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 2004 - 2005 | June 2006 | DOE/BP-00016988-2

This Document should be cited as follows:

Murdoch, Keely, Scott Prevatte, Corydon Kamphaus, "Mid-Columbia Coho Reintroduction Feasibility Study; Monitoring and Evaluation", 2004-2005 Annual Report, Project No. 199604000, 114 electronic pages, (BPA Report DOE/BP-00016988-2)

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 FEASIBILITY STUDY

2004 Monitoring and Evaluation Report
February 1, 2004 through January 31, 2005

Prepared by:
Keely G. Murdoch
Scott A. Prevatte
Corydon M. Kamphaus

Yakama Nation
Fisheries Resource Management
P.O. Box 151
Toppenish, Washington 98948

1 June 2006

Prepared for:
Project #1996-040-000
Contract #00016988
Bonneville Power Administration
P.O. Box 3621
Portland, Oregon 97283-3621

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 at biologically sustainable levels which will provide opportunities for harvest for tribal and non-tribal fishers. The feasibility of reestablishing 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 2004 focused on addressing these two central issues.

• We repeated the 2003 radio-telemetry evaluation with the objective to determine 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 293 coho were radio-tagged during 2004. Of the 293, 61.4% were tracked to probable spawning locations. The drop-out rate for coho that were tracked within the Wenatchee River was estimated to be 34.1% for fish tagged at Priest Rapids Dam. The dropout rate within the Methow was estimated at 72.7%. As measured with a PIT tag control group, we believe that the behavior of radio-tagged coho was negatively impacted by the radio-tag and/or the handling stress of the tagging procedure. Radio-tagged coho dropped out at significantly higher rates than non-radio tagged coho.

• During spawning ground surveys in the Wenatchee Basin, we found a total of 714 coho redds: 504 redds in Icicle Creek, 35 redds in Nason Creek, 121 redds in the Wenatchee River and a combined 54 redds in Brender, Mission, and Peshastin creeks. In the Methow Basin we located a total of 22 redds (Methow River and tributaries).

• A population estimate of naturally produced coho smolts emigrating from the Wenatchee basin was calculated from data collected at WDFW's rotary smolt trap located near Monitor on the Wenatchee River (RK 11.4). We estimate that 5,826 naturally produced yearling coho emigrated between March 29th and July 9th, 2004. From the population estimate we calculated an egg-to-emigrant survival rate of 7.8% (28 coho redds, 2683 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 (Miller 2005).

• We estimate that the average smolt-to-adult survival rate for brood year 2001 hatchery coho smolts released in the Wenatchee River basin is 0.39% (3375 adults and 75 jacks) for all release groups. The SARs for lower Columbia River brood coho released from Icicle Creek (0.45%) was lower than first-generation mid-Columbia River brood released from the same acclimation pond (0.56%). Using scale analysis for identification, we estimated the SAR for the second return of naturally produced coho to be 0.40%, or 4.0% of the coho return to the Wenatchee Basin. The SARs for hatchery coho returning to the Methow River was 0.16%.

• Based on PIT-tag detections, we estimate that 55%-61% of brood year 2002 mid-Columbia River brood coho survived from release in Icicle Creek to McNary Dam. We estimated that 30%-36% of fish released into Nason Creek (Butcher Creek, and Mahar acclimation ponds) survived to McNary Dam. Release to McNary Dam survival rates for coho smolts released from the Methow River were 26%-29%.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

We are thankful to the many people involved in the coho reintroduction feasibility study. Bonneville Power Administration funded the study. Linda Hermeston administered funding. Theresa Blodgett, Jerald Reed, Anne Hudson, Sam Shavehead, Windcloud Washines, Lana Goudy, John Jorgensen, Rick Alford, Ralph Kiona, and Matthew Collins helped collect the field data. Doug Neeley (International Statistical Training and Technical Services) provided statistical consultation for survival estimates of PIT-tagged fish. 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 Judy DeLaVergne. Several employees at WDFW provided assistance throughout the year, including Janet Eckenberg at the Priest Rapids Dam trap, Rick Stillwater, and his crew during broodstock collection, John Sneva aged and determined origin (hatchery or wild) based on scale analysis, and Todd Miller provided the population estimate of naturally produced coho emigrating from the Wenatchee 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 reestablishing coho in the tributaries of the mid-Columbia River may initially depend upon the resolution of two central issues: the adaptability of 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.

The mid-Columbia coho reintroduction 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 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.

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: COHO RADIO-TELEMETRY - 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 seven and nine mainstem hydropower facilities, respectively. 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 non-imprinted 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 smolt-to-adult survival rates (SARs) for reintroduced coho and a reduction in drop-out and stray rates along the migratory route.

High drop-out 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 previous years 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 and other locations is unknown.

In 2004 we implemented a radio-telemetry evaluation to examine stray and drop-out rates of 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.

In addition to the four objectives listed above, in 2004 we investigated the effect of handling and the radio-tag on the drop-out rate of study fish.

Study Area

The study area includes 238 river kilometers (RK) 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).

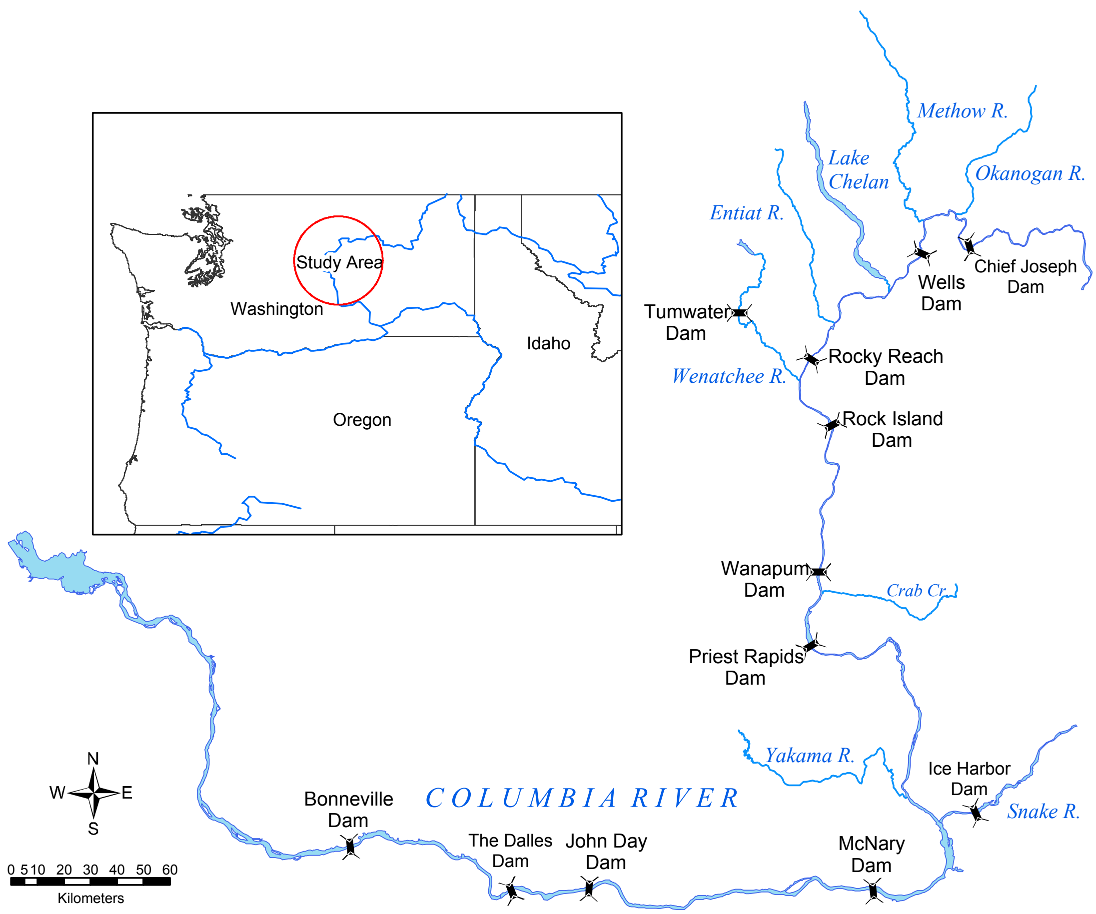


Figure 1. The mid-Columbia coho radio-telemetry study area extends from Priest Rapids Dam to Chief Joseph Dam in the Columbia River and includes all the major tributaries in this reach with a focus on the Wenatchee and Methow rivers.

METHODS

Study Design

To answer the questions posed in the study objectives, a total of 320 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 the predicted 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 probable spawning locations.

Priest Rapids Dam

We planned to radio-tag 260 coho at Priest Rapids Dam between September 7th and November 11th, 2004. To evaluate the effect of run timing on return, stray, and drop-out rates, the tagging schedule was divided into 3 tag groups with weekly tagging goals (Table 1).

Table 1. Tag group timing, dates, and tagging goals at Priest Rapids Dam, 2004.

Timing	Dates	Tagging Goal
Early Run	Sept. 7 – Sept. 26	60 fish at 20 fish/week
Middle Run	Sept. 27 – Oct. 25	140 fish at 35 fish/week
Late Run	Oct. 26 – Nov. 11	60 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 coordination 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 upstream passage through the fish ladder resumed.

During the trapping operations at Priest Rapids Dam, all coho greater than 49 cm fork length (FL) were radio-tagged by YN personnel. Forty-nine centimeters FL was chosen as a cut-off due to limitations of the tag size. This FL also corresponded with the typical cut-off between jack (2-year old) and adult (3-year old) coho. 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 300 gallon 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 or the Little Wenatchee River), the radio-tags used at Tumwater Dam allowed for a more detailed evaluation of spawning areas in the upper Wenatchee basin. Up to 35 coho were scheduled to be tagged at Tumwater Dam in the Wenatchee River basin. A weekly tagging goal of 10 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 4th through October 20th, 2004. 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 upstream 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 approximately 1 kilometer upstream to the release site. The upstream transport was intended to prevent fallbacks over Tumwater Dam. All incidentally trapped fish were enumerated and released back to the Wenatchee River.

Wells Dam

To coho returning to the Methow River, we planned to radio-tag 25 coho adults at Wells Dam. Due to the limited number of coho returning to the Methow River, we prioritized broodstock collection over radio-tagging, therefore no weekly tagging goals were identified.

Trapping and tagging occurred at the east fish ladder trap 3 days per week from September 27th to October 14th. The trap was 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 300 gallon transport tank with freshwater circulation and oxygen. After recovery (minimum 1 hour), the fish were transported to the release site located approximately 3 kilometers upstream of Wells Dam.

Tagging Procedures – All Locations

All trapped coho were anesthetized in a solution of MS-222. 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 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) manufactured by Lotek Engineering Inc. of Newmarket, Ontario were used in the evaluation. Individually coded tags were distributed across 4 frequencies. The transmitters were compatible with the digital spectrum processors (DSPs) used at some of the detection sites. The transmitters used 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.

Receivers

Lotek receivers 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).

Coho detection data 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. YN personnel 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 2004 mid-Columbia River study.

River of Detection	Site Location	Site Administrator
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	Wood Bridge at Butcher Creek (RK 13.2)	YN
Little Wenatchee River	Old Weir Site (RK 2)	USFWS/ 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

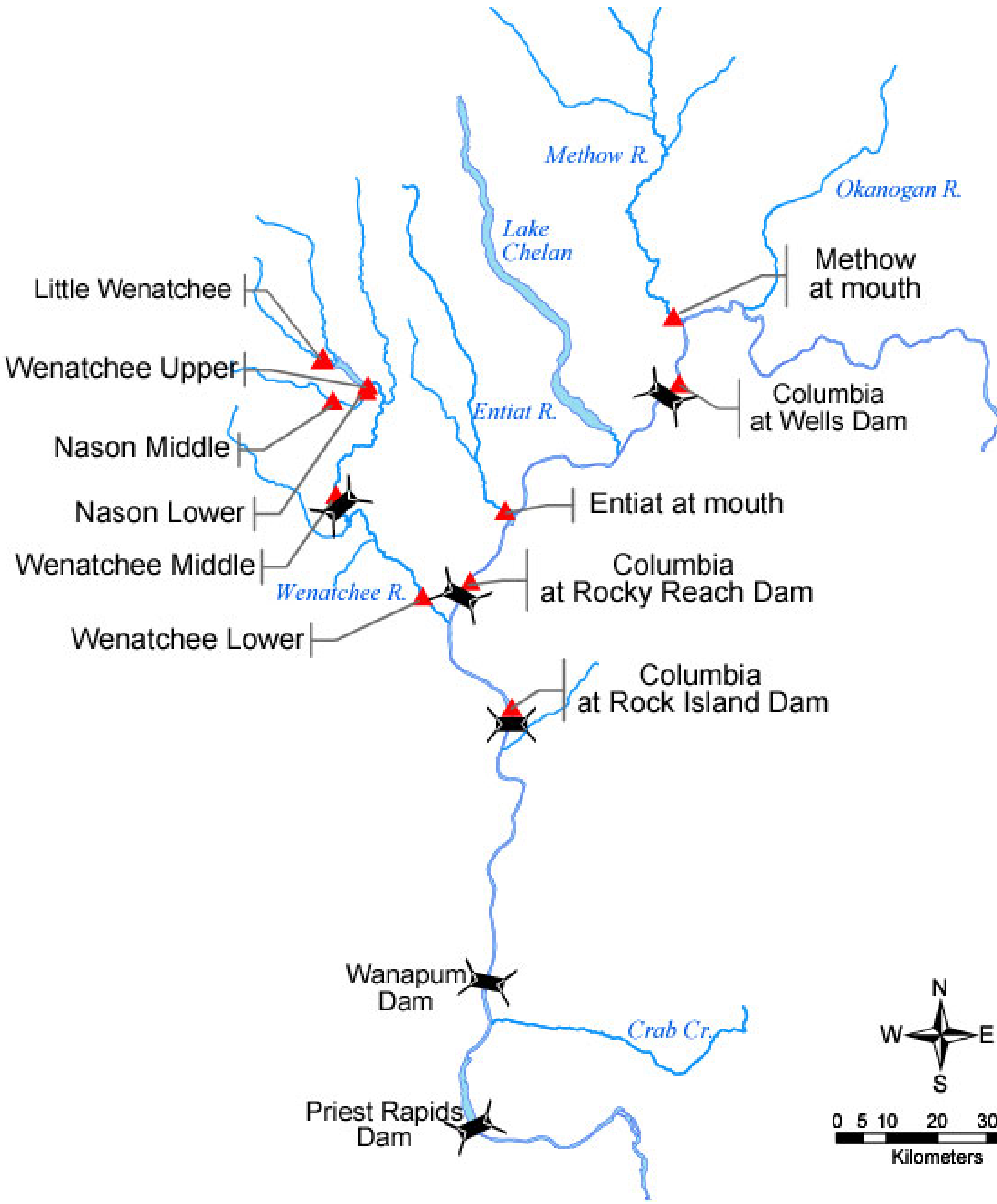


Figure 2. Location of fixed-station detection sites operated in the mid-Columbia River study area during the 2004 coho study.

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 4 receivers, all having GPS interface capabilities with each receiver scanning 2 channels and the scanning sequence between receivers offset.

Truck surveys

Tracking by road, while traveling to download receivers, was conducted on the upper Wenatchee River, Nason Creek, and 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 accomplished 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 completed in the Wenatchee and Methow rivers during spawning ground surveys. Rafts were also used to track fish in Icicle Creek.

RESULTS

Tagging

A total of 293 radio-tags were deployed between all 3 tagging locations (Table 3). The Priest Rapids Dam collection site was the focus of the study with 234 tagged fish; 35 coho were tagged at Tumwater Dam, and 24 at Wells Dam. No mortality due to handling was observed. Three tags were regurgitated in the transport tank and were recovered and reused. Appendix A 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 3 tagging locations in 2004.

Tagging Location	Total Tagged
Priest Rapids	234
Tumwater	35
Wells	24

The peak migration over Priest Rapids Dam occurred between September 11th and October 7th. During this period, 79% of the run passed the facility and 51% of the tags were used (Figure 3). The tagging goal of 250 fish was not met due to the limited number of coho passing the dam during the late tagging period; only 5% of the run passed the dam during this time (Table 1 and Table 3).

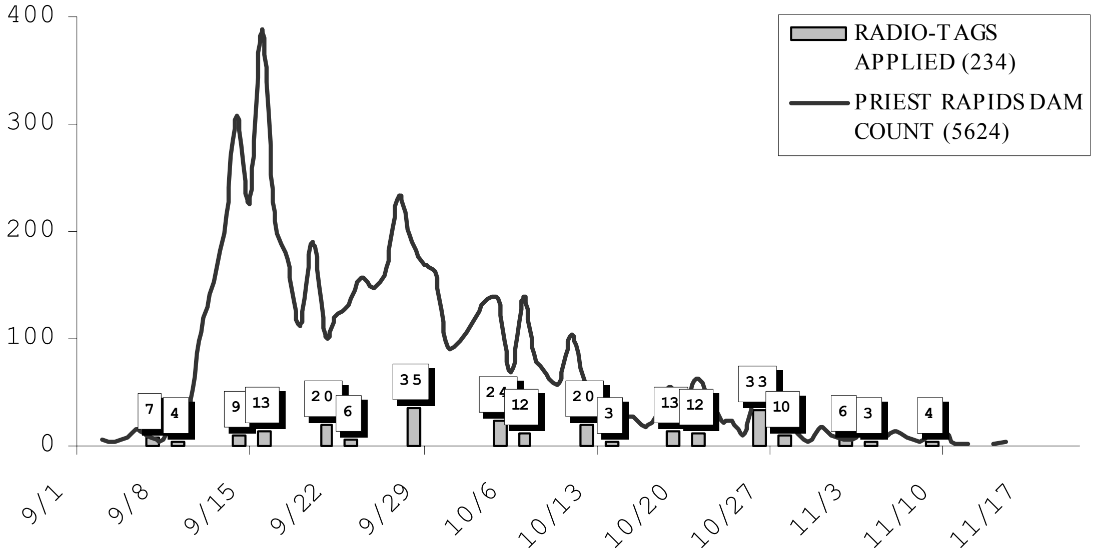


Figure 3. Distribution of adult coho passage counts and number of fish tagged per day at Priest Rapids Dam, 2004.

Overall, 143 male and 150 female coho were radio-tagged (Table 4). The mean fork length was 64.3 cm (SD 6.0 cm) for males and 67.1 cm (SD 4.2 cm) for females. See Appendix A for complete gender and size data.

Table 4. Radio-tagged coho gender and size summary for each tagging location, 2004.

Tagging Location	Gender and Fork Length (cm)							
	Male				Female			
	Count	Mean	Range	SD	Count	Mean	Range	SD
Priest Rapids Dam	115	63.4	49.5 to 76	6.5	119	67.1	55.5 to 74.5	4.3
Tumwater Dam	16	64.2	54 to 75	6.8	19	67.5	62 to 73.5	3.6
Wells Dam	12	65.4	60.5 to 76.5	4.7	12	66.8	57 to 73.5	4.7

Tracking Effort Success

Of the 293 radio-tagged coho, 180 (61.4%) were tracked at some point during their migration (Table 5). The total number of telemetry records collected from radio-tagged coho during this study exceeded 176,500 (Table 6). Approximately 98% of this data was obtained at the three mainstem Columbia River fixed detection sites of Rock Island, Rocky Reach, and Wells dams. The detailed final locations of radio-tagged coho was determined through mobile tracking data; the data provided by aerial surveys was the most beneficial in answering the questions posed in the objectives of the study. 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 2,180 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 2004 study.

Tagging Location	Combined		Priest Rapids		Tumwater		Wells	
	No.	%	No.	%	No.	%	No.	%
Tagged	293		234		35		24	
Tracked	180	61.4	123	52.6	35	100.0	22	91.7
No Data	113	38.6	111	47.4	0	0.0	2	8.3

Table 6. Total radio-telemetry records analyzed throughout the study and the number of overall unique daily locations provided by the different tracking methods during the 2004 study.

Tracking Method	Total Detections	Unique Locations
Fixed -station	~ 175,000	1692
Aerial survey	959	395
Truck	178	79
Boat/Raft	483	17

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 other Wenatchee and Methow river sites, the Nason Creek sites, and the Little Wenatchee site were downloaded and maintained weekly by YN. The majority of the data set from fixed-station downloads was generated by fish holding in areas near receiver antennas at Rock Island and Rocky Reach dams and being recorded multiple times. After sorting, 1692 unique locations were identified as radio-tagged fish migrated upstream.

Aerial surveys

Aerial surveys of the entire study area were repeated 3 times; October 27th, November 13th, and November 30th. The use of aerial surveys generated 395 unique locations and provided the most complete and precise information of final spawning and holding areas.

Truck surveys

Surveys were conducted by truck wherever roads followed streams in the study area. The Wenatchee and Methow rivers 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 in these locations. While traveling to the tagging sites, staff tracked by road along the Columbia River with some success. Deep water in the Columbia River and the distance from roads to the river limited our ability to detect radio-tagged fish. The truck surveys produced 79 unique radio-tag locations throughout the study period.

Raft/Boat surveys

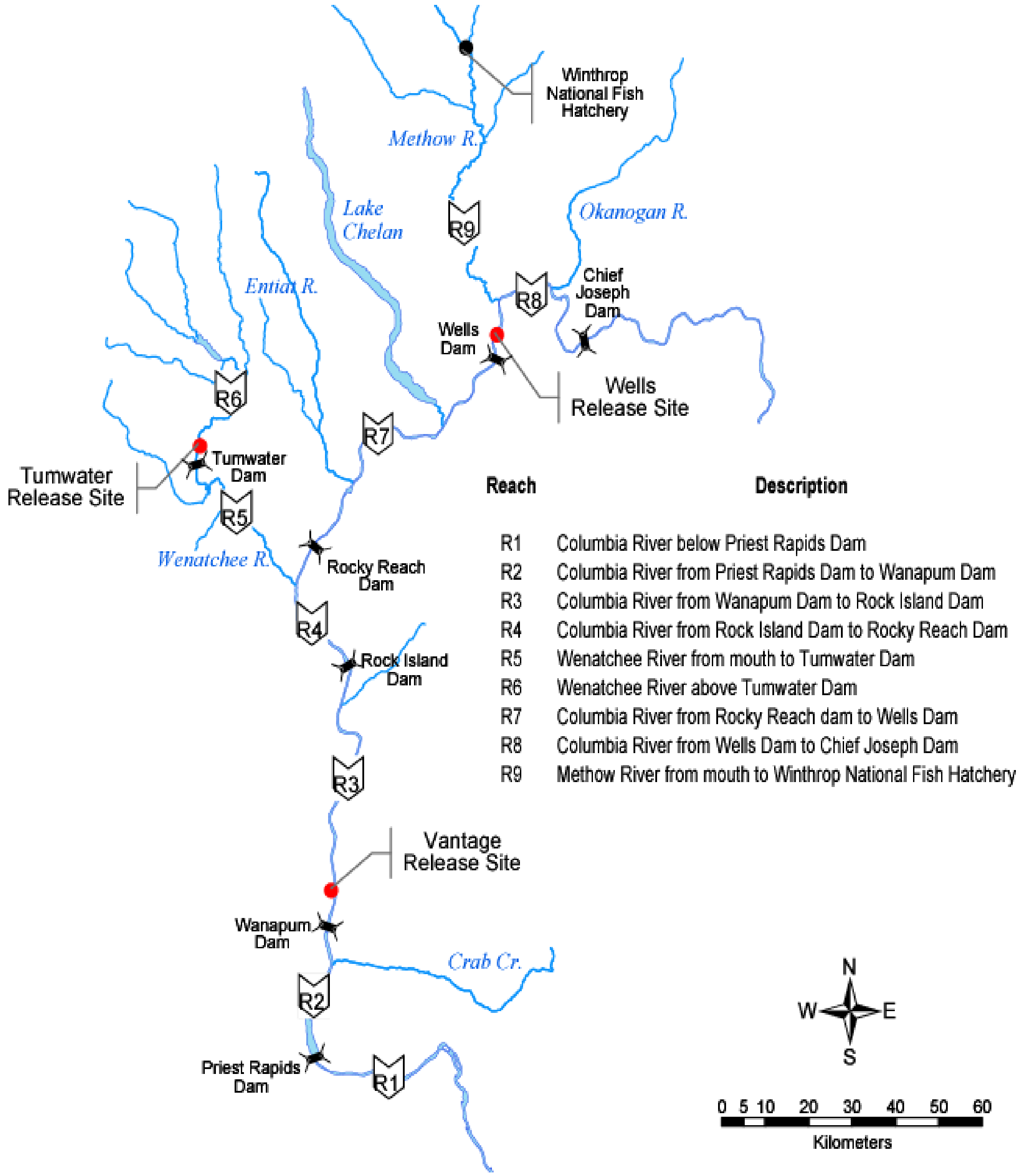
A raft was used to collect radio-telemetry data on the Wenatchee River and Icicle Creek during weekly spawning ground surveys between October 15th and December 30th. Use of this tracking method identified 17 unique locations. A power boat was used in the Columbia River during the 2003 study between Rock Island Dam and Rocky Reach Dam. However, no radio-tags were detected during these surveys and tracking by powerboat was not attempted in 2004.

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 returned downstream from their upper-most known location and were monitored holding in another area. After further data analysis, in some cases, this area was determined to be the most likely spawning location. See Appendix B for final location details.



Reach	Description
R1	Columbia River below Priest Rapids Dam
R2	Columbia River from Priest Rapids Dam to Wanapum Dam
R3	Columbia River from Wanapum Dam to Rock Island Dam
R4	Columbia River from Rock Island Dam to Rocky Reach Dam
R5	Wenatchee River from mouth to Tumwater Dam
R6	Wenatchee River above Tumwater Dam
R7	Columbia River from Rocky Reach dam to Wells Dam
R8	Columbia River from Wells Dam to Chief Joseph Dam
R9	Methow River from mouth to Winthrop National Fish Hatchery

Figure 4. Reach locations and descriptions used during analysis in relation to the three release sites of the 2004 mid-Columbia coho study.

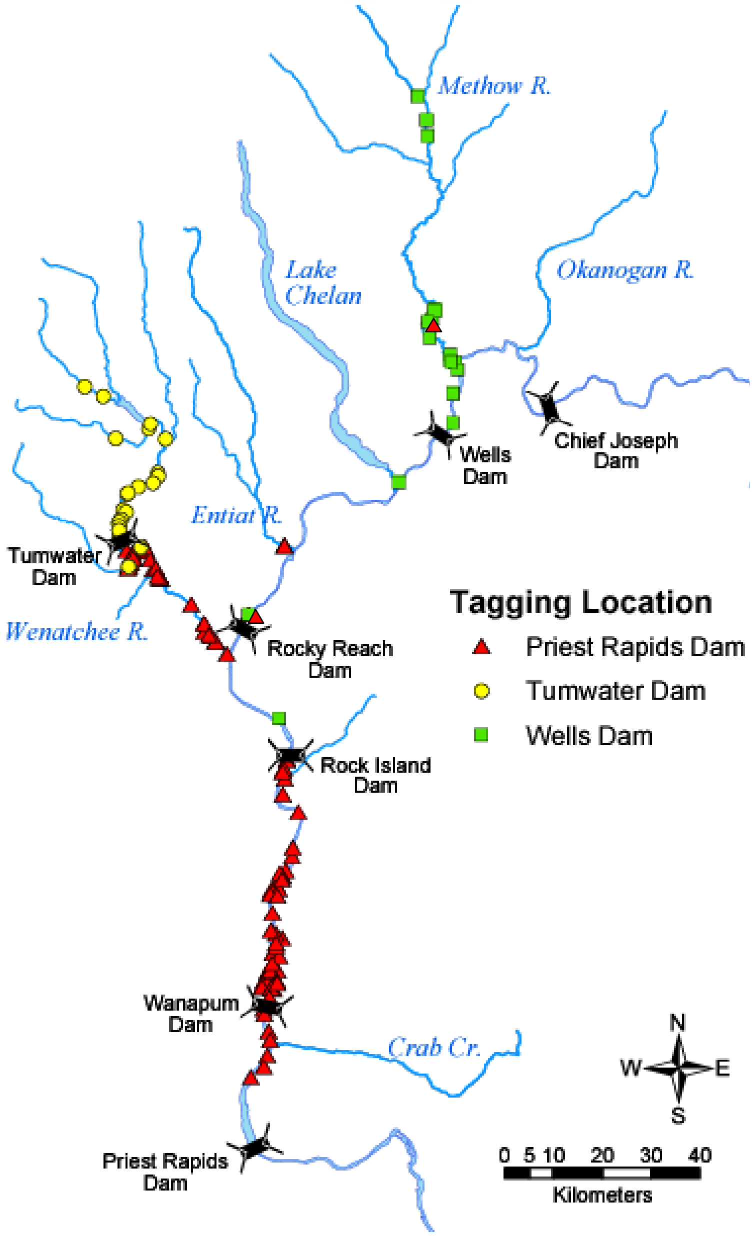


Figure 5. The probable spawning distribution of radio-tagged coho in the mid-Columbia River study area during 2004 (some points on the map represent multiple fish in the same location).

Coho spawning locations were widely distributed throughout the Mid-Columbia study area (Figure 5, Table 7). Stray radio-tagged fish were found in spawning areas very similar to the 2003 evaluation. Sandhollow Wasteway, a tributary to the Columbia River between Wanapum Dam and Vantage, attracted 3 radio-tagged coho, and another 7 were detected in the vicinity of the mouth. Chelan Falls, a tributary to the Columbia River at the outlet of Lake Chelan, had 1 radio-tagged fish detected. In the Wenatchee River, one stray fish was detected in Peshastin Creek. Also, as seen in 2003, a relatively large number of radio-tagged coho (51%) remained in the Columbia River between Wanapum Dam and Rock Island Dam. The spawning success of this group of fish is unknown. Possible reasons for this mainstem drop-out, including a tag or handling effect, were investigated and discussed (See 'Discussion').

Table 7. Probable spawning locations of radio-tagged coho by study area reach during 2004.

Reach	Reach Description	Tagging Location			
		Priest Rapids	Tumwater	Wells	Total
R1	Columbia R. below Priest Rapids				0
R2	Priest Rapids to Wanapum	6			6
R3	Wanapum to Rock Island	63			63
R4	Rock Island to Rocky Reach			1	1
R5	Wenatchee River to Tumwater	48	5		53
R6	Wenatchee River above Tumwater		30		30
R7	Rocky Reach to Wells	5		3	8
R8	Wells to Chief Joseph			3	3
R9	Methow River to Winthrop NFH	1		15	16

Areas of concentrated spawning occurred in the mainstem of the Wenatchee River below Tumwater Canyon; 53 radio-tagged fish were located in this reach including 12 that were detected in Icicle Creek, a tributary near the bottom of the canyon. The mainstem of the Methow River contained 16 radio-tagged coho, with 3 returning to the area just below Winthrop National Fish Hatchery acclimation site.

Results indicate that many radio-tagged fish remained in the Columbia River within study reach 2 (Figure 4). It is likely that some successful spawning took place at the confluence of many small tributaries along the 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 were not attempted in study reach 2, other than at Sandhollow, due to inaccessibility.

Stray rates

Combined tracking efforts accounted for the locations of 180 radio-tagged coho (Table 5 and Figure 6). Overall, 61.4% of the tagged fish were tracked. The fate of the remaining 38.6% radio-tagged fish was unknown. Some of the unaccounted radio-tags may be the result of post tagging and release mortality due to handling or regurgitated tags at depths greater than the 10-meter limit on receiving capability. Another possibility is fallback below Priest Rapids Dam and subsequent 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. There may also have been fish caught incidentally during sport fisheries in the Columbia River above Priest Rapids Dam. The following analysis is based on the results of the 180 fish that were accounted for.

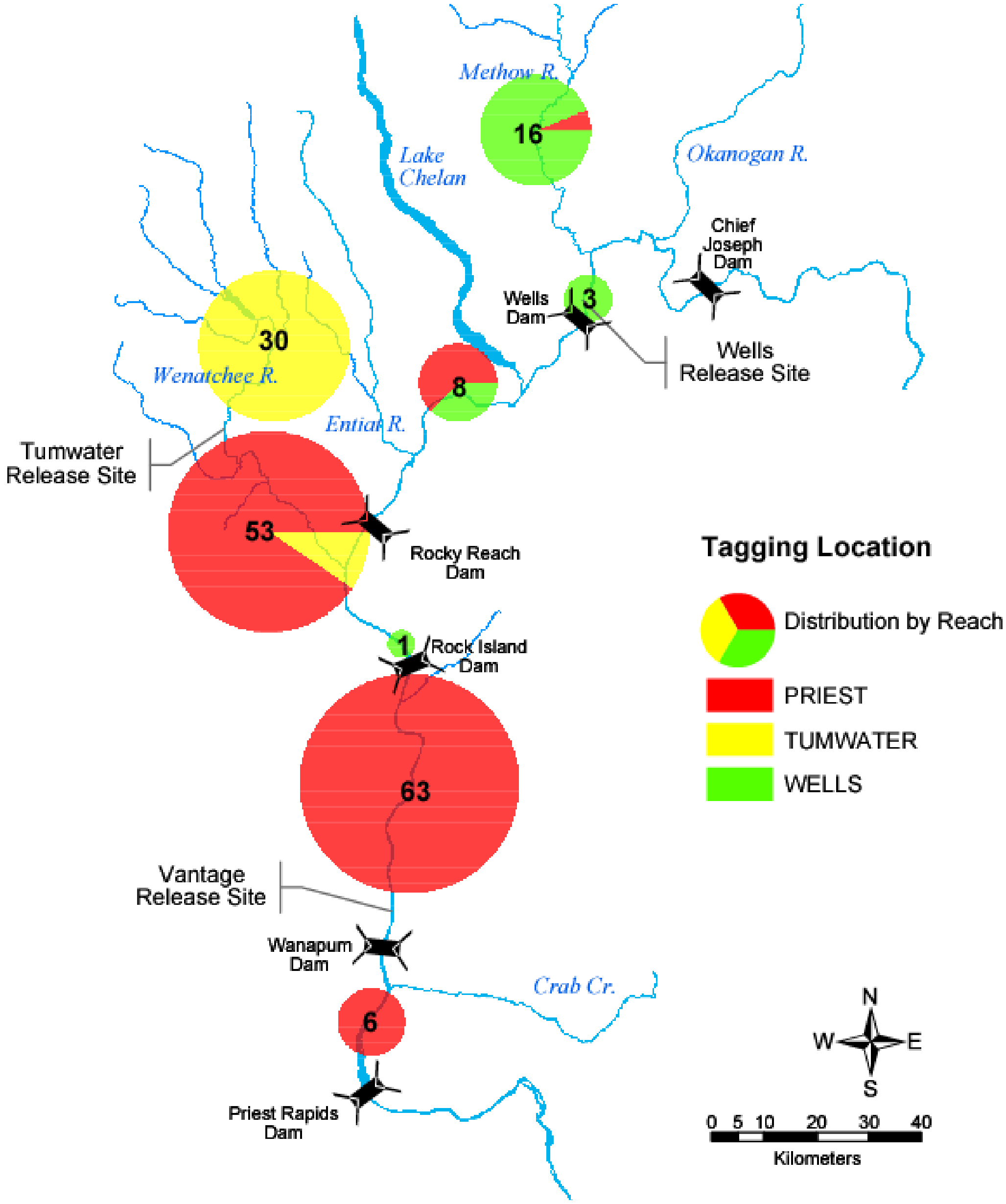


Figure 6. Final locations of radio-tagged coho showing sample size proportions from each tagging location by river reach in the mid-Columbia River study area, 2004.

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 2004 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 Drop-out	Returned to the mainstem Wenatchee or Methow river
Drop-out/Stray	Remained in the Columbia River or other tributary

Eighteen (10.0%) of the radio-tagged coho were determined to be successful in migrating all the way to their original tributary or site of acclimation (Table 9). The majority, 12 out of 18 fish, returned to Icicle Creek where they were most likely released as smolts. Two fish tagged at Tumwater Dam successfully migrated through Lake Wenatchee and returned to the Little Wenatchee River. Two other successful migrants were tagged at Tumwater Dam and tracked to Nason Creek. None of the 22 Methow River migrants swam into Winthrop National Fish Hatchery, however 3 were tracked in the Methow River just below the hatchery.

Table 9. Radio-tagged coho stray and drop-out rates shown by tagging location during the 2004 study.

	Combined		Priest Rapids		Tumwater		Wells	
Performance	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Homing Success	18	10.0	11	8.9	7*	20.0	0	0.0
Home Basin Stray	1	0.6	1	0.8	0	0.0	0	0.0
Home Basin Drop-out	86	47.8	42	34.1	28	80.0	16	72.7
Drop-out/Stray	75	41.7	69	56.1	0	0.0	6	27.3

**Three fish tagged at Tumwater Dam fell back and ascended Icicle Creek to spawn. Without knowing the origin of these fish their migration success can not be accurately determined.*

Radio-tagged coho that returned to a tributary of the Wenatchee or Methow rivers where acclimation did not occur are considered home basin strays; only 1 (0.6%) of the study fish was in this category. This fish was tagged at Priest Rapids Dam and tracked to Peshastin Creek which is located in the middle reach of the Wenatchee River. Three fish tagged at Tumwater Dam fell back and descended to Icicle Creek were they remained to spawn. 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 drop-outs and accounted for the largest portion, 47.8%, of the study group. Of the 35 fish tagged at Tumwater Dam, 28 (80.0%), remained in the mainstem of the Wenatchee River. Forty two fish (34.1%) tagged at Priest Rapids Dam made it into the Wenatchee River and likely spawned in the mainstem. In the Methow River Basin, 16 (72.7%) stayed in the mainstem and were considered home basin drop-outs because they did not return to the hatchery.

Radio-tagged coho that remained in the Columbia River after being tagged at Priest Rapids Dam or Wells Dam make up a large portion of the study group. This 41.7% of the fish that were tracked after tagging are described as drop-outs remaining in the Columbia River or its smaller tributaries. The group tagged at Priest Rapids Dam comprised the majority, with 69 out of 234 fish (56.1%). Of the 24 fish tagged at Wells Dam, 6 (27.3%) remained in the Columbia River including 2 fallbacks over the dam. One of these fish was found spawning at the Chelan Falls Hatchery outfall. None of the fish tagged at Tumwater Dam were included in the drop-out category because they did not descend back to the Columbia River after tagging. Three fish tagged at Priest Rapids Dam that strayed into the mouth of the Entiat River are included in the drop-out category.

Run timing and migration success

One of the objectives of this study was to determine if a correlation exists 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 from 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, September 7th to September 26th, had the highest percentage drop-outs in the Columbia River. This was the smallest of the 3 tag groups and had the highest drop-out rate, 16 of 20 fish (80%) and no successful migrants. The middle run from September 27th to October 25th, had a proportionally higher percentage of drop-outs than home basin fish but did better than the early group. The late run, October 18th to November 14th, had the most successful migrants and proportionally the most fish making it back to their home basin.

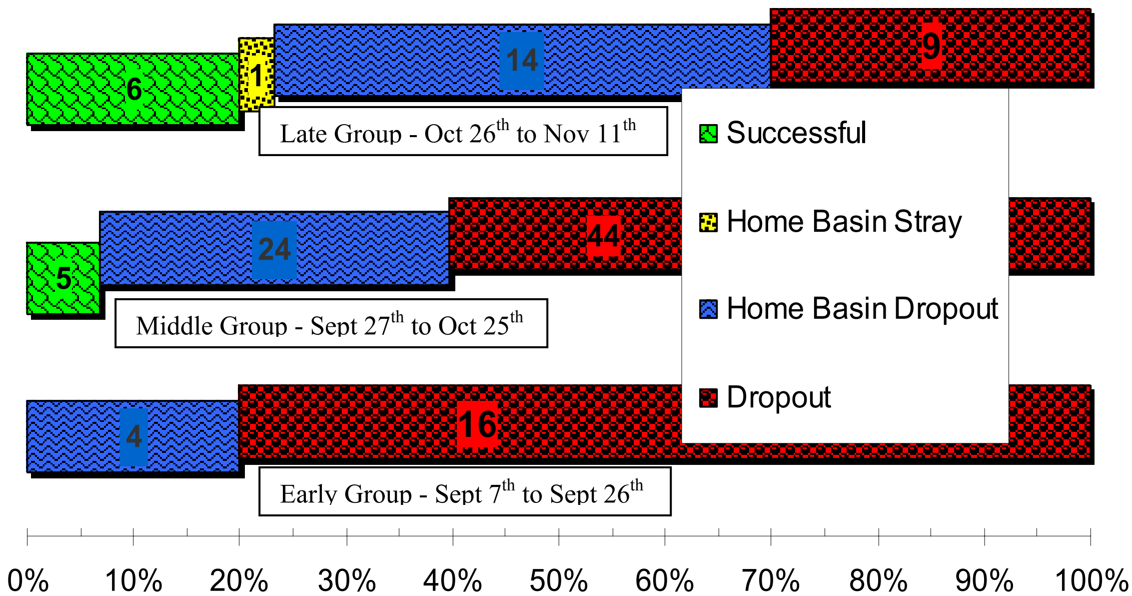


Figure 7. Comparison of migration performance to run timing for coho radio-tagged at Priest Rapids Dam during the 2004 study.

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). Generally, females achieved more overall success with 44% making it back to their home basin, compared to 37% for males. Overall, drop-out rate in the mainstem Columbia River was higher in males at 63%, while females had a 56%.

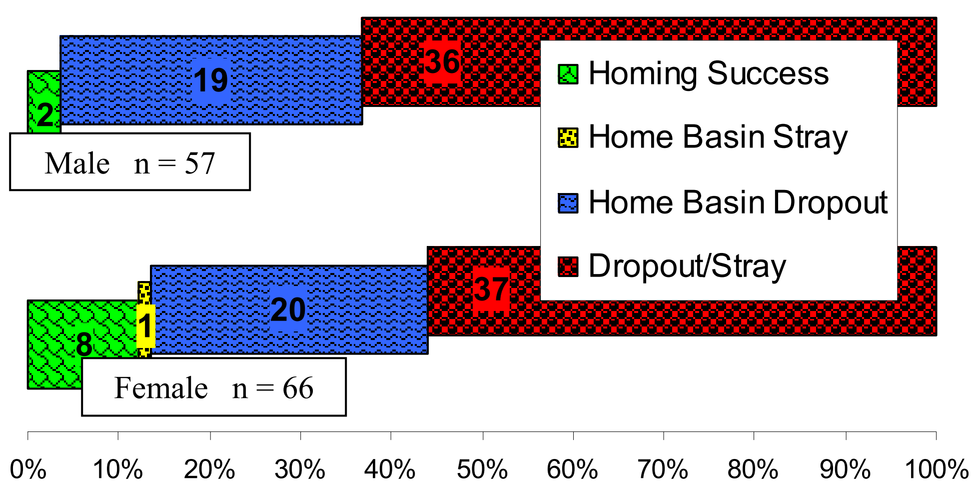


Figure 8. Comparison of migration performance and fish gender for coho radio-tagged at Priest Rapids Dam during the 2004 study.

A comparison was made between gender and distance traveled from the release site at Vantage, Washington (Figure 9). Four males and two females traveled downstream approximately 12 RK and fell over Wanapum Dam while one other male fish remained in the upstream vicinity of the dam. The first large spike on the graph is comprised of 28 radio-tagged coho that remained near the release site. This group of 13 males and 15 females includes three drop-outs that are known to have strayed into Sandhollow Wasteway and likely spawned there; 2 of these fish were males and 1 was female. In the Columbia River between Vantage and Rock Island Dam there were two locations where holding fish were recorded, possibly spawning at the mouths of small tributaries such as Trinidad Creek, this group consisted of 11 males and 14 females. Four fish, 3 males and 1 female, remained near Rock Island Dam. In the Wenatchee River between Monitor and Icicle Creek, the ratio was 17 females to 13 males and in Icicle Creek 6 of the 10 radio-tagged fish from the Priest Rapids tag group were males. No radio-tagged coho from Priest Rapids were tracked above Tumwater Dam. The coho that traveled the farthest was a male that swam 216 RK to the middle reach of the Methow River.

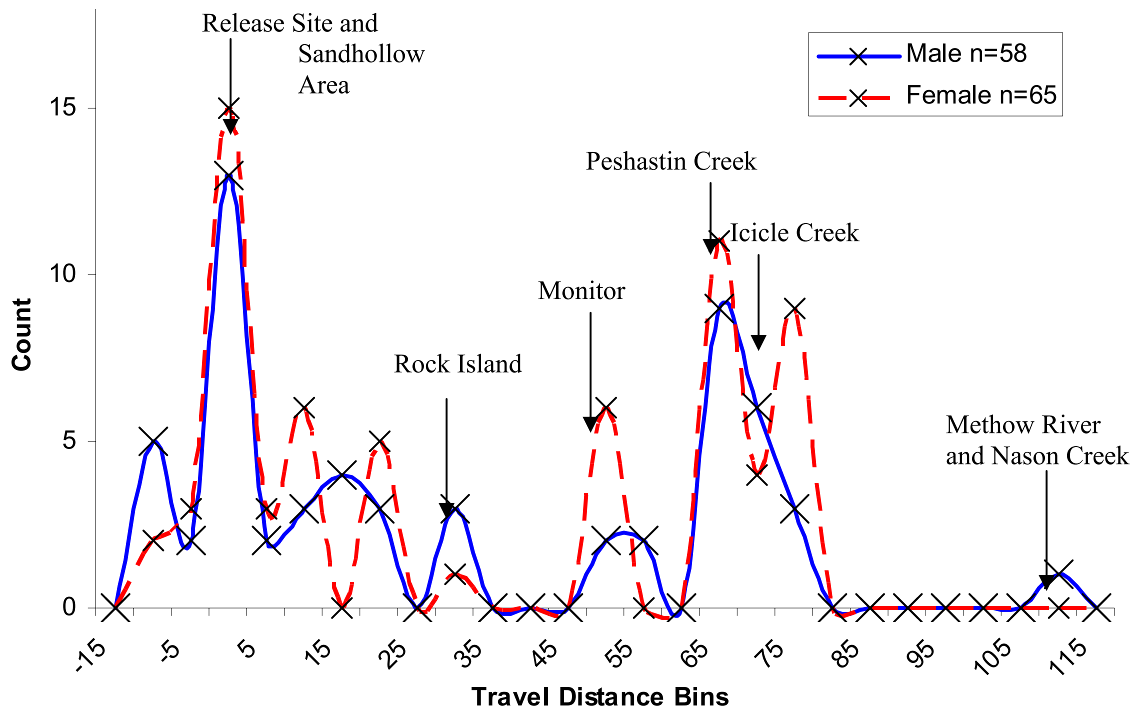


Figure 9. Comparison of migration distance after tagging to fish gender for coho radio-tagged at Priest Rapids Dam during the 2004 study.

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 65.7 cm. The maximum and minimum distances traveled by the first three size (FL) groups were the same; they ranged from 75 kilometers upstream from the release site to 12 kilometers downstream. The largest size (FL) group traveled farther on average, between 112 kilometers upstream from the release site to 5 kilometers downstream. The smallest fish in the study, a 49.5 cm male, traveled 0 RK and the largest fish in the study, two 75.5 cm females, made it 70 RK upstream from the release site.

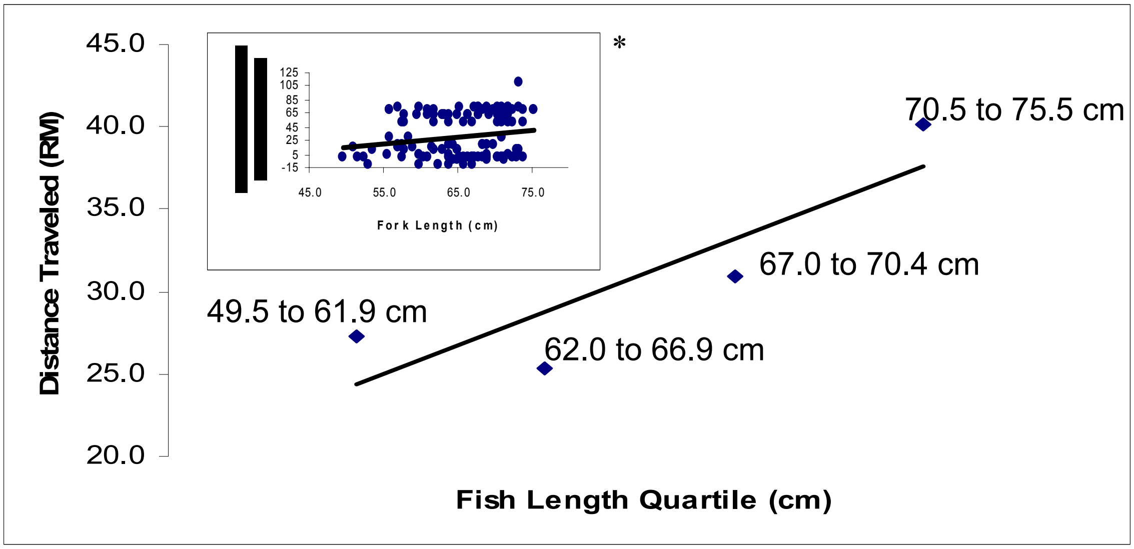


Figure 10. Comparison of migration distance after tagging to fish size quartiles for coho radio-tagged at Priest Rapids Dam during the 2004 study.
*Inset shows the entire length distribution.

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 third 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. In 2003, we were able to trap and tag 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 2004 were a mixture of both first generation mid-Columbia brood and lower Columbia River brood produced in 2001. Smolt releases to the Wenatchee River were 100% mid-Columbia brood and in the Methow, 40% mid-Columbia brood and 60% lower Columbia River brood. We expect some level of straying and/or drop-out during the broodstock development process. It is likely that the proportion of drop-outs 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.

The proportion of drop-outs (fish that do not return to natal tributaries and may 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 upon traits and behaviors that help accrue energy in preparation for migration and that conserve energy during migration (Crossin et al. 2004).

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 already energetically challenged fish. In 2004, we used PIT tags in addition to radio-tags to investigate handling and tag effects on fish behavior and performance. We compared the migration success between three treatment groups, which were handled as adults at Priest Rapids Dam, and one unhandled group: 1) radio-tag only, 2) radio-tag and PIT tag, 3) PIT tag only, 4) no handling – PIT tagged as a juvenile. We measured drop out rates between release, and detection (PIT and radio-tag) at Rock Island Dam. There was no difference in drop-out rates between the two radio-tagged groups (radio-tag only, and radio-tag plus PIT tag) with approximately 20 % reaching Rock Island Dam. Significantly more radio-tag fish dropped out than fish without radio-tags (Table 10 and Figure 11). The effect of the tag could be separated from the handling effect by comparing the two PIT tag only groups. There was no difference in drop-out rates between handled PIT tag fish and PIT tag fish which were not handled but were detected at interrogation sites within the fish ladder with approximately 60% from each group reaching Rock Island Dam. The results of these comparisons indicate that the radio-tag and/or radio-tagging procedure increased the drop-out rate in the Columbia River during this study (Table 10; Figure 11).

Table 10. Evaluation of radio-tagging and handling effect on coho stray and drop-out rates during the 2004 study.

Handling Description Priest Rapids Dam	Sample Size Priest Rapids Dam	Interrogated Rock Island Dam		Interrogated Dryden Dam	
Handled + Radio-Tag Implant	234	54	23.1%	0	0.0%
Handled + Radio-Tag + PIT Tag Implant	98	20	20.4%	0	0.0%
Handled + PIT Tag Implant	95	60	63.2%	5	5.3%
Not Handled, PIT Tagged as Juvenile	129	79	61.2%	17	13.2%

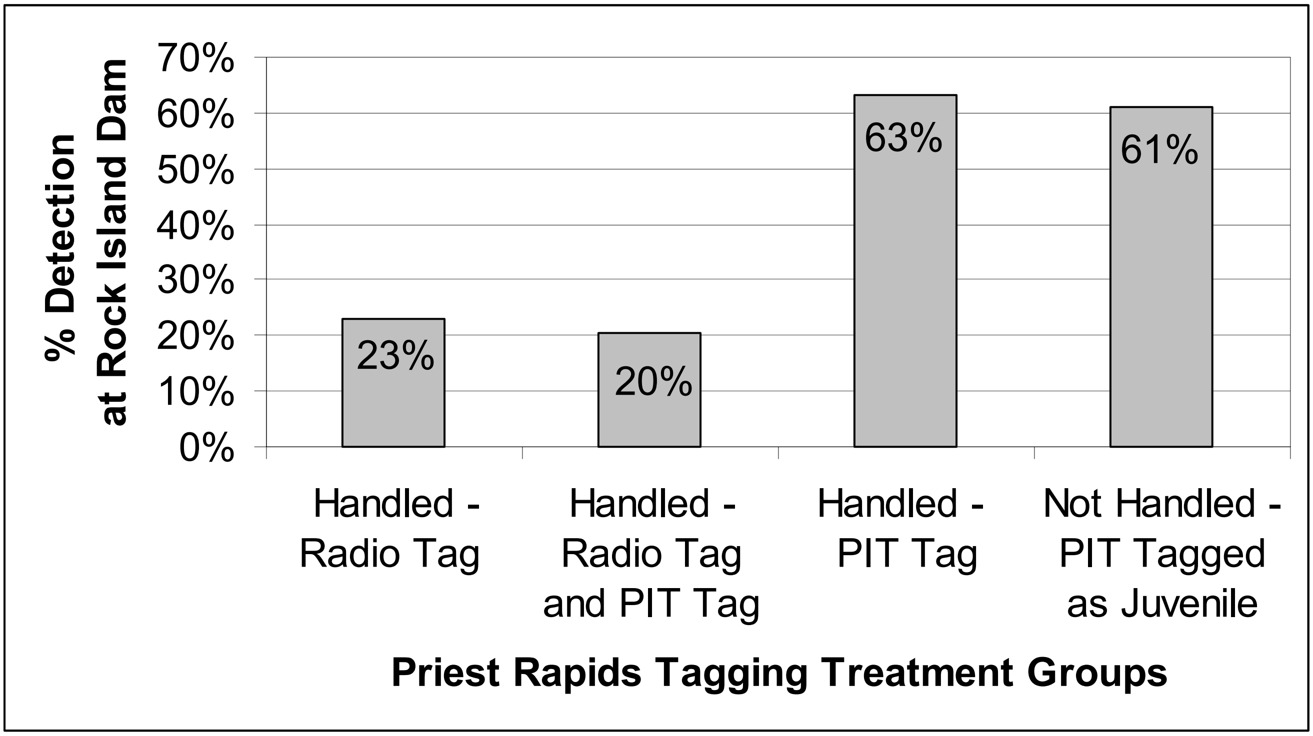


Figure 11. Comparison of handling and tag effects, Priest Rapids Dam 2004.

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-migrating sockeye populations tend to be smaller and more streamlined than short-migrating populations (Crossin et al. 2004); these are mechanical adaptations 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 radio-telemetry data collected during the 2004 evaluation indicate that larger coho were able to travel further than smaller coho. This result is inconsistent with the radio-tag data we collected in 2003 where the smallest fish traveled the furthest (Murdoch and Prevatte 2003).

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 during the 2003 radio-telemetry evaluation (Murdoch et. al. 2005).

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. However, the results of this study show that radio tagged coho salmon in the "early" group (Table 1) had the highest percentage of drop-outs and no success at returning to their natal stream. The "late" group had the greatest proportion of successful migrants, possibly the result of more favorable water temperatures.

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 (English 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) (Columbia River DART). In 2004, the months of September and October had near normal temperatures; during 41 of the 81-day trapping period, temperatures exceeded 17.0 degrees C and 10 days above 19.0 degrees C. This could have been an influencing factor in the large number of undetected fish and the drop-outs that remained in the Columbia River. Complete mean daily water temperature data for the Priest Rapids Dam forebay during the trapping period of 2004 can be found in Appendix C.

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 2004.

Month/Year	2001	2002	2003	2004
August	18.9	20.0	20.0	20.0
September	18.7	19.0	19.2	18.9
October	15.6	17.0	16.9	16.7
November	13.0	N/A	12.2	12.6

Due in part to the observed tag effect, future evaluations using radio-telemetry to study coho migration behavior in the upper-Columbia River are not currently planned; other monitoring efforts (i.e., spawning ground surveys, adult trapping, and mainstem dam counts) are being used to further evaluate the four objectives of this study. Objective two - to determine if stray and drop-out rates will decrease through the development of a locally adapted broodstock, will be addressed through continued PIT tagging efforts as juveniles and/or adults. Planned PIT interrogation sites in the Wenatchee and Methow rivers will help facilitate such an evaluation. Through other projects, PIT tag detection in the adult fish ladder at Tumwater Dam, along with in-stream PIT antenna arrays in both the Wenatchee and Methow basins are expected in 2007.

SUMMARY

1. A total of 293 coho returning to the Wenatchee and Methow rivers were radio-tagged at three locations during 2004.

2. Of the 293 radio-tagged coho, 61.4% (180 fish) were tracked from the release site to probable and known spawning areas.

3. Of the 180 radio-tagged coho that were tracked, 18.0% (10 fish) migrated to their stream of origin.

4. Straying rates of the 180 radio-tagged coho that were tracked within tributaries to the Wenatchee River were estimated to be 0.5 % (1 fish); no stray coho were located in tributaries to the Methow River.

5. Drop-out rates of the coho that were tracked within the Wenatchee River were estimated to be 34.1% (42 fish) for coho tagged at Priest Rapids Dam and 80.0% (28 fish) for coho tagged at Tumwater Dam. Drop-out rate within the Methow River was estimated at 72.7% (16 fish).

6. Drop-out rates of the coho that were tracked in the Columbia River were estimated at 56.1% (69 fish) for coho tagged at Priest Rapids Dam and 273.3% (6 fish) for coho tagged at Wells Dam.

7. Fallback rates of the 180 radio-tagged coho that were tracked varied by release site and were estimated at 3.3% (6 fish) for coho released above Wanapum Dam, 16.7% (4 fish) for coho released above Wells Dam, and 14.3% (5 fish) for coho released above Tumwater Dam.

8. The ability of radio-tagged coho to successfully reach their stream of origin and spawn may be influenced by elevated water temperature in the Columbia River during the early part of the run.

9. The behavior of radio-tagged coho may be negatively impacted by the radio-tag and/or the handling stress of the tagging procedure. Radio-tagged coho dropped out at significantly higher rates than non-radio-tagged coho.

10. Inconsistency between the 2004 study findings and the 2003 study conclusions may have resulted from influence by environmental variables such as river temperature, river discharge, and overall fish condition.

LITERATURE CITED

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.

English, K. K., C. Sliwinsky. B. Nass, and J. R. Stevenson. 2001. Assessment of adult steelhead migration through the Mid-Columbia River using radio-telemetry techniques, 1999-2000. *Prepared for:* Public Utility District No. 2 of Grant County, Ephrata WA; Public Utility District No. 1 of Chelan County, Wenatchee, WA; and Public Utility District No. 1 of Douglas County, East Wenatchee WA.

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.

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.

Linley, T.J. 1993. Patterns of life history variation among sockeye salmon in the Fraser River, British Columbia. Ph.D. dissertation, University of Washington, Seattle.

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.

Murdoch, K.G., and C.M. Kamphaus. 2005. Mid-Columbia Coho Reintroduction Feasibility Study: 2003 Annual Broodstock Development Report. *Prepared for*: Bonneville Power Administration. Project Number 199604000. Portland, OR.

Murdoch, K.G., C.M Kamphaus, and S.A Prevatte. 200***5***.. Mid-Columbia Coho Reintroduction Feasibility Study: 2003 Annual Monitoring and Evaluation Report. *Prepared for*: Bonneville Power Administration. Project Number 199604000. Portland, OR.

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

CHAPTER 2: COHO SPAWNING GROUND SURVEYS

INTRODUCTION

The long-term goal of the mid-Columbia Coho Restoration Project is to re-establish a naturally reproducing coho salmon population in mid-Columbia tributaries at biologically sustainable levels. 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 fifth year of adult returns to the Wenatchee and Methow river basins. The 2004 returning brood was mostly comprised of reprogrammed lower Columbia River coho due to the poor parental return of 2002. Unfavorable juvenile out-migration conditions in 2001 were the primary reason for reduced survival. Our efforts described below are fundamental to measuring spawn timing and quantifying natural production. As the reintroduced coho become locally adapted, it is conceivable 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.

METHODS

As in previous years, Wenatchee Basin spawning ground survey efforts focused on Nason Creek, Icicle Creek, and the Wenatchee River. Surveys also included other tributaries where coho were not released such as the Chiwawa River, Mission and Peshastin creeks. Methow River survey efforts concentrated on the mainstem Methow River and lower portions of select tributaries in which we have previously identified coho spawning activity.

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 high spawner density areas, such as Icicle Creek, weekly surveys were required to obtain clear and distinct redd identification. The mainstem Wenatchee River and tributaries (Little Wenatchee River, Beaver, Brender, Chiwaukum, Peshastin, and Mission creeks) were 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 a measure of spawn timing. In the Methow Basin, Beaver Creek was surveyed on a weekly basis. The mainstem 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/creek 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 riparian vegetation.. 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, coho carcasses were recovered. 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, recovered, and read. Carcass gender was recorded. Female carcasses were checked for egg retention by visual estimation of the number of eggs present in the body cavity. Egg voidance was calculated by subtracting the known eggs of an individual female from the average fecundity of the current years' broodstock. Egg voidance was expressed as a percentage of void eggs from the total fecundity. 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, 2004.

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
	Little Wenatchee River	
LW1	Mouth to Log Jam	0.0-3.2
	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 13th and December 29th. Five-hundred and four coho redds were counted and recorded in 2004 (Figure 1; Table 2). The first redd was observed on October 20th. Peak spawn occurred during the third week of November, one week later than the mean peak spawn for 2000-2003 broods (Figure 2). One-hundred and twenty-six coho carcasses were recovered and sampled by YN personnel: 80 females, 40 males, and 6 unknown. The unknown carcasses lacked distinguishable features, both external and internal, used for sex identification purposes. The sample rate for Icicle Creek was 11.9% which was significantly lower than the 2003 season (26.3%). The low sample rate was correlated to multiple high flow events encountered during the recovery periods on Icicle Creek. One-hundred and four coho snouts were collected for CWT analysis, while 16 carcasses lacked snouts, primarily due to avian and mammalian predation. An additional 16 coho carcasses were recovered by WDFW during summer chinook spawning ground surveys located at the confluence of Icicle Creek. Mean POH for both male and female coho was 58.3 cm (SD = 4.2) and 58.5 cm (SD = 4.2), respectively. All females with intact body cavities were examined for the presence of eggs. Mean egg voidance was 86.1% (*n=66*) and ranged between 0% and 100%. Coded wire tag analysis determined that 89.7% of the tags recovered originated from Icicle Creek. Coho released from the Little Wenatchee River, Butcher, Beaver, and Coulter creeks comprised 10.3% of the total tags recovered in Icicle Creek. The remaining 40 coho either lost or did not have a CWT (Table 2). Scale analysis was used to confirm the origin of fish that did not have a CWT. Redd distribution was evenly distributed throughout Icicle Creek with the highest proportion of redds located in the uppermost reach (203 redds; reach I3). 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 Appendix D.

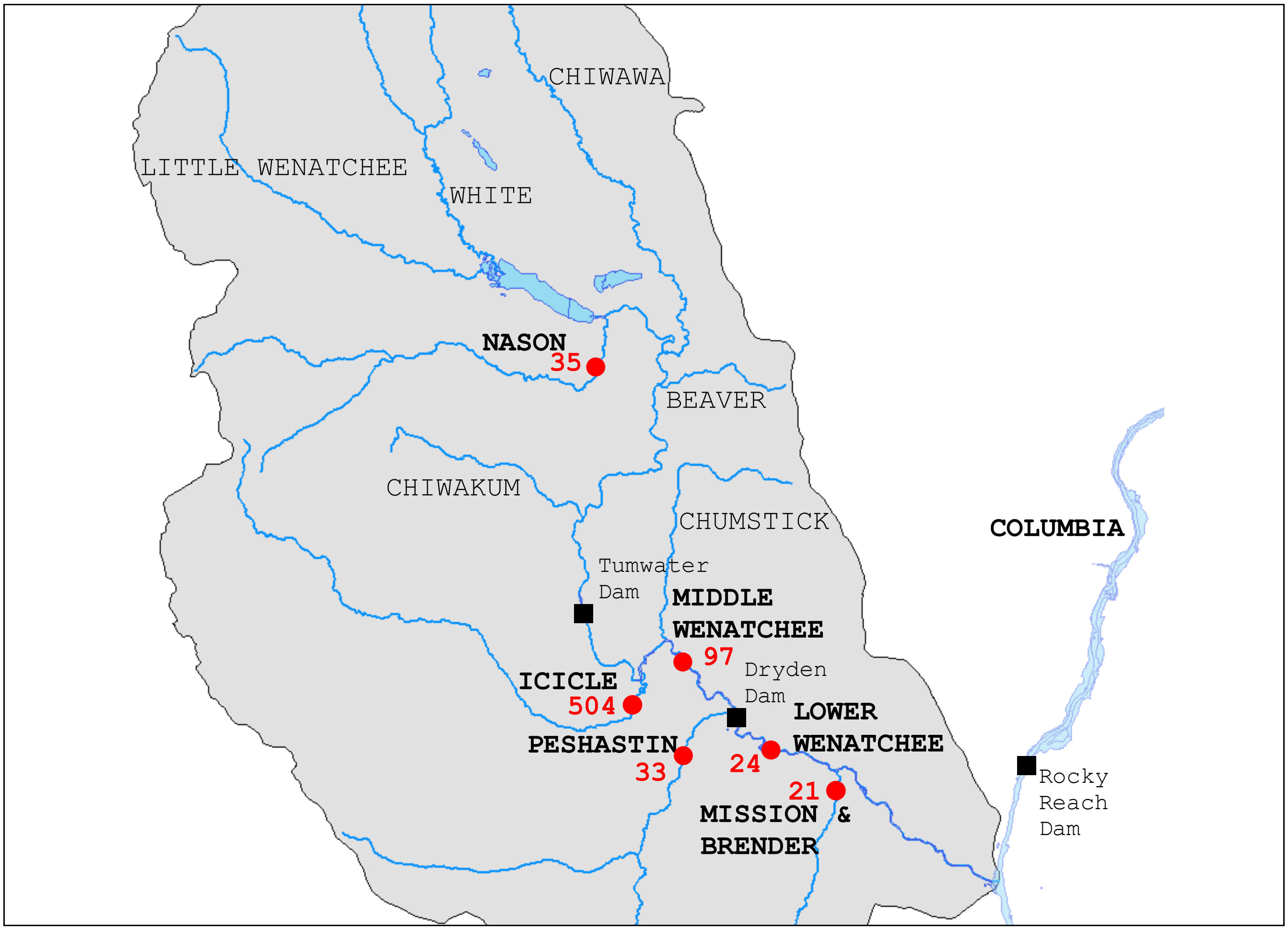


Figure 1. Spatial distribution and number of coho redds in the Wenatchee River basin, 2004.

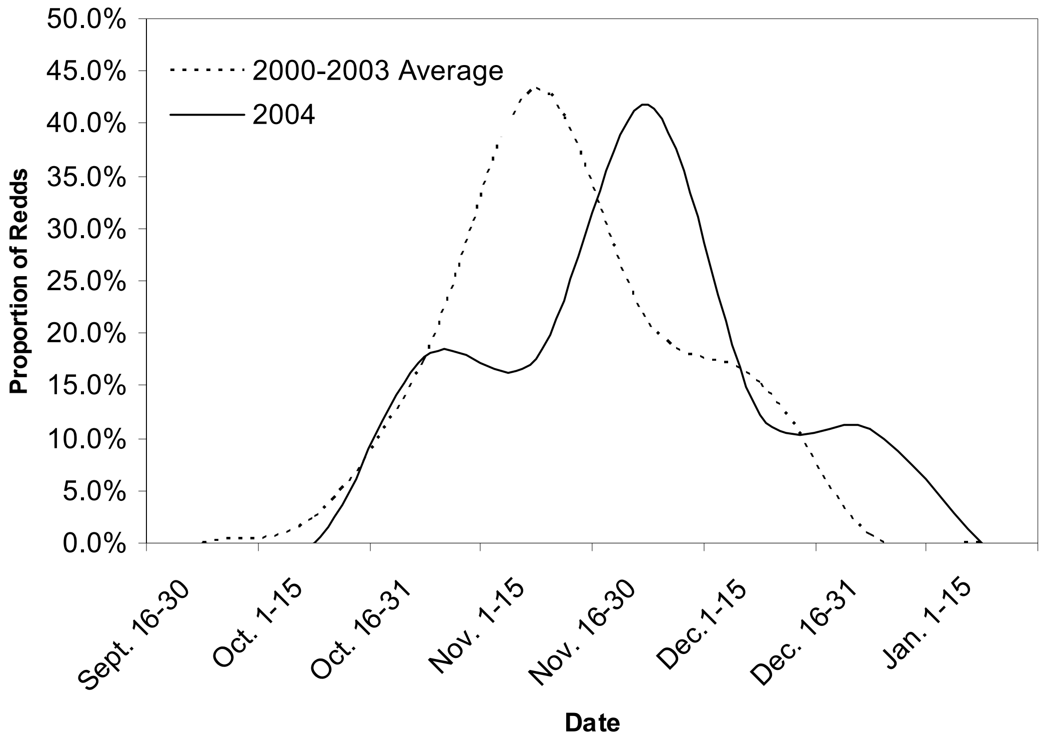


Figure 2. Coho spawn timing in Icicle Creek, 2004.

Table 2. Coded-wire tag (CWT) analysis from carcasses recovered on Icicle Creek, 2004.

Tagcode	**Release origin**	**Number of recoveries (%)***
050971 054320 054531 054533	Icicle Creek	72 (60.0%)
050972	Butcher Creek	2 (1.7%)
050582	Beaver Creek	2 (1.7%)
050968 054326	Coulter Creek	2 (1.7%)
054324 052427	Two Rivers Acc. Site	2 (1.7%)
Lost Tag or No Tag	Unknown Hatchery	33 (27.5%)
No Tag	Unknown Origin**	3 (2.5%)
No Tag	***Natural Origin***	***4 (3.3%)***
Total		**120 (100%)**

*Smolt-to-Adult survival rates for each tag group can be found in Chapter 4.

** Some tags may be unreadable due to scale regeneration

Table 3. Summary of coho redds counted in the Wenatchee River basin and the percentage of redds within each waterway, 2004.

River	No. of Redds	% Of Redds
Icicle Creek	504	70.6%
Nason Creek	35	4.9%
Peshastin Creek	33	4.6%
Mission Creek	17	2.4%
Brender Creek	4	0.6%
Wenatchee River upstream of Dryden Dam	97	13.5%
Wenatchee River downstream of Dryden Dam	24	3.4%
Total	**714**	**100%**

Nason Creek

Spawning ground surveys were conducted on Nason Creek between October 15th and December 3rd (Appendix F). Nason Creek survey reaches can be found in Table 1. A program high of 35 redds were identified in Nason Creek, with peak spawn occurring the week of November 23rd (*n=16*). Eight carcasses were recovered in Nason Creek, three males and five females. The sample rate from Nason Creek was 9.5%. Mean POH for both males and females was 55.0 cm (SD=2.6) and 56.8 cm (SD=4.8), respectively. Egg voidance was 99.7% (*n=4*). Fifty-four percent of redds (*n=19*) identified in Nason Creek were located in the downstream-most reach (N1). CWT analysis indicated that six of the seven (85.7%) coho carcasses recovered originated from 2003 Nason Creek releases. The remaining carcass recovered was a stray originating from Two Rivers acclimation site located on the Little Wenatchee River. Nason Creek redds represented 4.9% 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 survey reaches can be found in Table 1. A total of 121 redds were found in the Wenatchee River (Table 2). The majority (69.3%) of spawning activity occurred in reach W5 (*n=76*). YN personnel found seven carcasses on the Wenatchee River, five females and two males. Mean POH for both males and females was 65.0 cm (SD=0.0) and 60.6 cm (SD=1.7), respectively. Egg voidance was 99.9% (*n=4*). Of the seven carcasses recovered, four had CWT's. All four coho originated from the 2003 Icicle Creek release. Snouts were unobtainable from three of the carcasses. An additional 40 coho carcasses were recovered in the Wenatchee River by WDFW personnel during summer chinook spawning ground/carcass surveys. Eighty percent of the carcasses recovered by WDFW were found downstream from Icicle Creek. Scale analysis verified that one of the carcasses recovered by WDFW was a natural origin three-year-old coho. The remaining coho were hatchery origin three-year-olds. Redds located on the Wenatchee River accounted for 16.9% of the total observed coho redds in the Wenatchee Basin (Table 2).

Other Tributaries

We surveyed smaller tributaries to the Wenatchee River to investigate spawning distribution and counts rather than timing. Survey areas included the lower reach of Beaver Creek, Brender Creek, Chiwawa River (lower), Chiwaukum Creek, Chumstick Creek, Peshastin Creek, Mission Creek, and Little Wenatchee River (Table 2). No redds were found in Beaver Creek, Chiwawa River (lower), Chiwaukum Creek, Little Wenatchee River, or Chumstick Creek. A total of 54 redds were found in Brender, Mission, and Peshastin creeks combined (Table 3).

Mission Creek/Brender Creek

Mission Creek survey reaches can be found in Table 1. Seventeen coho redds were identified in Mission Creek between November 4th and December 15th. Four redds were also located in Brender Creek during this same time period and were 5-10 meters upstream from the Mission Creek confluence. All 17 redds identified in Mission Creek were in the lowest reach (M1). We recovered 10 carcasses—7 females and 3 males. We were able to collect snouts for CWT analysis on eight of the ten carcasses. Mean POH for both males and females was 46.0 cm (SD=11.3) and 54.7 cm (SD=3.3), respectively. Egg voidance was 50.0% ($n=2$). CWT recovery and analysis demonstrated that five tags were recovered from the carcasses. Four of the CWT'ed coho originated from the 2003 Icicle Creek release while the other was released from Coulter Creek. No carcasses were recovered in Brender Creek but due to the location of the redds, it is possible that carcasses collected in Mission Creek resulted from Brender Creeks redds. Redds located in Mission and Brender creeks represented 2.9% of the coho redds in the Wenatchee River basin.

Peshastin Creek

Peshastin Creek was divided into three reaches for spawning ground surveys (Table 1). Thirty-three coho redds were identified between October 29th and December 21st. Five carcasses were recovered; four females and 1 male. Again, the low carcass recovery was a result of multiple freshet events during surveys. Mean POH for both male and female coho was 57.0 cm (SD = 0.0) and 59.8 cm (SD = 3.3), respectively. Mean egg voidance was 97.9% ($n=4$). Four of the five carcasses had CWT tags; three originated from 2003 Icicle Creek releases while the remaining tag originated from the 2003 Coulter Creek release. Scale analysis determined that the one remaining fish collected was of natural origin. Redds located in Peshastin Creek represented 4.6% of the coho redds in the Wenatchee River basin.

Methow River

Methow River surveys were conducted in 2004 to determine distribution rather than spawn timing. These surveys were divided into seven reaches (Table 1). A total of 22 redds were identified in the Methow River, which included the Methow Fish Hatchery (FH) outfall (Table 4). The Methow FH is a state operated facility approximately 1 kilometer upstream from Winthrop NFH. YN personnel found 1 carcass in the Methow FH outfall; a female. The POH was 48.0 cm (SD=0.0). Egg voidance was 100.0%. Redds in the mainstem Methow River and hatchery outfall comprised 70.9% of all redds identified within the basin for 2004.

Other tributaries

Spawning ground surveys were expanded in 2004 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, Gold Creek, Twisp River, or Wolf Creek. A total of 9 redds were found in Beaver and Spring creeks (Table 3).

Beaver Creek

Beaver Creek surveys were conducted as one reach (Table 1). One coho redd was identified in Beaver Creek approximately 200 meters upstream. Beaver Creek redds represented 3.2% of the total coho redds located 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 2004 (Table 1). Eight coho redds were identified between November 8th and December 7th. Redds located in Spring Creek accounted for 25.8% 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, 2004.

Table 4. Summary of coho redds counted in the Methow River basin and the percentage of redds within each waterway, 2004.

River Reach	No. of Redds	% Of Redds
Methow River	13	41.9%
Methow FH outfall	9	29.0%
Beaver Creek	1	3.2%
Chewuch River	0	0.0%
Gold Creek	0	0.0%
Libby Creek	0	0.0%
Spring Creek	8	25.8%
Wolf Creek	0	0.0%
Twisp River	NA	NA
Total	**31**	**100%**

DISCUSSION

The 2004 adult coho returns to the Wenatchee River Basin exceeded all previous year's counts with 714 redds. Broodstock development may, in part, account for the increasing trend in spawner escapement (Murdoch et.al. 2005). We estimate that 3,594 coho returned to the Wenatchee River basin, as measured by Tumwater Dam counts plus redds downstream of Tumwater Dam and broodstock collected (Chapter 4). A total of 1,576 coho were handled during adult trapping, of which, 1,450 were incorporated into the broodstock (Kamphaus and Strickwerda 2006). The minimum spawning escapement of 2,144 coho was estimated from the total calculated escapement minus broodstock collected. From the 2,144 coho estimated to have escaped to the Wenatchee Basin, we found 714 redds (3.0 fish per redd). The sex ratio observed at Dryden Dam predicts 2.2 fish per redd. A discrepancy in fish-per-redd estimates could result from unidentified redds and pre-spawn mortality Coho redd identification on the Wenatchee River can be difficult because spawn timing overlaps with summer chinook, which are widespread in the basin. Coho redds in heavily used summer chinook spawning areas cannot be positively identified without seeing individual fish on these redds. In addition to the species overlap, two major high flow events could have contributed to redds being missed during surveys.

Most of the coho passing over Tumwater Dam were unaccounted for during spawning ground surveys. A total of 674 coho were counted passing over Tumwater Dam in 2004. It was likely that video counts were 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 2004, was 14.3% (Chapter 1). This fallback rate may be artificially low because of the telemetry release location for 2004 was further upstream. The new post-tagging release location was decided upon to potentially reduce the high fallback rate observed in 2003. If the fall back rate observed in radio-tagged fish was representative of the population of non-radio-tagged fish, we estimate that 578 coho migrated upstream; destined for the upper basin. The sex ratio of coho passing over Tumwater Dam was 1F:1.4M which predicts a 2.4 fish per redd upstream of the dam. Two-hundred and forty-one females potentially spawned in the upper basin (Nason Creek, Little Wenatchee River, and Beaver Creek returning adults). Forty-six redds were found upstream of Tumwater Dam; 35 in Nason Creek and 11 in the Wenatchee River. Based on the results of the telemetry evaluation (Chapter 1) and observations during trapping, we believe that females were not dropping out earlier than males and were able to navigate though Tumwater Canyon, unlike past years' data has suggested; therefore, the sex ratio observed could be a result of the first-generation adult returns that occurred in 2004. Increased stamina could have allowed for increased migration through Tumwater Canyon and further upstream to favorable spawning areas.

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.

As the broodstock development process continues, we plan to continue spawning ground surveys to track the distribution and abundance of coho spawners.

SUMMARY

- During spawning ground surveys in Icicle Creek, we observed 504 coho redds and recovered 126 coho carcasses. The mean egg voidance was of 86.1% (*n=66*).

- During spawning ground surveys in Nason Creek, we counted 35 coho redds and recovered 8 carcasses. The mean egg voidance was 99.7% (*n=4*).

- We found 121 coho redds in the mainstem Wenatchee River and a combined 54 redds in Brender, Mission, and Peshastin creeks. A total of 47 carcasses were recovered in the Wenatchee River by WDFW and YN personnel. A total of 15 carcasses were recovered on Mission (*n=10*) and Peshastin (*n=5*) with mean egg voidances of 50.0% (*n=2*) and 97.9% (*n=4*), respectively.

- A total of 31 redds were identified in the Methow River and associated tributaries in 2004. One carcass was recovered with an egg voidance of 100.0% in the Methow River basin.

LITERATURE CITED

Kamphaus, C. K. and C. Strickwerda. 2006. Mid-Columbia coho reintroduction feasibility study: 2004 annual broodstock development report. *Prepared for*: Bonneville Power Administration, Project Number 199604000, Portland OR.

Murdoch, K.G, C.K. Kamphaus, and S.A. Prevatte. 2005. Mid-Columbia coho reintroduction feasibility study: 2003 annual monitoring and evaluation report. *Prepared for*: Bonneville Power Administration, Project Number 199604000, Portland OR.

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.

CHAPTER 3: POPULATION ESTIMATE OF NATURALLY PRODUCED COHO SALMON SMOLTS *ONCORHYNCHUS KISUTCH* IN THE WENATCHEE RIVER BASIN

INTRODUCTION

Efforts to restore naturally reproducing coho to tributaries of the mid-Columbia River depend 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 evaluating fitness and productivity in terms of egg-to-smolt survival, 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 biological data from all emigrating salmonids in the basin.

The 2004 smolt emigration included the third year of naturally produced coho smolts in the Wenatchee River in close to a century. Our efforts described below mark an important step in evaluating both the potential for reintroduced hatchery coho salmon to reproduce successfully in mid-Columbia tributaries and the reintroduction process itself.

METHODS

In 2004, WDFW personnel collected emigrating coho, both hatchery and natural, from March 24th to July 9th at the Monitor smolt trap on the Wenatchee River. 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 effect 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 (2001-2004) were used to calculate trap efficiency. The efficiency estimates were stratified by flow and three trap positions. Data analysis details can be found in Miller (2005).

RESULTS

Coho Run Timing

Naturally produced coho smolts were captured between March 29th and July 9th. Peak migration occurred between May 27th and June 18th (*n=19*; Figure 1). Hatchery coho were observed emigrating between March 24th and June 26th (volitional releases began on April 23rd), with a peak emigration between May 7th and 27th (*n=10,555*; 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 to be correlated with river discharge (Figure 1).

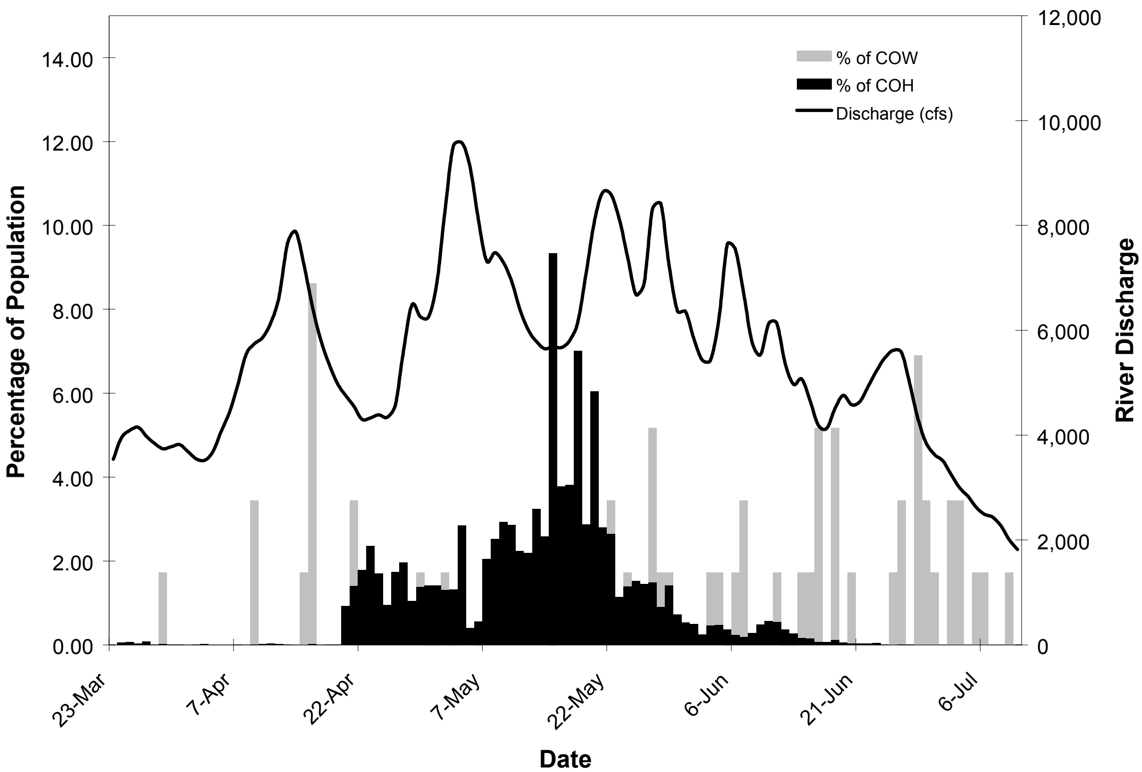


Figure 1. Run timing of natural and hatchery coho emigrating from the Wenatchee River, 2004.

Emigration Expansion

A total of 58 naturally produced coho smolts (brood year 2002) were trapped during 2004. Trap efficiencies used to produce an estimate of naturally produced coho emigrating from the Wenatchee River ranged between 0.29% and 0.78% (T. Miller, WDFW, unpublished data). Wenatchee River flows used to stratify the efficiency trials ranged from 1820 cfs to 9580 cfs.

Based on the efficiency estimates, river flow, and trap position, we estimate that approximately 5,826 naturally produced coho yearlings emigrated from the Wenatchee River in 2004 (Miller 2005).

Egg-to-Emigrant Survival

We estimate the Wenatchee River basin was seeded with 75,124 coho salmon eggs in 2002 (28 redds times 2,683 eggs/female). Using the naturally produced coho emigration estimate, we calculate an egg-to-emigrant survival rate of 7.8%. This value should be viewed as a maximum because it is possible that not all coho redds within the Wenatchee basin successfully identified and counted. Any unaccounted for redds would artificially inflate the egg-to-emigrant survival rate.

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 2004 data may provide a population estimate with a 95% confidence interval.

The egg-to-emigrant survival rate (10.6%) 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 2004 (4.7% to 18.1%) (Miller 2005).

The 2004 migration of naturally produced coho smolts demonstrates that successful natural production of reintroduced hatchery coho has occurred. Successful reproduction, even on a small scale, can provide valuable insight on the feasibility of reintroduction. With each generation of coho returns to the Wenatchee River, the stock should become increasingly adapted to conditions within mid-Columbia tributaries. We expect continued 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. 2005. 2004 Chiwawa and Wenatchee River Smolt Estimates. Washington State Department of Fish and Wildlife, Wenatchee WA. 33pgs.

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.

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 4: 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 1,129,319 yearling coho smolts into Wenatchee River tributaries in 2004 (Kamphaus and Strickwerda 2006). Release sites, the estimated number 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 Mid-Columbia acclimation sites, 2004.

Basin	Tributary	Acc. Site	Broodstock Origin	Est. No. Released[1]	No. of PIT tags	CWT
Wenatchee	Icicle Ck.	Dam 5	LCR	603,969	8323	100%
		LNFH SFL	Mid. Col.	125,168	3980	100%
	Nason Ck.	Butcher Ck. Pd.	LCR & LCRxMCR	77,848 31,674	4015 4475	100% 100%
	Nason Ck.	Coulter Pd	LCR	110,930	N/A	100%
		Mahar Pd.	MCR. LCR	33,166 71,815	3705	100% 100%
	Beaver Ck.	Beaver Ck.	LCR	74,751	N/A	100%
Methow	Methow R	WNFH	MCR	16,377	N/A	100%
	Methow R	WNFH	LCR	291603	8944	100%

[1]Estimated number of smolts released is based on the number of fish transported minus the estimated number of mortalities. (Kamphaus and Strickwerda 2006).

PIT-tagged fish released from Dam 5, Leavenworth NFH small Foster Lucas ponds (SFLs), Butcher Creek Pond, Mahar Pond, and Winthrop NFH (Table 1) were detected at McNary, John Day and Bonneville dams. From these data, estimates of release-to-McNary survival were 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 passage is stratified into sequential days having similar detection rates. The estimate of a stratum's passage is given in Appendix E. 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 Dam is the estimated total passage (stratum passage estimates added over all the strata) divided by either the number of tagged fish or the number of fish detected leaving the acclimation pond (number released). For the 2004 survival rates, detection-rate estimates were calculated for Nason Creek, Icicle Creek, and Methow River releases separately. Detailed methods can be found in Appendix E.

Methow and Wenatchee River Basin Smolt-Adult Survival Rates (SAR)

In 2003, The Yakama Nation acclimated and released 242,355 coho smolts into the Methow River (Kamphaus and Murdoch 2005). 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. Coded wire tags (CWTs) and analysis of scale samples from non-CWT fish were used to distinguish naturally produced fish from hatchery fish.

The Yakama Nation acclimated and released 907,807 coho smolts into the Wenatchee River basin in 2003 (Kamphaus and Murdoch 2005). The smolts were released from six acclimation sites within the Wenatchee River basin: 139,919 coho smolts were released from the Butcher Creek acclimation site on Nason Creek, 82,631 from the Coulter Creek acclimation site on Nason Creek, 33,344 from Mahar

Pond acclimation site on Nason Creek, 70,477 smolts were released from the Beaver Creek acclimation site, 97,807 smolts were released from the Two Rivers acclimation site on the Little Wenatchee River, and 482,828 smolts were released from Dam 5 on Icicle Creek (behind the Leavenworth NFH). We calculated smolt-to-adult survival for BY 2001 adult returns using four 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) Broodstock collected at Dryden Dam, Tumwater Dam counts, and redds counted downstream of Tumwater Dam
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 fall river flows experienced in 2004) or may overestimate the number of coho returning if fallback rates of fish not collected in the broodstock are high. Method two and three may also underestimate the number of coho to return to the Wenatchee River because it does not take pre-spawn mortalities, or unidentified coho redds into account. Method four is likely an overestimate, as it assumes no fallbacks or drop-outs occurred between Rock Island and Rocky Reach Dams. SARs calculated from methods one and two have been very similar in previous years.

RESULTS

Smolt Survival, Release to McNary Dam

Stratified McNary detection-rate estimates were used to calculate the survival index for Wenatchee and Methow basin releases. The methods of estimation of daily passages and detection rates and the identification of detection-rate strata are described in Neeley 2005 (Appendix H). We calculated survival indices for coho released into Icicle Creek from the Small Foster Lucas ponds (SFLs) and Dam 5 acclimation sites. Release to McNary Dam survival indices were also calculated from releases into Nason Creek (Butcher Creek and Mahar Pond), and from the Winthrop NFH in the Methow basin. The calculated survival indices for all releases can be found in Table 2.

Table 2. Survival indices Mid-Columbia smolt releases, 2004.

Basin	Release Tributary	Release Location	Rearing Facility	Brood Origin	n	Survival to McNary
Wenatchee	Icicle Creek	Dam 5	Cascade FH	LCR	3982	0.6083
Wenatchee	Icicle Creek	Dam 5	Willard NFH	LCR	4341	0.5509
Wenatchee	Icicle Creek	SFL	Cascade FH	LCR	3980	0.5626
Wenatchee	Nason Creek	Rolfing's Pond	Willard NFH	MCR	3940	0.3622
Wenatchee	Nason Creek	Butcher Ck. Pond	Willard NFH	LCR	4475	0.3051
Wenatchee	Nason Creek	Butcher Pond	Willard NFH	LCR x MCR	4015	0.3441
Methow	Methow River	Winthrop NFH	Willard NFH	LCR	4463	0.2610
Methow	Methow River	Winthrop NFH	Cascade FH	LCR	4481	0.2951

Source: Neeley 2005 (Appendix E).

The passage of PIT-tagged coho volitionally released on April 23th, 2004 from the acclimation site behind the LNFH peaked at McNary Dam on May 31st, with 73 PIT-tagged fish per day (Figure 1). The mean McNary Dam detection date for coho released on Icicle Creek was May 28th.

Run timing to McNary Dam for PIT-tagged mid-Columbia brood coho volitionally released into Nason Creek from Butcher Creek and Mahar Acclimation Ponds was similar, peaking on June 3rd and 4th, with 39 and 21 detections per day respectively (Figure 1). However the mean detection data at McNary Dam was almost a week earlier for coho released from Butcher Creek Pond (June 3rd) than for those released from Mahar Pond (June 9th). The later mean passage/detection date at McNary Dam for fish released from Mahar is not surprising considering that they were released from the acclimation pond on May 6th, eight days after smolts were released from the Butcher Creek Pond (April 28th). See Kamphaus and Strickwerda (2006) for more information regarding fish release dates, numbers, and sizes.

The passage of PIT-tagged coho volitionally released between April 19th and April 29th from Winthrop NFH peaked at McNary Dam on June 1st, with 28 PIT-tagged fish per day (Figure 1). The mean McNary Dam detection date for coho released from Winthrop NFH was June 6th (Figure 1).

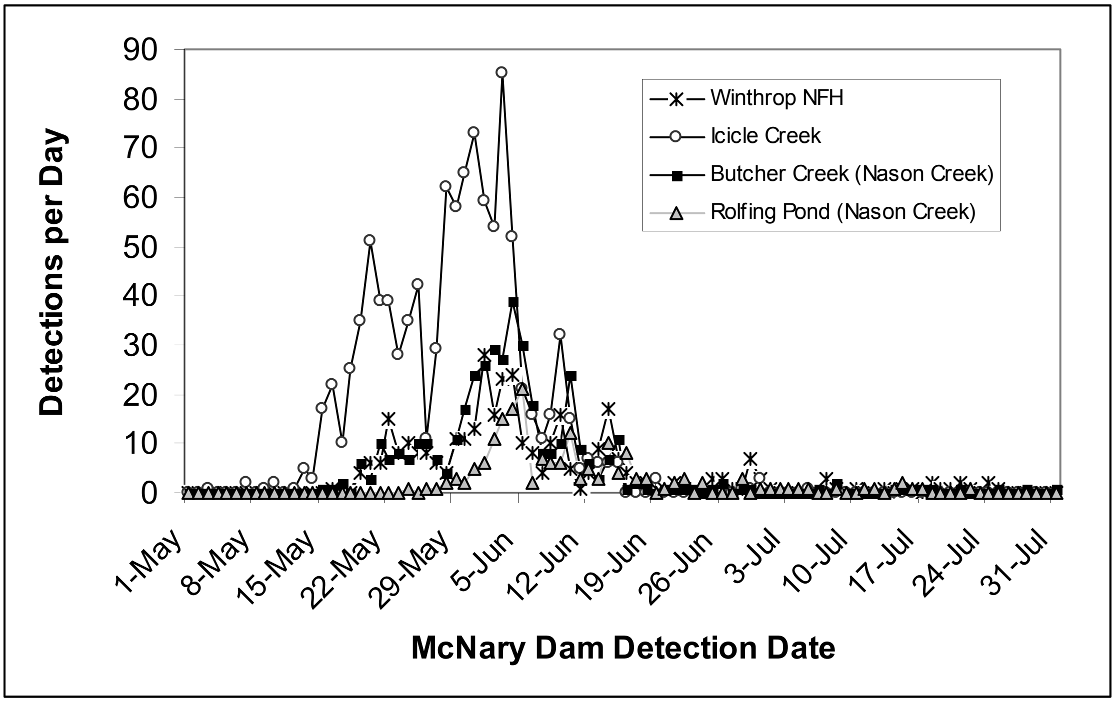


Figure 1. Daily PIT-tag detections at McNary Dam for hatchery coho released from Mid-Columbia tributaries, 2004.

Methow River Basin Smolt-to-Adult Survival

Based on coho enumeration method one (broodstock collected through volunteers to the Winthrop NFH and trapped at Wells Dam combined with an estimate of spawning escapement enumerated through redd counts), we estimate that 194 adults (BY 2001) and 20 coho jacks (BY 2002) returned to the Methow River in 2004. One additional jack (BY 2001) was estimated to have returned in 2003 (Murdoch et. al. 2005). Using method one for BY 2001 returns, we estimate the SAR for coho returning to spawn in the Methow River to be 0.08% (Table 3). Based on Wells Dam counts combined with broodstock collected at Wells Dam (method two), an estimated 279 coho adults (BY 2001) and 28 coho jacks (BY 2002) returned to the Methow River, with an additional 11 jack coho in 2003 (BY 2001), resulting in a SAR of 0.16%. Because it is unlikely that we were able to locate and identify all coho redds within the Methow Basin, method number two may be a more accurate estimate of smolt-to-adult survival for BY 2001.

Table 3. Smolt-to-Adult survival rates for brood year 2001 returns to the Methow River, 2004.

Method	2004 return estimate (BY 2001 & 2002)	2003 Jack Estimate (BY 2001)	SAR
1) Broodstock and redd counts	194 adult & 20 jack	1 jack	0.08%
2) Wells Dam Counts & Broodstock Collected at Wells Dam	279 adult & 28 jack	11 jack	0.16%

Wenatchee River Smolt-to-Adult Survival Rate (SAR)

Coho counts at Tumwater Dam, and an estimate of spawning escapement based on redd counts downstream of Tumwater Dam predict that 3594 coho returned to the Wenatchee basin in 2004. From CWT recovery and scale analysis from fish without CWTs, we estimate that 4.0% of the adult coho returning to the Wenatchee River were naturally produced, resulting in a return of 3375 hatchery origin adults, 75 hatchery origin jacks, and 144 natural origin adults. The 75 brood year 2002 jacks which returned in 2004 were excluded from SAR calculations, but 41 BY 2001 jacks which returned in 2003 were included. Based on this run size estimate, we calculate a SAR for hatchery coho returning to the Wenatchee River of 0.39% (Table 4).

As described on page 48, in an attempt to provide the most accurate estimate of smolt-to-adult survival, we present four methods of enumerating run size and spawning escapement (Table 4) for coho returning to the Wenatchee River. Of the four methods, we felt that method number three, described above, may have provided the most accurate estimate of run size. Method number one, expanded Dryden Dam trap counts is likely an underestimate. Due to high flows during fall freshets, coho were able to navigate over Dryden Dam without passing through the fish traps, resulting in a presumed underestimate of spawning escapement and run size. Similarly, estimates of spawning escapements based upon redd counts (methods 2 and 3) may also underestimate the actual run size, because it is unlikely that all redds were identified and counted. However, estimates calculated based upon redd counts were higher than those estimated through expanding the Dryden Dam trap counts; and therefore may be closer to the true value. Conversely, run size estimates based on the difference in counts at Rock Island Dam and Rocky Reach Dam may over estimate run escapement (Table 4), due to fall back and pre-spawn mortality. The true value is likely somewhere between 5134 (0.55%) and 3594 (0.39%; Table 4)

Table 4. Brood year 2001 coho smolt-to-adult survival in the Wenatchee River basin.

Method	2004 return estimate (BY 2001 & 2002)*	2003 Jack Estimate (BY 2001)	SAR – Hatchery Origin Returns	SAR – Natural Origin Returns*
1) Dryden Dam counts expanded for non- trapping days plus redd counts downstream from Dryden Dam	1880 hatchery origin adults, 42 jacks, & 80 natural origin adults	43 jacks	.219%	0.218%
2) Broodstock collected at Dryden Dam and redd counts	2837 hatchery origin adults, 63 jacks & 120 natural origin adults	33 jack	0.326%	0.327%
3) Tumwater Dam Counts and redds counted downstream from Tumwater Dam	3375 hatchery origin adults, 75 jacks, & 144 natural origin adults	41 jacks	0.389%	0.393%
4) Rock Island Dam Count minus Rocky Reach Dam counts	4827 hatchery origin adults, 106 jacks, & 201 natural origin adults	51 jacks	0.555%	0.548%

* An estimate of BY 2001 naturally produced coho smolts emigrating from the Wenatchee River (n=36,678: Murdoch et al. 2005) was provided by WDFW from data collected at a rotary smolt trap near the town of Monitor (RM 7.1). The accuracy of this estimate is not known due to extremely low and variable trap efficiencies.

In addition to calculating SARs for the composite of hatchery coho returning to the Wenatchee River, we calculated SARs for each release site based on the recovery of CWTs. The SARs coho returning to Nason Creek ranged from a low of 0.18% for the Butcher Creek Pond to a high of 0.53% for Coulter Pond (Figure 2). Predation is suspected as the reason for low survival at Butcher Creek Pond. Because 2004 represents the first adult return to Coulter Pond, the reasons for higher survival is unknown. Continued data collection from Coulter Pond will indicate whether higher survival rates will continue or were unique to the 2004 adult return. The SAR for adults returning to the Little Wenatchee River was 0.30% (Figure 2). Within the Dam 5 release site, SARs for the developing local broodstock (MCB; 0.56%) were higher than for reprogrammed lower Columbia River stocks (LCB; 0.45%). Of the fish released from Dam 5, MCB coho reared at Winthrop NFH had the lowest SAR (0.22%; Figure 2). The lower return rate observed in fish reared at Winthrop NFH and transferred to Icicle Creek for acclimation and release may be explained by high stray rates from this group back to the Methow River where they comprised approximately 5.5% of the spawning population in the Methow River.

The SAR for natural-origin returns was based on scale analysis of adult returns and a smolt population estimate calculated by WDFW from data collected at a rotary smolt trap located on the Wenatchee River near Monitor (See Chapter 3). SARs for naturally produced coho can be found in Table 4 and Figure 2. The accuracy of the smolt population estimate is not known due to extremely low and variable trap efficiencies, leading to an uncertainty in the accuracy of the SAR.

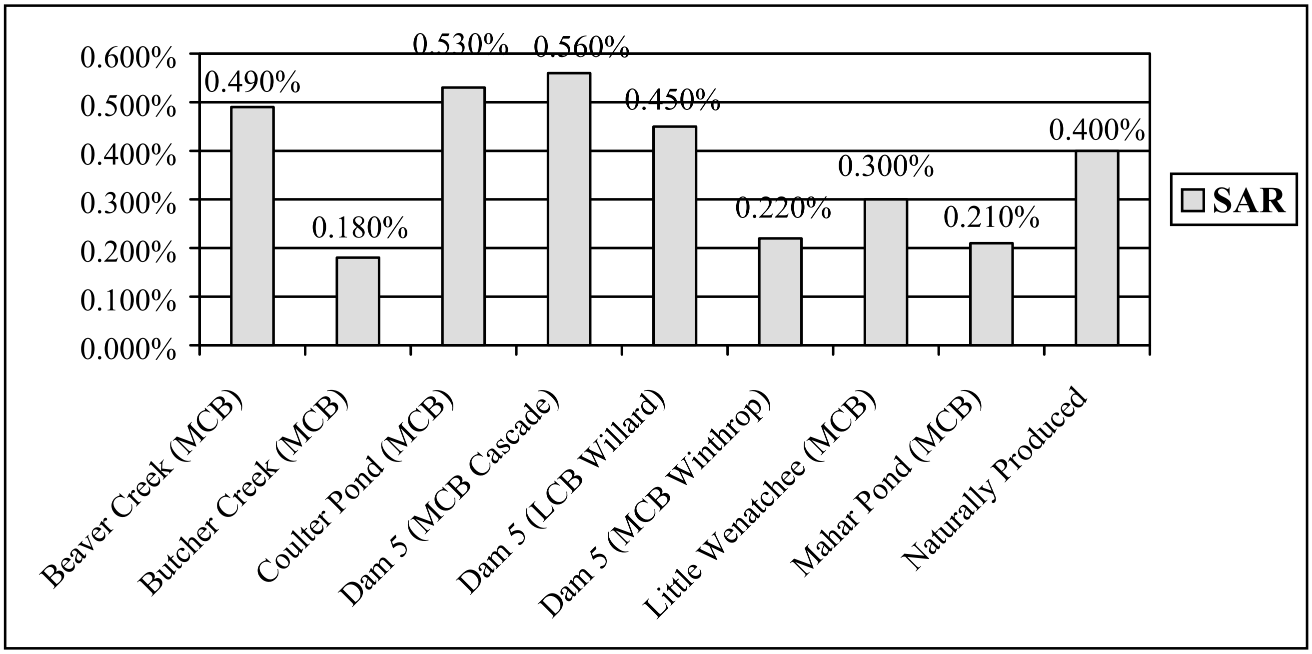


Figure 2. Wenatchee Basin acclimation /release site, and naturally produced coho in the Wenatchee River Basin, 2004 (BY 2001).

DISCUSSION

The downstream hatchery coho smolt survival index from release in Icicle Creek to McNary Dam (0.55% to 0.61%) was substantially higher than the downstream smolt survival estimates for hatchery coho released from acclimation sites on Nason Creek (0.31% to 0.37%). This difference in downstream survival rates between Icicle Creek and Nason Creek is typical of what we have observed in previous years. Differences in the survival indices could be the result of differing predation rates in the acclimation sites, differing migration routes, or differences in run timing. 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. Juvenile and adults survival rates from previous years can be found in Table 5.

Both release-to-McNary Dam and smolt-to-adult survival rates in the Wenatchee are 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. We believe the difference in smolt-to-adult survival is, at least in part, the result of the high proportion of mid-Columbia brood returning to the

Wenatchee River. Over the course of the reintroduction program we have consistently observed higher SARs for MCB coho than LCB coho when released from the same acclimation pond.

Due to life history differences between coho and the other anadromous salmonids in the Wenatchee and Methow Rivers, it is yet possible to compare BY 2001 coho SARs to those of chinook or steelhead, however the coho SARs observed to date (including BY 2001), comport well with the range of SARs observed for other species in the basin (Appendix F). We are optimistic that the increasing trend in SARs will continue as local adaptation progresses.

Table 5. Comparison of smolt-smolt survival, smolt travel time, and smolt-adult survival rates for mid-Columbia coho releases, 1999-2004.

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)*	Nason Creek 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	0.16%	13.3	13.5	62.8%	37.2%	0.33% - 0.55%
2004	9.5	26.1% - 29.5%	N/A	9.31	10.7- 11.7	56.3% - 60.8%	30.5%- 36.2%	N/A

Within the Wenatchee Basin, the discrepancy between the four smolt-to-adult survival rates may be due to drop-out rates, or to stray rates in the Columbia River and lower Wenatchee River, or may simply be the result of counting errors at the mainstem dams and/or our inability to locate and identify coho redds. However, both smolt-to-adult survival rates calculated from Wenatchee River spawning escapements were similar. With both of these methods, uncounted redds or pre-spawn mortalities may result in an underestimate of the total number of returning adults. The in-basin estimates were lower than the SAR calculated from the difference between Rock Island Dam counts and Rocky Reach counts.

LITERATURE CITED

HGMP. 2002. Hatchery and Genetics Management Plan: Mid-Columbia Coho Reintroduction Program. Bonneville Power Administration, Portland OR.

Kamphaus, C., and K. Murdoch. 2005. Mid-Columbia Coho Reintroduction Feasibility Study: 2003 Annual Broodstock Development Report. *Prepared for*: Bonneville Power Administration. Project Number 199604000. Portland, OR.

Kamphaus, C., and C. Strickwerda. 2006. Mid-Columbia Coho Reintroduction Feasibility Study: 2004 Annual Broodstock Development Report. *Prepared for*: Bonneville Power Administration. Project Number 199604000. Portland, OR.

Murdoch, K.G., C.M. Kamphaus, and S.A. Prevatte. 2005. Mid-Columbia Coho Reintroduction Feasibility Study: 2003 Monitoring and Evaluation Report. *Prepared for*: Bonneville Power Administration. Project Number 199604000. Portland, OR.

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: Radio-Telemetry Tagging Data

Appendix A: Radio-Telemetry Tagging Data

Tagging Date	Chan	Code	Sex	FL (cm)	Tagging Location
09/07/04	213	27	F	63.0	Priest
09/07/04	213	29	F	70.5	Priest
09/07/04	210	39	F	65.0	Priest
09/07/04	212	97	M	60.0	Priest
09/07/04	212	98	M	56.0	Priest
09/07/04	212	99	M	60.0	Priest
09/07/04	212	100	M	60.0	Priest
09/09/04	213	26	M	66.0	Priest
09/09/04	213	28	F	69.0	Priest
09/09/04	210	40	M	53.0	Priest
09/09/04	210	50	F	69.5	Priest
09/14/04	210	41	M	65.0	Priest
09/14/04	210	42	F	72.0	Priest
09/14/04	210	43	M	65.0	Priest
09/14/04	210	44	M	65.0	Priest
09/14/04	210	45	M	64.5	Priest
09/14/04	210	46	M	72.5	Priest
09/14/04	210	47	M	69.0	Priest
09/14/04	210	48	M	51.0	Priest
09/14/04	210	49	F	56.0	Priest
09/16/04	213	24	M	61.5	Priest
09/16/04	213	25	M	66.0	Priest
09/16/04	212	71	M	68.0	Priest
09/16/04	212	72	M	63.5	Priest
09/16/04	212	73	F	64.0	Priest
09/16/04	212	74	F	64.5	Priest
09/16/04	212	75	M	54.5	Priest
09/16/04	213	144	F	64.5	Priest
09/16/04	213	147	F	67.0	Priest
09/16/04	213	148	M	66.0	Priest
09/16/04	213	149	F	65.5	Priest
09/16/04	213	150	F	67.5	Priest
09/16/04	212	160	F	63.0	Priest
09/21/04	213	20	M	67.0	Priest
09/21/04	213	21	M	60.5	Priest
09/21/04	213	22	M	58.0	Priest
09/21/04	213	23	M	57.0	Priest
09/21/04	212	56	M	63.0	Priest
09/21/04	212	57	F	65.0	Priest
09/21/04	212	62	F	56.5	Priest
09/21/04	212	63	M	51.0	Priest
09/21/04	212	65	M	57.0	Priest
09/21/04	212	66	M	71.0	Priest
09/21/04	212	69	M	68.0	Priest
09/21/04	213	137	M	64.0	Priest
09/21/04	213	138	M	58.0	Priest
09/21/04	213	139	F	70.5	Priest

Tagging Date	Chan	Code	Sex	FL (cm)	Tagging Location
09/21/04	213	140	F	69.0	Priest
09/21/04	213	141	F	62.0	Priest
09/21/04	213	142	F	57.5	Priest
09/21/04	213	145	F	55.5	Priest
09/21/04	213	146	M	55.0	Priest
09/21/04	213	153	F	65.0	Priest
09/23/04	211	42	F	71.0	Priest
09/23/04	211	43	M	57.0	Priest
09/23/04	210	65	F	64.0	Priest
09/23/04	210	67	M	58.5	Priest
09/23/04	210	69	F	71.0	Priest
09/23/04	210	70	F	64.5	Priest
09/27/04	213	2	M	67.4	Wells
09/27/04	212	22	M	61.5	Wells
09/28/04	213	1	M	64.5	Wells
09/28/04	213	3	F	71.1	Wells
09/28/04	213	5	F	63.0	Wells
09/28/04	211	15	M	67.0	Wells
09/28/04	211	16	F	57.0	Wells
09/28/04	212	19	F	70.8	Wells
09/28/04	212	20	F	70.0	Wells
09/28/04	212	21	F	63.5	Wells
09/28/04	210	26	M	76.5	Wells
09/28/04	210	27	F	69.0	Wells
09/28/04	210	28	M	64.5	Wells
09/28/04	211	28	M	61.0	Wells
09/28/04	210	29	F	73.5	Wells
09/28/04	211	36	M	62.5	Priest
09/28/04	211	37	M	51.0	Priest
09/28/04	211	38	M	71.0	Priest
09/28/04	211	39	F	71.5	Priest
09/28/04	211	40	M	57.0	Priest
09/28/04	211	41	F	71.0	Priest
09/28/04	211	44	M	60.0	Priest
09/28/04	211	45	F	73.0	Priest
09/28/04	210	56	F	67.5	Priest
09/28/04	210	57	F	68.0	Priest
09/28/04	210	58	F	64.0	Priest
09/28/04	210	59	F	70.5	Priest
09/28/04	210	60	F	63.0	Priest
09/28/04	210	61	M	76.0	Priest
09/28/04	210	62	F	64.5	Priest
09/28/04	210	63	F	73.5	Priest
09/28/04	210	64	F	61.0	Priest
09/28/04	210	66	M	57.0	Priest
09/28/04	210	68	F	66.0	Priest
09/28/04	210	71	F	70.0	Priest
09/28/04	210	72	F	64.0	Priest
09/28/04	210	73	F	60.5	Priest
09/28/04	210	74	F	63.0	Priest
09/28/04	210	75	M	61.5	Priest
09/28/04	212	90	M	58.5	Priest
09/28/04	212	91	F	67.0	Priest
09/28/04	212	94	M	66.0	Priest
09/28/04	212	95	M	59.5	Priest
09/28/04	212	96	F	70.0	Priest
09/28/04	213	169	F	70.5	Priest
09/28/04	213	170	F	69.0	Priest
09/28/04	213	172	F	67.0	Priest
09/28/04	213	173	F	71.0	Priest
09/28/04	213	174	M	68.5	Priest
09/28/04	213	175	F	69.0	Priest
09/29/04	212	23	F	68.2	Wells
09/29/04	211	26	M	71.5	Wells
09/29/04	210	30	F	62.5	Wells
10/04/04	212	25	M	73.0	Tumwater
10/05/04	213	4	F	65.0	Wells
10/05/04	211	32	F	68.0	Wells
10/05/04	213	34	F	66.0	Priest
10/05/04	213	36	F	68.0	Priest
10/05/04	213	37	M	63.0	Priest
10/05/04	213	38	F	68.5	Priest
10/05/04	213	39	M	63.0	Priest
10/05/04	213	41	F	66.0	Priest
10/05/04	213	42	F	74.5	Priest
10/05/04	213	43	F	68.0	Priest
10/05/04	210	51	M	62.0	Wells
10/05/04	212	76	M	65.0	Priest
10/05/04	212	77	F	69.5	Priest
10/05/04	212	78	M	69.0	Priest
10/05/04	212	79	F	64.0	Priest
10/05/04	212	80	F	59.0	Priest
10/05/04	212	81	F	71.0	Priest
10/05/04	212	82	M	53.5	Priest
10/05/04	212	83	F	61.0	Priest
10/05/04	212	84	M	57.5	Priest
10/05/04	212	85	M	71.5	Priest
10/05/04	212	86	F	58.0	Priest
10/05/04	212	87	M	63.5	Priest
10/05/04	212	88	F	65.5	Priest
10/05/04	212	89	M	61.0	Priest
10/05/04	212	92	F	70.5	Priest
10/05/04	212	93	F	64.0	Priest
10/06/04	213	9	F	66.0	Tumwater
10/06/04	211	29	M	54.0	Tumwater
10/06/04	212	30	M	68.0	Tumwater
10/06/04	210	31	F	71.0	Tumwater
10/06/04	210	32	M	69.0	Tumwater
10/06/04	210	35	F	66.0	Tumwater
10/06/04	210	38	M	65.0	Tumwater
10/15/04	212	32	F	72.0	Tumwater

Tagging Date	Chan	Code	Sex	FL (cm)	Tagging Location
10/07/04	213	30	M	60.5	Wells
10/07/04	212	31	M	66.0	Wells
10/07/04	211	51	F	70.5	Priest
10/07/04	211	52	F	62.0	Priest
10/07/04	211	53	M	69.0	Priest
10/07/04	211	54	F	68.5	Priest
10/07/04	210	76	F	61.5	Priest
10/07/04	210	77	F	60.5	Priest
10/07/04	210	81	F	71.5	Priest
10/07/04	210	85	M	59.0	Priest
10/07/04	210	86	F	71.5	Priest
10/07/04	210	89	M	49.5	Priest
10/07/04	210	90	M	69.0	Priest
10/07/04	210	100	F	73.5	Priest
10/08/04	213	10	M	75.0	Tumwater
10/08/04	210	34	F	68.0	Tumwater
10/08/04	210	36	F	66.0	Tumwater
10/08/04	210	37	F	64.0	Tumwater
10/12/04	213	40	M	58.0	Priest
10/12/04	212	44	F	62.0	Priest
10/12/04	212	45	F	71.0	Priest
10/12/04	213	46	F	69.0	Priest
10/12/04	212	46	M	67.0	Priest
10/12/04	213	47	F	65.0	Priest
10/12/04	213	48	F	67.0	Priest
10/12/04	213	49	F	66.0	Priest
10/12/04	213	50	F	71.0	Priest
10/12/04	211	55	F	66.5	Priest
10/12/04	211	56	M	70.0	Priest
10/12/04	211	57	M	66.5	Priest
10/12/04	211	58	F	68.0	Priest
10/12/04	211	59	F	72.5	Priest
10/12/04	211	60	F	72.0	Priest
10/12/04	211	61	F	69.5	Priest
10/12/04	211	62	M	64.0	Priest
10/12/04	210	79	F	67.0	Priest
10/12/04	210	91	M	62.5	Priest
10/12/04	210	92	F	62.0	Priest
10/13/04	213	12	M	57.0	Tumwater
10/13/04	212	28	M	59.0	Tumwater
10/13/04	212	29	F	62.5	Tumwater
10/13/04	211	30	F	71.0	Tumwater
10/13/04	211	35	F	63.0	Tumwater
10/14/04	210	52	M	62.5	Wells
10/14/04	210	87	F	72.5	Priest
10/14/04	210	94	M	67.0	Priest
10/14/04	210	95	F	65.5	Priest
10/15/04	213	11	F	62.0	Tumwater
10/15/04	213	13	F	70.0	Tumwater
10/15/04	212	24	F	64.5	Tumwater
10/15/04	211	31	F	67.0	Tumwater

Tagging Date	Chan	Code	Sex	FL (cm)	Tagging Location
10/15/04	211	34	M	55.5	Tumwater
10/19/04	211	63	F	72.5	Priest
10/19/04	211	65	M	64.0	Priest
10/19/04	211	69	F	71.5	Priest
10/19/04	210	78	M	52.5	Priest
10/19/04	210	80	F	70.5	Priest
10/19/04	210	82	F	73.0	Priest
10/19/04	210	83	F	67.0	Priest
10/19/04	210	84	F	68.5	Priest
10/19/04	210	88	F	74.0	Priest
10/19/04	210	96	F	70.0	Priest
10/19/04	210	97	F	61.5	Priest
10/19/04	210	98	F	63.5	Priest
10/19/04	210	190	F	71.0	Priest
10/20/04	213	6	F	72.0	Tumwater
10/20/04	213	7	F	70.5	Tumwater
10/20/04	213	8	M	58.0	Tumwater
10/20/04	212	26	F	73.5	Tumwater
10/20/04	212	27	M	66.0	Tumwater
10/20/04	211	33	F	70.0	Tumwater
10/20/04	212	42	M	68.0	Tumwater
10/20/04	213	44	M	55.5	Tumwater
10/20/04	212	47	F	64.0	Tumwater
10/20/04	212	48	M	71.5	Tumwater
10/20/04	212	49	M	68.0	Tumwater
10/20/04	212	50	M	65.0	Tumwater
10/21/04	213	14	F	72.5	Priest
10/21/04	213	51	M	53.5	Priest
10/21/04	213	52	F	66.5	Priest
10/21/04	211	64	M	70.5	Priest
10/21/04	211	66	M	64.0	Priest
10/21/04	211	67	M	52.0	Priest
10/21/04	211	68	M	69.0	Priest
10/21/04	211	70	M	51.5	Priest
10/21/04	211	71	M	57.5	Priest
10/21/04	213	128	M	61.0	Priest
10/21/04	213	130	F	60.0	Priest
10/21/04	213	131	F	67.0	Priest
10/26/04	213	15	M	64.0	Priest
10/26/04	213	16	F	64.0	Priest
10/26/04	213	19	F	68.0	Priest
10/26/04	212	36	M	60.0	Priest
10/26/04	212	37	M	72.0	Priest
10/26/04	212	38	M	65.5	Priest
10/26/04	212	39	M	74.0	Priest
10/26/04	212	40	F	70.5	Priest
10/26/04	212	41	M	63.0	Priest
10/26/04	212	43	M	57.0	Priest
10/26/04	213	45	M	67.0	Priest
10/26/04	212	51	M	68.5	Priest

10/26/04	212	52	M	61.5	Priest
10/26/04	212	53	M	70.5	Priest
10/26/04	212	54	M	72.0	Priest
10/26/04	212	55	M	71.0	Priest
10/26/04	212	58	M	60.0	Priest
10/26/04	212	59	M	75.5	Priest
10/26/04	212	60	F	68.0	Priest
10/26/04	212	61	M	73.0	Priest
10/26/04	212	64	F	70.0	Priest
10/26/04	212	67	M	66.5	Priest
10/26/04	212	68	M	62.0	Priest
10/26/04	211	73	M	75.5	Priest
10/26/04	211	74	M	68.0	Priest
10/26/04	211	75	F	68.5	Priest
10/26/04	210	93	M	74.0	Priest
10/26/04	210	99	M	57.5	Priest
10/26/04	213	129	F	73.0	Priest
10/26/04	213	132	F	72.0	Priest
10/26/04	213	151	F	62.0	Priest
10/26/04	213	152	M	59.0	Priest
10/26/04	213	154	M	68.0	Priest
10/28/04	213	18	M	73.0	Priest
10/28/04	211	82	M	62.5	Priest

Tagging Date	Chan	Code	Sex	FL (cm)	Tagging Location
10/28/04	211	85	M	68.0	Priest
10/28/04	211	86	F	67.5	Priest
10/28/04	213	133	M	56.0	Priest
10/28/04	213	134	F	69.0	Priest
10/28/04	213	135	F	66.5	Priest
10/28/04	213	136	M	50.0	Priest
11/02/04	211	76	M	70.5	Priest
11/02/04	211	80	M	72.0	Priest
11/02/04	211	91	F	63.5	Priest
11/02/04	211	97	M	73.5	Priest
11/02/04	211	98	M	73.5	Priest
11/02/04	211	99	F	62.0	Priest
11/04/04	211	77	M	61.0	Priest
11/04/04	211	87	M	59.0	Priest
11/04/04	211	100	M	69.0	Priest
11/09/04	211	81	M	61.0	Priest
11/09/04	211	88	M	62.0	Priest
11/09/04	211	92	M	62.0	Priest
11/09/04	211	95	F	72.0	Priest

Appendix B: Radio-Telemetry Tracking Data

Appendix B
Radio-Telemetry Tracking Data

Tag Date	Detect Date	Chan	Code	Final Location	Latitude	Longitude
09/07/04	11/23/04	212	98	truck	47.581722	-120.615722
09/07/04	10/12/04	210	39	truck	47.003611	-119.971778
09/07/04		212	100	no data		
09/07/04		212	99	no data		
09/07/04		212	97	no data		
09/07/04		213	29	no data		
09/07/04		213	27	no data		
09/09/04	11/09/04	210	40	aerial	46.840944	-119.941778
09/09/04		210	50	no data		
09/09/04		213	28	no data		
09/09/04		213	26	no data		
09/14/04	11/03/04	210	43	dryden dam	47.554644	-120.571711
09/14/04	11/29/04	210	49	aerial	47.306556	-120.086889
09/14/04		210	47	wanapum	46.912750	-119.991694
09/14/04	10/14/04	210	44	truck	46.883528	-119.955167
09/14/04		210	48	no data		
09/14/04		210	46	no data		
09/14/04		210	45	no data		
09/14/04		210	42	no data		
09/14/04		210	41	no data		
09/16/04	11/04/04	212	71	dryden dam	47.554644	-120.571711
09/16/04	10/12/04	213	150	truck	46.925750	-119.953111
09/16/04	11/09/04	213	144	aerial	46.898389	-119.964500
09/16/04		212	160	no data		
09/16/04		212	75	no data		
09/16/04		212	74	no data		
09/16/04		212	73	no data		
09/16/04		212	72	no data		
09/16/04		213	149	no data		
09/16/04		213	148	no data		
09/16/04		213	147	no data		
09/16/04		213	25	no data		
09/16/04		213	24	no data		
09/21/04	11/09/04	213	137	aerial	47.554722	-120.572389
09/21/04	12/15/04	213	22	rocky reach	47.532256	-120.299025
09/21/04	12/15/04	213	20	rocky reach	47.532256	-120.299025
09/21/04	11/29/04	212	66	aerial	47.289889	-120.088972
09/21/04	10/27/04	213	142	aerial	47.111306	-120.024472
09/21/04	11/09/04	213	141	aerial	47.072694	-120.014722
09/21/04	11/29/04	213	145	aerial	46.992750	-119.984944
09/21/04		212	69	no data		
09/21/04		212	65	no data		
09/21/04		212	63	no data		
09/21/04		212	62	no data		
09/21/04		212	57	no data		
09/21/04		212	56	no data		
09/21/04		213	153	no data		

Tag Date	Detect Date	Chan	Code	Final Location	Latitude	Longitude
09/21/04		213	140	no data		
09/21/04		213	139	no data		
09/21/04		213	138	no data		
09/21/04		213	23	no data		
09/21/04		213	21	no data		
09/23/04	11/09/04	210	67	aerial	47.284639	-120.089389
09/23/04	11/09/04	210	70	aerial	47.272333	-120.079556
09/23/04	11/29/04	211	43	aerial	47.145528	-120.003000
09/23/04	11/29/04	210	65	aerial	46.927639	-119.961806
09/23/04		210	69	no data		
09/23/04		211	42	no data		
09/27/04	11/21/04	213	2	rocky reach	47.532256	-120.299025
09/27/04		212	22	no data		
09/28/04	10/27/04	213	173	aerial	47.556278	-120.669944
09/28/04	10/05/04	212	95	dryden dam	47.554644	-120.571711
09/28/04	10/21/04	210	64	dryden dam	47.554644	-120.571711
09/28/04	10/30/04	210	68	monitor	47.497858	-120.416667
09/28/04	10/27/04	213	174	aerial	47.282806	-120.089889
09/28/04	11/09/04	210	71	aerial	47.118556	-120.010222
09/28/04	11/29/04	211	37	aerial	47.108306	-120.017139
09/28/04	11/09/04	210	75	aerial	47.107722	-120.015611
09/28/04	11/09/04	210	66	aerial	47.107722	-120.015611
09/28/04	11/29/04	211	45	aerial	47.079528	-120.036333
09/28/04	11/09/04	210	63	aerial	47.008139	-119.992139
09/28/04	10/27/04	211	44	aerial	46.974556	-119.987111
09/28/04	10/19/04	210	59	truck	46.940778	-119.978556
09/28/04	10/12/04	211	38	truck	46.923528	-119.991500
09/28/04	10/12/04	210	56	truck	46.922250	-119.991278
09/28/04	10/12/04	212	91	truck	46.912750	-119.991694
09/28/04	11/29/04	211	36	aerial	46.876167	-119.971556
09/28/04	10/27/04	212	94	aerial	46.756667	-119.959000
09/28/04		210	74	no data		
09/28/04		210	73	no data		
09/28/04		210	72	no data		
09/28/04		210	62	no data		
09/28/04		210	61	no data		
09/28/04		210	60	no data		
09/28/04		210	58	no data		
09/28/04		210	57	no data		
09/28/04		211	41	no data		
09/28/04		211	40	no data		
09/28/04		211	39	no data		
09/28/04		212	96	no data		
09/28/04		212	90	no data		
09/28/04		213	175	no data		
09/28/04		213	172	no data		
09/28/04		213	170	no data		
09/28/04		213	169	no data		
09/28/04	11/23/04	211	28	truck	48.125722	-119.998889
09/28/04	11/23/04	211	15	truck	48.125722	-119.998889
09/28/04	11/24/04	211	16	truck	48.110028	-120.000278
09/28/04	11/29/04	210	27	aerial	48.077528	-119.993389

Tag Date	Detect Date	Chan	Code	Final Location	Latitude	Longitude
09/28/04	11/19/04	212	20	truck	48.047417	-119.904028
09/28/04	11/23/04	210	29	truck	48.047417	-119.904028
09/28/04	11/03/04	213	3	truck	48.046361	-119.914694
09/28/04	11/19/04	213	1	truck	48.035500	-119.889778
09/28/04	11/23/04	213	5	truck	47.993833	-119.885000
09/28/04	11/23/04	212	19	truck	47.944194	-119.865972
09/28/04	11/27/04	210	26	chelan falls	47.820250	-119.973944
09/28/04	10/07/04	212	21	truck	47.371222	-120.137694
09/29/04	11/29/04	210	30	aerial	48.477889	-120.204361
09/29/04	11/24/04	211	26	truck	48.125722	-119.998889
09/29/04	11/19/04	212	23	truck	48.102833	-120.011611
10/04/04	11/09/04	212	25	aerial	47.650806	-120.716667
10/05/04	11/09/04	212	88	aerial	47.581944	-120.667722
10/05/04	10/27/04	213	36	aerial	47.576778	-120.663194
10/05/04	10/09/04	213	39	dryden dam	47.554644	-120.571711
10/05/04	11/03/04	213	43	dryden dam	47.554644	-120.571711
10/05/04	10/30/04	212	93	monitor	47.497858	-120.416667
10/05/04	11/09/04	213	38	aerial	47.245389	-120.073500
10/05/04	10/27/04	212	82	aerial	47.090750	-120.024861
10/05/04	11/09/04	212	86	aerial	47.084639	-120.015889
10/05/04	11/29/04	212	76	aerial	47.041917	-120.016694
10/05/04	10/27/04	213	37	aerial	47.011806	-120.007861
10/05/04	10/27/04	212	92	aerial	46.944222	-119.980472
10/05/04	10/07/04	212	85	truck	46.941750	-119.974528
10/05/04	10/12/04	212	78	truck	46.930333	-119.957472
10/05/04	10/27/04	212	84	aerial	46.922444	-119.980111
10/05/04		212	89	no data		
10/05/04		212	87	no data		
10/05/04		212	83	no data		
10/05/04		212	81	no data		
10/05/04		212	80	no data		
10/05/04		212	79	no data		
10/05/04		212	77	no data		
10/05/04		213	42	no data		
10/05/04		213	41	no data		
10/05/04		213	34	no data		
10/05/04	11/26/04	211	32	truck	48.442581	-120.162036
10/05/04	11/27/04	210	51	methow	48.049722	-119.921917
10/05/04		213	4	no data		
10/06/04	11/29/04	210	35	aerial	47.790667	-120.659528
10/06/04	11/09/04	210	31	aerial	47.730889	-120.656889
10/06/04	11/29/04	210	32	aerial	47.681139	-120.727056
10/06/04	10/16/04	211	29	tumwater dam	47.616136	-120.722097
10/06/04	11/09/04	213	9	aerial	47.602250	-120.715611
10/06/04	11/22/04	212	30	truck	47.597722	-120.649556
10/06/04		210	38	icicle	47.560167	-120.669361
10/07/04	11/09/04	210	100	aerial	47.576028	-120.662972
10/07/04	11/09/04	210	86	aerial	47.556056	-120.572917
10/07/04	10/07/04	210	77	truck	46.942000	-119.987472
10/07/04	10/07/04	210	89	truck	46.941194	-119.984639
10/07/04	10/07/04	211	53	truck	46.941167	-119.984778
10/07/04	10/12/04	211	54	truck	46.927889	-119.955583

Tag Date	Detect Date	Chan	Code	Final Location	Latitude	Longitude
10/07/04		210	90	no data		
10/07/04		210	85	no data		
10/07/04		210	76	no data		
10/07/04		211	52	no data		
10/07/04		211	51	no data		
10/07/04	11/03/04	212	31	truck	48.057389	-119.921917
10/07/04	11/24/04	213	30	truck	47.993833	-119.887389
10/08/04	10/22/04	213	10	upper wenatchee	47.809547	-120.714244
10/08/04	11/09/04	210	36	aerial	47.628861	-120.728333
10/08/04	11/09/04	210	33	aerial	47.628861	-120.728333
10/08/04	11/23/04	210	34	truck	47.628028	-120.726111
10/08/04	10/15/04	210	37	tumwater dam	47.616136	-120.722097
10/12/04	11/07/04	211	61	entiat	47.663583	-120.249292
10/12/04	11/29/04	211	59	aerial	47.599778	-120.638639
10/12/04	11/23/04	211	60	truck	47.586694	-120.686667
10/12/04	11/02/04	213	40	dryden dam	47.554644	-120.571711
10/12/04	11/04/04	211	58	dryden dam	47.554644	-120.571711
10/12/04	11/04/04	211	55	dryden dam	47.554644	-120.571711
10/12/04	10/27/04	212	45	aerial	47.483889	-120.410444
10/12/04	11/29/04	213	47	aerial	47.072556	-120.035889
10/12/04	11/29/04	213	46	aerial	46.987917	-119.982722
10/12/04	11/09/04	211	62	aerial	46.972111	-119.966667
10/12/04	10/14/04	210	79	truck	46.928361	-119.956194
10/12/04	10/19/04	213	49	truck	46.928361	-119.956167
10/12/04	11/09/04	213	50	aerial	46.914889	-119.966806
10/12/04	10/14/04	210	91	truck	46.827694	-119.931639
10/12/04		210	92	no data		
10/12/04		211	57	no data		
10/12/04		211	56	no data		
10/12/04		212	46	no data		
10/12/04		212	44	no data		
10/12/04		213	48	no data		
10/13/04	11/09/04	212	28	aerial	47.834361	-120.866667
10/13/04	11/29/04	212	29	aerial	47.724528	-120.655139
10/13/04	11/29/04	211	30	aerial	47.698139	-120.700750
10/13/04	11/09/04	211	35	aerial	47.634111	-120.726278
10/13/04	10/23/04	213	12	tumwater dam	47.616136	-120.722097
10/14/04	10/14/04	210	95	truck	46.941139	-119.985417
10/14/04	10/14/04	210	94	truck	46.941139	-119.985417
10/14/04	10/14/04	210	87	truck	46.941139	-119.985417
10/14/04	11/27/04	210	52	truck	48.415761	-120.146903
10/15/04	10/27/04	212	32	aerial	47.724722	-120.653000
10/15/04	11/23/04	212	24	truck	47.652722	-120.726472
10/15/04	10/22/04	211	34	tumwater dam	47.616136	-120.722097
10/15/04		211	31	icicle	47.560167	-120.669361
10/15/04		213	13	icicle	47.560167	-120.669361
10/15/04		213	11	no data		
10/19/04	11/09/04	210	96	aerial	47.598611	-120.637333
10/19/04	11/09/04	210	84	aerial	47.593778	-120.628722
10/19/04	11/03/04	211	69	dryden dam	47.554644	-120.571711
10/19/04	11/07/04	210	190	dryden dam	47.554644	-120.571711
10/19/04	11/29/04	210	88	aerial	47.457167	-120.330972

Tag Date	Detect Date	Chan	Code	Final Location	Latitude	Longitude
10/19/04	11/29/04	210	82	aerial	46.927639	-119.961806
10/19/04	11/29/04	211	65	aerial	46.867833	-119.965861
10/19/04	11/29/04	210	83	aerial	46.800278	-119.928444
10/19/04		210	98	no data		
10/19/04		210	97	no data		
10/19/04		210	80	no data		
10/19/04		211	63	no data		
10/20/04	10/31/04	212	48	little wenatchee	47.841900	-120.926200
10/20/04	10/30/04	212	42	nason campground	47.800314	-120.715667
10/20/04	10/30/04	213	8	nason woodbridge	47.769172	-120.799839
10/20/04	11/29/04	212	49	aerial	47.711056	-120.662806
10/20/04	11/29/04	212	50	aerial	47.683472	-120.725500
10/20/04	10/27/04	212	26	aerial	47.636750	-120.724694
10/20/04	11/29/04	213	6	aerial	47.630750	-120.727972
10/20/04	10/27/04	213	7	aerial	47.623778	-120.725694
10/20/04	10/26/04	212	47	tumwater dam	47.616136	-120.722097
10/20/04	10/27/04	213	44	tumwater dam	47.616136	-120.722097
10/20/04	10/29/04	212	27	tumwater dam	47.616136	-120.722097
10/20/04	12/22/04	211	33	tumwater dam	47.616136	-120.722097
10/21/04	11/29/04	213	128	aerial	47.599056	-120.638528
10/21/04	11/29/04	213	14	aerial	47.480472	-120.395056
10/21/04	11/29/04	211	64	aerial	46.932639	-119.962972
10/21/04	11/09/04	211	70	aerial	46.931944	-119.966667
10/21/04	11/09/04	213	52	aerial	46.914889	-119.966806
10/21/04	11/29/04	213	130	aerial	46.779528	-119.930222
10/21/04		211	71	no data		
10/21/04		211	68	no data		
10/21/04		211	67	no data		
10/21/04		211	66	no data		
10/21/04		213	131	no data		
10/21/04		213	51	no data		
10/26/04	11/29/04	212	59	aerial	47.596611	-120.653778
10/26/04	11/09/04	210	93	aerial	47.593861	-120.636139
10/26/04	11/29/04	212	43	aerial	47.585056	-120.667583
10/26/04	11/29/04	212	36	aerial	47.575194	-120.663972
10/26/04	11/09/04	212	40	aerial	47.567028	-120.665000
10/26/04	11/09/04	211	73	aerial	47.565444	-120.600000
10/26/04	11/22/04	213	151	truck	47.557278	-120.580972
10/26/04	11/04/04	212	54	dryden dam	47.554644	-120.571711
10/26/04	11/05/04	211	74	dryden dam	47.554644	-120.571711
10/26/04	11/23/04	212	53	truck	47.524556	-120.467028
10/26/04	11/23/04	210	99	truck	47.472528	-120.370389
10/26/04	11/29/04	212	55	aerial	47.303778	-120.086528
10/26/04	11/29/04	213	16	aerial	47.160556	-120.007528
10/26/04	11/09/04	213	152	aerial	47.101694	-120.013917
10/26/04	10/27/04	213	132	aerial	46.956889	-119.981222
10/26/04	11/09/04	212	39	sandhollow	46.929389	-119.957306
10/26/04	11/09/04	213	15	sandhollow	46.929389	-119.957306
10/26/04		211	75	no data		
10/26/04		212	68	no data		
10/26/04		212	67	no data		

Tag Date	Detect Date	Chan	Code	Final Location	Latitude	Longitude
10/26/04		212	61	no data		
10/26/04		212	60	no data		
10/26/04		212	58	no data		
10/26/04		212	52	no data		
10/26/04		212	51	no data		
10/26/04		212	41	no data		
10/26/04		212	38	no data		
10/26/04		212	37	no data		
10/26/04		213	154	no data		
10/26/04		213	129	no data		
10/26/04		213	45	no data		
10/28/04	11/29/04	213	133	aerial	47.570111	-120.591806
10/28/04	11/29/04	211	86	aerial	47.562722	-120.669056
10/28/04	11/09/04	213	134	aerial	47.560167	-120.669361
10/28/04		211	85	icicle	47.560167	-120.669361
10/28/04	11/08/04	211	84	dryden dam	47.554644	-120.571711
10/28/04	11/16/04	213	135	dryden dam	47.554644	-120.571711
10/28/04		211	83	no data		
10/28/04		211	82	no data		
10/28/04		213	136	no data		
10/28/04		213	18	no data		
11/02/04		211	98	methow	48.112806	-120.009611
11/02/04	12/08/04	211	91	entiat	47.663583	-120.249292
11/02/04	11/22/04	211	80	truck	47.479556	-120.386639
11/02/04	11/22/04	211	99	truck	47.472361	-120.371556
11/02/04		211	97	no data		
11/02/04		211	76	no data		
11/04/04	11/29/04	211	100	aerial	47.222889	-120.017833
11/04/04	11/29/04	211	77	aerial	46.914500	-119.958556
11/04/04		211	87	no data		
11/09/04	11/10/04	211	88	entiat	47.663583	-120.249292
11/09/04	11/29/04	211	95	aerial	47.566028	-120.666833
11/09/04		211	92	no data		
11/09/04		211	81	no data		

Appendix C: Radio-Telemetry Tagging Temperature Data

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

Date	Water Temp (C)
August 1, 2004	20.5
August 2, 2004	20.2
August 3, 2004	20.0
August 4, 2004	20.0
August 5, 2004	20.1
August 6, 2004	19.8
August 7, 2004	19.5
August 8, 2004	19.9
August 9, 2004	20.2
August 10, 2004	20.4
August 11, 2004	20.4
August 12, 2004	20.4
August 13, 2004	20.5
August 14, 2004	20.5
August 15, 2004	20.4
August 16, 2004	20.7
August 17, 2004	20.6
August 18, 2004	20.4
August 19, 2004	20.6
August 20, 2004	20.6
August 21, 2004	0.0
August 22, 2004	0.0
August 23, 2004	20.6
August 24, 2004	20.2
August 25, 2004	19.9
August 26, 2004	19.9
August 27, 2004	19.9
August 28, 2004	19.8
August 29, 2004	19.9
August 30, 2004	20.0
August 31, 2004	20.3
September 1, 2004	20.0
September 2, 2004	19.7
September 3, 2004	19.3
September 4, 2004	19.2
September 5, 2004	19.1
September 6, 2004	19.1
September 7, 2004	19.4
September 8, 2004	19.7
September 9, 2004	19.6
September 10, 2004	19.4
September 11, 2004	19.5
September 12, 2004	19.4

Date	Water Temp (C)
September 13, 2004	19.3
September 14, 2004	19.0
September 15, 2004	19.0
September 16, 2004	18.8
September 17, 2004	18.7
September 18, 2004	18.4
September 19, 2004	18.2
September 20, 2004	18.0
September 21, 2004	17.8
September 22, 2004	17.9
September 23, 2004	18.0
September 24, 2004	18.0
September 25, 2004	18.3
September 26, 2004	18.4
September 27, 2004	18.6
September 28, 2004	18.7
September 29, 2004	18.7
September 30, 2004	18.6
October 1, 2004	18.6
October 2, 2004	18.7
October 3, 2004	18.7
October 4, 2004	18.7
October 5, 2004	18.6
October 6, 2004	18.5
October 7, 2004	18.4
October 8, 2004	18.3
October 9, 2004	18.2
October 10, 2004	17.9
October 11, 2004	17.9
October 12, 2004	17.7
October 13, 2004	17.6
October 14, 2004	17.6
October 15, 2004	17.4
October 16, 2004	17.2
October 17, 2004	17.0
October 18, 2004	16.4
October 19, 2004	16.4
October 20, 2004	16.3
October 21, 2004	16.2
October 22, 2004	15.7
October 23, 2004	15.4
October 24, 2004	15.0
October 25, 2004	14.7

Date	Water Temp (C)
October 26, 2004	14.4
October 27, 2004	14.3
October 28, 2004	14.1
October 29, 2004	13.8
October 30, 2004	13.6
October 31, 2004	13.3
November 1, 2004	13.1
November 2, 2004	13.0
November 3, 2004	13.0
November 4, 2004	12.9
November 5, 2004	12.8
November 6, 2004	12.7
November 7, 2004	12.5
November 8, 2004	12.4
November 9, 2004	12.5
November 10, 2004	12.6
November 11, 2004	12.6
November 12, 2004	12.5
November 13, 2004	12.5
November 14, 2004	12.5
November 15, 2004	12.5
November 16, 2004	12.4
November 17, 2004	12.3
November 18, 2004	12.1
November 19, 2004	12.0

Appendix D: Coho Spawning Ground Survey Records, 2004

APPENDIX D: 2004 COHO SPAWNING 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	13-Oct	0	15	0
			20-Oct	24	27	0
			27-Oct	3	46	0
			4-Nov	23	50	0
			10-Nov	11	50	0
			17-Nov	19	20	3
			23-Nov	49	80	26
			3-Dec	23	45	16
			10-Dec	**UNABLE TO SURVEY**		
			15-Dec	**UNABLE TO SURVEY**		
			16-Dec	39	92	2
			22-Dec	9	39	28
			29-Dec	3	0	2
	I2					
	Hatchery to Bridge	4.5 – 3.7	13-Oct	0	12	1
			20-Oct	16	35	0
			27-Oct	26	65	0
			4-Nov	13	50	0
			10-Nov	18	120	0
			17-Nov	34	30	0
			23-Nov	36	20	0
			3-Dec	29	35	0
			10-Dec	**UNABLE TO SURVEY**		
			15-Dec	**UNABLE TO SURVEY**		
			20-Dec	2	2	0
	I1					
	Bridge to Mouth	3.7 - 0.0	13-Oct	0	30	1
			20-Oct	7	45	0
			27-Oct	13	100	9
			4-Nov	5	50	6
			10-Nov	18	30	3
			17-Nov	32	30	29
			23-Nov	40	100	0
			3-Dec	10	60	0
			10-Dec	**UNABLE TO SURVEY**		
			15-Dec	**UNABLE TO SURVEY**		
			20-Dec	2	1	0
	Total			**504**	**1,279**	**126**

APPENDIX D: 2004 COHO SPAWNING GROUND SURVEYS CONT'

Water Body	Section	River Kilometer	Date	New Redds	Live Fish	Dead Fish
Nason Creek	**N5**					
	Upper RR. Bridge to Whitepine Creek	25.4-20.9	15-Oct	0	0	0
			22-Oct		**NOT SURVEYED**	
			29-Oct	0	0	0
			5-Nov		**NOT SURVEYED**	
			12-Nov		**NOT SURVEYED**	
			18-Nov		**NOT SURVEYED**	
			3-Dec	0	0	0
	N4					
	Rayrock to Wood Bridge	20.9-13.3	15-Oct	0	0	0
			22-Oct	2	2	0
			29-Oct	8	12	0
			5-Nov	0	0	0
			12-Nov	3	1	0
			18-Nov	0	0	0
			3-Dec	0	0	0
	N3					
	Wood bridge to High Volt Line 1	13.3-10.3	15-Oct		**NOT SURVEYED**	
			22-Oct	2	0	0
			29-Oct		**NOT SURVEYED**	
			5-Nov		**NOT SURVEYED**	
			12-Nov	0	0	0
			18-Nov		**NOT SURVEYED**	
			2-Dec	0	0	0
	N2					
	High Volt Line 1 to Kahler Cr. Br.	10.3-6.3	15-Oct	1	0	0
			22-Oct		**NOT SURVEYED**	
			29-Oct		**NOT SURVEYED**	
			5-Nov	0	0	0
			12-Nov		**NOT SURVEYED**	
			18-Nov	0	0	1
			2-Dec		**NOT SURVEYED**	
Nason Creek	**N1**					
	Kahler Cr. Br. to Mouth	6.3-0.0	15-Oct	3	5	1
			22-Oct	3	0	3
			29-Oct	8	2	2
			5-Nov	3	0	0
			12-Nov	2	0	0
			18-Nov	0	0	0
			3-Dec	0	0	0
	Total			35	22	7

APPENDIX D: 2004 COHO SPAWNING GROUND SURVEYS CONT'

Water Body	Section	River Kilometer	Date	New Redds	Live Fish	Dead Fish
Wenatchee	**W8**					
River	Lake Wenatchee to	86.3-57.3	27-Oct	1	16	0
	Tumwater Bridge		18-Nov	3	1	0
	W7					
	Tumwater Bridge to	57.3-42.5	13-Nov	7	0	0
	Icicle Road Bridge					
	W6					
	Icicle Road Bridge to	42.5-38.5	28-Oct	6	21	0
	Leavenworth Bridge		4-Nov	4	16	0
			10-Nov	28	22	0
			17-Nov	11	15	5
			23-Nov	13	25	0
			3-Dec	6	10	0
			28-Dec	8	3	0
	W5					
	Leavenworth Bridge to	38.5-28.2	22-Oct	1	0	0
	Dryden Dam		19-Nov	7	5	0
			24-Nov	2	4	0
			28-Dec	0	0	2
	W4					
	Dryden Dam to	28.2-15.3	28-Oct	2	6	0
	Lower Cashmere Br.		12-Nov	4	10	0
			19-Nov	8	10	0
	W3					
	Lower Cashmere Br.	15.3-9.3	21-Oct	3	1	0
	to Monitor Bridge		8-Nov	2	1	0
	W2					
	Monitor Bridge to	9.3-5.6	14-Oct	1	4	0
	Sleepy Hollow Bridge		21-Oct	4	1	0
	W1					
	Sleepy Hollow Bridge	5.6-0.0	14-Oct	0	0	0
	to Mouth					
	Total			**121**	**171**	**7**

APPENDIX D: 2004 COHO SPAWNING 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	17-Nov	0	0	0
			8-Dec	0	0	0
Peshastin Creek	Mile 4.0 to Mouth	6.4-0.0	29-Oct	9	3	1
			1-Nov	1	4	0
			12-Nov	11	7	2
			23-Nov	4	2	0
			7-Dec	3	2	0
			21-Dec	5	1	2
Mission Creek	Brender Creek to Mouth	3.2-0.0	4-Nov	1	8	0
			22-Nov	2	3	0
			7-Dec	5	6	0
			15-Dec	9	5	9
			21-Dec	0	0	1
Brender Creek	100 meters Upstream To Mouth	0.1-0.0	19-Nov	2	0	0
			15-Dec	2	0	0
Chiwawa River	Hatchery to Mouth	0.8-0.0	na	na	na	na
Beaver Creek	Beaver Creek Acc. Pd. to Mouth	2.4-0.0	17-Nov	0	0	0
			8-Dec	0	0	0
			27-Dec	0	0	0
	Total			**54**	**41**	**15**

Appendix E: Release-to-McNary Survival Indices of 2004 Releases into the Wenatchee and Methow Basins

IntSTATS

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

Release-to-McNary Survival Indices of
2004 Releases into the Wenatchee and Methow Basins

Submitted by Doug Neeley

1. Introduction

There was little opportunity to make release comparisons because most releases involved confounded comparisons. As examples, 1) Cascade Releases at Small Foster-Lucas and Dam-5 Ponds (Icicle Creek) were made on different dates and 2) Lower Columbia and Mid-Columbia River Brood were released from different ponds (Butcher Creek and Mahar Ponds, respectively) on Nelson Creek.

Further, very few of the experimental releases were replicated. Many of the treatments assigned to rearing ponds were assigned to only one pond (one experimental unit). Even though there were two tag codes per treatment, since these codes were assigned to the same pond, they could not be regarded as independent releases.

The estimates for survival given in this report are for smolt-to-smolt survival from tagging to McNary Dam passage, or, when fish are detected leaving the acclimation ponds, the estimates are from volitional release to McNary Dam (McNary) passage. A release's passage estimate at McNary is the number of the release's PIT-tagged fish that are detected at McNary divided by estimated McNary detection rate. The detection rate is the proportion of fish actually passing McNary that are detected within McNary's bypass system. McNary passage is stratified into sequential days having similar detections rates. The estimate of a stratum's passage is given in Equation 1.

Equation 1.

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

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

Equation 2.

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

The detection rate is based on downstream detections of all PIT-tagged fish released into the Wenatchee and Methow Basins. The detection rate is applied to only fish that actually pass McNary, not to those removed for transportation or sampled and sacrificed at McNary for research purposes. This is why that the removed fish are not expanded in Equation 1.

A release's survival index is the estimated total passage (stratum passage estimates added over all strata) divided by either the number of tagged fish or the number of fish detected leaving the acclimation pond (number released), Equation 3. In the case of number detected leaving the acclimation ponds, only those fish detected leaving the ponds are tallied at McNary. The estimates should be regarded as indices because there are biases associated with estimates. These biases are discussed in Appendix A along with a more detailed discussions of the estimation procedures.

Equation 3.

$$\text{Smolt - to - Smolt Survival Index to McNary}$$
$$=$$
$$\frac{\sum_{\text{Strata}} \text{Estimated Number of tagged Fish passing McNary during stratum}}{\text{Number of Fish tagged or released}}$$

Appendix B gives the estimated detection rates and passage numbers for each stratum as well as the passage estimates pooled over strata and the survival index estimates.

2. 2004 Tumwater Releases

Figure 1 presents as bars the estimated survival rates of upstream (US) and downstream (DS) Tumwater releases for each release day and the US and DS survival rates pooled over release days. Also presented in Figure 1 are the upstream/downstream survival ratios. Although there is tremendous variability in the US/DS ratios, the estimate over release days is nearly 1.0. Table 1.a. gives the actual survival and ratio estimates and Table 1.b. gives a logistic analysis of variation of the survival estimates which indicates no significant difference between the US and DS McNary survival estimates, leading to the pooled US/DS survival estimate being nearly 1.0.

Figure 1. Tagging-to-McNary-Dam Survivals and Survival Proportions for 2004 Releases upstream and downstream of Tumwater Dam

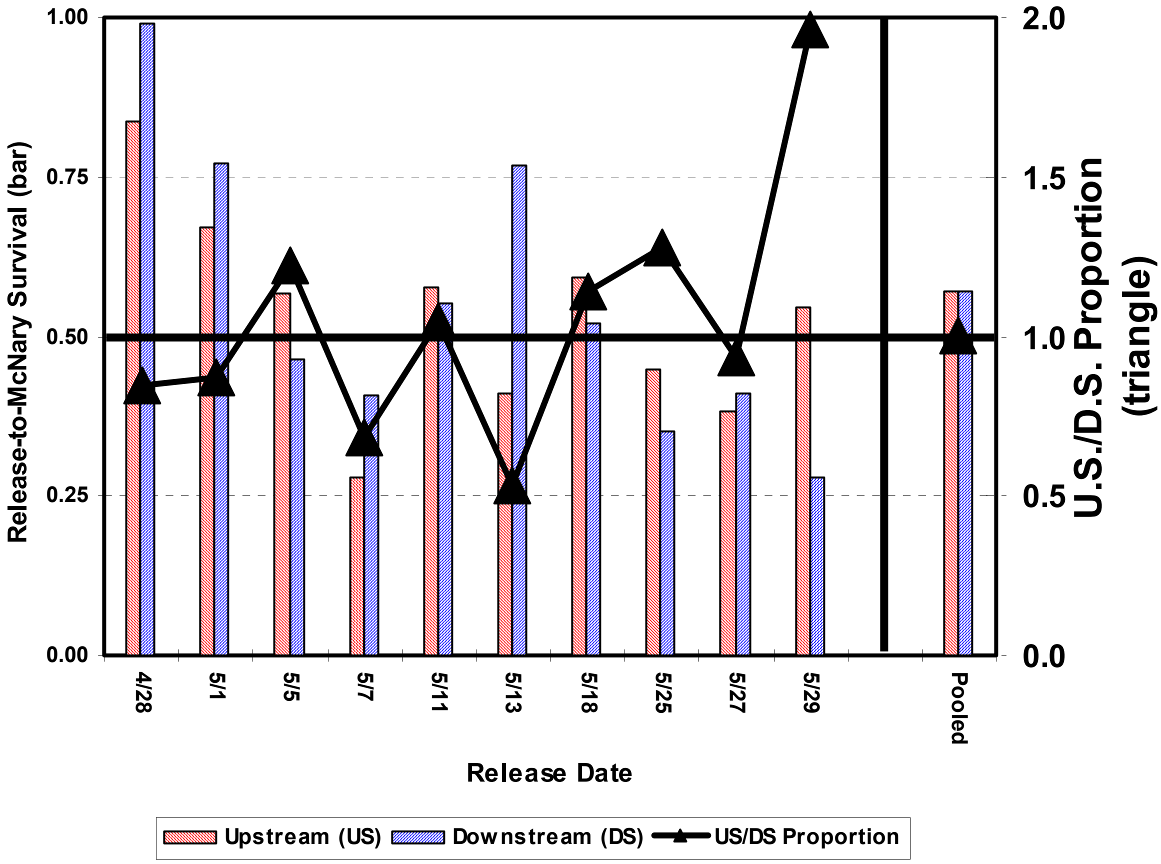


Table 1.a. 2004 Release Numbers and Smolt-to-Smolt[1] Survival Estimates for Tumwater-Dam Releases Upstream (US) and Downstream (DS) and US/DS Survival Ratio[2] Estimates.

Release Dates	Upstream (US) Release Logistic Coefficienct	Upstream (US) Release Number Released	Upstream (US) Release Survival to McNary	Downstream (DS) Release Logistic Coefficient	Downstream (DS) Release Number Released	Downstream (DS) Release Survival to McNary	US/DS Survival Ratio*
4/28	1.64149	268	0.8377	4.74882	268	0.9914	0.8450
5/1	0.71292	217	0.6710	1.21275	217	0.7708	0.8706
5/5	0.27513	390	0.5684	-0.14526	391	0.4637	1.2256
5/7	-0.95033	121	0.2788	-0.37604	146	0.4071	0.6849
5/11	0.31475	347	0.5780	0.207	319	0.5516	1.0480
5/13	-0.36555	160	0.4096	1.19537	150	0.7677	0.5336
5/18	0.37663	513	0.5931	0.08033	514	0.5201	1.1403
5/25	-0.20297	191	0.4494	-0.61614	153	0.3507	1.2817
5/27	-0.4759	84	0.3832	-0.36583	131	0.4095	0.9357
5/29	0.1776	138	0.5443	-0.95688	116	0.2775	1.9614
Pooled		2429	0.5719		2405	0.5703	1.0027

Table 1.b. Weighted Logistic Analysis of Variation for 2004 Tumwater Release-to-McNary Survival Estimates presented in Table 1.a. (Weights are Number of PIT-Tagged Fish Released.)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 Error P
Between Upstream (US) and Downstream (DS) Releases (US vs DS)	0.01	1	0.01	0.00	0.9802
US vs DS adjusted for Release Date Comparisons	0.00	1	0.00	0.00	1.0000
Among Release Dates*	505.84	9	56.20	3.67	0.0331
Among Dates* | adjusted for US vs DS	505.83	9	56.20	3.67	0.0331
Error	137.89	9	15.32		

* 10 Different Dates of paired U and D releases

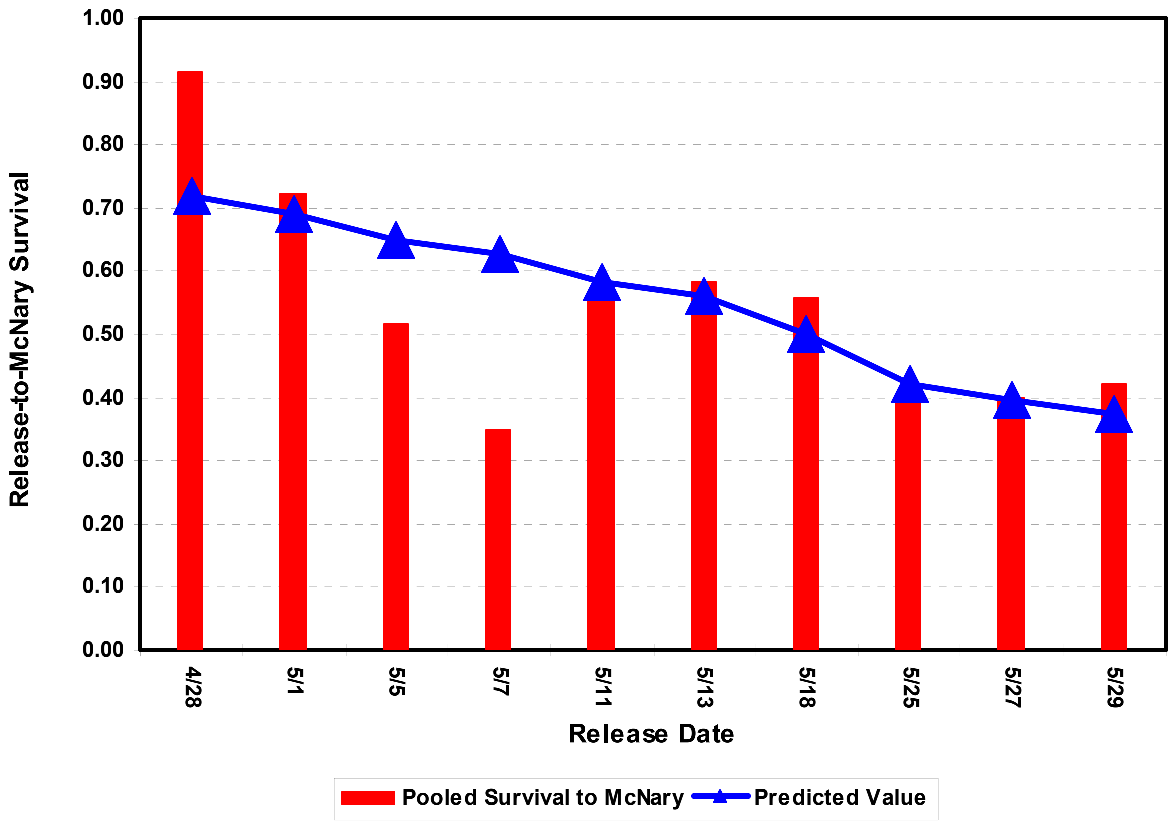
There is appears to be a tendency for the survival to decrease with later release date. With no significant difference between the upstream and downstream estimates, the estimates were pooled and the survival was fit against Julian release date using logistic regression. The resulting logistic fit is given in Equation 4 and the survival estimates and predicted survival estimates from the equation are given in Figure 2.

Equation 4. $$\text{Predicted Survival} = \frac{1}{1 + \exp\{-[6.55359 - 0.04688 * (\text{Julian Date})]\}}$$

[1] Survival from Release-Site Tagging to McNary detection

[2] The ratio is an estimate of survival from the upper-release site to the lower-release site.

Figure 2. Tagging-to-McNary-Dam Survivals and Weighted Logistic Fit of Survival as a Response Variable on Julian Release Date as a Predictor Variable (Weights are Release Numbers)



The survival estimates pooled over upstream and downstream releases and the predicted values are given in Table 1.c. The logistic analysis of variation justifying the pooling of the upstream and downstream estimates and using the single[3] logistic regression coefficient is given in Table 1.d.

[3] Two coefficients were estimated, one for the upstream and for the downstream releases, but were found not to significantly different from each other (P = 0.3465). A pooled coefficient, used in Equation 1, is significantly different than 0 (P = 0.0095).

Table 1.c. 2004 Tumwater Release Numbers and Smolt-to-Smolt[4] Survival Estimates, pooled over Upstream and Downstream Releases, and Predicted Survival Estimates based on Equation 4.

Release Dates		Upstream and Downstream Estimates Pooled		
Calendar	Julian	Number Released	Pooled Survival to McNary	Predicted Value
04/28/04	120	536	0.9146	0.7195
05/01/04	123	434	0.7209	0.6902
05/05/04	127	781	0.5160	0.6492
05/07/04	129	267	0.3490	0.6270
05/11/04	133	666	0.5654	0.5823
05/13/04	135	310	0.5829	0.5593
05/18/04	140	1027	0.5565	0.5010
05/25/04	147	344	0.4055	0.4195
05/27/04	149	215	0.3993	0.3969
05/29/04	151	254	0.4224	0.3746

Table 1.d. Analysis of Variation of Weighted Logistic Regression of 2004 Tumwater Release-to-McNary Survival Estimates on Julian Release Date presented in Table 1.c. (Weights are Number of PIT-Tagged Fish Released.)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance (Dev/DF)	F-Ratio	Type 1 Error P
Between Upstream (US*) and Downstream (DS**) Means	0.01	1	0.01	0.00	0.9843
Single Slope	218.25	1	218.25	8.69	0.0095
US versus DS Slope	23.63	1	23.63	0.94	0.3465
Selected Model: Intercept + One Slope	**425.51**				
One Slope adjusted for One Intercept	**218.22**	**1**	**218.22**	**8.69**	**0.0095**
Error	401.84	16	25.12		

* US - Upstream releases
** DS - Downstream Releases

[4] Survival from Release-Site Tagging to McNary detection

3. 2004 Willard and Cascade Hatchery-Origin Stock Releases

Hatchery-Origin Fish from both the Cascade and Willard Hatcheries were PIT-tagged and introduced into acclimation ponds at Icicle Creek in the Wenatchee River Basin and at Winthrop on the Methow River. Estimates of survival are given in Table 2.a for each of the PIT-tagged groups, two tagged groups for each hatchery source within each pond.

Table 1.b. gives a logistic analysis of variation of the survival estimates. The Hatchery (Cascade versus Wenatchee) and Subbasin effects are initially tested against the Hatchery x Subbasin Interaction. Since there is only one-degree of freedom associated with the interaction and the interaction variation is not significantly greater than release-group-within-pond variation, and since the interaction variation is actually less than that associated with the group-within-pond variation ("Error"), the Site and Treatment effects were also tested against the release groups within pond which is not a true source of error. The results are given in Table 2.b.

The Hatchery effect adjusted for the Subbasin is nearly significant at the 10% level (P = 0.101) when tested against interaction and is significant at the 1% level (P = 0.003) when tested against "Error". The Willard stock had the highest pooled survival for each Subbasin. The survival from Icicle Creek is higher than that from the Methow, perhaps because Icicle Creek is closer to McNary Dam.

Table 2.a. 2004 Release Numbers and Smolt-to-Smolt[1] Survival Estimates for Willard and Cascade Hatchery-Origin Fish released from Acclimation Ponds in the Wenatchee and Methow River Systems.

	Cascade Source of LCR* Brood			**Willard Source of LCR* Brood**		
Release	Tagged Group**	Number Tagged	Survival to McNary	Tagged Group**	Number Tagged	Survival to McNary
Winthrop on Methow River	MR1	2613	0.3214	MR3	1671	0.2111
	MR2	1868	0.2585	MR4	2792	0.2909
	Pooled	4481	**0.2951**	**Pooled**	4463	**0.2610**
Icicle Creek	IC3	2353	0.5888	IC5	2027	0.5398
	IC4	1629	0.6364	IC6	2314	0.5606
	Pooled	3982	**0.6083**	**Pooled**	4341	**0.5509**

* Brood: Lower Columbia River (LCR)

** PIT-Tag File Name Extender

Table 3.b. Weighted Logistic Analysis of Variation for 2004 Icicle Creek and Winthrop Releases of Willard-Origin and Cascade-Origin Smolt-to-Smolt[1] Survival Estimates presented in Table 1.a. (Weights are Number of PIT-Tagged Fish Released.)

Source	Deviance (Dev)	Degrees of Freedom (DF)	Mean Deviance	F-Ratio (1)*	Type 1 Error P (1)*	F-Ratio (2)**	Type 1 Error P (2)**
Hatchery (unadjusted)	26.25	1	26.25	25.49	0.1245	1.56	0.0072
Hatchery (adjusted for Subbasin)	40.03	1	40.03	38.86	**0.1013**	2.38	**0.0034**
Subbasin (unadjusted)	1616.61	1	1616.61	1569.52	0.0161	96.28	0.0000
Subbasin (adjusted for Hatchery)	1630.39	1	1630.39	1582.90	**0.0160**	97.10	**0.0000**
Hatchery x Subbasin	1.03	1	1.03			0.06	1.0000
"Error"	67.16	4	16.79				

* Using Hatchery x Subbasin interaction as a base of comparison

* Using "Error" variation between tag groups within Hatchery x Subbasin ponds as a base of comparison

This evaluation of Willard versus Cascade stock should be regarded as tentative because the use of group-within-pond variation as error is not really appropriate since the tag groups do not represent true replicates; that is why the site x hatchery-source interaction was the initial test used.

It is worth noting that replicated releases were made into the Yakima River of fish from Yakima-return brood-stock and from Willard brood-stock in 1999 and of Yakima-return brood-stock and Cascade brood-stock in 2000 through 2003. The Willard had a significantly higher smolt-to-smolt survival than the Yakima in the one year of release ($P=0.014$), and the Cascade had a significantly lower smolt-to-smolt survival in the other four years ($P < 0.001$).

4. Other Comparisons

There are no site x treatment interactions or true replications that can be used as sources of error in the other releases. Therefore, other survival estimates are presented without comments about statistically significant differences.

4.a. Mahar and Butcher Creek Acclimation Pond Releases

Acclimation-Pond Volitional-Release Detection Rates and Pre-release Mortality at Mahar and Butcher Creek Acclimation Ponds: Last year PIT-tag detectors were used to detect PIT-tagged fish as they volitional left the acclimation ponds. The detection efficiencies of these fish was extremely low, with a vast majority of the fish detected at McNary not being detected earlier leaving the acclimation sites. The detection systems at the Mahar and Butcher Creek acclimation sites were improved prior to the 2004 releases. The detection rates increased dramatically. The detection rates were estimated by dividing unexpanded McNary detections of releases previously detected at the acclimation sites by the respective releases' total McNary detections, whether or not they were previously detected at the acclimation sites. The estimated detection efficiencies for those releases are given in Table 3.a. for each release (identified by the PIT-tag files' file extension *value).*

Table 3.a. 2004 Detection Rates of PIT-tagged Detectors at Mahar and Butcher Creek Acclimation Ponds.

Butcher Creek Release				Mahar Releases	
LCR Brood		**LCR x MCR Brood**		**MCR Brood**	
Group	Shedding	Group	Shedding	Group	Shedding
BL1	1.0000	MP1	1.0000	BW1	0.9833
BL2	0.9848	MP2	1.0000	BW2	0.9563
Pooled	0.9922	Pooled	1.0000	Pooled	0.9679

The proportions of fish that died or shed their tags prior to release were then estimated. This was done by dividing the number of fish detected leaving the ponds by the pond's detector efficiencies. The resulting adjusted pond-detection numbers were then divided by the number of tagged fish. These proportions were then subtracted from 1 to estimate the proportions lost through mortality or tag loss, which are given in Table 3.b.

Table 3.b. Proportion* Estimates of Fish Mortality or Tag Loss prior to leaving Mahar and Butcher Creek Acclimation Sites in 2004.

Butcher Creek Release				Mahar Releases	
LCR Brood		**LCR x MCR Brood**		**MCR Brood**	
Tagged Group	Mortality/ Shedding	Tagged Group	Mortality/ Shedding	Tagged Group	Mortality/ Shedding
BL1	0.1367	MP1	0.1279	BW1	0.0455
BL2	0.0909	MP2	0.1187	BW2	0.0153
Pooled	0.1116	Pooled	0.1225	Pooled	0.0284

* 1 - [(Acclimation Site Detection Number)/(Site Detector Efficiencie)]/
(Number of Tagged Fish)

As can be seen from the above tables, three sets of brood were released into these ponds. Lower Columbia River Stock (LCR) brood, Mid-Columbia River Stock (MCR) brood, and a brood that is cross between the two stock LCR x MCR brood. In should be noted that even informal comparisons should avoided with MRC brood in the above tables as well as in Table 3.c. (to be discussed below) because the brood was acclimated in and released from a different pond than the LCR and LCR x MCR broods. If these three stocks are to be evaluated in the future, then consideration should be given to releasing each of the three into each of two ponds or more in order to have true complete block replicates.

Brood Survival: Table 3.c. presents the estimated smolt-to-smolt survivals for the three broods. Table 3.c.1) are estimates for all tagged fish (the type of estimates presented in previous years' reports). Table 3.c.2) are estimates for only volitional releases and represent the best estimate of actual in-stream survival. The fact that Table 3.c.1) has lower survival /estimates stems is because those estimates are probably affected by pre-release mortality and tag loss as well as in-stream mortality.

Table 3.c. 2004 Release Numbers and Smolt-to-Smolt Survival Estimates for Lower Columbia River (LCR), Mid-Columbia Brood (MCR), and LCR x MCR Broods from Nason Creek Acclimation Ponds.

1) Tagging-to-McNary Dam Survival

Butcher Creek Releases						Mahar Releases		
LCR Brood			LCR x MCR Brood			MCR Brood		
Group	Tagged	McNary	Group	Tagged	McNary	Group	Tagged	McNary
BL1	1741	0.3893	MP1	1837	0.3403	BW1	1611	0.3761
BL2	2274	0.3094	MP2	2638	0.2805	BW2	2329	0.3526
Pooled	4015	**0.3441**	**Pooled**	4475	**0.3051**	**Pooled**	3940	**0.3622**

2) Volitional-Release-to-McNary Dam Survival

Butcher Creek Releases						Mahar Releases		
LCR Brood			LCR x MCR Brood			MCR Brood		
Tagged Group	Number Tagged	Survival** to McNary	Tagged Group	Number Tagged	Survival** to McNary	Tagged Group	Number Tagged	Survival** to McNary
BL1	1503	0.4510	MP1	1602	0.3903	BW1	1512	0.3927
BL2	2036	0.3394	MP2	2325	0.3183	BW2	2193	0.3580
Pooled	3539	**0.3868**	**Pooled**	3927	**0.3476**	**Pooled**	3705	**0.3722**

4.b. Small Foster-Lucas and Dam-5 Pond Releases.

Release numbers and survival estimates for Icicle Creek's Small Foster-Lucas (SFL) and Dam-5 releases of Cascade Origin Fish are given in Table 4. It should be noted that that releases differ in their release dates as well as their release locations (April 19 for SFL and April 23 for Dam-5).

Table 4. 2004 Release Numbers and Smolt-to-Smolt[1] Survival Estimates for Icicle Creek's Small Foster-Lucas (SFL) and Dam-5 Pond Releases of Cascade Hatchery Stock.

SFL Pond Releases			**Dam 5 Releases**		
Tagged Group	Number Tagged	Survival** to McNary	Tagged Group	Number Tagged	Survival** to McNary
IC1	2368	0.5646	IC3	2353	0.5888
IC2	1612	0.5595	IC4	1629	0.6364
Pooled	3980	**0.5626**	**Pooled**	3982	**0.6083**

Appendix A. Survival Index

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

Equation A.1

$$\text{Smolt - to - Smolt Survival Index to McNary} = \frac{\sum_{\text{Strata}} \text{Estimated Number of Released (or Tagged) Fish Passing McNary during a given Stratum}}{\text{Number of Fish Released (or Tagged)}}$$

If PIT-tagged fish are actually enumerated (interrogated and tallied) at the 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 release 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 tag-shedding in addition to 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

$$\text{Estimated Number of Released Fish Passing McNary during Statum} = \frac{\text{(Number of Fish Detected at McNary during Stratum) - (Number of Detected Fish Removed during Statum)}}{\text{McNary Detection Rate associated with Stratum}} + \text{Number of Detected Fish Removed during Straum}$$

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 <u>all</u> PIT-tagged releases into the Wenatchee and Methow subbasins[5] 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

5 . 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.

assumption is that detection rates at McNary are independent of the time and place of release into the subbasin

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. 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 during a given stratum is divided (expanded) by detection efficiency for the stratum containing the day to obtain the estimated passage.

The detection efficiency 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 some 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 following method of estimating daily detection efficiencies:

a. For each downstream dam, <u>joint</u> 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 <u>joint</u> 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 corresponding total detections 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.

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 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.

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 over-estimate the detection efficiency. What is done to adjust for such an overestimation is to:

a. Take such a downstream dam date and use offset[6] 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.

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).

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.

---

[6] 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.

Assumption a: 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.

Assumption b: 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.

Assumption c: 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: 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. Estimates McNary Detection Rates, Passage, and Survival Indices

Table B.1 McNary Detection Rates

	McNary Passage Date				Bonneville			John Day			Pooled		
	Beginning		Ending		Detections		McN Detection	Detections		McN Detection	Detections		McN Detection
Stratum	Calendar	Julian	Calendar	Julian	Total*	Joint**	Rate	Total*	Joint**	Rate	Total*	Joint**	Rate
1	4/2/2004	92	5/28/2004	149	484.2	76.0	0.15697	831.5	117.0	0.14070	1315.7	193	0.14669
2	4/13/2004	150	6/1/2004	153	132.9	24.0	0.18062	376.2	67.0	0.17811	509.1	91	0.17876
3	5/1/2004	154	6/4/2004	156	111.9	28.0	0.25024	213.1	58.0	0.27223	325.0	86	0.26466
4	5/4/2004	157	9/30/2004	274	229.0	45.0	0.19647	436.2	79.0	0.18110	665.3	124	0.18639

* Total downstream-dam McNary 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

Table B.2. Expansions and Survival Indices.

1) Butcher Creek and Mahar Pond – Tagging-to-McNary Survival

	Stratum	Detection Rate (RD)	Release Site > Brood/Hatchery > Release Date > Tag Group >	Butcher LCR, Willard 04/28/04 KGM04022.BL1	Butcher LCR, Willard 04/28/04 KGM04022.BL2	Butcher LCRxMCR,Willard 05/06/04 KGM04022.MP1	Butcher LCRxMCR,Willard 05/06/04 KGM04022.MP2	Mahar MCR, Mahar 04/28/04 KGM04023.BW1	Mahar MCR, Mahar 04/28/04 KGM04023.BW2
STRATUM 1	1	0.1467	Total (T)	33	32	23	18	3	7
	from		Removal (R)	1	0	0	0	0	1
	01-May-04		T-R	32	32	23	18	3	6
	to		Expansion (E) = (T-R)/DR	218.15	218.15	156.80	122.71	20.45	40.90
	28-May-04		Passage = E+R	219.15	218.15	156.80	122.71	20.45	41.90
STRATUM 2	2	0.1788	Total (T)	26	31	18	34	20	19
	from		Removal (R)	0	1	0	0	0	0
	29-May-04		T-R	26	30	18	34	20	19
	to		Expansion (E) = (T-R)/DR	145.44	167.82	100.69	190.20	111.88	106.29
	01-Jun-04		Passage = E+R	145.44	168.82	100.69	190.20	111.88	106.29
STRATUM 3	3	0.2647	Total (T)	23	32	37	25	24	29
	from		Removal (R)	0	1	1	0	0	0
	02-Jun-04		T-R	23	31	36	25	24	29
	to		Expansion (E) = (T-R)/DR	86.91	117.13	136.03	94.46	90.68	109.58
	04-Jun-04		Passage = E+R	86.91	118.13	137.03	94.46	90.68	109.58
STRATUM 4	4	0.1864	Total (T)	43	37	43	62	73	105
	from		Removal (R)	1	0	0	0	2	0
	05-Jun-04		T-R	42	37	43	62	71	105
	to		Expansion (E) = (T-R)/DR	225.33	198.51	230.70	332.64	380.92	563.33
	08-Sep-04		Passage = E+R	226.33	198.51	230.70	332.64	382.92	563.33
	Over Strata		Total Passage >	677.83	703.61	625.21	740.00	605.94	821.10
			Number Tagged >	1741	2274	1837	2638	1611	2329
			Survival Index >	0.3893	0.3094	0.3403	0.2805	0.3761	0.3526

2) Butcher Creek and Mahar Pond – Volitional Release-to-McNary Survival

	Stratum	Detection Rate (RD)	Release Site > Brood/Hatchery > Release Date > Tag Group >	Butcher LCR, Willard 04/28/04 KGM04022.BL1	Butcher LCR, Willard 04/28/04 KGM04022.BL2	Butcher LCRxMCR,Willard 05/06/04 KGM04022.MP1	Butcher LCRxMCR,Willard 05/06/04 KGM04022.MP2	Mahar MCR, Mahar 04/28/04 KGM04023.BW1	Mahar MCR, Mahar 04/28/04 KGM04023.BW2
STRATUM 1	1	0.1467	Total (T)	33	32	23	18	2	7
	from		Removal (R)	1	0	0	0	0	1
	01-May-04		T-R	32	32	23	18	2	6
			Expansion (E) =						
	to		(T-R)/DR	218.15	218.15	156.80	122.71	13.63	40.90
	28-May-04		Passage = E+R	219.15	218.15	156.80	122.71	13.63	41.90
STRATUM 2	2	0.1788	Total (T)	26	30	18	34	20	19
	from		Removal (R)	0	1	0	0	0	0
	29-May-04		T-R	26	29	18	34	20	19
			Expansion (E) =						
	to		(T-R)/DR	145.44	162.23	100.69	190.20	111.88	106.29
	01-Jun-04		Passage = E+R	145.44	163.23	100.69	190.20	111.88	106.29
STRATUM 3	3	0.2647	Total (T)	23	32	37	25	24	28
	from		Removal (R)	0	0	1	0	0	0
	02-Jun-04		T-R	23	32	36	25	24	28
			Expansion (E) =						
	to		(T-R)/DR	86.91	120.91	136.03	94.46	90.68	105.80
	04-Jun-04		Passage = E+R	86.91	120.91	137.03	94.46	90.68	105.80
STRATUM 4	4	0.1864	Total (T)	43	36	43	62	72	99
	from		Removal (R)	1	1	0	0	2	0
	05-Jun-04		T-R	42	35	43	62	70	99
			Expansion (E) =						
	to		(T-R)/DR	225.33	187.78	230.70	332.64	375.56	531.14
	08-Sep-04		Passage = E+R	226.33	188.78	230.70	332.64	377.56	531.14
	Over Strata		Total Passage >	677.83	691.07	625.21	740.00	593.75	785.13
			Number Tagged >	1503	2036	1602	2325	1512	2193
			Survival Index >	0.4510	0.3394	0.3903	0.3183	0.3927	0.3580

3) Icicle Creek Releases– Tagging-to-McNary Survival

	Stratum	Detection Rate (RD)	Release Site > Brood/Hatchery > Release Date > Tag Group >	Icicle LCR, Cascade SFL Ponds KGM04021.IC1	Icicle LCR, Cascade SFL Ponds KGM04021.IC2	Icicle LCR, Cascade Dam 5 KGM04020.IC3	Icicle LCR, Cascade Dam 5 KGM04020.IC4	Icicle LCR, Willard Dam 5 KGM04027.IC5	Icicle LCR, Willard Dam 5 KGM04027.IC6
STRATUM 1	1	0.1467	Total (T)	134	96	73	60	72	87
	from		Removal (R)	2	3	2	1	0	0
	01-May-04		T-R	132	93	71	59	72	87
	to		Expansion (E) = (T-R)/DR	899.87	634.00	484.02	402.22	490.84	593.10
	28-May-04		Passage = E+R	901.87	637.00	486.02	403.22	490.84	593.10
STRATUM 2	2	0.1788	Total (T)	45	19	60	50	42	43
	from		Removal (R)	0	0	0	0	0	1
	29-May-04		T-R	45	19	60	50	42	42
	to		Expansion (E) = (T-R)/DR	251.73	106.29	335.64	279.70	234.95	234.95
	01-Jun-04		Passage = E+R	251.73	106.29	335.64	279.70	234.95	235.95
STRATUM 3	3	0.2647	Total (T)	23	15	52	34	39	43
	from		Removal (R)	0	0	1	0	0	0
	02-Jun-04		T-R	23	15	51	34	39	43
	to		Expansion (E) = (T-R)/DR	86.91	56.68	192.70	128.47	147.36	162.48
	04-Jun-04		Passage = E+R	86.91	56.68	193.70	128.47	147.36	162.48
STRATUM 4	4	0.1864	Total (T)	18	19	69	42	42	57
	from		Removal (R)	0	0	0	0	1	0
	05-Jun-04		T-R	18	19	69	42	41	57
	to		Expansion (E) = (T-R)/DR	96.57	101.94	370.19	225.33	219.97	305.81
	08-Sep-04		Passage = E+R	96.57	101.94	370.19	225.33	220.97	305.81
	Over Strata		Total Passage >	1337.08	901.90	1385.56	1036.72	1094.12	1297.33
			Number Tagged >	2368	1612	2353	1629	2027	2314
			Survival Index >	0.5646	0.5595	0.5888	0.6364	0.5398	0.5606

4) Winthrop Releases– Tagging-to-McNary Survival

	Stratum	Detection Rate (RD)	Release Site > Brood/Hatchery > Release Date > Tag Group >	Winthrop LRC, Cascade KGM04020.MR1	Winthrop LRC, Cascade KGM04020.MR2	Winthrop LRC, Willard KGM04026.MR3	Winthrop LRC, Willard KGM04026.MR4
STRATUM 1	1	0.1467	Total (T)	31	12	16	30
	from		Removal (R)	0	0	2	0
	01-May-04		T-R	31	12	14	30
	to		Expansion (E) = (T-R)/DR	211.33	81.81	95.44	204.52
	28-May-04		Passage = E+R	211.33	81.81	97.44	204.52
STRATUM 2	2	0.1788	Total (T)	19	12	13	26
	from		Removal (R)	0	0	0	0
	29-May-04		T-R	19	12	13	26
	to		Expansion (E) = (T-R)/DR	106.29	67.13	72.72	145.44
	01-Jun-04		Passage = E+R	106.29	67.13	72.72	145.44
STRATUM 3	3	0.2647	Total (T)	30	10	10	17
	from		Removal (R)	0	0	0	0
	02-Jun-04		T-R	30	10	10	17
	to		Expansion (E) = (T-R)/DR	113.35	37.78	37.78	64.23
	04-Jun-04		Passage = E+R	113.35	37.78	37.78	64.23
STRATUM 4	4	0.1864	Total (T)	77	56	27	75
	from		Removal (R)	1	1	0	1
	05-Jun-04		T-R	76	55	27	74
	to		Expansion (E) = (T-R)/DR	407.75	295.08	144.86	397.02
	08-Sep-04		Passage = E+R	408.75	296.08	144.86	398.02
	Over Strata		Total Passage >	839.72	482.80	352.81	812.21
			Number Tagged >	2613	1868	1671	2792
			Survival Index >	0.3214	0.2585	0.2111	0.2909

5) Tumwater Upstream Releases– Tagging-to-McNary Survival

	Stratum	Detection Rate (RD)	Release Site >	Tumwater	Tumwater	Tumwater	Tumwater	Tumwater	Tumwater
			Brood/Hatchery >	UpStream	UpStream	UpStream	UpStream	UpStream	UpStream
			Release Date >	04/28/04	05/01/04	05/05/04	05/07/04	05/11/04	05/13/04
			Tag Group >	KGM04118_TDT	KGM04121_TDT	KGM04125_TDT	KGM04127_TDT	KGM04131_TDT	KGM04133_TDT
STRATUM 1	1	0.1467	Total (T)	23	13	13	2	10	1
	from		Removal (R)	0	1	0	0	0	0
	01-May-04		T-R	23	12	13	2	10	1
	to		Expansion (E) = (T-R)/DR	156.80	81.81	88.62	13.63	68.17	6.82
	28-May-04		Passage = E+R	156.80	82.81	88.62	13.63	68.17	6.82
STRATUM 2	2	0.1788	Total (T)	5	7	10	1	8	3
	from		Removal (R)	0	0	1	0	0	0
	29-May-04		T-R	5	7	9	1	8	3
	to		Expansion (E) = (T-R)/DR	27.97	39.16	50.35	5.59	44.75	16.78
	01-Jun-04		Passage = E+R	27.97	39.16	51.35	5.59	44.75	16.78
STRATUM 3	3	0.2647	Total (T)	2	2	6	1	9	4
	from		Removal (R)	0	0	0	0	0	0
	02-Jun-04		T-R	2	2	6	1	9	4
	to		Expansion (E) = (T-R)/DR	7.56	7.56	22.67	3.78	34.01	15.11
	04-Jun-04		Passage = E+R	7.56	7.56	22.67	3.78	34.01	15.11
STRATUM 4	4	0.1864	Total (T)	6	3	11	2	10	5
	from		Removal (R)	0	0	0	0	0	0
	05-Jun-04		T-R	6	3	11	2	10	5
	to		Expansion (E) = (T-R)/DR	32.19	16.10	59.02	10.73	53.65	26.83
	08-Sep-04		Passage = E+R	32.19	16.10	59.02	10.73	53.65	26.83
	Over Strata		Total Passage >	224.51	145.62	221.66	33.74	200.58	65.54
			Number Tagged >	268	217	390	121	347	160
			Survival Index >	0.8377	0.6710	0.5684	0.2788	0.5780	0.4096

	Stratum	Detection Rate (RD)	Release Site >	Tumwater	Tumwater	Tumwater	Tumwater
			Brood/Hatchery >	UpStream	UpStream	UpStream	UpStream
			Release Date >	05/18/04	05/25/04	05/27/04	05/29/04
			Tag Group >	KGM04138_TDT	KGM04145_TDT	KGM04147_TDT	KGM04149_TDT
STRATUM 1	1	0.1467	Total (T)	0	0	0	0
	from		Removal (R)	0	0	0	0
	01-May-04		T-R	0	0	0	0
	to		Expansion (E) = (T-R)/DR	0.00	0.00	0.00	0.00
	28-May-04		Passage = E+R	0.00	0.00	0.00	0.00
STRATUM 2	2	0.1788	Total (T)	6	0	0	0
	from		Removal (R)	0	0	0	0
	29-May-04		T-R	6	0	0	0
	to		Expansion (E) = (T-R)/DR	33.56	0.00	0.00	0.00
	01-Jun-04		Passage = E+R	33.56	0.00	0.00	0.00
STRATUM 3	3	0.2647	Total (T)	12	0	0	0
	from		Removal (R)	0	0	0	0
	02-Jun-04		T-R	12	0	0	0
	to		Expansion (E) = (T-R)/DR	45.34	0.00	0.00	0.00
	04-Jun-04		Passage = E+R	45.34	0.00	0.00	0.00
STRATUM 4	4	0.1864	Total (T)	42	16	6	14
	from		Removal (R)	0	0	0	0
	05-Jun-04		T-R	42	16	6	14
	to		Expansion (E) = (T-R)/DR	225.33	85.84	32.19	75.11
	08-Sep-04		Passage = E+R	225.33	85.84	32.19	75.11
	Over Strata		Total Passage >	304.24	85.84	32.19	75.11
			Number Tagged >	513	191	84	138
			Survival Index >	0.5931	0.4494	0.3832	0.5443

6) Tumwater Downstream Releases– Tagging-to-McNary Survival

	Stratum	Detection Rate (RD)							
			Release Site >	Tumwater	Tumwater	Tumwater	Tumwater	Tumwater	Tumwater
			Brood/Hatchery >	Down Stream	Down Stream	Down Stream	Down Stream	Down Stream	Down Stream
			Release Date >	04/28/04	05/01/04	05/05/04	05/07/04	05/11/04	05/13/04
			Tag Group >	KGM04118.TDC	KGM04121.TDC	KGM04125.TDC	KGM04127.TDC	KGM04131.TDC	KGM04133.TDC
STRATUM 1	1	0.1467	Total (T)	28	15	11	2	5	4
	from		Removal (R)	0	0	0	0	0	0
	01-May-04		T-R	28	15	11	2	5	4
	to		Expansion (E) = (T-R)/DR	190.88	102.26	74.99	13.63	34.09	27.27
	28-May-04		Passage = E+R	190.88	102.26	74.99	13.63	34.09	27.27
STRATUM 2	2	0.1788	Total (T)	3	7	7	3	12	1
	from		Removal (R)	0	0	0	0	0	0
	29-May-04		T-R	3	7	7	3	12	1
	to		Expansion (E) = (T-R)/DR	16.78	39.16	39.16	16.78	67.13	5.59
	01-Jun-04		Passage = E+R	16.78	39.16	39.16	16.78	67.13	5.59
STRATUM 3	3	0.2647	Total (T)	4	4	5	2	7	9
	from		Removal (R)	0	0	0	0	0	0
	02-Jun-04		T-R	4	4	5	2	7	9
	to		Expansion (E) = (T-R)/DR	15.11	15.11	18.89	7.56	26.45	34.01
	04-Jun-04		Passage = E+R	15.11	15.11	18.89	7.56	26.45	34.01
STRATUM 4	4	0.1864	Total (T)	8	2	9	4	9	9
	from		Removal (R)	0	0	0	0	0	0
	05-Jun-04		T-R	8	2	9	4	9	9
	to		Expansion (E) = (T-R)/DR	42.92	10.73	48.29	21.46	48.29	48.29
	08-Sep-04		Passage = E+R	42.92	10.73	48.29	21.46	48.29	48.29
	Over Strata		Total Passage >	265.70	167.26	181.33	59.43	175.95	115.16
			Number Tagged >	268	217	391	146	319	150
			Survival Index >	0.9914	0.7708	0.4637	0.4071	0.5516	0.7677

	Stratum	Detection Rate (RD)					
			Release Site >	Tumwater	Tumwater	Tumwater	Tumwater
			Brood/Hatchery >	Down Stream	Down Stream	Down Stream	Down Stream
			Release Date >	05/18/04	05/25/04	05/27/04	05/29/04
			Tag Group >	KGM04138.TDC	KGM04145.TDC	KGM04147.TDC	KGM04149.TDC
STRATUM 1	1	0.1467	Total (T)	6	0	0	0
	from		Removal (R)	0	0	0	0
	01-May-04		T-R	6	0	0	0
	to		Expansion (E) = (T-R)/DR	40.90	0.00	0.00	0.00
	28-May-04		Passage = E+R	40.90	0.00	0.00	0.00
STRATUM 2	2	0.1788	Total (T)	8	0	0	0
	from		Removal (R)	0	0	0	0
	29-May-04		T-R	8	0	0	0
	to		Expansion (E) = (T-R)/DR	44.75	0.00	0.00	0.00
	01-Jun-04		Passage = E+R	44.75	0.00	0.00	0.00
STRATUM 3	3	0.2647	Total (T)	14	0	0	0
	from		Removal (R)	0	0	0	0
	02-Jun-04		T-R	14	0	0	0
	to		Expansion (E) = (T-R)/DR	52.90	0.00	0.00	0.00
	04-Jun-04		Passage = E+R	52.90	0.00	0.00	0.00
STRATUM 4	4	0.1864	Total (T)	24	10	10	6
	from		Removal (R)	0	0	0	0
	05-Jun-04		T-R	24	10	10	6
	to		Expansion (E) = (T-R)/DR	128.76	53.65	53.65	32.19
	08-Sep-04		Passage = E+R	128.76	53.65	53.65	32.19
	Over Strata		Total Passage >	267.32	53.65	53.65	32.19
			Number Tagged >	514	153	131	116
			Survival Index >	0.5201	0.3507	0.4095	0.2775

APPENDIX F: COMPARISON OF SMOLT-TO-ADULT SURVIVAL RATES FOR MID-COLUMBIA RIVER HATCHERY PROGRAMS

APPENDIX F: COMPARISON OF SMOLT-TO-ADULT SURVIVAL RATES FOR MID-COLUMBIA RIVER HATCHERY PROGRAMS

SARS for Chiwawa Spring Chinook, Methow spring Chinook, steelhead, sockeye, and summer Chinook were provided by WDFW

SARS for Leavenworth NFH, Entiat NFH, and Winthrop NFH were provided by D. Carie, USFWS

SARS for coho salmon include both lower Columbia River brood and developing mid-Columbia River brood.

Brood Year**

Stock	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	
Wenatchee Combined Coho[1]									0.28	0.18[a]	0.03	0.41	0.39	N
Methow Combined Coho[2]										0.17	0.05	0.15	0.016	N
Chiwawa Spring Chinook	0.81	0.04	0.06	0.04	0.13	0.07	No Program	0.57	0.95	1.45	No Program	1.08+	0.94+	N
Leavenworth Spring Chinook	0.33	0.009	0.03	0.1	0.32	0.08	0.15	0.62	0.99	1.07	NYA	NYA	NYA	N
Wenatchee Summer Steelhead								0.34	0.4	0.12	1.24	0.27	NYA	N
Wenatchee Sockeye*	1.3	0.12	0.003	0.14	0.06	0.01	0.49	2.14	1.16	0.08	NYA	NYA	NYA	N
Wenatchee Summer Chinook	0.7	0.09	0.03	0.08	0.06	0.34	0.21	0.08	0.98	0.39	NYA	NYA	NYA	N
Carlton Summer Chinook	0.81	0.09	0.03	0.41	0.03	0.17	0.05	0.02	0.09	0.37	NYA	NYA	NYA	N
WNFH Spring Chinook	0.03	0.002	0.002	0.04	0.05	0.07	0.38	0.38	0.84	0.83	NYA	NYA	NYA	N
Methow Spring Chinook					0.09	0.02	0.85	0.24	0.24	0.46	0.04	NYA	NYA	N
Twisp Spring Chinook				0.06	0.02	0.03	N/A	0.35	0.24	0.13	0.07	NYA	NYA	N
Chewuch Spring Chinook				0.09	0.04	0	N/A	0.04	0.27	N/A	N/A	N/A	N/A	N
Wells Steelhead				0.47	0.36	1.17	0.68	0.50	0.85	1.57	2.04	0.32	NYA	N
Entiat Spring Chinook	0.06	0.01	0.03	0.05	0.06	0.07	0.37	0.60	0.87	0.69	NYA	NYA	NYA	N

[1]Combined Coho includes all release sites and brood sources: Brood years 1997-1999 are primarily LCR brood coho, 2000 is a combination of LCR and MCR, 2001 is primarily MCR coho.
[2] Methow combined coho includes in-basin survival to Winthrop NFH and in parenthesis, survival to Wells Dam
[3] SAR may be as high as 0.86% if calculated based upon dam counts (RI-RR)
*Low sampling effort prior to 1996 may underestimate actual survival performance
** Brood year X coho, spring chinook, and sockeye emigrate in X+2
** Brood year X steelhead and summer chinook emigrate year X+1

+ Data is not yet complete