Intensive Evaluation and Monitoring of Chinook Salmon and Steelhead Trout Production, Crooked River and Upper Salmon River Sites

Annual Report
1995

DOE/BP-21182-11

October 1999

This Document should be cited as follows:

Kiefer, Russell, Jerald Lockhart, ''Intensive Evaluation and Monitoring of Chinook Salmon and Steelhead Trout Production, Crooked River and Upper Salmon River Sites'', Project No. 1991-07300, 65 electronic pages, (BPA Report DOE/BP-21182-11)

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P.O. Box 3621
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This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views in this report are the author's and do not necessarily represent the views of BPA.

FISHERY RESEARCH

INTENSIVE EVALUATION AND MONITORING OF CHINOOK SALMON AND STEELHEAD TROUT PRODUCTION, CROOKED RIVER AND UPPER SALMON RIVER SITES

ANNUAL PROGRESS REPORT
January 1, 1995–December 31, 1995

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IDFG Report Number 00-15
October 1999

INTENSIVE EVALUATION AND MONITORING OF CHINOOK SALMON AND STEELHEAD TROUT PRODUCTION, CROOKED RIVER AND UPPER SALMON RIVER SITES

Annual Progress Report

By

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Project Number 91-73
Contract Numbers DE-B179-91BP21182

IDFG Report Number 00-15
October 1999

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ABSTRACT

The purpose of this intensive monitoring project is to determine the number of returning chinook salmon and steelhead trout adults necessary to achieve optimal smolt production and develop habitat enhancement mitigation accounting based on increases in wild/natural smolt production. Two locations in Idaho are being intensively studied to meet these objectives. Information from this research will be applied to parr monitoring streams statewide to develop escapement objectives and determine success of habitat enhancement projects.

The project to date has developed good information on the relationship between chinook salmon adult escapement and smolt production at low to medium seeding levels. Adult chinook salmon escapements have been too low for us to test carrying capacity. For steelhead trout, we have developed a relationship between parr populations and smolt production at low to high seeding levels, with limited information on carrying capacity.

Major findings of the project to date:

1. Estimates of chinook salmon egg-to-parr survival for brood year 1987-1994 in the headwater Salmon River averaged 25.5%, and for brood year 1989-1994 in Crooked River averaged 15.6%.

2. Estimates of chinook salmon parr-to-smolt survival for migratory years 1988-1995 in the upper Salmon River averaged 18.1%, and for migratory years 1989-1995 in Crooked River averaged 30.0%.

3. Estimates of age-2+ and older steelhead trout parr-to-smolt survival for migratory years 1988-1995 in the upper Salmon River averaged 26.3%, and for migratory years 1989-1995 in Crooked River averaged 37.6%. However, age-2+ and older steelhead trout parr-to-smolt survival has declined dramatically in the upper Salmon River, from an average of 51.4% for migratory years 1988 and 1989 to an average of 17.9% for migratory years 1990-1995. This decrease in upper Salmon River steelhead trout age-2+ and older parr-to-smolt survival coincided with the discovery of whirling disease in the upper Salmon River and our observation of juvenile steelhead trout with visual signs of the disease.

4. In all migratory years studied (1988-1995), the wild/natural spring chinook salmon smolts from both study areas arrived at Lower Granite Dam later than the majority of chinook salmon smolts (which are comprised predominately of hatchery fish). Migration improvement decisions should consider that wild/natural spring chinook salmon smolts arrive later at Lower Granite Dam than the more numerous hatchery spring chinook salmon smolts (Kiefer and Lockhart, 1993).

5. Our research indicates that in streams degraded by dredge mining, connecting off-channel ponds to the stream can increase the carrying capacity for chinook salmon parr (Kiefer and Forster, 1991), and complex instream structures can increase the carrying capacity for steelhead trout parr (Kiefer and Lockhart, 1995a).

6. Our data indicate that anglers can have a major impact on wild/natural steelhead trout parr populations in streams with high angler use and general fishing regulations. In 1992, we estimated that 10.9% of the age-1+ and 45.5% of the age-2+ wild/natural steelhead trout pre-fishing season populations in Crooked River were fishing mortalities with an estimated angler effort of 206 hours per hectare (Kiefer and Lockhart, 1995a).

7. Mortality of wild/natural chinook salmon parr PIT tagged in August and returned to their natural rearing habitat was not significantly different than for unhandled wild/natural chinook salmon parr in the same habitat over a two-month period (Kiefer and Lockhart, 1995a).

INTRODUCTION

Project 83-7 was established under the Northwest Power Planning Council's 1982 Fish and Wildlife Program, Measure 704 (d)(1) to monitor natural production of anadromous fish, evaluate Bonneville Power Administration habitat improvement projects, and develop a credit record for off-site mitigation projects in Idaho. Project 83-7 is divided into two subprojects: general and intensive monitoring. Results of the intensive monitoring subproject are reported here. Results from the general monitoring subproject will be reported in a separate document (Hall-Griswold and Petrosky in press). Fieldwork for the intensive monitoring subproject began in 1987 in the upper Salmon River and Crooked River (South Fork Clearwater River tributary) study areas.

The goals of the intensive monitoring subproject are to quantify escapement objectives for wild/natural anadromous stocks that optimize smolt production and provide mitigation accounting based on increases in smolt production. Our approach to determine escapement needs for wild/natural anadromous stocks is: 1) to estimate egg deposition using weir counts of returning adults, redd counts, and carcass surveys; 2) to use snorkel counts and stratified random sampling to estimate parr abundance and egg-to-parr survival; 3) to PIT tag representative groups of parr and use PIT tag detections at the lower Snake and Columbia rivers' smolt collecting dams to estimate parr-to-smolt survival; and 4) to use adult outplants into tributary streams to estimate egg-to-parr survival and carrying capacity. Our approach to mitigation accounting based on increases in smolt production is: 1) to estimate parr production attributable to habitat projects; 2) to quantify relationships between spawning escapement, parr production, and smolt production; and 3) to use smolt production as a basis for assessing habitat improvement benefits.

OBJECTIVES

The objectives of this project are to determine:

1. The mathematical relationship between spawning escapement, parr production, and smolt production,

2. Carrying capacity and optimal smolt production, and

3. Habitat factors relating to substrate, riparian, and channel quality that limit natural smolt production.

STUDY AREAS

Upper Salmon River

The Salmon River originates at elevations above 2,800 m in the Smoky Mountains in south central Idaho. The upper Salmon River study area is the entire Salmon River drainage upstream of the Sawtooth Hatchery weir at 1,980 m elevation (Figure 1). Tributary streams in the upper Salmon River drain watersheds of the Sawtooth Range and Smoky Mountains on the west and the Boulder

Mountains and White Cloud Peaks on the east. The Salmon River and tributaries upstream from and including Pole Creek are considered as the headwaters Salmon River.

The river above Sawtooth Fish Hatchery is a major production area for spring chinook salmon *Oncorhynchus tshawytscha* and A-run summer steelhead trout *O. mykiss*. Other resident salmonids in the upper Salmon River drainage are native rainbow trout *O. mykiss*, cutthroat trout *O. clarki*, bull trout *Salvelinus confluentus*, mountain whitefish *Prosopium williamsoni*, and non-native brook trout *S. fontinalis* (Mallet 1974).

Historically, sockeye salmon *O. nerka* existed in all moraine lakes in the Stanley Basin (Everman 1895). An extremely depressed remnant run of sockeye salmon returns to Redfish Lake. The outlet of Redfish Lake enters the Salmon River approximately 2.7 km downstream from Sawtooth Hatchery. Occasionally, adult sockeye salmon have been seen in Alturas Lake Creek (K. Ball, Idaho Department of Fish and Game, personal communication), but an irrigation diversion that completely dewatered the stream every summer made adult passage to the lake unlikely (Bowles and Cochnauer 1984). In 1992, most of the Alturas Lake Creek water rights were purchased, and the irrigation diversion was rebuilt with Bonneville Power Administration mitigation funding. Adult sockeye salmon passage is now possible. No other sockeye salmon runs are known to exist in the Salmon River drainage.

Nearly pristine water quality and an abundance of high quality spawning gravel and rearing habitat is present throughout much of the upper basin. Water flows at the Sawtooth Hatchery range from lows of 1.73-3.46 m^3/s from July through April to highs of 11.2-23.3 m^3/s during May and June. Conductivity in the upper Salmon River drainage ranges from 37-218 mhos/cm (Emmett 1975).

Livestock grazing and hay production are the predominant uses of private land throughout the upper Salmon River basin. In localized areas, grazing within riparian zones has degraded aquatic habitat. Additionally, diversion of water from the river and its tributaries has impaired the production potential for chinook salmon and steelhead trout. Flow diversion from other tributary streams varies from partial to complete dewatering. Five major tributary creeks in the upper Salmon River (Fourth of July Creek, Champion Creek, Fisher Creek, Williams Creek, and Beaver Creek) are completely dewatered on their lower ends during the summer and early fall. In 1992, most of the water rights to Busterback Ranch on the Salmon River between Alturas Lake Creek and Pole Creek were purchased with Bonneville Power Administration mitigation funds. Until this time, the Busterback Ranch diversion at river kilometer 639 dewatered a section of the Salmon River during the summer and early fall in low to average water flow years.

In 1982, a water user along Pole Creek converted from flood irrigation to overhead sprinkler irrigation. This has decreased the withdrawal of water from Pole Creek. In 1983, Bonneville Power Administration funded the construction of a fish screen for the Pole Creek irrigation diversion. From 1985 to 1989 steelhead trout fry were outplanted into upper Pole Creek (Idaho Department of Fish and Game, unpublished data). Additionally, as part of this project's research, adult chinook salmon were outplanted into Pole Creek from 1988 to 1990 and adult steelhead trout were outplanted in 1991.

The Sawtooth Fish Hatchery was constructed in cooperation with the U.S. Fish and Wildlife Service and the U.S. Army Corps of Engineers through the Lower Snake River Compensation Plan. The hatchery program involves trapping adult chinook salmon and steelhead trout and releasing smolts and other life stages. The hatchery is designed to produce 2.4 million chinook salmon smolts per year. Eyed steelhead trout eggs are sent to other facilities for rearing. The steelhead trout smolts are transported back to Sawtooth Hatchery for release. The plan is to release 4.5 million steelhead trout smolts at Sawtooth Hatchery.

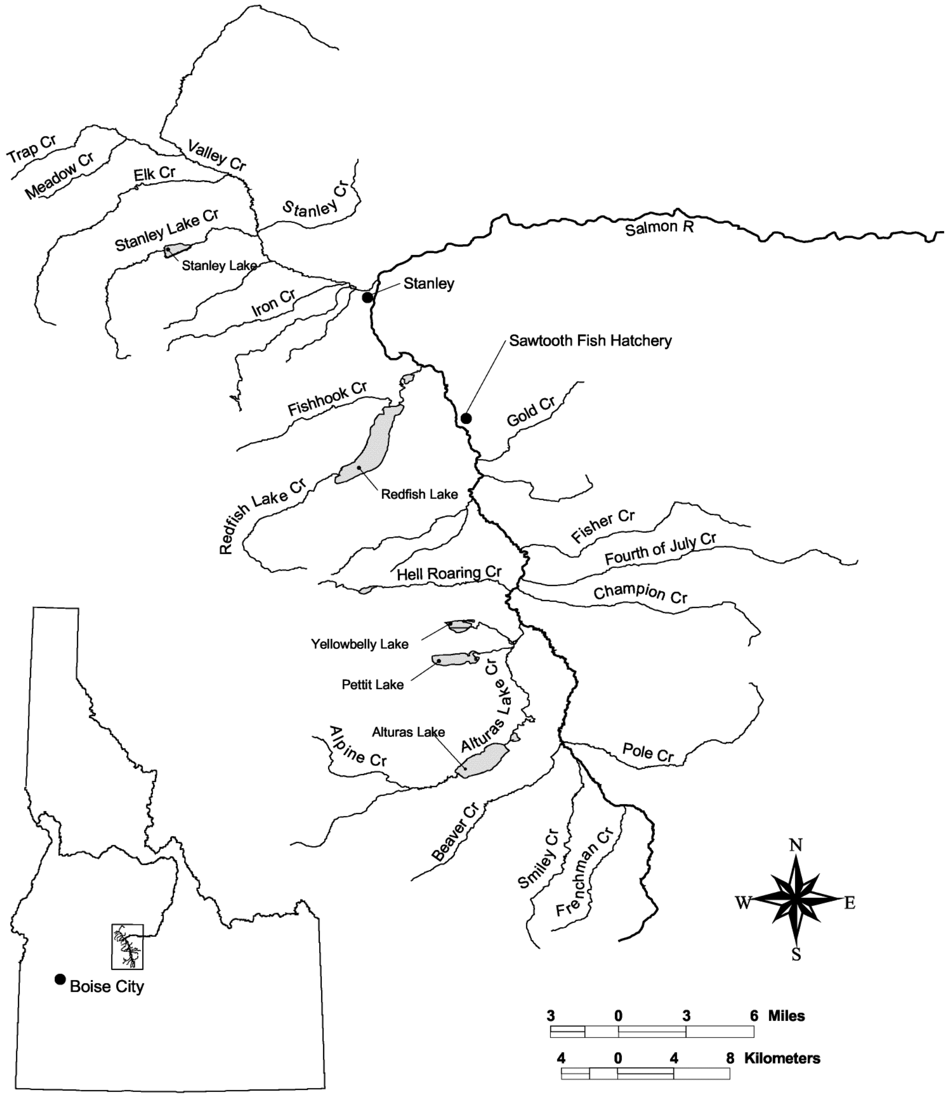

Figure 1. Location of upper Salmon River study area.

Crooked River

Crooked River originates at an elevation of 2,070 m in the Clearwater Mountains within the Nez Perce National Forest and enters the South Fork Clearwater River at river kilometer 94 at an elevation of 1,140 m (Figure 2). The study area includes the entire Crooked River drainage. Historical chinook salmon and steelhead trout runs were eliminated in 1927 by the construction of Harpster Dam on the South Fork Clearwater River. Following removal of the dam in 1962, spring chinook salmon and B-run summer steelhead trout were reestablished in Crooked River. Other resident salmonids in the Crooked River drainage are native rainbow trout, cutthroat trout, bull trout, mountain whitefish, and non-native brook trout (Petrosky and Holubetz 1986). Measured flows on Crooked River from 1991 through 1994 ranged from 0.285-6.88 m^3/s. Conductivity ranges from 29-39 µmhos/cm in flowing sections and 38-51 µmhos/cm in off-channel ponds (Mann and Von Lindern 1987).

During the 1950's, dredge mining activities severely degraded habitat within the two meadow reaches of the stream. In the upstream meadow reach, the stream was forced to the outside of the floodplain. This resulted in a mostly straight, high gradient channel. In the lower meadow reach, dredge tailings have forced the stream into long meanders with many ponds and sloughs. During runoff, juvenile trout and chinook salmon use some of these ponds and can be trapped as flows recede.

Fish density and habitat surveys were initiated in 1984 by Idaho Department of Fish and Game (IDFG) and the Intermountain Forest and Range Experiment Station, U.S. Forest Service, Boise, Idaho. In 1984, in an effort to compensate for stream gradient and to increase the pool to riffle ratio, the U.S. Forest Service, with Bonneville Power Administration funds, placed a series of log structures, rock and boulder deflectors, organic debris structures, and loose rock weirs in the upper meadow stream section. In addition, stream sides were stabilized and revegetated, an off-channel pond was connected with a side channel, and a culvert blocking adult passage was removed (Hair and Stowell 1986). Recent efforts have concentrated on connecting additional ponds in the dredge tailings to the main channel and developing side channels to provide continuous water supply during low flow periods.

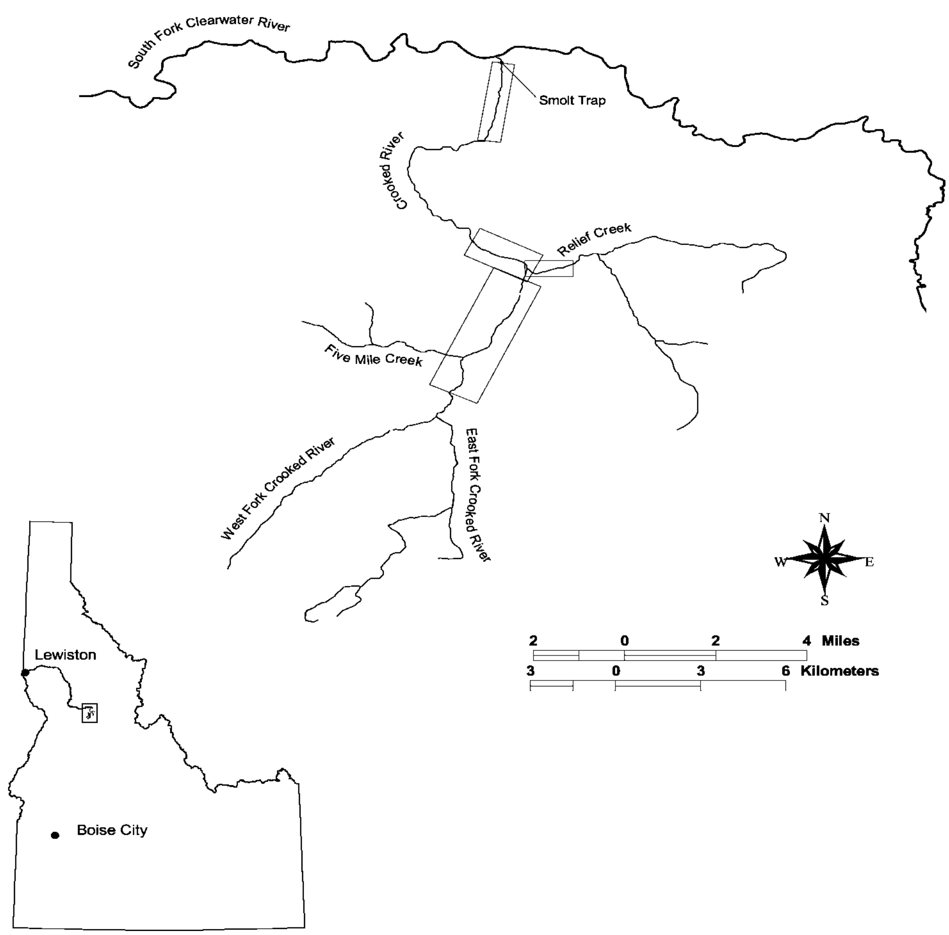

Figure 2. Location of Crooked River study area. Areas impacted by dredge mining are boxed.

METHODS

Study Area Structure

The upper Salmon River study area (Figure 1) was divided into strata that were established during Idaho habitat enhancement studies (Petrosky and Holubetz 1986). Each stratum contained at least two study sites of approximately 100 m length. The study area began at river kilometer 617 and ended at river kilometer 656. Tributary streams within the study area were divided into strata and each stratum had at least two study sites.

The Crooked River study area (Figure 2) also was divided into strata that were established during Idaho habitat enhancement studies (Petrosky and Holubetz 1986). In general, the strata were separated by habitat type. Off-channel ponds were included as two separate strata. B-ponds were off-channel ponds downstream of the Canyon stratum, and A-ponds were above the Canyon stratum (Figure 2). Relief Creek had two strata and Five Mile Creek had one stratum.

Adult Escapements

Adult escapements for chinook salmon and steelhead trout in the upper Salmon River and Crooked River were obtained from Sawtooth and Clearwater Fish Hatchery records, respectively. Except for the possibility of a small number of early adults which may have passed before weir placement, or when weir panels were pulled because of high water flow, the escapement into the study areas consisted of fish that were trapped at the weirs and released upstream to spawn naturally.

Adult Outplants

Upper Salmon River

The source of all adult chinook salmon and steelhead trout used for outplants in the upper Salmon River was adults trapped at the Sawtooth Fish Hatchery weir. Adults were released immediately above the weir.

Crooked River

Adult steelhead trout for outplants into Crooked River came from the Crooked River adult trap. Adults were released immediately above the weir. Crooked River was walked twice weekly to count redds and mortalities following the adult steelhead outplants. Mid-eye-to-hypural plate length (MEH length) was measured on female mortalities and egg retention was estimated.

No female adult chinook salmon were captured at the Crooked River trap in 1995.

Redd Counts and Estimated Egg Deposition

Aerial redd counts were conducted by IDFG fisheries personnel on Crooked River for steelhead trout. This was a one-day peak count via helicopter. The steelhead trout redd count for Crooked River was conducted via helicopter from the town of Orogrande downstream to the weir excluding the Canyon stratum.

In addition to aerial counts, project personnel conducted ground redd counts of the entire probable steelhead trout and chinook salmon spawning areas and adult outplant areas in upper Salmon River and Crooked River. The counts were done in early May for steelhead trout and early September for chinook salmon. In 1995, since no adult female chinook salmon returned, no redd counts were conducted on Crooked River. The number of redds counted are reported in Elms-Cockrum, IDFG (in progress).

The numbers of effective female chinook salmon and steelhead trout spawning in the upper Salmon River were estimated as the number of females released above the Sawtooth Fish Hatchery weir multiplied by pre-spawning survival observed at Sawtooth Fish Hatchery (Coonts 1995, Snider 1995). The average fecundity for the females released above the weir was assumed to be the same as the average fecundity for those females spawned at Sawtooth Hatchery (Coonts 1995, Snider 1995).

The number of female steelhead trout effectively spawning in Crooked River was determined from carcass examinations. Egg deposition for steelhead trout was estimated as the number of effective female spawners multiplied by the average fecundity for B-run steelhead trout observed at Dworshak National Fish Hatchery (Ralph Rosenberg, personal communication) after adjusting fecundity for estimated egg retention.

Parr Abundance

Parr abundance by species and age class was estimated in both study areas by visual snorkel counts in established study sites. Densities (#parr/100 m^2) for each site were calculated using the visual counts and the surface area that the count encompassed. Snorkel counts were conducted in late July for Crooked River and late July and early August for upper Salmon. Total abundance of steelhead trout and chinook salmon parr for each study area was estimated by a multistage sampling design with visual estimation methods (Hankin 1986, Hankin and Reeves 1988).

August PIT Tagging

Chinook salmon and steelhead trout parr were PIT (Passive Integrated Transponder) tagged in their summer rearing areas during August in upper Salmon River and Crooked River. Depending on site suitability and species availability, fish were collected for PIT tagging with a minnow seine or with a Smith-Root model 12 electrofisher. Seines were used primarily to sample low gradient sections for chinook salmon parr and the electrofisher was used primarily to sample high gradient sections for steelhead trout parr. The electrofisher was operated with a 30.5 cm diameter anode ring on a 2.0 m pole and a 2.4 m rattail cathode trailing behind. A voltage setting between 200 and 400 V was used due to low conductivities in the two systems. Pulse rates of 90 cycles/sec are used when fishing primarily for chinook salmon and 30 cycles/sec when fishing for steelhead trout. To reduce the incidence of electrical burn marks and fish mortality, nylon netting was tied completely around the anode ring. This modification did not appear to impair capture effectiveness.

When collecting parr with seines, a herder/driver technique was normally used. A snorkeler herded fish upstream until enough fish were concentrated above a suitable seine placement site. A bag or minnow seine was then placed across the stream downstream of the fish. The snorkeler then walked around the fish, got back into the stream, and drove the fish into the seine. This was a very effective method for most areas with adequate stream depth.

Tagging procedures included anesthetizing fish with MS-222 (buffered with sodium bicarbonate) and injecting PIT tags into the body cavity using a 12-gauge hypodermic needle and modified syringe (Kiefer and Lockhart 1995a). Prior to use, PIT tags, needles, and syringes were sterilized by soaking in a 70% alcohol solution for at least 20 minutes. Syringes and needles were not reused until they were resterilized.

After each tag was inserted, a loop style PIT tag detector was used to detect and send the tag codes to a battery powered laptop computer. The National Marine Fisheries Service (NMFS) has found that once a functional tag has been successfully implanted in a fish, the tag failure rate has been less than 1% (Prentice et al., 1986). Fork length was measured to the nearest millimeter with a CalComp digitizer scale on all fish that were PIT tagged and all fish that were too small to tag (<55 mm for chinook salmon and <60 mm for steelhead trout). For most tagged fish, the weight was measured to the nearest 0.1 g on a Port-O-Gram balance. Perforated 1.0 m x 0.5 m x 0.7 m plastic tote boxes were used to hold fish before tagging, during recovery, and for 24-hour delayed mortality tests. Tags were retrieved from any mortalities.

Emigration Trapping

To monitor fall and spring emigration of juvenile anadromous fish, we used floating scoop traps equipped with a 1.0 m wide inclined traveling screen (manufactured by Midwest Fabrications Inc., Corvallis, Oregon). The upper Salmon River trap was located directly below the permanent weir at the Sawtooth Fish Hatchery. Water was funneled to the upper Salmon River trap from a 3.1 m wide bay of the weir. The funnel was constructed of a picket weir with 3.8 cm spaces. To evaluate the spring emigration, the trap was operated continuously (except for breakdowns) from early March to mid-June. To evaluate the fall emigration, the trap was operated from late August to early November. Due to low population estimates for 1995, a second trap was operated at the Sawtooth Hatchery intake bypass structure in the upper Salmon River. Fish marked and released at this intake trap and recaptured at the trap downstream at the weir were used to estimate numbers of fish emigrating from the upper Salmon River.

On Crooked River, the trap was located 0.2 km above the mouth about 20 m below the adult trapping weir. A rock weir installed in 1990 helps direct fish into the trap. To evaluate the spring emigration, the trap was operated continuously from early March to mid-June. To evaluate the fall emigration, the trap was operated from early September to early November.

At both sites, all juvenile chinook salmon and steelhead trout juveniles captured were anesthetized and scanned with a PIT tag reader to determine if they had been previously tagged. All untagged juveniles (up to 100 per species and age group) were PIT tagged using the same procedures described previously. After tagging, these fish were held in perforated live boxes 300-400 m upstream of the trap and released at dusk. Recaptures of these fish were used to calculate trap efficiency.

During spring 1995, the number of emigrating juveniles from upper Salmon River was low. Trap efficiencies were determined by grouping total daily releases. Daily releases of PIT-tagged juveniles for a particular species and age class were grouped until a large enough release group was made to expect an average of eight recaptures for each group. The proportion recaptured in each group was assumed to represent trap efficiency. During fall 1995 in upper Salmon River, due to low steelhead trout numbers the chinook salmon trap efficiency was used for steelhead trout. In Crooked River during the spring emigration, two groups were selected based on stream flows for estimating chinook salmon trap efficiency. Flows for the first group were $\leq 3.43\ m^3/s$, and flows for the second group were $>3.43\ m^3/s$. Steelhead trout trap efficiencies were estimated from total season catch.

The overall run estimates and 90% C.I. were obtained by summing the daily run estimates and recalculating confidence intervals. The daily run estimates were calculated by dividing the daily trap catches by the estimated trap efficiencies.

We used the fork-length frequency of the steelhead trout caught to estimate age composition of the steelhead trout emigrants. In the fall, steelhead trout parr <90 mm were considered fry, 90 mm to 124 mm were considered age-1+, and >124 mm were considered age-2+ and older. In the spring, steelhead trout <90 mm were considered age-1 parr, 90 mm to 129 mm were considered age-2 parr, and >129 mm were considered age-3 and older smolts.

Survival Rates

Estimates of the egg-to-parr survival (parr = age-0 for chinook salmon and age-1+ for steelhead trout) were calculated by dividing the parr population estimate by the estimated egg deposition that produced the parr.

The estimate of steelhead trout age-1+ to age-2+ survival was calculated using PIT tag detection rates at the smolt collecting facilities. For brood year 1992 steelhead trout, we divided the proportion of age-1+ parr PIT tagged in August 1993 and detected at the smolt collecting dams in spring 1995 by the proportion of age-2+ parr PIT tagged in August 1994 and detected at the smolt collecting dams in spring 1995.

We estimated the survival of age-0 chinook salmon and age-2+ and older steelhead trout PIT tagged in August to the onset of smolt migration in the spring using PIT tag detections at the smolt collecting dams on the lower Snake and Columbia rivers. We assumed that the groups being compared suffered the same tagging mortality and that smolts from both groups that survived to the dams were detected at the same rate. The equation for the estimate of August tagged parr-to-smolt was as follows:

$$S_{\text{Study Area}} = PTD_A / PTD_S$$

Where:

PTD_A = Proportion of August PIT-tagged parr detected at the dams
PTD_S = Proportion of spring PIT-tagged smolts detected at the dams
$S_{\text{Study Area}}$ = The proportion of August parr surviving to smolts at the onset of smolt migration.

We used a similar methodology to estimate survival to the head of Lower Granite Reservoir (LGR) pool for chinook salmon and steelhead trout smolts captured and PIT tagged at our emigrant traps in the spring. For these estimates, we assumed that LGR pool tagged smolts were detected at the dams at the same rate as smolts we tagged, that both groups suffered the same tagging mortality, and that both groups suffered the same migration mortality through LGR pool. The equation for the estimate was as follows:

$$S_{LGR\ pool} = PTD_{Study\ Area} / PTD_{LGR\ pool}$$

Where:

$S_{LGR\ pool}$ = the proportion of the study area PIT-tagged smolts surviving to head of LGR pool.
$PTD_{Study\ Area}$ = proportion of the study area PIT-tagged emigrating smolts detected at the dams
$PTD_{LGR\ pool}$ = proportion of LGR pool PIT-tagged smolts detected at the dams

RESULTS

Upper Salmon River

Spring 1995 Emigration Trapping

In spring 1995, we operated a juvenile out-migrant trap on the upper Salmon River to estimate smolt emigration for chinook salmon, steelhead trout, and sockeye/kokanee. This trap was operated continuously from March 10 to June 6 except for June 1 when a log jammed the trap and no fish were captured. We captured 629 chinook salmon smolts, 73 steelhead trout juveniles, and 7 emigrating sockeye/kokanee juveniles. We estimated spring 1995 upper Salmon River emigrations of 12,096 chinook salmon smolts, 1,259 steelhead trout juveniles, and 135 sockeye/kokanee juveniles (Appendix A.) Daily run estimates are shown in Figure 3. Age composition of steelhead trout emigrants based on size of trapped fish was 5.7% (72) age-1, 42.9% (540) age-2, and 51.4% (647) age-3 and older smolts.

On March 27, 1995, 98,196 hatchery chinook salmon smolts from Sawtooth Hatchery were released 25 km upstream of the emigrant trap. We captured 11,092 of these hatchery chinook salmon smolts in the emigrant trap. We PIT tagged and released 303 of these smolts 0.5 km upstream of the trap to estimate trap efficiency for hatchery chinook salmon smolts. We estimated that 69,761 (71.0%) of this hatchery chinook salmon smolt release emigrated past the Sawtooth Hatchery Weir (Appendix A). We assumed that the remainder of the hatchery chinook salmon smolts either died or residualized.

Estimated Steelhead Trout Egg Deposition

In spring 1995, 532 (153 female) adult steelhead trout were captured at the Sawtooth Fish Hatchery Adult trap (Snider 1995). Four natural adults (2 female) and 2 hatchery adults (male) were released immediately above the weir to spawn naturally. On April 12 and May 9, a total of 12 adult hatchery males and 7 adult hatchery females were released into a 1.3 km study section of Beaver Creek. Movement out of the study section was prevented by a temporary weir.

No aerial or ground redd counts were conducted in the upper Salmon River. Seven redds were observed in the Beaver Creek study section.

We used the average fecundity observed by Snider (1995) at Sawtooth Hatchery (4,407) to estimate egg disposition. We assumed the two natural females released immediately above the weir spawned successfully and completely. No carcasses were recovered for evaluation of egg retention. Estimated total steelhead trout egg deposition in the upper Salmon River in 1995 was 39,663 (Table 1).

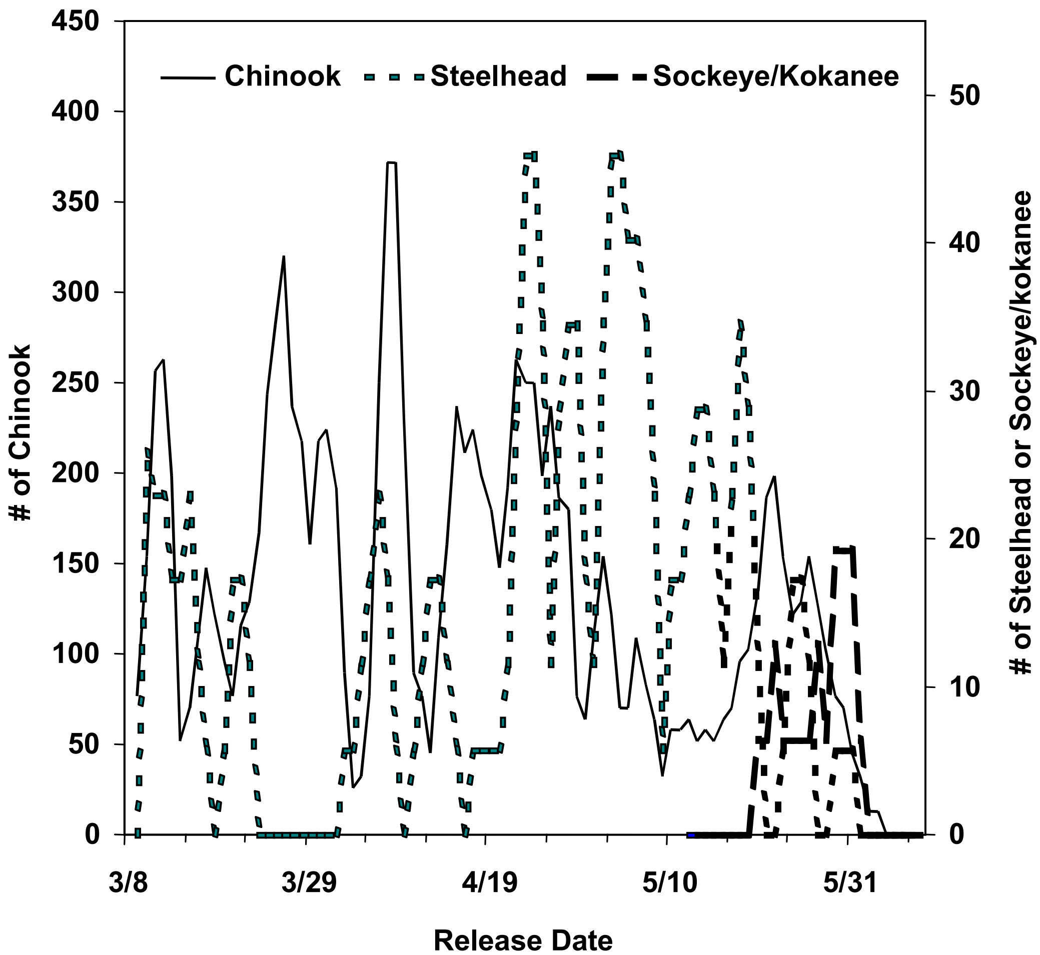

Figure 3. Spring 1995 upper Salmon River chinook salmon and steelhead trout daily run estimates (3-day moving average).

Table 1. Adult steelhead trout escapement, redd counts, and estimate of eggs deposited (in thousands) for upper Salmon River, brood years 1987-1995. Total escapement, female escapement, and eggs/female data are from Sawtooth Hatchery brood year reports. Redd count data are from Idaho Fish and Game redd count reports.

Brood Year	Total escapement	Female escapement	Helicopter redd counts; mainstream	Ground redd counts; tributaries	Eggs per female	Estimated eggs deposited
1987	979	383	-	-	4,854	1,859.0
1988	635	136	-	-	5,069	689.3
1989	378	157	-	-	5,637	885.0
1990	528	219	56	4	4,734	1,036.7
1991	91	15	15	2	4,019	60.3
1992	672	175	29	-	4,581	760.4
1993	668	178	36	14	4,460	753.7
1994	57	27	-	21	5,731	120.4
1995	25	9	-	7	4,407	39.7[a]

[a] It is assumed that the two natural adult females released above the weir in 1995 were successful spawners.

PIT Tag Detections

Detections of PIT-tagged smolts at the lower Snake and Columbia rivers' smolt collecting dams provide information on chinook salmon and steelhead trout smolt migration characteristics. For chinook salmon smolts and emigration date from the upper Salmon River, we observed a significant negative correlation with travel time to Lower Granite Dam and a significant positive correlation with combined detection rate at the smolt collecting dams (Figure 4). Mean smolt travel times to Lower Granite Dam and 90% confidence intervals were estimated to be 34.5 ± 1.9 days for chinook salmon (n = 178), and 26.7 ± 12.9 days for steelhead trout (n = 10).

The combined PIT-tag detection rates at the smolt collecting dams for juvenile chinook salmon and steelhead trout captured and PIT tagged in the upper Salmon River are summarized in Table 2. The combined detection rate for wild/natural smolts PIT tagged by Buettner and Brimmer (1995) at the Snake River trap near Lewiston in 1995 was 80.9% for chinook salmon and 84.4% for steelhead trout.

In spring 1995 no upper Salmon River chinook salmon smolt length group had a significantly different detection rate (χ^2 = 1.79; 0.90 > P > 0.75) (Table 3). We assume that most of the steelhead trout juveniles smaller than 130 mm in fork length will rear another year or more before smolting.

Parr Abundance

During the second half of July, we conducted snorkel counts in established study sites of the upper Salmon River to estimate densities and total abundance of chinook salmon and steelhead trout parr. For the upper Salmon River, estimated total parr abundances were: 12,344 age-0 chinook salmon, 2,002 age-1+ steelhead trout, and 315 age-2+ and older steelhead trout (Appendix B).

Estimated total abundance and densities for both age-0 chinook salmon and age-2+ and older steelhead trout were the lowest observed since intensive evaluation began in 1987 (Appendices B, C1 and C2). Estimated total abundance and densities for age-1+ steelhead trout were among the lowest observed as well (Appendices A and C3).

PIT Tagging

We collected and PIT tagged 1,049 age-0 chinook salmon parr during August in the upper Salmon River. August collection mortalities totaled 0.06% (1 of 1,818) chinook salmon. August PIT tagging and 24-hour delayed mortalities totaled 0.0% (0 of 1,049) for chinook salmon. Most of the parr collected and not tagged were either too small to tag or enough parr had been tagged in that stratum for our evaluation group.

The PIT-tagged age-0 chinook salmon were divided into the following three different evaluation groups: lower study area (446 tagged), Frenchman Creek (501 tagged), and headwaters Salmon River (97 tagged). We decided not to collect and PIT tag steelhead trout juveniles during August because densities were too low to meet sample size requirements for an evaluation group.

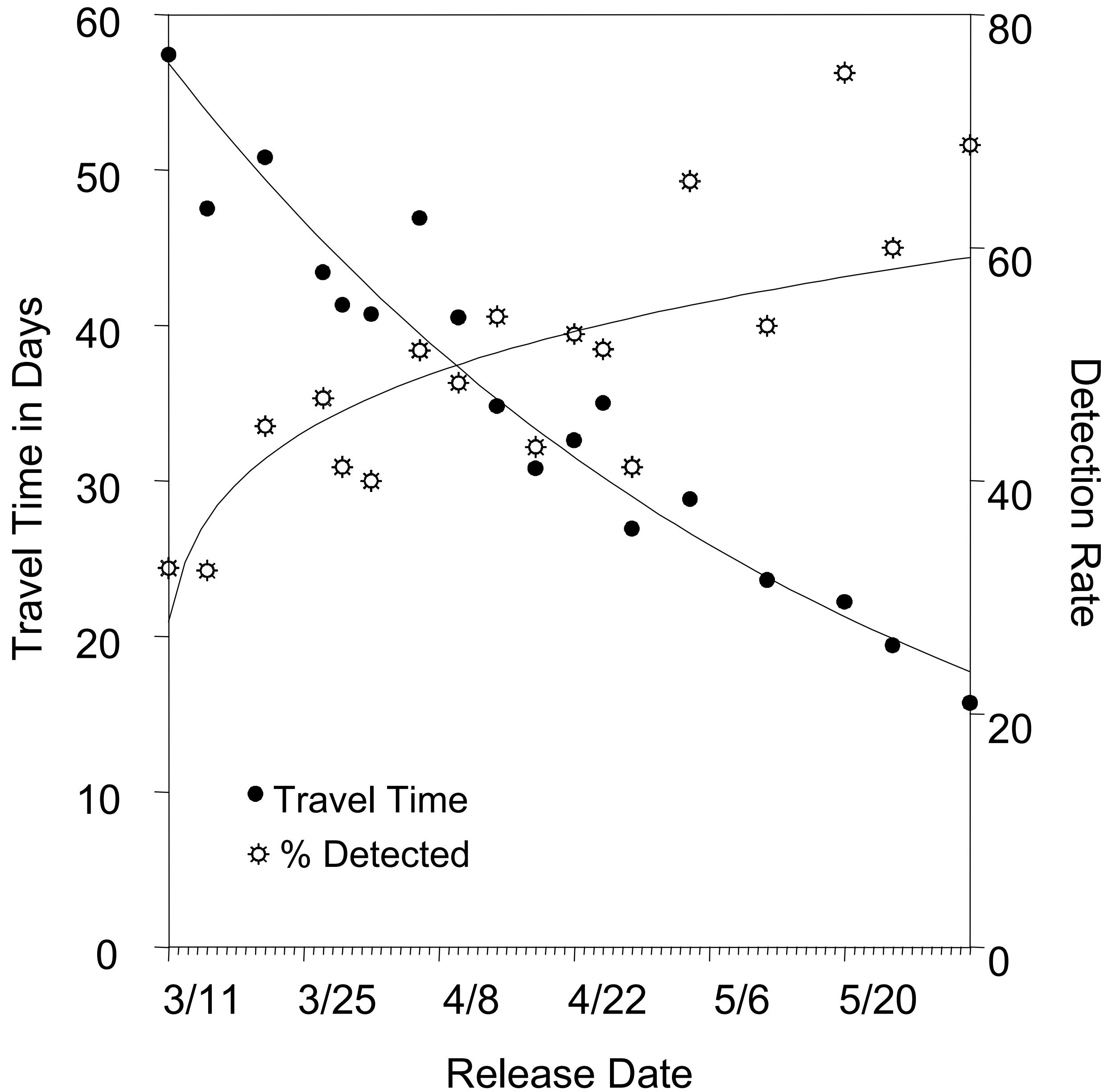

Figure 4. Spring 1995 PIT-tagged chinook salmon smolt travel time from the upper Salmon River trap to Lower Granite Dam and detection rate. Data shown are an average for a minimum 30-smolt release group.

Table 2. Detections in 1995 at the Lower Snake and Columbia River smolt collecting dams of PIT-tagged juveniles from upper Salmon River.

Stratum	Brood Year 1993 Chinook Number tagged	Brood Year 1993 Chinook Number detected	Brood Year 1993 Chinook Percent detected	Steelhead age-2+ and Older Number tagged	Steelhead age-2+ and Older Number detected	Steelhead age-2+ and Older Percent detected
Alturas Lake C.	331	13	3.9	0	0	0.0
Beaver C.	534	40	7.5	23	2	8.7
Frenchman C.	593	35	5.9	0	0	0.0
Huckleberry C.	259	31	12.0	6	0	0.0
Pole C.	189	3	1.6	1	0	0.0
Smiley C.	499	26	5.2	19	7	36.8
SR-3[a]	531	19	3.6	1	0	0.0
SR-9 & 10[b]	641	16	2.5	96	3	3.1
August 1994 Totals	3,577	183	5.1	146	12	8.2
Fall 94 Totals	1,141	167	14.6	13	2	15.4
Spring 95 Totals	637	315	49.5	36	11	30.6

[a] SR-3 is the Salmon River from the Sawtooth Hatchery Weir upstream to Williams Creek (river km 622).
[b] SR-9&10 is the Salmon River upstream of Pole Creek (river km 642).

Table 3. Smolt length and PIT tag detection at lower Snake and Columbia River smolt collecting facilities for upper Salmon River, spring 1995.

Length(mm)	Number tagged	Number detected	Percent detected
	Chinook		
<80	31	14	45.2
80-89	203	93	45.8
90-99	294	140	47.6
100-109	118	58	49.2
>109	24	8	33.3
Total	670	313	46.7
	Steelhead		
<90	4	0	0.0
90-129	31	1	3.2
>129	39	11	28.2
Total	74	12	16.2

Fall 1995 Emigration Trapping

The juvenile trap at the Sawtooth Hatchery Weir captured 383 chinook salmon presmolts and 14 juvenile steelhead. We estimated fall 1995 upper Salmon River emigrations to be 9,821 chinook salmon presmolts and 359 steelhead trout juveniles (Appendix D). Daily run estimates are shown in Figure 5. Age composition of steelhead trout emigrants based on size at trapped fish was 31% (112) age-0, 0% age-1+, and 69% (247) age-2+ and older. We did not recapture any steelhead trout juveniles to estimate trap efficiency, and we assumed that they were captured with the same trap efficiency as chinook salmon presmolts. Because of this assumption and the small number captured, we are not very confident in the estimate of steelhead trout emigration.

Estimated Chinook Salmon Egg Deposition

In 1995, 20 (2 female) of the 37 (4 female) adult chinook salmon captured at the Sawtooth Fish Hatchery adult trap were released above the weir to spawn naturally (Table 4).

On September 7 and 8, no chinook salmon redds were observed via ground counts in all probable natural spawning areas (Table 4). Because no redds were observed, the estimated number of eggs deposited is zero.

Survival Rates

The brood year 1994 chinook salmon egg-to-parr survival for the headwaters of the Salmon River was estimated to be 27.8%, and for brood years 1987-1994 averaged 25.5% (Table 5). Estimated brood year 1993 steelhead trout egg-to-age-1+ parr survival rate for the entire upper Salmon River was only 0.9%.

We estimated that 1995 chinook salmon parr-to-smolt survival in the upper Salmon River was 10.3%, and for migration years 1988-1995 averaged 18.1% (Table 6). For chinook salmon smolts PIT tagged during the spring 1995 smolt emigration, the estimated survival to the head of LGR was 61.2%, and for migration years 1988-1995 averaged 48.5% (Table 6).

We estimated that 1995 steelhead trout age-2+ and older parr-to-smolt survival was 26.8%, and for migration years 1988-1995 averaged 25.1% (Table 7). For age-3 and older steelhead trout smolts PIT tagged during the spring 1995 smolt emigration, the estimated survival to the head of LGR pool was 36.3%, and for migration years 1988-1995 averaged 38.4% (Table 7).

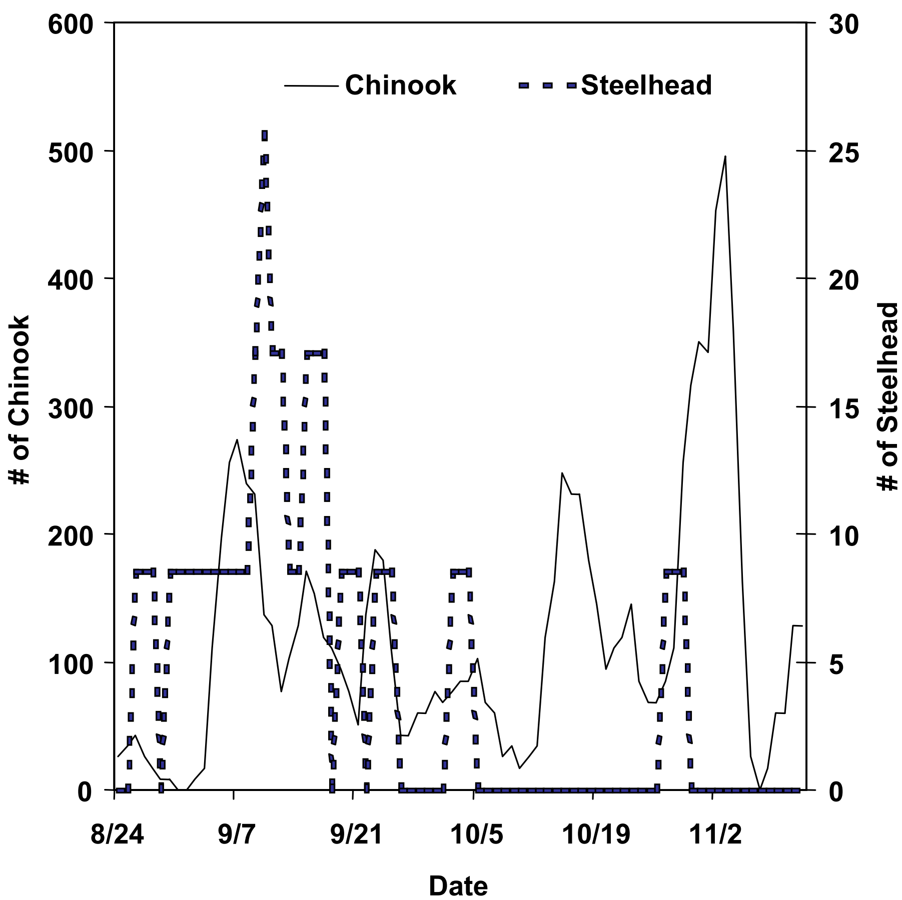

Figure 5. Fall 1995 upper Salmon River chinook salmon and steelhead trout daily run estimates (3-day moving average).

Table 4. Adult chinook salmon escapement, redd counts, and estimate of eggs deposited (in thousands) for upper Salmon River, brood year 1986-1995. Total escapement, female escapement, and eggs/female data are from Sawtooth Hatchery brood year reports. Redd count data are from Idaho Fish and Game redd count reports.

Year	Total Escapement	Female escapement	Helicopter redd count	Ground redd count	Eggs per female[a]	Estimated eggs deposited[b]
1986	876	248	105	-	5,156	1,278.7
1987	506	252	124	-	5,399	1,360.5
1988	552	275	76	261	5,653	1,554.5
1989	470[c]	73[c]	52	123	5,456	671.1
1990	615	167[d]	60	100	4,501	450.1
1991	238	94	46	67	5,192	347.9
1992	145	56	29	27	4,503	193.7[e]
1993	423	209	61	127	4,834	613.9
1994	83	33	-	22	4,482	98.6
1995	20	2	-	0	3,750	0

[a] Number is average eggs/female observed at Sawtooth Fish Hatchery.
[b] Estimates of average egg retention are incorporated in calculating egg deposition.
[c] Portions of the Sawtooth Fish Hatchery weir were pulled due to high water, and uncounted fish probably passed the weir.
[d] Chinook escapement above Sawtooth Hatchery was reduced by at least 65 adults due to a rotenone kill.
[e] Because we believe we conducted our redd counts too early in 1992, we used the 1987-1992 average prespawning mortality observed at Sawtooth Fish Hatchery (5%) to estimate that 44 females spawned in 1992.

Table 5. Estimated chinook salmon egg-to-parr survival rates (%) from the headwaters of the upper Salmon River adult outplants and natural spawners, brood years 1987-1994. Brood years 1987-1994 headwaters of the Salmon River chinook salmon egg-to-parr survival averaged 25.5% (90% C.I.; 14.9% - 37.8%).

	Outplanted Adults		Natural Spawners;	Combined Numbers		
Brood Year	**Females outplanted**	**Redds observed**	**Redds Observed**	**Egg deposition**	**Parr production**	**Egg to parr survival (%)**
1987	6	5	0	26,995	8,625	32.0
1988	30	30	6	203,508	35,938	17.7
1989	9	9	4	72,800	5,054	6.9
1990	40	13[a]	0	58,513	18,214	31.1
1991	13	10	0	51,917	19,838	38.2
1992	10	9	0	39,627	1,509[b]	7.1[b]
1993	39	21	8	145,108	81,394	56.1
1994	8	5	0	22,410	6,240	27.8

[a] In 1990, we were unable to estimate total egg deposition in two of our outplant streams and data from these streams were not included in estimating egg-to-parr survival.

[b] Parr production estimates were biased downward due to uneven distribution of parr populations in outplant areas. We collected 503 parr for PIT tagging from the outplant area and collected no more that 1/3 of the population present. We therefore believe that at least 1,509 parr were produced.

Table 6. Headwaters upper Salmon River chinook salmon survival rate estimates, brood years 1987-1993.

Brood Year	Egg-to-Parr[a]	Parr-to-smolt (overwinter)	Egg-to-smolt	Smolt migration; trap to Lower Granite pool
1987[b]	32.0%	20.3%	6.5%	45.2%
1988[c]	17.7%	18.9%	3.3%	33.7%
1989[d]	6.9%	17.4%	1.2%	39.6%
1990[e]	31.1%	18.2%	5.7%	31.1%
1991[f]	38.2%	23.2%	8.9%	57.6%
1992	7.1%	22.0%	1.6%	39.4%
1993	56.1%	10. 3%	5.8%	61.2%

[a] Data from Table 5.
[b] Data except for egg-to-parr survival from Kiefer and Forster 1990.
[c] Data except for egg-to-parr survival from Kiefer and Forster 1991.
[d] Data except for egg-to-parr survival from Kiefer and Forster 1992.
[e] Data except for egg-to-parr survival from Kiefer and Lockhart 1993.
[f] Data except for egg-to-parr survival from Kiefer and Lockhart 1995a.

Crooked River

Spring 1995 Emigration Trapping

In spring 1995, the Crooked River juvenile emigrant trap captured 5,343 wild chinook salmon smolts and 421 steelhead trout juveniles (118 wild and 303 hatchery). We estimated total spring emigrations of 13,991 wild chinook salmon smolts, and 4,210 steelhead trout juveniles (1,180 wild) (Appendix E). Daily run estimates for wild/natural juveniles are shown in Figure 6. Age composition of wild steelhead trout emigrants based on size of trapped fish was 35.6% (421) age-1, 35.6% (421) age-2, and 28.7% (339) age-3 and older smolts.

During spring 1995, we captured hatchery chinook salmon smolts at the Crooked River emigrant trap from the following two releases: 415,535 (2,000 PIT tagged) presmolts on September 22, 1994; and 258,293 (2,397 PIT tagged) smolts on April 12, 1995. By April 12, we had captured 30,364 of the fall release hatchery chinook salmon with an estimated trapping efficiency of 41.0% and a run estimate of 74,059. After April 12, we captured 66,215 hatchery chinook salmon smolts with an estimated trapping efficiency of 40.0% and a run estimate of 165,538. We used the proportion of the released PIT-tagged hatchery chinook salmon that was recaptured at the emigrant trap after April 12 to calculate the proportions of the 165,538 that were released as presmolts in fall 1994 and those that were released as smolts in spring 1995. With this method, we estimated that 19,368 were released as presmolts in fall 1994, and 146,150 were released as smolts in spring

1995. We used these run estimates to calculate overwinter survival for the hatchery chinook salmon presmolt release to be 34%. For the hatchery chinook salmon smolt release in spring 1995, we estimated that 57% emigrated past our trap site. We assume that the remainder either died or residualized.

On April 29, 1994, two groups (71,566 Selway stock and 104,450 Dworshak stock) of age-1 steelhead trout juveniles were released from the hatchery ponds on Crooked River after two weeks of acclimation. In 1994, we estimated that approximately 85% and 40% of them respectively did not emigrate in spring 1994. In spring of 1995, we captured 196 Selway stock and 107 Dworshak stock steelhead trout juveniles in the emigrant trap, and we estimated emigrations of 1,960 (3% of original release group) Selway stock and 1,070 (1% of original release group) Dworshak stock.

Table 7. Upper Salmon River age-2+ and older steelhead trout survival rate estimates, migratory years 1988 to 1995.

Migratory Year	Parr-to-smolt (overwinter)	Smolt migration; trap to Lower Granite pool
1988[a]	54.9%	42.6%
1989[b]	48.0%	42.4%
1990[c]	24.8%	31.6%
1991[d]	14.5%	25.7%
1992[e]	10.2%	29.5%
1993[f]	16.0%	68.6%
1994[g]	15.5%	31.8%
1995	26.6%	36.5%

[a] Data from Kiefer and Forster 1990.
[b] Data from Kiefer and Forster 1991.
[c] Data from Kiefer and Forster 1992.
[d] Data from Kiefer and Lockhart 1993.
[e] Data from Kiefer and Lockhart 1995a.
[f] Data from Kiefer and Lockhart 1995b.
[g] Data from Kiefer and Lockhart (in progress).

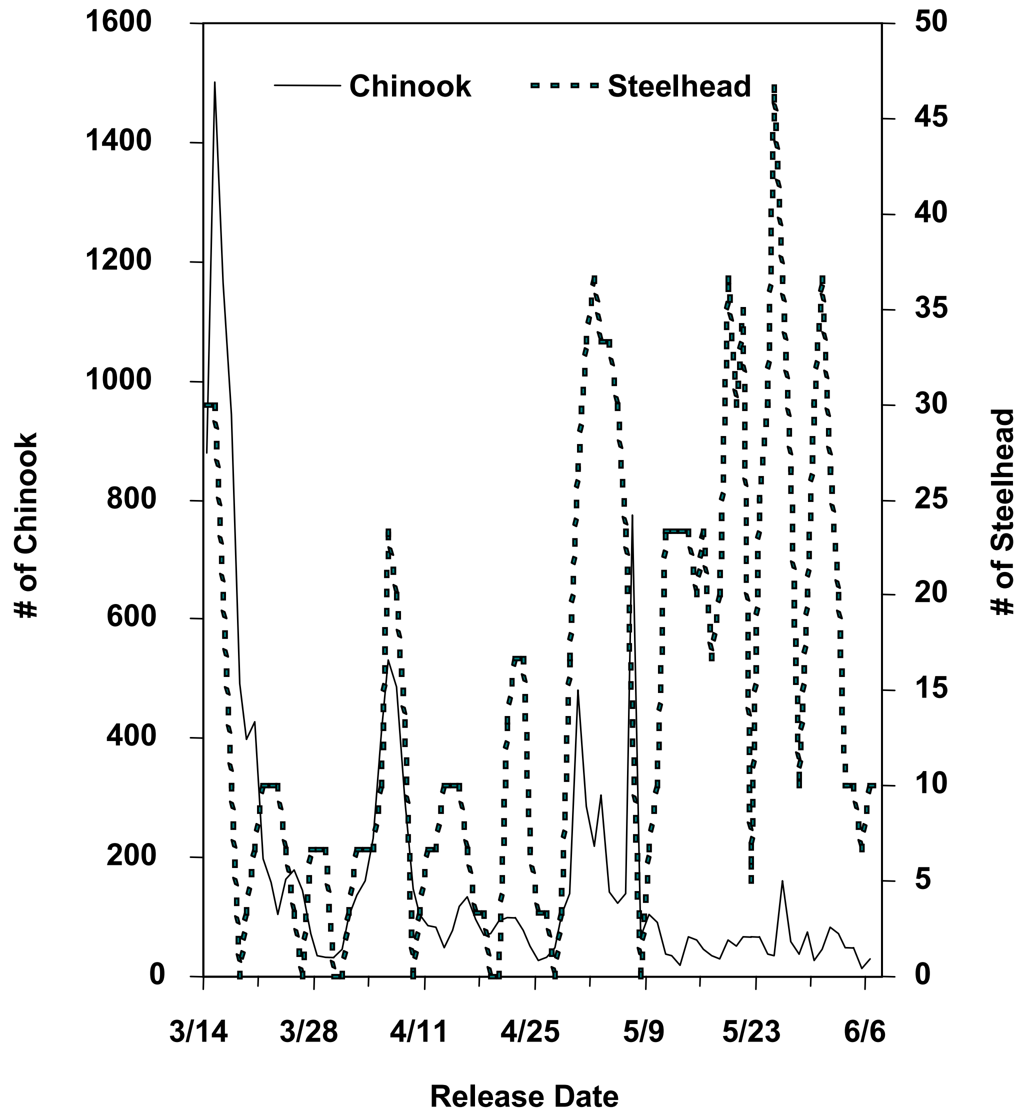

Figure 6. Spring 1995 Crooked River chinook salmon and steelhead trout daily run estimates (3-day moving averages).

Steelhead Trout Egg Deposition

In 1995, 17 adult steelhead trout (12 males, 4 females, and one unknown) were captured at the Crooked River adult trap. The first fish was trapped on April 8 and the last fish on May 24. Thirteen of the adults captured (10 males and 3 females) were wild/natural fish and were released upstream of the weir to spawn naturally.

The length of all wild/natural steelhead trout adults was measured, and scale samples were collected. A sterilized hole punch was used to collect an anal fin sample from the wild adult steelhead trout for a National Biological Survey (NBS) research project.

Aerial steelhead trout redd counts were conducted by fisheries research personnel on May 8, and four redds were observed. The weir had been removed several times in April for high water conditions, and adults possibly passed upstream during these times.

Our best estimate is that in 1995, four adult female steelhead trout spawned successfully and completely in Crooked River. Average egg retention was not calculated because no carcasses were found. The average fecundity for B-run steelhead trout observed at Dworshak National Fish Hatchery in 1995 was 6,470 eggs/female. From this information, we estimate that 25,880 steelhead trout eggs were successfully deposited in Crooked River in 1995.

PIT Tag Detections

Detections of PIT-tagged smolts at lower Snake and Columbia rivers' smolt collection facilities provide information on chinook salmon and steelhead trout smolt migration characteristics. For emigration date of chinook salmon smolts from Crooked River we observed a significant negative correlation with travel time to Lower Granite Dam and a significant positive correlation with combined detection rate at the smolt collection facilities (Figure 7). Mean smolt travel times with 90% C.I. to Lower Granite Dam were estimated to be 61.7 ± 2.0 days for 543 chinook salmon and 10.5 ± 2.6 days for 16 steelhead trout.

The combined PIT-tag detection rates at all the smolt collection facilities for wild/natural juvenile chinook salmon and steelhead trout captured, PIT tagged, and released in Crooked River are summarized in Table 8. The combined detection rate for wild/natural smolts PIT tagged by Buettner and Brimmer (1995) at the Clearwater River smolt trap in 1995 were 72.5% for chinook salmon and 79.9% for steelhead trout.

To determine if fish size had an effect on survival, we compared PIT tag detection rate and fish size for spring emigrants. In spring 1995 there was a significant difference in detection rate for chinook salmon smolt length groups ($\chi^2 = 56.2$; $P < 0.001$), with larger smolts being detected at a higher rate (Table 9).

On April 29, 1994, two groups (71,566 Selway stock and 104,450 Dworshak stock) of age-1 steelhead trout juveniles were released from the hatchery ponds on Crooked River after two weeks of acclimation. In 1994, we estimated that approximately 85% and 40% of these groups, respectively, did not emigrate in spring 1994. These steelhead trout juvenile releases in spring 1994 included 300 PIT-tagged Selway stock and 467 PIT-tagged Dworshak stock. In spring 1995 the smolt collection dams detected 1.7% (5) of the PIT-tagged Selway stock and 0.9% (4) of the Dworshak stock from the original releases in spring 1994.

In summer 1994, we estimated that approximately 18,000 Selway stock and 9,000 Dworshak stock were still in Crooked River. In August 1994 we PIT tagged 551 of the Selway stock and 336 of the Dworshak stock. In spring 1995, the smolt collecting dams detected only 1.8% (10) of the Selway stock and 3.3% (11) of the Dworshak stock from our tagging in August 1994. In spring 1995, we captured 196 Selway stock and 107 Dworshak stock steelhead trout juveniles in our emigrant trap. We PIT tagged or recaptured 140 of the Selway stock and 90 of the Dworshak stock. The smolt collection facilities detected 35% (49) of the Selway stock and 58.9% (53) of the Dworshak stock.

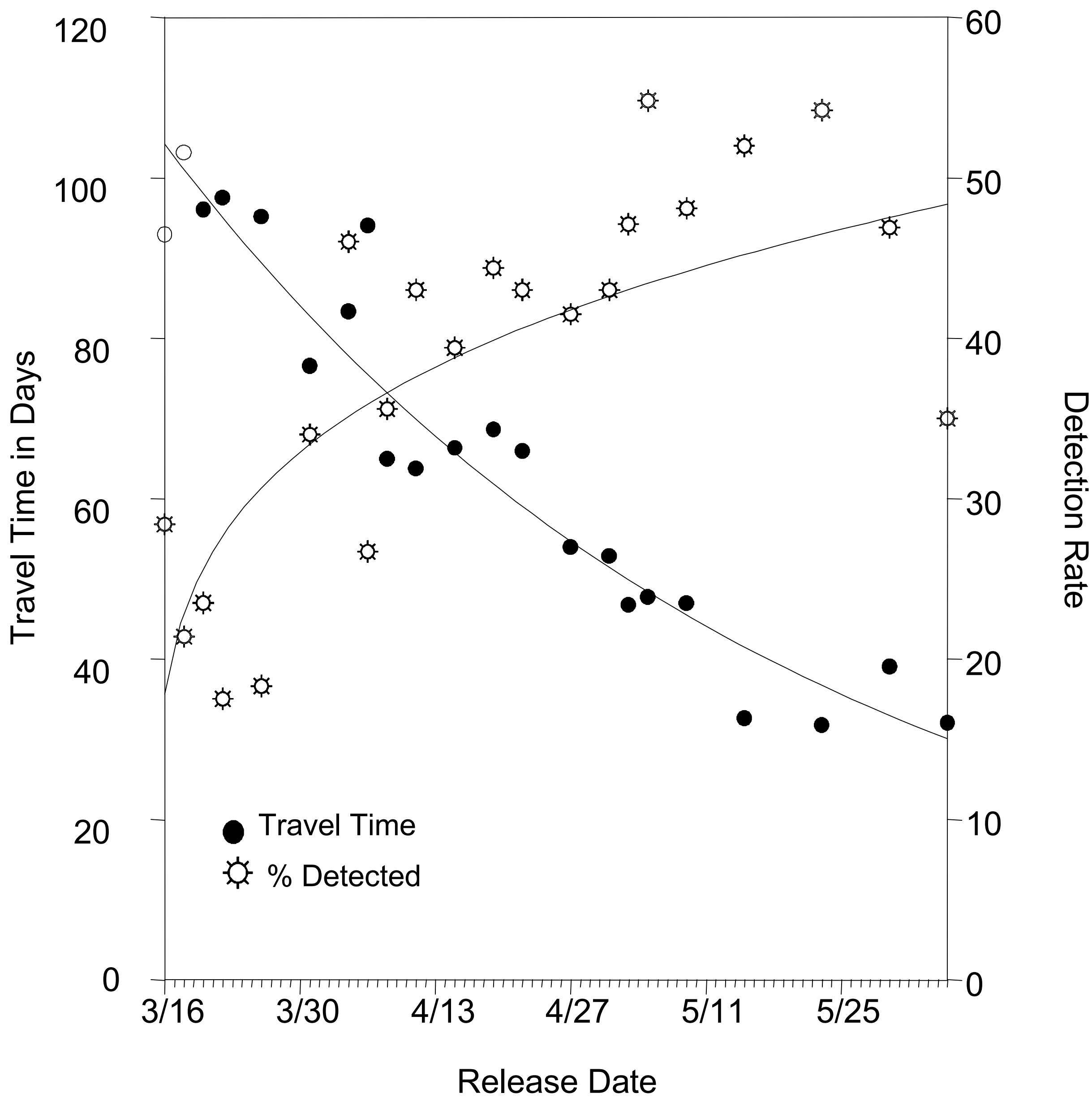

Figure 7. Spring 1995 PIT-tagged chinook salmon smolt travel time from the Crooked River trap to Lower Granite Dam and detection rate. Data shown is an average for a minimum 100-smolt release group.

Table 8. Detections in 1995 at the Lower Snake and Columbia River smolt collecting dams of PIT-tagged juveniles from Crooked River.

	Brood Year 1993 Chinook			Steelhead age-2+ and Older		
Stratum	Number tagged	Number detected	Percent detected	Number tagged	Number detected	Percent detected
CR 1&2[a]	407	65	16.0	12	1	8.3
Canyon	547	77	14.1	41	5	12.2
CR 3[b]	299	42	14.0	-	-	-
CR 4[c]	511	38	7.4	-	-	-
CR 3 & 4	-	-	-	31	8	25.8
Ponds A[d]	209	75	35.9	-	-	-
Ponds B[e]	273	86	31.5	-	-	-
August 94 Totals	2,246	383	17.0	84	14	16.7
Fall 94 Totals	1,165	121	10.4	35	14	40.0
Spring 95 Totals	2,451	940	38.4	37	24	64.9

[a] Strata CR 1 & 2 is Crooked River from the Canyon stratum upstream to the East and West forks.
[b] Stratum CR 3 is the more natural stream sections of Crooked River downstream of the Canyon stratum.
[c] Stratum CR 4 is the forced meandering section of Crooked River downstream of the Canyon stratum.
[d] Stratum Ponds A is the connected off-channel ponds upstream of the Canyon stratum.
[e] Stratum Ponds B is the connected off-channel ponds downstream of the Canyon stratum.

Table 9. Smolt length and PIT tag detection at lower Snake and Columbia River smolt collecting facilities for Crooked River, spring 1995.

Length(mm)	Number released	Number detected	Percent detected
	Chinook		
<70	104	20	19.2
70-80	828	246	29.7
80-89	1,002	406	40.5
90-99	392	197	50.3
100-109	108	59	54.6
>109	16	12	75.0
Total	2,450	940	38.4
	Steelhead		
<90	33	0	0.0
90-129	39	3	7.7
>129	37	24	64.9
Total	109	27	24.8

Parr Abundance

During the first half of July 1995, we conducted snorkel counts in established study sites on Crooked River to estimate densities and abundance of chinook salmon and steelhead trout parr. Estimated total parr abundances with 90% confidence intervals were: 4,601 ± 2,521 age-0 chinook salmon, 10,252 ± 2,702 age-1+ steelhead trout, and 2,598 ± 582 age-2+ and older steelhead trout (Appendix F). We also estimated that 6,708 Selway stock and 2,005 Dworshak stock hatchery steelhead trout residuals were still in Crooked River from the releases in spring 1994.

Chinook salmon parr densities and abundance in 1995 were the lowest we have estimated in Crooked River since 1989 (Appendix G1). Steelhead trout age-1+ and age-2+ and older parr densities and abundance in 1995 were about average (Appendix G2).

On July 15, 1994, NBS researchers released 19,243 Selway stock and 18,976 Dworshak stock steelhead trout fry into Crooked River as part of their research. These fry had been otolith marked so that they could be distinguished from naturally-produced steelhead trout of the same age. In summer 1995, the NBS researchers worked cooperatively with us to collect 200 juvenile steelhead trout to determine from otolith samples what proportion were naturally produced. The NBS analysis of these otoliths determined that 13.8% of the age-1+ steelhead trout juveniles collected were naturally produced. We therefore estimate that 1,415 of age-1+ steelhead trout in Crooked River were naturally produced.

PIT Tagging

During the first half of August, we collected and PIT tagged representative groups of chinook salmon and steelhead trout parr in Crooked River. We PIT tagged a total of 505 age-0 chinook salmon, 191 wild/natural steelhead trout parr, 340 residualized Selway stock steelhead trout smolts, and 134 residualized Dworshak stock steelhead trout smolts. The age composition of wild/natural steelhead trout parr PIT tagged was: 0.5% (1) age-0, 30.9% (59) age-1+, and 65.6% (131) age-2+ and older. August collecting and PIT tagging mortalities combined totaled 0% for both chinook salmon and steelhead trout. We PIT tagged only enough age-0 chinook salmon (505) and wild/natural age-2+ and older steelhead trout (131) for one evaluation group.

Fall Emigration Trapping

During fall 1995, we operated a juvenile emigrant trap on Crooked River to estimate chinook salmon and steelhead trout presmolt emigration. This trap was operated continuously from August 30 to November 2, 1995. We only captured 36 chinook salmon presmolts and 11 steelhead trout juveniles (8 wild/natural and 3 hatchery). Because we captured so few fall emigrants, we were unable to calculate trap efficiencies. We used a six-year trap efficiency average (1989-1994) to calculate an emigration estimate for fall 1995. This average efficiency was 28.2% for age-0 chinook salmon and 13.2% for juvenile steelhead. For 1995, we estimate that 128 age-0 chinook salmon smolts and 61 wild/natural steelhead trout juveniles and 22 hatchery steelhead trout juveniles emigrated from Crooked River. Daily run estimates are shown in Figure 8. All steelhead trout juvenile emigrants trapped were age-2+ and older juveniles.

Estimated Chinook Salmon Egg Deposition

In 1995, no adult chinook salmon females were captured at the Crooked River adult trap (McGehee 1995). Five adult chinook salmon males were captured. The weir was in place during the entire time we would expect adult chinook salmon to arrive at Crooked River. Because no females were captured, we did not conduct any chinook salmon redd counts and believe no chinook salmon eggs were deposited (Table 10).

Survival Rates

The brood year 1994 chinook salmon egg-to-parr survival rate for Crooked River was estimated to be 25.9% and averaged 15.6% for brood years 1989-1994 (Table 11). The estimated brood year 1994 steelhead trout egg-to-age-1+ parr survival rate for Crooked River was estimated to be 11.8%.

We estimated the brood year 1992 steelhead trout age-1+ to age-2+ parr survival for Crooked River to be 64.1%. This estimate was made by dividing the 1995 detection rate at the smolt collection facilities for age-1+ steelhead trout parr tagged in August 1993 [0.107 (29 of 272)] by the 1995 PIT tag detection rate for age-2+ steelhead trout parr tagged in August 1994 [0.167 (14 of 84)].

We estimated that brood year 1993 chinook salmon parr-to-smolt survival in Crooked River was 44.2% and averaged 30.0% for brood years 1988-1993 (Table 12). For chinook salmon smolts

PIT tagged during the spring 1995 out-migration, the estimated survival to the head of LGR was 53.0% and averaged 50.2% for migration years 1989-1995 (Table 12).

We estimated that migration year 1995 steelhead trout age-2+ and older parr-to-smolt survival in Crooked River was 25.7% and averaged 37.6% for migration years 1989-1995 (Table 13). For Crooked River age-3 and older steelhead trout smolts PIT tagged during the spring 1995 emigration, the estimated survival to the head of LGR was 81.2% and averaged 74.8% for migration years 1989-1995 (Table 13).

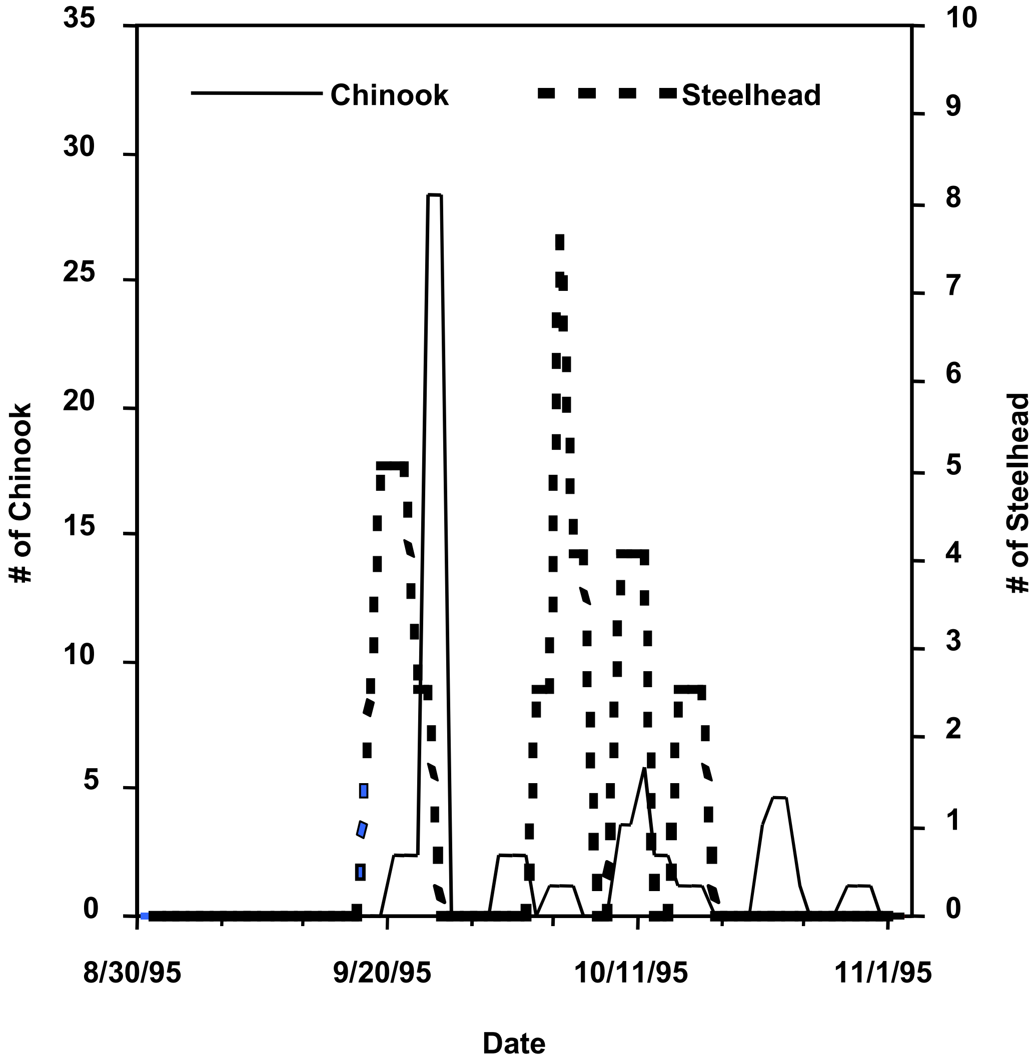

Figure 8. Fall 1995 Crooked River chinook salmon and steelhead trout daily run estimates (3-day moving average).

Table 10. Estimated chinook salmon adult escapement, redd counts, and number of eggs deposited for Crooked River, 1985-1995.

Brood year	Female escapement[a]	Trend Redd Count	Ground Redd Count	Eggs/female[c]	Estimated number of eggs deposited (x1000)
1985	16	10	-	-	67.54
1986	14	9	-	-	59.09
1987	27	17	-	4,010	108.27
1988	43	27	43	-	181.50
1989	15	3	15	4,400	66.00
1990	95	-	10[b]	4,200	399.00
1991	5	-	4	4,400	17.60
1992	91	-	54	3,805	205.47
1993	75	-	54	4,766	247.85
1994	6	4	4	4,440	17.76
1995	0.0000	0.0000	0.0000	-	0.00000000

[a] Female escapement was estimated for 1985-1987 based on 1/1 ratio of female escapement to ground counts observed in upper Salmon River, and 43/27 ratio of ground to trend redd counts observed in 1988. Female escapement in 1988 and 1989 was assumed to equal the ground redd count. Prespawning mortality is included.

[b] Redd counts were conducted before 157 adult chinook salmon (86 females) were outplanted into Crooked River from Dworshak National Fish Hatchery.

[c] Average number of eggs/female obtained from nearby Red River trapping facility minus average egg retention observed during ground redd counts.

Table 11. Estimated egg-to-parr survival rates for natural chinook salmon in Crooked River, brood years 1989-1994.

Brood Year	Estimated egg deposition in thousands[a]	Estimated parr production in thousands	Estimated Egg-to-parr survival
1989	66.00	9,893	15.0%
1990	399.00	36,346	9.6%
1991	17.60	2,601	14.8%
1992	205.47	24,435	11.9%
1993	247.85	45,567	18.4%
1994	17.76	4,600	25.9%

[a] From Table 10.

Table 12. Crooked River chinook salmon survival rate estimates, brood years 1988-1993.

Brood Year	Egg-to-parr[a]	Parr-to-smolt (overwinter)	Egg-to-smolt	Smolt migration; trap to Lower Granite pool
1988[b]	-	12.0%	-	47.4%
1989[c]	15.0%	36.2%	5.4%	63.4%
1990[d]	9.6%	34.7%	3.3%	34.1%
1991[e]	14.8%	13.7%	2.0%	76.0%
1992	11.9%	39.1%	4.7%	36.7%
1993	18.4%	44.2%	8.1%	53.0%

[a] Data from Table 11.
[b] Data from egg-to-parr survival from Kiefer and Forster 1990.
[c] Data from egg-to-parr survival from Kiefer and Forster 1991.
[d] Data from egg-to-parr survival from Kiefer and Forster 1992.
[e] Data from egg-to-parr survival from Kiefer and Lockhart 1993.

Table 13. Crooked River age-2+ and older steelhead trout survival rate estimates, migratory years 1989-1995.

Migratory Year	Parr-to-smolt (overwinter)	Smolt migration; trap to Lower Granite pool
1989[a]	62.9%	53.2%
1990[b]	25.2%	55.8%
1991[c]	48.4%	82.5%
1992[d]	48.2%	68.1%
1993	20.9%	92.1%
1994	32.0%	82.2%
1995	25.7%	81.2%

[a] Data from Kiefer and Forster 1991.
[b] Data from Kiefer and Forster 1992.
[c] Data from Kiefer and Lockhart 1993.
[d] Data from Kiefer and Lockhart 1995a.

DISCUSSION

Smolt Production

Chinook Salmon

We estimated that chinook salmon survival from adult female escapement to successful spawner averaged 72.5% (90% C.I.; 65%-80.9%) for the years we have complete data (Tables 4 and 10). These estimates have ranged from a low of 59.3% to a high of 94.9%. The low estimate was from Crooked River in 1992. In 1992, we found evidence of illegal adult chinook salmon harvest in Crooked River that probably resulted in part of this low spawner success (Kiefer and Lockhart 1995a).

We believe the parr population estimates to be minimums using the multi-stage sampling design with visual estimation (Hankin 1986, Hankin and Reeves 1988). We also believe this method is fairly accurate under good conditions, but that the population is underestimated at an increasing rate under the following conditions:

1. as stream temperatures drop below 10° C;
2. as flow increases above normal summer time levels;
3. as the percentage of small, hard-to-sample habitat (tiny side channels, small tributaries, beaver ponds, etc.) increases.

Peery and Bjornn (1992) found that a high percentage of the chinook salmon fry produced from adults spawning above the Sawtooth Fish Hatchery weir emigrate out of the study area before July when parr production was estimated. Because of this fry emigration, we moved the area we use to estimate egg-to-parr survival to the headwaters Salmon River (Salmon River and tributaries above Pole Creek). For brood years 1987-1994, chinook salmon egg-to-parr survival for the headwaters Salmon River averaged 25.5% (Table 5). For brood years 1989-1994, chinook salmon egg-to-parr survival for Crooked River averaged 15.6% (Table 11).

We used comparative PIT-tag detection rates at the smolt collecting facilities to estimate chinook salmon parr-to-smolt survival. This method assumes that the ratio of the detection rate of the parr we PIT tagged in the summer divided by the detection rate of the smolts we PIT tagged during the spring emigration is an estimate of parr-to-smolt survival. Parr-to-smolt survival for brood years 1987-1993 in the upper Salmon River averaged 18.1% (Table 6), and for brood years 1988-1993 in Crooked River averaged 30.0% (Table 12).

We estimated chinook salmon egg-to-smolt survival by combining the estimates of egg-to-parr survival and parr-to-smolt survival for a particular brood year. With this method we estimated the Chinook salmon egg-to-smolt survival for brood year 1987-1993 in the headwaters Salmon River averaged 4.7% (Table 6), and for brood years 1989-1993 in Crooked River averaged 4.7% (Table 12).

Steelhead Trout

We have been able to estimate steelhead trout egg-to-age-1+ parr survival in Crooked River for brood years 1993 and 1994. These two estimates averaged 13.2%.

We have been able to estimate age-1+ to age-2+ steelhead trout survival for brood year 1986 in upper Salmon River and brood years 1988-1992 in Crooked River. These combined estimates averaged 31.7%. These estimates were made by comparing the PIT-tag detection rates at the smolt collecting facilities of parr from the same BY that were tagged as age-1+ parr in one year and as age-2+ parr the following year. We believe this method gives us a fairly accurate estimate of steelhead trout age-1+ to age-2+ survival.

Estimates of age-2+ and older steelhead trout parr-to-smolt survival are made with the same method used for chinook salmon parr-to-smolt survival except we report them by migratory year instead of brood year. For migratory years 1988-1995 the upper Salmon River steelhead trout age-2+ and older parr-to-smolt survival averaged 26.3% and for migratory years 1989-1995 in Crooked River averaged 37.6%. In the upper Salmon River, this survival estimate has dropped dramatically from an average of 51.4% for migratory years 1988 and 1989 to an average of 17.9% for migratory years 1990-1995. This decrease in upper Salmon River steelhead trout age-2+ and older parr-to-smolt survival coincided with the discovery of whirling disease in the upper Salmon River and our observation of juvenile steelhead trout with visual signs of the disease.

Carrying Capacity and Optimal Smolt Production

Chinook Salmon

We have found that outplanting Sawtooth Fish Hatchery adult chinook salmon to the low gradient meandering headwater streams of the Salmon River results in egg-to-parr survival rates similar to naturally-escaping adults in this habitat. We have used natural adult chinook salmon escapement and adult outplants in this habitat to develop a good relationship between redds/hectare and parr density at low to medium redd densities (Figure 9). Because of low adult returns to the upper Salmon River, we have been unwilling to outplant more adults than we estimate could fully seed the habitat, and therefore, have been unable to quantify carrying capacity.

Determining optimal smolt production is based on the theory that at carrying capacity there may be a density dependent reduction in smolt-to-adult survival, and optimal smolt production (producing the most returning adults) may be less than maximum smolt production. We have observed several cases of lower smolt survival to LGR for smaller smolts within a year class (e.g., Crooked River, 1995). A density-dependent growth reduction at high abundance is one mechanism that would result in a descending limb of a Ricker curve (Ricker, 1975). Because we have not been able to quantify carrying capacity, we have not been able to test this theory.

Steelhead Trout

By outplanting large numbers of adults into Crooked River, we may have been able to estimate steelhead trout carrying capacity (Figure 10). However, with only one year’s data defining the flattening of the curve, we urge caution in using this estimate of carrying capacity. Also, because of the habitat degradation from dredge mining and the low productivity of the water (low conductivity), we believe that steelhead trout carrying capacity in Crooked River is less than carrying capacity in most of the steelhead trout rearing streams in Idaho.

To be able to determine if optimal smolt production was less than maximum smolt production, we would need several years of data when 10-40 females/hectare spawned and much greater smolt-to-adult survival rates than the Snake River system is currently experiencing. Because of the declining trend in Snake River steelhead trout adult returns, it is unlikely that we will be able to further test carrying capacity in the near future.

Habitat Factors and Smolt Production

The project has provided insight into several questions concerning the benefits of some stream rehabilitation efforts on smolt production. Research by Scully and Petrosky (1991) found that chinook salmon egg-to-parr survival decreased if sand in the spawning areas was greater than 30%. We have observed a shift in spawning area by adult chinook salmon to cleaner gravel areas produced by habitat rehabilitation structures in Crooked River (Kiefer and Lockhart 1993). In streams with more than 30% sand in spawning areas, habitat structures that collect cleaner gravel with less than 30% should increase smolt production. In addition to the increase in egg-to-parr survival, lower sediment levels should increase smolt production by increasing interstitial spaces that provide better hiding and overwinter cover and increase macro-invertebrate food production.

Data compiled by Scully and Petrosky (1991) indicates that stream rehabilitation efforts that decrease the percentage of sand in spawning areas from 30-40% to less than 30% will more than double chinook salmon egg-to-parr survival, and approximately a tenfold increase will occur if the percentage of sand changes from greater than 40% to less than 30%.

In streams degraded by dredge mining, connecting off-channel ponds to the stream will increase the habitat available for juvenile rearing and the carrying capacity for the stream. Chinook salmon parr densities in these off-channel ponds are consistently among the highest we observe for a given year in Crooked River (Appendix G1) and are usually in the mid-range for steelhead trout age-1+ and age-2+ (Appendix G2).

Complex habitat enhancement structures apparently can increase the carrying capacity for age-1+ steelhead trout in streams with low habitat complexity. Dredge mining has reduced the habitat complexity in the upper meadow section of Crooked River by forcing the channel against the canyon wall on the east side of the meadow. Because of the large number of adult steelhead we outplanted to this section of Crooked River in 1990, we believe that age-1+ steelhead trout were approaching carrying capacity in 1992. We observed more than double the density of age-1+ steelhead trout in complex habitat study sites than we observed in control or simple sill log habitat study sites in 1992 (Kiefer and Lockhart, 1995).

We suspect that the amount of anchor ice formation in spawning areas is the primary variable in chinook salmon egg-to-parr survival in high elevation streams like the upper Salmon River. We propose to determine if anchor ice formation in the upper Salmon River can be quantified and correlated with chinook salmon egg-to-parr survival. If there is a relationship, habitat rehabilitation and land use management that reduce anchor ice formation should increase smolt production.

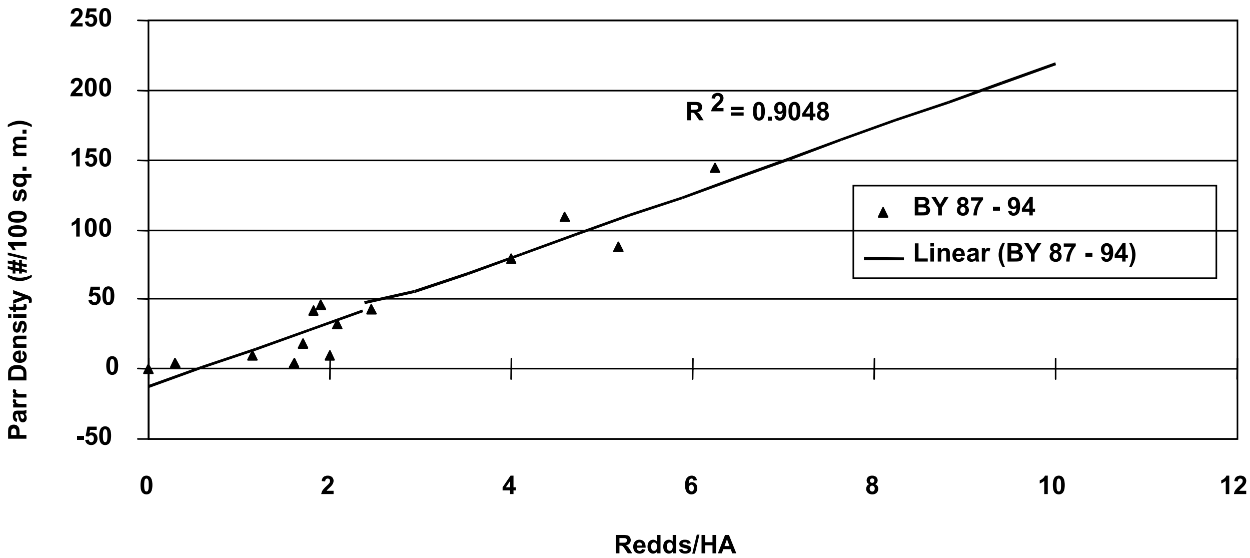

Figure 9. Relationship between chinook salmon redd density and parr density in headwaters Salmon River.

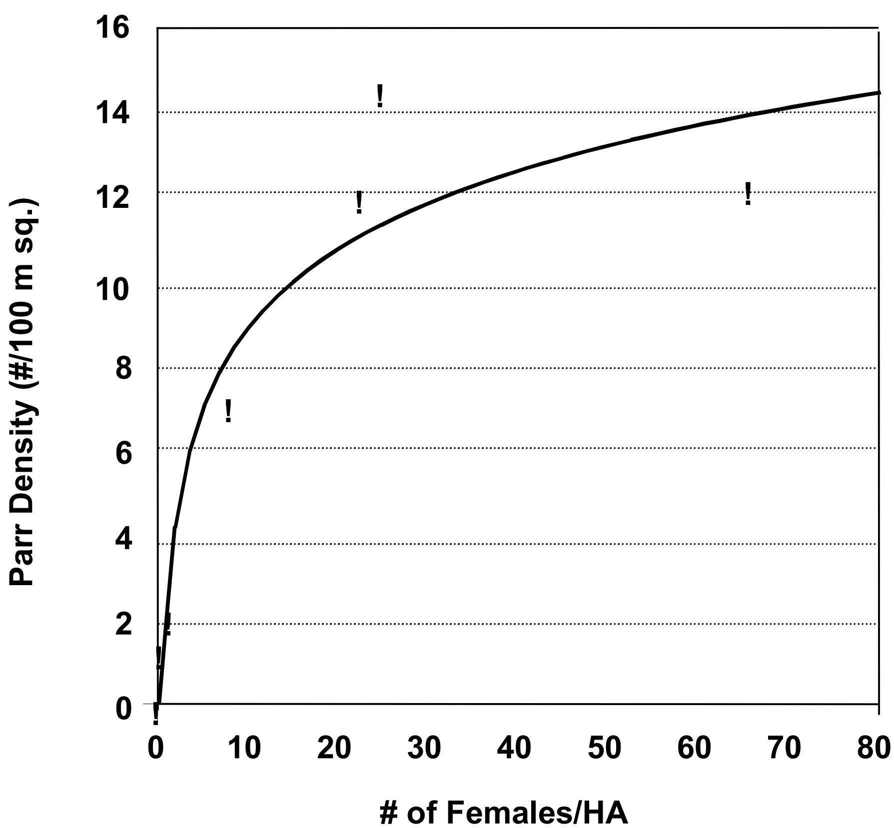

Figure 10. Crooked River steelhead trout adult escapement and resulting age-1+ parr densities (Brood years 1985, 1987, and 1990-1993).

1995 Findings

PIT Tag Detections

Detections of PIT-tagged smolts at lower Snake and Columbia rivers' smolt collecting facilities indicate excellent survival for migrating year 1995 chinook salmon parr rearing in Crooked River off-channel ponds. The chinook salmon parr we PIT tagged in these off-channel ponds in August 1994 were detected at almost three times the rate (33.4%) of those tagged in main river sites (12.6%) (Table 8). We have identified two factors that contributed to the excellent survival of the Crooked River chinook salmon parr rearing in the off-channel ponds. First, migrating year 1995 chinook salmon juveniles overwintering in Crooked River survived at a higher rate than those emigrating in the fall, and almost all of those rearing in the off-channel ponds overwintered in Crooked River. The evidence for these two conclusions are that, with good sample sizes, the chinook salmon juveniles we PIT tagged in August 1994 were detected at a higher rate than those we tagged during the fall 1994 out-migration. The second part is that of the total number of August PIT-tagged chinook salmon parr recaptured at the emigrant trap during the fall 1994 and spring 1995 seasons, only 2% (1 of 51) of these tagged in the off-channel ponds were in the fall, while 52% (105 of 203) of those tagged in the main river were in the fall.

The second reason the migration year 1995 Crooked River chinook salmon parr rearing in the off-channel ponds survived so well is that they grew larger, and larger smolts from Crooked River in 1995 survived better. For Crooked River chinook salmon parr tagged in August 1994, those from the off-channel ponds averaged 70 mm in fork length, while those from main river sites averaged 67 mm. Of the PIT-tagged chinook salmon parr we recaptured as smolts at our trap in spring 1995, those from the off-channel ponds averaged 90 mm in fork length, while those from the main river sites averaged 80 mm. In spring 1995 there was a significant positive correlation between Crooked River chinook salmon smolt fork length and a PIT tag detection rate (Table 9).

The PIT tag detection data show that very few (less than 5%) of the residualized Selway and Dworshak stock age-1 steelhead trout juvenile originally released into Crooked River in spring 1994 smolted in spring 1995. We did not expect very many of the Dworshak stock to smolt in 1995 based on data from migratory year 1989 when we PIT tagged an evaluation group of residualized Dworshak stock steelhead in Crooked River and only 0.6% (3 of 486) were detected. However, we had expected the Selway stock residuals to smolt at a higher rate than they apparently did, because they were in good condition in August 1994 and wild/natural steelhead trout normally smolt at age-2 or age-3. There is still some hope that a significant number of these Selway fish will smolt in 1996 at age-3.

RECOMMENDATIONS

1. We recommend that hatchery steelhead trout smolts be at least 130 mm in fork length before release to reduce residualism and increase survival.

2. We recommend research to determine if PIT tag mark/recapture data or another method can be used to estimate egg-to-smolt survival more accurately and precisely than our current methodologies.

3. We recommend that research be conducted to determine if anchor ice formation is having an effect on chinook salmon egg-to-parr survival.

4. We recommend that mainstem migration survival be increased quickly, or the naturally-reproducing chinook salmon populations in Crooked River and upper Salmon River (and probably many other Snake River populations) will be lost.

5. We recommend that, when practical, off-channel ponds be connected to the stream in chinook salmon-rearing streams degraded by dredge mining. These connected off-channel ponds increase the carrying capacity and provide good wintering habitat for chinook salmon juveniles.

6. We recommend that in years with good snowpack, hatchery chinook salmon smolts be released in late April to early May. Our data from wild/natural chinook salmon smolts indicates that this later release (in good water years) of hatchery chinook salmon smolts would result in decreased migration time and increased survival.

7. We recommend that if hatchery adults (chinook salmon or steelhead trout) are to be released for natural reproduction they be held, when possible, until they are one to two weeks from spawning and then released directly into high quality spawning areas.

ACKNOWLEDGMENTS

We would like to extend our thanks to the following people who assisted us with this report:

Our field crew: Paul Bunn, Chris Restall, and Jane Mauser helped to collect field data, entered the data into the computers, and assisted with analysis of the data. Our office crew: Brad Alcorn and Tara Hamilton, analyzed data, assembled report tables, figures and edited the report.

Brent Snider and his staff at the IDFG Sawtooth Fish Hatchery and Jerry McGehee and his staff at the IDFG Clearwater Fish Hatchery provided technical information, manpower assistance, use of equipment, and housing for our trap tenders.

Tom Curet and Chip Moller with the IDFG Salmon Regional Office helped with snorkeling and PIT tagging in upper Salmon River and Crooked River. Jody Brostrom, Doug Nelson, and Vince Pero from the IDFG Clearwater Regional Office assisted with trapping operations and snorkeling in Crooked River. Rod Scarpella and Laura Garmann from the IDFG Wild Trout program assisted with snorkeling in upper Salmon River. Idaho Department of Fish and Game Sawtooth Fish Hatchery personnel Phil Coonts, Bill Stutz, Brian Malaise, and Doug Cutting assisted with trapping operations; Doug Cutting, Jeff Shellberg, and Lara Trandahl assisted with snorkeling. Tony Lamansky of the IDFG Sockeye Research program assisted with trapping operations. Kurtis Plaster, Clint Rasmussen, Kevin Kramer, and Eric Peterson from the IDFG General Parr Monitoring project assisted us with snorkeling in the upper Salmon River.

Steve Rubin, Jay Hensleigh, and Julie Smith from the National Biological Service assisted us with snorkeling and PIT tagging in Crooked River. Paul Moran and Jeff Hard from National Marine Fisheries Service assisted with PIT tagging in upper Salmon River. Lucy Wold, U. S. Forest Service, assisted with snorkeling.

Douglas Cutting with IDFG assisted with chinook ground redd counts on the upper Salmon River; Terry Holubetz, Jody Brostrom, and Pete Hassemer (IDFG) conducted the aerial redd counts for steelhead and chinook.

Joe Bumgarner (Washington Department of Fish and Wildlife), and Mike Larkin and Charles Petrosky (IDFG) reviewed and edited the report.

A special thanks to Kathie Fitzgerald, our staff Word Processing Specialist, and her assistants who assisted us with all aspects of the project's administration.

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APPENDICES

Appendix A. Spring 1995 upper Salmon River Trap Efficiencies and Emigration Estimates.

Wild/Natural Chinook Salmon

Release Dates	Number Released	Number Recaptured	Trap Efficiency (%)
3/10 - 3/27	159	6	3.8
3/28 - 4/14	149	7	4.7
4/15 - 4/27	156	14	9.4
4/28 - 6/6	162	6	3.7

Trap efficiency estimate: $\bar{x}$ = 5.2%; 90% C.I. = 2.7% - 8.5%
Total number captured = 629: Run estimate = 12,096; 90% C.I. = 7,400 - 23,296

Wild/Natural Steelhead Trout

Release Dates	Number Released	Number Recaptured	Trap Efficiency (%)
3/11 - 5/30	69	4	5.8

Total number captured = 73: Run estimate = 1,259

O. nerka

We assumed trap efficiencies were the same as wild chinook salmon.
Total number captured = 7: Run estimate = 135; 90% C.I. = 82 - 259

Hatchery Chinook Salmon

Release Dates	Number Released	Number Recaptured	Trap Efficiency (%)
3/28 - 3/29	104	22	21.2
3/30 - 3/31	99	15	15.2
4/1 - 4/2	100	12	12.0

Trap efficiency estimate: $\bar{x}$ = 15.9%; 90% C.I. = 11.59% - 20.75%
Total number recaptured = 11,092: Run estimate = 69,761; 90% C.I.=53,455 - 95,703

Appendix B. July 1995 upper Salmon River parr abundance estimates and confidence intervals (α = 0.10).

Stream/Strata	Area (m^2)	Age-0 Chinook	Age-1+ Steelhead	Age-2+ Steelhead
Salmon River				
SR-3/4	527,390	789 ± 1,491	28 ± 52	63 ± 82
SR-5/6	163,761	83 ± 121	0	0
SR-7	103,095	84 ± 521	0	0
SR-8	51,058	0	0	0
SR-9/10	61,360	1,819 ± 2,272	370 ± 533	93 ± 89
Stream Total	906,664	2,775 ± 2,266	398 ± 432	156 ± 102
Salmon River Side Channels				
SR-3/4	39,610	2,349 ± 4,691	0	28 ± 63
SR-5/6	6,700	13 ± 63	0	0
SR-7/8	16,258	306 ± 637	0	0
Stream Total	62,568	2,668 ± 4,054	0	28 ± 54
Gold Creek	2,522	0	0	0
Huckleberry Creek	18,164	53 ± 88	0	12 ± 25
4th of July Creek	17,185	0	0	0
Alturas Lake Creek				
ALC-1	37,631	0	0	0
ALC-2	21,969	10 ± 27	0	0
ALC-3	31,258	173 ± 93	9 ± 25	18 ± 51
ALC-4	107,756	0	58 ± 359	0
ALC-5	75,691	0	0	0
ALC-Tribs[a]	33,227	511 ± 901	0	0
Stream Total	307,232	695 ± 625	67 ± 116	18 ± 35
Pole Creek				
PC-1	15,587	0	0	0
PC-2	22,850	0	69 ± 428	69 ± 428
Stream Total	38,437	0	69 ± 198	69 ± 198
Smiley Creek	98,442	36 ± 72	675 ± 1,294	0
Beaver Creek	14,132	103 ± 137	543 ± 257	23 ± 32
Frenchman Creek				
FC-1	3,619	9 ± 56	113 ± 174	9 ± 56
FC-2	23,423	4,406 ± 6,185	137 ± 154	0
Stream Total	27,042	4,415 ± 6,193	250 ± 154	9 ± 19
Williams Creek	2,835	1,599 ± 6,603	0	0
Study Area Total	1,495,223	12,344 ± 11,987	2,002 ± 1,103	315 ± 198

[a] Yellowbelly Lake Creek and Petit Lake Creek combined.

Appendix C1. Density (number/100m^2) of age-0 chinook salmon parr in the upper Salmon River during July, 1988-1995.

Stratum	1988	1989	1990	1991	1992	1993	1994	1995
Salmon River								
3,4	13.8	9.7	0.4	2.5	3.5	0.2	8.2	0.2
5,6	4.1	3.6	0.1	0.1	0.4	<0.1	0.6	<0.1
7	13.3	32.9	3.2	0.1	0.1	0	0.2	<0.1
8	3.9	0.6	0	0	0.1	0	<0.1	0
9	1.4	2.6	7.1	0	0	0	22.5	0.4
10	0	32.0	9.8	0	0	0	42.5	4.7
Salmon River, side channels								
3,4	16.0	24.6	1.0	5.2	19.1	12.2	55.4	5.9
5,6	17.9	0.6	1.2	0	0	0	0.1	0.2
7	16.1	85.7	4.7	0	1.4	0	49.7	3.6
8,9,10	6.8	1.7	0	0	0.4	0	32.1	0.2
Pole Creek								
1	2.0	0.9	0	0	0	0	0	0
2	4.3	11.2	0.3	0.1	0	0	4.1	0
3	0.1	55.8	12.6	5.0	0	0.3	1.0	
4	0	0.3	0	0	0			
5		0	0	0	0			
Alturas Lake Creek								
1[a]	8.6	20.3	1.9	0.3	<0.1	0	3.8	0
2[a]			0.9	1.3	9.6		9.6	<0.1
3[a]			6.4	1.0	9.3		9.3	0.6
4[a]	0.9	2.5	0.4	0	0.2	0	0.6	0
5[a]	0	7.7	0.1	0	0	0	3.8	0
Alturas Lake Creek tributaries[b]								
1				0	4.9	2.9	16.6	1.5
Smiley Creek								
1A[c]	6.9	14.1	0.3	0	0	0.2	10.3	0.1
1B[c]			0	1.6	42.3		42.3	0
2[c]	13.5	23.4	0	0.3	0	0	7.4	0
Beaver Creek								
1	2.1	0.4	0	0	0	0	11.5	0.3
2	0.4	20.8	0.1	0	0	0	45.9	1.5
Frenchman Creek								
1	0.6	4.0	0.4	0.3	0	1.0	8.2	0.3
2	41.4	109.5	10.2	87.9	79.4	4.7	144.8	18.8
Huckleberry Creek								
1				0.2	2.3	0	1.4	0.5
2				0.2			4.2	0.1
Gold Creek								
1				30.2	0	0	10.1	0

Appendix C1. Continued.

Stratum	1988	1989	1990	1991	1992	1993	1994	1995
Fourth of July Creek								
1				0.0	4.0	0	10.4	0
2				0				
Champion Creek								
1					0	2.0		
2							0.6	
Williams Creek								
1 & 2						5.4	45.5	56.4

[a] In 1992, Alturas Lake Creek stratum 1 was subdivided into three strata (1, 2, and 3). Stratum 2 was renamed stratum 4, and stratum 3 was renamed stratum 5.
[b] Alturas Lake Creek tributaries are Pettit Lake Creek and Yellowbelly Lake Creek.
[c] In 1993, Smiley Creek stratum 1 was divided into two strata; stratum 1A and stratum 1B.

Appendix C2. Density (number/100m^2) of age-2+ steelhead trout parr in the upper Salmon River during July from 1988-1995.

Stratum	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Salmon River								
3,4	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	0.1	<0.1
5,6	<0.1	0	0	0	0	0	0	0
7	0.1	0.2	0.1	0.3	0	0	0	0
8	0.1	0.7	0	0	0	0	0	0
9	0.8	0.9	0.4	0.1	0.6	0.8	2.2	0.2
10	2.9	4.4	0.5	0.2	0.2	0.7	1.7	0.1
Salmon River, side channels								
3,4	0	0.2	0	0.1	0	0.2	<0.1	<0.1
5,6	0	0	0	0	0	0	0	0
7	0	0.4	1.2	0.2	0	0	0	0
8,9,10	0	0	0	0	0.1	0	0	0
Pole Creek								
1	0.6	0.1	0	0	0	0.4	0	0
2	0	0.3	0	0.1	0	<0.1	0.2	0.3
3	0	1.2	0.1	0	0	0	0	
4	0.5	0.9	0.2	0	0.4			
5	0.7	0	0	0	0			
Alturas Lake Creek								
1[a]	<0.1	0.1	<0.1	0	0	<0.1	0	0
2[a]					0	0.2	<0.1	0
3[a]					0	0.3	0.1	<0.1
4[a]	0.3	0.1	0	0	0.1	0	<0.1	0
5[a]	0.1	0.1	0.1	0	<0.1	0	0	0
Alturas Lake Creek tributaries[b]								
1					<0.1	0.7	0.3	0
Smiley Creek								
1A[c]	0	0.6	0.3	0	0	0	0.6	0
1B[c]					0	0	1.1	0
2[c]					0	<0.1	<0.1	0
Beaver Creek								
1	0	0.1	0.4	0	0	0	0.4	0.2
2	<0.1	0	0.3	0	0	0	0	0
Frenchman Creek								
1	0.6	2.3	1.0	0	0	0.9	0.6	0.3
2	0.1	0.1	0	0	0	0.2	0.1	0
Huckleberry Creek								
1					0	0	0	0
2								0.1
Gold Creek								
1					0	0	0	0

Appendix C2. Continued.

Stratum	1988	1989	1990	1991	1992	1993	1994	1995
Fourth of July Creek								
1					0.7	0.2	0.6	0.0
2								
Champion Creek								
1					0	0.2		
2					0	0	0	
Williams Creek								
1 & 2						0	0	0

[a] In 1992, Alturas Lake Creek stratum 1 was subdivided into three strata (1, 2, and 3). Stratum 2 was renamed stratum 4 and stratum 3 was renamed stratum 5.
[b] Alturas Lake Creek tributaries are Pettit Lake Creek and Yellowbelly Lake Creek.
[c] In 1993, Smiley Creek stratum 1 was divided into two strata; stratum 1A and stratum 1B.

Appendix C3. Density (number/100m^2) of age-1+ steelhead trout parr in the upper Salmon River during July from 1988-1995.

Stratum	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Salmon River								
3,4	0.2	<0.1	<0.1	0.1	0.1	0	<0.1	<0.1
5,6	0.1	0	0	<0.1	0	<0.1	<0.1	0
7	0.4	0.2	0.3	0.5	0	0	0	0
8	0.4	0	0	0	0	0	0	0
9	2.8	2.6	4.5	0.1	0	3.6	2.1	1.3
10	3.5	8.4	4.5	0.1	0	3.5	1.2	0.1
Salmon River, side channels								
3,4	0.6	0.2	0.2	0.1	<0.1	<0.1	<0.1	0
5,6	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0.4	0
8,9,10	0.3	0	0	0.2	0	0	0.5	0
Pole Creek								
1	2.1	0.1	0.2	0.2	0.4	1.1	0	0
2	0	0.5	0.3	1.0	0.3	0.5	0.7	0.3
3	0	0.3	0.2	0.2	0	0	0	
4	4.8	0.8	0	0	0			
5	0	0	0	0	0			
Alturas Lake Creek								
1[a]	0.6	0.1	<0.1	<0.1	0	<0.1	<0.1	0
2[a]					0	0.3	0.1	0
3[a]					0.1	0.4	0.2	<0.10
4[a]	0.4	0	<0.1	0	0	0	<0.1	0
5[a]	0.1	0.1	0.1	0	0	0	0	
Alturas Lake Creek tributaries[b]								
1				0.2	0	0.9	0.4	0
Smiley Creek								
1A[c]	0	0.5	0.5	0.1	0	0	0.6	2.0
1B[c]						1.1	<0.1	<0.1
2[c]	0.2	0.1	0	0	0	0.1	0.2	0
Beaver Creek								
1	0.5	0.1	0.6	0.3	0	0	15.6	2.7
2	0.2	0	2.0	0	0	0	0.6	<0.1
Frenchman Creek								
1	0	1.5	2.6	0	0	2.7	3.2	3.1
2	0.1	0	0	0	0	1.5	0.1	0.6
Huckleberry Creek								
1				0	0	0	0.1	0
2				0.5			0	0
Gold Creek								
1				0	0	0	0.4	0

Appendix C3. Continued.

Stratum	**1988**	**1989**	**1990**	**1991**	**1992**	**1993**	**1994**	**1995**
Fourth of July Creek								
1				0.7	0.1	0.7	1.0	0.0
2				0.4				
Champion Creek								
1						1.1		
2					0	0	0	
Williams Creek								
1 & 2					0	0.2	0	0

[a] In 1992, Alturas Lake Creek stratum 1 was subdivided into three strata (1, 2, and 3). Stratum 2 was renamed stratum 4 and stratum 3 was renamed stratum 5.
[b] Alturas Lake Creek tributaries are Pettit Lake Creek and Yellowbelly Lake Creek.
[c] In 1993, Smiley Creek stratum 1 was divided into two strata; stratum 1A and stratum 1B.

Appendix D. Fall 1995 upper Salmon River Trap Efficiencies and Emigration.

Dates	Wild/Natural Chinook Salmon Number Released	Number Recaptured	Trap Efficiency (%)
8/24 - 9/18	102	5	4.9
9/20 - 10/16	159	6	3.8
10/17 - 11/1	162	7	4.3
11/2 - 11/11	105	3	2.9

Trap efficiency estimate: $\bar{x}$ = 3.9%; 90% C.I. = 3.0% - 5.0%
Total number captured by SWT = 383: Run estimate = 9,821; 90% C.I. = 7,660 - 12,767

Wild/Natural Steelhead Trout

Trap efficiency estimate is the same as the wild/natural chinook salmon estimate.
Total number captured = 14: Run estimate = 359; 90% C.I. = 280 - 467

Appendix E. Spring 1995 Crooked River Trap Efficiencies and Emigration.

Release Dates	Number Released	Number Recaptured	Trap Efficiency (%)
	Wild/Natural Chinook Salmon when Flows <3.4 m^3/s		
3/15 - 3/20	249	100	40.2
3/21 - 4/1	275	95	34.6
4/2 - 4/6	251	109	43.4
4/7 - 4/16	280	98	35.0
4/17 - 4/29	189	99	52.4

Trap efficiency estimate: $\bar{x}$ = 41.0%; 90% C.I. = 34.2% - 48.1%
Total number captured = 4,123: Run estimate = 10,056; 90% C.I. = 8,572 - 12,056

Release Dates	Number Released	Number Recaptured	Trap Efficiency (%)
	Wild/Natural Chinook Salmon when Flows ≥ 3.4 m^3/s		
4/30 - 5/2	151	49	32.5
5/3 - 5/5	127	41	32.3
5/8 - 5/15	134	36	26.9
5/16 - 5/26	149	49	32.9
5/27 - 6/5	144	43	29.9

Trap efficiency estimate: $\bar{x}$ = 31.0%; 90% C.I. = 28.4% - 33.4%
Total number captured = 1,220: Run estimate = 3,935; 90% C.I. = 3,653 - 4,296
Total wild/natural Chinook salmon run estimate = 13,991; 90% C.I. = 12,224 - 16,352

Release Dates	Number Released	Number Recaptured	Trap Efficiency (%)
	All Steelhead Trout		
3/15 - 5/1	72	17	23.6
5/2 5/10	67	5	7.5
5/11 - 5/20	67	2	3.0
5/21 - 6/5	68	7	10.3

Trap efficiency estimate: $\bar{x}$ = 10.0%; 90% C.I. = 2.5% - 21.8%
Wild/Natural Steelhead Trout:
Total number captured = 118; Run estimate = 1,180; 90% C.I. = 541 - 4,720
Selway Hatchery Steelhead Trout:
Total number captured = 196; Run estimate = 1,960; C.I. = 899 - 7,840

Dworshak Hatchery Steelhead Trout:
Total number captured = 107; Run estimate = 1,070; C.I. = 491 - 4,280

Appendix F. July 1995 Crooked River abundance estimates and confidence intervals ($\alpha = 0.10$).

Stream/strata	Area(m^2)	Age-0 chinook	Age-1+ steelhead	Age-2+ steelhead
Crooked River				
CR-4	31,131	22 ± 60	205 ± 119	72 ± 132
CR-3	33,124	21 ± 37	861 ± 1,059	122 ± 210
CAN	66,759	68 ± 195	4,250 ± 3,879	463 ± 678
RC-1	3,993	0	240 ± 131	123 ± 112
RC-2	5,760	0	175 ± 33	173 ± 167
CR-2	37,389	311 ± 554	1,597 ± 1,240	652 ± 341
CR-1	56,636[a]	4,092 ± 2,761	1,559 ± 668	574 ± 226
HDW	60,497	0	350 ± 491	203 ± 143
PND-A	10,019	87 ± 231	812 ± 614	157 ± 274
PND-B	5,952	0	203 ± 318	59 ± 84
Study Area Total	311,260	4,601 ± 2,521	10,252 ± 2,702	2,598 ± 582

[a] For 1995, Stratum 1 included the Orogrande site from the Headwaters Stratum

Appendix G1. Density (number/100m^2) of age-0 chinook salmon parr in Crooked River, August 1986 to 1995.

	Stratum									
Year	Head-waters	I[a]	II	Canyon	III	IV	Relief Creek	Ponds A[b]	Ponds B	Five Mile Creek
1986	-	14.0	1.1	-	57.8	71.8	-	62.9	-	-
1987	-	3.0	16.5	-	22.3	15.4	-	3.2	-	-
1988	<0.1	23.8	19.7	8.0	36.6	42.2	0.8	65.4	-	-
1989	0.1	28.4	19.7	10.3	58.7	59.0	45.5	206.1	268.0	-
1990	0.0	<0.1	<0.1	1.0	5.0	4.7	0.0	0.6	8.1	-
1991[c]	-	-	-	-	-	-	-	-	-	-
1992	0.0	0.0	0.6	<0.1	0.1	0.1	0.9	0.3	0.0	0.0
1993	-	1.1	11.2	9.4	11.3	3.1	8.7	53.4	31.7	0.8
1994	0.0	21.4	10.4	9.3	15.8	45.9	5.1	35.6	29.3	-
1995	0.0	7.2	0.8	0.1	<0.1	<0.1	0.0	0.9	0.0	-

[a] For 1994 and 1995, Stratum I included the Orogrande site from the Headwaters stratum.
[b] In 1986-1988, the data for connected ponds was combined and is reported here as Ponds A.
[c] Snorkel counts were conducted before the chinook age-0 parr probably emerged from the gravel and none were observed.

Appendix G2. Density (number/100 m^2) of age-1+ and age-2+ steelhead trout parr in Crooked River, 1988-1995.

Stratum	1988	1989	1990	1991	1992	1993	1994	1995
	Age-1+ Steelhead Trout							
Headwaters	1.5	0.2	0.4	0.1	0.1	-	0.4	0.6
I[a]	5.2	1.9	0.2	0.7	3.9	1.7	1.8	2.8
II	8.8	4.4	1.5	7.3	10.5	1.5	1.2	4.3
Canyon	11.4	4.1	1.0	4.7	8.4	0.7	1.3	6.4
III	10.3	6.5	2.5	2.8	13.3	1.2	1.1	2.6
IV	7.5	3.4	1.5	3.7	11.4	<0.1	3.2	0.7
Relief Creek	19.1	5.2	0.2	5.3	10.1	2.1	3.9	4.8
Ponds A[b]	17.8	7.2	1.2	0.6	3.4	0.7	1.3	8.1
Ponds B	-	10.1	0.1	1.7	8.3	0.0	1.6	3.4
Five Mile Creek	-	-	-	-	0.5	7.1	-	-
	Age-2+ Steelhead Trout							
Headwaters	0.2	0.3	0.1	0	<0.1	-	0.1	0.3
I[a]	0.2	0.8	0.3	0.1	0.8	1.3	0.2	1.0
II	0.4	1.4	1.3	0.4	2.0	1.7	0.2	1.7
Canyon	1.2	2.1	1.2	0.4	2.2	1.8	1.3	0.7
III	0.5	1.8	1.4	0.1	2.4	1.4	0.7	0.4
IV	7.1	1.5	1.1	0.1	1.7	0.2	1.4	0.2
Relief Creek	0.6	1.8	0.1	0.5	2.4	0.7	1.1	3.0
Ponds A[b]	1.6	1.7	1.0	<0.1	1.2	0.8	<0.1	1.6
Ponds B	-	2.2	0.3	0.2	0.8	0.0	0.4	1.0
Five Mile Creek	-	-	-	-	0.0	0.5	-	-

[a] For 1994 and 1995, Stratum 1 included the Orogrande site from the Headwaters Stratum.
[b] In 1986-1988, the data for connected ponds was combined and is reported here as Ponds A.

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