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CHINOOK SALMON SEMINATURAL REARING EXPERIMENT: SAWTOOTH AND CLEARWATER FISH HATCHERIES, IDAHO

Project Progress Report

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Chinook Salmon Seminatural Rearing Experiment: Sawtooth and Clearwater Fish Hatcheries, Idaho

1992—2003 Progress Report

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ABSTRACT

We tested the utility of a Natural Rearing Enhancement System (NATURES) to increase juvenile out-migration survival and smolt-to-adult returns for spring chinook salmon *Oncorhynchus tshawytscha*. Juvenile spring chinook salmon were exposed to various NATURES treatments during their final ten months of rearing at Clearwater and Sawtooth fish hatcheries (Idaho Department of Fish and Game; IDFG). This paper satisfies the reporting component most recently identified as Objective 4, Study 1 in the IDFG fiscal year 2003 Lower Snake River Compensation Plan Statement of Work. This report summarizes the findings of two pilot studies and serves as a progress report for a research study designed with the same objective.

Work performed at the Clearwater Fish Hatchery with brood years 1992, 1993, and 1994 and at the Sawtooth Fish Hatchery with brood year 1992 was considered pilot work to determine if NATURES technology could be adapted to a production level facility and if fish reared in these environments would exhibit increased out-migration survival and adult returns. Upon completion of the pilot studies, a formal research study was initiated at Sawtooth Fish Hatchery using brood years 1997, 1998, and 1999.

Fish reared at Clearwater Fish Hatchery were released from the Powell satellite facility (brood years 1992, 1993, and 1994), Papoose Creek (brood year 1993), and the Crooked River satellite facility (brood year 1993). Fish reared at Sawtooth Fish Hatchery were released from the hatchery directly into the Salmon River (brood years 1992, 1997, 1998, and 1999).

We evaluated out-migration survival for groups of fish reared in raceways retrofitted with NATURES modifications and for those reared in conventional raceways. In addition, when marking data was available, we evaluated smolt-to-adult survival between the two rearing methods.

Out-migration survival during the pilot work was variable, showing no benefit for NATURES raceway modifications to improve survival over conventional rearing practices at either Sawtooth or Clearwater fish hatcheries.

Out-migration survival during the research study at the Sawtooth Fish hatchery showed that brood year 1997 conventionally-reared fish survived statistically greater than NATURES-reared fish (χ^2 = 13.5604, df = 1, P = 0.0002), while there was no difference in survival between the two groups for brood year 1998 (χ^2 = 1.7901, df = 1, P = 0.1809). Releases were not evaluated for brood year 1999.

Smolt-to-adult return rates during the pilot and study work were variable showing no consistency in NATURES to improve survival over conventional rearing practices at either Sawtooth or Clearwater fish hatcheries. Fish reared under seminatural conditions survived statistically better to adult collections than fish reared under traditional conditions in two of the five examples reported on. Smolt-to-adult return rates during the research study will not be complete until data from the 2004 return year has been analyzed.

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INTRODUCTION

For over a century, fish hatcheries have been used to supplement selected runs of anadromous salmonid fishes, starting with chinook salmon in 1895. Artificial production of salmon has increased since its conception and peaked in the 1990s (Mahnken et al. 1998). Established under the premise that anadromous systems could be simplified, controlled, and made more productive (Brannon et al. 1998), hatcheries quickly became the "solution" to overharvest and habitat loss. By 1910, all Pacific salmon species had been supplemented using hatchery programs.

Hatchery management has undergone a number of paradigm shifts since its inception. Originally, hatcheries were constructed to produce and release large numbers of fish to maintain sustainable fisheries and to mitigate for habitat loss and over fishing. More recently, in some cases, hatcheries have been charged with the responsibility of maintaining or supplementing listed stocks and pursuing conservation objectives (Anders 1998; Flagg and Nash 1999; Waples 1999; Flagg et al. 2000).

The controlled environment of hatchery rearing for anadromous fishes allows for intervention during virtually the entire freshwater juvenile lifecycle, resulting in increased egg-to-smolt survival (Brannon et al. 1998). Hatchery-reared anadromous fishes generally exhibit greater egg-to-smolt survival than their wild counterparts. However, domestication selection in the hatchery environment may lead to lower post-release survival, reductions in fitness, lower smolt-to-adult return rates (SARs), and altered adult return timing and age at maturity potentially negating the advantages of increased egg-to-smolt survival (Reisenbichler and McIntyre 1977; Nickelson et al. 1986; Goodman 1990; Waples 1991; Hilborn 1992; Mahnken et al. 1998; Waples 1999). Behavioral, physiological, and morphological differences (resulting from domestication selection) are thought to be responsible for poor post-release survival of hatchery-reared fishes (Maynard et al. 1995; Maynard et al. 1996a; Maynard et al. 2001).

Increased post-release survival of hatchery-reared chinook salmon could benefit hatchery programs by reducing broodstock needs and operational costs associated with rearing fewer fish. Furthermore, releasing fewer fish could potentially reduce competition between hatchery-reared and wild- or natural-origin fish. Increased post-release survival should also enable the return of more hatchery-origin fish back to sport fisheries or for natural production (Flagg and Nash 1999; Levin and Williams 2002).

Since the early 1990s, much work has been done to assess the potential for increasing post-release survival of hatchery-reared fish by using a variety of methods to make rearing conditions more natural in hopes of producing fish that exhibit more "wild-like" behavior. Natural Rearing Enhancement Systems (NATURES) have shown, in some cases, that enriched rearing environments can increase the post-release survival of hatchery-reared juvenile fishes by 10 to 50% over conventional hatchery rearing environments (Maynard et al. 1996b). Natural Rearing Enhancement System modifications may include simulated substrate, in-stream structure, overhead cover, automated underwater feeders, altered current velocities, live food diets, reduced rearing densities, and predator avoidance training.

In Idaho, anadromous fish hatcheries were built to compensate for the construction of dams (Idaho Power Company funded facilities) and to mitigate for reduced fish survival following the construction of four dams on the lower Snake River (Lower Snake River Compensation Plan; LSRCP facilities). Since construction of the first anadromous fish hatchery in Idaho, the Idaho Department of Fish and Game (IDFG) has intensively monitored and evaluated fish production strategies to improve adult returns to the state and to meet specific compensation/mitigation objectives. Success at meeting these objectives has been inconsistent.

Chinook salmon runs to Idaho have experienced declines over the last 30 years. Adult returns to Idaho fish hatcheries are far below expectations (Hassemer et al. 2000), and wild runs remain at low levels of abundance (Greg Mauser, IDFG, unpublished data). Hatchery releases of juvenile chinook salmon outnumber wild/natural recruitment annually. However, over the past decade SARs for wild- or natural-origin fish have averaged over 65% greater than those of their hatchery counterparts (Sandford and Smith 2002). Despite these drastic differences in the SARs of hatchery-reared and wild- or natural-origin fish, the IDFG believes changes in hatchery rearing strategies (e.g., NATURES) are worth investigating in an effort to increase post-release survival and ultimately adult returns.

The purpose of the pilot and research studies described in this report was to implement techniques used by others (Maynard et al. 1996b, 1996c) at production level rearing densities and to assess the ability of seminatural raceway habitats to increase juvenile out-migration survival and SARs of spring chinook salmon to Clearwater and Sawtooth fish hatcheries.

This report serves as documentation of NATURES pilot work performed at Sawtooth Fish Hatchery (brood year 1992) and Clearwater Fish Hatchery (brood years 1992, 1993, and 1994) and a progress report, to date, of the NATURES research study work performed at Sawtooth Fish Hatchery (brood years 1997, 1998, and 1999). Final results of the research study will not be available until the analysis of the 2004 adult return data is complete.

STUDY SITES

The Clearwater Fish Hatchery is located on the north bank of the North Fork Clearwater River, 2.4 km downstream from Dworshak Dam, 117 km upstream from Lower Granite Dam (LGR), and 811 km upstream from the mouth of the Columbia River (PSMFC 2001). Clearwater Fish Hatchery includes three satellite facilities: Crooked River, Red River, and Powell.

The Crooked River satellite facility consists of two separate sites. The first is an adult trap and a support cabin located 0.13 km upstream from the mouth of Crooked River and the South Fork of the Clearwater River. The second is located 6 km upstream from the adult trap on Crooked River. Crooked River is 266 km upstream of LGR and 961 km upstream from the mouth of the Columbia River (PSMFC 2001).

The Red River satellite facility is 24 km east of Elk City, Idaho. The facility includes a fish trap, which directs migrating adults from Red River through a ladder into two raceways, and a rearing pond for summer rearing and spring acclimation of smolts. Red River is 299 km upstream of LGR and 995 km upstream from the mouth of the Columbia River (PSMFC 2001).

The Powell satellite facility is located at the headwaters of the Lochsa River. The facility includes a fish trap, which directs migrating adults from the Lochsa River through a ladder into two raceways, a rearing pond for acclimating juveniles, and a support cabin. The Powell satellite facility is located 310 km upstream of LGR and 1,004 km upstream from the mouth of the Columbia River.

Sawtooth Fish Hatchery is located 8 km south of Stanley, Idaho. The facility's 29 ha borders the Salmon River to the west, Highway 75 to the east, Sawtooth National Forest (USFS) ground to the south, and Idaho Department of Lands ground to the north. The Sawtooth Fish Hatchery weir is approximately 644 km upstream of LGR and 1,529 km upstream from the mouth of the Columbia River.

OBJECTIVE

1. Examine the utility of using NATURES rearing techniques at a production level facility to increase post-release survival and smolt-to-adult return rates of spring chinook salmon.

METHODS

Rearing

Clearwater Fish Hatchery

As a pilot study, treatment groups from brood years 1992, 1993, and 1994 were exposed to seminatural rearing environments at Clearwater Fish Hatchery.

All juvenile chinook salmon reared at Clearwater Fish Hatchery for the NATURES experiment were raised to full-term smolts prior to release. These fish were transferred from indoor vats (1.2 x 0.9 x 12.2 m) to outside raceways (3.0 x 0.9 x 61.0 m) when fry reached approximately 57 fish per pound. At that time, fish were placed in either treatment (NATURES) raceways or control (conventional) raceways for approximately ten months before being transported to their respective release locations. Full-term smolts were transported via truck to the Powell and Crooked River satellite facilities (McGehee and Dredge 1996; McGehee and Patterson 1998). Additionally, treatment and control fish from brood year 1992 were released at Papoose Creek, a tributary to the Lochsa River (Clearwater River drainage).

Juvenile chinook salmon were placed into 12 experimental raceways—six modified with seminatural habitats (treatments) and six untreated, conventional raceways (controls). Treatment raceway modifications included raceway floors painted a natural stream camouflage pattern to simulate natural substrate and floating shade structures made of heavy-plastic PVC netting (approximately 50% shading) placed along the entire length of the raceways. Control raceways had conventionally painted floors and lacked shade covering.

Sawtooth Fish Hatchery

As a pilot study, treatments groups from brood year 1992 were exposed to seminatural rearing environments at Sawtooth Fish Hatchery. Later, as part of a research study, treatment groups from brood years 1997, 1998, and 1999 were exposed to seminatural rearing environments at Sawtooth Fish Hatchery.

All juvenile chinook salmon reared at Sawtooth Fish Hatchery for the NATURES experiment were raised to full-term smolts prior to release. These fish were transferred from indoor vats (1.2 x 0.9 x 12.2 m) to outside raceways (3.7 x 0.7 x 30.5 m) when fry reached a size of 68 to 114 fish per pound. At that time, fish were placed in either treatment (NATURES) raceways or control (conventional) raceways for approximately ten months. Brood year 1992 smolts were allowed to volitionally migrate for five days before the remaining fish were forced to migrate, whereas brood years 1997, 1998, and 1999 were forced to migrate from the raceways directly into the Salmon River.

Brood year 1992 juvenile chinook salmon were separated into 11 groups—seven treatments and four controls. Treatment raceway modifications included baffles that were spaced every 2.1 m along the length of the raceway similar to methods described by Kindschi et al. (1991), and sheets of lattice-shaped plastic (1.2 x 2.5 m) simulating overhead cover were suspended across the width and length of the raceway. Control raceways had conventionally painted floors, no instream cover, but some form of overhead cover (periodic panels of shade cloth) to guard against bird predation.

Brood year 1997 juveniles were separated into six groups—three treatments and three controls. Brood year 1998 juveniles were separated into five groups—three treatments and two controls. Brood year 1997-1999 treatment raceways were modified to include simulated substrate, in-stream structure, and overhead cover. To simulate substrate, epoxy (Rapid Response Color System, Ameron International) was used to paint rock patterns on the bottom of the raceways. Epoxy was painted on the floor of selected raceways using templates to provide consistent results. Templates were cut into sheets of plywood and acetate using cobble-sized substrate collected from the local Salmon River. Separate overlapping templates were made for each color. Six colors representing those commonly observed in the local Salmon River were chosen. Raceways were painted during the summer while they were vacant to allow adequate curing before being used in the fall. All epoxy was approved by the Environmental Protection Agency for use in water storage containers. To simulate in-stream structure, deneedled trees (conifers; approximately 10 cm in diameter and two meters long) were suspended from a cable over the center and along the length of each raceway. Trees were submerged but removed periodically during raceway cleaning. To simulate overhead cover, camouflage colored lattice-shaped cloth sheets (1.2 x 2.5 m) were suspended over half of each raceway, alternating from left to right side down the length of the raceway. Control raceways had conventionally painted floors, no instream cover, but some form of overhead cover (periodic panels of shade cloth) to guard against bird predation.

Evaluations

Research study evaluations included assessments of juvenile out-migration and adult return performance. Passive integrated transponder (PIT) tag data was used to assess out-migration survival and arrival timing to LGR. We retrieved PIT tag data from the PIT Tag Information System (PTAGIS) (http://www.psmfc.org/pittag/) database maintained by the Pacific States Marine Fisheries Commission in Gladstone, Oregon. Coded-wire tags (CWT) collected from adults and jacks returning to the hatchery were used to determine SARs. We received CWT data from the IDFG CWT laboratory in Lewiston, Idaho. Both marks meet the criteria established by the Washington Department of Fish and Wildlife Planning and Research Group for suitability in assessing NATURES (Maynard et al. 2001).

Juvenile Out-migration Conditions

We evaluated the out-migration survival of PIT-tagged fish from each experimental group detected at lower Snake River dams with interrogation capabilities: Lower Granite, Little Goose, Lower Monumental, and McNary dams. A chi-square analysis ($\alpha = 0.05$) was used to make statistical comparisons between experimental groups based on unique first detections of PIT-tagged fish (through all four Lower Snake River dams). We restricted our comparisons to groups of fish released at similar times within the same year. This was considered necessary because seasonally varying flow and spill conditions could potentially affect sampling rates, making comparisons among groups released at different times, years, or locations inappropriate.

The total number of unique first detections also represents the number of marked fish that survive to LGR (the first dam out-migrating anadromous fishes encounter) regardless of whether the fish were detected at LGR. Detection rates were reported only to LGR, because the disposition of smolts downstream of LGR is variable (e.g., smolts can be barged, spilled, or pass through the turbines at any of the dams). For releases that occurred over an extended period from the same location within the same year, such as volitional releases, we used the first date of the release period to calculate travel times.

The detection (interrogation) rate of PIT-tagged juvenile salmonids at lower Snake River dams serves as relative or minimum index of survival. The index is considered relative or minimum because: 1) an unknown (but we believe small) number of PIT-tagged fish that die in the hatchery may go undetected, although all dead fish are scanned; 2) not all fish pass through detectors; 3) approximately 0.3% of PIT tags fail (Kiefer and Lockhart 1994) or are lost between tagging and arrival at detection sites; 4) some fish arrive while detection gear is not being operated; and 5) mortality occurs between dams.

Although not part of the statistical analysis, we also used graphical interpretation to determine if arrival-timing patterns to LGR for these same PIT-tagged fish were similar among release groups.

Smolt-to-Adult Return Rates

Adult returns were evaluated using SARs, the most commonly used estimator of adult return survival. Before juveniles were released, CWTs were administered to a representative number of fish from each experimental group and used as a mark to identify returning adults. Smolt-to-adult return rates in this report represent a minimum estimate of survival from tagging to adult returns to the hatchery and are not expanded to include fish harvested or detected downstream.

RESULTS

Releases

Clearwater Fish Hatchery—Brood Year 1992

Powell Satellite Facility—Control group smolts (n = 70,987) were released on April 13, 1994 from the Powell satellite facility pond (Table 1); 500 of these smolts received PIT tags (Table 2). Treatment group smolts (n = 69,490) were released on April 13, 1994 from the Powell satellite facility pond (Table 1); 500 of these smolts received PIT tags (Table 2).

Control group smolts survived at a minimum of 58.0% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 7 (Figure 1). Treatment group smolts survived at a minimum of 47.0% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 8 (Figure 1). No statistical difference was detected between the control and treatment group (χ^2 = 3.7832, df = 1, P = 0.0518). These data indicate that out-migration survival of spring chinook salmon from the Powell satellite facility pond to LGR in 1994 was independent of NATURES rearing treatments applied.

Papoose Creek—Control group smolts (n = 29,596) were released on April 15, 1994 from Papoose Creek (Table 1); 250 of these smolts received PIT tags (Table 2). Treatment group smolts (n = 29,631) were released on April 15, 1994 from Papoose Creek (Table 1); 250 of these smolts received PIT tags (Table 2).

Control group smolts survived at a minimum of 42.8% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 6 (Figure 2). Treatment group smolts survived at a minimum of 44.8% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 6 (Figure 2). No statistical difference was detected between the control and treatment group (χ^2 = 0.079, df = 1, P = 0.7781). These data indicate that out-migration survival of spring chinook salmon from Papoose Creek to LGR in 1994 was independent of NATURES rearing treatments applied.

Clearwater Fish Hatchery—Brood Year 1993

Powell Satellite Facility—Control group smolts (n = 161,139) were released on April 13, 1995 from the Powell satellite facility pond (Table 1); 1,200 of these smolts received PIT tags (Table 2). Treatment group smolts (n = 129,278) were released on April 13, 1995 from the Powell satellite facility pond (Table 1); 1,200 of these smolts received PIT tags (Table 2). Control group smolts survived at a minimum of 57.6% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 5 (Figure 3). Treatment group smolts survived at a minimum of 59.3% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 5 (Figure 3). No statistical difference was detected between the control and treatment group (χ^2 = 0.1801, df = 1, P = 0.6713). These data indicate that out-migration survival of spring chinook salmon from the Powell satellite facility pond to LGR in 1995 was independent of NATURES rearing treatments applied.

Crooked River Satellite Facility—Control group smolts (n = 152,560) were released on April 10, 1995 from the Crooked River satellite facility pond (Table 1); 1,200 of these smolts received PIT tags (Table 2). Treatment group smolts (n = 159,126) were released on April 10, 1995 from the Crooked River satellite facility pond (Table 1); 1,200 of these smolts received PIT tags (Table 2). Control group smolts survived at a minimum of 54.0% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 7 (Figure 4). Treatment group smolts survived at a minimum of 54.8% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date to LGR for these fish was May 9 (Figure 4). No statistical difference was detected between the control and treatment group (χ^2 = 0.0402, df = 1, P = 0.8411). These data indicate that out-migration survival of spring chinook salmon from the Crooked River satellite facility pond to LGR in 1995 was independent of NATURES rearing treatments applied.

Clearwater Fish Hatchery—Brood Year 1994

Powell Satellite Facility—Control group smolts (n = 108,405) were released on April 11, 1996 from the Powell satellite facility pond (Table 1); 5,720 of these smolts received PIT tags (Table 2). Treatment group smolts (n = 112,786) were released on April 11, 1996 from the Powell satellite facility pond (Table 1); 5,712 of these smolts received PIT tags (Table 2). Control group smolts survived at a minimum of 34.3% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 12 (Figure 5). Treatment group smolts survived at a minimum of 36.2% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 12 (Figure 5). No statistical difference was detected between the control and treatment group (χ^2 = 2.2532, df = 1, P = 0.1333). These data indicate that out-migration survival of spring chinook salmon from the Powell satellite facility pond to LGR in 1996 was independent of NATURES rearing treatments applied.

Sawtooth Fish Hatchery—Brood Year 1992

Control group smolts (n = 65,270) were released on April 8 through April 11, 1994 directly from the Sawtooth Fish Hatchery into the Salmon River (Table 3); 995 of these smolts received PIT tags (Table 4). Treatment group smolts (n = 48,412) were released directly from the Sawtooth Fish Hatchery into the Salmon River on April 8, 1994 (Table 3); 873 of these smolts received PIT tags (Table 4). Control group smolts survived at a minimum of 14.5% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 2 (Figure 6). Treatment group smolts survived at a minimum of 15.2% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 3 (Figure 6). No statistical difference was detected between the control and treatment group (χ^2 = 0.1587, df = 1, P = 0.6904). These data indicate that out-migration survival of spring chinook salmon from the Sawtooth Fish Hatchery to LGR in 1994 was independent of NATURES rearing treatments applied.

Sawtooth Fish Hatchery—Brood Year 1997

Control group smolts (n = 30,033) were released on April 16, 1999 directly from the Sawtooth Fish Hatchery into the Salmon River (Table 3); 1,480 of these smolts received PIT tags (Table 4). Treatment group smolts (n = 68,316) were released on April 16, 1999 directly from the Sawtooth Fish Hatchery into the Salmon River (Table 3); 1,486 of these smolts received PIT tags (Table 4). Control group smolts survived at a minimum of 37.6% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 13 (Figure 7). Treatment group smolts survived at a minimum of 28.6% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 17 (Figure 7). A statistical difference was detected between the control and treatment group (χ^2 = 13.5604, df = 1, P = 0.0002). These data indicate that out-migration survival of spring chinook salmon from the Sawtooth Fish Hatchery to LGR in 1999 was not independent of NATURES rearing treatments applied (e.g., control group smolts exhibited statistically higher interrogation rates than NATURES-reared smolts).

Sawtooth Fish Hatchery—Brood Year 1998

Control group smolts (n = 73,285) were released on April 12, 2000 directly from the Sawtooth Fish Hatchery into the Salmon River (Table 3); 508 of these smolts received PIT tags (Table 4). Treatment group smolts (n = 50,140) were released on April 12, 2000 (Table 3); 496 of these smolts received PIT tags (Table 4). Control group smolts survived at a minimum of 34.7% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 4 (Figure 8). Treatment group smolts survived at a minimum of 40.7% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 4 (Figure 8). No statistical difference was detected between the control and treatment group (χ^2 = 1.7901, df = 1, P = 0.1809). These data indicate that out-migration survival of spring chinook salmon from the Sawtooth Fish Hatchery to LGR in 2000 was independent of NATURES rearing treatments applied.

Sawtooth Fish Hatchery—Brood Year 1999

Control group smolts (n = 29,965) were released on April 20, 2001 directly from the Sawtooth Fish Hatchery into the Salmon River; however, no control group smolts were PIT tagged as part of NATURES investigation in 2001. Treatment group smolts (n = 57,134) were released on April 20, 2001 (Table 3); 500 of these smolts received PIT tags (Table 4). Treatment group smolts survived at a minimum of 51.2% to LGR (based on cumulative unique interrogations of PIT tag detections). The median arrival date at LGR for these fish was May 12.

<u>Adult Returns</u>

Clearwater Fish Hatchery—Brood Year 1992

<u>Powell Satellite Facility</u>—A total of 268 adult spring chinook salmon were trapped at the Powell satellite facility from brood year 1992 releases. Adult returns from a control group release of 68,791 CWT smolts included 29 CWT rack recoveries, yielding an SAR of 0.042% (Table 1). Adult returns from a treatment group release of 67,340 CWT smolts included 22 CWT rack recoveries, yielding an SAR of 0.033% (Table 1). No statistical difference was detected between the control and treatment group (χ^2 = 0.8178, df = 1, P = 0.3658). These data indicate that adult returns of spring chinook salmon to the Powell satellite facility from brood year 1992 were independent of NATURES rearing treatments applied.

Papoose Creek—Papoose Creek was only used as a juvenile release site; adults were not trapped at this location.

Clearwater Fish Hatchery—Brood Year 1993

Powell Satellite Facility—A total of 942 adult spring chinook salmon were trapped at the Powell satellite facility from brood year 1993 releases. Adult returns from a control group release of 157,175 CWT smolts included 328 CWT rack recoveries, yielding an SAR of 0.209% (Table 1). Adult returns from a treatment group release of 127,824 CWT smolts included 341 CWT rack recoveries, yielding an SAR of 0.267% (Table 1). A statistical difference was detected between the control and treatment group (χ^2 = 10.1571, df = 1, P = 0.0014). These data indicate that adult returns of spring chinook salmon to the Powell satellite facility from brood year 1993 were not independent of NATURES rearing treatments applied (e.g., treatment adults returned statistically better than control adults).

Crooked River Satellite Facility—A total of 1,274 adult spring chinook salmon were trapped at the Crooked River satellite facility from brood year 1993 releases. Adult returns from a control group release of 151,200 CWT smolts included 247 CWT rack recoveries, yielding an SAR of 0.163% (Table 1). Adult returns from a treatment group release of 157,354 CWT smolts included 374 CWT rack recoveries, yielding an SAR of 0.238% (Table 1). A statistical difference was detected between the control and treatment group (χ^2 = 21.2048, df = 1, P < 0.0001). These data indicate that adult returns of spring chinook salmon to the Crooked River satellite facility from brood year 1993 were not independent of NATURES rearing treatments applied (e.g., treatment adults returned statistically better than control adults).

Clearwater Fish Hatchery—Brood Year 1994

Powell Satellite Facility—A total of 232 adult spring chinook salmon were trapped at the Powell satellite facility from brood year 1994 releases. Adult returns from a control group release of 61,735 CWT smolts included 45 CWT rack recoveries, yielding an SAR of 0.073% (Table 1). Adult returns from a treatment group release of 63,489 CWT smolts included 57 CWT rack recoveries, yielding an SAR of 0.090% (Table 1). No statistical difference was detected between the control and treatment group (χ^2 = 1.0967, df = 1, P = 0.2950). These data indicate that adult returns of spring chinook salmon to the Powell satellite facility from brood year 1994 were independent of NATURES rearing treatments applied.

Sawtooth Fish Hatchery—Brood Year 1992

A total of 213 adult spring chinook salmon were trapped at the Sawtooth Fish Hatchery from brood year 1992 releases. Adult returns from a control group release of 56,771 CWT smolts included 15 CWT rack recoveries, yielding an SAR of 0.026% (Table 3). Adult returns from a treatment group release of 48,412 CWT smolts included no CWT rack recoveries, yielding an SAR of 0.000% (Table 3). A statistical difference was detected between the control and treatment group (χ^2 = 12.7932, df = 1, P = 0.0003). These data indicate that adult returns of spring chinook salmon to the Sawtooth Fish Hatchery from brood year 1992 were not independent of NATURES rearing treatments applied (e.g., control adults returned statistically better than treatment adults).

DISCUSSION

The use of NATURES has been demonstrated to increase post-release survival of hatchery-reared salmonids (Maynard et al. 1995). Seminatural rearing methods implemented through NATURES have included: camouflage patterned raceway floors to simulate substrate, in-stream structure, overhead cover, predator avoidance training, swimming conditioning, foraging training, underwater feeding, supplemental dissolved oxygen, and reduced rearing densities. In our work, the application of selected NATURES methods in a production-based operation was challenging. Despite the number of NATURES techniques presented in the literature, we were limited to applying those modifications that could be retrofitted to the existing raceways at Sawtooth and Clearwater fish hatcheries. Furthermore, modifications could not interfere with fish culture practices such as raceway cleaning or other maintenance requirements already in place at each facility.

The implementation of multiple NATURES methods in combination has been shown to provide greater post-release survival benefits compared to applying single modifications (Maynard et al. 1996d). During our research study we used a combination of simulated substrate, in-stream structure, and overhead cover at the Sawtooth Fish Hatchery. Fuji (1993) suggested that a natural, cryptic colored smolt (generated through exposure to NATURES environments) appears to have a better chance of surviving following release. Additionally, Berejikian et al. (1999) noted that fish reared in seminatural hatchery environments with overhead cover and in-stream structure were likely to prefer these same attributes post-release, further increasing chances for survival. We did not use predator training during this study because of fish health concerns associated with implementing this technique on a production scale. However, when predator training has been used with other NATURES methods, out-migration survival in some cases was higher than for fish reared without predator training (Berejikian et al. 1999). Predation is believed to be a primary source of mortality to migrating smolts. As such, adaptations like cryptic coloration or body camouflage, utilization of cover, predator avoidance, or swimming endurance (that can be achieved using NATURES modifications) would likely improve post-release survival.

Our results indicate that fish reared under seminatural conditions failed to experience statistically better out-migration survival to LGR compared to fish reared under traditional conditions. In fact, in one study year at the Sawtooth Fish Hatchery (brood year 1997), fish reared under traditional conditions migrated statistically better than the NATURES treatment group. Results of SAR evaluations conducted on Clearwater Fish Hatchery data indicate that brood year 1993 fish reared under seminatural conditions at Powell and Crooked River satellite facilities returned to rack locations statistically better than fish reared under traditional conditions. However, no statistical differences were observed for brood year 1992 and 1994 adult SAR data sets. For the one complete Sawtooth Fish Hatchery adult SAR data set (brood year 1992), results indicate that fish reared under traditional conditions returned to the hatchery statistically better than fish reared under seminatural conditions.

Several factors may have confounded our results from releases made at the Powell satellite facility, Papoose Creek, and Sawtooth Fish Hatchery between 1994 and 1997, including a coinciding acclimated/nonacclimated release experiment, varying levels of bacterial kidney disease in the different experimental groups, and differences in size at release between treatment and control groups (Hassemer et al. 2000). Other factors that could have affected the outcome of our experiment included duration of exposure to NATURES environments, volitional

v. forced-emigration releases, similar rearing environments between control and treatment groups, and a lack of replication of experimental methods within and among years.

Conventional-rearing raceways at Sawtooth Fish Hatchery included overhead shade similar to NATURES raceways. Furthermore, the lattice shaped sheets used for overhead shade cover on the conventional-rearing raceways cast a mottled shade pattern on the raceway floors that could potentially function like the simulated substrate in the NATURES raceways. The effect of these potentially similar raceway environments may have influenced the post-release survival and adult return results observed for fish exposed to NATURES and conventional rearing environments.

Juvenile chinook salmon spent approximately ten months rearing in outdoor raceways at Sawtooth Fish Hatchery, during which time there was an inconsistent application of NATURES methods. In mid-September each year, juvenile chinook salmon were coded-wire tagged. During tagging, overhead and in-stream cover were removed from all raceways. Additionally, by the end of October until the early spring (approximately five months), overhead cover and in-stream cover were again removed due to the accumulation of ice and snow. Only the overhead cover was reinstalled in the spring six to eight weeks prior to release. During the times when overhead and in-stream cover were removed, the simulated substrate in the NATURES raceways was the only difference between the control and treatment environments. The effect of these potentially similar raceway environments may have influenced the post-release survival and adult return results observed for fish exposed to NATURES and conventional rearing environments.

Seminatural rearing modifications used during our study were tested for approximately ten months at both hatcheries. Other investigators (Donnelly and Whoriskey 1991; Maynard et al. 1996d, 1998, and 1998b) exposed fish to seminatural environments for three to four months before release and saw advantages of NATURES; the effect of longer exposure to seminatural environments or exposure during different stages of juvenile development is not known. Additionally, it is unknown if the release strategy (e.g., volitional, forced-emigration, or acclimated release) in combination with NATURES or conventional-rearing can influence the results of control or treatment rearing methods. Volitional release strategies have been shown to increase post-release survival compared to traditional forced emigration release strategies (Evenson and Ewing 1992; Rottiers and Redell 1993; Viola and Shuck 1995).

The duration and timing of high water events during migration may have influenced PIT tag detections during the research study (Figures 7 and 8). In years of higher flows, out-migrating smolts are more likely to travel over the dams they encounter while water is being spilled, thus avoiding detection and portraying an artificially low survival. Contrary to survival estimates based on PIT tag detections during these years, survival is higher. Therefore, during these conditions, SARs may be a better indicator of post-release success than juvenile detections.

New and more ‘natural’ NATURES methods continue to be tested for their ability to improve post-release survival in retrofitted hatchery raceways. For example, within the last five years efforts to simulate natural stream substrate have changed from painting camouflage patterns on raceway floors to resurfacing the raceways with built in pebbles, which provide a more natural benthic cover and may be easier to clean than other simulated substrates. Furthermore, advances in the application of predator avoidance, foraging behavior, underwater feeding, and exercise have allowed evaluations of these methods, in addition to refining previous methods. Efforts such as these not only offer greater potential to increase post-release survival but also may provide a more production friendly option. Despite advances in technology, the need to test selected methods at different facilities to determine applicability exists because of results in published studies and intraspecific behavior (Healey and Reinhardt 1995).

While our pilot and research studies failed to consistently demonstrate a benefit of NATURES modified raceways, there is adequate literature available to demonstrate that the concept of providing more natural rearing environments should not be abandoned. Final results for work in progress (adult SARs) are still pending.

Table 1. Releases from fish reared at Clearwater Fish Hatchery during the NATURES rearing experiment. All releases were made with full-term smolts. Recoveries listed are summed by experimental group.

Brood Year	Control / Treatment	Release Site	Total Release	# CWT Tagged	# Untagged	PIT Tags	Marks	CWT File	Total Recoveries at Hatchery Racks
1992	Control	Powell Pond	70,987	68,791	2,196	500	All AD Clip	104656	
								104657	
								Total	**29**
1992	Treatment	Powell Pond	69,490	67,340	2,150	500	All AD Clip	104658	
								104659	
								Total	**22**
1992	Control	Papoose Creek	29,596	28,680	916	250	All AD Clip	104655	**22**
1992	Treatment	Papoose Creek	29,631	28,714	917	250	All AD Clip	104654	**9**
1993	Control	Powell Pond	161,139	157,175	3,964	0	All AD Clip	103521	
								103517	
								103518	
								Total	**328**
1993	Treatment	Powell Pond	129,278	127,824	1,454	0	All AD Clip	103520	
								103516	
								103519	
								Total	**341**
1993	Control	Crooked River Pond	152,560	151,200	1,360	0	All AD Clip	103531	
								103527	
								103530	
								Total	**247**
1993	Treatment	Crooked River Pond	159,126	157,354	1,772	0	All AD Clip	103532	
								103528	
								103529	
								Total	**374**
1994	Control	Powell Pond	108,405	61,735	46,670	5,720	All AD Clip	104544	
								104542	
								104543	
								Total	**45**
1994	Treatment	Powell Pond	112,786	63,489	49,297	5,712	All AD Clip	104546	
								104541	
								104545	
								Total	**57**

Table 2. Interrogations of PIT-tagged juvenile chinook salmon reared at Clearwater Fish Hatchery for the NATURES rearing experiment. (LGR = Lower Granite Dam, LGO = Little Goose Dam, LMN = Lower Monumental Dam, MCN = McNary Dam).

Brood Year	Release location	Control/ Treatment	PIT Tag File	# in Group	Release Date	LGR No.	LGR %	LGO No.	LGO %	LMN No.	LMN %	MCN No.	MCN %	Total #	Total %	Median Travel Time to LGR (days)
1992	Powell Pond	Control	DAC94062.C4A	250	04/13/94	70	28.00	16	6.40	24	9.60	42	16.80	152	60.80	24.68
			DAC94062.C3A	250	04/13/94	75	30.00	16	6.40	16	6.40	31	12.40	138	55.20	25.99
		Control Total		**500**	04/13/94	**145**	**29.00**	**32**	**6.40**	**40**	**8.00**	**73**	**14.60**	290	**58.00**	**25.33**
1992	Powell Pond	Treatment	DAC94063.C5A	250	04/13/94	50	20.00	23	9.20	17	6.80	28	11.20	118	47.20	25.98
			DAC94063.C6A	250	04/13/94	62	24.80	18	7.20	12	4.80	25	10.00	117	46.80	25.91
		Treatment Total		**500**	04/13/94	**112**	**22.40**	**41**	**8.20**	**29**	**5.80**	**53**	**10.60**	**235**	**47.00**	**25.95**
1992	Powell Pond	High BKD	DAC94063.C9A	500	04/14/94	99	19.80	19	3.80	23	4.60	50	10.00	191	38.20	24.49
1992	Papoose Creek	Control	DAC94063.C2A	250	04/15/94	63	25.20	6	2.40	11	4.40	27	10.80	107	42.80	23.42
1992	Papoose Creek	Treatment	DAC94063.C1A	250	04/15/94	68	27.20	15	6.00	12	4.80	17	6.80	112	44.80	23.38
1993	Powell Pond	Control	DAC95044.C1B	400	04/13/95	128	32.00	67	16.75	41	10.25	13	3.25	249	62.25	19.87
	Powell Pond	Control	DAC95045.C2A	400	04/13/95	118	29.50	49	12.25	42	10.50	8	2.00	217	54.25	22.68
	Powell Pond	Control	DAC95045.C3A	400	04/13/95	110	27.50	49	12.25	51	12.75	15	3.75	225	56.25	24.47
		Control Total		**1,200**	04/13/95	**356**	**29.67**	**165**	**13.75**	**134**	**11.17**	**36**	**3.00**	**691**	**57.58**	**22.68**
1993	Powell Pond	Treatment	DAC95044.C1A	400	04/13/95	94	23.50	65	16.25	55	13.75	25	6.25	239	59.75	25.48
	Powell Pond	Treatment	DAC95045.C2B	400	04/13/95	123	30.75	59	14.75	48	12.00	15	3.75	245	61.25	21.67
	Powell Pond	Treatment	DAC95045.C3B	400	04/13/95	107	26.75	64	16.00	45	11.25	11	2.75	227	56.75	23.44
		Treatment Total		**1,200**	04/13/95	**324**	**27.00**	**188**	**15.67**	**148**	**12.33**	**51**	**4.25**	**711**	**59.25**	**23.44**
1993	Crooked River	Control	DAC95046.4AC	400	04/10/95	99	24.75	64	16.00	47	11.75	8	2.00	218	54.50	29.57
	Crooked River	Control	DAC95048.C5B	400	04/10/95	90	22.50	62	15.50	39	9.75	8	2.00	199	49.75	23.45
	Crooked River	Control	DAC95048.C6B	400	04/10/95	118	29.50	61	15.25	42	10.50	10	2.50	231	57.75	27.61
		Control Total		**1,200**	04/10/95	**307**	**25.58**	**187**	**15.58**	**128**	**10.67**	**26**	**2.17**	**648**	**54.00**	**27.61**
1993	Crooked River	Treatment	DAC95046.C4B	400	04/10/95	107	26.75	59	14.75	52	13.00	11	2.75	229	57.25	29.61
	Crooked River	Treatment	DAC95048.C5A	400	04/10/95	96	24.00	60	15.00	39	9.75	8	2.00	203	50.75	32.73
	Crooked River	Treatment	DAC95048.C6A	400	04/10/95	115	28.75	62	15.50	37	9.25	11	2.75	225	56.25	22.38
		Treatment Total		**1,200**	04/10/95	**318**	**26.50**	**181**	**15.08**	**128**	**10.67**	**30**	**2.50**	**657**	**54.75**	**29.61**

Table 2, continued.

Brood Year	Release location	Control/ Treatment	PIT Tag File	# in Group	Release Date	LGR No.	LGR %	LGO No.	LGO %	LMN No.	LMN %	MCN No.	MCN %	Total #	Total %	Median Travel Time to LGR (days)
1994	Powell Pond	Control	DAC96066.2A	300	04/11/96	44	14.67	24	8.00	27	9.00	2	0.67	97	32.33	33.71
			DAC96066.C2A	300	04/11/96	55	18.33	30	10.00	24	8.00	6	2.00	115	38.33	32.42
			DAC96072.C31	1,473	04/11/96	237	16.09	138	9.37	118	8.01	23	1.56	516	35.03	31.41
			DAC96072.C32	656	04/11/96	146	22.26	56	8.54	36	5.49	11	1.68	249	37.96	32.40
			DAC96072.C41	1,218	04/11/96	175	14.37	114	9.36	75	6.16	32	2.63	396	32.51	32.82
			DAC96072.C42	573	04/11/96	77	13.44	51	8.90	42	7.33	8	1.40	178	31.06	32.13
			DAC96066.3A	275	04/11/96	29	10.55	26	9.45	21	7.64	4	1.45	80	29.09	31.50
			DAC96066.3AC	325	04/11/96	53	16.31	38	11.69	22	6.77	7	2.15	120	36.92	33.37
			DAC96066.4A	250	04/11/96	38	15.20	32	12.80	22	8.80	1	0.40	93	37.20	30.76
			DAC96066.4AC	350	04/11/96	56	16.00	29	8.29	28	8.00	4	1.14	117	33.43	32.62
		Control Total		**5,720**	04/11/96	**910**	**15.91**	**538**	**9.41**	**415**	**7.26**	**98**	**1.71**	**1,961**	**34.28**	**32.31**
1994	Powell Pond	Treatment	DAC96066.1A	300	04/11/96	47	15.67	23	7.67	24	8.00	6	2.00	100	33.33	31.50
			DAC96066.1AC	300	04/11/96	42	14.00	27	9.00	20	6.67	5	1.67	94	31.33	30.90
			DAC96071.1A1	1,025	04/11/96	178	17.37	101	9.85	83	8.10	23	2.24	385	37.56	32.16
			DAC96071.1A2	1,367	04/11/96	242	17.70	115	8.41	103	7.53	37	2.71	497	36.36	32.03
			DAC96071.1A3	465	04/11/96	84	18.06	41	8.82	35	7.53	9	1.94	169	36.34	32.39
			DAC96071.C1A	1,057	04/11/96	172	16.27	100	9.46	77	7.28	27	2.55	376	35.57	31.42
			DAC96065.5A	330	04/11/96	72	21.82	31	9.39	22	6.67	5	1.52	130	39.39	32.60
			DAC96065.C5A	270	04/11/96	48	17.78	18	6.67	17	6.30	4	1.48	87	32.22	31.93
			DAC96065.6A	338	04/11/96	64	18.93	35	10.36	29	8.58	5	1.48	133	39.35	32.03
			DAC96065.6AC	260	04/11/96	50	19.23	23	8.85	21	8.08	4	1.54	98	37.69	32.70
		Treatment Total		**5,712**	04/11/96	**999**	**17.49**	**514**	**9.00**	**431**	**7.55**	**125**	**2.19**	**2,069**	**36.22**	**31.96**

Table 3. Releases from fish reared at Sawtooth Fish Hatchery during the NATURES rearing experiment. All releases were made with full-term smolts. Recoveries listed are summed by experimental group. All unmarked fish were part of the Idaho Supplementation Studies research. Coded-wire tag analysis is not complete for brood years 1998 and 1999.

Brood Year	Control/ Treatment	Release Site	Total Release	CWT # Tagged	# Untagged	PIT Tags	Marks	CWT File	Total Recoveries at Hatchery Racks
1992	Control	Sawtooth Fish Hatchery	65,270	56,771	8,499	500	All AD Clip	104612	
								104604	
								104927	
								104929	
								Total	**15**
1992	Treatment	Sawtooth Fish Hatchery	48,412	48,412	5,984	501	All AD Clip	104611	
								104605	
								104928	
								104930	
								Total	**0**
1997	Control	Sawtooth Fish Hatchery	30,033	28,920	1,113	0	All AD Clip	104619	
								105239	
								Total	**249**[a]
1997	Treatment	Sawtooth Fish Hatchery	68,316	67,698	618	0	Unmarked	105262	
								104620	
								104631	
								104632	
								105240	
								Total	**75**[a]
1998	Control	Sawtooth Fish Hatchery	73,285	71,654	1,631	0	Unmarked	105,429	
								105422	
								105423	
								105428	
								Total	NA
1998	Treatment	Sawtooth Fish Hatchery	50,140	49,249	891	0	Unmarked	105421	
								105420	
								Total	NA
1999	Treatment	Sawtooth Fish Hatchery	57,134	55,600	1,534	0	Unmarked	103,607	NA
		-No control group releases were made from brood year 1999-							

[a] These numbers do not include 5-year-old returns.

Table 4. Interrogations of PIT-tagged juvenile chinook salmon reared at Sawtooth Fish Hatchery for the NATURES rearing experiment. (LGR = Lower Granite Dam, LGO = Little Goose Dam, LMN = Lower Monumental Dam, MCN = McNary, SAWT = Sawtooth Fish Hatchery).

						LGR		LGO		LMN		MCN				
Brood Year	**Release location**	**Control/ Treatment**	**PIT Tag File**	**# in Group**	**Release Date**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**Total #**	**Total %**	**Median Travel Time to LGR (days)**
1992	SAWT	Control	DAC93272.S08	373	04/11/94	35	9.38	1	0.27	6	1.61	13	3.49	55	14.75	20.58
		Control	DAC93272.S11	364	04/08/94	31	8.52	7	1.92	6	1.65	6	1.65	50	13.74	25.33
		Control	DAC93272.S12	258	04/08/94	23	8.91	3	1.16	7	2.71	6	2.33	39	15.12	26.30
	Control Total			**995**		**89**	**8.94**	**11**	**1.11**	**19**	**1.91**	**25**	**2.51**	**144**	**14.47**	**25.33**
1992	SAWT	Treatment	DAC93271.S13	381	04/08/94	40	10.50	4	1.05	10	2.62	12	3.15	66	17.32	25.59
		Treatment	DAC93272.S10	333	04/08/94	23	6.91	6	1.80	10	3.00	5	1.50	44	13.21	25.82
		Treatment	DAC93272.S14	159	04/08/94	13	8.18	4	2.52	3	1.89	3	1.89	23	14.47	24.58
	Treatment Total			**873**	**04/08/94**	**76**	**8.71**	**14**	**1.60**	**23**	**2.63**	**20**	**2.29**	**133**	**15.23**	**25.59**
1997	SAWT	Control	KEP99066.01S	983	04/16/99	107	10.89	175	17.80	67	6.82	23	2.34	372	37.84	28.56
	SAWT	Control	KEP99067.05S	497	04/16/99	41	8.25	96	19.32	25	5.03	22	4.43	184	37.02	28.22
	Control Total			**1,480**	**04/16/99**	**148**	**10.00**	**271**	**18.31**	**92**	**6.22**	**45**	**3.04**	**556**	**37.57**	**28.39**
	SAWT	Treatment	KEP99066.02S	492	04/16/99	42	8.54	49	9.96	30	6.10	20	4.07	141	28.66	33.48
	SAWT	Treatment	KEP99066.04S	495	04/16/99	44	8.89	86	17.37	25	5.05	10	2.02	165	33.33	31.76
	SAWT	Treatment	KEP99067.06S	499	04/16/99	29	5.81	57	11.42	21	4.21	12	2.40	119	23.85	28.99
	Treatment Total			**1,486**	**04/16/99**	**115**	**7.74**	**192**	**12.92**	**76**	**5.11**	**42**	**2.83**	**425**	**28.60**	**31.76**
1998	SAWT	Control	KEP00063.S01	262	04/12/00	52	19.85	19	7.25	9	3.44	9	3.44	89	33.97	23.10
	SAWT	Control	KEP00063.S03	246	04/12/00	48	19.51	25	10.16	4	1.63	10	4.07	87	35.37	22.07
	Control Total			**508**	**04/12/00**	**100**	**19.69**	**44**	**8.66**	**13**	**2.56**	**19**	**3.74**	**176**	**34.65**	**22.58**
	SAWT	Treatment	KEP00063.S02	250	04/12/00	61	24.40	23	9.20	14	5.60	5	2.00	103	41.20	22.25
	SAWT	Treatment	KEP00063.S04	246	04/12/00	53	21.54	31	12.60	8	3.25	7	2.85	99	40.24	23.10
	Treatment Total			**496**	**04/12/00**	**114**	**22.98**	**54**	**10.89**	**22**	**4.44**	**12**	**2.42**	**202**	**40.73**	**22.67**
1999	SAWT	Treatment	DTV01055.S02	500	04/20/01	197	39.40	54	10.80	5	1.00	0	0.00	256	51.20	23.31
	NO CONTROL PIT TAGS															

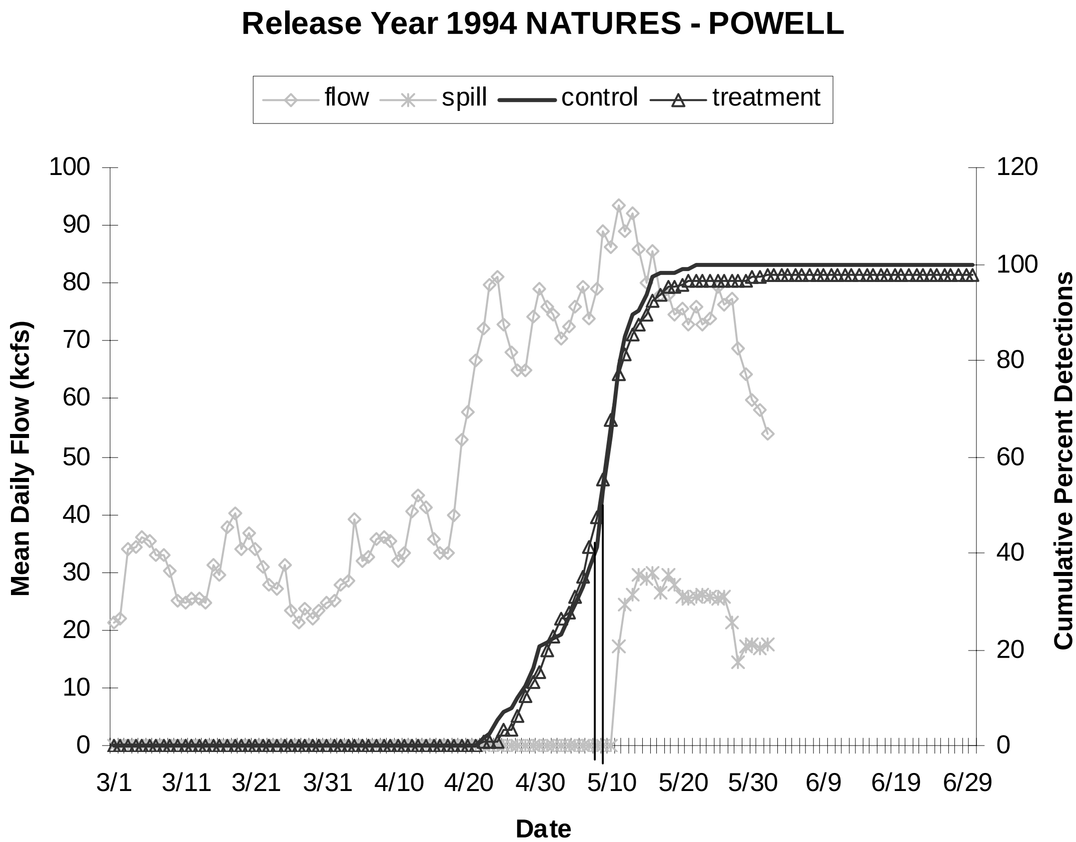

Figure 1. Migration year 1994 arrival timing and detection rates for PIT-tagged juvenile spring chinook salmon reared at Clearwater Fish Hatchery and released in the Powell Pond, Idaho. Vertical lines indicate median arrival date (Control 5/7 and Treatment 5/8). Daily flows and spill (kcfs) measured at Lower Granite Dam during the 1994 smolt emigration period. Travel times and arrival dates are based on PIT tag detections at only Lower Granite Dam.

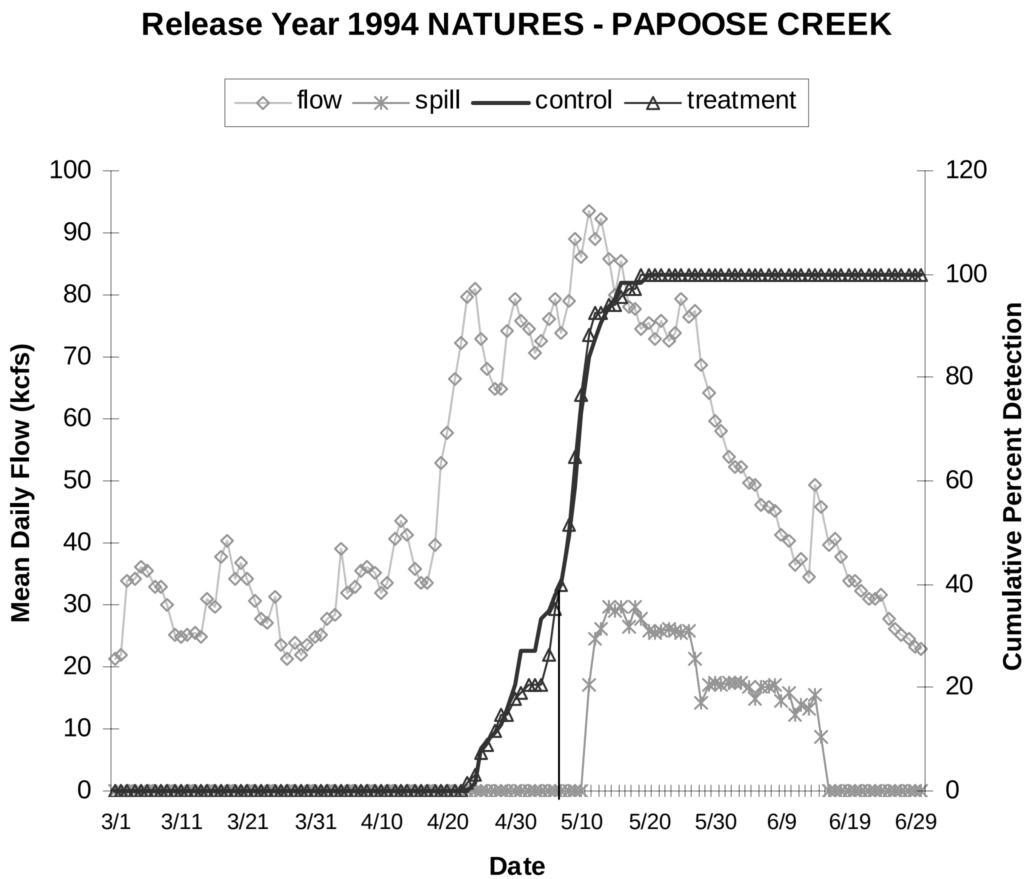

Figure 2. Migration year 1994 arrival timing and detection rates for PIT-tagged juvenile spring chinook salmon reared at Clearwater Fish Hatchery and released in Papoose Creek, Idaho. Vertical line indicates median arrival date (Control 5/6 and Treatment 5/6). Daily flows and spill (kcfs) measured at Lower Granite Dam during the 1994 smolt emigration period. Travel times and arrival dates are based on PIT tag detections at only Lower Granite Dam.

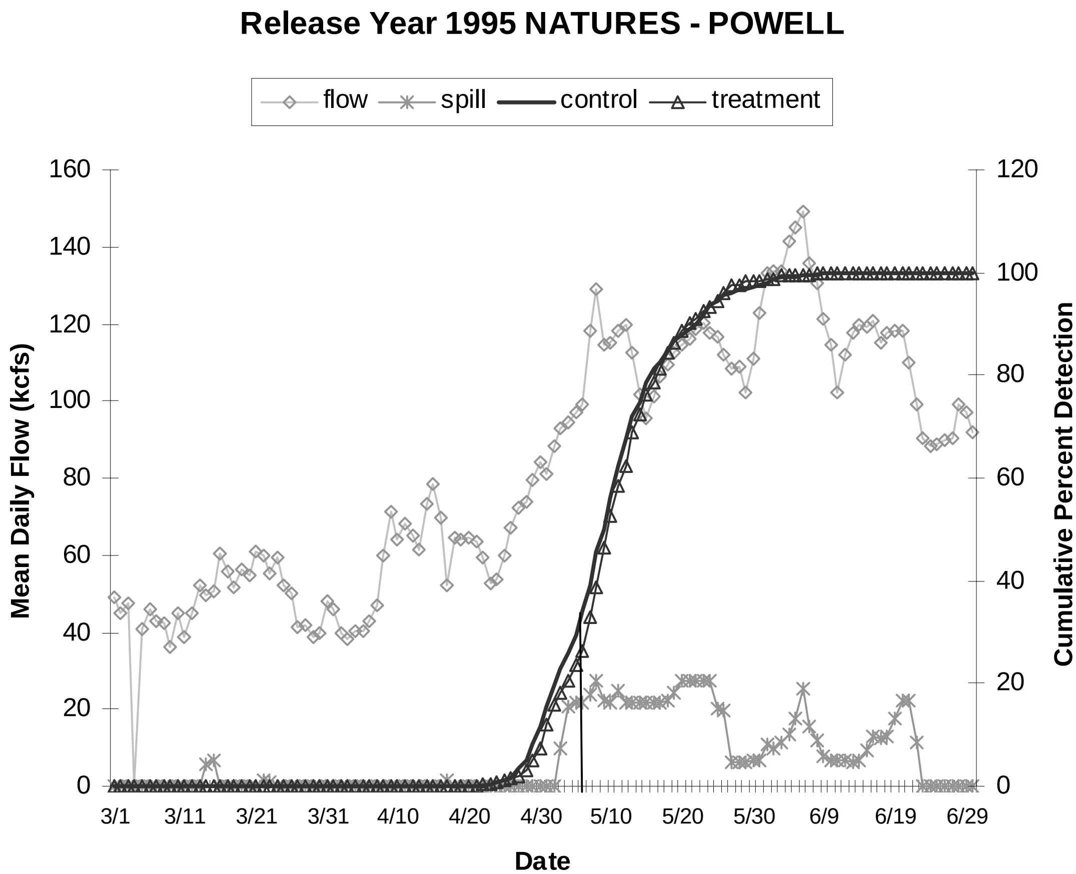

Figure 3. Migration year 1995 arrival timing and detection rates for PIT-tagged juvenile spring chinook salmon reared at Clearwater Fish Hatchery and released in the Powell Pond, Idaho. Vertical line indicates median arrival date (Control 5/5 and Treatment 5/5). Daily flows and spill (kcfs) measured at Lower Granite Dam during the 1994 smolt emigration period. Travel times and arrival dates are based on PIT tag detections at only Lower Granite Dam.

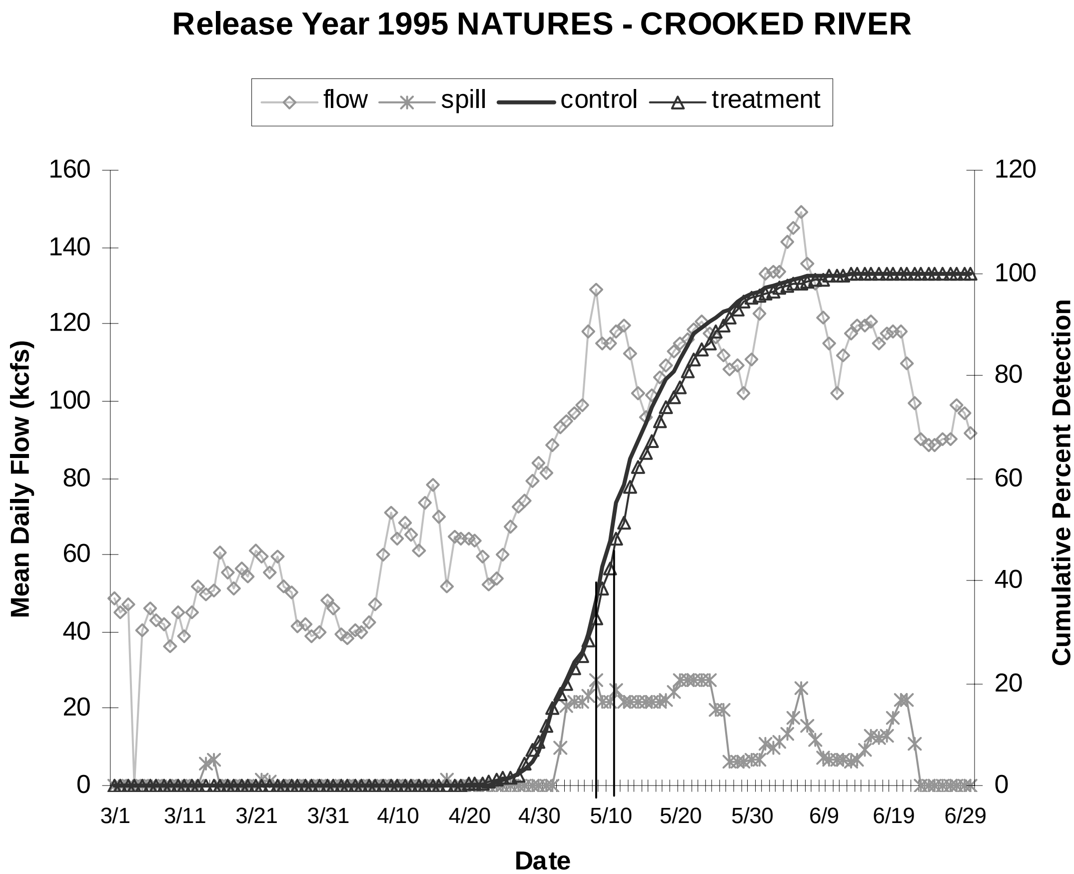

Figure 4. Migration year 1995 arrival timing and detection rates for PIT-tagged juvenile spring chinook salmon reared at Clearwater Fish Hatchery and released in the Crooked River, Idaho. Vertical lines indicate median arrival date (Control 5/7 and Treatment 5/9). Daily flows and spill (kcfs) measured at Lower Granite Dam during the 1994 smolt emigration period. Travel times and arrival dates are based on PIT tag detections at only Lower Granite Dam.

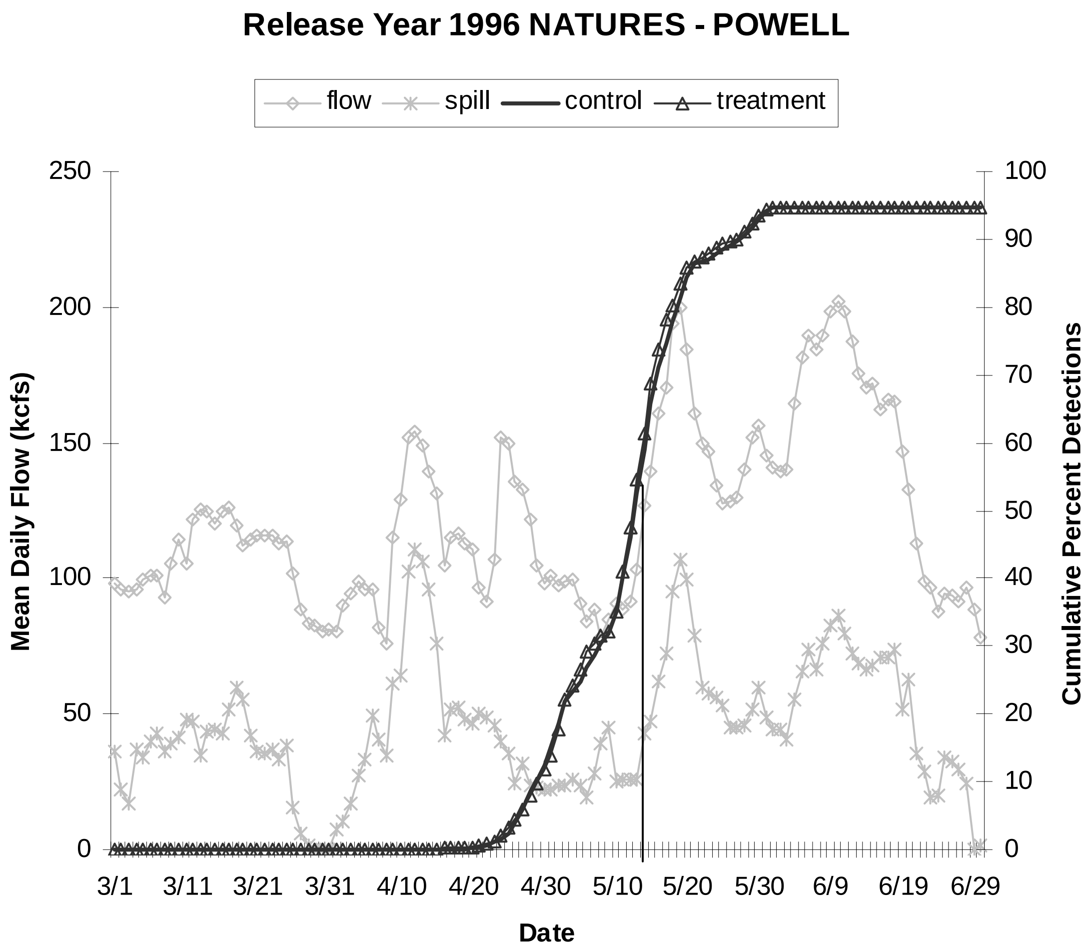

Figure 5. Migration year 1996 arrival timing and detection rates for PIT-tagged juvenile spring chinook salmon reared at Clearwater Fish Hatchery and released in the Powell Pond, Idaho. Vertical line indicates median arrival date (Control 5/12 and Treatment 5/12). Daily flows and spill (kcfs) measured at Lower Granite Dam during the 1994 smolt emigration period. Travel times and arrival dates are based on PIT tag detections at only Lower Granite Dam.

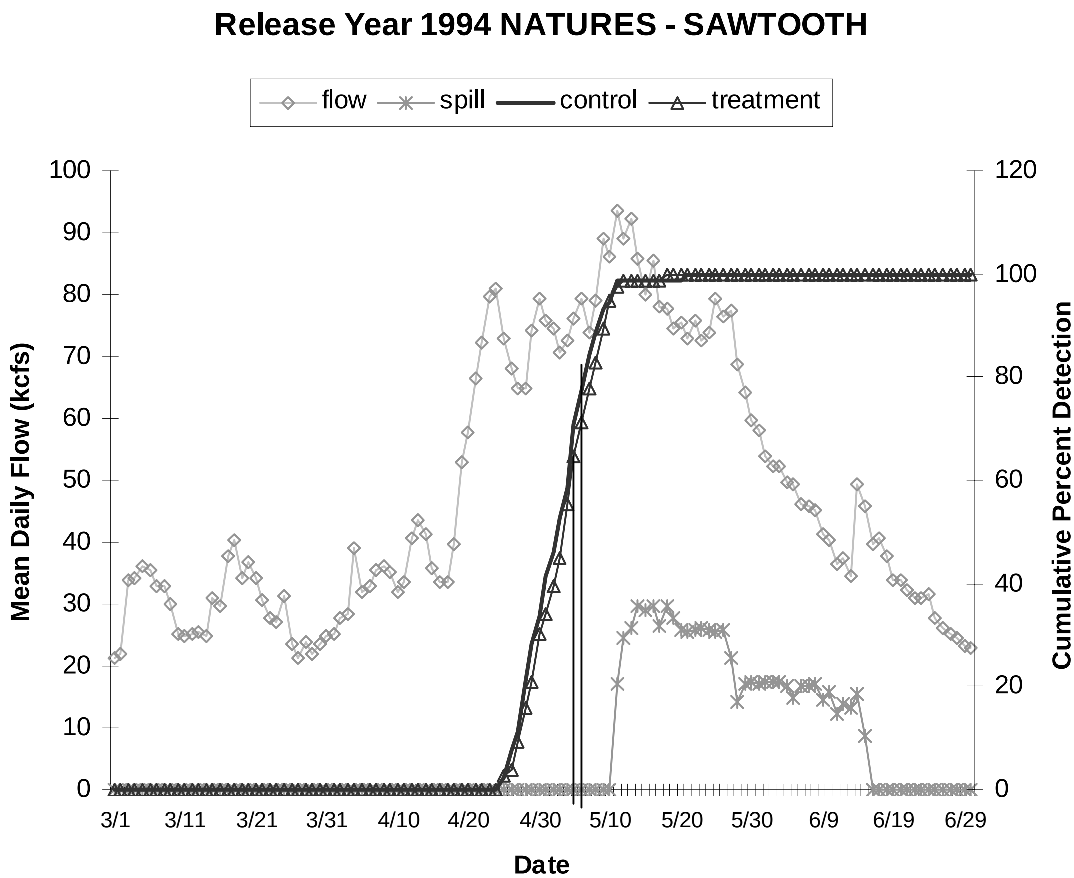

Figure 6. Migration year 1994 arrival timing and detection rates for PIT-tagged juvenile spring chinook salmon reared and released from the Sawtooth Fish Hatchery, Idaho. Vertical lines indicate median arrival date (Control 5/2 and Treatment 5/3). Daily flows and spill (kcfs) measured at Lower Granite Dam during the 1994 smolt emigration period. Travel times and arrival dates are based on PIT tag detections at only Lower Granite Dam.

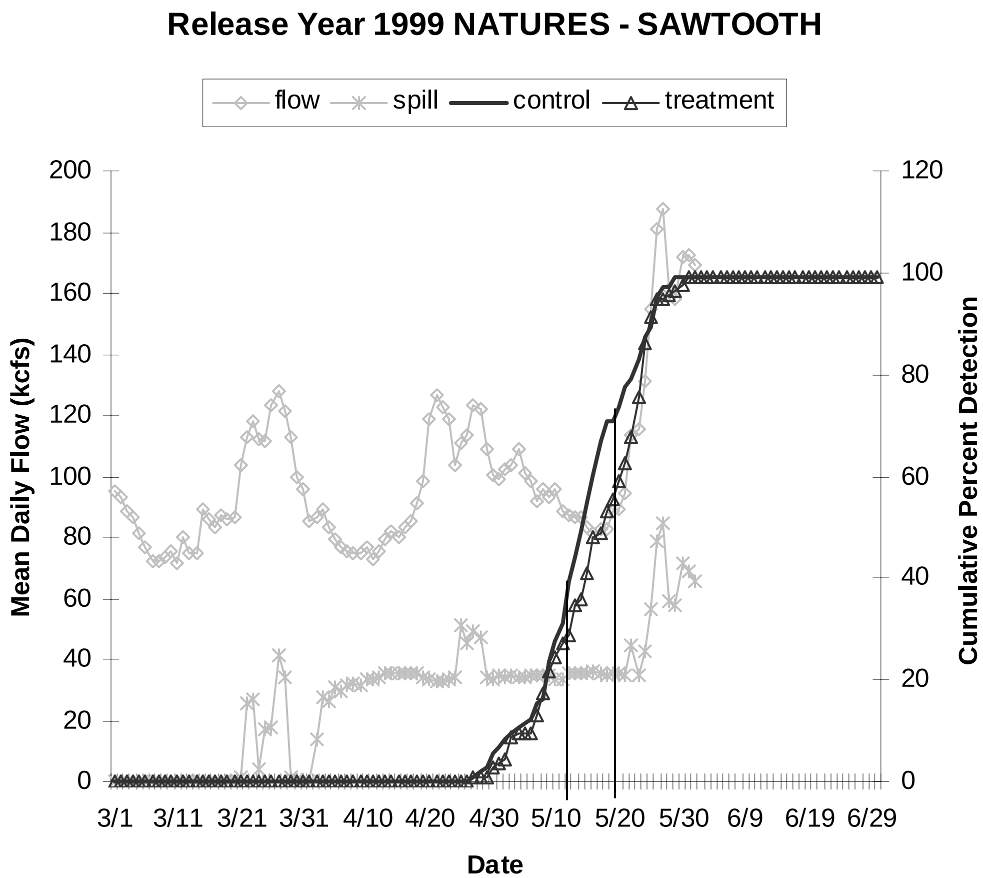

Figure 7. Migration year 1999 arrival timing and detection rates for PIT-tagged juvenile spring chinook salmon reared and released from Sawtooth Fish Hatchery, Idaho. Vertical lines indicate median arrival date (Control 5/13 and Treatment 5/17). Daily flows and spill (kcfs) measured at Lower Granite Dam during the 1994 smolt emigration period. Travel times and arrival dates are based on PIT tag detections at only Lower Granite Dam.

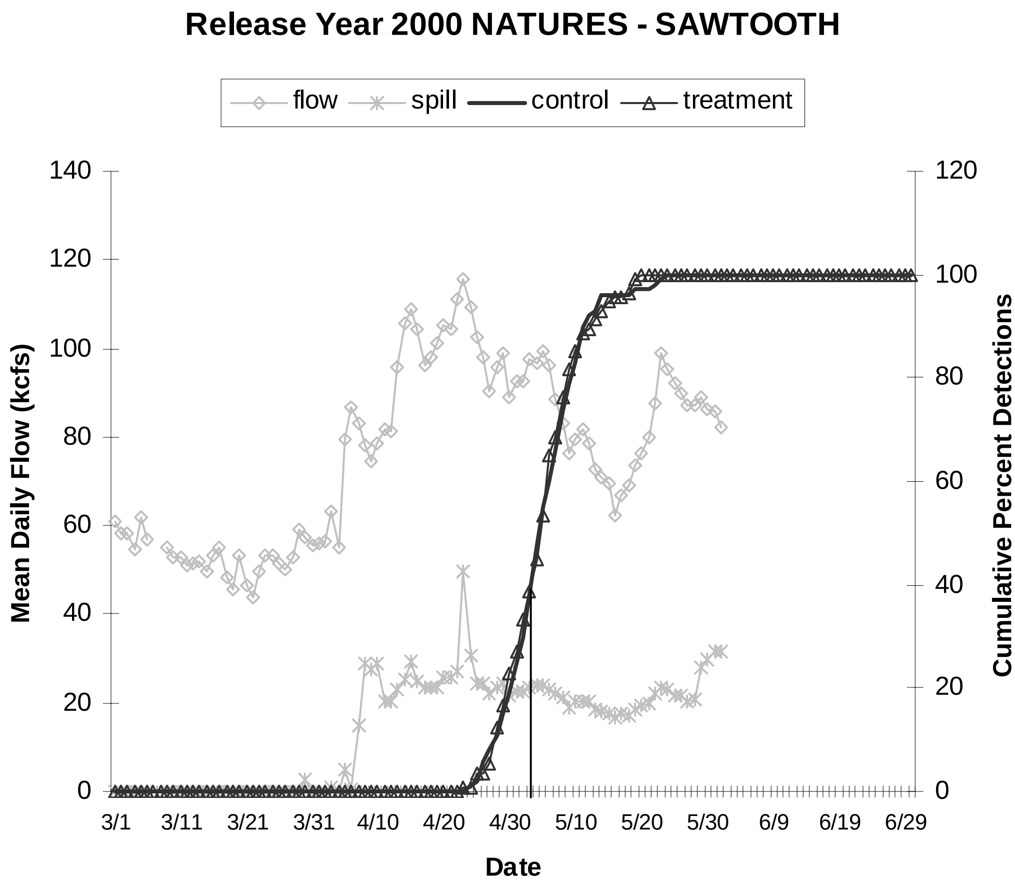

Figure 8. Migration year 2000 arrival timing and detection rates for PIT-tagged juvenile spring chinook salmon reared and released from Sawtooth Fish Hatchery, Idaho. Vertical line indicates median arrival date (Control 5/4 and Treatment 5/4). Daily flows and spill (kcfs) measured at Lower Granite Dam during the 1994 smolt emigration period. Travel times and arrival dates are based on PIT tag detections at only Lower Granite Dam.

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