	45	50		0.0006	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	9	0.00009	0.000000
11	50	55		0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	9	0.00001	0.000000
12	55	60			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001		7	0.00002	0.000000
13	60	65			0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007		7	0.00011	0.000000
14	65	70				0.0000	0.0000	0.0000	0.0001				4	0.00003	0.000000
15	70	75					0.0000	0.0000					2	0.00000	0.000000
		Mean	0.0372	0.0050	0.0038	0.0042	0.0037	0.0042	0.0074	0.0125	0.0129	0.0098			

Table 4. Summary of population estimates for all fish combined and sockeye fry alone from acoustic surveys of Lake Wenatchee in spring 2003. Abundance of fry was calculated from fish traces with TS<-50 dB.

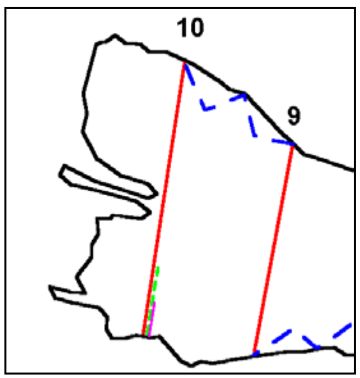
Survey	Date	Fish type	Pop est	SE of pop est	Lower 95% CL	Upper 95% CL	95%CI as % *
1	16-Apr	all fish	1,743,152	107,506	1,530,607	1,955,698	12%
"	"	sockeye fry	1,158,406	65,643	1,028,627	1,288,186	11%
2	29-Apr	all fish	2,163,449	311,326	1,547,941	2,778,958	28%
"	"	sockeye fry	1,724,075	309,435	1,112,304	2,335,846	35%
3	20-May	all fish	5,048,043	596,454	3,868,821	6,227,265	23%
"	"	sockeye fry	4,763,607	582,052	3,612,858	5,914,357	24%

* 95% confidence interval as a percentage of the population estimate, e.g., +/- 12%.

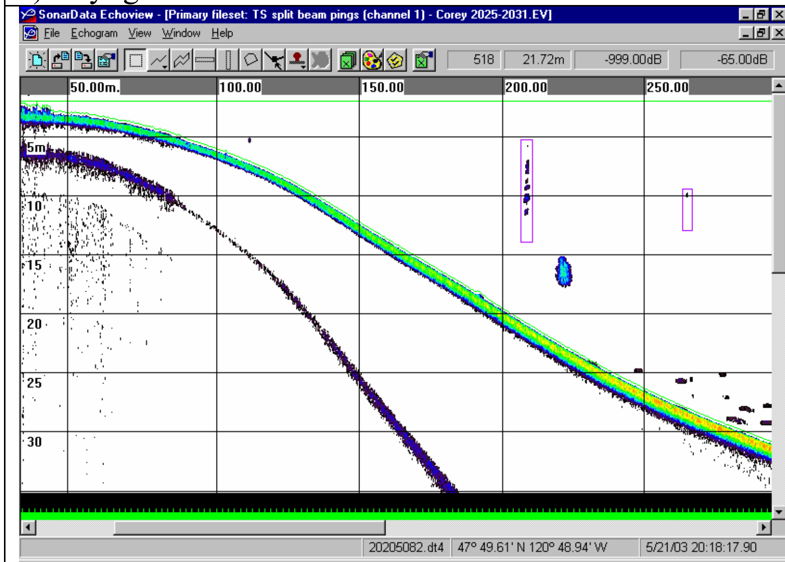
Appendix A

Snorkeling was performed by Yakama Nation Fisheries Resource Management Program personnel in conjunction with dusk acoustic sampling at the west end of Lake Wenatchee on May 21, 2003. A single snorkeler swam along the surface looking downward in the shallows (<2 m deep) and over deeper water (2-30 m deep) along acoustic transect 10. Observations were made during daylight and darkness. Data recorded were visibility range, time of day, fish species and age group, and approximate location of sighting.

Appendix A Figure 1. Location of snorkeling in relation to acoustic sampling at the west end of Lake Wenatchee on May 21, 2003. Snorkeling was performed concurrently with acoustics along the south end of transect 10 where the depth was greater than 2 meters (magenta line), and independently in the south shore littoral zone (depth < 2m) at the end of transect 10, which was too shallow for acoustics. Snorkeling in conjunction with acoustics extended from shallows to a point about 200 m off shore where the depth was about 30 m. Key to lines: Lake outline: black, snorkeling transect: magenta, crepuscular acoustic transect: green, main acoustic transects: red, shoreline acoustic transects: blue.

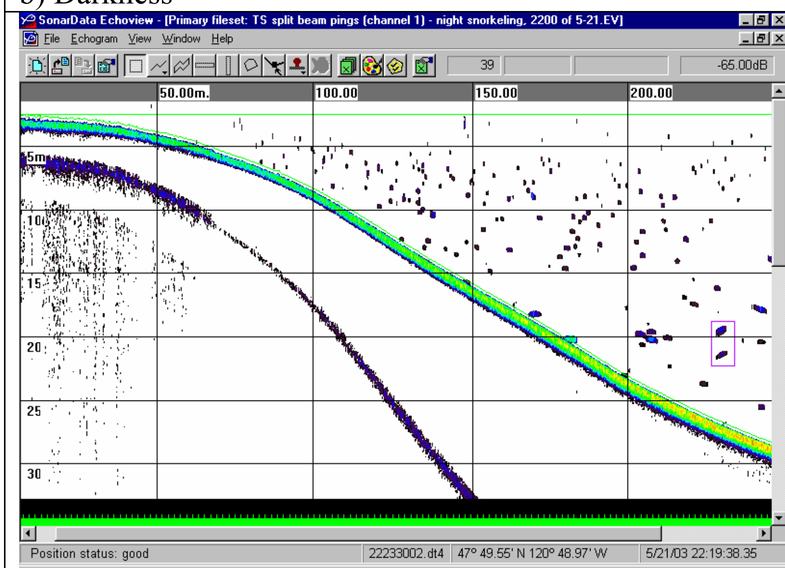


a) Daylight



a) Echogram made during daylight at about 2030 hours, right after the sun dipped below the western mountains. This transect was snorkeled concurrently from weedy shallows (left side) to a point where the depth was 18 meters. The echogram shows one fish trace at 5 m and nothing else in the portion that was snorkeled. Farther offshore, the echogram shows some bubbles (boxed), a fish school from 15-18 meters, and a fish layer below 25 m.

b) Darkness



b) Echogram made during darkness at about 2200 hours. The transect was snorkeled concurrently from weedy shallows (left side) to point where the depth was 30 meters. The echogram along the same line shows fish at all depths, including many in the upper 5 meters. The echogram also showed some bubbles (boxed). No fish schools were seen.

Appendix A Figure 2. Echograms made concurrently with snorkeling at the south end of Transect 10 on May 21, 2003

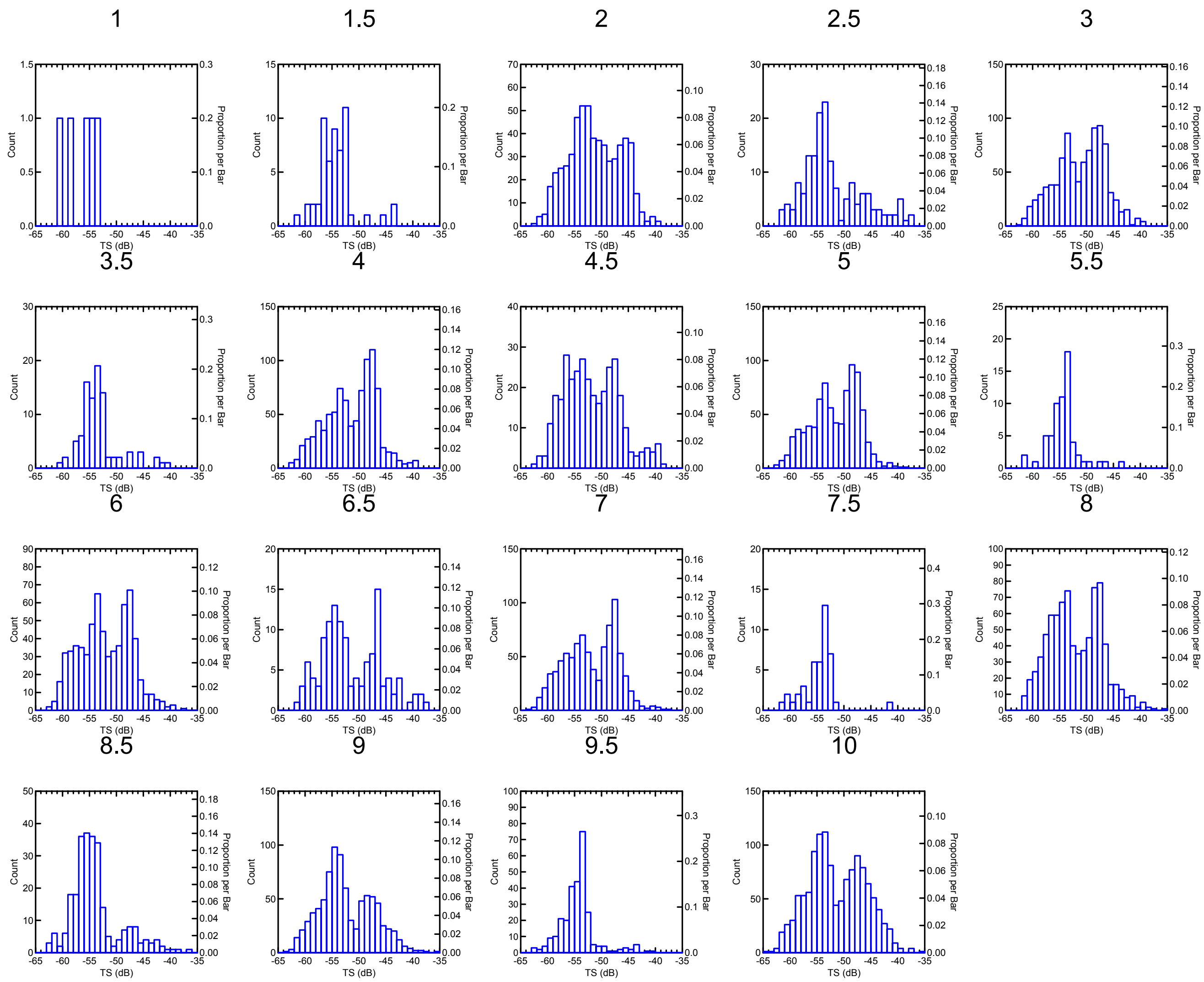
Appendix A Table 1. Snorkeling results from May 21, 2003.

Light level	Time Start	End	Location	Snorkel Distance	Water Visibility	Observations COH1+	SOC1+	SOCfry	CK1+	SCUL	WF	BT	NPM
Dusk	20:00:00	20:17:00	along south shore-approx.10-15ft off bank	50 yds	10-12ft*	0	0	0	0	0	0	0	0
Dusk	20:22:00	20:34:00	south-to-north directional snorkel	50yds	20ft	0	0	0	0	0	0	2	0
Dusk	20:44:00	21:07:00	along south shore-approx.10-15ft off bank	50 yds	10-12ft*	0	0	0	0	0	0	0	0 **
Night	21:41:00	21:53:00	47-54 along south shore-approx.10-15ft off bank	50 yds	10-12ft*	7	4	2	0	15	2	0	0
Night	22:00:00	22:27:00	south-to-north directional snorkel	100 yds	10-12ft	0	6	43	0	0	0	0	0
Night	23:00:00	23:20:00	boat launch-east end of lake at outlet	20 yds	3-8ft*	40-50	0	0	4	10	0	0	3

COH1+ coho yearlings
SOC1+ sockeye yearlings
SOCfry sockeye fry
CK1+ chinook yearlings
SCUL sculpins
WF whitefish
BT bull trout
NPM northern pike minnow

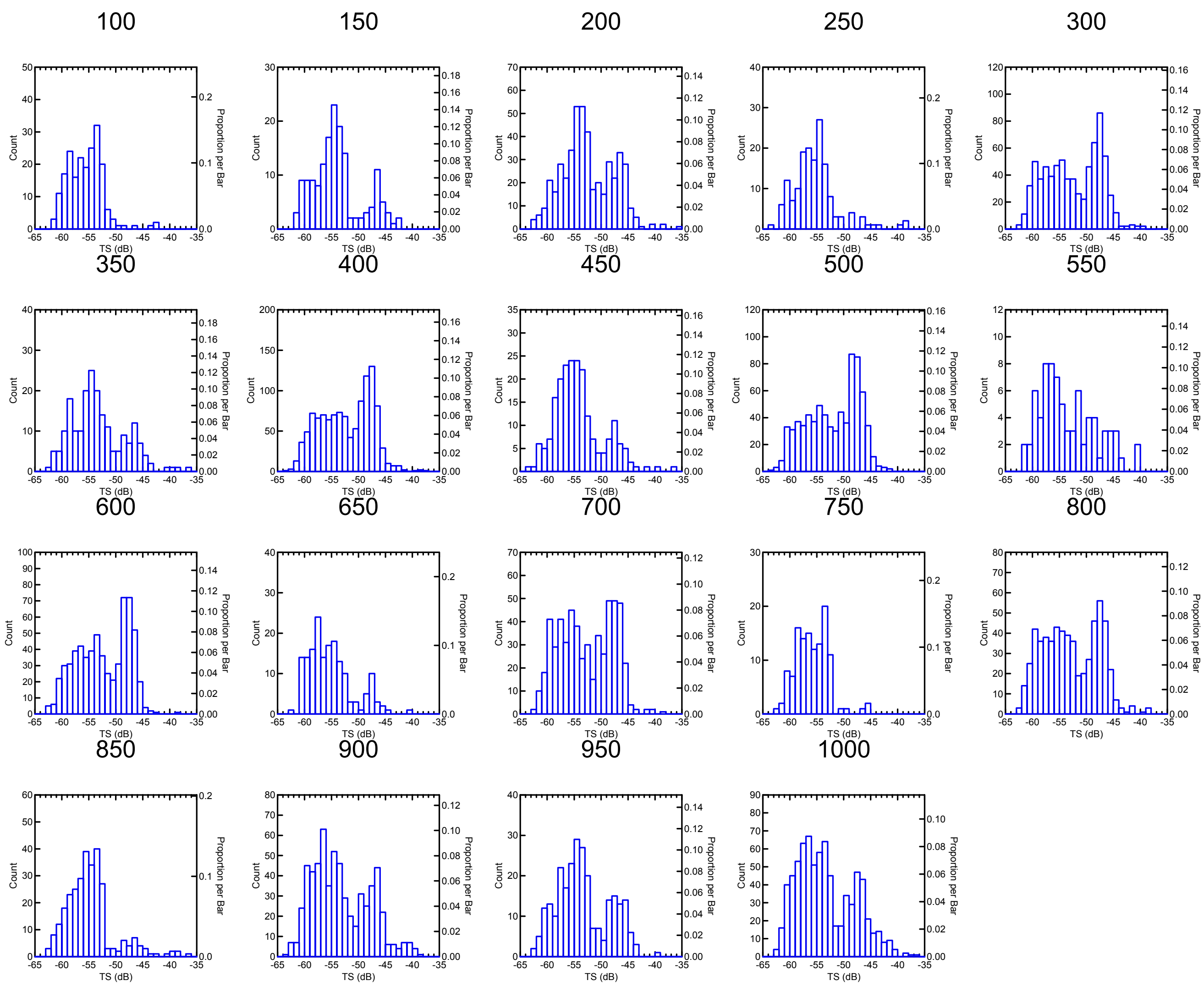
*to bottom
**Noticed juveniles feeding on the surface

APPENDIX B-1



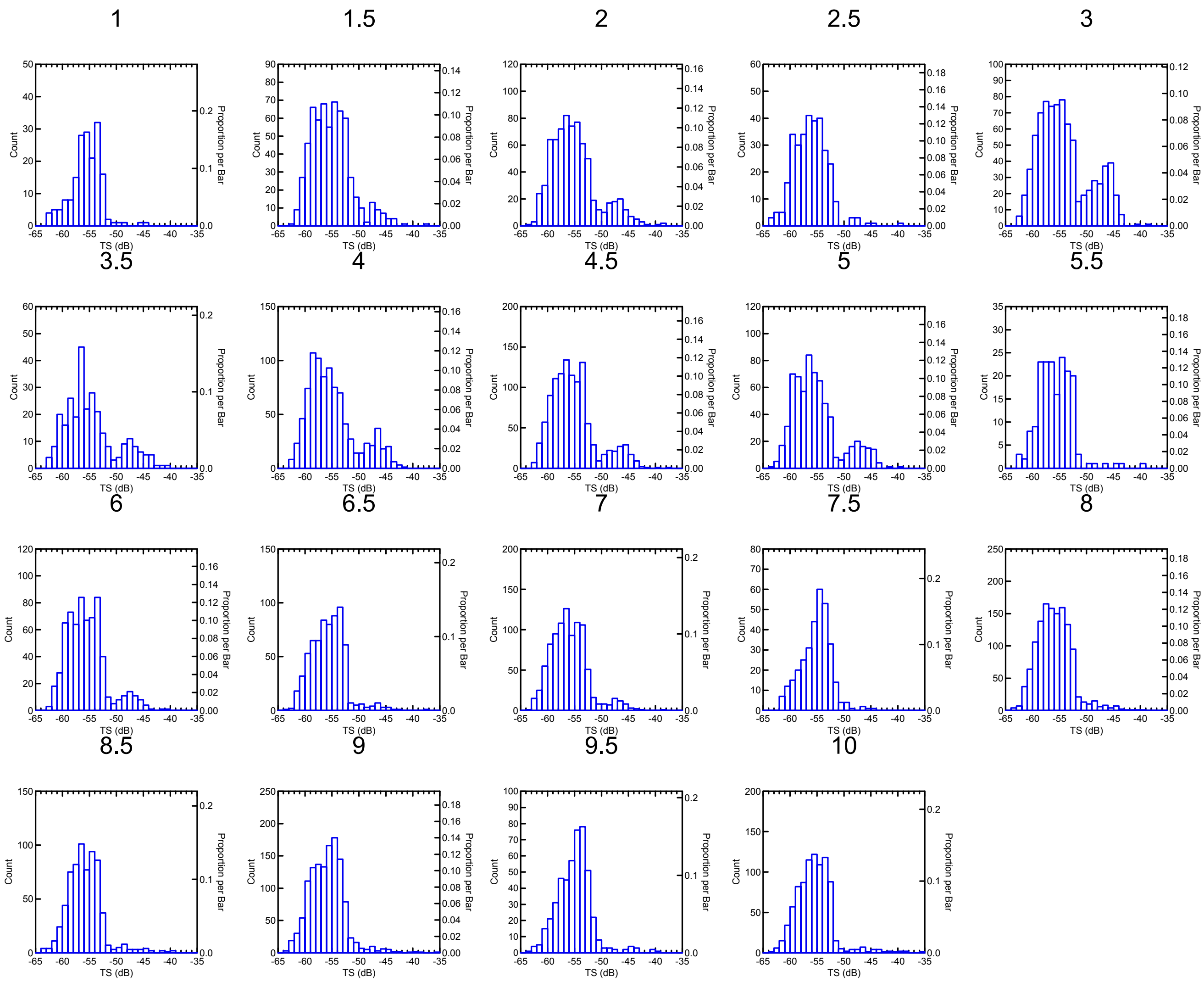
Appendix b-1. Frequency distribution of TS for individual transects with all depths combined from Survey 1 (April 16-18) of Lake Wenatchee.

APPENDIX B-2



Appendix b-2. Frequency distribution of TS for individual transects with all depths combined from Survey 2 (April 29 - May 1, 2003) of Lake Wenatchee.

Appendix B-3



Appendix b-3. Frequency distribution of TS for individual transects with all depths combined from Survey 3 (May 20-22, 2003) of Lake Wenatchee.

Appendix C-1

Appendix c-1. Population estimates for fish of all species and sizes combined in Lake Wenatchee during acoustic surveys conducted spring 2003. Shoreline areas with depth < 2 m and the upper 2 m of the water column were not sampled.

Survey 1 (April 16-18, 2003)

Depth interval	Upper limit (m)	Lower limit (m)	Mean no. per cubic m	Variance	Sample size *	Stratum Volume (cubic m)	Pop est	SE of pop est	Lower 95% CL	Upper 95% CL
1	0	5	0.00322	6.71E-06	10	5.04E+07	162,100	41,247	68,792	255,407
2	5	10	0.00308	6.43E-06	10	4.97E+07	153,127	39,876	62,920	243,333
3	10	15	0.00150	1.06E-07	10	4.87E+07	72,940	5,021	61,582	84,299
4	15	20	0.00308	5.35E-07	9	4.74E+07	145,792	11,551	119,155	172,428
5	20	25	0.00403	3.37E-06	9	4.57E+07	184,112	27,955	119,647	248,577
6	25	30	0.00325	3.93E-06	9	4.36E+07	141,998	28,820	75,540	208,456
7	30	35	0.00330	6.64E-06	9	4.12E+07	136,296	35,422	54,613	217,979
8	35	40	0.00634	1.62E-05	9	3.85E+07	243,986	51,632	124,924	363,049
9	40	45	0.00764	1.30E-05	9	3.52E+07	269,159	42,304	171,605	366,713
10	45	50	0.00491	5.01E-06	8	3.15E+07	154,580	24,924	95,644	213,515
11	50	55	0.00211	1.72E-06	8	2.71E+07	57,228	12,554	27,542	86,914
12	55	60	0.00071	7.89E-08	7	2.17E+07	15,335	2,304	9,698	20,971
13	60	65	0.00043	3.57E-08	7	1.47E+07	6,314	1,050	3,745	8,882
14	65	70	0.00021	5.81E-09	4	8.86E+05	186	34	79	294
15	70	75	0.00000	0.00E+00	2	8.86E+03	0	0	0	0
Total					155	4.96E+08	1,743,152	107,506	1,530,607	1,955,698
						95% CI is the population estimate			+/-	12%

* Number of transects with corresponding depth interval.

Survey 2 (April 29 - May 1, 2003)

Depth interval	Upper limit (m)	Lower limit (m)	Mean no. per cubic m	Variance	Sample size *	Stratum Volume (cubic m)	Pop est	SE of pop est	Lower 95% CL	Upper 95% CL
1	0	5	0.00405	9.11E-06	10	5.04E+07	204,126	48,058	95,411	312,841
2	5	10	0.00867	5.82E-05	10	4.97E+07	431,093	120,037	159,551	702,635
3	10	15	0.01110	3.32E-04	10	4.87E+07	541,031	280,745	-94,059	1,176,120
4	15	20	0.00323	1.84E-06	10	4.74E+07	153,134	20,335	107,134	199,135
5	20	25	0.00237	4.18E-07	9	4.57E+07	108,268	9,838	85,581	130,954
6	25	30	0.00237	5.72E-07	9	4.36E+07	103,298	11,004	77,923	128,674
7	30	35	0.00310	1.15E-06	9	4.12E+07	127,702	14,713	93,773	161,630
8	35	40	0.00509	6.23E-07	9	3.85E+07	195,583	10,122	172,241	218,925
9	40	45	0.00467	1.66E-06	9	3.52E+07	164,383	15,131	129,492	199,275
10	45	50	0.00255	1.37E-06	9	3.15E+07	80,424	12,294	52,073	108,774
11	50	55	0.00108	3.88E-07	8	2.71E+07	29,145	5,957	15,059	43,231
12	55	60	0.00068	6.19E-08	7	2.17E+07	14,702	2,041	9,708	19,696
13	60	65	0.00067	5.74E-07	7	1.47E+07	9,823	4,210	-478	20,124
14	65	70	0.00082	3.38E-07	4	8.86E+05	730	258	-90	1,549
15	70	75	0.00094	2.67E-06	3	8.86E+03	8	8	-28	44
Total					155	4.96E+08	2,163,449	311,326	1,547,941	2,778,958
						95% CI is the population estimate			+/-	28%

* Number of transects with corresponding depth interval.

Survey 3 (May 20-22, 2003)

Depth interval	Upper limit (m)	Lower limit (m)	Mean no. per cubic m	Variance	Sample size *	Stratum Volume (cubic m)	Pop est	SE of pop est	Lower 95% CL	Upper 95% CL
1	0	5	0.02092	4.79E-04	10	5.04E+07	1,053,301	348,386	265,196	1,841,406
2	5	10	0.02351	2.41E-04	10	4.97E+07	1,169,355	244,385	616,518	1,722,192
3	10	15	0.02264	2.75E-04	10	4.87E+07	1,103,143	255,359	525,481	1,680,805
4	15	20	0.02038	4.62E-04	10	4.74E+07	965,589	321,979	237,221	1,693,957
5	20	25	0.00884	1.32E-05	9	4.57E+07	403,555	55,266	276,112	530,999
6	25	30	0.00462	7.93E-06	9	4.36E+07	201,422	40,970	106,945	295,900
7	30	35	0.00226	3.80E-06	9	4.12E+07	93,383	26,782	31,625	155,142
8	35	40	0.00109	1.92E-06	9	3.85E+07	41,905	17,761	947	82,863
9	40	45	0.00027	5.89E-08	9	3.52E+07	9,418	2,850	2,846	15,990
10	45	50	0.00011	3.38E-08	9	3.15E+07	3,606	1,928	-841	8,053
11	50	55	0.00002	3.42E-09	9	2.71E+07	527	527	-689	1,744
12	55	60	0.00002	1.81E-09	7	2.17E+07	454	349	-400	1,308
13	60	65	0.00016	1.23E-07	7	1.47E+07	2,356	1,947	-2,408	7,120
14	65	70	0.00003	3.94E-09	4	8.86E+05	28	28	-61	116
15	70	75	0.00000	0.00E+00	2	8.86E+03	0	0	0	0
Total					155	4.96E+08	5,048,043	596,454	3,868,821	6,227,265
						95% CI is the population estimate			+/-	23%

Appendix C-2

Appendix c-2. Population estimates for sockeye fry (fish with TS<-50 dB) in Lake Wenatchee during acoustic surveys conducted spring 2003. Shoreline areas with depth < 2 m and the upper 2 m of the water column were not sampled.

Survey 1 (April 16-18, 2003)

Depth interval	Upper limit (m)	Lower limit (m)	Mean no. per cubic m	Variance	Sample size *	Stratum Volume (cubic m)	Pop est	SE of pop est	Lower 95% CL	Upper 95% CL
1	0	5	0.00232	2.52E-06	10	5.04E+07	117,044	25,259	59,903	174,184
2	5	10	0.00208	2.38E-06	10	4.97E+07	103,571	24,283	48,639	158,503
3	10	15	0.00143	8.90E-08	10	4.87E+07	69,575	4,597	59,176	79,974
4	15	20	0.00303	5.39E-07	9	4.74E+07	143,337	11,597	116,595	170,078
5	20	25	0.00391	3.35E-06	9	4.57E+07	178,446	27,860	114,201	242,692
6	25	30	0.00293	3.14E-06	9	4.36E+07	127,982	25,792	68,506	187,458
7	30	35	0.00212	1.88E-06	9	4.12E+07	87,462	18,830	44,041	130,884
8	35	40	0.00312	4.03E-06	9	3.85E+07	120,165	25,743	60,801	179,529
9	40	45	0.00330	2.27E-06	9	3.52E+07	116,222	17,709	75,386	157,058
10	45	50	0.00207	1.03E-06	8	3.15E+07	65,039	11,323	38,264	91,815
11	50	55	0.00079	2.56E-07	8	2.71E+07	21,269	4,840	9,825	32,713
12	55	60	0.00022	1.03E-08	7	2.17E+07	4,837	833	2,800	6,874
13	60	65	0.00023	3.57E-08	7	1.47E+07	3,376	1,050	807	5,945
14	65	70	0.00009	3.83E-09	4	8.86E+05	82	27	-6	169
15	70	75	0.00000	0.00E+00	2	8.86E+03	0	0	0	0
Total					155	4.96E+08	1,158,406	65,643	1,028,627	1,288,186
						95% CI is the population estimate			+/-	11%

* Number of transects with corresponding depth interval.

Survey 2 (April 29 - May 1, 2003)

Depth interval	Upper limit (m)	Lower limit (m)	Mean no. per cubic m	Variance	Sample size *	Stratum Volume (cubic m)	Pop est	SE of pop est	Lower 95% CL	Upper 95% CL
1	0	5	0.00362	7.52E-06	10	5.04E+07	182,417	43,654	83,664	281,170
2	5	10	0.00819	5.87E-05	10	4.97E+07	407,412	120,538	134,737	680,087
3	10	15	0.01067	3.31E-04	10	4.87E+07	520,082	280,298	-113,997	1,154,161
4	15	20	0.00292	1.52E-06	10	4.74E+07	138,283	18,459	96,525	180,041
5	20	25	0.00199	4.63E-07	9	4.57E+07	91,041	10,357	67,158	114,924
6	25	30	0.00168	4.27E-07	9	4.36E+07	73,182	9,503	51,267	95,097
7	30	35	0.00179	4.88E-07	9	4.12E+07	73,749	9,600	51,612	95,885
8	35	40	0.00236	1.60E-07	9	3.85E+07	90,625	5,128	78,801	102,449
9	40	45	0.00232	3.19E-07	9	3.52E+07	81,703	6,636	66,401	97,005
10	45	50	0.00124	2.99E-07	9	3.15E+07	39,005	5,737	25,775	52,235
11	50	55	0.00048	5.97E-08	8	2.71E+07	12,917	2,339	7,387	18,446
12	55	60	0.00033	1.89E-08	7	2.17E+07	7,239	1,127	4,481	9,996
13	60	65	0.00040	2.49E-07	7	1.47E+07	5,869	2,775	-923	12,660
14	65	70	0.00061	2.35E-07	4	8.86E+05	544	215	-139	1,228
15	70	75	0.00094	2.67E-06	3	8.86E+03	8	8	-28	44
Total					155	4.96E+08	1,724,075	309,435	1,112,304	2,335,846
						95% CI is the population estimate			+/-	35%

* Number of transects with corresponding depth interval.

Survey 3 (May 20-22, 2003)

Depth interval	Upper limit (m)	Lower limit (m)	Mean no. per cubic m	Variance	Sample size *	Stratum Volume (cubic m)	Pop est	SE of pop est	Lower 95% CL	Upper 95% CL
1	0	5	0.02080	4.72E-04	10	5.04E+07	1,047,555	345,968	264,921	1,830,188
2	5	10	0.02319	2.41E-04	10	4.97E+07	1,153,682	244,162	601,349	1,706,016
3	10	15	0.02194	2.79E-04	10	4.87E+07	1,069,334	257,311	487,257	1,651,412
4	15	20	0.01803	3.96E-04	10	4.74E+07	854,254	298,116	179,869	1,528,640
5	20	25	0.00739	9.62E-06	9	4.57E+07	337,512	47,210	228,645	446,379
6	25	30	0.00398	5.93E-06	9	4.36E+07	173,599	35,426	91,906	255,292
7	30	35	0.00201	3.52E-06	9	4.12E+07	82,927	25,801	23,429	142,425
8	35	40	0.00087	1.43E-06	9	3.85E+07	33,551	15,333	-1,806	68,909
9	40	45	0.00017	2.52E-08	9	3.52E+07	5,955	1,865	1,655	10,256
10	45	50	0.00009	3.51E-08	9	3.15E+07	2,792	1,967	-1,743	7,328
11	50	55	0.00001	1.92E-09	9	2.71E+07	396	396	-517	1,308
12	55	60	0.00002	1.81E-09	7	2.17E+07	454	349	-400	1,308
13	60	65	0.00011	7.09E-08	7	1.47E+07	1,567	1,480	-2,055	5,188
14	65	70	0.00003	3.94E-09	4	8.86E+05	28	28	-61	116
15	70	75	0.00000	0.00E+00	2	8.86E+03	0	0	0	0
Total					155	4.96E+08	4,763,607	582,052	3,612,858	5,914,357
						95% CI is the population estimate			+/-	24%

* Number of transects with corresponding depth interval.

Appendix C: 2003 Nason Creek Snorkel Counts

2003 Nason Creek Snorkel Counts
Survey 1

				Coho		Chinook		RBT/STHD				Bull Trout		Cutthroat		Brook Trt.
Reach	Date	Unit	P,R,G	Wild	Plants	Subyear	Adult	Fry	Yearling	>6"	Hat. Res.	<6 "	>6"	<6"	>6"	>6"
1	07/21/2003	G19	G	0	0	20	0	20	1	0	0	0	0	0	0	0
1	07/18/2003	G14	G	0	0	0	0	4	0	0	0	0	0	0	0	0
1	07/18/2003	G14	G	1	0	30	0	37	2	0	0	0	0	0	0	0
1	07/18/2003	G9	G	0	0	82	0	0	0	0	0	0	0	0	0	0
1	07/21/2003	G24	G	0	0	86	0	0	0	0	0	0	0	0	0	0
1	07/21/2003	G29	G	0	0	2	0	0	0	0	0	0	0	0	0	0
1	07/21/2003	G4	G	0	0	36	0	0	0	0	0	0	0	0	0	0
1	07/21/2003	G24	G	0	0	49	0	0	2	0	5	0	0	0	0	0
1	07/21/2003	P24	P	0	0	61	0	22	0	0	0	0	0	1	0	0
1	07/18/2003	P9	P	0	0	0	0	12	0	0	0	0	0	0	0	0
1	07/18/2003	P19	P	0	0	209	0	0	17	0	0	0	0	0	0	0
1	07/18/2003	P14	P	0	0	36	0	26	0	0	0	0	0	0	0	0
1	07/18/2003	P9	P	0	0	4	0	12	1	0	0	0	0	0	0	0
1	07/21/2003	P4	P	0	0	68	0	0	0	0	6	0	0	0	0	0
1	07/21/2003	R24	R	0	0	3	0	0	10	0	0	0	0	0	0	0
1	07/18/2003	R19	R	0	0	37	0	13	3	0	0	0	0	1	0	0
1	07/18/2003	R9	R	0	0	18	0	0	0	0	0	0	0	0	0	0
1	07/21/2003	R29	R	0	0	1	0	0	0	0	0	0	0	0	0	0
1	07/21/2003	R4	R	0	0	58	0	0	3	0	2	0	0	0	0	0
1	07/21/2003	R24	R	0	0	14	0	1	25	0	0	0	0	0	0	0
Totals				1	0	814	0	147	64	0	13	0	0	2	0	0

2003 Nason Creek Snorkel Counts
Survey 1

				Coho		Chinook		RBT/STHD				Bull Trout		Cutthroat		Brook Trt.
Reach	Date	Unit	P,R,G	Wild	Plants	Subyear	Adult	Fry	Yearling	>6"	Hat. Res.	<6 "	>6"	<6"	>6"	>6"
3	07/22/2003	G22	G	0	0	94	0	14	4	0	5	0	0	0	0	1
3	07/22/2003	G7	G	0	0	24	0	11	3	0	0	0	0	0	0	0
3	07/22/2003	G12	G	0	0	2	0	0	0	0	2	0	0	0	0	0
3	07/22/2003	G17	G	0	0	84	1	0	1	0	3	0	0	0	0	0
3	07/22/2003	P2	P	0	0	11	3	8	0	1	0	0	0	0	0	0
3	07/22/2003	P3	P	0	0	3	2	4	0	0	0	0	0	0	0	0
3	07/22/2003	P7	P	0	0	1	4	0	0	0	0	0	0	0	0	0
3	07/22/2003	P12	P	0	0	84	0	0	0	0	0	0	0	0	0	0
3	07/22/2003	R12	R	0	0	4	0	0	2	0	8	0	0	0	0	0
3	07/22/2003	R17	R	0	0	13	0	0	0	0	5	0	0	1	1	0
3	07/22/2003	R22	R	0	0	11	1	0	0	0	1	0	0	0	0	0
	Total			0	0	331	11	37	10	1	24	0	0	1	1	1

2003 Nason Creek Snorkel Counts
Survey 2

				Coho		Chinook		RBT/STHD				Bull Trout		Cutthroat		Brook Trt.
Reach	Date	Unit	P,R,G	Wild	Plants	Subyear	Adult	Fry	Yearling	>6"	Hat. Res.	<6 "	>6"	<6"	>6"	>6"
1	08/13/2003	G4	G	0	3	16	0	13	1	0	0	0	0	0	0	0
1	08/13/2003	G9	G	0	77	142	0	0	1	0	0	0	0	0	0	0
1	08/14/2003	G14	G	0	12	33	0	0	7	0	0	0	0	0	0	0
1	08/14/2003	G19	G	0	0	31	0	0	0	0	0	0	0	0	0	0
1	08/15/2003	G24	G	0	47	123	0	0	4	0	0	0	0	0	0	0
1	08/15/2003	G29	G	0	0	34	0	0	3	0	0	0	0	0	0	0
1	08/13/2003	P4	P	0	60	97	0	26	1	0	5	0	0	0	0	0
1	08/14/2003	P9	P	0	3	8	0	14	0	0	0	0	0	0	0	0
1	08/14/2003	P14	P	0	10	12	0	8	0	0	0	0	0	0	0	0
1	08/14/2003	P19	P	0	29	66	0	0	0	0	0	0	0	0	0	0
1	08/15/2003	P24	P	0	3	8	0	4	0	0	0	0	0	0	0	0
1	08/13/2003	R4	R	0	0	21	0	9	2	0	4	0	0	0	0	0
1	08/13/2003	R9	R	0	74	138	0	0	8	0	4	0	0	0	0	0
1	08/14/2003	R14	R	0	0	11	0	0	0	0	0	0	0	0	0	0
1	08/14/2003	R19	R	0	8	16	0	0	0	0	0	0	0	0	0	0
1	08/15/2003	R24	R	0	2	12	0	0	2	0	0	0	0	0	0	0
1	08/15/2003	R29	R	0	0	5	0	0	10	0	0	0	0	0	0	0
Totals				0	328	773	0	74	39	0	13	0	0	0	0	0

2003 Nason Creek Snorkel Counts
Survey 2

Reach	Date	Unit	P,R,G	Wild	Plants	Subyear	Adult	Fry	Yearling	>6"	Hat. Res.	<6 "	>6"	<6"	>6"	>6"
3	08/11/2003	G7	G	0	0	66	0	1	0	0	1	0	0	0	0	0
3	08/12/2003	G12	G	0	0	0	0	4	0	0	0	0	0	0	0	0
3	08/12/2003	G17	G	0	0	134	0	0	0	0	0	0	0	0	0	0
3	08/12/2003	P17	P	0	0	347	0	3	6	0	0	0	0	0	0	0
3	08/11/2003	P2	P	0	0	1	0	14	0	0	0	0	0	0	0	0
3	08/11/2003	P3	P	0	0	5	3	0	0	0	0	0	0	0	0	0
3	08/11/2003	P7	P	0	0	101	1	2	20	0	6	0	0	0	0	0
3	08/11/2003	R7	R	0	0	3	0	0	0	0	0	0	0	0	0	0
3	08/12/2003	R17	R	0	0	1	0	3	0	0	0	0	0	0	0	0
3	08/12/2003	R22	R	0	0	74	0	0	9	0	0	0	0	0	0	0
Totals				0	0	732	4	27	35	0	7	0	0	0	0	0

2003 Nason Creek Snorkel Counts
Survey 3

				Coho		Chinook		RBT/STHD				Bull Trout		Cutthroat		Brook Trt.
Reach	Date	Unit	P,R,G	Wild	Plants	Subyear	Adult	Fry	Yearling	>6"	Hat. Res.	<6 "	>6"	<6"	>6"	>6"
1	08/27/2003	G4	G	0	8	26	0	0	0	0	0	0	0	0	0	0
1	08/27/2003	G24	G	0	0	0	0	0	2	0	0	0	0	0	0	0
1	08/28/2003	G14	G	0	0	5	0	12	0	0	0	0	0	0	0	0
1	08/28/2003	G29	G	0	0	7	0	10	0	0	0	0	0	0	0	0
1	08/27/2003	G9	G	0	23	73	0	0	0	0	0	0	0	0	0	0
1	08/27/2003	P4	P	0	32	87	0	0	0	0	0	0	0	0	0	0
1	08/27/2003	P4	P	0	9	30	0	0	3	0	0	0	0	0	0	0
1	08/27/2003	P24	P	0	37	140	0	0	2	0	0	0	0	0	0	0
1	08/28/2003	P9	P	0	4	8	0	0	0	0	0	0	0	0	0	0
1	08/27/2003	P24	P	0	2	8	0	0	0	0	0	0	0	0	0	0
1	08/27/2003	R9	R	0	18	24	0	0	0	0	0	0	0	0	0	0
1	08/27/2003	R4	R	0	8	65	0	15	0	0	0	0	0	0	0	0
1	08/28/2003	R14	R	0	0	8	0	0	0	0	0	0	0	0	0	0
1	08/28/2003	R19	R	0	4	24	0	1	1	0	0	0	0	0	0	0
1	08/28/2003	R29	R	0	0	9	0	6	4	0	0	0	0	0	0	0
1	08/27/2003	R9	R	0	16	30	0	0	1	0	0	0	0	0	0	0
1	08/27/2003	R24	R	0	0	12	0	0	5	0	0	0	0	0	0	0
Totals				0	161	556	0	44	18	0	0	0	0	0	0	0

2003 Nason Creek Snorkel Counts
Survey 3

				Coho		Chinook		RBT/STHD				Bull Trout		Cutthroat		Brook Trt.
Reach	Date	Unit	P,R,G	Wild	Plants	Subyear	Adult	Fry	Yearling	>6"	Hat. Res.	<6 "	>6"	<6"	>6"	>6"
3	08/26/2003	G22	G	0	0	157	0	0	1	0	0	0	0	0	0	0
3	08/25/2003	G2	G	0	0	0	0	0	2	0	0	0	0	0	0	0
3	08/25/2003	G7	G	0	0	16	0	19	1	0	0	0	0	0	0	0
3	08/26/2003	G17	G	0	0	81	0	30	0	0	0	0	0	0	0	0
3	08/25/2003	P2	P	0	0	33	0	0	0	0	0	0	0	0	0	0
3	08/25/2003	P3	P	0	0	1	0	1	0	0	0	0	0	0	0	0
3	08/25/2003	P7	P	0	0	88	6	0	2	0	2	0	0	0	0	0
3	08/26/2003	P12	P	0	0	169	0	0	6	0	0	0	0	0	0	0
3	08/25/2003	R2	R	0	0	6	0	7	1	0	0	0	0	0	0	0
3	08/25/2003	R7	R	0	0	1	0	0	0	0	0	0	0	0	0	0
3	08/25/2003	R12	R	0	0	2	0	11	0	0	0	0	0	0	0	0
3	08/26/2003	R17	R	0	0	1	0	12	0	0	0	0	0	0	0	0
3	08/26/2003	R22	R	0	0	54	0	28	3	0	4	0	0	0	0	0
3	08/26/2003	R27	R	0	0	5	0	0	0	0	0	0	0	0	0	0
Totals				0	0	614	6	108	16	0	6	0	0	0	0	0

Appendix D: Radio-Telemetry Tagging Data

Appendix D
Radio-Telemetry Tagging Data

Date Tagged	Time Tagged	Time Released	Channel	Code	Sex	Fork Length (mm)	Tagging Location
09/02/03	3:50 PM	4:50 PM	11	190	M	540	Priest Rapids
09/04/03	3:45 PM	5:45 PM	12	203	M	550	Priest Rapids
09/07/03	9:35 AM	10:25 AM	11	185	F	540	Bonneville
09/08/03	2:12 PM	5:40 PM	11	198	M	495	Priest Rapids
09/08/03	3:34 PM	5:40 PM	12	200	F	610	Priest Rapids
09/08/03	9:50 AM	5:40 PM	11	179	M	535	Priest Rapids
09/08/03	4:35 PM	3:40 PM	12	201	F	610	Priest Rapids
09/09/03	8:15 AM	8:30 AM	11	183	M	640	Bonneville
09/10/03	7:15 AM	7:25 AM	11	184	M	620	Bonneville
09/11/03	1:35 PM	1:45 PM	10	197	F	660	Bonneville
09/11/03	10:20 AM	10:30 AM	10	198	M	610	Bonneville
09/11/03	9:15 AM	9:20 AM	11	200	M	575	Bonneville
09/11/03	7:00 AM	7:10 AM	11	201	M	665	Bonneville
09/11/03	9:15 AM	9:24 AM	12	180	M	640	Bonneville
09/11/03	9:10 AM	9:15 AM	12	181	M	635	Bonneville
09/11/03	9:06 AM	9:16 AM	13	166	F	620	Bonneville
09/11/03	8:52 AM	9:02 AM	13	167	F	630	Bonneville
09/11/03	8:33 AM	8:43 AM	13	169	F	610	Bonneville
09/11/03	1:15 PM	1:30 PM	12	179	F	650	Bonneville
09/11/03	8:35 AM	8:43 AM	10	196	M	635	Bonneville
09/11/03	7:00 AM	7:10 AM	10	199	M	640	Bonneville
09/11/03	1:00 PM	3:40 PM	11	191	M	610	Priest Rapids
09/11/03	3:10 PM	3:40 PM	11	195	M	560	Priest Rapids
09/11/03	3:00 PM	3:40 PM	11	197	M	560	Priest Rapids
09/11/03	4:35 PM	5:30 PM	12	186	F	545	Priest Rapids
09/11/03	3:00 PM	3:40 PM	12	196	M	615	Priest Rapids
09/11/03	2:10 PM	3:30 PM	12	190	M	490	Priest Rapids
09/11/03	10:00 AM	3:40 PM	12	199	M	600	Priest Rapids
09/11/03	4:00 PM	5:30 PM	11	194	M	500	Priest Rapids
09/11/03	4:05 PM	5:30 PM	11	202	F	590	Priest Rapids
09/11/03	1:00 PM	3:40 PM	12	202	M	590	Priest Rapids
09/11/03	12:30 PM	3:40 PM	11	193	M	497	Priest Rapids
09/15/03	10:00 AM	10:50 AM	11	196	M	610	Priest Rapids
09/15/03	9:50 AM	10:50 AM	11	199	M	490	Priest Rapids
09/15/03	9:58 AM	10:53 AM	11	203	M	530	Priest Rapids
09/15/03	1:45 PM	3:30 PM	12	154	M	575	Priest Rapids
09/15/03	2:20 PM	3:30 PM	12	158	F	670	Priest Rapids
09/15/03	9:15 AM	10:30 AM	12	160	M	560	Priest Rapids
09/15/03	11:45 AM	12:45 PM	12	169	F	520	Priest Rapids
09/15/03	2:00 PM	3:30 PM	12	170	F	620	Priest Rapids
09/15/03	11:57 AM	12:45 PM	12	171	F	560	Priest Rapids

Date Tagged	Time Tagged	Time Released	Channel	Code	Sex	Fork Length (mm)	Tagging Location
09/15/03	11:50 AM	12:45 PM	12	172	M	640	Priest Rapids
09/15/03	2:30 PM	3:30 PM	12	173	M	620	Priest Rapids
09/15/03	11:37 AM	12:45 PM	12	174	M	580	Priest Rapids
09/15/03	11:53 AM	12:45 PM	12	175	M	630	Priest Rapids
09/15/03	1:50 PM	3:30 PM	12	176	M	610	Priest Rapids
09/15/03	2:50 PM	3:30 PM	12	177	F	550	Priest Rapids
09/15/03	1:40 PM	3:30 PM	12	178	M	665	Priest Rapids
09/15/03	1:48 PM	3:30 PM	12	182	F	520	Priest Rapids
09/15/03	9:54 AM	10:50 AM	12	191	F	630	Priest Rapids
09/15/03	11:36 AM	12:45 PM	12	192	M	560	Priest Rapids
09/15/03	1:55 PM	3:30 PM	12	193	F	620	Priest Rapids
09/15/03	11:33 AM	12:45 PM	12	194	F	670	Priest Rapids
09/15/03	2:05 PM	3:30 PM	12	195	F	570	Priest Rapids
09/15/03	1:38 PM	3:30 PM	12	197	M	655	Priest Rapids
09/15/03	11:31 AM	12:45 PM	12	198	F	500	Priest Rapids
09/15/03	9:48 AM	5:30 PM	12	189	M	485	Priest Rapids
09/15/03	9:57 AM	10:50 AM	11	180	M	570	Priest Rapids
09/16/03	11:18 AM	12:30 PM	11	155	F	550	Priest Rapids
09/16/03	11:30 AM	12:30 PM	11	156	F	630	Priest Rapids
09/16/03	11:40 AM	12:30 PM	11	157	F	655	Priest Rapids
09/16/03	1:09 PM	2:15 PM	11	158	M	530	Priest Rapids
09/16/03	11:32 AM	12:30 PM	11	160	M	585	Priest Rapids
09/16/03	1:18 PM	2:15 PM	11	163	M	580	Priest Rapids
09/16/03	1:16 PM	2:15 PM	11	164	M	560	Priest Rapids
09/16/03	1:00 PM	2:15 PM	11	165	M	565	Priest Rapids
09/16/03	1:12 PM	2:15 PM	11	166	F	620	Priest Rapids
09/16/03	1:06 PM	2:15 PM	11	167	F	560	Priest Rapids
09/16/03	1:15 PM	2:15 PM	11	168	F	605	Priest Rapids
09/16/03	1:07 PM	2:15 PM	11	169	M	585	Priest Rapids
09/16/03	1:28 PM	2:15 PM	11	170	M	520	Priest Rapids
09/16/03	11:15 AM	12:30 PM	11	171	F	645	Priest Rapids
09/16/03	11:20 AM	12:30 PM	11	172	F	600	Priest Rapids
09/16/03	1:20 PM	2:15 PM	11	173	F	580	Priest Rapids
09/16/03	1:22 PM	2:15 PM	11	174	F	560	Priest Rapids
09/16/03	11:25 AM	12:30 PM	11	175	M	590	Priest Rapids
09/16/03	1:30 PM	2:15 PM	11	176	M	610	Priest Rapids
09/16/03	10:00 AM	10:30 AM	12	155	M	560	Priest Rapids
09/16/03	9:10 AM	10:30 AM	12	165	F	580	Priest Rapids
09/16/03	9:55 AM	10:30 AM	12	166	F	520	Priest Rapids
09/16/03	9:35 AM	10:30 AM	12	167	F	530	Priest Rapids
09/16/03	9:30 AM	10:30 AM	12	168	F	600	Priest Rapids
09/16/03	1:28 PM	2:15 PM	11	161	M	545	Priest Rapids
09/16/03	9:45 PM	10:30 AM	12	157	M	565	Priest Rapids
09/16/03	10:00 AM	10:30 AM	12	162	M	570	Priest Rapids
09/16/03	1:05 PM	2:15 PM	11	154	M	580	Priest Rapids

Date Tagged	Time Tagged	Time Released	Channel	Code	Sex	Fork Length (mm)	Tagging Location
09/16/03	9:40 AM	10:30 AM	12	161	F	600	Priest Rapids
09/23/03	1:40 PM	2:30 PM	10	159	M	585	Priest Rapids
09/23/03	1:27 PM	2:30 PM	10	160	M	610	Priest Rapids
09/23/03	1:23 PM	2:30 PM	10	163	M	665	Priest Rapids
09/23/03	1:27 PM	2:30 PM	10	165	M	565	Priest Rapids
09/23/03	9:25 AM	10:30 PM	10	167	M	570	Priest Rapids
09/23/03	1:29 PM	2:30 PM	10	168	M	665	Priest Rapids
09/23/03	1:17 PM	2:30 PM	10	170	M	610	Priest Rapids
09/23/03	1:19 PM	2:30 PM	10	171	F	650	Priest Rapids
09/23/03	11:30 AM	12:30 PM	10	172	F	560	Priest Rapids
09/23/03	1:21 PM	2:30 PM	10	173	M	610	Priest Rapids
09/23/03	11:20 AM	12:30 PM	10	174	F	590	Priest Rapids
09/23/03	11:22 AM	12:30 PM	10	175	M	510	Priest Rapids
09/23/03	11:24 AM	12:30 PM	10	176	F	605	Priest Rapids
09/23/03	11:26 AM	12:30 PM	10	177	M	580	Priest Rapids
09/23/03	11:28 AM	12:30 PM	10	178	F	680	Priest Rapids
09/23/03	9:27 AM	10:30 AM	10	179	M	595	Priest Rapids
09/23/03	9:29 AM	10:30 AM	10	180	M	580	Priest Rapids
09/23/03	9:31 AM	10:30 AM	10	181	F	585	Priest Rapids
09/23/03	9:34 AM	10:30 AM	10	182	M	540	Priest Rapids
09/23/03	9:40 AM	10:30 AM	10	184	M	610	Priest Rapids
09/23/03	9:32 AM	10:30 AM	10	185	M	620	Priest Rapids
09/23/03	9:22 AM	10:30 AM	10	186	M	690	Priest Rapids
09/23/03	9:49 AM	10:30 AM	10	188	M	665	Priest Rapids
09/23/03	11:32 AM	12:30 PM	10	189	F	570	Priest Rapids
09/23/03	9:40 AM	10:30 AM	10	190	F	520	Priest Rapids
09/23/03	11:35 AM	12:30 PM	10	191	F	620	Priest Rapids
09/23/03	11:40 AM	12:30 PM	10	192	F	580	Priest Rapids
09/23/03	9:48 AM	10:30 AM	10	193	M	530	Priest Rapids
09/23/03	9:45 AM	10:30 AM	10	194	F	560	Priest Rapids
09/23/03	9:43 AM	10:30 AM	10	195	M	600	Priest Rapids
09/23/03	11:46 AM	12:30 PM	10	200	M	605	Priest Rapids
09/23/03	11:50 AM	12:30 PM	10	201	F	590	Priest Rapids
09/23/03	11:55 AM	12:30 PM	10	202	M	555	Priest Rapids
09/23/03	11:57 AM	12:30 PM	10	203	M	620	Priest Rapids
09/23/03	11:59 AM	12:30 PM	10	204	F	640	Priest Rapids
09/23/03	1:22 PM	2:30 PM	10	162	F	660	Priest Rapids
09/23/03	1:25 PM	2:30 PM	10	164	F	560	Priest Rapids
09/23/03	1:15 PM	2:30 PM	10	169	F	645	Priest Rapids
09/23/03	1:42 PM	2:30 PM	10	158	F	650	Priest Rapids
09/23/03	3:00 PM	3:30 PM	211	207	M	590	Tumwater
09/29/03	4:15 PM	4:45 PM	211	209	M	570	Tumwater
09/29/03	12:00 PM	11:10 AM	11	162	F	630	Wells
09/29/03	12:00 PM	11:00 AM	11	186	M	570	Wells
09/29/03	12:00 PM	10:30 AM	11	189	M	670	Wells

Date Tagged	Time Tagged	Time Released	Channel	Code	Sex	Fork Length (mm)	Tagging Location
09/30/03	9:24 AM	10:30 AM	10	157	M	590	Priest Rapids
09/30/03	9:30 AM	10:30 AM	10	161	M	520	Priest Rapids
09/30/03	9:32 AM	10:30 AM	10	166	M	540	Priest Rapids
09/30/03	9:35 AM	10:30 AM	11	159	F	660	Priest Rapids
09/30/03	9:37 AM	10:30 AM	11	177	M	680	Priest Rapids
09/30/03	9:39 AM	10:30 AM	11	178	M	645	Priest Rapids
09/30/03	11:03 AM	12:00 PM	13	168	M	535	Priest Rapids
09/30/03	11:05 AM	12:00 PM	13	175	M	660	Priest Rapids
09/30/03	9:45 AM	10:30 AM	13	176	M	680	Priest Rapids
09/30/03	11:08 AM	12:00 PM	13	183	M	620	Priest Rapids
09/30/03	11:18 AM	12:00 PM	13	192	F	710	Priest Rapids
09/30/03	11:10 AM	12:00 PM	13	194	M	590	Priest Rapids
09/30/03	11:25 AM	12:00 PM	13	195	F	630	Priest Rapids
09/30/03	11:20 AM	12:00 PM	13	203	F	650	Priest Rapids
09/30/03	9:20 AM	10:30 AM	10	155	M	610	Priest Rapids
09/30/03	11:28 AM	12:00 PM	13	188	F	595	Priest Rapids
09/30/03	9:40 AM	10:30 AM	13	162	M	630	Priest Rapids
09/30/03	11:08 AM	12:00 PM	13	173	F	620	Priest Rapids
09/30/03	9:22 AM	10:30 AM	10	156	M	700	Priest Rapids
09/30/03	11:15 AM	12:00 PM	13	196	F	680	Priest Rapids
09/30/03	4:43 PM	5:10 PM	210	209	M	620	Tumwater
09/30/03	4:49 PM	5:10 PM	210	208	M	660	Tumwater
09/30/03	4:40 PM	5:10 PM	213	205	M	720	Tumwater
10/01/03	3:23 PM	4:00 PM	211	211	M	645	Tumwater
10/01/03	4:30 PM	2:00 PM	11	181	M	580	Wells
10/06/03	4:00 PM	4:30 PM	213	209	M	730	Tumwater
10/06/03	4:30 PM	3:40PM	12	185	F	511	Wells
10/06/03	4:30 PM	1:40 PM	11	187	M	570	Wells
10/07/03	12:18 PM	1:30 PM	13	156	F	660	Priest Rapids
10/07/03	10:15 AM	11:30 AM	13	157	M	630	Priest Rapids
10/07/03	10:45 AM	11:30 AM	13	160	M	575	Priest Rapids
10/07/03	9:30 AM	11:30 AM	13	165	M	710	Priest Rapids
10/07/03	12:15 PM	1:30 AM	13	172	F	645	Priest Rapids
10/07/03	10:05 AM	11:30 AM	13	174	M	685	Priest Rapids
10/07/03	12:20 PM	1:30 PM	13	177	F	615	Priest Rapids
10/07/03	12:40 PM	1:30 PM	13	182	F	570	Priest Rapids
10/07/03	9:35 AM	11:30 AM	13	159	M	580	Priest Rapids
10/07/03	12:42 PM	1:30 PM	13	184	F	615	Priest Rapids
10/07/03	10:25 AM	11:30 AM	13	164	F	590	Priest Rapids
10/07/03	10:50 AM	11:30 AM	13	158	F	640	Priest Rapids
10/07/03	10:40 AM	11:30 AM	13	161	M	680	Priest Rapids
10/07/03	12:00 PM	1:30 AM	13	171	F	620	Priest Rapids
10/07/03	10:20 AM	11:30 AM	13	155	M	665	Priest Rapids
10/07/03	9:45 AM	11:30 AM	13	163	F	640	Priest Rapids
10/07/03	12:35 PM	1:30 PM	13	179	M	540	Priest Rapids

Date Tagged	Time Tagged	Time Released	Channel	Code	Sex	Fork Length (mm)	Tagging Location
10/07/03	12:50 PM	1:30 PM	13	187	M	720	Priest Rapids
10/07/03	12:30 PM	1:30 PM	13	178	M	730	Priest Rapids
10/07/03	12:45 PM	1:30 PM	13	185	M	735	Priest Rapids
10/07/03	2:30 PM	1:35PM	12	183	M	668	Wells
10/07/03	2:30 PM	1:30PM	12	184	F	654	Wells
10/07/03	2:30 PM	1:40 PM	12	187	M	526	Wells
10/08/03	2:04 PM	3:00 PM	210	206	M	535	Tumwater
10/08/03	2:24 PM	3:00 PM	213	208	M	620	Tumwater
10/08/03	2:15 PM	3:00 PM	213	210	M	675	Tumwater
10/08/03	2:00 PM	3:00 PM	212	211	M	595	Tumwater
10/09/03	3:35 PM	4:00 PM	212	206	M	580	Tumwater
10/09/03	3:25 PM	4:00 PM	212	210	F	620	Tumwater
10/13/03	4:30PM	3:41PM	13	190	F	512	Wells
10/13/03	4:30PM	3:34PM	13	191	F	578	Wells
10/14/03	12:25 PM	1:45 PM	10	8	M	665	Priest Rapids
10/14/03	12:55 PM	1:45 PM	10	12	F	660	Priest Rapids
10/14/03	12:59 PM	1:45 PM	10	24	M	580	Priest Rapids
10/14/03	9:55 AM	11:30 AM	13	193	M	500	Priest Rapids
10/14/03	11:30 AM	11:30 AM	13	201	F	710	Priest Rapids
10/14/03	12:23 PM	1:45 PM	10	7	M	640	Priest Rapids
10/14/03	12:50 PM	1:45 PM	10	11	F	595	Priest Rapids
10/14/03	10:25 AM	11:30 AM	10	2	M	570	Priest Rapids
10/14/03	10:20 AM	11:30 AM	10	1	M	575	Priest Rapids
10/14/03	12:20 PM	1:45 PM	10	6	M	720	Priest Rapids
10/14/03	12:35 PM	1:45 PM	10	9	M	715	Priest Rapids
10/14/03	12:45 PM	1:45 PM	10	10	M	590	Priest Rapids
10/14/03	1:10 PM	1:45 PM	10	14	F	700	Priest Rapids
10/14/03	1:05 PM	1:45 PM	10	17	F	665	Priest Rapids
10/14/03	9:20 AM	11:30 AM	13	197	F	660	Priest Rapids
10/14/03	9:30 AM	11:30 AM	13	189	M	600	Priest Rapids
10/14/03	10:30 AM	11:30 AM	10	3	M	695	Priest Rapids
10/14/03	10:45 AM	11:30 AM	10	4	F	600	Priest Rapids
10/14/03	10:55 AM	11:30 AM	10	5	M	620	Priest Rapids
10/14/03	2:00PM	1:11PM	13	186	F	605	Wells
10/14/03	2:00PM	1:00PM	13	200	M	670	Wells
10/15/03	12:20 PM	1:00 PM	211	208	M	560	Tumwater
10/15/03	12:25 PM	1:00 PM	212	204	M	585	Tumwater
10/15/03	12:20 PM	1:00 PM	212	205	M	670	Tumwater
10/15/03	12:15 PM	1:00 PM	213	211	M	710	Tumwater
10/15/03	12:15 PM	1:00 PM	210	205	M	590	Tumwater
10/16/03	3:05 PM	3:35 PM	210	210	M	590	Tumwater
10/16/03	2:55 PM	3:35 PM	212	208	F	660	Tumwater
10/16/03	2:45 PM	3:35 PM	212	209	M	680	Tumwater
10/16/03	2:45 PM	3:35 PM	213	207	M	600	Tumwater
10/20/03	4:08 PM	4:45 PM	213	206	M	670	Tumwater

Date Tagged	Time Tagged	Time Released	Channel	Code	Sex	Fork Length (mm)	Tagging Location
10/20/03	3:58 PM	4:45 PM	210	211	M	650	Tumwater
10/20/03	4:12 PM	4:45 PM	211	204	M	580	Tumwater
10/20/03	4:07 PM	4:45 PM	211	206	M	580	Tumwater
10/21/03	11:58 AM	1:10 PM	10	19	M	630	Priest Rapids
10/21/03	12:00 PM	1:10 PM	10	22	M	730	Priest Rapids
10/21/03	2:00 PM	3:00 PM	11	10	F	565	Priest Rapids
10/21/03	11:50 AM	1:10 PM	10	13	M	650	Priest Rapids
10/21/03	11:55 AM	1:10 PM	10	15	M	600	Priest Rapids
10/21/03	12:05 PM	1:10 PM	11	1	F	660	Priest Rapids
10/21/03	12:15 PM	1:10 PM	11	2	F	690	Priest Rapids
10/21/03	12:20 PM	1:10 PM	11	3	M	650	Priest Rapids
10/21/03	12:25 PM	1:10 PM	11	4	M	645	Priest Rapids
10/21/03	12:30 PM	1:10 PM	11	5	M	610	Priest Rapids
10/21/03	12:35 PM	1:10 PM	11	6	F	675	Priest Rapids
10/21/03	1:45 PM	3:00 PM	11	7	M	585	Priest Rapids
10/21/03	1:50 PM	3:00 PM	11	8	M	580	Priest Rapids
10/21/03	1:55 PM	3:00 PM	11	9	M	735	Priest Rapids
10/21/03	2:10 PM	3:00 PM	11	12	M	645	Priest Rapids
10/21/03	2:13 PM	3:00 PM	11	13	M	655	Priest Rapids
10/21/03	2:15 PM	3:00 PM	11	14	M	565	Priest Rapids
10/21/03	2:20 PM	3:00 PM	11	15	M	725	Priest Rapids
10/21/03	2:23 PM	3:00 PM	11	16	M	765	Priest Rapids
10/21/03	2:05 PM	3:00 PM	11	11	M	600	Priest Rapids
10/23/03	4:30PM	3:34PM	10	18	F	581	Wells
10/27/03	9:45 AM	1:00 PM	12	1	M	570	Priest Rapids
10/27/03	11:15 AM	1:00 PM	12	7	M	690	Priest Rapids
10/27/03	11:00 AM	1:00 PM	12	6	F	590	Priest Rapids
10/27/03	9:55 AM	1:00 PM	12	3	M	635	Priest Rapids
10/27/03	12:25 PM	1:00 PM	12	8	F	680	Priest Rapids
10/27/03	9:50 AM	1:00 PM	12	2	F	615	Priest Rapids
10/27/03	1:55 PM	4:00 PM	11	17	F	615	Priest Rapids
10/27/03	1:57 PM	4:00 PM	11	18	M	590	Priest Rapids
10/27/03	1:59 PM	4:00 PM	11	19	M	535	Priest Rapids
10/27/03	2:01 PM	4:00 PM	11	20	F	720	Priest Rapids
10/27/03	2:10 PM	4:00 PM	11	21	M	495	Priest Rapids
10/27/03	2:40 PM	4:00 PM	11	22	M	650	Priest Rapids
10/27/03	2:45 PM	4:00 PM	11	23	M	550	Priest Rapids
10/27/03	3:15 PM	4:00 PM	11	24	F	610	Priest Rapids
10/27/03	3:20 PM	4:00 PM	11	25	M	700	Priest Rapids
10/27/03	10:20 AM	1:00 PM	12	4	M	675	Priest Rapids
10/27/03	1:50 PM	4:00 PM	12	9	M	680	Priest Rapids
10/27/03	1:52 PM	4:00 PM	12	10	M	560	Priest Rapids
10/27/03	1:54 PM	4:00 PM	12	11	F	685	Priest Rapids
10/27/03	10:45 AM	1:00 PM	12	5	M	595	Priest Rapids
10/29/03	4:30 PM	3:39 PM	10	16	M	621	Wells

Date Tagged	Time Tagged	Time Released	Channel	Code	Sex	Fork Length (mm)	Tagging Location
10/29/03	4:30PM	3:36PM	10	20	F	643	Wells
10/29/03	4:30PM	3:37PM	10	21	F	736	Wells
10/29/03	4:30PM	3:40PM	10	23	M	611	Wells
10/29/03	4:30PM	3:38PM	10	25	F	612	Wells
10/29/03	4:30PM	3:35PM	13	204	M	682	Wells
10/30/03	3:35 PM	4:30 PM	210	207	M	730	Tumwater
10/30/03	3:30 PM	4:30 PM	211	210	M	545	Tumwater
10/30/03	3:40 PM	4:30 PM	212	207	M	675	Tumwater
10/30/03	3:45 PM	4:30 PM	211	205	M	565	Tumwater
11/03/03	9:50 AM	3:00 PM	12	17	M	625	Priest Rapids
11/03/03	11:30 AM	3:00 PM	12	12	M	625	Priest Rapids
11/03/03	12:00 PM	3:00 PM	12	13	F	660	Priest Rapids
11/03/03	12:45 PM	3:00 PM	12	14	F	620	Priest Rapids
11/06/03	9:50 AM	3:45 PM	12	15	M	565	Priest Rapids
11/06/03	2:40 PM	3:45 PM	12	16	M	560	Priest Rapids
11/13/03	12:15 PM	3:25 PM	12	18	M	660	Priest Rapids

Appendix E: Radio-Telemetry Tracking Data

Appendix D
Radio-Telemetry Tagging Data

Date Detected	Date Tagged	Chan	Code	Probable Spawning Location	Latitude	Longitude
11/24/03	09/16/03	12	163	Below Wanapum Dam, Aerial 11/24/03	46.756972	-119.947389
11/24/03	10/07/03	13	184	Below Wanapum Dam, Aerial 11/24/03	46.834278	-119.942389
11/10/03	09/16/03	11	168	Below Wanapum Dam, Truck	46.836528	-119.939028
11/24/03	09/23/03	10	167	Below Wanapum Dam, Aerial 11/24/03	46.837139	-119.945194
10/23/03	09/11/03	11	197	Below Wanapum, Aerial 10/23/03	46.849083	-119.941667
10/23/03	09/23/03	10	188	Below Wanapum, Aerial 10/23/03	46.853250	-119.957917
11/24/03	09/23/03	10	169	Near Wanapum, Aerial 11/24/03	46.878556	-119.968278
11/24/03	09/16/03	12	162	Between Wanapum and Vantage, Aerial 11/24/03	46.889278	-119.946278
11/06/03	09/23/03	10	184	Between Wanapum and Vantage, Truck	46.889639	-119.954944
11/24/03	09/08/03	11	198	Between Wanapum and Vantage, Aerial 11/24/03	46.897694	-119.947611
11/24/03	10/27/03	12	5	Between Wanapum and Vantage, Aerial 11/24/03	46.905944	-119.948444
11/24/03	10/07/03	13	159	Between Wanapum and Vantage, Aerial 11/24/03	46.915056	-119.949417
11/24/03	09/23/03	10	165	Between Wanapum and Vantage, Aerial 11/24/03	46.920944	-119.968000
11/10/03	10/21/03	11	4	Between Wanapum and Vantage, Truck	46.924028	-119.951889
11/10/03	09/23/03	10	170	Near mouth of Sandhollow, Truck	46.926111	-119.953389
11/06/03	09/15/03	12	172	Sandhollow, Truck	46.929056	-119.956861
11/10/03	10/07/03	13	161	Sandhollow, Truck	46.929250	-119.957139
11/03/03	10/21/03	11	15	Sandhollow, recovered	46.929694	-119.953378
10/30/03	10/21/03	11	16	Sandhollow, recovered	46.929594	-119.953478
11/10/03	10/27/03	11	18	Sandhollow, Truck	46.929794	-119.953178
11/03/03	10/27/03	11	25	Sandhollow, Truck	46.929494	-119.953278
11/10/03	10/27/03	12	8	Sandhollow, Truck	46.929750	-119.952361
11/10/03	10/27/03	11	23	Sandhollow, Truck	46.930667	-119.949778
11/13/03	09/11/03	11	194	Above mouth of Sandhollow, Truck	46.930861	-119.957222
11/13/03	10/21/03	11	12	Above mouth of Sandhollow, Truck	46.931028	-119.957194
11/10/03	10/21/03	11	7	Sandhollow, Truck	46.931667	-119.947222
11/10/03	10/27/03	12	1	Sandhollow, Truck	46.931861	-119.946222
11/13/03	11/06/03	12	16	Sandhollow, Truck	46.931944	-119.944389
11/10/03	09/15/03	12	176	Above Sandhollow, Truck	46.932056	-119.958111
11/10/03	10/14/03	10	7	Above Sandhollow, Truck	46.933972	-119.958889
10/02/03	09/30/03	11	159	Above Vantage, Aerial 10/02/03	46.935083	-119.980861
11/24/03	10/07/03	13	187	Above Sandhollow, Aerial 11/24/03	46.936056	-119.952472
11/10/03	09/23/03	10	171	Above Vantage, Truck	46.941167	-119.984944
11/10/03	09/11/03	11	191	Above Vantage, Truck	46.941194	-119.984667
11/24/03	09/23/03	10	164	Above Vantage, Aerial 11/24/03	46.963594	-119.979544
11/24/03	09/30/03	11	178	Above Vantage, Aerial 11/24/03	46.963694	-119.979444
11/10/03	09/08/03	12	201	Above Vantage, Truck	46.963889	-119.967056
10/23/03	09/16/03	11	158	Above Vantage, Aerial 10/23/03	46.990278	-119.990722
10/23/03	09/16/03	11	165	Above Vantage, Aerial 10/23/03	47.009861	-120.000167
11/24/03	09/15/03	12	194	Between Vantage and Rock Island, Aerial 11/24/03	47.047472	-120.021639
10/02/03	09/30/03	13	183	Between Vantage and Rock Island, Aerial 10/02/03	47.058750	-120.025083
11/24/03	10/07/03	13	171	Between Vantage and Rock Island, Aerial 11/24/03	47.064722	-120.034028
10/23/03	09/15/03	12	198	Between Vantage and Rock Island, Aerial 10/23/03	47.069333	-120.037056

Date Detected	Date Tagged	Chan	Code	Probable Spawning Location	Latitude	Longitude
10/23/03	09/23/03	10	168	Between Vantage and Rock Island, Aerial 10/23/03	47.092361	-120.028472
10/23/03	09/30/03	10	161	Between Vantage and Rock Island, Aerial 10/23/03	47.112139	-120.014333
11/24/03	09/23/03	10	195	Between Vantage and Rock Island, Aerial 11/24/03	47.133456	-120.003011
11/24/03	09/16/03	11	173	Between Vantage and Rock Island, Aerial 11/24/03	47.133556	-120.003211
11/24/03	10/14/03	13	201	Between Vantage and Rock Island, Aerial 11/24/03	47.133656	-120.003111
11/24/03	10/07/03	13	172	Between Vantage and Rock Island, Aerial 11/24/03	47.166889	-120.003306
11/24/03	09/11/03	12	186	Between Vantage and Rock Island, Aerial 11/24/03	47.179750	-120.010222
11/24/03	09/23/03	10	194	Between Vantage and Rock Island, Aerial 11/24/03	47.180694	-120.010667
10/23/03	09/23/03	10	204	Between Vantage and Rock Island, Aerial 10/23/03	47.183056	-120.007556
11/24/03	10/21/03	11	1	Between Vantage and Rock Island, Aerial 11/24/03	47.187239	-120.014417
11/24/03	09/11/03	11	195	Between Vantage and Rock Island, Aerial 11/24/03	47.187039	-120.014417
11/24/03	09/23/03	10	176	Below Rock Island Dam, Aerial 11/24/03	47.207139	-120.026389
11/24/03	09/23/03	10	202	Below Rock Island Dam, Aerial 11/24/03	47.208056	-120.026917
10/23/03	09/11/03	12	202	Below Rock Island Dam, Aerial 10/23/03	47.213111	-120.003528
11/24/03	10/27/03	12	4	Below Rock Island Dam, Aerial 11/24/03	47.218056	-120.033250
11/24/03	10/27/03	11	21	Below Rock Island Dam, Aerial 11/24/03	47.221083	-120.010750
10/23/03	09/15/03	12	159	Below Rock Island Dam, Aerial 10/23/03	47.222389	-120.011944
10/23/03	10/14/03	10	2	Below Rock Island Dam, Aerial 11/24/03	47.226306	-120.074583
12/18/03	10/14/03	13	197	Below Rock Island Dam, Aerial 12/18/03	47.247528	-120.093361
11/24/03	10/07/03	13	155	Below Rock Island Dam, Aerial 11/24/03	47.271306	-120.093139
11/24/03	09/08/03	12	200	Below Rock Island Dam, Aerial 11/24/03	47.277378	-120.091511
11/24/03	10/07/03	13	174	Below Rock Island Dam, Aerial 11/24/03	47.277278	-120.091611
11/24/03	09/15/03	12	154	Above Rock Island Dam, Aerial 11/24/03	47.342944	-120.093389
10/22/03	10/14/03	10	10	Rock Island Center, last detection	47.343175	-120.091728
09/27/03	09/23/03	10	186	Rock Island Left, closest to exit	47.343275	-120.091628
10/31/03	10/21/03	11	3	Rock Island Left, closest to exit	47.343375	-120.091528
11/24/03	10/21/03	11	6	Above Rock Island, Aerial 11/24/03	47.343475	-120.091428
10/28/03	10/21/03	11	10	Rock Island Right, closest to exit	47.343575	-120.091328
11/02/03	10/27/03	12	9	Rock Island Right, closest to exit	47.343675	-120.091228
09/23/03	09/16/03	12	167	Rock Island Right, closest to exit	47.343775	-120.091928
10/04/03	09/30/03	13	188	Rock Island Right, closest to exit	47.343075	-120.091828
11/10/03	10/07/03	13	158	Above Rock Island Dam, Truck	47.352528	-120.101528
11/24/03	09/23/03	10	201	Above Rock island Dam, Aerial 11/24/03	47.376278	-120.203500
11/03/03	09/23/03	10	163	Above Rock Island Dam, Aerial 11/03/03	47.380278	-120.244222
10/02/03	09/15/03	11	199	Above Rock Island, Aerial 10/02/03	47.383806	-120.220972
11/24/03	09/16/03	11	164	Below mouth of Wenatchee, Aerial 11/24/03	47.402861	-120.293528
11/19/03	10/14/03	13	189	Wenatchee below Monitor, Truck	47.472250	-120.372250
11/19/03	09/23/03	10	179	Wenatchee below Monitor, Truck	47.477861	-120.388139
11/10/03	10/27/03	11	17	Wenatchee below Monitor, Truck	47.482389	-120.398972
09/25/03	09/16/03	11	155	Monitor, last detection	47.486900	-120.412389
11/10/03	09/16/03	11	157	Monitor, first and only detection	47.487000	-120.412489
11/17/03	10/27/03	12	3	Monitor, last detection	47.486800	-120.412189
09/28/03	09/15/03	12	177	Monitor, last detection	47.486700	-120.412289
11/24/03	11/03/03	12	17	Wenatchee above Monitor, Aerial 11/24/03	47.502556	-120.433500
11/10/03	09/30/03	13	202	Wenatchee above Monitor, Truck	47.503472	-120.426000
11/13/03	09/11/03	12	190	Peshastin Creek, Truck	47.519306	-120.626528

Date Detected	Date Tagged	Chan	Code	Probable Spawning Location	Latitude	Longitude
10/23/03	09/16/03	12	157	Wenatchee between Monitor and Dryden, Aerial 10/23/03	47.523389	-120.460528
11/21/03	09/15/03	12	169	Wenatchee between Monitor and Dryden, Truck	47.523694	-120.459194
11/24/03	09/16/03	12	168	Wenatchee between Monitor and Dryden, Aerial 11/24/03	47.525528	-120.467722
11/21/03	09/23/03	10	174	Wenatchee between Monitor and Dryden, Truck	47.528750	-120.492889
11/21/03	11/03/03	12	13	Wenatchee between Monitor and Dryden, Truck	47.534972	-120.528000
12/12/03	10/21/03	10	15	Wenatchee between Monitor and Dryden, Truck	47.538444	-120.516667
11/10/03	10/21/03	11	11	Wenatchee between Monitor and Dryden, Truck	47.545111	-120.571528
11/24/03	09/23/03	10	200	Icicle River Side Channel, Aerial 11/24/03	47.550861	-120.674111
10/02/03	09/15/03	12	193	Peshastin Creek, Aerial 10/02/03	47.552111	-120.604444
11/24/03	11/03/03	12	12	Icicle River Side Channel, Aerial 11/24/03	47.552861	-120.671167
10/02/03	09/15/03	11	180	Wenatchee between Monitor and Dryden, Aerial 10/02/03	47.552889	-120.573056
10/23/03	09/16/03	12	165	Peshastin Creek, Aerial 10/23/03	47.555222	-120.600028
11/10/03	10/27/03	11	20	Mouth of Peshastin Creek, Truck	47.555472	-120.574361
11/24/03	09/15/03	11	196	Icicle River Side Channel, Aerial 11/24/03	47.556139	-120.669889
10/02/03	09/15/03	12	195	Mouth of Peshastin Creek, Aerial 10/02/03	47.556194	-120.574750
10/23/03	09/16/03	11	170	Peshastin Creek, Aerial 10/23/03	47.556556	-120.595861
11/03/03	09/30/03	13	176	Icicle River Side Channel, Aerial 11/03/03	47.557861	-120.669222
11/24/03	11/06/03	12	15	Icicle River, Aerial 11/24/03	47.558111	-120.673917
11/24/03	09/15/03	12	160	Icicle River, Aerial 11/24/03	47.558750	-120.673278
10/23/03	09/30/03	13	173	Icicle River, Aerial 10/23/03	47.559139	-120.671167
11/24/03	09/30/03	10	157	Icicle River, Aerial 11/24/03	47.561400	-120.670500
11/24/03	09/23/03	10	159	Icicle River, Truck	47.561500	-120.670500
11/05/03	10/14/03	10	1	Icicle River, Raft	47.567733	-120.664872
10/23/03	09/30/03	10	166	Icicle River, Raft	47.567633	-120.664772
11/05/03	09/16/03	11	161	Icicle River, Raft	47.567533	-120.664672
11/24/03	10/27/03	12	11	Icicle River, Aerial 11/24/03	47.567433	-120.664572
10/23/03	09/11/03	12	196	Icicle River, Raft	47.567333	-120.664472
10/23/03	09/30/03	13	195	Icicle River, Raft	47.567833	-120.664372
11/24/03	09/30/03	13	196	Icicle River, Aerial 11/24/03	47.567933	-120.664972
10/03/03	09/15/03	12	171	Wenatchee between Peshastin and Icicle, Truck	47.571517	-120.603917
11/03/03	10/07/03	13	164	Icicle River, Aerial 11/03/03	47.572722	-120.663472
11/03/03	09/15/03	12	175	Icicle River, Aerial 11/03/03	47.578167	-120.663167
11/03/03	09/16/03	11	169	Bottom of Tumwater Canyon, Aerial 11/03/03	47.583444	-120.675167
10/20/03	09/23/03	10	172	Bottom of Tumwater Canyon, Truck	47.586830	-120.686450
11/24/03	10/21/03	11	2	Below mouth of Icicle, Aerial 11/24/03	47.587278	-120.665083
12/03/03	09/16/03	11	154	Nason Creek Campground, Truck 12/03/03	47.803639	-120.712667
09/21/03	09/16/03	12	155	Mouth of Methow, Aerial 12/18/03	47.944389	-119.870472
12/02/03	10/27/03	12	10	Below WNFH, John mobile	48.207986	-120.117314
11/03/03	09/16/03	12	161	Below WNFH, John mobile	48.311614	-120.067422
11/24/03	09/15/03	12	189	WNFH, John mobile	48.475117	-120.184544
11/24/03	10/30/03	11	205	Mouth of Wenatchee Aerial 11/24/03	47.433639	-120.307639
11/24/03	09/30/03	10	209	Icicle River side channel, Aerial 11/24/03	47.556139	-120.669889
11/21/03	10/08/03	13	210	Peshastin Creek, Truck	47.556694	-120.575306
11/03/03	09/30/03	13	205	Icicle River, Aerial 11/03/03	47.562389	-120.668028
10/17/03	10/08/03	10	206	Icicle River, Truck	47.569550	-120.661050
10/17/03	10/06/03	13	209	Icicle River, Truck	47.569350	-120.661050

Date Detected	Date Tagged	Chan	Code	Probable Spawning Location	Latitude	Longitude
11/24/03	10/16/03	13	207	Icicle River, Aerial 11/24/03	47.570972	-120.662722
12/18/03	10/16/03	12	208	Icicle River, Aerial 12/18/03	47.575694	-120.663639
11/24/03	09/29/03	11	209	Wenatchee above Icicle, Aerial 11/24/03	47.575750	-120.668889
11/14/03	10/20/03	11	204	Lower Tumwater Canyon, Truck	47.582528	-120.696667
11/03/03	10/30/03	10	207	Lower Tumwater Canyon, Aerial 11/03/03	47.583472	-120.694972
10/20/03	10/15/03	12	205	Lower Tumwater Canyon, Truck	47.584750	-120.692850
10/20/03	10/01/03	11	211	Lower Tumwater Canyon, Truck	47.586833	-120.686450
11/03/03	10/20/03	10	211	Lower Tumwater Canyon, Aerial 11/03/03	47.586889	-120.682806
12/03/03	10/20/03	13	206	Lower Tumwater Canyon, Truck 12/03/03	47.591139	-120.710222
11/14/03	10/30/03	12	207	Lower Tumwater Canyon, Truck	47.593222	-120.711972
12/09/03	10/15/03	12	204	Lower Tumwater Canyon, Truck 12/09/03	47.594917	-120.712889
10/17/03	10/09/03	12	210	Below Tumwater Dam, Truck	47.608167	-120.717200
12/09/03	10/15/03	10	205	Below Tumwater Dam, Truck 12/09/03	47.610722	-120.718444
11/08/03	09/23/03	11	207	Lake Yolanda, Tumwater receiver	47.616136	-120.722097
11/03/03	10/30/03	11	210	Lake Yolanda, Tumwater receiver	47.616250	-120.722722
11/14/03	10/20/03	11	206	Lake Yolanda, Truck	47.617361	-120.723028
10/02/03	09/30/03	10	208	Lake Yolanda, Truck	47.617733	-120.723400
11/14/03	10/16/03	10	210	Lake Yolanda, Truck	47.619194	-120.724139
11/03/03	10/09/03	12	206	Above Lake Yolanda, Aerial 11/03/03	47.627889	-120.727556
12/03/03	10/16/03	12	209	Between Dam and Bridge, Truck 12/03/03	47.652167	-120.725639
11/24/03	10/15/03	11	208	Below Tumwater Bridge, Aerial 11/24/03	47.669889	-120.736806
11/14/03	10/15/03	13	211	Below Tumwater Bridge, Truck	47.670028	-120.735639
12/03/03	10/08/03	13	208	Below Tumwater Bridge, Truck	47.674889	-120.734389
12/18/03	10/08/03	12	211	Beaver Creek above pond, Aerial 12/18/03	47.770333	-120.655778
10/24/03	10/06/03	11	187	WNFH, recovered	48.474225	-120.188525
10/27/03	10/07/03	12	183	WNFH, recovered	48.474125	-120.188325
10/28/03	10/07/03	12	184	WNFH, recovered	48.474325	-120.188425
11/03/03	10/23/03	10	18	Lower Methow, Truck	48.049358	-119.923389
11/03/03	10/01/03	11	181	Lower Methow, Aerial 11/03/03	47.977556	-119.880278
11/03/03	10/07/03	12	187	WNFH, recovered	48.474125	-120.188425
11/05/03	10/07/03	10	187	Below Carlton, Truck	48.152267	-120.059911
11/05/03	10/13/03	13	190	Lower Methow, John mobile	47.964728	-119.878497
11/10/03	10/29/03	10	16	Chelan Falls, Truck	47.806797	-119.986447
11/10/03	10/29/03	10	20	Chelan Falls, Truck	47.820900	-119.973694
11/12/03	10/14/03	13	200	Lower Methow, John mobile	47.984067	-119.886722
11/13/03	09/29/03	11	162	Okanagon, Truck	48.109247	-119.760444
11/24/03	10/29/03	10	23	Between Entiat and Chelan, Aerial 11/24/03	47.774361	-120.042361
11/24/03	10/13/03	13	191	Above Carlton, recovered	48.293967	-120.063139
11/24/03	10/29/03	13	204	Below Carlton, Truck	48.207217	-120.115222
12/03/03	10/29/03	10	21	Below Carlton, Truck	48.132186	-120.002283
12/03/03	09/29/03	11	186	Okanagon, Truck	48.004386	-119.662864
12/12/03	10/29/03	10	25	Mouth of Entiat, Truck 12/12/06	47.643861	-120.216667
10/22/03	09/11/03	13	166	Long Pine, caught	45.686214	-121.270108
11/05/03	09/11/03	10	199	Icicle River, Raft	47.550861	-120.674111
11/14/03	09/11/03	10	198	Wallula, found	46.185981	-119.018656
11/24/03	09/07/03	11	185	Mouth of Wenatchee, Aerial 11/24/03	47.458028	-120.331556

Appendix F: Radio-Telemetry Tagging Temperature Data

Appendix F
Radio-Telemetry Tagging Temperature Data
At Priest Rapids Dam

	Temp (C)		
Day/Year	2001	2002	2003
08/26/03	18.5	19.8	20.3
08/27/03	18.8	19.9	19.9
08/28/03	18.7	20.2	19.9
08/29/03	18.8	20.2	20.0
08/30/03	19.2	20.1	20.0
08/31/03	19.3	20.0	20.1
09/01/03	19.2	20.0	19.9
09/02/03	19.1	20.1	20.2
09/03/03	19.0	19.7	20.3
09/04/03	19.0	19.4	20.7
09/05/03	18.8	19.5	20.9
09/06/03	18.3	19.4	21.0
09/07/03	17.9	19.2	20.7
09/08/03	17.9	19.0	20.5
09/09/03	18.1	19.1	20.2
09/10/03	18.5	19.2	19.7
09/11/03	18.7	19.2	19.7
09/12/03	18.7	19.5	19.8
09/13/03	18.9	19.4	19.4
09/14/03	19.1	19.6	19.5
09/15/03	19.2	N/A	19.2
09/16/03	19.5	19.3	18.7
09/17/03	19.3	19.1	18.2
09/18/03	19.0	18.7	18.2
09/19/03	18.5	18.6	18.2
09/20/03	18.5	18.6	18.0
09/21/03	18.7	18.7	18.0
09/22/03	18.8	18.7	18.1
09/23/03	18.9	18.6	18.2
09/24/03	18.8	18.6	18.4
09/25/03	18.8	18.6	18.4
09/26/03	18.5	18.4	18.3
09/27/03	18.3	18.1	18.3
09/28/03	18.2	18.1	18.5
09/29/03	18.4	18.1	18.7
09/30/03	18.3	17.6	18.9
10/01/03	18.4	17.2	19.0
10/02/03	18.3	17.1	18.9
10/03/03	18.2	17.0	19.0

	Temp (C)		
Day/Year	2001	2002	2003
10/04/03	18.0	17.1	19.0
10/05/03	17.8	16.9	19.0
10/06/03	17.7	16.8	19.1
10/07/03	17.2	16.8	18.9
10/08/03	17.0	N/A	18.6
10/09/03	16.5	N/A	18.3
10/10/03	16.2	N/A	18.0
10/11/03	15.9	N/A	17.8
10/12/03	15.8	N/A	17.3
10/13/03	15.7	N/A	17.0
10/14/03	15.9	N/A	16.9
10/15/03	15.6	N/A	16.7
10/16/03	15.5	N/A	16.3
10/17/03	15.4	N/A	16.1
10/18/03	15.1	N/A	16.1
10/19/03	14.9	N/A	16.0
10/20/03	14.8	N/A	16.0
10/21/03	14.7	N/A	16.2
10/22/03	14.6	N/A	16.2
10/23/03	14.1	N/A	16.0
10/24/03	14.1	N/A	15.8
10/25/03	14.2	N/A	15.6
10/26/03	14.1	N/A	15.4
10/27/03	14.1	N/A	15.2
10/28/03	13.8	N/A	15.2
10/29/03	13.5	N/A	14.8
10/30/03	13.5	N/A	14.3
10/31/03	13.6	N/A	13.8
11/01/03	13.7	N/A	13.5
11/02/03	13.6	N/A	13.2
11/03/03	13.5	N/A	12.8
11/04/03	13.4	N/A	12.7
11/05/03	13.3	N/A	12.5
11/06/03	13.1	N/A	12.1
11/07/03	13.1	N/A	12.1
11/08/03	12.9	N/A	11.9
11/09/03	12.7	N/A	11.7
11/10/03	12.6	N/A	11.4
11/11/03	12.4	N/A	11.6
11/12/03	12.4	N/A	11.6

Appendix G: Coho Spawning Ground Surveys Records, 2003

APPENDIX G: 2003 COHO SPAWINING GROUND SURVEYS

Water Body	Section	River Kilometer	Date	New Redds	Live Fish	Dead Fish
Icicle	**I3**					
	Side-channel Head gate to Hatchery	4.7 – 4.5	15-Oct	6	5	0
			23-Oct	53	80	0
			29-Oct	10	15	11
			6-Nov	3	6	14
			12-Nov	27	11	2
			20-Nov	UNABLE TO SURVEY		
			2-Dec	2	10	137
			10-Dec	18	22	56
			15-Dec	5	5	1
	I2					
	Hatchery to Bridge	4.5 – 3.7	15-Oct	6	5	0
			23-Oct	4	9	0
			29-Oct	0	17	1
			6-Nov	40	18	16
			12-Nov	1	50	15
			20-Nov	UNABLE TO SURVEY		
			5-Dec	7	4	10
			10-Dec	0	7	0
			17-Dec	0	1	3
	I1					
	Bridge to Mouth	3.7 - 0.0	15-Oct	7	6	0
			23-Oct	11	18	0
			29-Oct	11	15	6
			6-Nov	140	42	44
			12-Nov	88	44	29
			20-Nov	UNABLE TO SURVEY		
			5-Dec	60	22	5
			10-Dec	3	10	9
			17-Dec	5	2	8
	Total			**507**	**424**	**367**

APPENDIX G: 2003 COHO SPAWINING GROUND SURVEYS CONT'

Water Body	Section	River Kilometer	Date	New Redds	Live Fish	Dead Fish
Nason Creek	**N5**					
	Upper RR. Bridge to Whitepine Creek	25.4-24.8	11-Dec	UNABLE TO SURVEY		
	Whitepine Creek to Camp	24.8-22.8	11-Dec	UNABLE TO SURVEY		
	Camp to Lower RR Bridge	22.8-21.2	11-Dec	UNABLE TO SURVEY		
	Lower RR Bridge to Rayrock	21.2-20.9	7-Nov	1	0	1
			21-Nov	0	0	0
			11-Dec	UNABLE TO SURVEY		
	N4					
	Rayrock to Merrit Bridge	20.9-18.3	7-Nov	0	0	0
			14-Nov	0	0	1
			25-Nov	UNABLE TO SURVEY		
			5-Dec	0	0	0
			11-Dec	0	0	0
	Merrit Bridge to Powerlines	18.3-16.4	7-Nov	0	0	1
			14-Nov	0	0	0
			25-Nov	UNABLE TO SURVEY		
			5-Dec	0	0	0
			11-Dec	0	0	0
	Powerlines to Wood bridge	16.4-13.3	7-Nov	0	0	0
			14-Nov	0	0	0
			25-Nov	UNABLE TO SURVEY		
			5-Dec	0	0	0
			11-Dec	0	0	0
	N3					
			24-Oct	0	0	0
	Wood bridge to 1st Powerline	13.3-12.6	31-Oct	0	0	0
			7-Nov	0	0	0
			25-Nov	UNABLE TO SURVEY		
			5-Dec	0	0	0
			11-Dec	0	0	0

Nason Creek Con't	1st Powerline to Butcher Ck Rd. Bridge	12.6-11.4	24-Oct	0	0	0
			31-Oct	0	0	0
			7-Nov	0	0	0
			25-Nov	UNABLE TO SURVEY		
			5-Dec	0	0	0
			11-Dec	0	0	0
	Butcher Ck Rd. Bridge to High Volt. Line 1	11.4-10.3	24-Oct	1	1	0
			31-Oct	0	0	0
			7-Nov	0	0	0
			25-Nov	UNABLE TO SURVEY		
			5-Dec	0	0	0
			11-Dec	0	0	0
	N2					
	High Volt. Line 1 to High Volt. Line 2	10.3-9.5	24-Oct	0	0	0
			31-Oct	0	0	0
			7-Nov	0	0	0
			25-Nov	UNABLE TO SURVEY		
			5-Dec	0	0	0
			11-Dec	0	0	0
	High Volt Line 2 to	9.5-6.3	14-Nov	0	0	1
	Kahler Ck. Bridge		25-Nov	UNABLE TO SURVEY		
	N1					
	Kahler Ck. Bridge to Fishing Pond	6.3-5.5	16-Oct	0	0	0
			24-Oct	0	0	0
			31-Oct	0	0	0
			7-Nov	0	0	0
			14-Nov	0	0	0
			25-Nov	UNABLE TO SURVEY		
			1-Dec	0	0	0
			11-Dec	0	0	0
	Fishing Pond to Campground	5.5-1.3	16-Oct	0	0	0
			24-Oct	0	0	0
			31-Oct	0	0	0
			7-Nov	0	0	1
			14-Nov	0	0	0
			25-Nov	UNABLE TO SURVEY		
			1-Dec	2	0	0
			11-Dec	1	0	0

Nason Creek Con't	Campground to Mouth	1.3-0.0	16-Oct	0	0	0
			24-Oct	0	0	0
			31-Oct	0	0	0
			7-Nov	0	0	0
			14-Nov	0	0	0
			25-Nov	UNABLE TO SURVEY		
			1-Dec	0	0	0
			11-Dec	0	0	0
	Total			**6**	**1**	**5**

APPENDIX G: 2003 COHO SPAWINING GROUND SURVEYS CONT'

Water Body	Section	River Kilometer	Date	New Redds	Live Fish	Dead Fish
Wenatchee River	**W8**					
	Lake Wenatchee to Plain Bridge	86.3-xx	21-Nov	0	0	0
			4-Dec	0	0	0
	Plain Bridge to Tumwater Bridge	xx-57.3	2-Nov	0	2	0
			5-Dec	0	0	0
	W7					
	Tumwater Bridge to Icicle Road Bridge	57.3-42.5	8-Dec	0	0	0
			12-Dec	0	0	0
	W6					
	Icicle Road Bridge to Leavenworth Bridge	42.5-38.5	13-Nov	30	10	8
	W5					
	Leavenworth Bridge to Dryden Dam	38.5-28.2	28-Oct	1	2	1
	W4					
	Dryden Dam to Lower Cashmere Br.	28.2-15.3	13-Nov	5	6	0
			23-Dec	1	0	0
	W3					
	Lower Cashmere Br. to Monitor Bridge	15.3-9.3	10-Nov	4	0	0
			22-Dec	5	0	0
	W2					
	Monitor Bridge to Sleepy Hollow Bridge	9.3-5.6	7-Nov	22	7	0
			13-Nov	5	0	0
	W1					
	Sleepy Hollow Bridge to Mouth	5.6-0.0	24-Dec	2	0	0
	Total			75	27	9

APPENDIX G: 2003 COHO SPAWINING GROUND SURVEYS CONT'

Water Body	Section	River Kilometer	Date	New Redds	Live Fish	Dead Fish
Chiwaukum Creek	Trail mile 1.0 to Mouth	1.6-0.0	12-Dec	0	0	0
Peshastin Creek	Mile 4.0 to Mouth	6.4-0.0	1-Nov	3	5	0
			12-Nov	2	0	11
			14-Nov	7	4	3
			11-Dec	1	0	2
			30-Dec	0	0	0
Mission Creek	Brender Creek to Mouth	3.2-0.0	10-Nov	5	5	0
			10-Dec	18	0	7
			16-Dec	0	0	2
Brender Creek	100 meters Upstream To Mouth	0.1-0.0	10-Dec	1	0	0
Chiwawa River	Hatchery to Mouth	0.8-0.0	4-Dec	0	0	0
Beaver Creek	Beaver Creek Acc. Pd. to Mouth	2.4-0.0	Nov-23	0	0	0
	Total			**37**	**14**	**25**

Appendix H: Release-To-McNary Dam Survival Indices for Year 2003 Releases into the Wenatchee and Methow Rivers

International Statistical Training
and Technical Services
712 12th Street
Oregon City, Oregon 97045
United States
Voice: (503) 650-5035
FAX: (503) 657-1955
e-mail: intstats@bctonline.com

McNary-Passage Time and Release-to-McNary Survival Index of 2003 Releases into the Wenatchee Basin

A release's daily passage estimate at McNary is based on number of the release's PIT-tagged fish that are detected at McNary and the estimate of McNary's detection rate. The detection rate is the proportion of fish actually passing McNary that are detected within McNary's bypass system. The estimate of daily passage is given in Equation 1.

Equation 1.

$$\text{Estimated Number of Released Fish Passing McNary on given Day} = \frac{(\text{Number of Fish Detected at McNary on given Day}) - (\text{Number of Detected Fish Removed on given Day})}{\text{McNary Detection Rate associated with given Day}} + \text{Number of Detected Fish Removed on given Day}$$

The estimate of the detection rate is essentially that given in Equation 2.

Equation 2.

$$\text{McNary Detection Efficieny} = \frac{\text{Number of Joint Detections at NcNary and Downstream Dam}}{\text{Total Number of Detections at Downstream Dam}}$$

Since the detection rate is based on downstream detections, it applies to only fish that actually pass McNary, not to those that are removed for transportation or that are sampled and sacrificed for research purposes. This is why that the removed fish are not expanded in Equation 1. The detection rates used are pooled daily detection-rate estimates over contiguous days among which the daily estimates are relatively homogeneous. The methods of estimation of daily passages and detection rates and the identification of detection-rate strata are described in Appendix A. The daily estimates, statistical analysis summaries, and strata estimates of detection rates are summarized in Appendix B. The detections and detection efficiencies leading to the passage estimates and the daily passage estimates are given in Appendix C.

A release's survival index is the estimated total passage (daily passage estimates added over passage days) divided by the number of tagged fish, Equation 3. Therefore, the survival index is an estimate of survival from date of tagging to date of passage detection at McNary. Survival-index estimates are given in Appendix D. The estimates are referred to as indices because there are biases associated with estimates. These biases are discussed in Appendix A along with discussions of the estimation procedures.

Equation 3.

$$\text{Smolt-to-Smolt Survival Index to McNary} = \frac{\sum_{\text{Days}} \text{Estimated Number of tagged Fish passing McNary on given Day}}{\text{Number of Fish tagged}}$$

Table 1 presents the estimates of the survival index and the mean travel time to McNary along with date of release and the river mile (the number of miles from the release point to the confluence of the Wenatchee River with the Columbia River. The mean travel time is the weighted mean date of detection minus the date of release. The weight is the estimated daily passage.

Table 1. Tagging-to-McNary Survival-Index and Release-to-McNary Mean Travel Time for the 2003 Coho Release Sites in the Wenatchee Basins

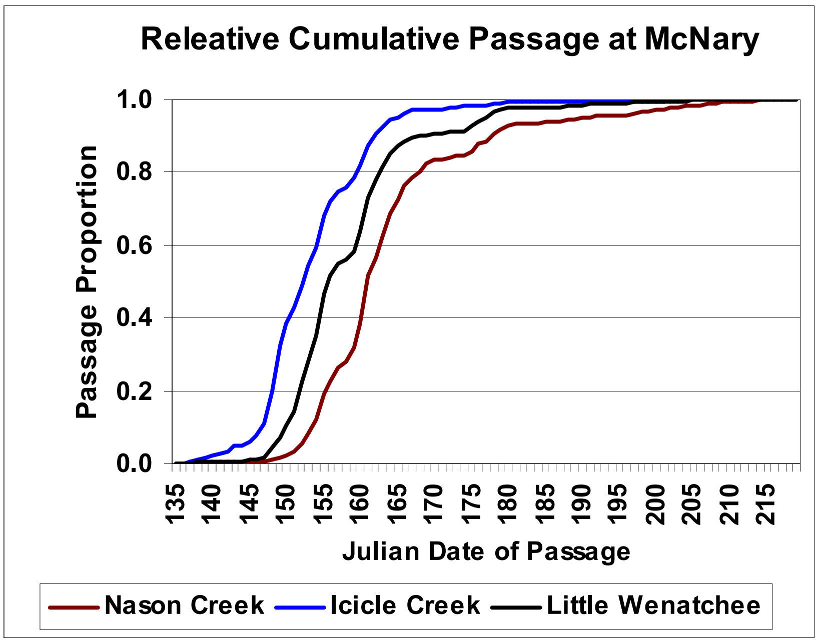
Acclimation Site	Release Site	Release River Mile from Columbia	Release Date	Number Released	Tagging-to-McNary-Detection Survival-Index (proportion of release)	Release-to-McNary Travel-Time (in days)
Two Rivers	Little Wenatchee	60.1	30-Apr-03	8984	0.2039	38.3
Butcher Creek	Nason Creek	61.8	1-May-03	7966	0.3719	42.9
Dam 5	Icicle Creek	28.4	23-Apr-03	7981	0.6282	40.4

There was no formal effort to determine whether there were statistically significant differences among the survival indices or among the travel-time means because there were no true replicated releases at each release site. There was more than one tagging file for each release (two files for Little Wenatchee, four for Nason Creek, and two for Icicle Creek releases). However, the fish within a release's tagging files were apparently reared and released together; therefore the tagging files within a release did not represent independent release groups.

The Table 1 releases are ranked by survival index. The lowest survival-index estimate is associated with Little Wenatchee release. Even though the river mile and the date of this release are almost identical to those of the release at Nason Creek, the Little Wenatchee release is made upstream of a lake and the Nason Creek release is made downstream of that lake. Keely Murdoch suggested that mortality in the lake reach may explain the difference between the Little Wenatchee and Nason Creek survival-index indices (Table 1). The Icicle Creek release has, by far, the highest survival-index estimate, and Icicle Creek is by far the release site nearest to McNary Dam.

Travel time means do not differ greatly among the release sites. The releases' cumulative relatives passages are separated throughout most the outmigration (Figure 1).

Figure 1. Cumulative relative McNary passage for the 2003 Coho Release Sites in the Wenatchee Basin



The above are informal observations. I note here that I did an analysis using the individual tagging files as if they were independent releases. The analysis procedures for survival indices utilized logistic[1] analysis of variation. If the tagging files contained fish homogeneously treated over tagging files within the three release groups, then the error mean deviance (logistic regression measure equivalent of the error mean square from traditional linear regression) would be expected to equal 1, the expected value under a binomial distribution. It turns out that the estimated mean deviance is more than 6 times what would expected (mean deviance = 6.7, Appendix D's Table D.2). One possible reason for this could be the handling of the fish at the time of tagging resulted in differential post-tagging, pre-release mortality among tag groups within releases. Another possibility is that the different tagged groups within releases were independent releases. If

[1] Logistic analysis of variation involved the logistic regression of individual tagging- file survival-index estimates on indicator variables for the release sties. The procedure assumes that the underlying distribution is a binomial distribution. Standard errors generated were adjusted for a measure of over-dispersion by multiplying assumed binomially-distribution stand errors by the square root of the error mean deviance which is analogous to the residual least squares regression error mean square.

the latter is the case for all releases, then statistical comparisons might be possible using the approximate t-statistic in Equation 4.a.

Equation 4.a.

$$t(\text{mean survival - index difference}) = \frac{\text{mean logit (i) - mean logit (j)}}{\sqrt{SE^2[\text{logit(i)}] + SE^2[\text{logit(j)}]}}$$

The logit means and standard errors (SE) in the equation are those given in Appendix D's Table D.2, the i and j in the equation representing two of the three different release sites. The degrees of freedom associated with the t-statistic is DF = 5, also given in Table D.2 of Appendix D. Individual tagging-file survival-index estimates are given toward the bottom of Appendix D's Table D.1.

If the separate tagging files within releases can be treated as independent releases, then the t-statistic in Equation 4.b could be used to compare release-site mean travel times.

Equation 4.b.

$$t(\text{mean travel - time difference}) = \frac{\text{Travel Time Mean (i) - Travel Time Mean (j)}}{\sqrt{SE^2(i) + SE^2(j)}}$$

The means and standard errors in the equation are those given in Appendix C's Table C.3, the t-statistic again being based on 5 degrees of freedom. Individual tagging-file mean travel times are given in Appendix C's Table C.2.

Appendix A. Survival Index

The estimated smolt-to-smolt survival index to McNary Dam (McNary) is given in Equation A.1:

Equation A.1

$$\text{Smolt - to - Smolt Survival Index to McNary} = \frac{\sum_{\text{Days}} \text{Estimated Number of Released (or Tagged) Fish Passing McNary on given Day}}{\text{Number of Fish Released (or Tagged)}}$$

If PIT-tagged fish are actually enumerated (interrogated and tallied) at time of release, and these fish are the only ones enumerated at McNary for passage estimation, then Equation A.1 estimates in-stream survival from release point to McNary passage. If the number of fish tagged is used as a base instead of the released number, then the survival-index is an estimate of survival from time of tagging to McNary passage, in which case Equation A.1 is affected by both pre-release mortality and in-stream mortality. Subsequent equations will denote release-to-McNary-passage survival, but the same procedures can be applied to time-of-tagging-to-McNary-passage survival.

Equation A.1's numerator's daily passage estimate is given in Equation A.2:

Equation A.2

$$\text{Estimated Number of Released Fish Passing McNary on given Day} = \frac{\text{(Number of Fish Detected at McNary on given Day) - (Number of Detected Fish Removed on given Day)}}{\text{McNary Detection Rate associated with given Day}} + \text{Number of Detected Fish Removed on given Day}$$

The McNary detection efficiency is the proportion of those fish passing McNary that are detected within the McNary bypass system excluding those removed from at McNary and not returned to the bypass system (e.g., transported fish or fish sampled and sacrificed).

It should be noted that all of the PIT-tagged releases into a given subbasin are used to estimate the detection rates. The resulting detection rates are applied to individual releases or groups of releases within the subbasin. The underlying assumption is that detection rates at McNary are independent of the time and place of release into the subbasin. Separate McNary detection rates are estimated for releases into the Yakima subbasin and for releases into the upper Columbia tributaries (e.g., Wenatchee and Methow subbasins) because these fish would enter the McNary pool at different points and may not mix well by the time they reach the McNary pool.

The McNary detection efficiency is not constant over days, and fish from a release may pass McNary over a period within which the detection efficiency varies. In this paper, groups of contiguous days are identified within which the daily McNary detection efficiencies are relatively homogeneous. These groups of days are referred to here as strata, and detection efficiencies are estimated for each of these strata by pooling the detections over days within the stratum. The number of a release's fish detected at McNary Dam on a given day is divided (expanded) by detection efficiency for the stratum containing the day to obtain the estimated passage given earlier in Equation A.2.

The detection efficiency (Equation A.3 below) is based on detections made at dams downstream of McNary and is estimated for the stratum by dividing the number of fish jointly detected at McNary and the downstream dams by the total detections at the downstream dam within the stratum

Equation A.3

$$\text{Stratum's McNary Detection Efficieny} = \frac{\text{Stratum's Number of Joint Detections at NcNary and Downstream Dam}}{\text{Stratum's Total Number of Detections at Downstream Dam}}$$

Initially, detection rates are estimated for each day of McNary passage. There are two downstream detection sites, John Day Dam (John Day) and Bonneville Dam (Bonneville). In some recent years, experiments have been conducted at John Day that varied the proportion of flow spilled during the day relative to the proportion spilled during the night. To meet electric power needs, Bonneville's spill was also varied within twenty-four periods. Given this situation, it is deemed more appropriate to pool individual John Day and Bonneville Dam-based estimates. This is effectively "sampling with replacement" for which the same fish will enter into the joint McNary-downstream-site tally twice or into the downstream tally twice when detected at both John Day and Bonneville.

Detection efficiency Estimation: Benjamin Sandford (NOAA Fisheries, Pasco Field Station, Washington) and Steven Smith (NOAA Fisheries, Seattle) recommended the general method of estimating daily detection efficiencies. The method is conceptually presented below:

a. For each downstream dam, joint McNary and downstream detections are cross-tabulated by McNary date of first detection and by down-stream-dam first date of detection [Table A.1)].

b. Within each downstream dam's detection date, the relative distribution of joint counts over McNary detection dates is estimated [Table A.2)].

c. The resulting relative distribution frequencies are then multiplied by the total downstream dam's detections for the corresponding downstream-detection date [Table A.3)].

d. Once this is done for each downstream dam's detection date, the estimated total downstream detections allocated to a given McNary detection date are added over downstream-dam detection dates [Table A.3), far-right-hand column]. This gives the estimated total downstream-dam detections that pass McNary on the given McNary date.

e. The total joint detections on a given McNary detection date from Table A.1) is then divided by the total from Table A.3) to estimate that date's McNary detection efficiency [Table A.4)].

Actually, before this last step, Table A.1)'s numbers are pooled over John Day and Bonneville Dams, and the same is done for Table A.3)'s downstream estimated total counts[2].

Daily detection efficiencies are then stratified into contiguous days of relatively homogeneous detection efficiencies, and the daily detection-efficiency estimates are pooled over days within the strata. The strata's beginning and ending dates are chosen in a manner such that the variation among daily detection efficiencies within strata is minimized and the detection-rate variation among strata is maximized. This is done using step-wise logistic regression partitioning based on all possible partitionings. In the first step, the partitioning that minimized the variation among daily detection efficiencies within-strata is selected. Then, the second partitioning is selected in a similar fashion within the two groups formed by first partitioning. The process is continued as long as the detection efficiencies of the strata created by the step's partitioning significantly differ at the 10% significance level (Type 1 error p estimate ≤ 0.1).

There are two exceptions to this process:

a. Separate John-Day-detection-based and Bonneville-detection-based estimates of McNary detection efficiencies are also made for each stratum; and, if the Bonneville-based estimate in one of the created strata is greater (or alternatively less) than that in another adjacent stratum, but the John-Day-based McNary detection efficiency in the one is less (or alternatively greater) than that in the other, then the partitioning is not accepted.

b. If the joint McNary and down-stream detections, pooled over Bonneville and John Day, in either of the two strata resulting from the partitioning resulted in less than 20 joint detections, the partitioning is not accepted.

[2] This was done for all years, except that Bonneville Powerhouse 1 was omitted from the 2001 detection efficiency estimation. There were few Powerhouse 1 detections of fish in 2001 because Powerhouse 1 was essentially offline because of the record low flows in 2001.

Table A. Conceptual method of estimating detection efficiencies

1) Joint McNary (McN), Downstream-Site (D.S.) Counts by McN and D.S. Dates

McNary Dam Date (Julian)	n(McNary Dam Date, DownstreamSite Dam) [n(McN,D.S.)]						TOTAL
	Downstream Site Date (Julian)						
	…	100	101	**102**	103	…	
90	…	…	…	**…**	…	…	**n(90,.)**
…	…	…	…	**…**	…	…	**…**
94	…	n(94,100)	n(94,101)	**0**	0	…	**n(94,.)**
95	…	n(95,100)	n(95,101)	**n(95,102)**	0	…	**n(95,.)**
96	…	0	n(96,101)	**n(96,102)**	n(96,103)	…	**n(96,.)**
97	…	0	0	**n(97,102)**	n(97,103)	…	**n(97,.)**
98	…	0	0	**n(98,102)**	n(98,103)	…	**n(98,.)**
99	…	0	0	**0**	0	…	**n(99,.)**
…	…	…	…	**…**	…	…	**…**
200	…	…	…	**…**	…	…	**n(200,.)**
TOTAL		n(.,100)	n(.,101)	**n(.,102)**		…	

2) For each Downstream Site Date, Estimate Distribution of McNary Date Contributions

McNary Dam Date (Julian)	p(McN,D.S.) = n(McN,D.S.)/n(D.S.) [n's from Table 1)]					
	Downstream Site Date (Julian)					
	…	100	101	**102**	103	…
90	…	…	…	**…**	…	…
…	…	…	…	**…**	…	…
94	…	p(94,100)	p(94,101)	**0**	0	…
95	…	p(95,100)	p(95,101)	**p(95,102)= n(95,102)/n(.,102)**	0	…
96	…	0	p(96,101)	**p(96,102)= n(96,102)/n(.,102)**	n(96,103)	…
97	…	0	0	**p(97,102)= n(97,102)/n(.,102)**	n(97,103)	…
98	…	0	0	**p(98,102)= n(98,102)/n(.,102)**	n(98,103)	…
99	…	0	0	**0**	0	…
…	…	…	…	**…**	…	…
200	…	…	…	**…**	…	…
TOTAL		1	1	**1**	1	

Table A. Conceptual method of estimating detection efficiencies (continued)

3) Allocate Daily Lower Site Counts [N(D.S.)] over McNary Dates using above distributions and add over Lower Dam Dates within McNary Dates [p's from Table 2)]

McNary Dam Date (Julian)	N'(McN,D.S.) = p(McN,D.S.)*N(D.S.)						McNary Dam TOTAL N'(McN,.)
	Downstream Site Date (Julian)						
	…	100	101	102	103	…	
		N(100)	N(101)	Lower Dam Detections = N(102)	N(103)		
90	…	…	…	…	…	…	N'(90,.)
…	…	…	…	…	…	…	…
94	…	N'(94,100)	N'(94,101)	0	0	…	N'(94,.)
95	…	N'(95,100)	N'(95,101)	N'(95,102)= p(95,102)*N(.,102)	0	…	N'(95,.)
96	…	0	N'(96,101)	N'(96,102)= p(96,102)*N(.,102)	N'(96,103)	…	N'(96,.)
97	…	0	0	N'(97,102)= p(97,102)*N(.,102	N'(97,103)	…	N'(97,.)
98	…	0	0	N'(98,102)= p(98,102)*N(.,102)	N'(98,103)	…	N'(98,.)
99	…	0	0	0	0	…	N'(99,.)
…	…	…	…	…	…	…	
200	…	…	…	…	…	…	
TOTAL		N(100)	N(101)	N(102)	N(103)	…	

4) Use McN-Date Joint (Table 1) and total to compute McN Detection Rates

McNary Dam Date (Julian)	Table 1) n Total	Table 3) N' Total	Estimated Detection Rate, D.R. = n/N'
90	n(90,.)	N'(90,.)	D.R.(90) = n(90,.)/N'(90,.)
…	…	…	…
94	n(94,.)	N'(94,.)	D.R.(94) = n(94,.)/N'(94,.)
95	n(95,.)	N'(95,.)	D.R.(95) = n(95,.)/N'(95,.)
96	n(96,.)	N'(96,.)	D.R.(96) = n(96,.)/N'(96,.)
97	n(97,.)	N'(97,.)	D.R.(97) = n(97,.)/N'(97,.)
98	n(98,.)	N'(98,.)	D.R.(98) = n(98,.)/N'(98,.)
99	n(99,.)	N'(99,.)	D.R.(99) = n(99,.)/N'(99,.)
…	…	…	..
200	n(200,.)	N'(200,.)	D.R.(200) = n(200,.)/N'(200,.)

On completion of the stepwise process, each partitioning is shifted at one-day increments between the two adjacent partitionings to see if the among-day within-stratum variation could be further reduced. If so, the partitioning that resulted in the greatest significant reduction in the variation in among-day within-stratum detection rates is selected, again subject to the exceptions listed above.

There are instances for which downstream dam dates have total counts but have no joint downstream-dam and McNary Dam counts. Ignoring these dates would tend to overestimate the detection efficiency. What is done to adjust for such an overestimation is to:

a. Take such a downstream dam date and use offset[3] McNary distributions from six contiguous downstream dates that immediately precede this non-joint detection date and from six contiguous dates that follow this non-joint detection date;

b. Pool the offset McNary passage-time distributions from these twelve adjacent group dates; and

c. Apply this distribution (as a relative distribution) to the total count for the non-joint-detection date.

The resulting McNary-date-distributed counts are then allocated to the stratum to which the McNary date of detection belongs. In most cases so far observed, these allocations occur for days very early in the passage or very late in passage. Usually the downstream dam detections from such non-joint-detection days are allocated to either the earliest or the latest detection stratum. So far, in cases in which there were no joint detections in any of the adjacent twelve non-joint detection dates, the downstream-dam detection-date could be assigned to either the first or the last stratum.

Assumptions behind the detection efficiency estimation procedures are as follows:

a. For a given McNary-passage date, survivals from McNary to downstream dam(s) are equal for all routes of McNary passage.

b. For a given McNary-passage date, fish from all routes of McNary passage are temporally and spatially well mixed before reaching downstream dams.

c. The probability of a fish being detected at a downstream dam is independent of whether or not the fish has been detected at an evaluated upstream dam (e.g., probability of being detected at Bonneville is independent of detection at John Day or McNary, probability of detection at John Day is independent of detection at McNary).

---

[3] The distribution for day I for the missing joint-count-distribution day J would use distributions from day I-1 for the downstream distribution day (ddd) J-1, day I-2 for the ddd J-2, …, I-6 for ddd J-6; similarly, it would use distributions from day I+1 for the ddd J+1, day I+2 for the ddd J+2, …, I+6 for ddd J+1.

d. For fish detected on a given day at a downstream dam, the distribution of McNary passage is the same for fish detected and for fish not detected at McNary.

Assumption a. is unlikely to hold. Downstream survivals from McNary of fish passing through the bypass, through the turbines, and over the spillway are unlikely to be equal. An example of how Assumption b. could fail is if a fish passing through the turbines is more likely to hold in the tailrace longer than a fish passing, say, over the spillway or through the bypass system. An example of how Assumption c. could fail would be if one fish tends to swim more shallowly than another fish when approaching the powerhouse. Such a fish would be more likely to be diverted into the bypass at each dam than the other fish. Assumption d. is unlikely to hold. The fact that jointly detected fish can be subjected to differential daily McNary detection rates over McNary detection days for a given day of downstream dam passage would guarantee that the distribution of McNary passage would differ for fish detected and for fish not detected at McNary. Further, since the daily estimates share portions of total daily passages [refer back to Table A.3)], the daily estimates will not be independent. The detection rates, as currently estimated, should be regarded as biased, and any derived estimates of passage time or of survival should be regarded as indices rather than absolute estimates.

Appendix B. McNary Detection Rates

Table B.1 Daily Detection Rate Estimates

Stratum	Date	Bonneville Dam Downstream Detections	Bonneville Dam Joint Detections	Bonneville Dam McNary Det Rate	John Day Dam Downstream Detections	John Day Dam Joint Detections	John Day Dam McNary Det Rate	Pooled Downstream Detections	Pooled Joint Detections	Pooled McNary Det Rate
1	10-May-03	1.00	0	0.0000	0.00	0	0.0000	1.00	0	0.0000
	11-May-03	0.38	0	0.0000	0.00	0	0.0000	0.38	0	0.0000
	12-May-03	0.86	0	0.0000	0.75	0	0.0000	1.61	0	0.0000
	13-May-03	0.36	0	0.0000	0.75	0	0.0000	1.11	0	0.0000
	14-May-03	1.00	0	0.0000	1.50	0	0.0000	2.50	0	0.0000
	15-May-03	3.71	1	0.2692	0.13	0	0.0000	3.84	1	0.2605
	16-May-03	2.31	1	0.4328	0.25	0	0.0000	2.56	1	0.3905
	17-May-03	6.29	2	0.3179	0.53	0	0.0000	6.82	2	0.2933
	18-May-03	3.41	1	0.2932	3.81	2	0.5244	7.22	3	0.4153
	19-May-03	3.97	1	0.2521	1.56	1	0.6393	5.53	2	0.3616
	20-May-03	10.30	3	0.2913	1.68	1	0.5954	11.98	4	0.3340
	21-May-03	10.62	2	0.1882	0.04	0	0.0000	10.66	2	0.1876
	22-May-03	3.26	1	0.3069	14.50	4	0.2759	17.76	5	0.2816
	23-May-03	16.55	3	0.1813	25.64	7	0.2730	42.19	10	0.2370
	24-May-03	11.31	3	0.2653	5.10	2	0.3922	16.41	5	0.3047
	25-May-03	16.53	5	0.3025	8.20	3	0.3659	24.73	8	0.3235
	26-May-03	14.29	5	0.3500	36.77	11	0.2991	51.06	16	0.3134
	27-May-03	35.98	10	0.2779	90.41	23	0.2544	126.39	33	0.2611
2	28-May-03	59.68	11	0.1843	115.91	23	0.1984	175.59	34	0.1936
	29-May-03	123.37	18	0.1459	249.88	41	0.1641	373.25	59	0.1581
	30-May-03	118.34	16	0.1352	122.64	19	0.1549	240.98	35	0.1452
3	31-May-03	63.25	13	0.2055	85.08	17	0.1998	148.33	30	0.2023
4	01-Jun-03	143.55	36	0.2508	109.00	31	0.2844	252.55	67	0.2653
	02-Jun-03	109.80	28	0.2550	67.07	19	0.2833	176.86	47	0.2657
5	03-Jun-03	186.23	30	0.1611	43.20	10	0.2315	229.43	40	0.1743
	04-Jun-03	245.32	45	0.1834	77.60	17	0.2191	322.92	62	0.1920
6	05-Jun-03	151.72	40	0.2636	44.00	12	0.2727	195.72	52	0.2657
	06-Jun-03	102.46	35	0.3416	41.14	12	0.2917	143.60	47	0.3273
	07-Jun-03	17.76	6	0.3379	9.51	3	0.3155	27.26	9	0.3301
	08-Jun-03	46.87	15	0.3201	18.96	6	0.3165	65.83	21	0.3190
	09-Jun-03	140.41	42	0.2991	63.42	17	0.2680	203.83	59	0.2895
7	10-Jun-03	150.40	37	0.2460	63.09	13	0.2060	213.50	50	0.2342
	11-Jun-03	75.94	16	0.2107	17.90	3	0.1676	93.84	19	0.2025
	12-Jun-03	50.43	12	0.2380	22.14	4	0.1807	72.56	16	0.2205
	13-Jun-03	101.52	25	0.2462	11.25	3	0.2667	112.77	28	0.2483
	14-Jun-03	44.00	11	0.2500	16.43	3	0.1825	60.43	14	0.2317
	15-Jun-03	15.63	4	0.2560	15.54	8	0.5149	31.17	12	0.3850
	16-Jun-03	18.18	4	0.2201	6.19	1	0.1617	24.36	5	0.2052
	17-Jun-03	8.61	2	0.2322	3.65	0	0.0000	12.26	2	0.1631
	18-Jun-03	11.62	2	0.1721	4.45	0	0.0000	16.07	2	0.1244
	19-Jun-03	3.79	0	0.0000	2.57	1	0.3887	6.36	1	0.1571
	20-Jun-03	1.31	0	0.0000	1.38	0	0.0000	2.69	0	0.0000
	21-Jun-03	9.37	2	0.2134	1.88	0	0.0000	11.25	2	0.1778
	22-Jun-03	1.49	0	0.0000	0.40	0	0.0000	1.89	0	0.0000
	23-Jun-03	1.00	1	1.0000	4.80	0	0.0000	5.80	1	0.1724
	24-Jun-03	9.00	3	0.3333	8.10	2	0.2469	17.10	5	0.2924
	25-Jun-03	50.33	7	0.1391	3.95	1	0.2532	54.28	8	0.1474
	26-Jun-03	6.74	2	0.2966	1.75	1	0.5714	8.49	3	0.3532
	27-Jun-03	23.67	6	0.2535	4.00	1	0.2500	27.67	7	0.2530

Appendix B. McNary Detection Rates (continued)

Table B.1 Daily Detection Rate Estimates (continued)

Stratum	DATE	Bonneville Dam Downstream Detections	Bonneville Dam Joint Detections	Bonneville Dam McNary Det Rate	John Day Dam Downstream Detections	John Day Dam Joint Detections	John Day Dam McNary Det Rate	Pooled Downstream Detections	Pooled Joint Detections	Pooled McNary Det Rate
8	28-Jun-03	1.04	0	0.0000	1.00	1	1.0000	2.04	1	0.4892
	29-Jun-03	4.74	1	0.2108	0.00	0	0.0000	4.74	1	0.2108
	30-Jun-03	1.31	0	0.0000	0.40	0	0.0000	1.71	0	0.0000
	01-Jul-03	3.84	1	0.2604	0.40	0	0.0000	4.24	1	0.2358
	02-Jul-03	0.33	0	0.0000	0.20	0	0.0000	0.53	0	0.0000
	03-Jul-03	3.17	1	0.3158	0.00	0	0.0000	3.17	1	0.3158
	04-Jul-03	0.17	0	0.0000	0.00	0	0.0000	0.17	0	0.0000
	05-Jul-03	0.50	0	0.0000	0.50	0	0.0000	1.00	0	0.0000
	06-Jul-03	1.00	1	1.0000	1.00	1	1.0000	2.00	2	1.0000
	07-Jul-03	0.00	0	0.0000	0.00	0	0.0000	0.00	0	0.0000
	08-Jul-03	0.00	0	0.0000	0.00	0	0.0000	0.00	0	0.0000
	09-Jul-03	1.00	1	1.0000	0.00	0	0.0000	1.00	1	1.0000
	10-Jul-03	2.00	1	0.5000	1.50	1	0.6667	3.50	2	0.5714
	11-Jul-03	0.00	0	0.0000	1.00	1	1.0000	1.00	1	1.0000
	12-Jul-03	0.00	0	0.0000	1.50	1	0.6667	1.50	1	0.6667
	13-Jul-03	0.00	0	0.0000	0.00	0	0.0000	0.00	0	0.0000
	14-Jul-03	0.00	0	0.0000	0.00	0	0.0000	0.00	0	0.0000
	15-Jul-03	0.00	0	0.0000	0.00	0	0.0000	0.00	0	0.0000
	16-Jul-03	0.00	0	0.0000	3.00	1	0.3333	3.00	1	0.3333
	17-Jul-03	0.00	0	0.0000	0.00	0	0.0000	0.00	0	0.0000
	18-Jul-03	0.00	0	0.0000	0.00	0	0.0000	0.00	0	0.0000
	19-Jul-03	0.00	0	0.0000	0.00	0	0.0000	0.00	0	0.0000
	20-Jul-03	0.00	0	0.0000	1.00	1	1.0000	1.00	1	1.0000
	21-Jul-03	0.00	0	0.0000	3.00	2	0.6667	3.00	2	0.6667
	22-Jul-03	0.00	0	0.0000	0.00	0	0.0000	0.00	0	0.0000
	23-Jul-03	0.00	0	0.0000	2.00	2	1.0000	2.00	2	1.0000
	24-Jul-03	0.00	0	0.0000	1.00	1	1.0000	1.00	1	1.0000
	25-Jul-03	0.00	0	0.0000	1.00	1	1.0000	1.00	1	1.0000
	26-Jul-03	0.00	0	0.0000	1.00	1	1.0000	1.00	1	1.0000

Table B.2 Logistic-Stepwise-Analysis-of-Variation-identified Strata Partitioning for Detection Rate Estimation

Step	Partitioning between dates		Deviance	Degrees of Freedom	Mean Deviance	F-Ratio	Type 1 p
1	04-Jun-03	05-Jun-03	16.51	1	16.51	21.83	0.0000
2	27-Jun-03	28-Jun-03	11.50	1	11.50	15.20	0.0002
3	27-May-03	28-May-03	10.69	1	10.69	14.13	0.0004
4	30-May-03	31-May-03	9.31	1	9.31	12.31	0.0009
5	09-Jun-03	10-Jun-03	8.65	1	8.65	11.44	0.0013
6	02-Jun-03	03-Jun-03	6.94	1	6.94	9.18	0.0036
7	31-May-03	01-Jun-03	2.43	1	2.43	3.21	0.0780
			46.14	61	0.7564		

Appendix B. McNary Detection Rates (continued)

Table B.3. McNary Detection Rate Estimation

Stratum	McNary Passage Calendar Date Beginning	McNary Passage Calendar Date Ending	Bonneville Detections Total*	Bonneville Detections Joint**	Bonneville McN Detection Rate	John Day Detections Total*	John Day Detections Joint**	John Day McN Detection Rate	Pooled Detections Total*	Pooled Detections Joint**	Pooled McN Detection Rate
1	5/10/03	5/27/03	142.1	38.0	0.26737	191.6	54.0	0.28180	333.7	92	0.27566
2	5/28/03	5/30/03	301.4	45.0	0.14931	488.4	83.0	0.16993	789.8	128	0.16206
3	5/31/03	5/31/03	63.3	13.0	0.20553	85.1	17.0	0.19982	148.3	30	0.20226
4	6/1/03	6/2/03	253.4	64.0	0.25261	176.1	50.0	0.28399	429.4	114	0.26548
5	6/3/03	6/4/03	431.5	75.0	0.17379	120.8	27.0	0.22351	552.3	102	0.18467
6	6/5/03	6/9/03	459.2	138.0	0.30052	177.0	50.0	0.28243	636.2	188	0.29548
7	6/10/03	6/27/03	583.0	134.0	0.22983	189.5	41.0	0.21640	772.5	175	0.22654
8	6/28/03	7/26/03	19.1	6.0	0.31413	19.5	14.0	0.71795	38.6	20	0.51813

* Total downstream-dam McN Dam count estimated from downstream daily count and joint count McNary date distributions

** Joint counts of fish detected at both downstream and McNary dams according to McNary day of first detection

Appendix C. McNary Passage (continued)

Table C.2. Estimates of Tagging Files' Mean Travel Time to McNary Dam

Release Site	Tagging File Extender	Mean Travel Time
Nason Creek	B7A	42.29440
	B7B	40.70520
	B8A	44.29824
	B8B	44.34223
Two Rivers	LW1	40.43232
	LW2	40.36533
Icicle Creek	LC1	37.95528
	LC2	38.60905

Table C.3. Weighted* Least Squares Regression Estimates of Releases' Mean Travel Time to McNary Dam and their Standard Errors based on Tagging Group Estimates (standard errors not to be used for making statistical comparisons over releases)

Release Site	Mean Travel Time	Standard Error
Little Wenatchee	38.3202	0.65996
Nason Creek	42.8948	0.70086
Icicle Creek	40.4043	0.7002

Residual Sums of Squares	19564.5
Degrees of Freedom	5
Mean Square	3912.9

Appendix D. McNary Survival Indices

Table D.1 Strata-based Totals and Expansions, Totals over Strata and Survival Indices

Stratum	Detection Rate	Release Site > Tag Group >	Nason Creek				Icicle Creek		Little Wenatchee		TOTAL
			B7A	B7B	B8A	B8B	LC1	LC2	LW1	LW2	
1	0.2757	TOTAL (T)	1	3	0	0	90	65	3	7	169
from		REMOVAL (R)	0	0	0	0	0	3	1	2	6
15-May-03		T-R	1	3	0	0	90	62	2	5	163
to		EXPANSIONS	3.63	10.88	0.00	0.00	326.49	224.92	7.26	18.14	591.31
27-May-03		PASSAGE	3.63	10.88	0.00	0.00	326.49	227.92	8.26	20.14	597.31
2	0.1621	TOTAL (T)	1	2	2	2	133	94	9	18	261
from		REMOVAL (R)	0	0	0	0	5	1	0	0	6
28-May-03		T-R	1	2	2	2	128	93	9	18	255
to		EXPANSIONS	6.17	12.34	12.34	12.34	789.82	573.85	55.53	111.07	1573.46
30-May-03		PASSAGE	6.17	12.34	12.34	12.34	794.82	574.85	55.53	111.07	1579.46
3	0.2023	TOTAL (T)	3	4	0	2	24	20	6	9	68
from		REMOVAL (R)	0	0	0	0	1	0	0	1	2
31-May-03		T-R	3	4	0	2	23	20	6	8	66
to		EXPANSIONS	14.83	19.78	0.00	9.89	113.72	98.88	29.67	39.55	326.32
31-May-03		PASSAGE	14.83	19.78	0.00	9.89	114.72	98.88	29.67	40.55	328.32
4	0.2655	TOTAL (T)	11	15	5	8	101	64	35	33	272
from		REMOVAL (R)	0	0	0	0	4	6	0	2	12
01-Jun-03		T-R	11	15	5	8	97	58	35	31	260
to		EXPANSIONS	41.43	56.50	18.83	30.13	365.38	218.47	131.84	116.77	979.36
02-Jun-03		PASSAGE	41.43	56.50	18.83	30.13	369.38	224.47	131.84	118.77	991.36
5	0.1847	TOTAL (T)	17	22	9	11	77	54	37	29	256
from		REMOVAL (R)	0	0	0	0	4	4	2	1	11
03-Jun-03		T-R	17	22	9	11	73	50	35	28	245
to		EXPANSIONS	92.06	119.13	48.74	59.57	395.30	270.76	189.53	151.62	1326.71
04-Jun-03		PASSAGE	92.06	119.13	48.74	59.57	399.30	274.76	191.53	152.62	1337.71
6	0.2955	TOTAL (T)	40	50	35	46	130	81	48	44	474
from		REMOVAL (R)	0	0	0	0	3	0	0	1	4
05-Jun-03		T-R	40	50	35	46	127	81	48	43	470
to		EXPANSIONS	135.37	169.21	118.45	155.68	429.80	274.13	162.44	145.52	1590.61
09-Jun-03		PASSAGE	135.37	169.21	118.45	155.68	432.80	274.13	162.44	146.52	1594.61
7	0.2265	TOTAL (T)	79	85	85	98	119	72	61	78	677
from		REMOVAL (R)	0	0	0	0	1	0	2	1	4
10-Jun-03		T-R	79	85	85	98	118	72	59	77	673
to		EXPANSIONS	348.73	375.22	375.22	432.60	520.89	317.83	260.45	339.90	2970.84
27-Jun-03		PASSAGE	348.73	375.22	375.22	432.60	521.89	317.83	262.45	340.90	2974.84
8	0.5181	TOTAL (T)	33	32	32	50	15	17	8	23	210
from		REMOVAL (R)	0	0	0	0	0	0	0	0	0
28-Jun-03		T-R	33	32	32	50	15	17	8	23	210
to		EXPANSIONS	63.69	61.76	61.76	96.50	28.95	32.81	15.44	44.39	405.31
22-Sep-03		PASSAGE	63.69	61.76	61.76	96.50	28.95	32.81	15.44	44.39	405.31
Over Strata		TOTAL PASSAGE	705.92	824.83	635.34	796.71	2988.35	2025.65	857.15	974.97	9808.92
		NUMBER RELEASED	1950	2050	1846	2120	4639	3342	3969	5015	24931
		SURVIVAL INDEX	0.3620	0.4024	0.3442	0.3758	0.6442	0.6061	0.2160	0.1944	0.3934
Over		NUMBER RELEASED				7966		7981		8984	24931
Tag Groups		SURVIVAL INDEX				0.3719		0.6282		0.2039	0.3934

Appendix D. McNary Detection Rates (continued)

Table D.2 Weighted* Logistic Analysis of Variation Estimates of Releases' Survival Indices and their Standard Errors based on Tagging Group Indices (standard errors not to be used for making statistical comparisons over releases)

Release Site	Mean Logit	Standard Error of Logit	Survival Index Transform = 1/[1+exp(-logit)]	Standard Error of Survival Index Transform
Little Wenatchee	-1.362	0.0678	0.2039	0.01100
Nason Creek	-0.524	0.0600	0.3719	0.01402
Icicle Creek	0.525	0.0599	0.6282	0.01400

Residual Deviance (Dev)	33.5
Degrees of Freedom	5
Mean Deviance = Dev/DF	6.7

*