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UPSTREAM PASSAGE, SPAWNING, AND STOCK IDENTIFICATION OF FALL CHINOOK IN THE SNAKE RIVER, 1992 AND 1993

Final Report 1992 - 1993

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UPSTREAM PASSAGE, SPAWNING, AND STOCK IDENTIFICATION OF FALL CHINOOK IN THE SNAKE RIVER, 1992 AND 1993

FINAL REPORT

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INTRODUCTION

Intensive monitoring of returning Snake River fall chinook salmon has been a coordinated effort over the last several years. The cooperating entities were the Washington Department of Fish and Wildlife (WDFW), Oregon Department of Fish and Wildlife (ODFW), Nez Perce Tribe (NPT), Idaho Power Company (IPC), U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS), U.S. Army Corps of Engineers (USACE), and Columbia River Inter-Tribal Fish Commission (CRITFC). Bonneville Power Administration (BPA) has provided funds and coordination activities. In addition, the Lower Snake River Fish and Wildlife Compensation Program (LSRCP) collected and analyzed genetic data which described the genetic relationships of Lyons Ferry Hatchery (LFH) fall chinook and mid-Columbia upriver bright fall chinook through 1990 (Bugert et al. 1990).

When these fish were petitioned for listing under the Endangered Species Act (ESA), three major questions were left unanswered:

1) What is the fate of 50 percent of the adults that have not been accounted for each between the counting windows at the first dam on the lower Snake River, Ice Harbor Dam (IHR) and when they were counted as they passed the fourth dam, Lower Granite (LGR)? Potential reasons for this discrepancy include fallback at dams, spawning in the lower Snake River, or pre-spawning mortality.
2) Why do redd counts (observed by helicopter survey) on the spawning grounds above LGR in recent years average only one redd per 8.5 adults passing the dam? As with dam counts, questions remain regarding the accountability of salmon upstream of LGR, and the possibility of deep--water spawning and/or differential spatial spawning distribution between wild fish and hatchery strays.
3) What is the stock composition or genetic profile of returning adults and their offspring above LGR, and how much hatchery straying is occurring?

A study was designed in 1991 by WDFW, in cooperation with the IJSFWS and Idaho Cooperative Fish and Wildlife Research Unit (ICFWRU) to answer these questions. Funding was provided that year by the NMFS, LSRCP, and WDFW. BPA provided funding the second year. This report describes the activities and results obtained during 1992.

Two separate but coordinated methodologies were used in this study. These methodologies included radio telemetry to address the questions (one and two) of salmon disposition and accountability, while stock identification techniques were used to address the question regarding stock composition.

We arranged this annual report into two self-contained chapters entitled:
1) Upstream Passage and Spawning of Fall Chinook Salmon in the Snake River, and
2) Stock Identification of Snake River Fall Chinook Salmon.

CHAPTER 1

UPSTREAM PASSAGE AND SPAWNING OF FALL CHINOOK SALMON IN THE SNAKE RIVER.

by

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May 1997

Acknowledgments

Many individuals and organizations contributed to this study. We are grateful to all those involved.

This study was truly a cooperative effort. Our trapping and radio tagging of fall chinook at IHR was conducted as we collected broodstock for Lyons Ferry Hatchery (Mendel et al. 1994a). We assisted personnel from the Idaho Cooperative Fish and Wildlife Research Unit (ICFWRU) at the University of Idaho to trap, tag, and track steelhead as part of their radio telemetry study involving spring and summer chinook salmon and steelhead in the Snake River Basin (Bjornn et al. 1992, 1994, 1995). They assisted us with implanting radio transmitters in fall chinook salmon at IHR. They also provided us with large quantities of telemetry data from their fixed-site tracking stations and mobile tracking efforts. The U.S. Fish and Wildlife Service (USFWS) Fishery Resource Office at Ahsahka, Idaho assisted us with radio tracking while attempting to identify and map spawning habitat for fall chinook salmon in the Snake River upstream of LGR Dam (Connor et al. 1994). Other WDFW personnel (Blankenship 1996) recovered fall chinook salmon carcasses and radio tags for a genetic analyses and baseline stock identification study. Idaho Power Company (IPC) personnel assisted with radio tracking while studying fall chinook salmon spawning locations and the effects of various water releases from Hells Canyon Dam (Groves 1993). We provided radio telemetry locations to Battelle, Pacific Northwest National Laboratory (PNNL), and USFWS personnel to assist with their efforts to identify spawning in the tailraces of the lower Snake River dams (Dauble et al. 1994 and Garcia et al. 1994). Personnel from the PNNL radio tracked our tagged fish in the Hanford Reach portion of the Columbia River as a separate study to evaluate habitat usage (Dave Geist, personal communication). Additionally, personnel from the National Marine Fisheries Service (NMFS) conducted a separate radio telemetry study in the upper Columbia River (Stuehrenberg et al. 1994). Both PNNL and NMFS provided us with supplemental tracking data for our radio tagged salmon. Personnel from the Nee Perce Tribe and the Oregon Department of Fish and Wildlife (ODFW) funded flight time and assistance in radio tracking or locating radio tagged fall chinook salmon upstream of LGR. All of these projects were interrelated and required substantial coordination, but they increased data collection and our understanding of movements and spawning locations of fall chinook salmon.

We wish to specifically acknowledge Dr. Ted Bjornn, Rudy Ringe, Joel Hunt, Ken Tolotti, Pat Keniry, Marc Petersen, Michelle Feely, and others at the University of Idaho ICFWRU. Their cooperation and assistance greatly benefitted this project and made completion of our tasks much easier. We thank Jerry Harmon, Neil Paasch, Ken Thomas, and Ken McIntyre (NMFS) for trapping and tagging fall chinook salmon for us at Lower Granite Dam. We also thank Lowell Stuehrenberg, Leslie Timme and Paul Ocker of NMFS, and Dave Geist and Judith Williams of Battelle, Pacific Northwest National Laboratory, for providing radio telemetry data for our radio tagged salmon, particularly in the Hanford Reach of the Columbia River.

Phil Groves and Chris Randolph of Idaho Power Company assisted by providing funding for helicopter flights and Phil operated our receiver for us during some trips in the upper Snake River. We appreciate their contributions to this project. Billy Connor, Aaron Garcia, and others at the USFWS Fishery Resource Office assisted with radio tracking by providing funding for cooperative flights and assisting us with boat tracking efforts. They also assisted with carcass and radio tag recovery.

We especially thank Steve Reed, Skyrunners Corporation, and Jim Pope, Sr., Valley Helicopter, and Doug Gadwa for providing safe, productive telemetry flights during this study.

We appreciate the assistance of WDFW personnel Lance Ross, Jerry Dedloff, Joe Bumgarner, Kelly Underwood, Mike Varney, Mark Lambert, Mike Deitchler, and Jesse Mings for assisting with various tasks such as trapping, hauling, tracking, tagging, record keeping, or data entry. Lee Blankenship provided recoveries of radio tagged fish and assisted us by handling the tag reward system and other aspects of this study. Micki Varney and Dale Williams deserve special recognition. They provided invaluable assistance with radio tagging and tracking. Micki also provided many months of assistance with data entry, verification, and summarization; including interpretation of tracking data. We greatly appreciate the assistance these individuals provided us. We also acknowledge all those individuals and organizations that returned tags and recovery data to us.

We thank Debbie Docherty and the Bonneville Power Administration for funding this project in 1992 and 1993. We are grateful for Debbie's cooperation and assistance during data collection and her patience during report preparation. We also thank Dan Herrig and Edouard Crateau, USFWS LSRCP Office, for providing funding in 1991 that initiated this three year project as well as some incidental funding in 1992-1997.

Dennis Rondorff, National Biological Service, assisted with the original development of the study plan. Also, we are indebted to Bob Bugert. He had the foresight to initiate this study while he was with WDFW. He developed the study plan and secured the initial funding. We greatly appreciate his planning efforts.

The following individuals provided comments after reviewing a draft of this report: Aaron Garcia, Debbie Docherty, Geraldine Vander Haegen, Larrie LaVoy, Cindy LeFleur, Pat Frazier, Mark Schuck, Joe Bumgamer, Dave Geist, Bob Bugert and Lee Blankenship. We sincerely appreciate their help.

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ABSTRACT

This report summarizes our activities and results for 1993, and it is our final report of this three year study. The objectives of this study were as follows:

1) to determine the source(s) of losses (or errors in accounting) for adult fall chinook salmon between Ice Harbor (IHR) Dam and Lower Granite (LGR) Dam, and upstream of LGR in the Snake River;
2) to identify spawning locations upstream of LGR to assist with calibration of aerial redd surveys, redd habitat mapping, carcass recovery (for genetic stock profile analysis), and correction of estimated adult/redd ratios; and
3) to estimate passage and migration times at Snake River dams and reservoirs.

We targeted unmarked adult fall chinook salmon for trapping and radio tagging at IHR and LGR Dams as they ascended the Snake River during their spawning migration. We used aerial, fixed-site, and ground mobile radio tracking to determine the movements of these fish.

Two hundred fall chinook salmon were radio tagged and released near IHR Dam in 1993. All fish were released 2.2 km upstream'of IHR Dam at Charbonneau Park (CHAR). We were able track or relocate 190 (95%) of the fish away from CHAR. Fifty-nine (3 1 .0%) fish descended downstream to below IHR dam (fell back at IHR) without crossing Lower Monumental Dam (LMO). Many of these fish were detected in the Columbia or Yakima Rivers, although some were detected as far downstream as the John Day River in Oregon. Another 128 salmon (66.8%) initially passed upstream of LMO Dam without previously falling back at IHR Dam. Only 80 (42.1%) radio tagged salmon initially passed Little Goose Dam (LGO) without previously falling back at a downstream dam. Sixty-six (34.7%) of these fish passed LGR Dam. Many of the fish that fell back reascended the dams. A total of 72 radio tagged salmon that were released at CHAR passed upstream of LGR Dam, including fish that had fallen back and reascended a downstream dam.

Over 80 percent of the radio tagged salmon that entered Lyons Ferry Hatchery each year had reached LGO Dam before descending to the hatchery. Extensive wandering was documented between LMO and upstream of LGR before salmon entered Lyons Ferry Hatchery or the Tucannon River. In 1993, forty-one radio tagged salmon were found to be of hatchery origin when recovered and analysis of marks and scale samples were completed. These fish entered Lyons Ferry Hatchery with similar movements to unmarked salmon. Each year a few radio tagged salmon have remained near the hatchery without entering, which suggests the hatchery may have inadequate attraction flows.

Radio tagged fall chinook passed lower Snake River dams in 2-5 days each, on average. Median travel times through LMO and LGO reservoirs were 1 .O- 1.3 days each, which was slower than travel times for spring chinook or steelhead in the Snake River in 1993 (Bjornn et al. 1995).

We documented losses or accounting errors of 38 percent for radio tagged salmon between IHR and LGR Dams. Our radio telemetry data suggests that 83 percent of the fish unaccounted for (loss) between these two dams can be attributed to fall back at IHR Dam in 1993. The loss explained by fall back between IHR and LGR was 62 percent in 1992. All but 3-6 percent of this loss is from fall back before fish crossed LMO Dam.

We supplemented radio tagged fish upstream of LGR by radio tagging and releasing another 20 salmon at that dam. We combined radio tagged salmon from both dams to examine fall back, accuracy of ladder counts, pre-spawning mortality and spawning location upstream of LGR for radio tagged salmon.

Fall back was common for salmon tagged either at IHR or LGR Dams. Some fish fell back, reascended, and fell back again at the same dam. Other salmon fell back at multiple dams. Untagged fall chinook salmon also fell back at LMO, LGO, and LGR Dams on the Snake River, as well as from McNary Dam (e.g., Wagner et al. 1992). We documented more fall back during all three years than Bjornn et al. (1995) has reported for spring/summer chinook salmon in the Snake River. Apparently, at least 74 percent and 86 percent of the salmon that fell back survived in 1993 and 1992, respectively, even though the primary fall back route was through the turbine intakes at all dams.

We documented frequent interchange of fish from the Snake River upstream of LGR with the Grande Ronde, Clearwater, and Salmon Rivers. Most spawning appeared to be in the Snake River between Asotin and the Grande Ronde River. Adult/redd ratios have been reduced from 6-10 to 3-5 by accounting for fall back at LGR and pre-spawning mortalities, along with improved redd counting methods. Tailrace spawning could not be determined by using radio telemetry because of the erratic fish movements and our inability to determine when spawning occurred for radio tagged fish.

Determining the number of salmon available to spawn upstream of a dam was complicated by fish that fell back or reascended a dam, extensive erratic fish movements to and from several different rivers, and our inability to ascertain the fate of each radio tagged salmon. For example, we estimate that salmon counts at LGR Dam were higher than the number of salmon available to spawn by 3 1 percent in 1993 and 54 percent in 1992. Consequently, fish counts should be adjusted to account for fall back and pre-spawning mortality. Otherwise, fish counts provide an overestimate of the number of fall chinook salmon available to spawn in the Snake River.

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INTRODUCTION

Washington Department of Fish and Wildlife (WDFW[1]) personnel annually monitor returns of fall chinook salmon to the Snake River. This is to assess progress towards the Lower Snake River Compensation Program (LSRCP) goal of returning 18,300 adult hatchery fall chinook salmon annually to the Snake River. Over several years we noticed that approximately 30-50 percent of the fall chinook salmon counted at Ice Harbor (IHR) Dam could not be accounted for at locations upstream to LGR (Bugert et al. 1991, Mendel et al. 1993b). We obtain counts of fall chinook salmon upstream of IHR from three sources:

1) Lyons Ferry Hatchery
2) Lower Granite (LGR) Dam, and
3) spawning escapement estimates in the Tucannon and Palouse Rivers.

We also noticed that many adult fall chinook salmon could not be accounted for upstream of LGR based on cooperative redd surveys conducted by several agencies and organizations. An average adult per redd ratio of 8.5: 1 has been estimated over several years in the late 1980s and early 1990s (Mendel et al. 1992a). Disparity of salmon counts between IHR and LGR, or upstream of LGR, may be due to:

1) fall back at IHR or LGR
2) pre-spawning mortality
3) interception in steelhead sport fisheries
4) spawning in tailraces of the lower Snake River dams, or
5) an inability to detect all redds upstream of LGR Dam (Mendel et al. 1992b).

We initiated this radio telemetry study in 1991, and continued it through 1993, to determine the fate of "missing" fish upstream of IHR and LGR. Our objectives were as follows:

1) Determine the source(s) of loss of adult fall chinook salmon between IHR and LGR Dams, and upstream of LGR. This objective consisted of the following sub-objectives:
   1A) Determine the extent of fall back at IHR and LGR Dams.
   1B) Determine if, and where, pre-spawning mortality occurs, and the causes of mortality.
   1C) Determine if salmon are holding, and possibly spawning, in the tailraces of dams or elsewhere in the reservoirs.
2) Identify spawning locations upstream of LGR to assist with the following:
   - calibration of aerial redd surveys
   - redd habitat mapping
   - salmon carcass recovery for genetic analyses, and
   - correction of estimated adult-per-redd ratios.

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[1] The Departments of Fisheries and Wildlife were merged into a single agency in March 1994. References to either agency will be indicated as WDFW.

3) Estimate the amount of time required by fall chinook to pass dams and migrate through reservoirs within the Snake River. This objective was added in 1993.

This report summarizes our radio telemetry activities and results for the contract period of 1 July 1993 to 3 1 March 1995, and it provides the results and conclusions for all three years of field study.

STUDY AREA

Initially, our study area consisted of that portion of Washington, Oregon, and Idaho from the mouth of the Snake River (RK 0.0) upstream to Hells Canyon Dam (RK 397.4), and the lower Clearwater, Imnaha, Tucannon, Palouse, and Grande Ronde Rivers (Figure 1). However, in 1991, we adjusted the study area to include at least that portion of the Columbia River from just downstream of McNary Dam (RK 469.8) upstream to Priest Rapids Dam (RK 638.3) including the Hanford Reach of the Columbia River (from the Tri-Cities upstream to Priest Rapids Dam) because radio tagged salmon were documented leaving the Snake River and entering the Columbia River. In 1992 we added several river segments to our study area in and effort to reduce the percentage of the radio tagged salmon that could not be accounted for within the study area in 1991:

1) the Columbia River below McNary Dam to just below Irrigon Fish Hatchery (RK **450.5);**
2) the Yakima River upstream from its mouth to Wapato Dam (RK 171 .5);
3) the lower Umatilla River to Three Mile Dam (RK 6.4); and
4) the lower Salmon River (Riggins to the mouth).

Reference landmarks and river kilometers (RK) are listed in Appendix A.

The study area included free-flowing river segments upstream of Pasco on the Columbia River (i.e., the "Hanford Reach"), in the lower Clear-water, Salmon, and Grande Ronde Rivers, portions of the Yakima and Umatilla Rivers, upstream of Asotin in the Snake River, and the lower Imnaha River. Most of the remaining river segments in the Snake and Columbia Rivers were reservoirs. Short portions of the rivers below each dam retain water velocities and other characteristics similar to free-flowing river conditions. Additionally, some relocations or recoveries were obtained from the John Day River and upstream of Priest Rapids Dam in the Columbia River from other concurrent radio telemetry studies.

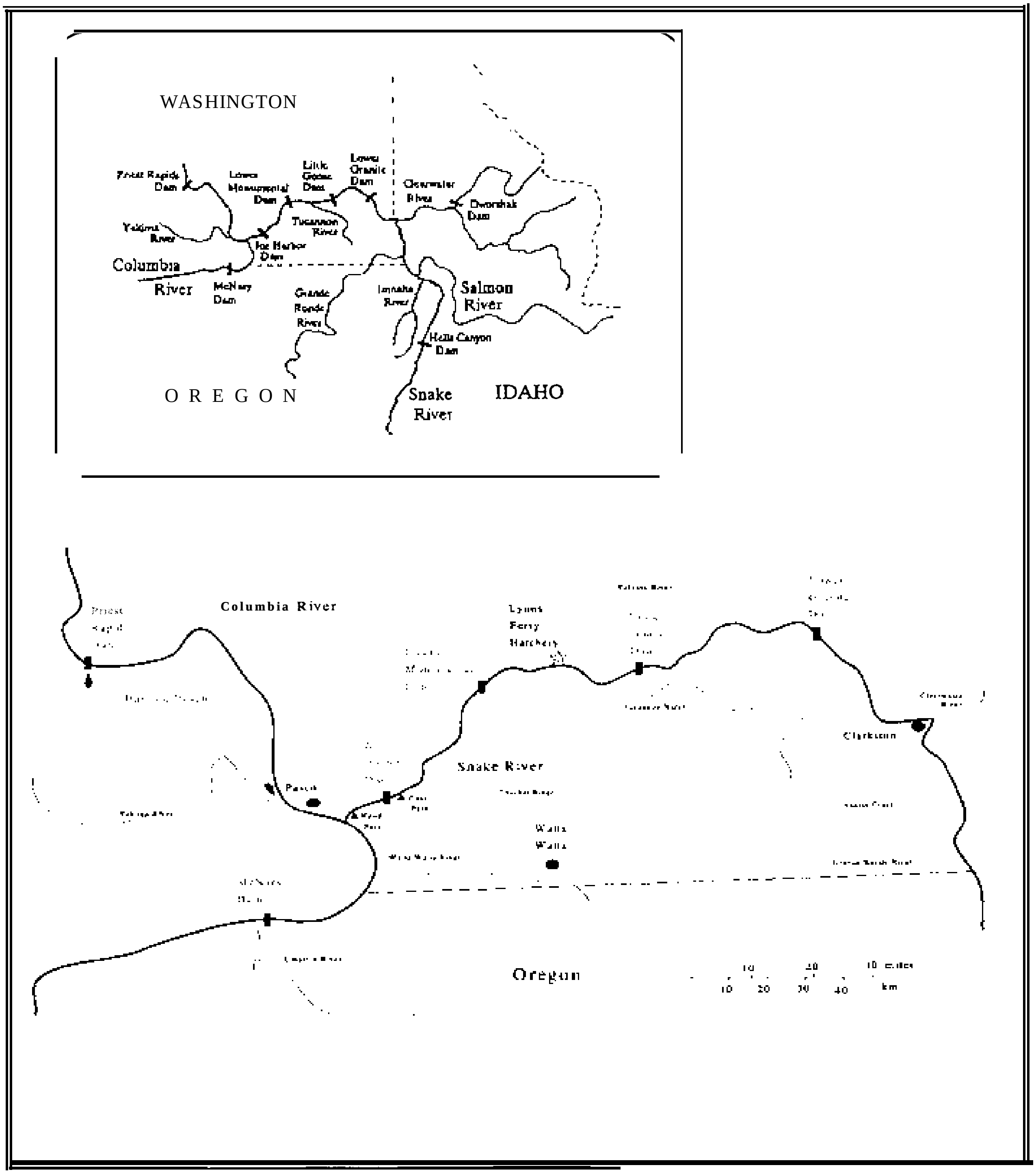


Figure 1. General study area and locations of landmarks, including Hood and Charbonneau (CHAR) parks, referred to in this fall chinook radio telemetry study (inset regional map courtesy of Aaron Garcia, USFWS, Ahsahka, ID).

METHODS AND MATERIALS

Tagging at Ice Harbor Dam (IHR)

We operated a floating trap in the upstream portion of the south shore fish ladder at IHR Dam from 7 September to 27 October 1993. Fall chinook salmon were captured both for use as broodstock at Lyons Ferry Hatchery (adipose clipped fish only) and for radio tagging (unmarked fish) after they had passed the fish counting window in the fish ladder. We trapped during daylight hours (0600-l 900 hrs) for 39 days; ten days of continuous trapping and four days without trapping every two weeks in 1993. Details concerning fish trapping have been previously described (Mendel et al. 1993a, 1994a, Bjornn et al. 1992, 1995).

Our goal was to collect, tag and track 200 unmarked salmon that were presumably naturally produced. Salmon were trapped for radio tagging after they were viewed through a submerged chamber in the fish trap and retained in a submerged holding pen. The lower portion of the fish holding pen was constructed of sheet metal with a canvas sleeve attached to a hole in the bottom. This allowed fish to remain in water at all times and to be loaded into the transport tank without being handled. The holding tank was lifted with a crane so fish could be loaded into a 1,135 L tank mounted on a truck or trailer. A dilute solution (approximately 1 O-20 mg/L) of tricane methanesulfonate (MS 222) was added to oxygenated water in the tank to sedate the fish. No more than ten salmon were loaded into the truck for each tagging session, although salmon were often loaded together with steelhead.

We transported salmon captured for radio tagging at IHR Dam to Charbonneau Park (2.2 km upstream of the dam). Fish were individually netted from the tank truck and placed into a 113 L trough with oxygenated water and anesthetized with MS 222 for tagging. Only salmon longer than 65 cm FL were radio tagged because of the size of the radio transmitters. A uniquely numbered jaw tag was attached to the mandible of each fish so that we could obtain recovery data if the fish was recaptured, or its transmitter was regurgitated. A blank-wire, or coded-wire tag was injected into the muscle just below the dorsal fin to activate the adult trap in the fish ladder at LGR (which uses a metal detector). Radio transmitters were implanted into the esophagus and stomach (inserted through the mouth to be held in place by the sphincter muscle at the top of the esophagus). After insertion, the transmitter antenna emerged from the mouth and was bent at the edge of the mouth to allow it to trail behind the fish's head. Fork length, sex, general condition, jaw tag number, radio frequency/channel, and numeric code (unique to each frequency/channel) were recorded for each fish tagged. Scales were sampled to determine fish age and provide some indication of origin (natural or hatchery). Tagged fish were individually carried in a transport bag (to calm the fish and ease transport) to a recovery pen in the river. They remained within the pen until they recovered and escaped into the river. After release, the recovery pen was checked for regurgitated transmitters or detached jaw tags. We reused recovered transmitters from three fall chinook salmon and adjusted our records. Salmon were radio tagged from 8 September to 25 October 1993.

Tagging at Lower Granite Dam (LGR)

Our goal was to radio tag salmon that appeared to be naturally produced and increase our sample size of radio tagged salmon from IHR that passed upstream of LGR. Trapping occurred in conjunction with broodstock collection for Lyons Ferry Hatchery (Mendel et al. 1994a). Twenty fall chinook salmon (with no wire tags and adipose fin intact) were captured and radio tagged at the adult trap in the south shore fish ladder at LGR (see Mendel et al. 1994a for additional information regarding trapping activities at Lower Granite Dam in 1993). Salmon were trapped from 10 August until 19 November at LGR, but salmon were radio tagged from 15 September until 6 November. Some unmarked salmon were captured when an entire group of fish passing the trap was directed into the trap for a random sample to obtain steelhead scale samples. We captured a few additional unclipped fall chinook salmon by watching the fish enter the chute near the metal detectors and then sending a false signal to the detector to open the gate into the trap.

Captured fall chinook salmon were netted out of the trap and anesthetized with MS 222. They were measured (fork length), examined for marks, radio tagged, jaw tagged, coded-wire tagged, scale sampled, and released into the fish ladder upstream of the trap. Tagged salmon were able to recover in an isolated, quiet area in the ladder before continuing their migration upstream. A barrier prevented them from descending in the ladder and returning to the tailrace of the dam. The recovery area was drained four times in the fall of 1993 to remove any non-game fish and a few radio tagged salmon or transmitters were “flushed” below the dam. Transmitters implanted at LGR as well as other equipment, tagging, and data recording procedures were similar to those used at IHR.

Transmitters and Receivers

We used radio transmitters and receivers manufactured by Lotek Engineering Inc.[2], of Newmarket, Ontario, Canada. We selected this equipment because it enabled us to track large numbers of fish that could be individually identified. Also, these transmitters were compatible with the University of Idaho’s Cooperative Fish and Wildlife Research Unit’s (ICFWRU) telemetry equipment which enabled us to obtain tracking data from tagged fall chinook salmon as they passed ICF WRU fixed-site receiver stations.

Transmitters (tags) were 16 x 83 mm and weighed 12.8 g in water. They had an operational life of approximately 3 10 days. Transmitters emitted a digitally coded signal at 148-149 MHz every five seconds during the three years of this study. At least a 10 Khz separation between transmitter frequencies on the same channel ensured signal separation and identification of unique codes by the receivers.

2 Use of trade names does not imply endorsement by the WDFW.

Each transmitter contained an externally visible note that listed the frequency, channel, numeric code, and notice of a reward for returning the tags to WDFW at a listed address. Jaw tags also had “Reward” and our address printed on them. Through posted notices and press releases we attempted to recover transmitters and jaw tags from the public.

All SRX receivers used for fixed site or mobile tracking were attached to one or more aerial or underwater antennas. The receivers were set to scan for coded transmitters on each channel/frequency every six seconds to accommodate the five second signal interval. This minimized total scan time to 18 seconds for all three channels used in this study. Digital signal processor (DSP) receivers used to monitor the fishways at dams instantaneously scanned all channels and all antennas.

Transmitter frequencies were programmed into the receivers with a 0.02 MHz separation between channels. Receivers interpreted these coded signals as a unique numeric code for each transmitter on each channel. Up to 100 fish with unique codes could be tracked on each channel in 1993. Upon detection of a signal from one of our transmitters the receiver produced a “chirp” sound that was not duplicated by extraneous noise or interference. If the signal was strong enough for the code to be identified, the receiver would display the channel, unique numeric code, power level of the signal, date, time, and antenna number. All data were recorded manually, or stored automatically in one of eight memory banks in the receiver.

Radio Tracking

We obtained telemetry data from numerous fixed-site receivers deployed by the ICFWRU to monitor spring chinook salmon and steelhead movements throughout the Snake River drainage in 1991-1993 (Bjornn et al. 1994, Mendel et al. 1994). Fixed-site receivers were installed 0.5 to 2.0 km downstream of each of the four lower Snake River dams, at various locations at each dam, and near the mouths of major tributaries. In 1993, additional antennas and receivers monitored fishway entrances and collection channels along the tailrace at all four lower Snake River dams, as well an antenna in the top of the fish ladder at McNary Dam. We received supplemental relocation data for fall chinook salmon obtained during ICFWRU mobile tracking for steelhead. Additionally, NMFS personnel provided relocation information for our radio tagged fall chinook from mobile tracking and fixed site receivers they operated for a separate telemetry study at Horn Rapids Dam (in the Yakima River), Priest Rapids Dam, and several other dams in the upper Columbia River in 1993. Supplemental mobile tracking data for our radio tagged salmon was also available in 1993 for the Hanford Reach of the Columbia River from a study conducted by Battelle Pacific Northwest National Laboratories. Radio tracking was incorporated into weekly helicopter flights as fall chinook salmon spawning surveys were conducted. Surveys by the U.S. Fish and Wildlife Service (USFWS) and Idaho Power included the Snake (upstream of Asotin) and the Grande Ronde Rivers from 25 October until 13 December 1993 (Garcia et al. 1994). The Clearwater River was radio tracked each year and the Salmon River was tracked in 1992 and 1993. In 1993, these two rivers were tracked by the Nez Perce Tribe between 2 November and 7 December.

Tracking efforts by WDFW consisted of extensive mobile tracking with aircraft, trucks, and boats, as well as compilation of relocations from other sources. We modified pickup trucks to accommodate the four element yagi antennas needed to receive the transmitter signals. Modified pickup trucks were used for mobile radio tracking in areas away from the fixed-site receivers, or to supplement tracking in areas with fixed-site receivers. Additionally, we occasionally used boats for mobile tracking in the Snake and Columbia Rivers. We closely coordinated our mobile tracking efforts with other organizations conducting radio telemetry to avoid data gaps and duplication of effort.

Our primary means of tracking over the three years involved aerial surveys using a Cessna 172 fixed-wing airplane in the larger river canyons and a Hiller helicopter in the narrower canyons. A four element yagi antenna was attached parallel to the fuselage along the wing strut of the airplane, pointing forward and down at about a 20-30 degree angle. The same four element yagi antenna, or a whip, or an "H" antenna was attached at various locations to the helicopter in 1991-92. In 1993, we used only the "H" antenna attached under the helicopter because that combination reduced extraneous "noise," improved transmitter signal detections, and minimized interference with the helicopter's operation. Receiver gain had to be set between 60-80 to minimize engine interference with the receiver and allow the transmitter code to log. Fixed-wing aircraft flew at altitudes of approximately 30-210 m and air speeds of 100-130 km/hr while tracking along the reservoirs. Tracking by helicopter consisted of low level flights (1 O-l 50 m altitude) and air speeds of 8-80 km/hr.

Our flights over reservoirs often consisted of tracking while traveling upstream near one shore, and then tracking while going downstream near the other shoreline, to enable us to adequately cover the width of the reservoirs. When flight time had to be limited, our tracking consisted of one pass over the middle of the reservoir. We conducted aerial radio tracking from upstream of Priest Rapids Dam to downstream of Irrigon Hatchery (below McNary Dam) along the Columbia River. We also surveyed from the mouth of the Yakima River to Wapato Dam (RK 171.5). Other areas surveyed included the following (from the river mouths):

1) the Umatilla River to Three Mile Dam;
2) the Snake River to Hells Canyon Dam;
3) the Clearwater River to the south fork of the Clearwater River (RK 120.2);
4) the lower Grande Ronde River to Troy (RK 72.9);
5) the lower Salmon River to the town of Riggins (approximately RK 139);
6) the lower Imnaha River to above Cow Creek (RK 6.1);
7) the lower Tucannon River to Marengo Bridge (RK 39.9);
8) the Palouse River to Palouse Falls (approximately RK 11); and
9) occasionally along portions of the Walla and Touchet Rivers (for steelhead and salmon). We attempted to conduct aerial telemetry surveys of the lower Snake and Columbia Rivers at least every two weeks from 16 September until 6 December 1993.

Recaptures and Recoveries

We captured tagged salmon at the LGR trap to verify passage at the dam, to examine the condition of the fish, and determine presence or absence of the radio transmitter. In 199 l-92, adult salmonids returning downstream were occasionally captured and examined at the juvenile fish bypass separators at LMO, LGO, and LGR by WDFW's, ICFWRU's, NMFS', or Corps of Engineers' personnel. Adult and jack fall chinook salmon were counted, but not examined at the bypass facilities in 1993.

We recaptured radio tagged salmon as voluntary returns at Lyons Ferry Hatchery on the Snake River (RK 95. 1), at Priest Rapids Fish Hatchery (RK 635.6) immediately below Priest Rapids Dam on the Columbia River, and Dworshak Fish Hatchery (RK 65.1) on the Cleat-water River in 1993. We also recovered tags or fish from near Three Mile Dam in the Umatilla River. We searched for salmon carcasses with radio tags during spawning surveys along the lower Tucannon and Palouse Rivers (Mendel et al. 1994a), and along the Hanford Reach of the Columbia River (L. LaVoy, WDFW, personal communication). Additional recoveries came from carcass recovery efforts above Lower Granite Reservoir (Blankenship 1996) in the Snake, Clearwater, and Grande Ronde Rivers. Recoveries from the public occurred in the Columbia, Snake, and Clearwater Rivers.

Data Analysis

We encountered a minor problem with data analysis concerning the transmitter code set in 1993. Transmitters used by the ICFWRU in 1992 (separate code set) had a much longer life than expected and continued to be detected well into our 1993 fall tracking season. The software program in our receivers could be set to decipher either the 1992 or 1993 code sets, but some of our fall chinook transmitters had the same tag codes and frequencies that were used with spring chinook salmon earlier in the year. To determine which code was a fall chinook salmon, we compared the last location for the 1992 transmitters with our tagging date in the fall of 1993 for the same channel and code. We kept a list of the problem codes and corrected our data as necessary.

<u>Initial Movements</u>

Initial movements of salmon after tagging were compiled into four categories in 1993:

1) no data;
2) fall back before passing upstream of the next dam;
3) neither fall back or movement upstream of the next dam; and
4) movement past the next dam upstream.

Initial passage at a dam or entry into Lyons Ferry Hatchery or the Tucannon River did not include previous fall back at a dam.

Dam Passage and Fall back

We determined that a radio tagged salmon passed a dam only if we could confirm passage with relocations upstream of the dam. Passage determination at LGR Dam was an exception. For the three years of this study we used recaptures or passage of radio tagged salmon at the adult trap half way up the fish ladder at LGR to indicate dam passage because of incomplete, or confusing data from the antenna at the top of the ladder. Use of the adult trap to determine passage causes some confusion as well. For example, when the adult trap at LGR is dewatered and the recovery area is "flushed," fish in the ladder just above the trap can be washed down a pipe to exit below the dam without actually crossing the dam or actively falling back.

We categorized radio tagged salmon as falling back at a dam if we have determined passage at the dam prior to strong detections downstream of the dam. In some cases, these fish apparently were flushed downstream of LGR dam at the adult fish trap. Consequently, if fish either fell back at Snake River dams or were flushed at LGR, they were relocated to the tailrace without having been subtracted from counts of fish passing upstream through the fish ladder at that dam.

Dam Passage Time

We calculated the number of days to pass a dam (elapsed passage time) with two different methods. Both methods estimate elapsed passage time based on different criteria than for our dam passage and fall back determinations described in the previous section. We modified our criteria for these calculations so our results would be more comparable to results reported for steelhead and salmon by Bjorrm et al. (1995) and Stuehrenberg et al. (1994).

The first method provides a rough estimate of passage times based on whole days. This method was used to compare passage times from 1992 and 1993. The small number of fish that could be used for elapsed passage time determinations in 1992 precluded a more detailed analysis. Passage times were estimated as the difference between the first date each fish was detected by any tailrace antenna at a dam, or by mobile tracking in the tailrace, (uninterrupted by relocations elsewhere or fall back) until the last date the fish was detected by the fixed-site receiver at the top of the ladder. This method does not include extended movements away from the dams. We included fish that apparently crossed LGR with no upstream verification, and fish last located at the top of a fish ladder, but without subsequent detections elsewhere. Note that we did not require detection at the lower tailwater site. All passage required detections at the top of the fish ladders, even at LGR (not just to the trap).

We also calculated elapsed passage time (in hours and minutes) for fall chinook salmon in 1993 with the method used by Bjomn et al. (1995) for spring chinook salmon and steelhead. That method includes the time a fish first left the downstream tailwater receiver (site 1) and the time of last detection at the top of the ladder, which includes searching or wandering away from the tailrace area (Joel Hunt, UI, personal communication). Both the first and last detections had to be confirmed in order for a fish to be included in elapsed time calculations. Mobile tracking data are not used in their estimates of migration rate (Joel Hunt, UI, personal communications). Stuehrenberg et al. (1994) used similar methods at upper Columbia River dams in 1993. However, they used the first detection at the face of the dam, not at the tailwater site downstream, to begin the calculation of elapsed time to pass a dam.

Migration Rate

In 1993, we documented the amount of time involved with migration through the reservoirs from one dam to another in the lower Snake River to compare with travel times and rates for other chinook salmon in the Snake (Bjornn et al. 1995) and in the upper Columbia Rivers (Stuehrenberg et al. 1994). We limited our comparison to 1993 because all three studies were conducted that year and our sample sizes were relatively small in previous years. Migration rate calculation consisted of elapsed time from the last detection at the top of the ladder to the first detection at the lower tailwater site at the next dam upstream. Fall back and recrossing dams is included because Bjornn et al. (1995) and Stuehrenberg et al. (1994) used these criteria.

Potential Spawning

Data for salmon that remained in a general area ("holding") for nearly a week or more, between 15 October and 15 December, were examined to determine if the fish had possibly spawned. We examined holding duration with regard to information on fall back, flushing, final location of the fish and any recovery data. Female salmon in particular will likely move upstream to a spawning location, spawn, hold in that area until they die and drift downstream (Burger et al. 1985). Males may move extensively upstream or downstream after spawning. Thus, extensive upstream movements after holding suggest female salmon may not have spawned.

RESULTS and DISCUSSION

Salmon Tagged at Ice Harbor Dam

Tagging Efforts

We attempted to radio tag fall chinook salmon throughout the duration of the run (Fig. 2), but warm water temperatures limited our trapping and tagging in August and early September. Also, radio and spaghetti tagging of large numbers of steelhead by ICFWRU personnel occasionally precluded our trapping and tagging of fall chinook salmon because limited personnel and equipment were available, and disturbance in the fish ladder caused by removing steelhead for tagging kept salmon from entering the trap.

In 1993,200 fall chinook salmon were captured at IHR, radio tagged, and released at Charbonneau Park (CHAR), 2.2 krn upstream of IHR Darn (Appendix B). Tagging may have killed two fish. One of these fish was recovered by an angler at CHAR Marina two days after tagging. The fish was found well on shore and appeared to be in good condition, but it was not examined internally. The other fish was recovered in the Columbia River near the Snake River confluence 22 days after tagging. This fish had been dead several days prior to recovery. We are uncertain if both of these mortalities should be attributed to radio tagging. Additionally, two other fish that we did not radio tag died in transport to the tagging site in 1993.

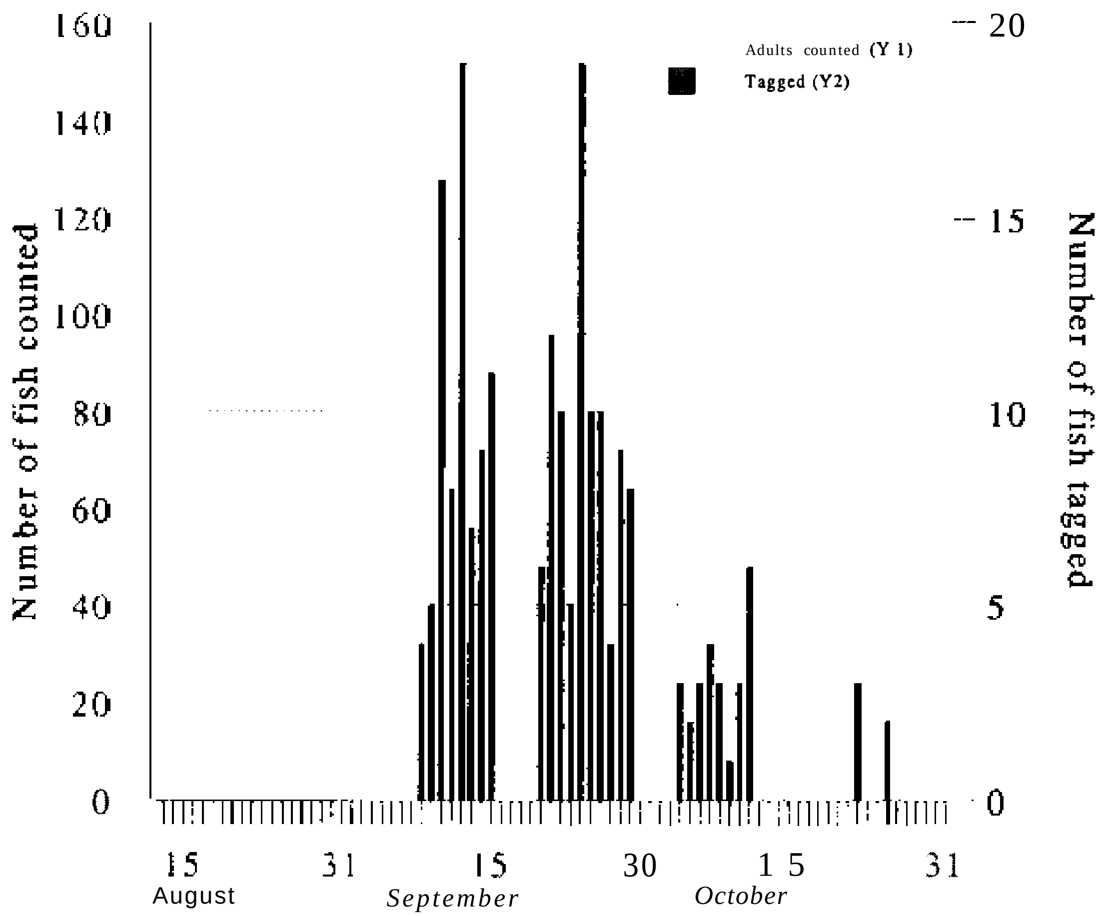


Figure 2. Fall chinook salmon run timing at Ice Harbor Dam compared with the number of fall chinook salmon radio tagged, 1993.

Radio Tracking and Initial Movements

We were able to relocate or recover 190 salmon (95%) away from the release site at CHAR in 1993 (Table 1). One fish was found dead at CHAR shortly after tagging. The extended duration of signal detection from nine transmitters (4.5%) at CHAR probably indicated regurgitated tags or dead fish. The loss of radio tagged fish in 1993 (5%) is similar to the 3.1 percent loss we experienced in 1992, but well below the 14.6 percent loss experienced in 1991 when our study area excluded the Yakima River.

Fifty-nine (3 1 .O%) of the fish relocated away from CHAR initially fell back at IHR Dam (Fig. 3). These fish include a carcass found in the Columbia River described above as a possible tagging mortality, and three fish that regurgitated their radios at CHAR but were later recovered in the Columbia or Umatilla Rivers. We assumed that these four fish fell back without crossing LMO Dam. Ten of the 12 fish that initially fell back reascended IHR and crossed LMO dam. Nine of these fish remained in the Snake River. The other three fish moved upstream to LGO before descending to the Columbia River in early November. Consequently, the net effect was that 50 fish fell back at IHR Dam at least once and remained outside the Snake River without having crossed LMO Dam.

Of the salmon relocated away from CHAR, 128 (67.4%) initially crossed LMO without previously falling back at IHR. Thirteen of these fish fell back at LMO without crossing LGO. Four fish that fell back at LMO reascended that dam after they had descended to the Columbia River. Later, one of these four fish entered Lyons Ferry Hatchery, while the other three fish moved upstream of LGO. Twenty-seven other fish entered Lyons Ferry Hatchery without crossing LGO Dam. Four fish were last located in the reservoir (two near Lyons Ferry Hatchery). Three fish entered and remained in the Tucannon River and one fish was last located at the top of the fish ladder at LGO. We cannot confirm that this fish actually crossed LGO Dam.

In 1993, 80 radio tagged salmon crossed LGO Dam without previously falling back at LMO or IHR Dams. Twelve salmon that initially passed LGO fell back without crossing LGR dam. Ten of these fish entered Lyons Ferry Hatchery. Two fish that had initially crossed LGO were last detected in either the tailwater of LGR or the forebay of LGO. Additionally, six fish that had fallen back at IHR and three that had fallen back at LMO crossed LGO dam. Two of these fish descended to the Tucannon River and one descended to the Yakima River. Therefore, 66 radio tagged salmon released from CHAR initially reached the adult trap in the fish ladder at LGR Dam without a previous fall back. Seventy-two total fish passed LGR including fish that had previously fallen back at downstream dams.

Table 1. Summary of initial[a] and other movements of radio tagged salmon between IHR and LGR Dams in 1993.

Number of fish with	Comments
200	Radio tagged at IHR.
-1	Found dead at CHAR.
- 9	No data (last detected at CHAR).
190	**Total relocated or recovered away from CHAR.**
-59	Fell back at IHR (1 found dead in Col. R. and 3 fish recovered in Col/Umatilla R. had regurgitated transmitters at CHAR).
	12 fish reascended IHR Dam and 10 crossed LMO 9 of 12 remained in the Snake River.
	50 net fall backs (59-12+3 fell back again).
- 3	Ascended to LMO (last detected in ladder or tailrace).
128	**Initially crossed LMO Dam without previously falling back at IHR.**
	13 8 total across LMO (10 had reascended IHR).
--13	Fell back at LMO.
	4 reascended IHR and LMO (one into Lyons Ferry and three above LGO).
-27	Into Lyons Ferry Hatchery (LFH).
- 2	Last located near LFH.
-1	To LGO then descended to below LFH.
-1	To mouth of the Tucannon River.
-3	Into the Tucannon River.
- 1	Last located at top of ladder at LGO.
80	**Initially crossed LGO Dam without previous fall back.**
	6 Crossed LGO after fall back at IHR (one to Tucannon, five over LGR).
	3 Crossed LGO after fall back at LMO (one to Yakima R., one to Tucannon, one over LGR).
	89 total across LGO (9 had reascended).
-12	Fell back at LGO (10 entered LFH, one below LGO, one below LMO).
-1	Last detected below LGR (tailrace).
- 1	Up to LGR then last detected in LGO forebay.
66	**Initially crossed LGR without fall backs.**
	6 crossed LGR after fall backs at downstream dams (five at IHR and one at LMO).
	72 total across LGR.
-28	Fell back at LGR (plus three after prior fall back at a downstream dam).
	10 reascended.

[a] Initial movements do not include previous fall back at a dam.

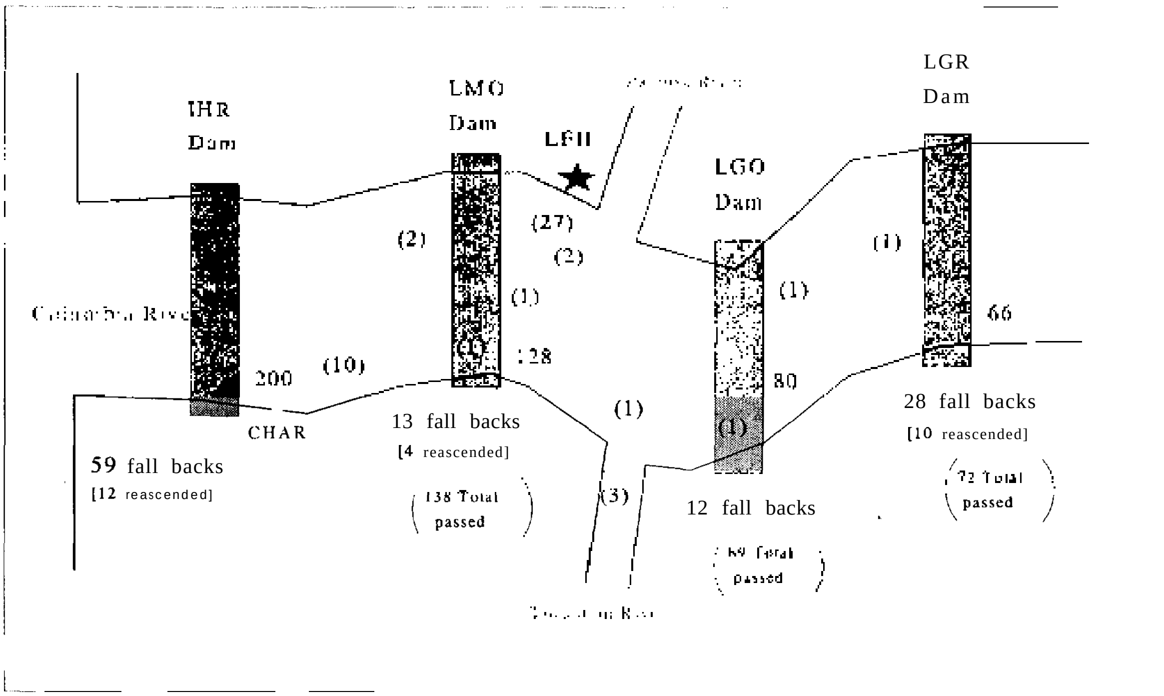


Figure 3. Initial movements of 200 radio tagged fall chinook salmon released near IHR Dam in the Snake River, 1993. Numbers in parentheses are fish that were "lost" in the reservoir, entered Lyons Ferry Hatchery (LFH), or entered the Tucannon River without crossing the next dam upstream (e.g., 128 fish initially crossed LMO Dam, 13 fish fell back and four were lost in the reservoir, three fish went into the Tucannon River, 27 fish went into LFH, and one was last located at the top of LGO ladder, so 80 fish initially crossed LGO Dam).

Four of the 72 salmon that passed LGR had regurgitated their transmitters shortly after tagging, and another fish was captured at LGR with the radio not activated. Four of these five were not relocated or recovered beyond the LGR trap. Four of the 72 salmon that crossed LGR were not detected in the fish ladder or recaptured at the adult trap. Some of these fish were last detected near the navigation locks below LGR and possibly locked upstream through the dam. Subsequent relocations upstream confirmed these fish had passed LGR Dam. Another salmon was not detected after reaching the top of the fish ladder at LGR. Twenty-eight fish fell back at LGR without a prior fall back at a downstream dam. Ten of these fish reascended. Three other fish that previously fell back at a downstream dam also fell back at LGR.

General Movements

As in the previous two years, radio tagged fall chinook salmon moved extensively downstream after passing IHR Dam. Approximately 3 1 percent (59 of 190) of the relocated tagged salmon from CHAR were found at some time outside the Snake River drainage (i.e., in the mid Columbia and its tributaries). Approximately 27 percent of the fish we tracked (52 of 190), and 83 percent (49 of 59) of the fish that initially returned to the Columbia River after tagging, did not cross LMO Dam (Figs. 4 and 5). Ten salmon that returned to the Columbia River also fell back at McNary Dam (Fig. 6); one of these fish apparently entered the John Day River before returning upstream to enter the Yakima River. Five other fish descended at least to the McNary Dam forebay. Eight fish moved upstream as far as LGO (including one fish upstream of LGR), without falling back at a dam, before returning downstream to the Columbia River (Figs. 7 & 8). The remaining six fish returned to the Columbia or Yakima Rivers before reentering, and remaining in, the Snake River (Fig 9). In 1992, 34 percent of the salmon we released at CHAR were found in the Columbia River, or elsewhere outside the Snake River Basin. We cannot provide a comparable estimate of the fish that left the Snake River- Basin in 199 1 because radio tagged fish were released downstream of IHR.

Many of the fall chinook salmon moved extensively upstream and downstream. As we noted in 1991 and 1992 (Mendel et al. 1992b, 1994), many tagged salmon in 1993 did not migrate directly upstream to their spawning location without at least some downstream movements, which often included fall backs and reascents. The locations of last detections for radio tagged fish provides a “snapshot” of their distribution. For example, 22 radio tagged salmon entered the Yakima River, but only 10 of these fish were last located there. Additionally, 30 fish were last located between McNary and Priest Rapids Dams, primarily in the Hanford Reach (4 fish entered Priest Rapids Hatchery). One of these 30 fish (23/17) went up the Columbia River as far up as Wanapum Dam, before descending to the Hanford Reach. Ten other fish were last located downstream of McNary Dam, including four fish in the Columbia River, one in the John Day River, and five in the Umatilla River. These relocation sites were similar to relocations in previous years, although in 1991 we did not search the Yakima River. We now suspect that many of our missing radio tagged fish that year might have been found in the Yakima River.

Movements of radio tagged salmon that entered Lyons Ferry Hatchery, or the Tucannon or Palouse Rivers, were similar.

Many fish moved back and forth between LMO Dam, Lyons Ferry and LGO Dam several times before entering the hatchery or a tributary stream.

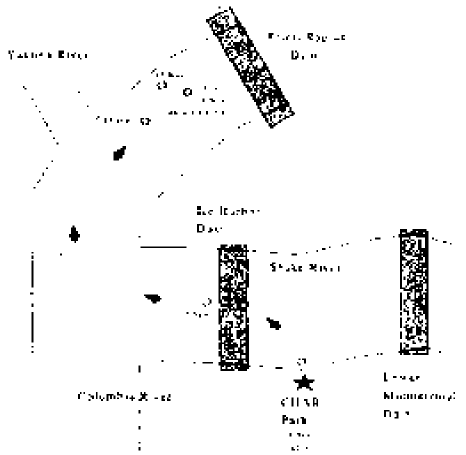


Figure 4. Movements of a salmon (22/80) that fell back immediately to the Hanford Reach to spawn (13 other fish had similar movements).

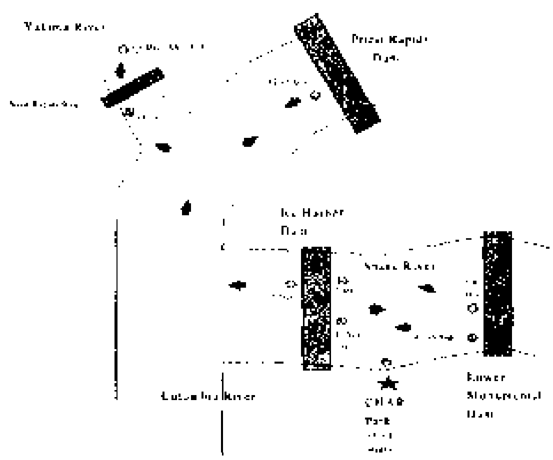


Figure 5. Movements of a salmon (23/1 0) that did not cross LMO Dam before falling back (generally represents 14 other fish).

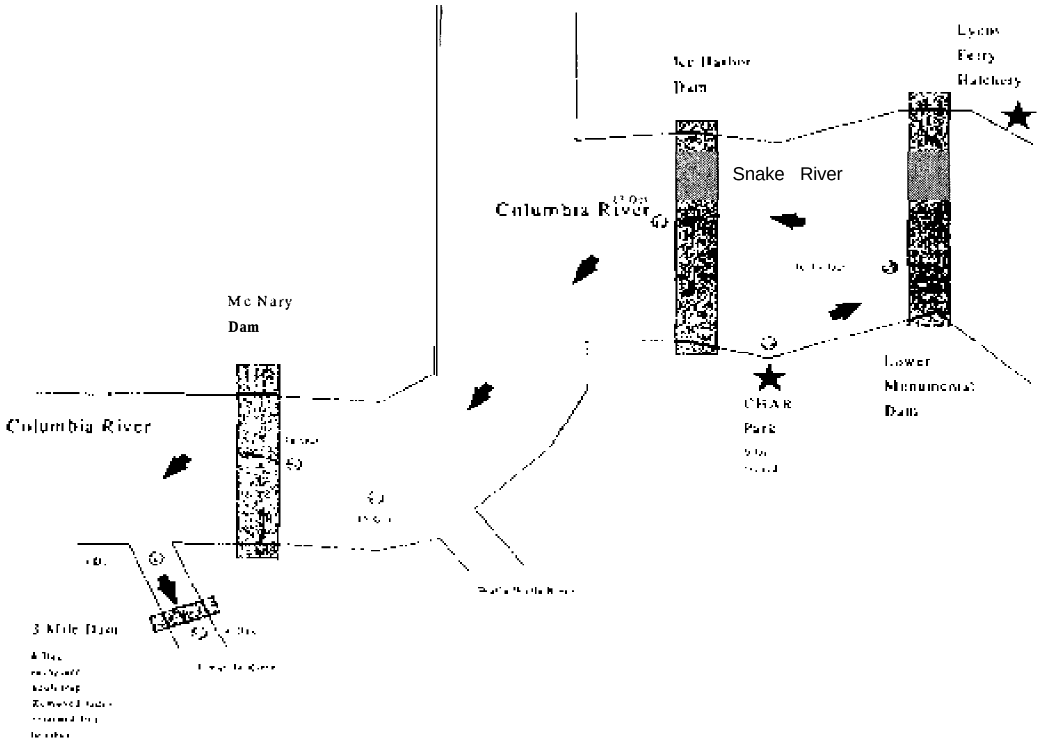


Figure 6. Movements of a salmon (23/93) that fell back downstream of McNary Dam without crossing upstream of LMO Dam (generally represents nine other fish).

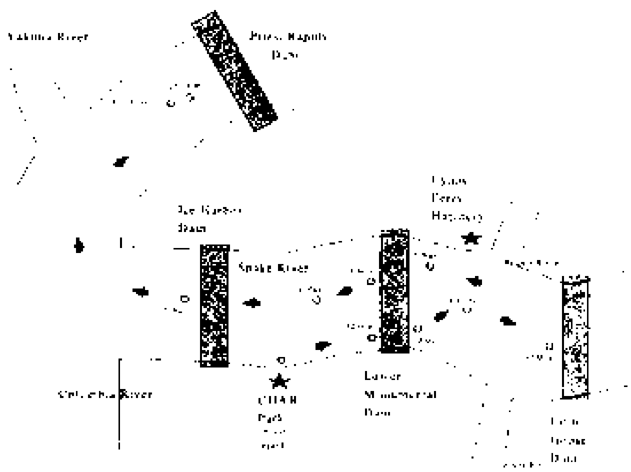


Figure 7. Movements of a salmon (22/53) that ascended the Snake River to LGO Dam before descending to the Columbia River (generally represents six other fish).

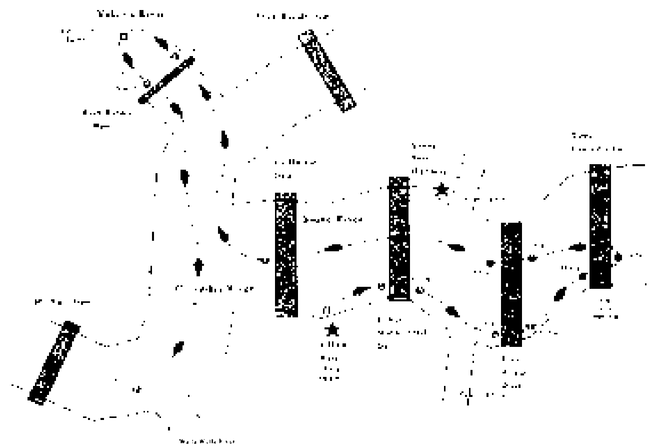


Figure 8. Movements of a salmon (23/90) that passed upstream of LGR Dam before descending to the Columbia and Yakima Rivers.

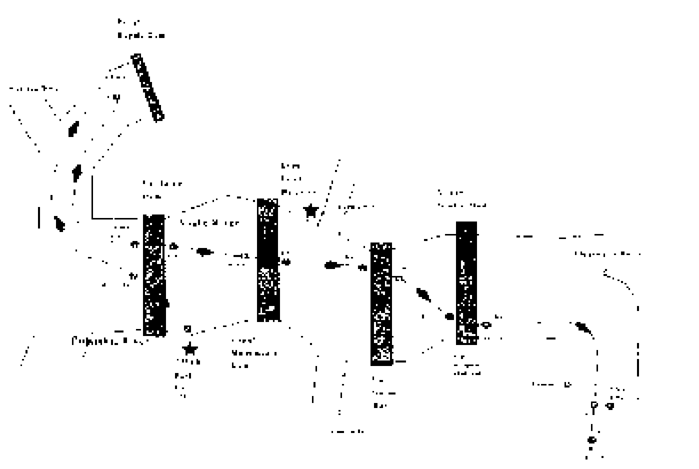


Figure 9. Movements of a salmon (24/7) that returned to the Columbia River before reentering, and remaining in the Snake River (generally represents five other fish).

Returns to Lyons Ferry Hatchery

Salmon that entered Lyons Ferry Hatchery generally passed upstream of the hatchery before entering. As in 199 1 and 1992, over 80 percent of the radio tagged salmon recovered at the hatchery in 1993 (36 of 43 fish tracked) were relocated as far upstream as LGO Dam before they entered the hatchery (Table 2, Fig. 10). Five fish appeared to enter the hatchery directly after passing LMO (Fig. 11). We could not follow three additional fish before recovery at the hatchery because they had regurgitated their radio transmitters at CHAR shortly after tagging. Twenty-four tagged fish entered Lyons Ferry Hatchery without crossing LGO first (excluding three with regurgitated transmitters), another ten fish passed LGO, and four fish crossed LGR before returning downstream and entering the hatchery (Table 2). Eight of the ten fish over LGO reached LGR before returning to the hatchery. One of these fish nearly reached the Grande Ronde River before returning downstream. Five other fish fell back below IHR then returned upstream to the hatchery. Four of these fish ascended to LGO, or upstream, before entering the hatchery. One other fish descended to the Columbia and Yakima Rivers before it reascended beyond LGR Dam, then returned downstream to the hatchery.

Table 2. General movements of 43 radio tagged fall chinook salmon before they entered Lyons Ferry Hatchery in 1993.

Unmarked or marked salmon[a]	Returned downstream of IHR[b]	Directly entered after LMO	Upstream to LGO	Upstream between LGO and LGR	Over LGR
Unmarked	4	4’	14	4	3
BWT	1		5	5	1
	—	1[d]		1[e]	—
Stray	5	5[f]	19	10	4

[a] Salmon with blank-wire tags (BWT) are from Lyons Ferry Hatchery. Strays are marked hatchery fish from elsewhere.

[b] Three unmarked and one BWT fish reascended to LGO or above (fish 24/23 over LGR) before entering the hatchery.

[c] Plus two fish that had regurgitated their transmitters at CHAR.

[d] Coded-wire tagged from Bonneville bypass study.

[e] This fish had a right ventral clip, presumably from Umatilla Hatchery.

[f] Plus one BWT fish that had regurgitated its transmitter at CHAR.

Thirteen radio tagged salmon that entered Lyons Ferry Hatchery contained blank wire tags (BWT) in their snouts (signifying the 1989 brood that originated from that hatchery) when processed at the hatchery. One of these fish had regurgitated its transmitter at CHAR shortly after tagging. The movements for untagged and BWT tagged salmon that entered the hatchery appeared to be similar (Figs. 10 & 12). All the fish with B WTs that could be tracked (12 fish) had ascended the river to LGO or LGR before entering the hatchery. One of these fish passed upstream of LGR and then descended downstream of IHR, before returning to the hatchery.

Two additional fish were last relocated near Lyons Ferry Hatchery, but they did not enter. We have tracked fish each year that remained for extended periods near the hatchery without entering. These observations are similar to those of Bjornn et al. (1992) for radio tagged spring chinook near other hatcheries in the Snake River Basin. The apparent searching by fish before entry into Lyons Ferry Hatchery, and the annual observations that some fish do not enter the hatchery, suggest the hatchery. attraction flows may be inadequate for salmon to easily locate and enter the facility.

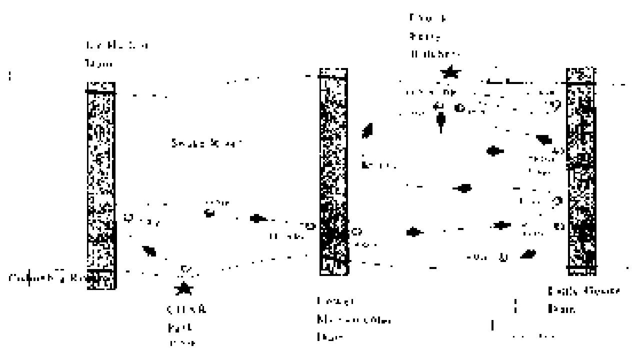


Figure 10. An example (22/57) of movements of salmon that reached LGO Dam before returning to enter Lyons Ferry Hatchery (generally represents 13 other fish).

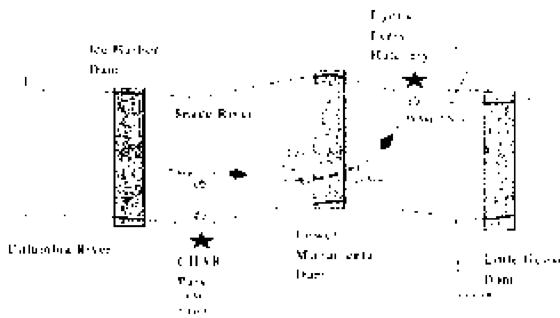


Figure 11. Movements of a salmon (22/3) that appeared to enter Lyons Ferry Hatchery directly after passing LMO Dam (represents four other fish and possibly three fish that regurgitated transmitters at CHAR).

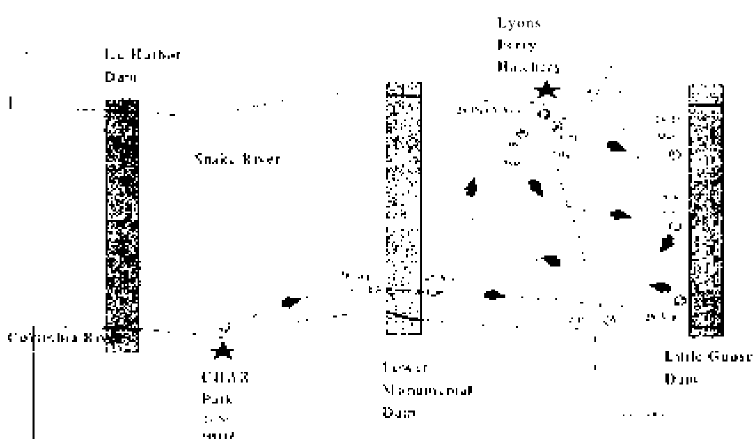


Figure 12. Movements of a BWT salmon (22/62) that entered Lyons Ferry Hatchery (generally represents 10 other fish).

Returns to the Tucannon or Palouse Rivers

Radio tagged salmon that entered the Tucannon and Palouse Rivers appeared to wander or search between LMO and LGO Dams. These movements are similar to those exhibited by salmon that entered Lyons Ferry Hatchery. Fish often entered these rivers before they were captured at Lyons Ferry Hatchery.

Eleven radio tagged fish entered the Tucannon River in 1993. Five of these fish had not previously passed upstream of LGR while six had (Figs. 13 & 14). Two of these eleven fish had also moved downstream of IHR before entering the Tucannon River. The presence of spawning salmon from Lyons Ferry Hatchery (with C WTs or B WTs) has been documented in the Tucannon River (Bugert et al. 1991, Mendel et al. 1994a).

We tracked two fish into the Palouse River in 1993. One of these fish later entered Lyons Ferry Hatchery. The other fish had been upstream of LGR before returning downstream to the LMO forebay (Fig. 14). It then entered the Palouse River almost to Palouse Falls before moving to the Tucannon River, where it apparently spawned.

Passage and Migration Rates

Although not one of our original objectives, we evaluated elapsed time for passage at Snake River dams and reservoir travel times for fall chinook salmon. Radio tagged fall chinook salmon crossed three of the lower Snake River dams at similar rates in 1993. The passage rate across IHR was not evaluated because all fish in 1993 were released above IHR Dam at CHAR. Passage time at IHR Dam was estimated in 1992 using fish tagged and released at Hood Park below IHR. However, that passage estimate may be biased because those fish had already crossed IHR Dam when they were captured for tagging. Our interest is in initial passage duration by naive fish, not elapsed time for recrossing a dam. Fish may react differently while passing a dam the second time.

Average passage times in 1993 were 2.5 days at LMO Dam, 2.3 days at LGO Dam, and 2.7 days at LGR Dam. We reevaluated the 1992 data using only salmon tagged and released at CHAR for a direct comparison with our 1993 results (Table 3 .).

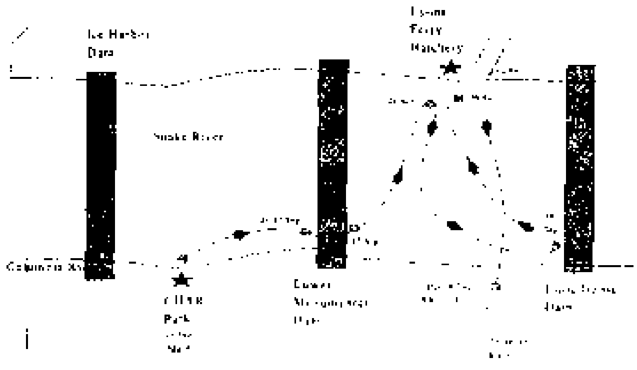


Figure 13. Movements of a salmon (22/29) that wandered between LMO and LGO before entering the Tucannon River (represents two other fish).

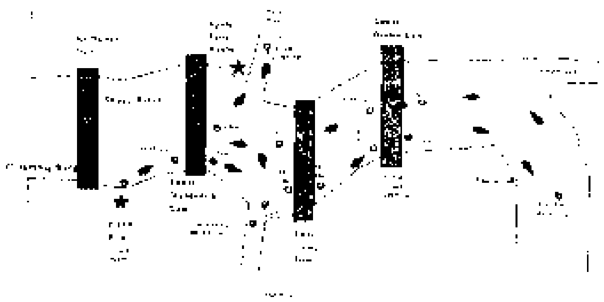


Figure 14. Movements of a salmon (23/88) that crossed LGR before returning downstream to enter the Tucannon River (represents four other fish).

Table 3. Comparison of initial dam passage duration in days (roughly estimated from whole days) for radio tagged fall chinook salmon released at CHAR, 1992 and 1993.

Year	Passage	LMO Dam	LGO Dam	LGR Dam
1992	median	2.0	2.0	2.0
	mean	3.3	2.9	2.9
	n	6	11	9
	SD	2.4	5.4	1.8
	range	1-7	1-19	1-7
1993”	median	2.0	2.0	2.0
	mean	2.5	2.3	2.7
	n	128	80	61
	SD	1.9	1.7	2.0
	range	l-l 1	l-9	1-14

[a] Includes one fish that may have fallen back at LGR and recrossed, plus three other fish that were last detected at the top of the fish ladders.

We also analyzed our 1993 data to determine elapsed passage time using the method described by Bjornn et al. (1995) which included distant movements away from the dam and detection at the lower tailwater site (Table 4). Estimates were made in hours and minutes from the downstream receiver to the upstream receiver at the exit of the ladder, similar to those of Bjomn et al. (1995) and Stuehrenberg et al. (1994). Comparisons of data collected in 1993 from our study and the studies by Bjornn et al. (1995) and Stuehrenberg et al. (1994) show fall chinook took slightly longer to pass Snake River dams than fall chinook passing dams in the Columbia River upstream of Priest Rapids Dam or for spring/summer chinook salmon to pass Snake River dams.

Table 4. Elapsed time in days (converted from hrs, minutes and seconds) for fall chinook salmon to pass Snake River dams in 1993 (using the method of Bjornn et al. 1995).

Passage	LMO	LGO	LGR
median	0.99	1.08	1.97
mean	2.31	4.74	2.28
n	75	63	28
SD	3.64	8.57	1.75
range	0.3-24.9	0.1-51.7	0.3-8.4

We believe that the full amount of time a fish spent near a particular dam (Table 3) may be a better measure of fish passage time at lower Snake River dams than elapsed time from the downstream antenna to the top of the ladder (with extensive movements away from the dam included). We documented that fall chinook salmon in the Snake River often made extensive downstream movements after reaching or passing a Snake River dam. We do not believe these movements are necessarily related to dam passage but may reflect wandering.

Fall chinook in the Snake River appear to take much longer to migrate through the reservoirs than spring chinook salmon (Table 5) or steelhead (median of 0.3-1.0 days, Bjornn et al. 1995). However, fall chinook in the Snake River migrate faster than fall chinook between Priest Rapids (PR), Wanapum (WAN) and Rock Island (RI) Dams (Stuehrenberg et al. 1994). We documented more wandering and fall backs for fall chinook than Bjornn et al. (1994, 1995) reported for spring/summer chinook salmon in the Snake River. Only one of our radio tagged fall chinook fell back in these calculations. This fall chinook salmon fell back at two dams and took over 38 days from LMO to LGO dam. We suspect that fall chinook salmon in the Snake River wander the mainstem river more than spring chinook or steelhead because fall chinook are destined to spawn in mainstem rivers or lower portions of large tributaries while spring chinook and steelhead migrate directly through the mainstem to spawn in smaller tributaries.

Table 5. Fall chinook salmon travel times in days (converted from hr., min. and sec) from the exit of one dam to the tailrace of the next based on radio telemetry in the Snake and Columbia Rivers, 1993.

		Fall chinook[a]		Spring chinook[b]		Fall chinook[c]	
		LMO-LGO	LGO-LGR	LMO-LGO	LGO-LGR	PR-WAN	WAN-RI
number of fish		97	37	295	274	19	23
range		0.3-38.7	0.7-5.5	-		0.7-12.0	0.5-24.9
median	(days)	1.33	1.05	0.8	0.9	2.6	1.5
	(km/d)	(34.7)	(57.0)	(60.1)	(65.3)	(11.3)	(40.3)
mean	(days)	3.07	1.45	0.9	1.0	--	--
	(km/d)	(15.0)	(41.3)	(50.3)	(59.5)	--	--
SD	(days)	5.23	1.01	0.65	0.40	--	--

[a] This study using methods of Bjomn et al. (1995).

[b] Bjomn et al. 1995.

[c] Stuehrenberg et al. 1994.

Inter-dam Losses

The conventional method of estimating losses between IHR and LGR consists of subtracting the number of fish recovered at Lyons Ferry Hatchery, the fish estimated to have spawned in the Tucannon or Palouse Rivers, and the number of fish passing LGR, from the total number of salmon that passed IHR. If we simply apply this method to the group of salmon we radio tagged we obtain the following:

190 fish tracked (of 200 salmon tagged)
(13 8 fish over LMO; 27.4% loss from IHR to LMO)
- 46 fish that entered Lyons Ferry Hatchery
- 9 fish that possibly spawned in the Tucannon River
- 72 fish passed LGR
63 fish not accounted for (33%)

However, several fish were counted twice with this procedure. In 1993, five of the 46 radio tagged fish recovered at Lyons Ferry Hatchery had crossed LGR Dam before recovery, and thus were counted at both LGR and Lyons Ferry. Double counting also occurred with six fish accounted for as spawning in the Tucannon River. This method assumes that fish passed upstream of IHR or LGR remained upstream of those two dams. Therefore, fish were counted twice if they fell back at IHR or LGR, and then recrossed those dams.

In 1993, we applied the conventional accounting procedure to the 3,137 fall chinook salmon adults and jacks counted at IHR Dam (Corps of Engineers 1994). From that total we subtracted the following:

- 127 fish trapped at IHR and transported to Lyons Ferry Hatchery
- 871 voluntary returns to Lyons Ferry Hatchery
- 85 fish estimated to spawn in the Tucannon and Palouse Rivers, and
- 1,209 fish reaching LGR Dam (Mendel et al. 1994a).

Consequently, we were unable to account for 845 salmon (26.9%) after they passed IHR Dam. The proportion of fish unaccounted for between IHR and LGR in 1993 is much lower than the previous two years (Table 6). However, the proportion of the annual total fish loss between IHR and LGR that was not accounted for below LMO from 199 1 - 1993 remained relatively constant at about 3-6 percent. It is noteworthy that in 1993 the percentages of fish not accounted for between IHR and LMO Dams are similar from ladder counts (24%) or radio telemetry (27%).

In 1993, we requested that fish counts be extended through November at LMO Dam because in 1992 we had noticed that a high percentage of the total fish loss appeared to occur below LMO. We were unsure if this loss could be explained by fish crossing LMO after the usual count termination date of 3 1 October. Forty-four salmon crossed LMO in November 1993. The addition of these fish reduced the loss between IHR and LMO to 670 fish (22.2% of the fish over IHR).

Table 6. Fall chinook salmon losses between IHR and LGR that could not be accounted for at various points between those two dams, 1991-l 993.

Number of adults &jacks	1991	1992	1993
Passed IHR[a]	6,026	5,530	3,137
Trapped at IHR	432	327	127
Returned to Lyons Ferry	1,538	1,074	871
Spawned in the Tucannon/Palouse[b]	150	69	85
Passed LGR	1,027	957	1,209
Unaccounted for	2,879	3,103	845
(percent of total over IHR)	(47.8)	(56.1)	(26.9)
Over LMO [a]	3,245	2,493	2,296
Unaccounted for (IHR-LMO)”	2,349	2,710	714
(percent loss IHR-LMO)	(42.0)	(52.1)	(23.7)

[a] Fish counts at the ladder through 3 1 October.
[b] Estimate from redd counts.
[c] Excluding fish trapped and transported to Lyons Ferry Hatchery.

We re–examined our 1993 radio telemetry data to account for each radio tagged fall chinook salmon (190 total) between IHR Dam and LGR Dam to determine the cause of disparities between salmon counts at these dams. We documented that 72 salmon could not be accounted for with the conventional dam count method (37.9%) instead of the 32.6 percent obtained by simply grouping the radio tagged fish. Radio tracking data revealed that 60 of 72 (83.3%) tagged salmon that were unaccounted for had fallen back at IHR Dam and remained below the dam for their final locations. None of these 60 fish crossed LGR Dam. The remaining 12 radio tagged fish were last located in the reservoirs downstream of LGR. The 83 percent portion of the loss that can be accounted for by fall back at IHR is more than the 62 percent we attributed to fall back from our radio telemetry study in 1992. The difference between the two years may be partially due to more complete tracking data and a larger sample size in 1993. The high rate of fish loss documented from fish counts at IHR and LMO Dams in 1991-1993, and the similar percentages of loss estimated by fish counts or radio telemetry, in 1993 support the results of our radio telemetry study. Both radio telemetry and fish counts suggest that the high fall back rate at IHR Dam accounts for most of the total losses between IHR and LGR Dams.

Salmon Tagged at Lower Granite Dam

Fish Movements

By our definition, we considered the 20 salmon radio tagged at the adult trap as having crossed the dam after being released into the ladder. One fish was last detected at the top of the fish ladder. Seventeen of the 19 fish we were able to track were relocated upstream of LGR Dam. Two fish fell back shortly after tagging and were not detected again.

In 1993, five (26.3%) fish fell back at LGR Dam an average of 19.2 days after tagging (SD = 17.2, range 7-43 days). Three of those fish were last detected below LGR Dam, but two others recrossed LGR and apparently spawned in the Clearwater and Snake Rivers (downstream of the Grande Ronde River). None of the fish tagged at LGR in 1993 fell back more than once at LGR Dam or were relocated downstream of LGO.

Fourteen fish radio tagged at LGR Dam remained above that dam throughout the tracking season. One salmon tagged in early November remained in the lower reservoir where it was last located in mid-November. Another radio tagged fish was relocated in the Clearwater River (RK 7.6) on 27-30 September. Nearly seven hours later on 30 September it was last relocated approximately 22 km downstream in Lower Granite Reservoir near Alpowa. Two other fish were last detected near Asotin in late September and late October. One fish was last found in the lower Grande Ronde River in early October. We do not know the fate of these fish because we had limited tracking data for them. We either cannot verify these fish were alive, or they were not in likely spawning areas, during the fall chinook spawning season (25 October-12 December). The remaining nine fish may have spawned upstream of LGR Dam as follows: two fish in the Clearwater River, one in the Salmon or upper Snake Rivers, and six in the Snake River between Asotin and the Salmon River.

Radio Tagged Salmon Released at IHR and LGR Dams

We combined salmon radio tagged at IHR (68 fish excluding four that had regurgitated transmitters) and LGR (20 fish) Dams to assess fish losses, fall back, and to identify likely spawning locations upstream of LGR (Figure 15).

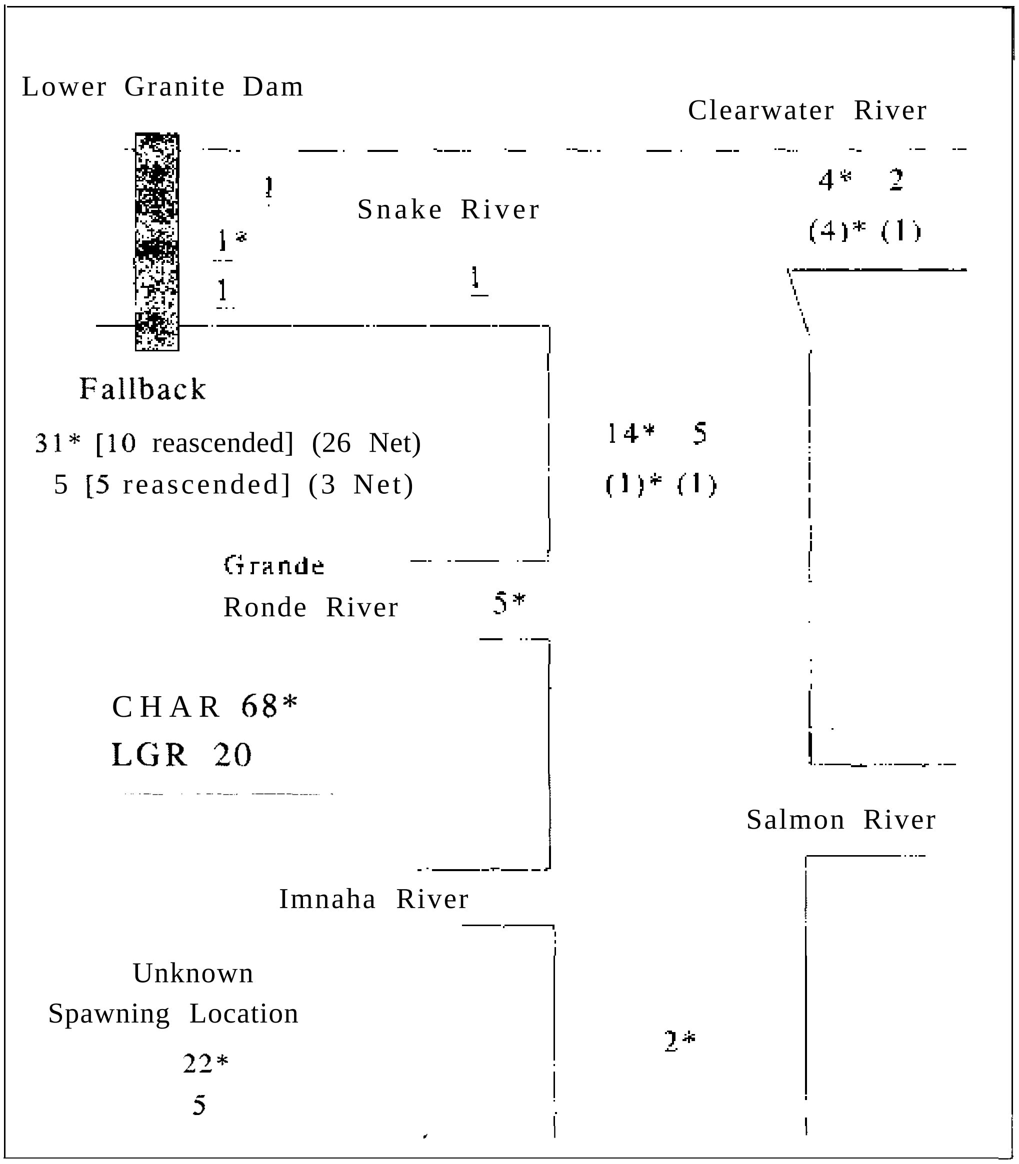


Figure 15. Fall backs, likely pre-spawning mortalities (underlined), and spawning distribution of radio tagged fall chinook salmon upstream of LGR Dam in 1993. Sixty-eight salmon were tagged at IHR (numbers followed by asterisk) and 20 were tagged at LGR. Numbers in parenthesis are fish that apparently spawned after falling back at LGR and reascending.

Fall Back at Dams

We tried to be conservative in our determination of whether a fish passed a dam and subsequently fell back downstream of that dam. Except at LGR Dam where fish pass through an adult trap, we required an upstream relocation to confirm upstream passage and fall back. We ignored apparent passage by six fish at LMO and LGO Dams because of a lack of upstream relocations.

Radio tagged fall chinook salmon commonly fell back at lower Snake River dams during 1993 (Table 7). We also documented fall back at dams in the Columbia (at McNary and Priest Rapids Dams) and in the Yakima River (at Horn Rapids Dam). In 1993, Stuehrenberg et al. (1994) documented fall back rates of 5-21 percent for fall chinook salmon at dams in the mid-Columbia River upstream of McNary Dam. Bjornn et al. (1995) reported a fall back rate of only 5 percent for spring chinook salmon in the Snake River in 1993. Our results for 1993 are similar to results we obtained in 1991 and 1992.

Many fish fell back at more than one dam during 1993 and some fish fell back at all four Snake River dams. No radio tagged salmon fell back at any one Snake River dam more than twice. We documented 12 multiple fall backs by 10 different fish. Five fish fell back twice at IHR Dam, one of which also fell back twice at LMO Dam. Another fish fell back twice at LGO and LGR Dams, plus once each at LMO and IHR. Four salmon (Fig. 16) fell back twice each at LGR Dam. Overall, we documented 180 total fall backs at Snake River dams by 112 different fish from the CHAR releases (58.9%), plus five fish tagged at LGR Dam fell back at that dam. Fall back rates were relatively constant, among dams and different dates.

Table 7. Summary of fall back events at lower Snake River dams by radio tagged fall chinook salmon, 1993. Data are presented to indicate those fall backs that occurred before spawning likely occurred (1 November).

	IHR	LMO	LGO	LGR	Total
Total number of fall backs	81	24	34	41	180
Number of fish[a]	(76)	(23)	(33)	(36)	(168)
Fall backs before 1 November	69	15	19	21	124
Number of fish	67	14	18	19	118
Rate (fall backs/fish)	1.0	1.1	1.1	1.1	1.0
Number of fall backs apparently survived	59 (86%)	12 (80%)	18 (95%)	17 (81%)	106 (85%)
Fall backs after 31 October	12	9	15	20	56
Number of fish	12[b]	9	15	19”	55
Rate (fall backs/fish)	1.0	1.0	1.0	1.1	1.1
Number of fall backs apparently survived	7 (58%)	2 (22%)	8 (53%)	11[de] (55%)	28[fg] (50%)

a In 1993, 117 individual salmon fell back at Snake River dams. This table includes five fish tagged at LGR. The breakdown for fall backs by LGR tagged salmon is as follows: four fall backs at LGR before 1 November (one survived and three unknown status) and one fall back at LGR after 3 1 October (survived). None of the fish tagged at LGR fell back at LGO.

b Three of these fish also fell back before 1 November (22/42, 23/7, 24/9).

c Three of these fish fell back before 1 November (22/70, 24/33, 22/59).

d Three of these fish were flushed below the dam without crossing the top of the ladder (22/1 1, 22/18, 24/23).

e Fish (22/68) was backing down the ladder after having crossed the dam when it was flushed downstream. Fish 23/91 fell back via the fish ladder.

f One of the fish (22/8) was flushed below the dam without crossing the top of the ladder.

g One of these fish also fell back before 1 November and survived (22/45).

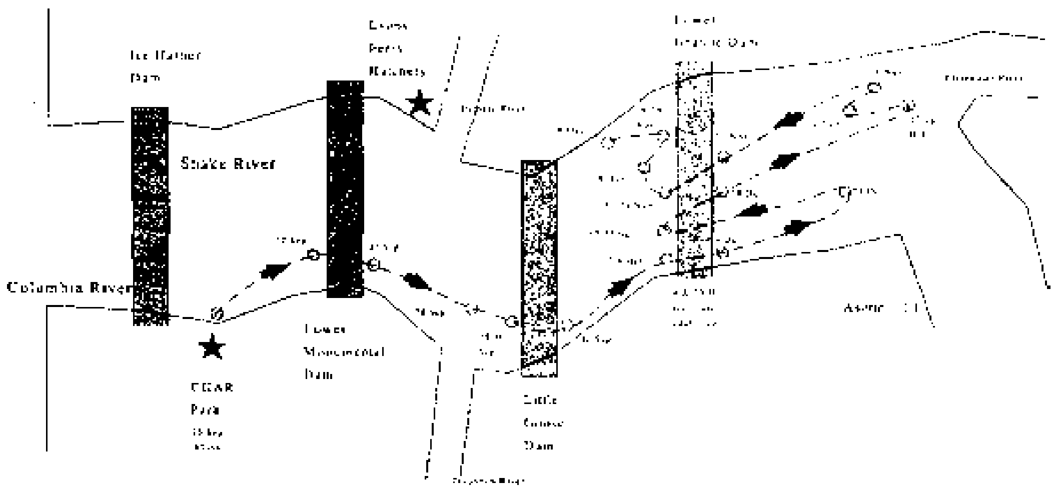


Figure 16. Movements of a salmon (22/70) that fell back twice at LGR Dam (represents three other fish; plotted locations across width of the river are for convenience only).

In 1993, 74.4 percent of radio tagged salmon apparently survived fall back at dams (134 of 180 total fall backs). Survival was at least 85.5 percent for fall backs before 1 November, and decreased to 50 percent after October (Table 7). In 1992, we documented minimum survival rates of 86.2 percent and 94.0 percent for total survival and before 1 November, respectively. These survival estimates should be used as minimum values based only on subsequent upstream movements or recapture of those fish after fall back. Radio tagged salmon may have survived additional fall backs but we do not have enough evidence to determine the fate of these fish.

Most fall backs (68.9%: 124 of 180) occurred before 1 November and the peak of spawning season in mid-November. Therefore, we believe that most of the fall backs occurred before these fish spawned. However, some fish that fell back at dams after October subsequently entered Lyons Ferry Hatchery and were spawned there (Fig. 17). Others apparently spawned and died in the Yakima River, or the Hanford Reach of the Columbia River, after fall back at dams in November (see Figs. 7 & 8). Only 3 1 .1% (56 of 180) of the fall backs at Snake River dams occurred after October.

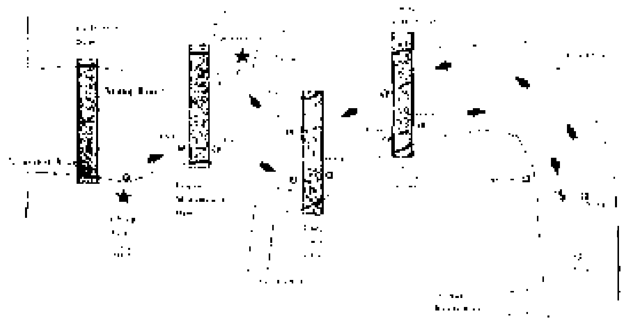


Figure 17. Movements of a salmon (24/37) that fell back at two dams in late October and November before entering Lyons Ferry Hatchery to spawn.

Unfortunately, we could not positively determine the routes of descent used by fall chinook salmon as they fell back at Snake River dams. Some salmon descended the fish ladders past fixed-site receivers and antennas, but the use of that route was limited. Water was not being spilled at any of the four dams from September through December, 1993, except on 1 September at IHR (3.3 kcfs - Corps of Engineers, 1994). Therefore, salmon could not have fallen back past dams via the spillways. A few salmon may have returned down river through the navigation locks, but we believe that most fish fell back through the turbine intakes. Fall back has been documented as relatively common in recent years for adult and jack fall chinook salmon and steelhead at juvenile bypass facilities at McNary Dam (Wagner 1991, Wagner and Hillson 1992), LMO, LGO, and LGR Dams (unpublished data from Corps of Engineers, NMFS, and ICFWRU). In 1993 for example, from 1 September - 1 November, 85 adult fall chinook salmon (8.5%) fell back through the juvenile bypass facility at LGR Dam of the 1,003 adults salmon passed upstream of the dam (Teri Barila, Corps of Engineers, personal communication). A few of our radio tagged salmon were observed falling back through juvenile bypass facilities at LGO or LGR Dams in 1991 and 1992, but none of our radio tagged fish were observed in 1993. Frequent observations of fall chinook in the juvenile bypass system support the conclusion that most fall chinook salmon fall back through the turbine intakes. Salmon are then either deflected into the juvenile bypass system or they pass through the turbine blades. Observations that fall back is relatively common for radio tagged and unmarked fall chinook salmon at juvenile bypass facilities supports our belief that movements of radio tagged salmon reflect movements of unmarked fish. , IHR Fall Back

Fall back has been shown to be relatively common for both marked and unmarked fall chinook salmon at IHR Dam from 199 1- 1993. We estimate from a detailed review of our telemetry data that 3 1 .O percent of the radio tagged fish (59/1 90 fish) we could track fell back at IHR without apparently spawning in the Snake River in 1993. The rate increases to 35 percent if we include all fish that fell back prior to 1 November as a quick estimate of fish that may not have been available to spawn in the Snake River. If we sum all fish that fell back through December without regard for whether they may have already spawned in the Snake River, the fall back rate increases 40 percent (76/1 90). In 1992 and 1993, 3 1.7 percent and 3 1 .O percent, respectively, of the fish released at CHAR initially fell back without crossing LMO Dam. In 1993 and 1992, approximately 27 percent and 37 percent, respectively, of the radio tagged fish never crossed LMO Dam.

We were concerned that the amount of fall back documented for radio tagged fall chinook at IHR Dam during the three years of this study could have been affected by our trapping and tagging activities at IHR. However, the large differences in fish counts at IHR and LMO (Table 7), the similar percentages of loss between these two dams in 1993 estimated by ladder counts and radio telemetry, and observations of adult fall chinook in juvenile bypass facilities, suggest that fall back of both radio tagged and untagged salmon was common at IHR Dam. During the three years of this study many unmarked hatchery fall chinook salmon from Lyons Ferry and Umatilla Hatcheries returned to the Snake River. Also, many unmarked hatchery fish returning to the Yakima may have entered the Snake River. Some of these unmarked hatchery fish may have been accidently incorporated into our radio telemetry study. Therefore, we suggest caution in applying our estimate of fall back at IHR Dam to other years. However, the fall back rates we documented for radio tagged salmon released at CHAR do not appear to be severely affected by tagging at IHR Dam. Radio tagged salmon had similar, or lower, fall back rates than the rates of loss documented from fish counts for unmarked salmon between IHR and LMO Dams (Table 7).

LGR Fall Back

Thirty-one radio tagged salmon from CHAR fell back at LGR Dam through December. Twenty-one of these fish remained below the dam. They were relocated at various downstream locations. Some of the fish subsequently entered Lyons Ferry (five fish) or the Tucannon River (three fish) to spawn. Most of the fish that fell back were last detected just below LGR, but some were detected as far downstream as below IHR Dam, and one fish descended to the Yakima River.

Ten of the fish that fell back, or were flushed below the dam, reascended the dam. Five of these fish later fell back again. One of five fish that fell back twice at LGR descended below IHR before reascending the river to enter Lyons Ferry Hatchery. Another two fish entered the Tucannon River, one of which previously ascended well into the Grande Ronde River. The other two fish remained below LGR after their second fall back. Thus, at LGR Dam net fall back rate for salmon radio tagged at CHAR was 38.8 percent (26 of 67 trackable or relocated fish). The net fall back rate for fish tagged at LGR was 15.8 percent (3 of 19 fish we could track) and combined net fall back was 33.7 percent. Total fall back rates, through December, for radio tagged salmon past the adult trap at LGR were 46.3 percent (3 1 of 67) for fish from IHR, and 26.3 percent for fish tagged at LGR Dam. However, detailed examination of telemetry data suggests that many of these fish had spawned before falling back at LGR. The appropriate fall back rates without spawning above LGR are 20.9 percent (14 of 67) and 10.5 percent (2 of 19) for salmon radio tagged at CHAR and LGR, respectively. The combined rate is 18.6 percent.

Four of the 3 I fish that fell back at LGR were apparently flushed below the dam from the adult trapping facility as they were not detected at the top of the ladder. One other fish was apparently flushed downstream of the dam as it descended the ladder. Another salmon fell back at LGR by descending the fish ladder after the trap had been removed for the season. Two additional fish may have been flushed from the ladder instead of falling back of their own volition. We documented other fish descending fish ladders at other Snake River dams in 1993. For example, four fish (CHAR) ascended the ladder to the top of LMO Dam then descended. These fish were not counted as crossing or falling back because they were not verified upstream of the dam.

<u>Fish Counts at Dams</u>

Overestimation of fish counts at dams has been suggested in the Columbia and Snake Rivers before this study. Bjornn et al. (1992, 1994, 1995) documented fall back of salmon and steelhead at Snake River dams, especially for steelhead. Stuehrenberg et al. (1994) discussed the need to adjust fish counts at upper Columbia River dams to reduce the upward bias associated with those counts. Monan and Liscom (1975) estimated 2.5 percent inflation of fall chinook salmon counts at Bonneville Dam due to fall back and reascent.

We compared the estimated fish counts of our radio tagged fish at IHR and LGR Dams with tracking and recovery results from our radio telemetry study for 1991-l 993. We could not determine the spawning date and location for each fish upstream of the dams. We did account for fish that fell back at LGR and remained downstream of that dam during the spawning season, and fish that descended after that date and apparently spawned at Lyons Ferry Hatchery, or in the Tucannon River. We assumed all radio tagged fish that passed upstream of IHR or LGR would have been enumerated at the fish counting windows. Fish that fall back through the fish ladder would be subtracted from fish passage, except at LGR where the fish trap blocked their descent to the counting window until late November when the trap was removed. A small portion of the fish that fell back reascended the dam (and presumably were recounted).

Determination of the number of fish available to spawn upstream of a particular dam is complicated by fall backs, reascents, erratic movements, and not knowing the fate of each fish (spawned, dead, lost, etc.). For the 190 radio tagged salmon we tracked from IHR in 1993, we estimate that 207 radio tagged fish would likely have been counted passing IHR Dam (because of

17 reascents). By subtracting or adding the fish that fell back or reascended the dam, we estimate that only 126 of the 190 tagged fish were likely available to spawn upstream of IHR Dam in 1993. Therefore, the fish count at IHR Dam may have overestimated the number of fish that could have spawned in the Snake River by approximately 64 percent (8 1/l 26 fish) in 1993 (Appendix D). For comparison, the net fall back for radio tagged salmon that may have spawned in the Snake River was 3 1 .O percent at IHR.

The number of available spawners was also apparently overestimated at LGR Dam in 1993. By adding reascents to fish counts and subtracting net fall backs during the season from fish above LGR, we estimate that 67.8 percent (59 fish remained of 99 radio tagged fish) more fish were counted than may have been available to spawn upstream of that dam in 1993. By refining that estimate with the assumption that fish spawned after 3 1 October, the over count estimate decreases to nearly 28.8 percent (77 fish remained after 3 1 October of 99 fish counted at the dam during the season). However, those simple estimates do not accurately reflect the availability of all fish to spawn upstream of the dam. For example, fish that fell back in early November and spawned at Lyons Ferry Hatchery or in the Tucannon River would be considered as possibly spawning upstream of LGR based solely on date of fall back. A detailed review of the radio telemetry data for each fish indicates that the dam counts overestimate the number of radio tagged fish available upstream of LGR by 3 1.4 percent (Table 8). This compares with a net fall back rate of 33.7 percent that may include some fish that probably fell back after spawning. Fall back accounted for 83.3 percent (15 of 18) and 90.9 percent (10 of 11) of the fish not accounted for (loss) during 1993 and 1992, respectively.

Table 8. Comparison of expected counts of radio tagged fall chinook salmon at LGR with their availability for spawning upstream of LGR (from review of telemetry data), 1993 and 1992.

Fish likely counted at LGR	Number of fish that likely spawned upstream of LGR
1993 LGR Tagged fish	
20 tagged fish	20 tagged fish passed
	-5 fell back (3 remained downstream)
+ 2 reascended[a]	+ 2 reascended and remained above LGR
22 total counted	17 fish may have spawned
CHAR Tagged fish	
68 tagged fish[b]	68 tagged fish passed
	17 fell back before 1 Nov.
	-8 fell back (2 Tuc., 2 LFH)[c]
+4	± 4 fell back and reascended
	- 4 fell back again (2 Tuc., 1 LFH)[c]
+5	± 5 fell back, reascended, remained above
	14 fell back after 31 October
	-3 fell back after 31 October (1 Tuc., 2 LFH to spawn)[c]
-1 ladder fall back	
+ 1 reascended	±1 fell back, reascended, remained above
77 total counted	53 fish may have spawned
Combined Total = 29.3% over count (99/70 available).	
1992 LGR Tagged fish	
20 'tagged fish	20 tagged fish passed
	-4 fell back to Lyons Ferry
	-1 dead in October in Clearwater R.
	-1 fell back to the Tucannon River
+1 reascended[a]	±1 fell back and reascended
21	14 fish may have spawned
CHAR (11) & HPK (6) Tagged fish	
17 tagged fish	17 tagged fish passed
	-3 fell back to Lyons Ferry
	-2 fell back before mid October[d]
+ 2 reascended[d]	
19 total counted	12 fish may have spawned
Combined Total = 35.0% over count (40/26 available).	

[a] After falling back at LGR.

[b] A total of 72 radio tagged fish crossed, but only 68 were relocated.

[c] Tuc.= Tucannon River, LFH = Lyons Ferry Hatchery.

[d] Fish 1/46 fell back three times and may have spawned above LGR.

Similarly, the number of fall chinook salmon available to spawn upstream of LGR was overestimated in 1992 (Table 8) and 199 1. Seventeen radio tagged salmon released near IHR and 20 tagged at LGR passed upstream of LGR dam in 1992. However, two fish were counted passing LGR five times and only 26 fish remained upstream of the dam. Therefore, fish counts at the dam in 1992 overestimated the actual number of radio tagged fish available to spawn by approximately 53.8 percent. In 1991, the number of radio tagged salmon available to spawn upstream of LGR may have been overestimated by 66.7 percent, based on only 15 salmon that could be tracked above LGR (Appendix E). Estimation of the error for the ladder count of salmon in 1991 should be used with caution because of the small number of radio tagged fish and insufficient tracking data that year.

Fish Losses and Spawning Unstream of LGR Dam

It was difficult for us to determine pre-spawning mortalities. Some radio tagged fish were not detected upstream of LGR and we are unsure of the fate of these fish. One fish from CHAR and one fish tagged at LGR were last detected at the top of the fish ladder at LGR Dam. One other fish did not move upstream of the lower portion of the reservoir before its last detection in November. One additional fish moved upstream a short distance into the Clearwater River, but it returned to the reservoir in early November where it was last detected. This fish may have died naturally or it could have been a hooking mortality from the active steelhead fishery in the lower Clearwater River. If we assume all these fish died or did not spawn, the loss rate above LGR would be 4.5 percent (4 of 88 fish we could track). This estimate should be considered a minimum pre-spawning mortality rate.

We documented extensive movements of fish from the Snake River into the Cleat-water and Grande Ronde Rivers (Fig. 18). Some of these fish moved from one river to the other several times during the tracking season. Several salmon moved downstream from the Grande Ronde River and entered the Cleat-water River (Fig. 19). Some fish appeared to move relatively directly to their probable spawning locations (Fig. 20). One fish traveled a long distance into the Salmon River before returning to the Snake River. Because of these frequent, and sometimes extended forays into other rivers, we are uncertain where these particular fish spawned. Radio telemetry alone does not allow definitive determinations of whether fish spawned, or where. We assumed fish probably spawned if they were in a free flowing portion of a river, or the tailrace of a dam, for at least 5-7 days between 1 November and early December and did not subsequently move upriver. Some spawning has been documented in late October in the Snake River or its tributaries (Mendel et al. 1992a, Garcia et al. 1994), but for convenience, we selected 1 November as the date spawning began upstream of LGR. However, we cannot assume that all fish spawned where they had held for extended periods. We tracked salmon that were in favorable spawning areas for extended periods in November, but when they were subsequently recaptured at Lyons Ferry Hatchery they were still unspent.

We tracked 55 radio tagged salmon that may have spawned upstream of LGR. We could not assign probable spawning locations to 17 of these fish because of extensive movements and holding in more than one river, or because of limited tracking data. The remaining 38 fish were assigned likely spawning locations as follows: Snake River = 22, Clearwater River = 11, Grande Ronde River = 5. Aerial spawning surveys in 199 1 - 1993 confirmed the presence of redds in these areas. The presence of radio tagged fish made finding spawning areas easier in some cases.

Radio tagged salmon carcasses were recovered from spawning areas in the Snake and Grande Ronde Rivers (Blankenship 1994, 1996, Bill Arnsberg, NPT, personal communication). One radio tagged fish entered Dworshak Hatchery where it was examined and released. Unfortunately, the radio was missing and the jaw tag was misread, therefore we do not know which fish entered the hatchery.

We have documented high adult/redd ratios (7-14 adults/redd) upstream of LGR for many years (Bugert et al. 1991, Mendel et al. 1994). These high ratios partially prompted initiation of this radio telemetry study. The adult/redd ratio upstream of LGR Dam in 1993 was 6.3 (952 adult salmon/l 52 redds) from boat and aerial surveys. However, if we include 67 additional redds obtained from underwater observation (Garcia et al. 1994) the adult/redd ratio is 4.3 (Table 9). Thirty-five jack salmon may have spawned upstream of LGR. Adding these fish to the spawning population produces a fish/redd ratio of 4.5. By including the LGR over count rate of 3 1.4 percent and 4.5 percent for pre-spawning mortalities, the adult/redd, and fish/redd ratios in 1993, both become 3.0. Similar estimates for 1992 are 4.2 fish/redd and 3.8 adults/redd.

With improved techniques for counting redds upstream of LGR (Garcia et al. 1994, Groves 1993) and a more complete understanding of fall back and over counting of fish at LGR, we find that adult or fish/redd ratios for fall chinook upstream of LGR are in the 3-4 fish/redd range that is closer estimates from other salmon populations. Estimates of adult/redd or fish/redd ratios upstream of LGR prior to 1992 are probably too high because of inaccurate estimates of the number of fish available to spawn or the number of redds in the Snake River Basin upstream of LGR. We suggest these earlier adult/redd estimates be used with caution.

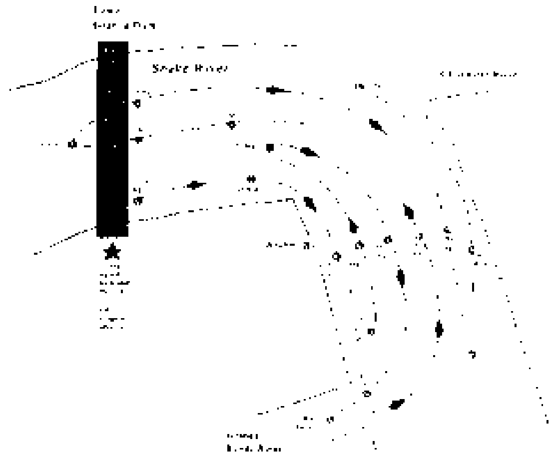


Figure 18. An example of movements of a salmon (24/96) both in the Snake and Grande Ronde Rivers.

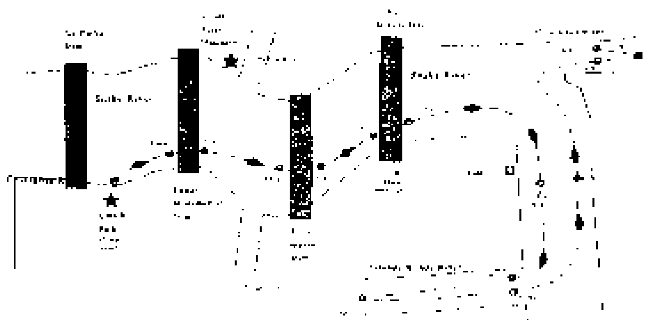


Figure 19. An example of a salmon (23/9) that moved from one river to another (Grande Ronde River to the Clearwater River) and could have potentially spawned in either river.

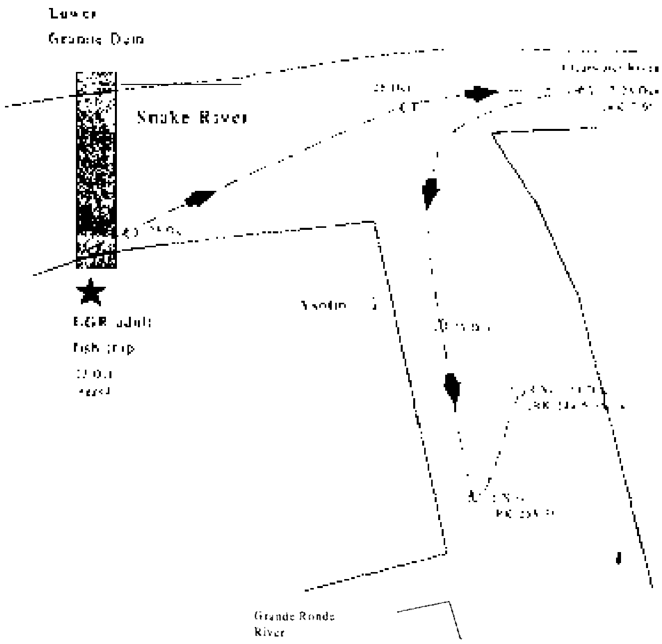


Figure 20. An example of a salmon (22/4) that moved relatively directly to its probable spawning location.

Tailrace Spawning

We attempted to use radio telemetry to determine whether fish spawned immediately downstream of the four lower Snake River dams during 199 1 - 1993. It has been commonly believed that the most likely location of spawning in the reservoirs would be in the tailrace areas downstream of the dams where the river has higher velocities than in the reservoirs. We noticed that many of our radio tagged salmon spent several days to a few weeks in tailwater areas (within two miles downstream of a dam) in the lower Snake River. However, subsequent movements of these fish were often either into the hatchery or upstream into typical spawning areas. Also, most extended holding in tailwaters of Lower Snake River dams during all three years was immediately after fall back at a dam. Although some of these fish may have spawned in the tailwaters of a dam, we think it is equally likely some may have died before spawning. In several instances the last detected location was in the tailrace area, or further downstream.

Table 9. Adults/redd and fish/redd estimates from fall chinook salmon counted at Lower Granite Dam, 1990- 1993.

		1993	1992	1991	1990
Adults counted at LGR		1,170	855	630	385
Adults trapped at LGR for Lyons Ferry		218	187	40	49
Jacks counted at LGR		39	102	397	190
Jacks trapped at LGR for Lyons Ferry		4	22	113	94
Past LGR dam	- adults	952	668	590	336
	-jacks	35	80	284	96
Redds from aerial or boat surveys	- Snake R.	60	47	41	37
	- in tributaries	92	35	8	8
Other Snake River redds[a]		67	0	5	
Adultslredd from aerial surveys only		6.3	8.1	12.0	7.5
Adults/redd (all redds)		4.3	8.1	10.9	7.5
Fish/redd (all redds)		4.5	9.1	16.2	9.6
Fish/redd adjusted for over count and loss[b]		3.0	4.2	---	---
Adults/redd (all redds) adjusted for over count and loss [b]		3.0	3.8	---	---

[a] This includes redds observed from deep water surveys using SCUBA or underwater cameras.

[b] Adjustments in 1993 were 3 1.4 percent for over count at the dam and 4.5 percent loss above the dam. Adjustments in 1992 were 53.8 percent over count and 8 percent loss.

Dauble et al. (1994) reviewed our preliminary data summaries and discussed individual fish that may have spawned in tailraces. We believe they erroneously reported some of our preliminary conclusions about which fish possibly spawned in tailrace areas. Also, we disagree with which fish they concluded may have spawned in tailraces. For fish that held for extended periods in tailwater areas during the three years of this study we believe there were insufficient data to draw any conclusions concerning spawning downstream of dams. Extensive, erratic fish movements, frequent fall backs, and present limitations of radio telemetry technology precluded us from determining whether salmon spawned in tailwater areas. However, we did document two fish holding during the spawning period at the juvenile bypass outfall at Lower Granite Dam in 1993. Several deep water redds were observed by underwater video and SCUBA searches in that area (Dauble et al. 1994).

Loss of Tags

We examined recaptures and recoveries of salmon that we had radio tagged in 1993 to determine tag loss. Lost or malfunctioning transmitters may have reduced our sample sizes for various analyses or caused us to misinterpret fish movements. Therefore, we summed all recoveries in 1993 from the following sources for 75 fish:

1) Priest Rapids and Lyons Ferry hatcheries;
2) LGR ladder and Umatilla River traps;
3) spawning surveys in the Hanford Reach, Umatilla, Snake, Tucannon, Cleat-water, and Grande Ronde Rivers; and
4) recoveries from the public.

Another 60 fish were recaptured, checked for tags, and released from traps at the LGR and Dworshak Fish Hatchery. Consequently, we evaluated 13.5 unique recoveries or recaptures for tag and radio retention. Jaw tag loss was 7.5 percent (10 of 133) and transmitter loss was 11 .1 percent (15 of 135). All transmitters were functioning upon recovery, except one that had not been activated when it was implanted. Two transmitters were recovered on shore, one above IHR and the other along the Tucannon River. The tag retention rates are acceptable for this study.

Hatchery Fish

The results of our radio telemetry study do not solely reflect the movements of naturally produced Snake River origin fall chinook salmon because we inadvertently radio tagged some marked and unmarked hatchery fish. Seventeen salmon that we radio tagged at IHR were found to contain wire tags when they were recovered. Five salmon with ventral fin clips at IHR, and one at LGR, were mistakenly radio tagged. Scale samples indicated 18 other fish we radio tagged at IHR were more than one year old (yearlings) when they left fresh water so they are presumed to be of hatchery origin. Scale samples that indicate fish migrated to the ocean as sub-yearlings could be from either hatchery or naturally produced fish. Many unmarked hatchery fish released as sub-yearlings or yearlings from both Lyons Ferry and Umatilla

Hatcheries returned to the Snake River in 1991-1993. Additionally, fish that were radio tagged at IHR could have been unmarked hatchery production from the Yakima or Columbia Rivers that "dipped in" to the Snake River.

We observed differences between movements of radio tagged salmon of hatchery origin and those of unknown origin (see Fig. 3 and Appendix F). Twenty-six of the forty hatchery salmon (65%) radio tagged at IHR entered Lyons Ferry Hatchery. Only 20 of the 150 (13.3%) salmon of unknown origin that we could track entered the hatchery. Known hatchery salmon had a net fall back rate at IHR of 20 percent, while 42.0 percent (63/150) of salmon of unknown origin fell back at that dam. Ladder counts of hatchery origin salmon at IHR over estimated the number of hatchery salmon available to spawn in the Snake River by 23.5 percent, and salmon of unknown origin by 79.3 percent (Appendix D). Differences between hatchery and unknown origin salmon were also present at LGR. Net fall back was 62.5 percent of the hatchery origin salmon from CHAR at LGR, with two fish each that subsequently spawned in the Tucannon River or at Lyons Ferry Hatchery. One other fish fell back to below LGR, but we doubt it spawned before falling back. Unknown origin fish had a 35 percent (21 of 60) net fall back rate, but detailed examination of telemetry data reveals that 83.3 percent (50 of 60) of these fish probably spawned upstream of LGR. Therefore, the net fall back rate is too high and is inappropriate to use in this case. Ladder counts at LGR overestimated hatchery fish from CHAR available to spawn upstream of LGR by 300 percent, and overestimated unknown origin fish by 30.0 percent.

CONCLUSIONS

Radio telemetry data for fall chinook salmon was often difficult to interpret and required careful examination. In many cases, the data were incomplete and we were unable to definitely determine passage or fall back at a dam, or the general location of spawning. We have attempted to be conservative in our interpretations of the data for determinations such as passage or fall back at a dam, etc. Radio telemetry did provide much new information regarding salmon movements and we were able to identify some probable causes of inter-dam losses. Jaw tag and transmitter loss or failure was about 10 percent or less, therefore sample sizes of marked fish remained relatively large in 1993.

Telemetry did not provide definitive information for determining spawning locations or the incidence of pre-spawning mortality. Detections of radio tagged- fish was helpful for identifying spawning sites upstream of LGR Dam. However, the occurrence of spawning in tailraces of Snake River dams could not be identified with radio telemetry. Fall chinook salmon movements in the Snake River are much too erratic to determine spawning locations based on fish holding downstream of a dam for a period of time. We identified many fish that remained stationary in the reservoirs for extended periods or vanished with no further detections. Many times these observations were made as fish passed a dam, or shortly after they fell back at a dam. We do not know the fate of these fish, although we suspect many of them died. The likelihood of radio malfunction or of fish escaping the area undetected was not supported from observations of recovered or recaptured radio tagged fish.

We believe that fall chinook salmon radio tagged in 1992- 1993 accurately represent the movements of the general run of fall chinook salmon into the Snake River. Our conclusions are supported by similar rates of fish “loss” between IHR and LMO, and from IHR to LGR Dams for radio tagged and untagged fall chinook salmon. The frequency of fall back of unmarked fall chinook at McNary, IHR, LGO, and LGR Dams reported by Wagner et al. (199 1, 1992), Corps of Engineers personnel and others, also supports our telemetry results. We have reservations about trapping and radio tagging at IHR Dam for assessing salmon passage behavior and passage duration at that dam. For example, we noted during 1991 and 1992 that dam passage for radio tagged salmon released downstream of the dam was prolonged at IHR Dam, relative to other Snake River darns. The fish evaluated for passage at IHR had negotiated the dam prior to tagging and should not be expected to represent the behavior of fish crossing the dam for the first time. Additionally, we cannot confirm that the proportion of radio tagged salmon that returned to the Columbia or Yakima Rivers represents salmon that were not captured and tagged. Although, we believe radio tagged fish do represent untagged salmon because ladder counts at dams suggests that a high proportion of salmon that were not radio tagged may have returned downstream after crossing IHR Dam in 1991-1993. Also, the percentage of loss between these two dams is similar in 1993 for both radio tagged salmon and total ladder counts. To adequately assess passage behavior and duration at IHR it may be necessary to capture, radio tag, and release salmon down river of IHR Dam (e.g., at McNary or John Day Dams). These radio tagged salmon would then be “naive” to IHR Dam and they could be expected to demonstrate natural behavior there.

Fall chinook in the Snake River do not migrate as fast through reservoirs as spring chinook salmon or steelhead, and fall chinook demonstrate much more fall back and reascent of dams. The differences in migration through the reservoirs may also be a reflection of their spawning destinations. Fall chinook remain in the mainstem Snake River or in lower portions of larger tributaries to spawn while spring chinook spawn in headwaters of tributaries.

Some of the most striking results of this study have been the extensive movements and interchange of fish among numerous rivers in the area. Fall chinook in this study generally did not simply move upstream to their spawning location without extensive upstream and downstream movements, or excursions into other rivers. The movements we documented for fall chinook salmon are radically different than the movements documented by Bjornn et al. (1995) for spring/summer chinook salmon or steelhead in the Snake River. Stuehrenberg et al. (1994) documented some wandering and fall back by fall chinook salmon in the mid Columbia River, but they did not document the extensive movements we commonly observed.

Our telemetry data suggest that fish may be unable to easily locate or enter Lyons Ferry Hatchery or the Tucannon River. Some fish wandered or searched extensively before entering the hatchery or adjacent tributaries. Therefore, fish that are unable to locate the hatchery may spawn in the nearby tributaries.

Although known hatchery salmon had different movements than unknown origin fish, we believe that results from the combined groups reflect the movements of the general fall chinook run in the Snake River during 199 1 - 1993. Many of the unknown origin fish were probably unmarked hatchery fish. A few may have been unmarked fish from Lyons Ferry Hatchery that were five years old in 1993, but the majority of the unmarked hatchery salmon were likely from the Umatilla or Yakima Rivers.

We determined that about 62 to 83 percent of the loss of radio tagged fall chinook between IHR and LGR was due to fall back at IHR Dam in 1992 and 1993, respectively. Fall back at dams was common for radio tagged salmon during all three years of this study and is reflected in differences in ladder counts between IHR and LMO Dams. Many of these fish were obviously alive after falling back at IHR because radio tagged fish apparently spawned in the Yakima River, or the Hanford Reach of the Columbia River after falling back at IHR. Additionally, we estimated that approximately 91 percent and 83 percent of the salmon that could not be accounted for upstream of LGR Dam fell back at that dam in 1992 and 1993, respectively. Net fall back at LGR Dam was estimated at 37.5 percent in 199 1, 3 5.1 percent in 1992, and 33.7 percent in 1993. These estimates probably include some fish that fell back after spawning. Fall back information provides us with some insight as to why the adult/redd ratios upstream of LGR Dam have been higher than expected in past years. By accounting for fall back and reascent at LGR, and improved redd survey methods (Garcia et al. 1994) the adult/redd ratios are reduced to approximately 3-4 adults/redd.

Most importantly, we find the counts of fall chinook salmon at IHR and LGR Dams apparently overestimated the actual number of fall chinook salmon that remained within the Snake River Basin because many salmon fell back and were recounted during reascents. Much of this population is federally listed as threatened under the Endangered Species Act. We estimate the error rates of the ladder counts at IHR and LGR were approximately 64 percent and 3 1 percent, respectively, in 1993. Uncorrected counts of salmon as they pass lower Snake River dams appear to provide unrealistically high estimates of fall chinook salmon that remain in the Snake River drainage to spawn. Therefore, the annual run size of fall chinook salmon is much less than fish counts at Snake River dams would lead us to believe.

REFERENCES

Bjornn, T., R. Ringe, K. Tolotti, P. Keniry, and J. Hunt. 1992. Migration of adult chinook and steelhead past dams and through reservoirs in the lower Snake River and into tributaries - 1991. Technical Report 92-2. To Walla District U.S. Army Corps of Engineers. Walla, WA

Bjornn, T. C., J. P. Hunt, K. R. Tolotti, P. J. Keniry, and R. R. Ringe. 1994. Migration of adult salmon and steelhead past dams and through reservoirs in the lower Snake River and into tributaries - 1992. Technical Report 94-l. To the Walla District U.S. Army Corps of Engineers. Walla, WA.

Bjornn, T.C., J. P. Hunt, K. R. Tolotti, P. J. Keniry, and R. R. Ringe. 1995. Migration of adult salmon and steelhead past dams and through reservoirs in the lower Snake River and into tributaries - 1993. Technical Report 95-l. To the Walla District U.S. Army Corps of Engineers. Walla, WA.

Blankenship, L. 1994. Stock identification of fall chinook salmon in the Snake River. *In* Blankenship, L., and G. Mendel, (Editors). 1994. Upstream passage, spawning, and stock identification of fall chinook salmon in the Snake River. Annual Rept. FY 92-93. To Bonneville Power Administration. Project No. 92-46. WA Department of Fisheries, Olympia, WA.

Blankenship, L. 1996. Stock identification of fall chinook salmon in the Snake River. *In* Blankenship, L. and G. Mendel, (Editors). 1996. Upstream passage, spawning, and stock identification of fall chinook salmon in the Snake River. Annual Rept. FY 93-94. To Bonneville Power Administration. Project No. 92-46. WA Department of Fish and Wildlife, Olympia, WA.

Bugert, R., C. Busack, G. Mendel, K. Petersen, D. Marbach, L. Ross, J. Dedloff. 1991. Lyons Ferry fall chinook salmon hatchery evaluation program. 1990 Progress Report to the U.S. Fish and Wildlife Service, Report # AFF 1/LSR-91-15. Wa Department of Fish and Wildlife, Olympia, WA.

Burger, C. V., R. L. Wilmot, and D. B. Wangaard. 1985. Comparison of spawning areas and times for two runs of chinook salmon (Onchorynchus tshawytscha) in the Kenai River, Alaska. Can. J. Fish. Aquat. Sci. 42: 693-700.

Connor, W. P., A. P. Garcia, A. H. Connor, R. H. Taylor, C. Eaton, D. Steele, R. Bowen, and R. D. Nelle. 1994. Fall chinook salmon spawning in free-flowing reaches of the Snake River. *In* Rondorf, D. and W. Miller, 1994. Identification of the spawning, rearing, and migration requirements of fall chinook salmon in the Columbia River Basin. Annual Rept. FY 91-92. to BPA. Project No. 91-029. U.S. FWS, Ahsahka, ID.

Corps of Engineers. 1994. Annual fish passage report, 1993, Columbia and Snake Rivers. North Pacific Division, US Army Corps of Engineers, Portland and Walla Districts.

Dauble, D.D., R. L. Johnson, R.P. Mueller, C. S. Abernethy, B. J. Evans, D. R. Geist. 1994. Identification of fall chinook salmon spawning sites near lower Snake River hydroelectric projects. Prepared for U. S. Army Corps of Engineers, Walla Walla, District, by Pacific NW Laboratory, Richland, WA.

Garcia, A. P., W. P. Connor, and R. H. Taylor. 1994. Fall chinook salmon spawning ground surveys in the Snake River. *In* Rondorf, D. and W. Miller, 1994. Identification of the spawning, rearing, and migration requirements of fall chinook salmon in the Columbia River Basin. Annual Rept. FY 91-92. to Bonneville Power Administration. Project No. 91-029. U.S. Fish and Wildlife Service, Ahsahka, ID.

Groves, P. 1993. Habitat available for, and used by, fall chinook salmon within the Hells Canyon Reach of the Snake River. Annual Progress Report, 1992. Environmental Affairs Department, Idaho Power Company, Boise, ID.

Mendel, G. K. Petersen, R. Bugert, D. Milks, L. Ross, J. Dedloff, L. LaVoy. 1992a. Lower Snake River Compensation Plan, Lyons Ferry fall chinook salmon hatchery program. 1991 Evaluation Report. Annual Rept. to the U.S. Fish and Wildlife Service, LSRCP Office, Boise, ID., Rept. No. AFF1/LSR/92-12. WA Department of Fisheries, Olympia, WA.

Mendel, G., D. Milks, R. Bugert, and K. Petersen. 1992b. Upstream passage and spawning of fall chinook salmon in the Snake River, 1991. Completion Report to the US Fish and Wildlife Service, LSRCP. Rept. No. AFF1/LSR/92-11. WA Department of Fisheries, Olympia, WA.

Mendel, G., J. Dedloff, L. Ross, R. Bugert, K. Petersen. 1992c. Fall chinook salmon trapping on the Snake River in 199 1. Annual Rept. to the US Fish and Wildlife Service, Lower Snake River Compensation Plan Office, 4696 Overland Rd., Rm. 560, Boise, ID., Rept. No. AFF 1/LSR/92-7. WA Department of Fisheries, Olympia, WA.

Mendel, G., L. Ross, R. Bugert. 1993a. Fall chinook salmon trapping on the Snake River in 1992. Annual Rept. to the U.S. FWS, LSRCP Office, Boise, ID., Cooperative Agreement No. 14- 16-000 l-92542. WA Department of Fisheries, Olympia.

Mendel, G., K. Petersen, R. Bugert, D. Milks, L. Ross, J. Dedloff, and J. Bumgarner. 1993b. Lyons Ferry fall chinook salmon hatchery evaluation program, 1992 Annual Report to

U.S. Fish and Wildlife Service, LSRCP Office, Boise, ID., Cooperative Agreement 14-16-0001-91534. WA Dept. of Fisheries, Olympia, WA.

Mendel et al. 1994. Upstream passage and spawning of fall chinook salmon in the Snake River, 1992. *In* Blankenship, L. and G. Mendel, (Editors). 1994. Upstream passage, spawning, and stock identification of fall chinook salmon in the Snake River. Annual Rept. FY 92-93. To Bonneville Power Administration. Project No. 92-46. WA Department of Fish and Wildlife, Olympia, WA.

Mendel et al. 1994a. Lower Snake River compensation plan, Lyons Ferry Hatchery evaluation program; fall chinook salmon, 1993 annual report to U.S. Fish and Wildlife Service, LSRCP Office, Boise, ID., Cooperative Agreement 14-48-0001-93539. WA Department of Fish and Wildlife, Olympia, WA.

Monan, G. and K. Liscom. 1975. Radio tracking studies of fall chinook salmon to determine effect of spillway deflectors and fallback on adult chinook salmon and steelhead trout at Bonneville Dam, 1973. Final Report to U. S. Army Corps of Engineers, Portland District. by Northwest Fisheries Center, National Marine Fisheries Service, Seattle, WA.

Stuehrenberg, L. C., G. A. Swan, L. K. Timme, P. A. Ocker, M. B. Eppard, R. N. Iwamoto, B. L. Iverson, and B. P. Sandford. 1994. Migrational characteristics of adult spring, summer, and fall chinook salmon passing through reservoirs and dams of the mid-Columbia River. Final Report to mid-Columbia River Public Utility Districts, by Northwest Fisheries Science Center, National Marine Fish. Service, Seattle, WA.

Wagner, P. 1991. 1990 Evaluation of the use of the McNary bypass system to divert adult fall backs away from turbine intakes. Final Report to US Army Corps of Engineers, modification to contract No. DACW68-82-C-0077, Task Order No. 9., WA Department of Fisheries, Olympia, WA.

Wagner, P. and T. Hillson. 1992. 1991 Evaluation of the use of the McNary bypass system to divert adult fall backs away from turbine intakes. Final Report to US Army Corps of Engineers, modification to contract No. DACW68-82-C-0077, Task Order No. 10., WA Department of Fisheries, Olympia, WA.

APPENDICES

APPENDIX A. Reference landmarks and river kilometer (RK) locations.

River kilometer	Location
Columbia River	
346.9	John Day Dam
351.0	John Day River
389.1	Arlington
450.5	Irrigon Fish Hatchery
464.7	Umatilla River
469.8	McNary Dam
479.6	Hat Rock Park
504.4	Walla River
521.8	Snake River
539.3	Yakima River
540.8	Hwy 182 Bridge (Richland)
571.2	Ringold
595.2	White Bluffs
624.3	Vemita Bridge
635.6	Priest Rapids Fish Hatchery
638.8	Priest Rapids Dam
668.1	Wanapum Dam
Yakima River	
0.0	Mouth
3.4	240 Bridge
7.2	I-82 Bridge
13.5	Van Giesen Bridge
21.2	Twin Bridges
29.0	Horn Rapids Dam
42.9	Songbird Island
47.9	Benton City Bridge
56.2	Kiona Diversion Dam
76.4	Prosser Dam
129.5	Toppenish Creek
132.6	Marion Drain
146.4	Zillah/Toppenish Bridge
149.8	Toppenish/Buena Bridge
157.8	Sawyer
171.5	Wapato Dam

Appendix A, continued.

River kilometer	Location
Snake River	
0.0	Mouth
3.7	Hood Park
16.1	Ice Harbor Dam
18.3	Charbonneau Park
62.3	Windust Park
66.9	Lower Monumental Dam
95.1	Lyons Ferry Fish Hatchery
95.7	Palouse River
100.1	Tucannon River
113.1	Little Goose Dam
133.9	Central Ferry Bridge
173.0	Lower Granite Dam
178.1	Wawawai Park
192.4	Blyton Landing
198.7	Nisqually John Landing
206.3	Steptoe Creek
210.1	Alpowa Creek
224.1	Clearwater River
233.8	Asotin Creek
241.8	10 Mile Creek
250.2	Redbird Creek
253.6	Couse Creek
261.5'	Captain John Creek
265.3	Billy Creek
271.4	Grande Ronde River
302.8	Salmon River
308.4	Imnaha River
397.4	Hells Canyon Dam
Clearwater River	
0.0	Mouth
7.4	Potlatch Mill
11.3	Hatwai Creek
19.3	Hwy 95 Bridge
24.0	Hwy 12 Bridge
26.4	Gibbs Eddy
29.4	Myrtle Bridge
34.4	Cherry Lane Bridge

Appendix A, continued.

River kilometer	Location
Clearwater River (continued)	
42.3	Bedrock Creek
46.3	Lenore
56.6	Peck
65.1	Dworshak Hatchery
71.8	Orofino Bridge
87.0	Lolo Creek
95.7	Six Mile Creek
107.8	Kamiah
120.2	South Fork of Clear-water
Grande Ronde River	
6.9	Joseph Creek
25.3	Schumaker Creek
42.2	Rattlesnake Creek
42.2	Highway 3 Bridge
46.2	Cottonwood Creek
57.8	Wenatchee Creek
64.4	Grouse Creek
72.9	Wenaha River
72.9	Troy, Oregon
Salmon River	
8.8	Flynn Creek
17.9	China Creek
24.1	Cottonwood Creek
33.5	Deep Creek
60.5	Road Bridge
86.2	Whitebird Creek
87.4	Road Bridge
106.4	Slate Creek
123.1	Road Bridge (Lucile)
135.3	Hwy 95 Bridge
138.9	Road Bridge (Riggins)
139.5	Little Salmon River

APPENDIX B. Fall chinook salmon radio tagged and released at Charbonneau Park (RK 18.3), upstream of Ice Harbor Dam in the Snake River, 1993.

Tagging Date	Code	Jaw tag no.	Sex[a]	Fork length (cm)	Scale age[b]	Comments
Channel 22						
09/15/93	02	W1149	F	79	4/1	
09/14/93	03	W1164	F	84	5/1	Recovered[c]
09/15/93	05	W1047	F	89	5/1	
09/14/93	07	W1165	F	80	4/1	Recovered[d]
09/15/93	08	W1151	F	81	5/2	
10/04/93	10	W1086	F	92	5/1	Recovered[c]
10/11/93	11	W892	M	87	4/1	Recovered [e]
09/15/93	12	W1048	M	92	4/1	
09/15/93	14	W1152	M	85	4/1	Recovered[f]
09/20/93	15	W1069	*M	83	4/1	
09/21/93	17	w1177	M	71	3/2	
09/20/93	18	W1181	F	82	4/1	
10/11/93	19	W1088	F	93	5/1	Recovered[g]
09/20/93	21	W1268	M	66	3/1	Recovered[h]
09/21/93	22	W1063	M	89	5/2	Recovered[c]
09/20/93	23	W1182	F	80	4/1	Recovered[c e]
09/21/93	24	W1254	F	75	4/1	
10/11/93	25	W803	*F	86	5/2	Recovered[c]
09/20/93	26	W1065	F	83	4/1	Recovered[c e]
09/22/93	27	W1067	*M	83	5/2	Recovered[c]
09/21/93	28	W1176	F	83	4/1	
09/24/93	29	W1053	M	102	4/1	
10/05/93	30	W820	M	88	4/1	
09/24/93	31	W1191	M	81	4/1	
09/22/93	32	W1172	F	87	4/1	Recovered’
10/11/93	33	W1282	M	70	3/1	
09/24/93	34	W1269	M	64		Recovered[c e]
10/06/93	35	W1097	M	85	4/1	Recovered[c]
09/22/93	36	W1173	F	82	4/1	
09/24/93	37	W1195	F	87	4/1	Removed radio[j]
09/22/93	38	W1171	F	77	4/1	Removed radio[k]
09/22/93	39	W1062	M	95	5/1	
09/24/93	40	W1098	F	83	5/2	
09/24/93	41	W1099	M	81	4/1	
09/22/93	42	W1050	F	81	4/1	
09/24/93	43	W1170	M	71	3/1	
09/24/93	44	W1190	F	79	4/1	

Appendix B, continued.

Tagging Date	Code	Jaw tag no.	Sex[a]	Fork length (cm)	Scale age[b]	Comments
09/22/93	45	W1199	F	78	4/1	
09/24/93	46	W1274	M	68	5/2	
09/23/93	47	W1175	M	69	3/1	
09/23/93	48	W1174	M	85	4/1	Recovered[c]
10/22/93	49	W1244	F	81	4/1	
09/24/93	50	W1193	F	75	4/1	Recovered[g]
09/14/93	51	W1166	M	80	4/1	
10/10/93	53	W802	F	89	5/1	
09/25/93	54	W1160	M	86	4/1	
09/25/93	55	W1161	F	85	4/1	
09/25/93	57	W1162	M	73	3/1	Recovered[c]
09/14/93	59	W1167	F	82	4/1	
09/25/93	61	W1082	F	87	4/1	
09/24/93	62	W1187	F	82	4/1	Recovered[c e]
09/24/93	63	W1060	F	105	5/1	
09/25/93	64	W1265	F	72	3/1	
09/25/93	65	W1194	F	89	4/1	
09/25/93	66	W1159	F	80	4/1	
09/26/93	67	W1085	F	84	4/1	Recovered[c e]
09/14/93	68	W1150	F	78	4/1	
09/25/93	70	W1168	F	76	4/1	
09/24/93	71	W1186	F	79	4/1	
09/25/93	72	W1163	F	79	4/1	Recovered”
09/24/93	73	W1192	M	82	4/1	Recovered[c e]
10/22/93	73	W1235	F	71	5/2	Reused radio
09/24/93	75	W1059	M	91	5/2	Recovered[c]
09/14/93	76	W1078	*M	82	5/2	
09/24/93	77	W1081	F	88	4/1	
09/24/93	78	W1272	F	76		Recovered[d]
10/08/93	79	W1249	F	86	4/1	
09/14/93	80	W1076	F	89	4/1	Recovered[f]
10/08/93	92	W1247	M	65	3/1	RV Clip ’[m]
Channel 23						
09/15/93	01	W1153	F	83	4/1	Recoveredc [e]
09/15/93	03	W1229	F	82	4/1	Recovered[c]
09/20/93	04	W1183	M	71	4/1	
09/15/93	06	W1154	F	87	4/1	Recoveredc
09/21/93	07	W1184	F	87	5/1	

Appendix B, continued.

Tagging Date	Code	Jaw tag no.	Sex[a]	Fork length (cm)	Scale age[b]	Comments
09/22/93	08	W1051	F	82	4/1	Recovered[c]
09/15/93	09	W1155	F	89	4/1	
09/21/93	10	W1185	F	87	4/1	
09/22/93	12	W1052	F	80	4/1	
09/15/93	13	W1049	M	90	4/1	
09/2 1/93	14	W1264	F	75	4/1	
09/22/93	15	W1156	F	76	4/1	Recovered[c e]
09/21/93	16	W1178	F	82	5/1	Recovered
09/24/93	17	W1158	M	76	4/1	
09/21/93	19	W1064	M	80	5/2	Recovered[c]
09/23/93	20	W1083	M	90	4/1	Recovered
09/21/93	21	W1066	F	87	4/1	
09/26/93	22	W1262	F	85	4/1	
09/21/93	24	W1263	F	73		Recovered [n]
09/24/93	25	W1189	F	88	4/1	
09/23/93	26	W1180	F	75	4/1	Recovered [e]
09/25/93	28	W1169	F	82	4/1	Recovered[f]
09/23/93	29	W1157	M	76	4/1	
09/26/93	31	W1267	*M	75	3/1	
10/04/93	32	W1087	F	95	5/1	
10/25/93	33	W1238	M	81	3/1	Recovered[c]
09/26/93	35	W1270	F	80	4/1	
09/29/93	36	W896	*M	69	3/1	Recovered[f l o]
09/26/93	37	W1261	M	65	3/1	Recovered[p q]
09/29/93	38	W1068	F	95	4/1	
10/04/93	39	W1074	F	85	4/1	
09/26/93	40	W1260	F	79	4/1	
09/28/93	41	W1279	F	70	3/1	
09/29/93	42	W1070	F	94	5/1	
09/26/93	43	W1084	*F	89	4/1	Recovered’
09/28/93	44	W806	F	83	4/1	Recovered’
10/25/93	44	W813	M	76		Reused radio
10/10/93	45	W1055	*F	90	4/1	Recovered[g]
09/26/93	46	W1259	F	81	4/1	
09/29/93	47	W1277	M	69	3/1	
09/29/93	48	W1061	M	96	4/1	
09/29/93	49	W1200	M	82	4/1	
09/26/93	50	W1258	M	69	3/1	

Appendix B, continued.

Tagging Date	Code	Jaw tag no.	Sex[a]	Fork length (cm)	Scale age[b]	Comments
09/26/93	55	W1257	F	72	3/1	
09/29/93	57	W1058	F	88	5/2	Recovered[c]
09/28/93	59	Wl196	F	86	4/1	
09/27/93	63	W1188	F	92	5/2	Recovered”
09/27/93	65	W1072	F	79	5/2	Recovered[c]
09/27/93	68	W1198	M	84	4/1	
09/27/93	71	w1197	F	84	4/1	
10/07/93	73	W1276	F	72	3/1	
09/28/93	75	W1073	M	94		
10/06/93	77	W1096	M	106	5/1	
09/28/93	80	W890	M	76	3/1	
10/07/93	81	W1275	F	75	4/1	
10/06/93	82	W1248	F	85	4/1	
09/28/93	83	W804	F	88	4/1	
10/22/93	84	W1240	F	75	3/1	
10/05/93	85	W801	M	85	4/1	
10/07/93	86	W1273	F	72	5/2	Recovered[c]
10/07/93	87	W1089	M	102	5/1	Recovered[g]
09/14/93	88	W1075	F	87	4/1	
Channel 24						
09/15/93	90	W1080[s]	M	98	5/1	
09/14/93	91	W1079	F	93	5/1	
10/08/93	92	W1280	M	69	3/1	RV Clip’ [m]
10/09/93	93	W1121	F	79	4/1	Removed radio[j]
09/28/93	94	W1266	F	81	4/1	Recovered[c]
10/10/93	95	W1233	F	71	3/1	
09/08/93	01	w1122	M	78	4/1	
09/08/93	02	W1022	M	86	4/1	
09/08/93	03	w1222	F			78
09/08/93	04	W1021	F	83	5/1	Recovered[d]
09/09/93	05	W1025	F	82	4/1	
09/09/93	07	W1 123	F	82	4/1	
09/09/93	08	W1124	F	85	4/1	Recovered”
09/09/93	09	W1223	F	83	4/1	
09/09/93	10	W1027	F	87	5/1	
09/10/93	11	W1024	F	97	5/1	
09/10/93	12	W1125	F	79	4/1	Recovered[c e]
09/10/93	13	W1224	F	85	4/1	

Appendix B, continued.

Tagging Date	Code	Jaw tag no.	Sex[a]	Fork length (cm)	Scale age[b]	Comments
09/10/93	14	W1126	F	87	4/1	Recovered[e n]
09/10/93	15	W1127	M	83	4/1	
09/10/93	16	W1026	M	99	5/1	
09/10/93	17	W1128	F	84	4/1	
09/10/93	18	W1129	F	84	4/1	
09/10/93	19	W1130	F	83	4/1	
09/10/93	20	W1225	M	77		Recoveredc [e]
09/10/93	21	W1226	*F	80	4/1	
09/28/93	22	W1278	F	73	4/1	Recovered[p t]
1 O/l1/93	23	W1250	F	80	4/1	Recovered[c]
09/10/93	24	W1029[s]	F	92	5/1	Recovered
09/10/93	25	W1227	F	80	4/1	Recoveredc [v]
09/10/93	26	W1228	F	70	3/1	Recoveredc [l]
09/10/93	27	W1030	M	93	4/1	
09/10/93	28	W1028	F	87	5/1	
09/11/93	29	W1131	F	83	4/1	Recovered[f]
09/11/93	30	W1132	*F	83	4/1	Recovered[c]
09/11/93	31	W1031	F	93	5/1	Recovered”
09/11/93	32	W1133	*F	81	4/1	
09/11/93	33	W1032	M	85	4/1	
09/11/93	34	W1033	F	87	5/1	
09/11/93	35	W1134	F	78	5/2	
09/11/93	36	W1034	M	91	4/1	Recovered[c e]
09/12/93	37	W1036[s]	M	104	5/1	Recovered
09/12/93	38	W1135	F	72	4/1	LV Clip’ [m]
09/12/93	39	W1035	F	89	4/1	
09/12/93	40	W1136	M	82	4/1	Recoveredc [e]
Channel 24						
09/28/93	41	W895	F	85	4/1	
09/12/93	42	W1037	M	98	4/1	
09/12/93	43	W1038	M	92	4/1	
09/12/93	45	W1137	*M	83	4/1	Recoveredc
09/12/93	46	W1138	F	81	4/1	Recovered[c]
09/12/93	47	W1039	F	87	4/1	
09/12/93	48	W1140	F	82	4/1	
09/12/93	49	w1139	F	82	4/1	
09/12/93	50	W1040	F	96	5/1	
09/12/93	73	W1041	M	83	4/1	Recovered?’ [w]

Appendix B, continued.

Tagging Date	Code	Jaw tag no.	Sex[a]	Fork length (cm)	Scale age[b]	Comments
09/12/93	81	W1141	*M	84	4/1	Recovered
09/12/93	82	W1142	F	80	4/1	
09/12/93	83	W1042	M	80	4/1	
09/12/93	84	W1043	F	90		Recovered[c]
09/12/93	85	W1044	M	82	4/1	
09/12/93	86	W1143	F	81	4/1	
09/13/93	87	W1045	F	93	5/1	
10/11/93	88	W1071	M	73	5/2	Recovered[c]
09/13/93	89	W1146	*M	85	4/1	
09/13/93	90	W1145	F	83	5/2	
09/13/93	91	W1144	F	86	4/1	
09/13/93	92	W1046	F	86	4/1	Recovered
09/13/93	93	W1148	M	78	4/1	
09/13/93	94	W1147	F	80	4/1	

[a] Sex determined at tagging unless redetermined upon recapture or recovery, noted by an asterisk.
[b] Total age/years in fresh water. Age 5/2 is hatchery origin.
[c] Recovery location was Lyons Ferry Hatchery.
[d] Recovery from carcass survey on the Clearwater River.
[e] Blank wire tags (BWT) were detected in snouts of some fish at time of recovery, indicating 1989 brood (Lyons Ferry Hatchery origin-from broodstock with high proportion of strays).
[f] Recovery from carcass survey on the Columbia River.
[g] Recovery location was Priest Rapids Hatchery.
[h] Recovery from carcass survey on the Umatilla River.
[i] Fish was recovered dead with a fishing line in its mouth.
[j] Fish recaptured at Umatilla River adult trap. Radio was removed and fish returned to the ladder/river.
[k] Fish recaptured at LGR adult trap. Radio was not activated at tagging. Radio was removed and fish returned to the ladder.
[m] Mark was detected during tagging at CHAR.
[n] Recovery location was the Tucannon River.
[o] Fish was recovered in a sport fishery.
[p] Fish was recovered dead.
[q] Recovered in the Columbia River at the confluence with the Snake River.
[r] Recovery from carcass survey on the Snake River.
[s] The original jaw tag was lost and the fish was re-jaw tagged later at LGR adult trap.

Appendix B, continued.

[t] Recovered at CHAR.
[u] Recovery from a carcass survey on the Grande Ronde River.
[v] Fish was not fin clipped, although a CWT was recovered. The CWT was from Bonneville Hatchery and was part of the Bonneville bypass study.
[w] Recovered in LGR Dam forebay.

APPENDIX C. Fall chinook salmon radio tagged and released at Lower Granite adult trap (RK 172.8) 1993.

Tagging Date	Code	Jaw tag no.	Sex[a]	Fork length (cm)	Scale age[b]	Comments
Channel 22						
10/30/93	01	W1102	F	84	4/1	
10/23/93	04	W1012	M	91	4/1	
10/02/93	06	W1018	M	88	4/1	
10/03/93	09	W1005	F	93	4/1	
11/01/93	13	0484	F	81	4/1	Stubby fins[c]
10/09/93	16	W1217	M	61	3/1	RV Clip[d e]
11/06/93	20	W1202	F	72		
10/11/93	38	W1006	M	92	4/1	Recovered[f]
Channel 23						
11/01/93	02	W1013	M	92	4/1	
10/19/93	05	W1010	M	89	4/1	
10/13/93	11	W1014	M	95	4/1	
10/02/93	18	W1208	F	80	4/1	
09/23/93	27	W1007	F	94	4/1	
10/07/93	30	W1116	M	76	4/1	
Channel 24						
09/30/93	95	W120	F	76	4/1	
09/21/93	96	W1220	M	72	4/1	
09/15/93	97	W1002	M	97	4/1	
09/24/93	98	1436	F	81	4/1	
09/19/93	99	W1219	F	78	4/1	
09/15/93	100	W1001	M	98	4/1	Recovered[g]

[a] Sex determined at tagging.
[b] Total age/years in fresh water.
[c] Possible hatchery fish, stubby fins noted at tagging.
[d] Fish was from Umatilla Hatchery with a right ventral (RV) fin clip.
[e] Mark was detected during tagging at LGR Dam adult trap.
[f] Fish was recovered dead on the Snake R. near the Grande Ronde River. This is the second fish that used this channel and code.
[g] Fish was recovered dead on the Clearwater River.

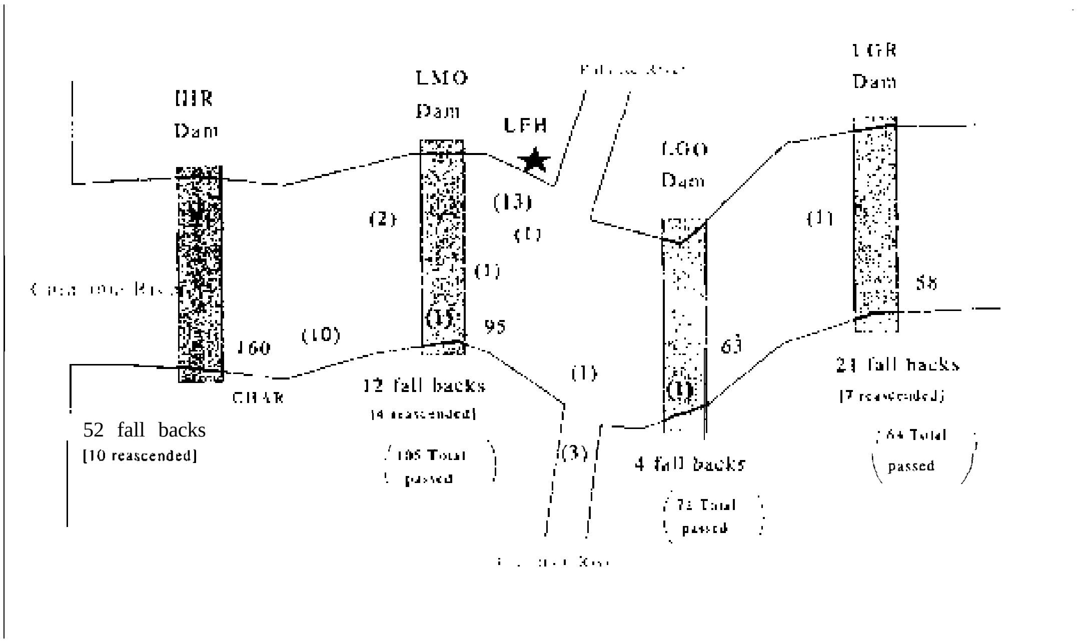
APPENDIX D. Comparison of expected counts of radio tagged fall chinook salmon from CHAR of hatchery and unknown origin with their likely availability for spawning upstream of IHR or LGR, 1993.

Fish likely counted	Number of fish that were likely available to spawn
Hatchery origin at IHR	
40 counted	40 counted
+2 reascended	-8 fell back
	+2 reascended and remained above
42	34
Counting Error = 23.5% overestimate of spawners (42/34 available)	
Unknown origin at IHR	
150 counted	150 counted
+ 15 reascended	-68 fell back
	+ 15 reascended
	- 5 fell back again before spawning
165	92
Counting Error = 79.3% overestimate of spawners (165/92 available)	
Hatchery origin at LGR	
8 counted	8 counted
	-7 fell back
+4 reascended	+4 reascended
	- 2 fell back again & spawned
12	3
Counting error = 300% overestimate of spawners (12/3 available)	
Unknown origin at LGR	
60 counted	60 counted
	-12 fell back before 1 Nov.
+3 reascended	+3 reascended and remained
1 reascended	+1 reascended (fell back in Nov.)
1 reascended	±1 reascended (fell back to Tucannon) (10 fell back after 3 1 October, 1 reascended and 2 spawned and fell back in Nov.)
+ 1 reascended	
-1 ladder fall back	
	-2 fell back and spawned below
65	50
Counting error = 30.0% overestimate of spawners (15/30 available)	

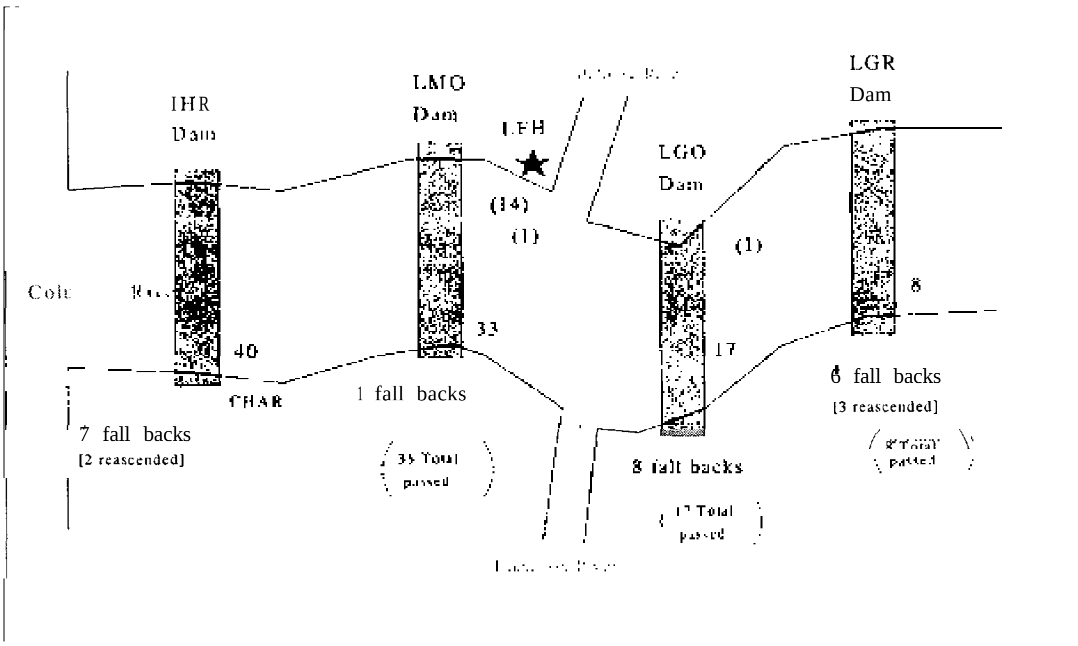
APPENDIX E. Comparison of radio tracked salmon to fish counts at LGR Dam in 199 1.

Counted at LGR	Remained above LGR	
7 from IHR	7	
	-4	fell back unspawned, or before 1 Nov.
	3	may have spawned above LGR
8 tagged at LGR	8	
	-2	fell back shortly after tagging in Nov.
	6	
combined total		
15 counted	9	(66.7%) total available to spawn
		(15/9 available)

APPENDIX F. Initial passage and fall back information for hatchery and unknown origin fall chinook salmon in 1993.



Appendix F; Figure 1. Initial passage and fall back information (similar to Fig. 3, page 15) for hatchery origin fall chinook salmon in 1993.



Appendix F, Figure 2. Initial passage and fall back information (similar to Fig. 3, page 15) for unknown origin fall chinook salmon in 1993.

CHAPTER 2

STOCK IDENTIFICATION OF SNAKE RIVER FALL CHINOOK SALMON

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ABSTRACT

This chapter describes the methods and results used to determine the amount of hatchery straying, stock composition and genetic profile of returning fall chinook salmon (*Oncorynchus tshawytscha)* and their offspring to the Snake River above Lower Granite Dam during 1992 and 1993. Stock identification techniques used to accomplish this included coded-wire tags, scale analysis, otolith analysis, and starch-gel electrophoresis for genetic analysis. Genetic and scale analysis provided evidence that there is probably not a spatial difference in spawning area between hatchery strays and native adult fall chinook salmon. Genetic analysis also indicated significant influence from mid-Columbia River chinook salmon stocks.

INTRODUCTION

Intensive monitoring of the returning Snake River fall chinook salmon has occurred over the last several years. When these fish were petitioned for listing under the Endangered Species Act (ESA), one of the major questions left unanswered was, "What is the amount of hatchery straying and the stock composition or genetic profile of the returning adults and their offspring?" Related to this question and a concern of National Marine Fisheries Service (NMFS) personnel after a listing was found justified was whether the Lyon's Ferry Hatchery (LFH) should be part of the evolutionary significant unit (ESU) and the hatchery should play a role in the recovery efforts for this stock. To address these questions three informational needs were identified.

5) What is the stock composition and population of adults passing Lower Granite Dam (LGR)?
6) Do different spawning grounds exist for hatchery strays (LFH and mid-Columbia) and wild Snake River fall chinook above LGR? (It was hypothesized that the original Snake River genetic profile might have been maintained by the natural spawners in the upper most section of the Snake River below Hells Canyon Dam).
7) What is the genetic profile of the naturally spawned Snake River fall chinook?

This study was designed to provide information to help answer these questions.

STUDY AREA

Intensive spawning ground surveys for collection of spawned adult salmon carcasses were conducted throughout the spawning area above LGR. This included the Snake River to Hells Canyon Dam as well as portions of the Clearwater, Grande Ronde, Salmon, and 'Imnaha Rivers. Adults were monitored and juveniles were sampled for electrophoresis at LGR. The USFWS previously trapped and tagged these juveniles with passive integrated transponder (PIT) tags between the confluence of the Salmon River and the upper portion of Lower Granite pool.

METHODS

To accomplish the work described below, permission had to be obtained from NMFS through a Section 10 Application of the Endangered Species Act. Although NMFS issued a permit to do the work, they added a request to collect all coded-wire tagged (CWT) adult fall chinook passing LGR and return these fish to LFH for spawning and stock identification. Prior to 1992 only a portion of adults with CWTs were collected to determine stock identification.

Adult fall chinook salmon passing LGR in 1992 and 1993 were counted throughout the migration. At LGR it is also possible to count nearly all fish with a CWT because the upstream fish passage system allows those fish possessing a CWT to be detected and trapped separately. Detection and trapping is not 100 percent efficient, but efficiency is high. In 1992 and 1993, NMFS requested that all fall chinook salmon with CWTs be removed from the population migrating past LGR and transported to LFH. They felt that by excluding as many hatchery origin chinook salmon as possible they could reduce the chance of compromising the genetic integrity of the natural run. These tagged fish were jaw tagged prior to being transported to LFH and held along with fall chinook salmon collected at Ice Harbor Dam (IHR).

On-site recovery of jaw tags and CWTs occurred during weekly spawnings at LFH. Additional samples were collected from hatchery pond mortalities. On spawning days CWTs were used to determine stock origin. Gametes from LFH origin CWT chinook (other than 1989 brood) were spawned separate from unknown and stray origin fish. It had previously been decided that 1989 brood LFH fish were genetically contaminated and should not be used as broodstock. All 1989 brood LFH chinook juveniles were tagged prior to release. Scales were collected on approximately 20 percent of the marked chinook and on 50 percent of the unmarked fish that voluntarily returned to the hatchery.

The method used by Washington Department of Fish and Wildlife (WDFW)[a], and accepted by NMFS, to estimate the number of wild fish passing LGR, was to expand the sample of CWTs recovered from adults passing LGR to the total number of fish passing LGR. The remaining number of fish are then assumed to be wild fish. These estimates should be considered approximations because of the low numbers of CWT recoveries and the presence of unmarked hatchery fish in the population (especially in 1990-91). The primary assumptions associated with these estimates are that all stray groups are represented by CWTs, the tagged fish are representative of their untagged counterparts, and that the tagged/untagged ratios reported are correct and few unmarked hatchery fish exist.

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[a] The Fisheries and Wildlife Departments in Washington State were merged into a single agency in March 1994. References to either agency will be indicated as WDFW.

Except for 1989 brood LFH origin chinook, stock composition was estimated by expanding the readable tags by their respective juvenile mark rates and then by an adipose mark collection rate. For 1989 brood LFH, contribution was estimated from expanding CWT chinook salmon by the marked fish trap efficiency rate and by a juvenile tag shed rate. All chinook processed at the hatchery were examined for adipose clips (100 percent sampling rate). The collection rate of dam-trapped fish was derived from the number of adipose clipped chinook salmon retained divided by an estimate of the total marks passing LGR as measured by fish counters at the viewing window.

A variety of stock identification tools were used in an attempt to identify juveniles and adults as to stock and origin. These included coded-wire tags (CWTs), passive integrated transponder (PIT) tags, fin marks, scale analysis, otolith analysis, and genetic stock identification.

Spawning ground observations to verify redds observed in aerial flights and sampling of spawned adult carcasses above LGR was done in cooperation with USFWS and IPC. This work was in conjunction with the USFWS research on identifying and describing spawning habitat. Coordination occurred to avoid unnecessary and multiple visual contacts or “harassment.” Spawned adults (dead or moribund) were collected with hook-and-line snagging gear. Salmon were collected on the spawning grounds by personnel very experienced with this collection method. Surveys were conducted throughout the spawning area in order to determine if an isolated area (e.g., above the confluence of the Salmon River) might contain only wild chinook salmon, as opposed to a mix of hatchery strays and wild fish.

Carcasses were measured (postorbital to hypural plate) and examined for CWTs, radio telemetry tags, and other identifying characteristics such as tin marks. Tissue samples (eye, heart, liver, and muscle) were taken for genetic analysis and scales were collected and aged. Otoliths were taken and analyzed in an attempt to determine if different daily increment patterns could be detected between known hatchery and wild fish.

Genetic identification is another potential technique for determining stock origin. Electrophoresis has been used successfully to estimate stock composition of mixed stock groups of chinook salmon using maximum likelihood estimation (MLE) techniques (Marshall et al.). This analysis separates groups of fish as opposed to individual fish. To develop a genetic baseline from the natural run of fall chinook salmon which spawned above LGR, we collected PIT tagged juveniles as they migrated downstream at LGR from June through August 1991. These juveniles were captured above the LGR pool and identified with PIT tags by USFWS prior to, or at the start, of their migration during April and May of the same year.

Using electrophoresis and the basic genetic stock identification techniques described by Marshall et al. (1991), we developed a way to analyze individual fish with a relatively high degree of accuracy if the genetic baselines are not too similar. This technique takes the genotypes of the individual and converts them to metric scores and uses linear discriminate analysis to classify individuals of unknown origin to the baseline group they most closely resemble. This technique was used to analyze the allele frequency data obtained from the tissues of carcasses which were sampled above LGR. Baseline group populations were from LFH and mid-Columbia River. The technique calculated the *a posteriori* probability of group membership for each individual fish. That is, the probability that a given fish was a member of either the LFH or mid-Columbia River group was calculated on the linear discriminant score for each fish.

RESULTS AND DISCUSSION

The final count of fall chinook salmon passing over LGR during the fall of 1992 was 855 adults (>22 inches total length) and 102 jacks (12-22 inches). Composition of the adult run was 306 hatchery origin and 549 natural origin fall chinook salmon (Table 1). Lyons Ferry Hatchery comprised 98 percent of the estimated hatchery portion. Jacks numbered 3 1 hatchery and 71 natural origin chinook salmon. Adult escapement passing LGR included 549 naturally produced chinook salmon and 119 hatchery origin fish (Table 2). Jack spawning escapement consisted of 9 hatchery and 71 natural fish. A total of 209 fall chinook salmon collected at LGR were trucked to LFH for spawning and were analyzed for stock composition from C WTs in 1992 (Table 3).

The final count at LGR during the fall of 1993 was 1170 adult (>22 inches total length) and 39 jacks (12-22 inches). The adult run contained 428 hatchery origin and 742 natural origin fall chinook (Table 4). LFH production comprised 52 percent of the hatchery portion of the adult run. The remaining hatchery run was dominated by fall chinook released into the Umatilla River. Adult escapement passing LGR included 742 naturally produced chinook and 2 10 hatchery origin fish, including 167 Umatilla River releases (Table 5). All of the jack chinook passing above LGR were natural origin fish. A total of 222 fall chinook salmon collected at LGR were trucked to LFH for spawning and analyzed for stock composition from CWTs in 1993 (Table 6).

Table 1. Stock composition of fall chinook salmon counted to Lower Granite Dam in 1992.

TO LOWER GRANITE DAM:	Adult (>22 inches TL)	Jack (12-22 inches TL)
Total Dam Count	855	102
Natural	549	71
Lyons Ferry H. Non-1989 brood	139	11
Lyons Ferry H. 1989 brood	135	9
Umatilla	29	5
Bonneville Bypass Study	2	0
Other	1	6

Table 2. Stock composition of fall chinook salmon escapement past Lower Granite Dam in 1992.

ESCAPEMENT PAST LOWER GRANITE DAM:	Adult (>22 inches TL)	Jack (12-22 inches TL)
Total Escapement #	668	80
Natural	549	71
Lyons Ferry H. Non-l 989 brood	90	2
Lyons Ferry H. 1989 brood	10	1
Umatilla	19	1
Bonneville Bypass Study	0	0
Other	0	5

Table 3. Stock composition of fall chinook salmon trucked from Lower Granite Dam to Lyons Ferry Hatchery in 1992.

TO LYONS FERRY HATCHERY:	Adult (>22 inches TL)	Jack (12-22 inches TL)
Total Transported	187	22
Lyons Ferry H. Non-l 989 brood	49	9
Lyons Ferry H. 1989 brood	125	8
Umatilia	10	4
Bonneville Bypass Study	2	0
Other		

Table 4. Stock composition of fall chinook salmon counted to Lower Granite Dam in 1993.

TO LOWER GRANITE DAM:	Adult (>22 inches TL)	Jack (12-22 inches TL)
Total Dam Count	1170	39
Natural	742	35
Lyons Ferry H. Non-1989 brood	53	3
Lyons Ferry H. 1989 brood	170	1
Umatilla	195	0
Bonneville Bypass Study	1	0
Other	9	0

Table 5. Stock composition of fall chinook salmon escapement past Lower Granite Dam in 1993.

ESCAPEMENT PAST LOWER GRANITE DAM:	Adult (>22 inches TL)	Jack (12-22 inches TL)
Total Escapement #	952	35
Natural	742	35
Lyons Ferry H. Non-1989 brood	26	0
Lyons Ferry H. 1989 brood	17	0
Umatilla	167	0
Bonneville Bypass Study	0	0
Other		

Table 6. Stock composition of fall chinook salmon trucked from Lower Granite Dam to Lyons Ferry Hatchery in 1993.

TO LYONS FERRY HATCHERY:	Adult (>22 inches TL)	Jack (12-22 inches TL)
Total Transported	218	4
Lyons Ferry H. Non-1989 brood	27	3
Lyons Ferry H. 1989 brood	153	1
Umatilla	28	0
Bonneville Bypass Study	1	0
Other	9	0

Table 7. Stock composition of fall chinook at Lower Granite Dam during 1990-93.

	1990		1991		1992		1993	
ESCAPEMENT TO LOWER GRANITE DAM:	Adult	Jack	Adult	Jack	Adult	Jack	Adult	Jack
Lower Granite Count	385	190	630	389	855	102	1170	39
Snake River Natural	78 (20%)	23 (12%)	318 (50%)	Not Available	549 (64%)	71 (70%)	742 (63%)	35 (90%)
Lyons Ferry Hatchery	208 (54%)	100 (53%)	232 (37%)	Not Available	274 (32%)	20 (20%)	223 (19%)	4 (10%)
Non-Snake River Hatchery	99 (26%)	67 (35%)	80 (13%)	Not Available	32 (4%)	11 (10%)	205 (18%	0 (0%)

	1990		1991		1992		1993	
ESCAPEMENT PAST LOWER GRANITE DAM:	Adult	Jack	Adult	Jack	Adult	Jack	Adult	Jack
Dam Count	385	190	630	389	855	102	1170	39
Trucked to Lyons Ferry H.	-50	-89	-40	-19	-187	-22	-218	-4
Escapement =	335	101	590	370	668	80	952	35
Natural	78	23	318	Not Available	549	71	742	35
Lyons Ferry Hatchery	174	47	202	Not Available	100	3	43	0
Non–Snake River Hatchery	83	31	70	Not Available	19	6	167	0

Table 8 Data from 44 fall chinook salmon carcasses collected in the Snake River Basin in 1992.

Date	Location	River km.	Post-Orbital to Hypural (cm)	Sex	Age*	Identifying Characteristics	Label #
111091	Gr. Ronde		75	F	4/1	None	92FF-1
11/10	Snake	311	75	F	4/1	None	92FF-2
11/10	Imnaha		66	F	4/1	None	92FF-3
11/10	Imnaha		71	F	4/1	Radio Tag	92FF-4
11116	Gr. Ronde		76	F	5/1	None	92FF-5
11/16	Gr. Ronde		76	F	5/1	None	92FF-6
11/16	Snake	245	57	F	3/1	None	92FF-7
11/16	Snake	245	71	F	4/1	None	92FF-8
11119	Dworshak		56	M	3/1	None	92FF-9
11/19	Snake	261	52	F	4/1	None	92FF-10
11/19	Snake	259	71	M	4/1	None	92FF-11
11/19	Snake	245	69	F	4/1	None	92FF-12
11/19	Snake	245	69	F	4/1	None	92FF-13
11/19	Snake	261	62	M	3/1	None	92FF-14
11/19	Snake	261	76	F	4/1	None	92FF-15
11/20	Snake	258	80	M	5/1	None	92FF-16
11/20	Snake	320	60	F	4/1	None	92FF-17
11120	Dworshak		50	M	3/1	None	92FF-41
11/20	Dworshak		72	F	4/1	None	92FF-42
11120	Dworshak		56	M	4/1	None	92FF-43
11/20	Dworshak		52	M	4/2	Yearling Out-Migrant	92FF-44
11120	Dworshak		60	M	3/1	None	92FF-45
11/20	Dworshak		58	M	3/1	None	92FF-46
11/20	Dworshak		68	F	4/1	None	92FF-47
11120	Dworshak		55	M	3/1	None	92FF-48
11/23	Clearwater		87	M	5/1	None	92FF-21
11123	Clear-water		64	F	4/1	None	92FF-22
11/23	Clear-water		72	F	5/2	Yearling Out-Migrant	92FF-23
11/23	Clear-water		73	F	4/1	None	92FF-24
11/24	Snake	245	72	F	4/1	None	92FF-25
11/24	Snake	245	57	F	4/2	Yearling Out-Migrant	92FF-31
11124	Snake	245	53	M	3/1	None	92FF-32
11/24	Clear-water		71	F	4/1	Scales Only	
11/27	Snake	245	61	F	5/2	Yearling Out-Migrant	92FF-56
11/27	Snake	245	57	M	3/1	None	92FF-57
12101	Snake	245	76	F	5/1	None	92FF-58
12101	Snake	245	57	F	3/1	None	92FF-59
12/02	Snake	332	54	F	4/2	Yearling Out-Migrant	92FF-60
12/04	Clearwater		71	F	4/1	None	92FF-61
12104	Clearwater		73	F	4/1	None	92FF-62
12104	Clear-water		69	F	5/1	None	92FF-63
12104	Clear-water		59	F	--	None	92FF-81
12/04	Clearwater		68	F	4/1	None	91FF-82
01120	Clearwater		76	--	4/1	Radio Tag/Scales Only	

* Age is given for age at return and age at ocean entrance (e.g., 4/2 denotes a 4 years old adult return that migrated to the ocean as a yearling or during its second year of life).

Table 9. Data from 36 fall chinook salmon carcasses collected in the Snake River Basin in 1993.

Date	Location	River km.	Post Orbital to Hypural (cm)	Sex	Age**	Identifying Characteristics	Label #
10/27	Gr. Ronde	61	74	F	4/1*	None	93EH-1
11/03	Gr. Ronde	25	77	F	4/1	Radio Tag/Jaw Tag	93EH-7
11/03	Gr. Ronde	25	77	F	4/1	None	93EH-2
11/03	Gr. Ronde	25	67	F	4/1	None	93EH-4
11/03	Gr. Ronde	25	72	M	4/1	None	93 EH-5
11/08	Imnaha R.	1	75	F	4/1	None	93EH-3
11/10	Dworshak	64	66	F	4/1	None**	93EH-39
11/10	Dworshak	64	69	F	I-	None**	93EH-40
11/10	Dworshak	64	71	F	4/1	None**	93EH-47
11/12	Snake R.	259	69	F	4/1	None	93EH-9
11/12	Snake R.	259	70	F	411	None	93EH-26
11/16	Dworshak	64	50	M	4/1	RV Clip/Umatilla stray	93EG-20
11/16	Gr. Ronde	6	76	F	4/1	Radio Tag/Jaw Tag	93EH-28
11/16	Snake R.	259	76	F	411	None	93EH-27
11/16	Snake R.	259	80	F	411	None	93EH-10
11/20	Gr. Ronde	25	68	F	3/1	None	93EH-6
11/20	Gr. Ronde	42	60	F	411	None	93EH-8
11/23	Snake R.	382	76	F	411	None	93EH-12
11/23	Snake R.	382	65	F	411	None	93EH-22
11/24	Clearwater	61	67	F	5/1	Jaw Tag	93EH-58
11/24	Clearwater	32	66	F	4/1	Radio Tag/Jaw Tag	93EH-11
11/24	Clearwater	32	69	F	5/1	Jaw Tag/Yearling	93EH-23
11/24	Clearwater	32	61	F	4/1	Radio Tag	93EH-24
11/24	Clearwater	61	56	F	5/2	Yearling out-migrant	93EH-21
11/26	Snake R.	258	73	F	4/1	None	93EH-29
11/30	Snake R.	382	62	F	4/1	None	93EH-36
11/30	Snake R.	237	67	F	4/1	None	93EH-25
12/01	Dworshak	64	68	M	4/1	None**	93EH-57
12/01	Snake R.	272	71	F	4/1	None	93EH-15
12/08	Clearwater	32	74	F	4/1	None	93EH-41
12/08	Clearwater	32	75	F	4/1	None	93EH-42
12/08	Clearwater	32	67	F	4/1	None	93EH-43
12/08	Clearwater	50	70	F	4/1	None	93EH-44
12/08	Clearwater	32	71	F	4/1	None	93EH-14
12/09	Snake R.	269	71	F	4/1	Jaw Tag	93EH-45
12/09	Snake R.	269	61	F	4/1	Scales onlv/CWT	None

* Age is given for age at return and age at ocean entrance (e.g., 4/2 denotes a 4 years old adult return that migrated to the ocean as a yearling or during its second year of life.

** Genetic analysis from cheek muscle only.

The return of fall chinook to LGR has improved steadily since the record low in 1990 (Table 7). The estimate of natural origin fall chinook returning to LGR increased in 1993 to 742 adults from a low of 78 adults in 1990 (Cooney 1991), 318 in 1991 (TAC 1992), and 549 in 1992. These estimates should be considered approximations because of the low numbers of CWT recoveries (especially in 1990-91) and the limited sampling of the population on the spawning grounds. Additionally, passage through the transportation locks or fall-back of fish through the juvenile bypass facilities or turbines could skew the actual abundance of fish upstream of the dam. The rates of fall-back and reascents documented in Chapter 1 of this study have not been accounted. The variable timing of summer and fall run chinook can also influence the run size estimates which are based on counts from a set cut-off date at the fish ladder window.

Straying of non-Snake River origin fall chinook increased in 1993 following a two year decline. The adult run arriving at LGR was estimated to contain about 18 percent non-Snake River chinook. This stray rate compares to 4 percent in 1992, 13 percent in 1991, and 26 percent in 1990. Strays have been consistently dominated by fall chinook released in the Umatilla River.

Forty-four carcasses were sampled on the spawning grounds above LGR in 1992 (Table 8) and 36 in the fall of 1993 (Table 9). One fish recovered at river km 269 in 1993 carried a CWT and was released as a juvenile from LFH. A fish recovered at Dworshak Hatchery in 1993 (river km 64) had a right ventral clip and was believed to be a stray from the Umatilla River.

A method for differentiating a “hatchery” versus “wild” fish was not identified using daily increment patterns from salmon otoliths. The otoliths from the carcasses were archived for further analysis should a method be discovered in the future.

Scales from adult fish were classified as age 0 or age 1 migrants. Age 1 or yearling migrants were assumed to be hatchery fish since wild fall chinook salmon are believed to migrate as 0s (at least, no evidence suggests yearling migration from mid-Columbia or Snake fall stocks). In 1992 and 1993, only nine fish were collected above the confluence of the Salmon River (River km 301). Of these nine, one fish (label # 92FF-60) at river km 332 was a female which migrated as a yearling. This is not conclusive evidence that it was a hatchery fish, but it is highly probable. If it was a hatchery fish, then the theory that a spatial separation exists between wild fish and hatchery fish is questionable. The ratio of yearling out-migrants observed above the confluence of the Salmon River (1/9) was not significantly different than the ratio (6/71) observed for the rest of the Snake River basin.

The *a posteriori* probabilities of group membership for individual adult recoveries using genetic data from 1992 and 1993 are given in Table 10 and Table 11. The fish number is listed in the first column followed by the probability a fish belongs to the LFH group followed by the probability of membership in the mid-Columbia River group. This model does not allow a great deal to be learned from these data for most of the fish because of the similarities between the two baselines. The majority of probabilities range from 0.3 to 0.7 with only 21 of 72 values falling outside that range. Those fish with the higher values are highlighted.

Two of these 21 fish (label # 92FF-17 and 93EH-12), however, were recoveries upstream of the Salmon River (River km 320) and both classified as mid-Columbia fish. These fish were also spawned females and again, they do not support spatial spawning separation.

This genetic analysis was also used on the fall chinook salmon that returned to Dworshak National Fish Hatchery. Seven of the 9 fish that returned in 1992 were spawned. However, *a posteriori* probabilities indicated both females (label 92FF-42 and label # 92FF-47) which were spawned, were most likely of mid-Columbia origin (Table 10). This analysis also indicated that a male returning to Dworshak in 1993 (label #93EH-20) was from the mid-Columbia. A right ventral fin mark on this fish supported this analysis. This information allowed NMFS and USFWS to. decide to not include these fish as part of the evolutionarily significant unit (ESU) of threatened Snake River fall chinook.

In 1991, 49 individual juveniles were recovered from the 1990 brood which had been previously captured and tagged by USFWS crews. When the 49 were genetically analyzed by MLE, using fall, spring and summer baseline stocks) as a group the analysis indicated there were probably 2-4 spring/summer chinook in the sample. WDFW Genetics Unit staff visually examined the genotypes at 28 variable loci for the 49 juveniles and dropped three fish from the sample that stood out as typical spring/summer genetic profiles. This was accomplishable because the allele frequencies of several variable loci are very different between mid-Columbia/Lyons Ferry fall chinook and Snake River spring/summer chinook, When the 46 remaining fish were re-analyzed by MLE, the stock composition estimate changed to 100 percent fall chinook. These 46 juveniles were then used to represent a genetic baseline of wild Snake River fall chinook. This baseline collection was used in a cluster analysis (un-weighted pair group method) based on the genetic distance, Cavallie-Sforza and Edwards (1967) chord distance, among Snake and mid-Columbia spring, summer, and fall stocks. The dendrogram resulting from the analysis is shown in Figure 1. The wild 1990 brood Snake River juveniles clustered with, and showed no significant genetic difference (G-test, 30 loci, $P \geq .05$) from, the LFH baseline. Significant differences did appear between these two chinook salmon baselines and the mid-Columbia fall chinook salmon baselines. This information coupled with the information from Bugert et al. (1991) which showed no significant difference between the original Snake River broodstock taken at IHR starting in 1977 and the present LFH broodstock is very encouraging because it indicates that the intent of the Snake River Wild Eggbank Program to maintain the genetic integrity of Snake River fall chinook salmon has been maintained. In fact, because of the hatchery practices at LFH where genetic integrity is being maintained by elimination of all non-LFH from the broodstock fish, the LFH fish may be a more true genetic representation of the original wild population than what is spawning in the wild at present. These results allowed NMFS to include LFH stock in the ESU of the Snake River fall chinook salmon. This will provide valuable options for a rebuilding plan of the ESU Snake River fall chinook salmon population.

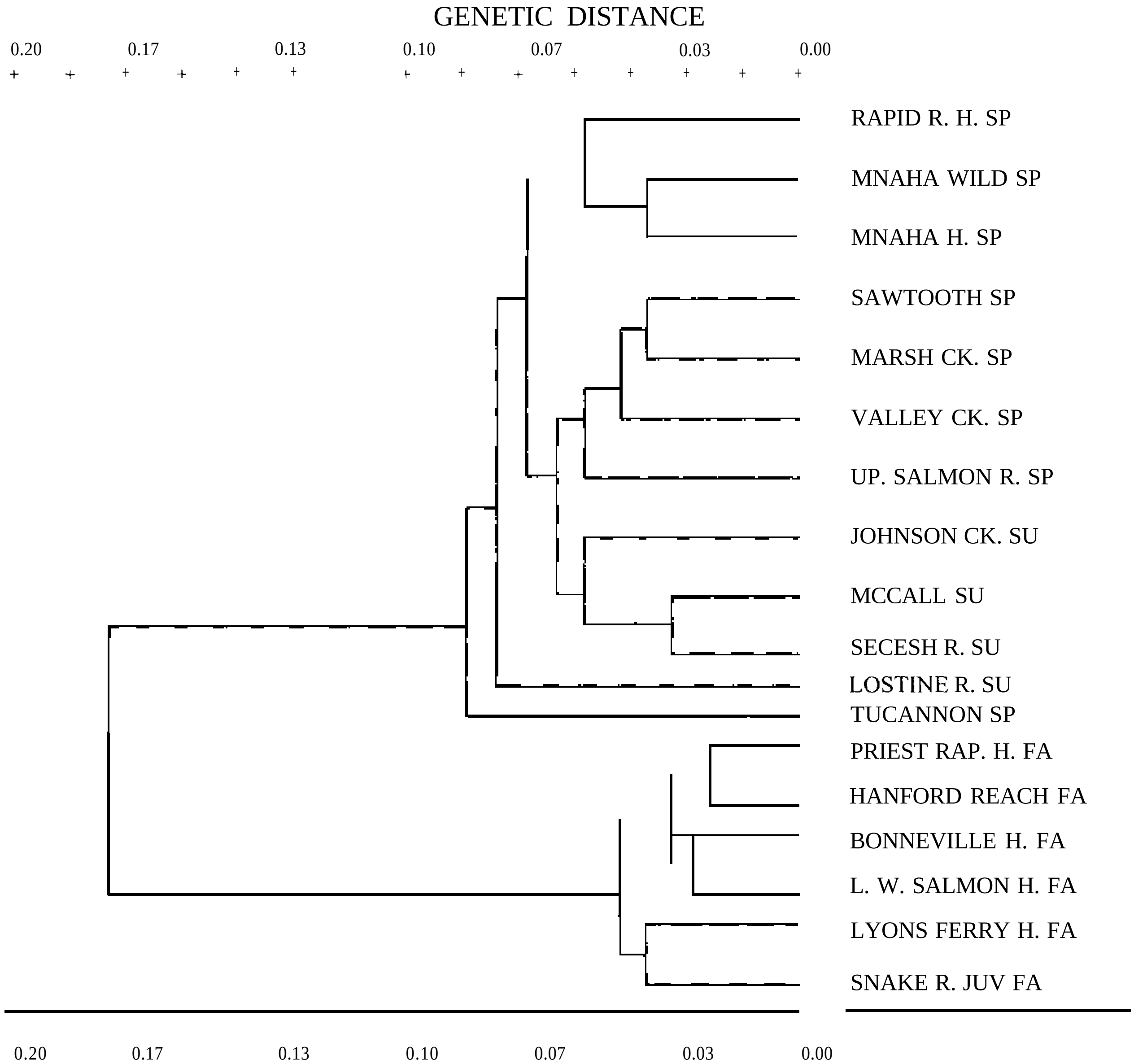
Table 10. The a *posteriori* probability values for membership to two baseline stocks for individual recoveries from the Snake River basin in 1992 are given based on genetic data. Probability values outside of the 0.3 to 0.7 are highlighted and are somewhat dependable as indicators of stock origin.

Fish ID	Location	River km.	Sex	Probability of Membership	
				Lyons Ferry	Mid-Columbia
92FF-1	Gr. Ronde		F	0.670	0.330
92FF-2	Snake	311	F	0.510	0.490
92FF-3	Imnaha		F	0.503	0.497
92FF-4	Imnaha		F	0.458	0.542
92FF-5	**Gr. Ronde**		**F**	**0.301**	**0.699**
92FF-6	Gr. Ronde		F	0.645	0.355
92FF-7	Snake	245	F	0.645	0.355
92FF-8	**Snake**	**245**	**F**	**0.177**	**0.823**
92FF-9	Dworshak		M	0.555	0.445
92FF-10	**Snake**	**261**	**F**	**0.296**	**0.704**
92FF-11	Snake	259	M	0.645	0.355
92FF-12	Snake	245	F	0.317	0.683
92FF-13	Snake	245	F	0.319	0.68 1
92FF-14	**Snake**	**261**	**M**	**0.165**	0.835
92FF-15	Snake	261	F	0.555	0.445
92FF-16	Snake	258	M	0.319	0.681
92FF-17	**Snake**	320	**F**	0.222	0.778
92FF-21	**Clearwater**		**M**	0.296	0.704
92FF-22	**Clearwater**		**F**	0.237	0.763
92FF-23	**Clearwater**		**F**	0.295	0.705
92FF-24	Clearwater		F	0.477	0.523
92FF-25	Snake	245	F	0.645	0.355
92FF-31	**Snake**	**245**	**F**	**0.814**	**0.186**
92FF-32	Snake	245	M	0.381	0.619
92FF-41	Dworshak		M	0.555	0.445
92FF-42	**Dworshak**		**F**	**0.242**	**0.758**
92FF-43	Dworshak		M	0.457	0.543
92FF-44	Dworshak		M	0.643	0.357
92FF-45	Dworshak		M	0.365	0.635
92FF-46	Dworshak		M	0.486	0.514
92FF-47	**Dworshak**		**F**	0.302	0.698
92FF-48	**Dworshak**		**M**	0.294	0.706
92FF-56	Snake	245	F	0.555	0.445
92FF-57	**Snake**	245	**M**	0.177	0.823
92FF-58	Snake	245	F	0.454	0.546
92FF-59	Snake	245	F	0.390	0.610
92FF-60	Snake	332	F	0.645	0.355
92FF-61	Clearwater		F	0.382	0.618
92FF-62	Clear-water		F	0.454	0.546
92FF-63	**Clearwater**		**F**	0.727	0.273
92FF-81	Clearwater		F	0.477	0.523
92FF-82	C learwater		F	0.555	0.445

Table *11*. The *aposteriori* probability values for membership to two baseline stocks for individual recoveries from the Snake River basin in 1993 are given based on genetic data. Probability values outside of the 0.3 to 0.7 are highlighted and are somewhat dependable as indicators of stock origin.

Fish ID	Location	River km.	Sex	Probability of Membership	
				Lyons Ferry	Mid-Columbia
93EH-1	Gr. Ronde		F	0.256	0.744
93EH-2	Gr. Ronde		F	0.367	0.633
93EH-3	Imnaha		F	0.350	0.650
93EH-4	Gr. Ronde		F	0.437	0.563
93EH-5	Gr. Ronde		M	0.332	0.668
93EH-6	**Gr. Ronde**		**F**	**0.083**	**0.917**
93EH-7	Gr. Ronde		F	0.424	0.576
93EH-8	Gr. Ronde		F	0.593	0.407
93EH-9	Snake R.	259	F	0.406	0.594
93EH-10	Snake	259	F	0.256	0.744
93EH-11	Clearwater		F	0.496	0.504
93EH-12	**Snake**	**382**	**F**	**0.189**	**0.811**
93EH-14	**Clearwater**		**F**	**0.281**	**0.719**
93EH-15	**Snake**	**272**	**F**	**0.242**	**0.758**
93EH-20	**Dworshak**		**M**	**0.197**	**0.803**
93EH-22	Snake	382	F	0.593	0.407
93EH-23	Clearwater		F	0.315	0.685
93EH-24	Clearwater		F	0.593	0.407
93EH-25	Snake	237	F	0.344	0.656
93EH-26	Snake	259	F	0.684	0.316
93EH-27	**Snake**	**259**	**F**	**0.242**	**0.758**
93EH-28	**Gr. Ronde**		**F**	**0.961**	**0.039**
93EH-29	Snake	258	F	0.315	0.685
93EH-36	Snake	382	F	0.437	0.563
93EH-41	Clearwater		F	0.503	0.497
93EH-42	Clearwater		F	0.424	0.576
93EH-43	Clearwater		F	0.593	0.407
93EH-44	Clearwater		F	0.496	0.504
93EH-45	Snake R.	269	F	0.344	0.656
93EH-58	Clearwater		F	0.406	0.594

Figure 1. Analysis of genetic distance among chinook stocks from the Upper Columbia and Snake Rivers. Dendrogram was constructed using 30 loci and unweighted pair group method with Cavalli-Sforza & Edwards (1967) chord distance.



REFERENCES

Bugert, R., C. Busack, G. Mendel, K. Petersen, D. Marback, L. Ross and J. Dedloff. 1991. 1990 Lower Snake River Compensation Plan, Lyons Ferry fall chinook salmon hatchery program. 1990 evaluation report to U. S. Fish and Wildlife Service. Report AFF 1/L SR-91-15 Cooperative Agreement 14-1600001-90525. Washington Department of Fisheries.

Cavalli - Sforza, L. L., and S. W. F. Edwards. 19'67. Phylogenetic analysis: models and estimation procedures. Evolution 2 1: 550-570.

Cooney, T. 199 1. Estimation of Snake River fall chinook returns to Ice Harbor, LF Hatchery, and over Lower Granite. Washington Department of Fisheries memorandum, May 7, 1991.

Marshall, A. R., M. Miller, C. Busack, and S. Phelps. 1991. Genetic stock identification analysis of three 1990 Washington ocean and Strait of Juan de Fuca chinook salmon fisheries. GSI summary report 91-1. Washington Department of Fisheries.

TAC. 1992 (Technical Advisory Committee to Columbia River Compact). Biological assessment of the impacts of anticipated 1992 summer and fall season Columbia River Fisheries on listed Snake River species under the Endangered Species Act. May 1992.

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