Post-construction evaluation

of the juvenile bypass collection channel, transportation flume, and fish-monitoring facilities at Bonneville Dam Second Powerhouse, 1999-2000

Fish Ecology Division

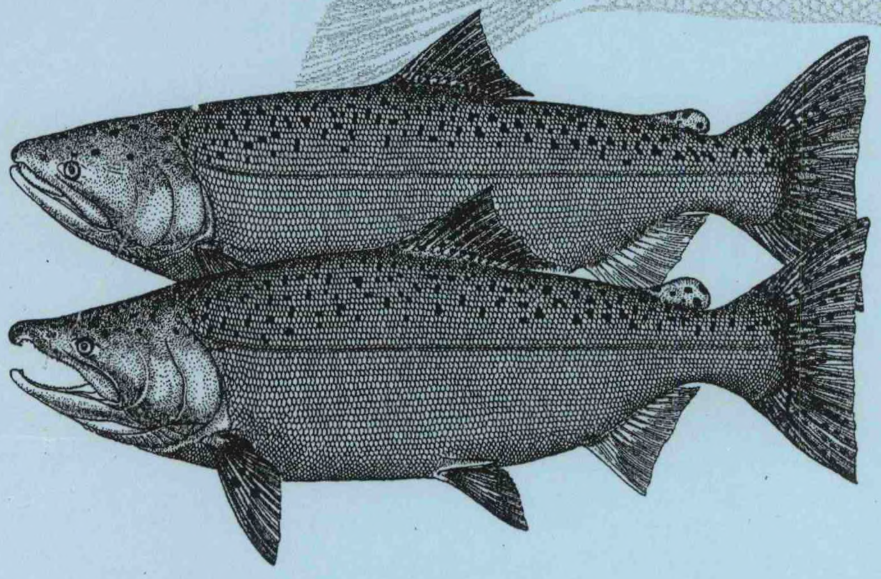
Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

by
Lyle G. Gilbreath, Earl F. Prentice,
and Sandra L. Downing

December 2004



Post-Construction Evaluation of the Juvenile Bypass Collection Channel, Transportation Flume, and Fish-Monitoring Facilities at Bonneville Dam Second Powerhouse, 1999-2000

Lyle G. Gilbreath, Earl F. Prentice, and Sandra L. Downing

Report of research by

Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

to

Portland District
U.S. Army Corps of Engineers
P.O. Box 2946
Portland, Oregon 97208-2946
Contract W66QKZ90281485
Contract W66QKZ00593474

December 2004

EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers redesigned and modified the juvenile fish bypass system (JBS) at Bonneville Dam Second Powerhouse to address problems with the original system. The rebuilt system included a modified collection channel, new gravity-flow transportation flume and PIT-tag monitoring system, and new juvenile fish-monitoring facilities and outfall structures. Except for the PIT-tag monitoring system and facilities, the JBS became operational prior to the 1999 juvenile salmonid migration season. Remaining components were completed prior to the 2000 migration.

In 1999, we conducted an initial reconnaissance-level study to determine if the rebuilt system components provided safe juvenile passage conditions. In 2000, we completed a second, more thorough evaluation of the completed system. Major objectives of the studies were to determine detection and separation efficiencies, assess physical effects, and evaluate passage timing of juvenile salmonids. We conducted tests using juvenile yearling and subyearling chinook salmon *Oncorhynchus tshawytscha*, juvenile steelhead *O. mykiss*, and juvenile sockeye salmon *O. nerka*. Test fish were obtained directly from hatcheries or from juvenile fish-monitoring facilities (river-run test fish).

We fabricated, installed, tested, and operated temporary PIT-tag detection and separation equipment at the juvenile monitoring site in 1999. The PIT-tag monitoring capability provided data for many research programs, and the separation capability provided a means to recapture test fish used in our study and in a companion study conducted by the U.S. Geological Survey. In 2000, we tested detection and separation efficiencies of the permanent PIT-tag monitoring system. Detection efficiencies of critical monitors ranged from 99 to 100%. Diversion efficiencies of the separation-by-code separator gate (a three-way rotational gate) varied from 96 to 100% in tests using hatchery subyearling chinook salmon and steelhead at gate-open times of 800 or 1,000 ms. Diversion efficiencies of the gate exceeded 99% in 2000 during release and recapture tests with river-run yearling and subyearling chinook salmon.

Based on releases of chinook salmon fry into the system in March 2000, we identified faulty gate seals at the upstream switch gate as a source of fry loss and injury. The problem has since been addressed through successive modifications to the gate seals. This situation illustrates that maintaining safe passage conditions for fry requires attention to what may appear to be minor leakage problems, particularly where a head difference exists.

We determined the extent to which bypass system passage affected fish condition through release and recapture of PIT-tagged river-run yearling chinook salmon, steelhead, and subyearling chinook salmon. In both study years, the incidence of mortality and external injury (abrasions, flesh wounds, torn fins, and opercle damage) was low (0-1%). Similarly, few river-run test fish were descaled at levels equaling or exceeding 20% (the Fisheries Transportation Oversight Team (FTOT) threshold level for fish classified as descaled). For river-run yearling chinook salmon released into the upstream collection channel or at the transportation flume entrance in 1999, we noted FTOT descaling in 5 (2.4%) of 209 fish examined. None of the river-run subyearling chinook salmon or steelhead released at these locations in 1999 and none of the river-run yearling and subyearling chinook released in 2000 were classified as descaled using FTOT criteria.

Careful comparison of pre-and post-passage fish condition suggested that low-level descaling (≤20% descaled) was occurring, particularly in yearling chinook salmon and steelhead. However, test releases of river-run chinook salmon in 2000 indicated that most low-level descaling was induced in the final handling stages (holding, pre-anesthetization, and transfer of fish to examination troughs) at the juvenile monitoring facility. Because most fish passing through the system are not subject to separation and handling, they would not be subject to descaling from these procedures.

Median passage times for river-run yearling and subyearling chinook salmon moving through the collection channel, transportation flume, and downstream components were slightly longer than estimated water travel times through the system. For these species, travel time data suggested movement of fish was generally straightforward, with some swimming against the flow. Passage times for river-run steelhead, although longer than those of chinook, were still rapid, and likely reflect species differences rather than passage delays.

Based on two years of study, we concluded that the new and rebuilt juvenile bypass components at Bonneville Dam Second Powerhouse allowed timely passage of juvenile migrants with minimal mortality, external injury, or descaling. We emphasize that the study only included evaluation of fish passing from the collection channel to the monitoring facility. Other potentially harmful effects of bypass, such as contact with intake guidance screens and passage through gatewell orifices, were evaluated separately.

CONTENTS

INTRODUCTION

The Bonneville Dam Second Powerhouse contains eight main generating units and two smaller turbine units that utilize water from the auxiliary fishway supply. The powerhouse was designed with a bypass system for diversion of juvenile salmonid migrants from turbine intakes. The juvenile bypass system (JBS), which was patterned after systems in use at other Snake and Columbia River dams in the late 1970s, became operational in 1982, prior to completion of the powerhouse. Its components were submersible traveling screens, vertical barrier screens, gatewell orifices, a collection channel, fish sampling facilities, and a pressurized 0.9-m-diameter outfall conduit. The outfall conduit terminated at a monolith submerged in the second powerhouse tailrace about 76 m downstream from the dam. Location of the outfall site in an area with consistent upstream to downstream flows of relatively high velocity was intended to provide juvenile salmonids a measure of protection from predation by northern pikeminnow *Ptychocheilus oregonensis* during egress from the system.

Initial evaluation of the new second powerhouse JBS took place during the spring and summer of 1982 (McConnell and Muir 1982). Since construction at the powerhouse was ongoing during this time, and turbine intake components of the JBS were not complete, the first year of evaluation focused on fish condition, sampling efficiency, and developing recommendations for system modifications.

Further evaluations, including fish guidance efficiency (FGE) were conducted from 1983 to 1989 (Krcma et al. 1984; Gessel et al. 1985, 1986, 1987, 1988, 1989, 1990, 1991), from 1993 to 1994 (Monk et al. 1994, 1995), and from 2001 to 2002 (Monk et al. 2002, 2004). The long period of post-construction evaluation was driven by the finding in 1983 that submersible traveling screens diverted an unacceptably low percentage (<70%) of juvenile migrants from turbine intakes into the bypass system (Krcma et al. 1984). Work in subsequent years tested FGE improvement potential of various structural changes associated with turbine intakes. A synthesis of results from FGE and other pertinent studies conducted from 1983 to 1998 was presented by Monk et al. (1999).

Although FGE improvement was the principal objective of these research efforts, other bypass system components were evaluated in studies conducted from 1983 to 1987. Evaluations during these years included orifice passage efficiency, fish quality and stress, potential of the bypass system for indexing smolt migrations, the feasibility of screen cycling, and use of the second powerhouse sampling room downwell as a release site for transported smolts. In addition, the temporal distribution of smolts passing through the juvenile bypass system was studied, as well as passage timing from the collection channel to the sampling room.

In 1988, following completion of these evaluations by the National Marine Fisheries Service (NMFS), operation of the bypass system sampling facilities was assumed by the Smolt Monitoring Program (SMP). However, there remained uncertainty over resolution of the FGE issue at the second powerhouse and the need to develop operational criteria which would meet fish-passage criteria.

To address these issues, NMFS conducted tests to determine relative survival of juvenile salmonids after passage through Bonneville Dam via various routes. From 1987 to 1990, NMFS released subyearling chinook salmon *Oncorhynchus tshawytscha* into the second powerhouse turbine intakes, bypass system, tailrace, and spillway (Dawley et al. 1988, 1989; Ledgerwood et al. 1990, 1991, 1994). Releases were evaluated based on beach- and purse-seine recaptures of coded-wire tagged and branded test fish at Jones Beach (Columbia River Kilometer 75).

Contrary to expectation, recovery data indicated that fish passing through the second powerhouse bypass system survived at lower rates than fish passing through the turbines. Subsequent inspections of the bypass system outfall conduit and examination of fish recaptured immediately after passage through the bypass system did not identify the source of mortality (Dawley et al. 1998). It was eventually determined that the probable source of mortality was predation by northern pikeminnow, and consequently, that the problem could not be resolved by measures other than relocation of the bypass system outfall.

Changes to the original second powerhouse juvenile bypass system and subsequent evaluation of the rebuilt system were recommended under the 1994-98 NMFS Biological Opinion (NMFS 1995). This report describes the post-construction evaluations conducted by NMFS under study summary BPS-W-00-12 of the U.S. Army Corps of Engineers Anadromous Fish Evaluation Programs for 1999 and 2000.

Evaluation of new or modified fish-passage facilities is conducted so that unforseen problems can be detected and corrected as soon as possible, thereby minimizing negative impacts to juvenile migrant salmonids. Other bypass systems evaluated by NMFS were at Bonneville (McConnell and Muir 1982; Krcma et al. 1984; Gessel et al. 1985, 1986, 1987, 1988), John Day (Absolon et al. 2000a,b), McNary (Marsh et al. 1996a), Ice Harbor (Gessel et al. 1997), Lower Monumental (Hockersmith et al. 1999; Marsh et al. 1995, 1996b), Little Goose (Hockersmith et al. 2003; Monk et al. 1992), and Lower Granite Dams (Hockersmith et al. 2002).

Most components of the rebuilt JBS became operational in spring 1999, including the modified collection channel, transportation flume, bypass and sample flumes, and outfalls. Operation in bypass mode started in March, followed by operation in sample mode from April to July. In bypass mode, juvenile migrants pass directly to the system outfall and do not pass through the PIT-tag interrogation and separation equipment. In sample mode, migrants are diverted into a separate flume system for PIT-tag interrogation and may be captured for examination. Remaining components of the rebuilt bypass system were completed prior to the start of the 2000 juvenile salmonid migration, and since that time, the system has been operated as an SMP sampling site.

The location and general features of the rebuilt second powerhouse JBS are shown in Figure 1. Further description of the rebuilt system may be found in a design report for the combined juvenile fish-monitoring facilities at Bonneville Dam (USACE 1996a). Details of system design may be found in Supplement No. 6 (USACE 1996b) and Supplement No. 7 (USACE 1996c) to the Bonneville Second Powerhouse Design Memorandum No. 9.

Objectives of our work in 1999 were as follows:

1) Fabricate two- and three-way fish diversion gates for the rebuilt JBS and provide interim PIT-tag interrogation and diversion capability
2) Install temporary fish-handling equipment at the site of the new smolt-monitoring facilities
3) Evaluate physical injury and passage timing for juvenile chinook salmon and steelhead *O. mykiss* transiting the modified JBS

Objectives during 2000 were:

1) Evaluate PIT-tag detection efficiencies and diversion-gate efficiencies at the completed juvenile facilities
2) Evaluate physical condition of fry passing through the JBS and potential loss from the system
3) Assess the effects of system passage on the condition of river-run yearling and subyearling chinook salmon
4) Conduct a pilot test to determine feasibility of using sockeye salmon *O. nerka* to evaluate system effects

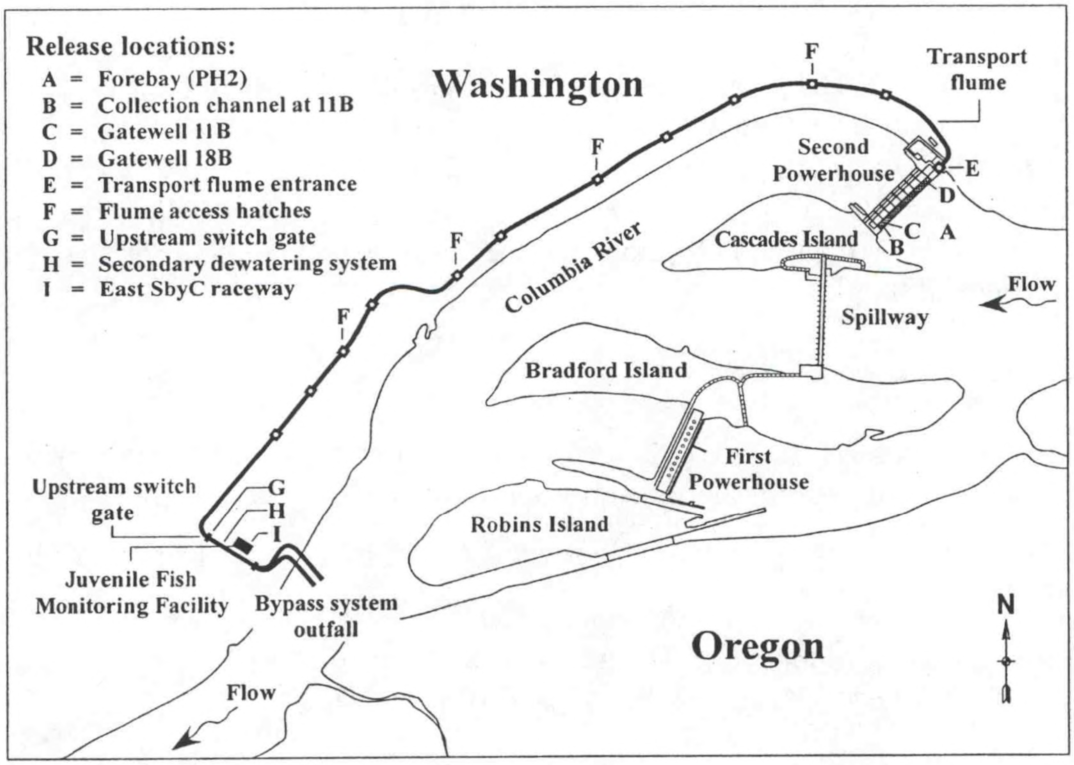


Figure 1. Study area showing the Bonneville Dam Second Powerhouse juvenile salmonid transportation flume and fish release locations used during post-construction evaluations of the bypass system in 1999 and 2000.

EQUIPMENT FABRICATION AND INSTALLATION

Two-way and three-way rotational fish diversion gates were fabricated by NMFS personnel and installed by the project contractor prior to the 1999 fish passage season. The three-way rotational gate provided automated, selective separation of PIT-tagged fish in 1999 and following years. The two-way rotational gate has been used for acquisition of subsamples for the SMP since 2000. In addition, since 1999, NMFS has trained personnel of the U.S. Army Corps of Engineers in gate maintenance and provided troubleshooting and repair of intermittent gate malfunctions.

Temporary PIT-tag monitoring and fish-handling equipment was installed at the work site by NMFS to allow bypass system evaluations to proceed in 1999, prior to completion of the permanent fish-monitoring facilities. We supplied four 400-kHz PIT-tag detection coils and set up other electronic components to provide monitoring and separation-by-code (SbyC) of PIT-tagged fish passing through the JBS. Interim fish-handling facilities were installed, including a 13,250-L capacity fish-holding tank with pre-anesthetic compartment, sorting troughs, anesthetic recovery tank, anesthetic wastewater treatment system, and associated supply and drain piping for all components. Anesthetic waste water was treated by passage through activated carbon followed by transport to the second powerhouse and disposal into the project sanitary sewer system.

PIT-TAG DETECTION AND SEPARATION EFFICIENCIES

We evaluated PIT-tag detection and separation efficiencies for the interim 400-kHz system installed for the 1999 juvenile fish passage season and also for the permanent 134.2-kHz system which became operational in 2000. Our evaluation in 1999 included an initial release of PIT-tagged fish to confirm that the interim monitor and three-way separation gate were functioning at acceptable levels of efficiency. Releases of PIT-tagged fish in subsequent evaluations of fish condition during 1999 were also used to obtain efficiency data. A more complete pre-season evaluation of the permanent system followed in 2000.

1999 Evaluation

Methods

In mid April 1999, we tested separation efficiency of the SbyC separator gate and detection efficiencies of the four associated detection coils (the interim 400-kHz SbyC separator gate monitor). We obtained about 200 subyearling chinook salmon (average fork length 80 mm; N = 179) from Spring Creek National Fish Hatchery (Spring Creek NFH; U.S. Fish and Wildlife Service) and transported the fish to Bonneville Dam in 120-L oxygenated containers. Following an 18-hour recovery period, test fish were injected with PIT tags and allowed a second recovery period prior to release. The computer program, MULTIMON, was programmed so that detection of test fish by any of the monitor's four coils would activate the three-way rotational gate.

The length of time that the gate stayed open (open time) varied from 1,000 to 2,500 ms. Prior to release, we checked for tag retention and rejected fish with lost tags. We released 180 fish, one at a time, at intervals of a few seconds, into the sampling flume upstream from the SbyC monitors. Fish successfully detected and separated accumulated in the holding/pre-anesthetic tank to await processing. At the conclusion of the test, we downloaded the interrogation files from MULTIMON and calculated detection efficiencies for each coil and for the monitor as a whole. Separation efficiency of the three-way gate was determined by comparing the number of fish recovered to the number detected. Recaptured fish were also examined for condition, as discussed in a following section.

Results and Discussion

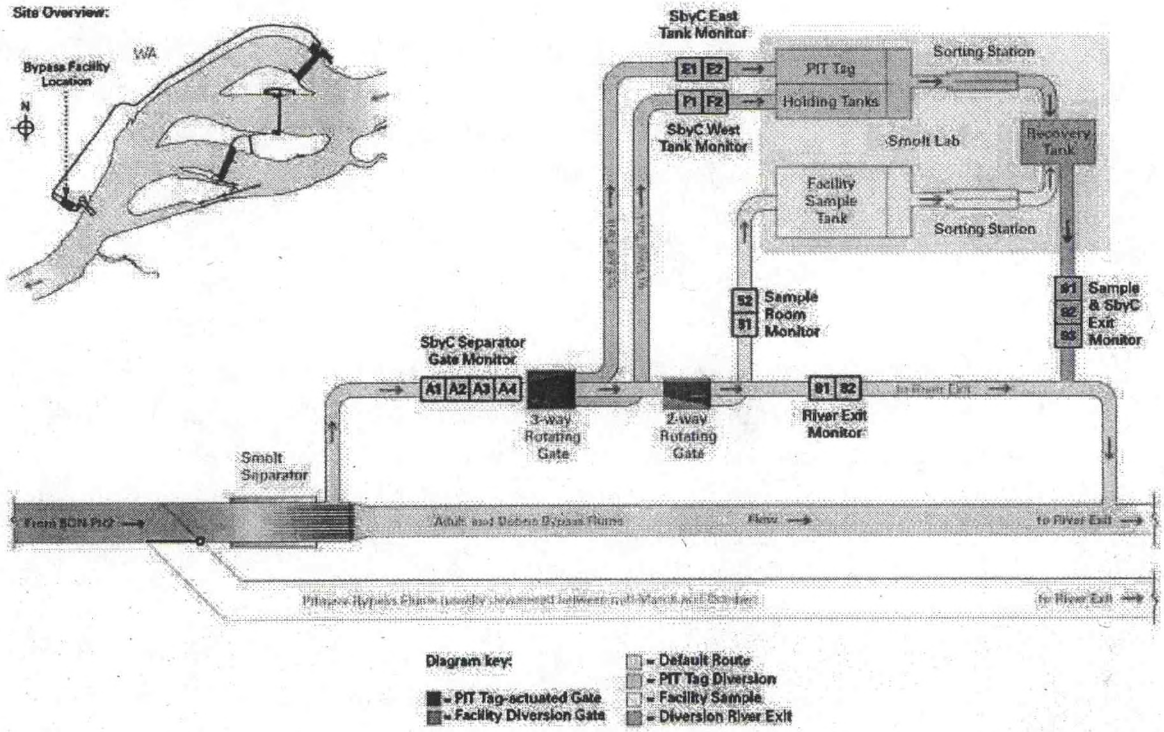
Of 180 subyearling chinook salmon released just upstream from the SbyC separator gate, the four SbyC monitor coils, in combination, detected all of the fish. Detection efficiencies for individual coils ranged from 91.1 to 97.2%. The SbyC separator gate separated all 180 subyearling chinook salmon released during the test.

In subsequent releases of fish for condition and timing evaluations in 1999, separation efficiencies were lower than for these initial release of subyearling chinook salmon. During 1999, the permanent air supply was not yet installed, and power to the rotational gate was supplied by a small utility compressor powered by a temporary electrical connection. This compressor failed on two occasions that we were aware of, and we may not have detected other brief failures. For releases of river-run fish not known to have been compromised by failure of the air supply to the rotational gate, overall separation efficiencies were 95, 96, and 94% for yearling chinook salmon, subyearling chinook salmon, and steelhead, respectively (Appendix Table 1). The SbyC gate-open times used during these tests (1,000-2,500 ms) resulted in ratios of bycatch to target fish of 3.4:1 during spring and 3.9:1 during summer test periods.

2000 Evaluation

In 2000, we evaluated PIT-tag detection efficiency for all monitors installed in the permanent 134.2-kHz system at the Bonneville Dam Second Powerhouse. An additional monitor (the sample room monitor) was added in 2002. The configuration of the juvenile monitoring site is shown in Figure 2 with a list of individual monitors evaluated by NMFS in 2000.

The SMP sample gate (two-way rotational gate) was not evaluated, since it is not actuated by the PIT-tag system. This gate is used by the SMP to obtain subsamples; sample duration is variable and controlled by a programmable logic controller. At low sample rates (≤20% of passage), the SMP sample gate overrides the separator function of the SbyC gate so that PIT-tagged fish programmed for separation pass through to the smolt monitoring sample instead of being routed to the PIT-tag holding tanks. However, at higher sample rates (>20% of passage) the SbyC separator gate has precedence, resulting in a "divert-during-sample" operation mode.



Monitor	Function	No. Coils
SbyC separator gate	Interrogate all fish passing through the system and provide programmable separation of specific PIT-tag codes to the east or west holding tank using three-way rotational gate.	4
River exit	Detects passage of PIT-tagged fish not diverted into the sampling facility.	2
SbyC east tank	Log passage of tagged fish into the respective PIT-tag holding tanks.	2
SbyC west tank	Log passage of tagged fish into the respective PIT-tag holding tanks.	2
Sample/SbyC exit monitor	The exit monitor records passage of PIT-tagged fish from the post-examination recovery tank.	3

Figure 2. Configuration of the juvenile bypass monitors and monitors evaluated by NMFS at Bonneville Dam Second Powerhouse in 2000. Diagram courtesy of Pacific States Marine Fisheries Commission.

Methods

For the 2000 evaluations of detection and separation efficiency, we obtained about 600 subyearling chinook salmon from Spring Creek NFH and about 600 steelhead from Skamania Hatchery (Washington State Department of Fish and Wildlife). Since the swimming ability of smolts can affect separation efficiency, we bracketed a range of smolt sizes by using small subyearling chinook salmon (average fork length 73 mm; N = 211) and relatively large juvenile steelhead (average fork length 189 mm; N = 261) for the tests.

We conducted the detection and separation efficiency tests in late March 2000, prior to the arrival of significant numbers of river-run smolts. Handling, tagging, and release procedures were similar to those described above for our 1999 evaluation. Allowing the gate to remain open for 1,000 ms had resulted in unacceptably high bycatch rates in 1999. Therefore, we tested gate-open times of 800 and 1,000 ms to see if the shorter open time would decrease bycatch rates while effectively separating targeted fish.

Prior to the test, MULTIMON was programmed so that about a third of the fish would pass straight through the system, a third would be separated into the east SbyC tank, and a third would be separated into the west SbyC tank. At the conclusion of testing, interrogation files were downloaded from MULTIMON and data tabulated to obtain separation efficiencies of the SbyC separator gate and detection efficiencies for each coil in the system.

Additional separation and detection data were obtained during our fish condition releases in 2000. These data provided more estimates of efficiencies, although they should be considered as minimums, since it was not desirable to handle and check for PIT-tag retention in each fish used for the condition evaluation. Releases made to evaluate fish condition also provided data on bycatch rates during separation with the gate-open time set at 800 ms.

Results and Discussion

Overall detection efficiencies (yearling chinook and steelhead combined) for the SbyC separator gate, river exit, SbyC east tank, and SbyC west tank monitors were 100.0, 99.2, 99.8, and 99.7%, respectively (Table 1). The Sample/SbyC exit monitor detected 100% of fish released one-by-one, but only 91.2% of fish released from the recovery tank in batches of 100 to 200. The low efficiency of this monitor was due to fish remaining in the tank until it was nearly drained and then exiting as a group, which resulted in tag codes not being logged due to interference from multiple tags in the tag-reading field simultaneously. Under normal operation of the facility, this would not be a problem because samples collected by the SMP seldom include more than a few PIT-tagged fish. In addition, fish movement from the tank can be somewhat regulated by cycling through several partial drain and refill sequences.

Separation efficiency of the SbyC separator gate was tested concurrently with detection efficiency using the same fish used for the efficiency tests. For subyearling chinook salmon released at respective gate-open times of 800 and 1,000 ms, 93.3 and 95.6% were routed to the correct destination (Table 2). All steelhead released at gate-open times of 800 and 1,000 ms went to the correct destination. For subyearling chinook salmon released at a gate-open time of 800 ms, separation efficiency was probably lower because fish were released five at a time rather than one-by-one (as in the other tests). If two PIT-tagged fish are near the gate at one time, they will typically both be routed based on the tag command f the first detected fish, since the gate would not have time to execute the second tag command before it finishes the first.

During the 2000 fish-condition tests using PIT-tagged fish, 99.4% of yearling chinook salmon and 99.2% of subyearling chinook salmon detected by the SbyC separator gate monitor were correctly diverted to the east SbyC tank or into the SMP sample (Appendix Table 2). Because the SMP typically samples only a small percentage of the fish passing through the system during peak times of the juvenile migration, the number of test fish lost to the SMP sample was minimal. We estimated that 0.7% of our yearling chinook and 2.8% of our subyearling chinook salmon entered the SMP sample instead of the PIT-tag holding raceways.

We also observed improvement (reduction) in the numbers of fish handled as bycatch during these tests. The lower bycatch resulted from use of a shorter gate-open time and from scheduling tests to avoid periods of heavy fish passage. In 2000, the ratio of bycatch to target fish was 0.5:1, compared to ratios of 3.4:1 during spring and 3.9:1 during summer test periods in 1999.

Table 1. PIT-tag detection efficiencies of the permanent 134.2-kHz system at the Bonneville Dam Second Powerhouse juvenile fish-monitoring facility. Tests were conducted in March 2000 using subyearling chinook salmon and juvenile steelhead obtained from hatcheries.

Coil ID	Monitor	Tags introduced	Tags read	Detection efficiency (%)	Not detected at monitor No.	Not detected at monitor %
A1	SbyC separator gate	1,192	1,183	99.2		
A2	SbyC separator gate	1,192	1,189	99.7		
A3	SbyC separator gate	1,192	1,179	98.9		
A4	SbyC separator gate	1,192	1,180	99.0		
	Overall[a]	1,192	1,192	100.0	0	0.0
81	River exit	396	385	97.2		
82	River exit	396	391	98.7		
	Overall[a]	396	393	99.2	3	0.8
E1	SbyC east tank	402	399	99.3		
E2	SbyC east tank	402	392	97.5		
	Overall[a]	402	401	99.8	1	0.2
F1	SbyC West tank	394	390	99.0		
F2	SbyC West tank	394	392	99.5		
	Overall[a]	394	393	99.7	1	0.3
91	Sample/SbyC exit[b]	796	641	80.5		
92	Sample/SbyC exit[b]	796	657	82.5		
93	Sample/SbyC exit[b]	796	671	84.3		
	Overall[a]	796	726	91.2	70	8.8
91	Sample/SbyC exit[c]	244	241	98.8		
92	Sample/SbyC exit[c]	244	238	97.5		
93	Sample/SbyC exit[c]	244	244	100.0		
	Overall[a]	244	244	100.0	0	0.0

a Results for the monitor coils working as a unit.

b Accumulations of 100 to 200 fish were allowed to recover from the effects of anesthesia and then exited the recovery tank volitionally as the tank drained.

c Fish were allowed to recover from anesthesia then introduced into the recovery tank outflow one at a time. The PIT-tag detection system also performed well during our fish condition test releases in 2000. The overall detection rates at the SbyC separator gate monitor for river-run fish used in condition tests were 99.5 and 100% for yearling and subyearling chinook salmon, respectively (Appendix Table 2).

Table 2. PIT-tag diversion efficiencies of the permanent 134.2-KHz system at the Bonneville Dam Second Powerhouse juvenile fish-monitoring facility. Tests were conducted in March 2000 using subyearling chinook salmon and juvenile steelhead obtained from hatcheries. Efficiencies are for the SbyC separator gate (a three-way rotational gate).

Species	Gate-open time (milliseconds)	Number released[ab]	Correct destination	Incorrect destination	Efficiency (%)
Subyearling chinook	800	298	278	20	93.3
Subyearling chinook	1,000	296	283	13	95.6
Steelhead	800	298	298	0	100.0
Steelhead	1,000	300	300	0	100.0

a Approximately 300 PIT-tagged fish were released for each test of species/gate-open time. MULTIMON was programmed so that the three-way gate diverted fish into the East or West SbyC tanks or allowed the fish to pass straight through at a ratio of about 1:1:1.

b During the test with subyearling chinook salmon at an 800 ms gate-open time, fish were released in groups of five. In other tests fish were released one at a time.

EVALUATIONS OF FISH CONDITION

Tests Conducted in 1999

Although construction work on the juvenile bypass system was ongoing during 1999, major system components had been completed by late winter, and the system was operational in bypass mode early in the juvenile migration season. System components necessary to operate in PIT-tag detection and sampling mode, including the primary and secondary dewatering systems and connecting flumes, were available in mid April.

We assumed responsibility for operation of the temporary PIT-tag system and fish sampling facilities at the fish-monitoring facility on 19 April 1999. To ensure safe fish passage conditions, our personnel monitored the site 24 hours per day, 7 days per week, until the system was switched from sampling to bypass mode on 26 July 1999. Our temporary fish-handling equipment was removed from the site in the following days so that the project contractor could resume construction activities suspended during our evaluation.

We PIT-tagged, released, and recaptured subyearling chinook salmon, yearling chinook salmon, and steelhead obtained from hatcheries and from the river-run population passing through the bypass system to determine passage timing and incidence of mortality, external injury, and descaling resulting from system passage. We used hatchery salmonids for the early test releases and then, depending on results, shifted to use of river-run smolts. Use of hatchery fish allowed us to determine if fish were severely impacted by system passage without unnecessarily exposing river-run smolts to potential hazards. Repetition of test releases with river-run smolts obtained on site was necessary because fish obtained from hatcheries are seldom good surrogates for the more smolted river-run fish in terms of descaling and passage-time evaluations.

Test fish obtained from hatcheries were netted from rearing ponds, transported to Bonneville Dam in 120-L oxygenated containers, and placed on flow-through water for about 18 h to recover from the stress of handling and transport. Following the recovery period, fish were anesthetized with tricaine methane sulfonate at a concentration of about 50 mg/L and sorted to remove injured or badly descaled fish. Fish selected for tests were measured to the nearest mm (fork length) and injected with PIT tags. After tagging, fish were transferred to 120-L containers or to 720-L tanks at the designated release locations and then allowed a second recovery period prior to release. Fish were typically released between 1800 and 2200 h, the exact time varying throughout the season to coincide with the dusk peak of smolt movement. Tagging files were uploaded to the PIT-tag Information System (PTAGIS), a regional database maintained by the Pacific States Marine Fisheries Commission (PSMFC 1996). The files were then used to derive lists of tag codes which were programmed into MULTIMON for SbyC. Recaptured test fish were diverted at the SbyC separator gate, routed to the 13,250-L holding tank, and processed using the pre-anesthetic compartment built into the tank. We examined each fish and recorded its condition in recapture files, which included the tag code and all incidences of mortality, injury, or descaling. To determine passage timing, discussed in more detail in a following section, we downloaded interrogation files from PTAGIS. Passage time was computed as the elapsed time from release to recapture. Test fish were returned to the river after recovering from examination.

River-run test fish were obtained from the JBS by programming the MULTIMON software so that the SbyC separator gate would divert 100% of tagged fish for brief periods. Test fish were PIT-tagged and handled, and data was collected as previously described for fish obtained directly from hatcheries. Yearling chinook salmon and steelhead smolts used in tests were of known hatchery origin, as determined by the absence of an adipose fin. Since a relatively small percentage of hatchery-origin subyearling chinook salmon smolts are adipose-fin clipped, we used both clipped and non-clipped fish of this species.

Descaling Criteria

Although assessing mortality and injury is straightforward, quantifying descaling is a difficult, subjective procedure. This is especially true when an evaluation calls for comparison of pre- and post-passage descaling using the same fish (identified through PIT-tag code). For many years, NMFS used a system in which the lateral surface on each side of a fish was divided into five sectors. If a fish was descaled in excess of 40% in two or more sectors on one side, it was classified as descaled. Descaling was noted by sector, and additional categories were created for scattered and patchy descaling.

In 1991, the Fish Transportation Oversight Team (FTOT) adopted the revised descaling criteria currently in use by the SMP. By these criteria, if cumulative scale loss on one side of a fish equals or exceeds 20% the fish is classified as descaled. A second category termed "partially descaled" was created for fish with cumulative scale loss on one side that is greater than 3% but less than 20%. The third FTOT category was "non descaled," defined as minor descaling up to 3% (Ceballos et al. 1993).

Early in the 1999 evaluation, we found that most prospective river-run test fish had pre-existing descaling that fell within the FTOT "partial descaling" category. For example, during selection of river-run yearling chinook salmon smolts for an initial test in April 1999, we found that only 17 of the 242 fish examined could have been classed in the FTOT "non-descaled" category. Thus, to obtain completely non-descaled test fish would have required handling unacceptably large numbers of fish. On the other hand, we anticipated that passage through the bypass system components being tested (collection channel, transportation flume, dewatering structures, and PIT-tag system) would be unlikely to result in descaling equal to or exceeding the 20% FTOT "descaled" level. Therefore, to partition descaling in the FTOT "partially descaled" category, we first used the NMFS descaling criteria and then converted the results into three categories, as follows:

A	non-descaled:	scale loss $>0\leq 10\%$
B	partially descaled:	scale loss $\geq 10\leq 20\%$
C	descaled:	scale loss $\geq 20\%$

Juvenile Salmonids Obtained from Hatcheries

Methods--We obtained steelhead from Skamania Hatchery and yearling chinook salmon from Carson NFH. Handling, tagging, and release protocols were similar to those used in 1999. The two primary locations for replicate test releases were the upper collection channel adjacent to gatewell 11B and the lower collection channel at the upstream entrance to the transportation flume (Figure 1). We also released smaller numbers of fish at intermediate locations along the transportation flume, at the upstream switch gate, and into gatewells 11B and 18B. A complete listing of release dates, locations, and numbers is given in Appendix Table 1.

Results--Yearling chinook salmon obtained from Carson NFH, released into the JBS, and recaptured following system passage showed no changes in descaling from their pre-release condition. We examined 188 fish released into the JBS collection channel adjacent to the 11B (north) orifice, 188 released at the upstream entrance to the transportation flume, 101 released into gatewells, 111 released into the transportation flume at various points along its length, and 57 released at the upstream switch gate (Appendix Table 3). None of the recaptured fish showed external injuries; however, two fish released into the collection channel and three fish released at the flume entrance died during passage. The mortalities showed no descaling, external injuries, or flaring of the gills characteristic of anoxia. Since passage effects were not implicated, we concluded that the relatively low overall mortality (<1%) was likely due to latent effects of handling.

None of the steelhead obtained directly from Skamania Hatchery and examined following system passage were descaled, injured, or died during passage. We examined 141 fish released into the collection channel at 11B, 164 released at the upstream flume entrance, 91 released into gatewells, and 49 released at the upstream switch gate (Appendix Table 3).

Our intention at this stage of testing was to use fish obtained directly from hatcheries to detect gross problems associated with passage through the new JBS. Results from these initial tests confirmed that serious passage problems were not present. Subsequent test series in 1999 utilized river-run chinook salmon and steelhead in order to obtain results more representative of the migrant population. River-run fish are generally more fully smolted than fish obtained directly from hatcheries and thus are better indicators of system effects, particularly descaling.

River-Run Juvenile Salmonids

Methods–River-run yearling chinook salmon, subyearling chinook salmon, and steelhead were obtained from the JBS as in 1999. Fish were released into the collection channel adjacent to Gatewell 11B and at the transportation flume entrance. These two locations were chosen to partition passage effects between 1) the collection channel and dewatering screen section and 2) the transportation flume, dewatering structures, and PIT-tag system. If problems were observed, we planned to add additional release sites to further isolate problem components. Pertinent details for test releases of river-run salmonids in 1999 are listed in Appendix Table 1.

Results–We recaptured and examined river-run yearling chinook salmon released into the collection channel at 11B (N = 121) and at the transportation flume entrance (N = 88). There were no passage mortalities for fish released at either location, and incidence of external injury was limited to a single fish released at the transportation flume entrance (Appendix Table 3). Descaling percentages for the two release groups are shown in Figure 3. As expected, river-run fish were more prone to descaling than conspecifics obtained directly from hatcheries. At examination, we determined that about 3% of fish released into the collection channel at 11B and about 1% of fish released at the transportation flume entrance sustained descaling equal to or exceeding 20% during system passage. Overall, 13% of fish released to the collection channel and 10% of releases to the transportation flume entrance showed increased low-level descaling as a result of system passage.

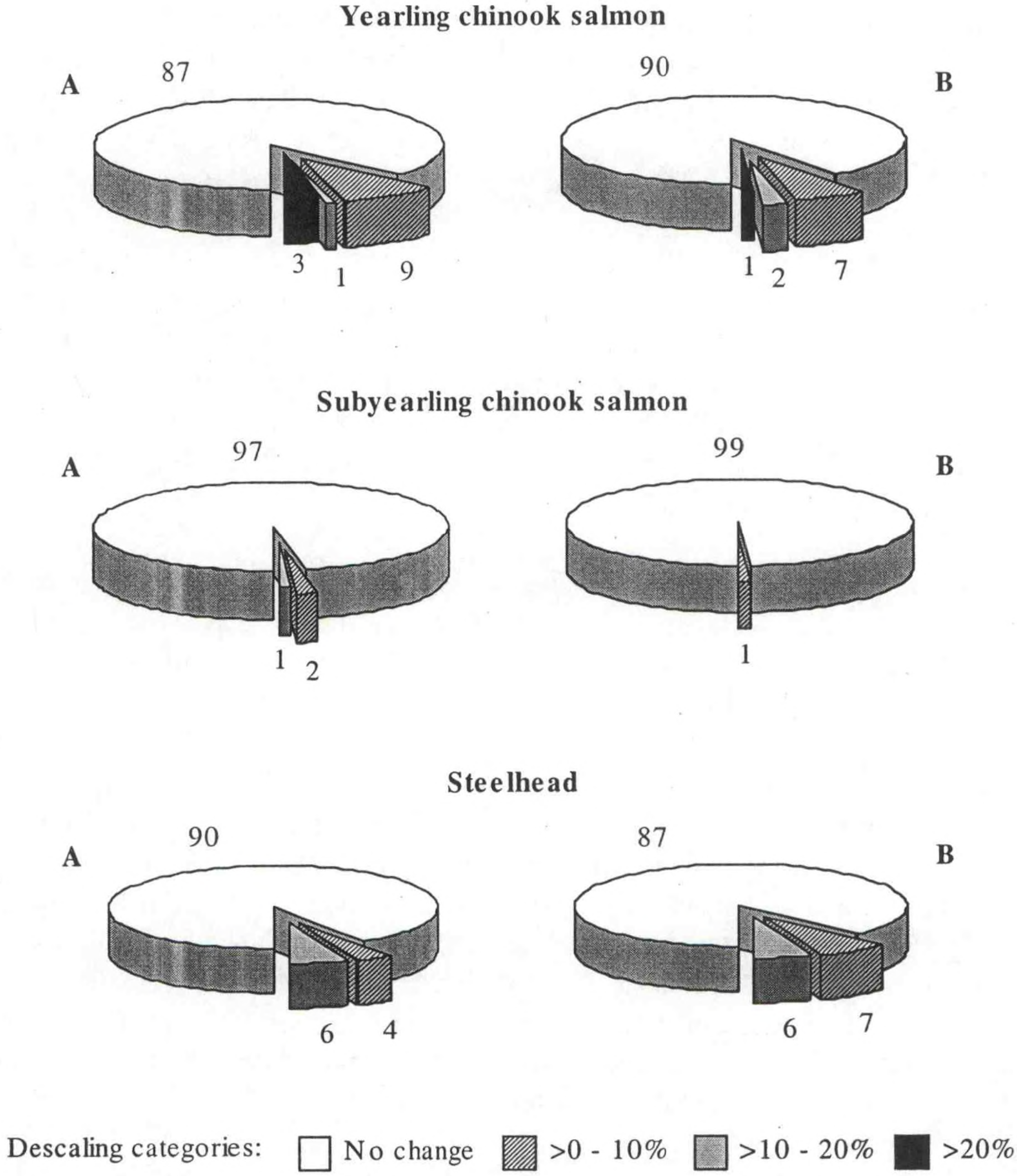


Figure 3. Descaling percentages (change from pre-release condition) of PIT-tagged river-run juvenile salmonids after passage through the Bonneville Dam Second Powerhouse bypass system during 1999. Release locations: A = collection channel adjacent to the Turbine 11, Gatewell B, north orifice discharge; B = entrance to transport flume.

We recaptured and examined river-run steelhead released into the collection channel at 11B (N = 172) and at the transportation flume entrance (N = 160). There were no injuries or mortalities (Appendix Table 3). Descaling percentages are shown in Figure 3. None of the recaptured steelhead were descaled at or above the 20% level. Overall, about 10% of fish released into the collection channel and about 13% of fish released at the transportation flume entrance showed some increase in descaling in the lower-level categories.

The final test series in 1999 consisted of river-run subyearling chinook salmon released into the collection channel at 11B (N = 170) and at the transportation flume entrance (N = 181). We noted no external injuries following system passage. One fish from the channel releases and two fish from flume entrance releases died prior to examination. None of the test fish were descaled in excess of 20%. Overall descaling percentages at the lower levels were 3 and 1% for channel and flume releases, respectively (Appendix Table 3).

The limited fish condition evaluation conducted in 1999 was designed to detect large adverse passage effects. Conduct of the work was difficult due to the ongoing construction activities at the recapture location (site of the future juvenile fish-monitoring facility), intermittent power outages, and water level control problems at the primary and secondary dewatering structures.

Based on recapture and examination of PIT-tagged, river-run test fish (Appendix Table 3), we concluded that there was no evidence of gross injury or mortality attributable to the rebuilt collection channel, the new transportation flume, or the new dewatering structures. We noted only one fish with an external injury out of a total of 892 river-run salmonids recaptured and examined after system passage. For river-run test fish, passage mortalities were limited to 3 of 351 subyearling chinook salmon, or less than 1% of the subyearling chinook salmon released. None of the river-run yearling chinook salmon or steelhead used in the tests died during system passage.

The rebuilt collection channel and new transportation flume were designed to safely pass salmonids as small as fry, and observation of the system suggested a benign passage route. If, however, descaling were to occur in the collection channel or transportation flume, we anticipated that it would most likely take place during passage through the collection channel, where fish are exposed to turbulence from gatewell orifice discharge and passage over dewatering screens. The overall descaling results (Figure 3) did not indicate substantial differences between fish released at the upstream end of the collection channel and fish released at the downstream end of the channel at the transition to the transportation flume. We therefore concluded that the rebuilt collection channel was not likely the source of descaling noted during this study.

It was also apparent from examination of the descaling results (Figure 3) that river-run test fish released at both locations were descaled at levels roughly equivalent to the FTOT "partially descaled" category (>3<20%), particularly yearling chinook salmon and steelhead. This result indicated that descaling at low levels was occurring during passage through the transportation flume or dewatering structures, or during diversion, holding, and processing of recaptured test fish. Unfortunately, the test design for 1999 did not include releases at additional locations, which would have allowed us to isolate the source of the descaling. This deficiency was corrected in 2000 by the addition of test groups released at the secondary dewatering structure (SDS) and into the east PIT-tag holding tank.

Tests Conducted in 2000

Construction of all Bonneville Dam Second Powerhouse JBS components was completed by spring 2000. Major components available for the first time in 2000 included the 134.2-kHz PIT-tag system and the fish-monitoring facility. In 2000, the site became a designated monitoring location of the SMP. As such, operation of the PIT-tag system and routine monitoring and sampling activities were assumed by personnel of the PSMFC.

In 2000, as in 1999, we released juvenile salmonids into the system in order to determine timing of fish passage as well as incidence of mortality, injury, and descaling. Unlike 1999, however, we used only river-run smolts for most releases in 2000. The only exception was for tests evaluating system effects on chinook salmon fry, for which we obtained fish from Little White Salmon NFH because sufficient numbers of river-run fry were not available. We also conducted a pilot study to determine passage effects for river-run sockeye salmon, which is more sensitive to descaling than other salmonid species.

Test procedures differed in some respects from those described previously for work in 1999. These differences are noted in following sections. Data collection was greatly improved during 2000, in that we made extensive use of the features of the PITTag2 data entry, editing, and validation software (PTOC 2000) to log data into computer files for later processing in spreadsheet and database programs.

Descaling Criteria

Results from the 1999 study of fish condition confirmed our expectation that fish moving through the JBS would sustain only minor descaling, which would be difficult to discern from handling effects. Since we expected this to be the case again in 2000, we believed that neither the traditional NMFS or the present FTOT descaling criteria would be sufficiently sensitive to partition low levels of descaling between passage and handling effects.

To address this concern, we developed procedures which would be more sensitive to low levels of descaling and also allow estimation of the total percentage of descaled lateral surface area. As in 1999, it was not feasible to obtain completely non-descaled test fish. It was therefore necessary to note the descaling condition of each fish selected for use in the tests in order to provide a basis for comparison when the fish was examined after recapture.

To allow computation of an estimate for descaled area of each fish, we needed first to estimate the lateral surface areas for fish of different species and lengths. Digital photos were taken for a number of fish of each species to cover the size-range used in tests. Images were scaled to actual size in a drawing program and area was determined in mm^2 for polygons drawn to enclose the lateral surfaces. We determined the linear trend lines for plots of lateral surface area vs. fork length for each species and used the treadling equation to estimate lateral surface areas for the full size-range of fish in tests. These data were entered into a table in a relational database program.

We noted, in millimeters, the approximate dimensions of descaled areas while examining fish at tagging and after recapture. Descaling notations for each record were entered as comments in PITTag2. The PITTag2 files were downloaded into a spreadsheet program with which we calculated cumulative descaled area, and the processed data were imported to a database. We then developed a simple database application that compared the estimated descaling percentages at tagging and after recapture. This application yielded an estimated percentage of "new" descaling for each test fish.

We acknowledge that surface-area estimates derived using this method are not completely accurate due to the curvature of the lateral surface. However, we believe that our method provided a reasonable approximation of actual surface area descaled while removing much of the subjectivity from observations. For comparison, we also interpreted the descaling data using FTOT criteria.

Chinook Salmon Fry

Methods–We obtained chinook salmon fry (upriver bright stock, 1999 brood) from Little White Salmon River NFH in late February and early March 2000. Fork length averaged 46 mm (N = 450) and ranged from 38 to 51 mm. Fry were transported from the hatchery to Bonneville Dam in 120-L containers supplied with oxygen. Hatchery and Columbia River water temperatures were 7.8 and 6.5°C, respectively.

All fry used in the tests were dye-marked by immersion in a 1:70,000 solution (grams dye to mL water) of bismark brown y (Deacon 1961; Krcma et al. 1986). The small quantity of dye required (0.8 g) was dissolved in ethanol and then added to about 60 L of water in a 120-L bucket. The dye container was nested within a second 120-L bucket and water supplied to the space between buckets to maintain the dye bath at river temperature. A 19-L bucket with a screened bottom was suspended within the larger container to hold fry during the dye exposure. Fry remained in the dye solution for 2 h with oxygenation.

Fry released at different bypass system locations on the same date were further differentiated by right-ventral, left-ventral, and partial-caudal fin clips. Fin clips were rotated between treatment groups so that the same clips were not used on consecutive days. We sacrificed 355 fry by overdose of tricaine methane sulfonate (MS-222; 200 ppm) in order to evaluate whether fish that died during passage would impinge on dewatering screens. If dead fry were impinged, and the trash sweeps did not remove them, then these fish would not appear in the catch, leading to the mistaken conclusion that fish were escaping the system (a concern at the collection channel dewatering screens).

Fry were released from 1 to 4 March 2000. Early test dates were chosen to coincide with a period when fry are present, while avoiding the large numbers of river-run smolts passing the dam later in the spring. The latter was an important consideration, since all fish passing through the system had to be sampled to conduct the test. Delaying the start date would have resulted in handling unacceptable numbers of bycatch.

We released fry into the upper bypass system collection channel near the discharge plume from the gatewell 11B north orifice and at the entrance to the circular transportation flume. Fry were released in the morning between 1055 and 1221, and tests were terminated between 1545 and 1630. During tests, we checked the recapture tank at 1-hour intervals. Trash sweeps of the dewatering screen in the collection channel and at the primary dewatering system were turned off during tests. When hourly checks indicated that passage of live fish was complete, we swept both screens to move any impinged fish downstream to the capture site and checked the holding tank a final time. If no fry were found, the test was terminated. Recaptured fry were carefully examined under magnification, and mortality, injury, and descaling were recorded. If fry condition indicated sources of injury, or if the catch rate indicated escape from the system, we planned to expand the number of release locations to locate the source of the problem.

Results–On 1 March 2000, we conducted a pilot release of 100 sacrificed and 100 live chinook salmon fry into the bypass system collection channel adjacent to the 11B (north) orifice. From the respective sacrificed and live release groups, we recaptured 98 and 80 fry. The recapture of a higher percentage (98%) of sacrificed fry vs. a relatively low percentage (80%) of live fry was surprising. We had anticipated the opposite, that dead or moribund fry would impinge on the dewatering screens and not be recaptured, whereas live fry moving through the system would be recaptured at a high rate. These preliminary results suggested that fry were either holding in the system upstream from the fish-monitoring facility or were escaping the system.

Results from this initial pilot release and three subsequent releases are given in Table 3. Subsequent tests included treatment groups released in the upper collection channel (live and killed groups), and a live group released into the lower collection channel at the transition to the transportation flume. Overall recapture percentages (pilot test included) were 85.3% for live fry released into the upper collection channel, 84.1% for live fry released into the lower collection channel, and 95.0% for sacrificed fry released into the upper collection channel. Statistical treatment of test data (ANOVA) indicated significant differences between recapture rates of live vs. sacrificed fry ($F = 5.99$, $P = 0.0257$).

Similar recapture percentages for live fry released at upstream and downstream collection-channel locations suggested that the collection channel (specifically the dewatering screens) was not the location of fry loss during tests. The other possible location where fry could be lost to the system was the upstream switch gate (USG).

Table 3. Releases of chinook salmon fry into the Bonneville Dam Second Powerhouse bypass system during 2000.

Date	Collection channel release location	No. released	No. recaptured	Recapture %
	Live fry			
1 March	Collection channel at 11B[a]	100	80	80.0
2 March	Collection channel at 11B	131	114	87.0
3 March	Collection channel at 11B	100	86	86.0
4 March	Collection channel at 11B	100	88	88.0
	Overall	431	368	85.3
2 March	Transport flume entrance[b]	121	108	89.3
3 March	Transport flume entrance	100	75	75.0
4 March	Transport flume entrance	100	88	88.0
	Overall	321	271	84.1
	Sacrificed fry			
1 March	Collection channel at 11B	100	98	98.0
2 March	Collection channel at 11B	100	98	98.0
3 March	Collection channel at 11B	50	45	90.0
4 March	Collection channel at 11B	105	102	97.1
	Overall	355	343	95.8

a Surface releases into the bypass system collection channel adjacent to the 11B (north) gatewell orifice.
b Releases at the transition from the channel dewatering screens to the circular transport flume.

The USG seals permitted a relatively small flow, driven by the head difference across the gate, to pass under the gate. Observations at the USG confirmed that fish were being impinged and lost at the gate. At the conclusion of each day's test, we observed fry washing free as the USG was switched from sample to bypass position. It was not possible to observe or to capture all impinged fry because of the volume and force of water in the flume; however, on 2 March 2000, we recovered three fry, one with the tail torn off and two others with bruising of the caudal peduncle. On 4 March, as we observed the USG area, four fry (three live and one dead) passed under the gate to the bypass side of the flume system.

In summary, visual observations at the USG confirmed that gate leakage was responsible for loss of fry, some of which were killed or injured as they passed under the gate. Similar recovery rates for live fry released into the upper collection channel and into the collection channel just downstream from the dewatering screens suggested that fry were not escaping the system at this location, although detection of small numbers of fish escaping at this location would have been difficult given the confounding effect of loss at the USG. We believe that recapture rates for live fry were lower because of the tendency of live fish to orient to the flume sides and bottom while passing the USG. In contrast, dead fry were more evenly dispersed through the flow passing the USG. As a consequence, live fry were more often in the vicinity of the gate seals and more frequently pulled under the gate by the head differential.

The USG gate seals were subsequently modified by the U.S. Army Corps of Engineers to minimize gate leakage. In 2002, Monk et al. (2004) released coho salmon fry into the bypass system to determine if loss was still occurring at the USG. Recovery percentages for two releases of 200 coho salmon fry in late March 2002 were 97 and 98%. Monk et al. (2004) did not observe fry passing under the USG or recapture any fry in nets placed to intercept them from the small volume of water leaking under the USG to the bypass side of the flume system. Monk et al. (2004) concluded that the recovery of less than 100% of their test fry was probably due to failure to recover a few fish from the large volumes of debris present in the catch tank.

In our study, we examined a total of 639 recaptured chinook salmon fry from live release groups. For fry not affected by impingement at the USG, there were no mortalities or visible injuries resulting from system passage. None of the recaptured fry were classified as "partially descaled" or "descaled" in the FTOT categories. Very minor descaling (estimated at less than 3% of lateral surface area) was noted in 2.5% of the recaptured fry.

River-Run Yearling Chinook Salmon

Methods--Test fish were obtained from the fish-monitoring facility. The capability to divert fish from the system by programming 100% sample rates for short time periods was not available to us in 2000 because the programmed sample feature of the PIT-tag system and the associated holding tank were in full-time use by the SMP. Therefore, we obtained test fish by closing the air supply to the SbyC separator gate, bleeding off remaining air pressure, and moving the gate manually into position to route fish to the east SbyC raceway. This allowed us to acquire fish as necessary, without the shortfalls or overages likely had the fish been acquired by adjusting diversion intervals for the daily SMP sample. We collected fish between programmed intervals of diversion for the SMP sample to avoid impacting that program.

In 2000, as in 1999, we released fish at the upstream end of the collection channel near the gatewell 11B north orifice discharge. Two other release locations, the secondary dewatering structure (SDS) and the east SbyC raceway, were used for the first time in 2000. Fish released into the upper collection channel passed through all system components included in our evaluation. Fish released at the SDS did not pass through the collection channel or transportation flume, but did pass the SbyC separator gate and associated flumes. These fish also entered the holding raceway and experienced the processing necessary to move fish from downstairs holding raceways to the upstairs examination area.

Fish released to the east SbyC raceway experienced only the processing (i.e., crowding, pre-anesthetization, transfer upstairs via hopper, and transfer to examination troughs). These fish were examined prior to transfer from the 120-L holding container to verify that marking and holding did not cause significant descaling. If large differences were seen in the condition of fish released at different locations, we planned to release at additional locations in order to identify problem areas.

Each yearling chinook salmon test release included approximately 300 PIT-tagged fish with about 100 released at each location. Releases took place on 3, 9, 16, and 23 May. A total of 1,125 fish were used in the tests (Appendix Table 2).

Prior to the start of testing, we provided the Pit Tag Operations Center (PTOC) with a list of PIT tag codes we expected to use during spring and summer tests. PTOC personnel programmed the PIT-tag interrogation and separation system at the fish-monitoring facility to divert yearling chinook into the east SbyC raceway.

Recaptured test fish and associated bycatch were examined from 0800 to 1700 the day following release. Fish were crowded the length of the holding raceway using the manually operated crowder trolley. Small portions of the catch (typically 20-50 fish) were then crowded under a raised entry gate into the pre-anesthetic tank built into the raceway at the downstream end. Once fish were in the tank and the sliding gate lowered, water was drained until about 95 L remained. We then added 60 mL MS-222 stock solution (100 g anesthetic/L of water), which resulted in anesthesia within 5 min. The pre-anesthetic tank was then elevated to the second level of the facility where fish were sluiced from the tank into examination troughs. All components of the fish-handling system were designed for water-to-water transfer of fish, in accordance with ESA-mandated fish-handling techniques.

During the post-recapture examination, we removed non-target species from the examination trough, routing the fish to a separate tank where they recovered from the effects of anesthesia and were subsequently released. Target species were electronically scanned for PIT tags and passed to the recovery tank if untagged or tagged by others (as determined by clip file validation).

We enumerated bycatch using a digitizer board and a laptop computer running the PITTag2 data entry, editing, and validation software. Fish were tallied by touching the digitizer pen to cells mapped to set the tag-code field to the standard "dot out" value (indicating no PIT-tag code). We also entered species, run, rearing-type, and mortality codes through the digitizer board. In practice, we found enumeration using the digitizer preferable to the use of mechanical counting meters. Data were exported from PITTag2 creating an ASCII DOS file which was processed through a spreadsheet program and imported into a database table.

Results–In 2000, we recaptured and examined 387 river-run yearling chinook salmon released into the upper collection channel, 416 released at the SDS, and 292 released into the east SbyC tank (Appendix Table 2). Mortality and injury data are summarized in Appendix Table 4. Passage mortalities were limited to two fish from releases into the collection channel (0.5% of the number released at this location). For the 2000 study, we expanded our observations of external condition to include not only physical injuries, but also conditions such as fungus infection, gas bubble trauma, and hemorrhage. We observed three fish from releases at the SDS with minor hemorrhaging, a condition which could have resulted from physical trauma or disease.

Gas bubble disease (GBD), manifested as visible bubbles in fins, was noted on about 10% of the fish released on 9 May 2000, but was not observed in fish from other release dates. We noted the GBD symptoms occurred on a date when saturation in the fish examination facility was about 115%, the highest observed on any of the yearling chinook salmon release dates. Symptoms of GBD were not noted in fish examined by the SMP program around this date. Our test fish were held in shallow containers from 24 to 48 h longer than SMP sample fish. We hypothesized that development of GBD symptoms resulted from the combination of moderately high saturation levels, shallow holding conditions, and longer holding time. Therefore, the GBD symptoms we observed were not representative of the general population of juvenile migrants.

We conducted careful examinations of test fish prior to release and after recapture in order to determine the net change in descaling. We also inspected fish just prior to release into the east SbyC raceway to determine if descaling was occurring during tagging and pre-release holding. We observed no net change in descaling attributable to these processes. After recapture, none of the 1,095 live fish examined were descaled at levels equal to or exceeding 20%.

We also determined descaling as a percentage of estimated total lateral surface area. Results of both methods of analysis are summarized in Appendix Table 5. By the second method, none of the recaptured test fish were descaled in excess of 5%. Descaling of less than 1% of total lateral surface area was observed in 10.4% of fish released into the upper collection channel, 10.1% of fish released at the SDS, and 11.4% of fish released into the east SbyC tank. Scale loss ranging from 1 to 5% of total lateral surface area was observed in 3.5% of fish released into the upper collection channel, 2.1% of fish released at the SDS, and 1.0% of fish released into the east SbyC tank.

A comparison of descaling for yearling chinook salmon released at the three locations in 2000 is shown in Figure 4. As previously noted, we were uncertain following our 1999 work as to the location where low-level descaling was taking place. The release sites used in 2000 allowed us to compare descaling for fish that had experienced 1) passage through the system from the upper collection channel through final handling, 2) passage through the system from the SDS through final handling, and 3) holding tank residence and final handling. This comparison suggests that although there may have been a slight degree of descaling associated with passage through the collection channel and transportation flume, most descaling occurred during final holding and handling. It should be emphasized that the general migrant population is not subjected to these procedures. Only PIT-tagged fish programmed for SbyC and fish that are included in the SMP sample experience these passage conditions. These results also suggest that there is a cost associated with even careful handling procedures using pre-anesthesia systems and water-to-water transfer techniques.

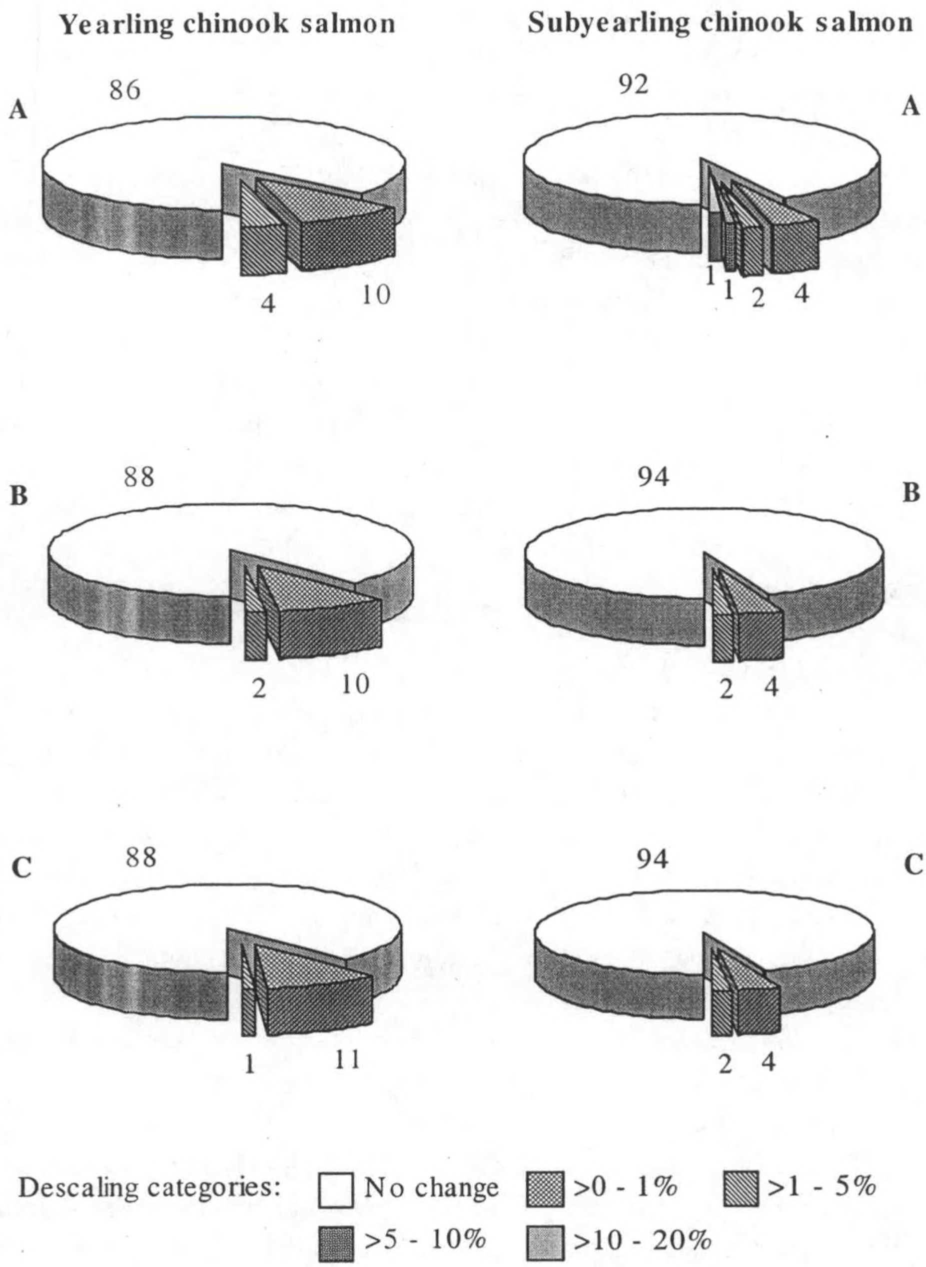


Figure 4. Descaling percentages (change from pre-release condition) of PIT-tagged river-run chinook salmon after passage through the Bonneville Dam Second Powerhouse bypass system during 2000. Release locations: A = collection channel adjacent to the Turbine 11, Gatewell B, north orifice discharge; B = bypass sample flume at the Secondary Dewatering Structure; and C = the east separation-by-code holding tank.

River-Run Subyearling Chinook Salmon

Methods–We were unable to obtain sufficient numbers of subyearling chinook salmon for test purposes at the second powerhouse fish-monitoring facility. Rapidly dropping river flows in late June 2000 resulted in sharply curtailed power generation at the second powerhouse, and most river flow was routed to the first powerhouse and to the spillway. Consequently, numbers of fish moving through the bypass system in a 24-hour period fell below the 300 to 400 fish required for each test. To continue the test, we had to obtain subyearling chinook from the first powerhouse sampling facility.

Test releases of subyearling chinook salmon were conducted on 27 June, 29 June, 6 July, and 11 July. Each test release typically included approximately 300 PIT-tagged fish, with about 100 fish released at each location. A total of 1,181 fish were used in the tests (Appendix Table 2).

Results–In 2000, we recaptured and examined 389 live subyearling chinook salmon released into the upper collection channel, 376 released at the SDS, and 367 released into the east SbyC tank (Appendix Table 2). Mortality and injury data are summarized in Appendix Table 4. Three fish died during system passage, one from channel releases (0.3% of number released) and two from releases at the SDS (0.5% of number released). Overall, hemorrhaging was observed in about 2% of recaptured test fish, typically appearing at the base and between the rays of the caudal and anal fins. We were unable to correlate incidence of hemorrhages with other external indications of trauma such as descaling. We observed GBD symptoms in fish released on 27 and 29 June 2000 but not on the other two release dates. Overall, about 5% of fish examined from the 27 and 29 June releases showed GBD symptoms. As in 1999, occurrence of GBD symptoms was related to dissolved gas percentages near the 115% level.

Only 3 of the 1,132 live subyearling chinook salmon recaptured and examined were descaled at levels equal to or exceeding 20% by FTOT criteria. We also determined descaling as a percentage of estimated total lateral surface area. Results of both methods of analysis are summarized in Appendix Table 5. By the second method, only three of the recaptured test fish were descaled in excess of 5%. Descaling of less than 1% of total lateral surface area was observed in 4.2% of fish released into the upper collection channel, 4.1% of fish released at the SDS, and 3.5% of fish released into the east SbyC tank. Descaling ranging from 1 to 5% of total lateral surface area was observed in 2.6% of fish released into the upper collection channel, 2.4% of fish released at the SDS, and 2.1% of fish released into the east SbyC tank.

A comparison of descaling for subyearling chinook salmon released at the three locations in 2000 is shown in Figure 4. This comparison suggests, as was the case for yearling chinook salmon, that descaling associated with passage through the collection channel and transportation flume was minimal, and most descaling occurred during the final holding and handling of test fish.

River-Run Sockeye Salmon

Methods–We included sockeye salmon in the 2000 evaluation in order to determine passage effects for this species, which is generally acknowledged to be more susceptible to descaling than other salmonids. Because the proportion of juvenile sockeye salmon available at Bonneville was so low relative to other salmonid species, obtaining test fish at Bonneville Dam would have involved sorting and handling excessive numbers of fish. Therefore, test fish were obtained from the JBS at John Day Dam, where sockeye salmon were being handled and returned to the river during the selection of spring chinook and coho salmon for a study at The Dalles Dam. Obtaining test fish at John Day Dam did not, therefore, entail handling additional fish. We planned to release sockeye salmon to the second powerhouse forebay, gatewells, collection channel, and fish-monitoring facility.

The first step in the test protocol was to release sockeye salmon into the second powerhouse forebay in order to determine the number of fish necessary to produce about 50 recaptures at the fish-monitoring facility. Past fish-guidance efficiency data for the second powerhouse indicated that we could expect between 21 and 49% of forebay-released fish to be guided into the bypass system (Monk et al. 1999).

To determine release-group size prior to the first full forebay release, we obtained and PIT-tagged 100 sockeye salmon at John Day Dam on 11 May. Unfortunately, this release had to be aborted due to a boat malfunction. The test fish were instead released into gatewells 11B and 18B. Because fish condition was the principal concern of the study, rather than orifice passage efficiency, fish were released at the surface from the same containers they had been placed in at marking. We did not use the type of release frame and canister apparatus typically used in gatewell releases (Absolon and Brege 2003) because we did not wish to subject the fish to additional handling steps during which they could have sustained descaling or injury.

On 17 May, we obtained a second group of test fish from John Day Dam, which we PIT-tagged and released into the forebay the following day. Points of release were inside the inner boat restricted zone (BRZ) upstream from turbines 12 and 18. A third set of test fish was obtained from John Day Dam on 22 May, then PIT tagged and released the following day into the forebay at two locations (inner BRZ upstream from turbines 14 and 16), gatewells 11B and 18B, and into the collection channel adjacent to the 11B-north orifice. The fourth set of test fish was obtained from John Day Dam on 30 May, then PIT-tagged and released on 1 June at the same release locations as the third set. A total of 970 sockeye salmon were used in the tests (Appendix Table 2).

Results–In 2000, we conducted a pilot test to evaluate physical condition of sockeye salmon passing through the bypass system. Our past smolt monitoring efforts and those of the SMP at Bonneville Dam have shown that sockeye salmon routinely exhibit the highest descaling rates of any species of juvenile migrant salmonid. Therefore, a bypass system with minimal impact to other species could cause substantial harm to sockeye salmon because of its higher sensitivity to descaling. Accordingly, we believe that sockeye salmon should be included in bypass system evaluations whenever possible. This was feasible at Bonneville Dam because the great majority of juvenile sockeye salmon in the lower river originate from mid Columbia River stocks which are not ESA-listed. Tests using a relatively small number of fish (100s rather than 1,000s) can be conducted with a low probability of impacting listed Snake River sockeye.

The pilot test included releases of PIT-tagged sockeye into the second powerhouse forebay (inner Boat Restricted Zone), gatewells 11B and 18B, and into the upper collection channel (Appendix Table 2). Release sites were chosen to compare effects of passage from 1) forebay to fish-monitoring facility, 2) gatewells to fish-monitoring facility, and 3) upper collection channel to fish-monitoring facility. Recapture rates for forebay-, gatewell-, and channel-released sockeye salmon were 47, 96, and 99%, respectively.

Injury and mortality results for the sockeye salmon releases are shown in Appendix Table 4. Overall, we observed more instances of external problems than were present in the other species we tested, but no occurrence of GBD symptoms. Mortality was much higher than for chinook salmon or steelhead. Overall mortality rates for the forebay, gatewell, and channel releases were 11.5, 10.6, and 6.7%.

Test fish were obtained from the JBS at John Day Dam, transported to Bonneville Dam, then PIT-tagged and released. Although recovery time was allowed between the transport, tagging, and release steps of the process, we believe it likely that the cumulative stress of the procedure contributed to the high mortality rates observed. Therefore, mortality rates should not be assumed to be representative for all juvenile sockeye passing Bonneville Dam.

Descaling data for the sockeye salmon releases are shown in Appendix Table 5. Using FTOT criteria, we estimated that 1.2% of forebay releases, 5.2% of gatewell releases, and 1.0% of collection channel releases were descaled at levels of 20% or greater. The higher descaling rates observed in releases to the gatewell than to the forebay were unexpected, but could have resulted from small sample sizes (we recaptured and examined 210 and 261 fish from gatewell and forebay releases, respectively) or from non-representative conditions in gatewells chosen as release sites. Descaling evaluations using total lateral surface area showed increased descaling from the pre-release condition in 29% of forebay releases, 42% of gatewell releases, and 33% of collection channel releases (Figure 5). Since the sockeye salmon test did not include control releases at the monitoring facility, we were unable to attribute observed descaling increases to system passage. We believe it likely that most of the low-level descaling increases we observed were caused by holding and handling of fish prior to final examination, as was the case in the chinook salmon tests.

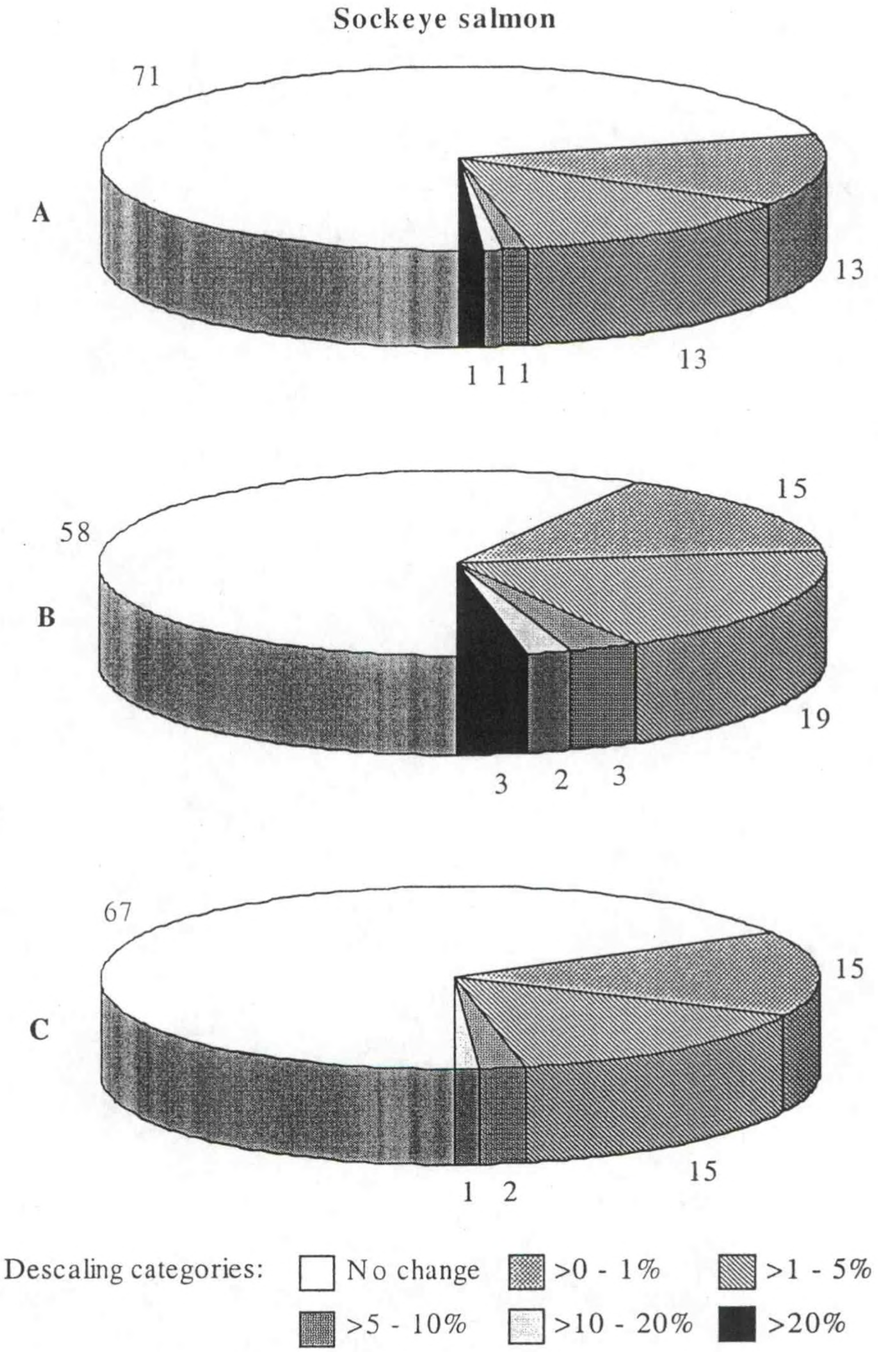


Figure 5. Descaling percentages (change from pre-release condition) of PIT-tagged river-run sockeye salmon after passage through the forebay and bypass system at the Bonneville Dam Second Powerhouse during 2000. Release locations: A = forebay; B = gatewells 11B or 18B; C = collection channel adjacent to the Turbine 11, Gatewell B, north orifice discharge.

BYPASS SYSTEM PASSAGE TIME

Methods

Each release group of PIT-tagged fish was represented by a tagging file which included a time of release. Subsequent to releases, we queried the PTAGIS database to determine time of first detection for test fish as they passed through the interrogation coils at the monitoring site. Passage timing from point of release to the monitoring site was then calculated as the difference between detection and release times. In practice, fish left the release container over a period of a few minutes rather than simultaneously, so we estimated the midpoint for each release and used that time value in the tagging file submitted to PTAGIS. As a result, actual passage times for some fish could vary by a few minutes over calculated values.

Data were retrieved from PTAGIS as CSV files and imported into spreadsheet and database programs for analysis. We calculated the minimum and maximum passage time, as well as the 10th, 50th (median), and 90th percentile passage times for each species at each release location. Although passage timing of river-run fish was the basis for our evaluation, we also derived timing values for fish obtained directly from hatcheries. These methods were used in both 1999 and 2000.

Results and Discussion 1999

Passage timing of juvenile salmonids released in the 1999 assessment was measured from 1) the south (upstream) end of the bypass system collection channel adjacent to Turbine 11 to the fish-monitoring facility and 2) the north (downstream) end of the collection channel at the transportation flume entrance to the fish-monitoring facility. Timing data for individual hatchery and river-run test groups is given in Appendix Table 6. In addition, overall timing of river-run test groups is shown graphically in Figure 6.

Hatchery and River-Run Yearling and Subyearling Chinook Salmon

Median passage times from the upper collection channel to the fish-monitoring facility for hatchery yearling chinook salmon, river-run yearling chinook salmon, and river-run subyearling chinook salmon were 46, 46, and 42 min, respectively. Median passage times from the lower collection channel to the fish-monitoring facility for

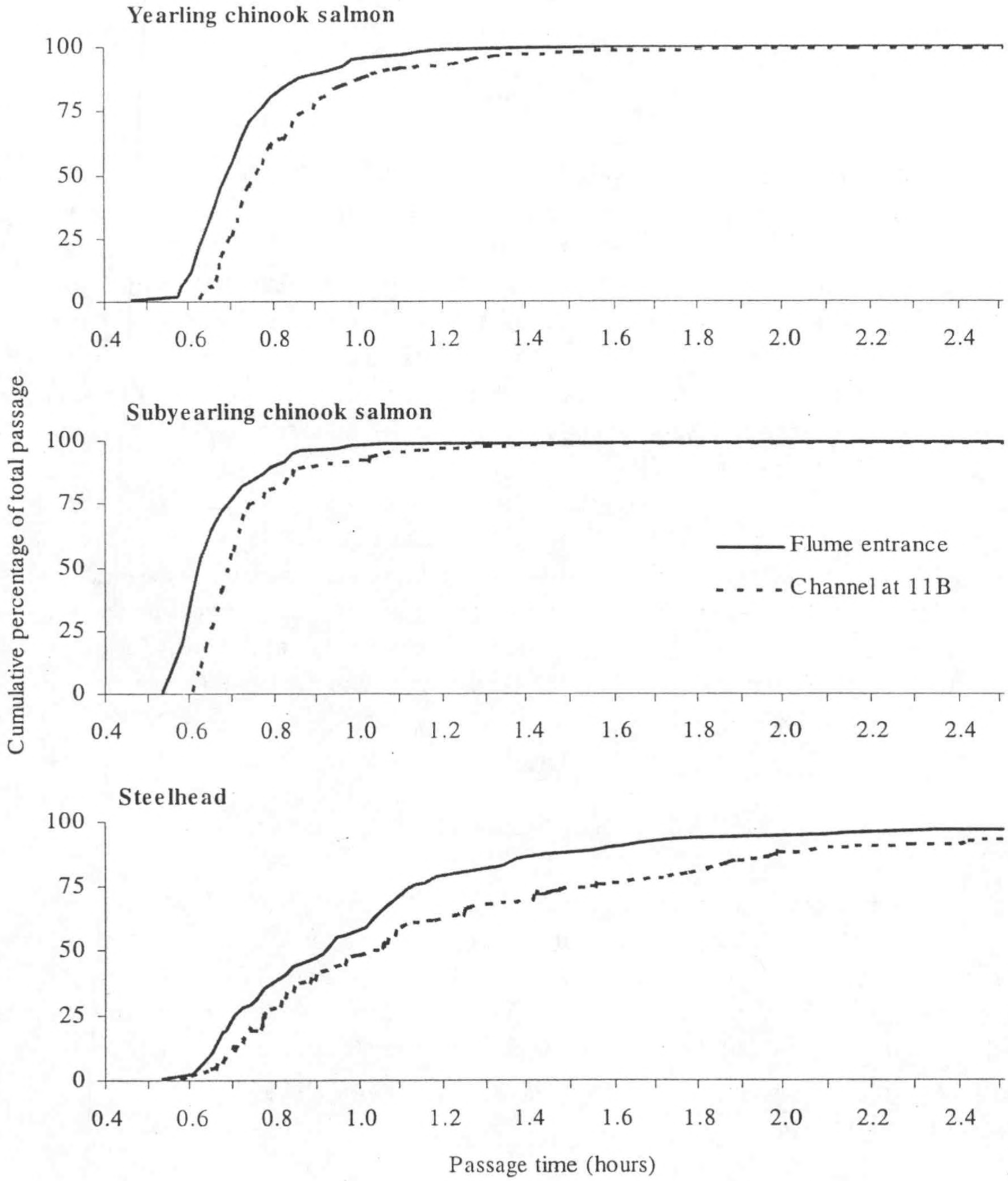


Figure 6. Passage timing of river-run juvenile chinook salmon and steelhead released at two locations within the Bonneville Dam Second Powerhouse Juvenile Bypass System during 1999.

hatchery yearling chinook salmon, river-run yearling chinook salmon, and river-run subyearling chinook salmon were 39, 42, and 37 min, respectively.

Since there was no PIT-tag interrogation at the lower end of the collection channel, we could not directly determine timing for collection channel passage. Differences in median passage times, however, were less than 10 min, indicating fish moved rapidly through the collection channel. The 90th percentile passage times for river-run yearling and subyearling chinook salmon from the upper collection channel to the fish-monitoring facility were 64 and 54 min, respectively, indicating that most fish moved through the system without prolonged holding.

Similar passage timing results were obtained in tests conducted by the U.S. Geological Survey (USGS) at Bonneville Dam in 1999 and 2000. In 1999, the USGS median passage times for radio-tagged fish from the lower end of the collection channel to the outfall area were 45 min for yearling chinook salmon and 51 min for subyearling chinook salmon (Holmgren et al. 1999). In 2000, USGS reported median passage times of 41 min for yearling chinook salmon and 37 min for subyearling chinook salmon (Holmgren et al. 2000).

Hatchery and River-Run Steelhead

In contrast to the comparable passage timing of hatchery and river-run yearling chinook salmon, passage times for hatchery steelhead were much less than for actively migrating river-run steelhead. Median passage time from the upstream end of the collection channel to the fish-monitoring facility was over 5 h for hatchery steelhead compared to about 1 hour for river-run steelhead. Estimated passage time through the length of the collection channel was about 2 h for hatchery steelhead, but only a few minutes for river-run steelhead. The 90th percentile of passage time of river-run steelhead was about 2 h, suggesting that steelhead delayed to a greater extent than chinook salmon while moving through the system.

Similar travel times were observed in USGS studies utilizing radio-tagged river-run steelhead in 1999 (Holmgren et al. 1999) and 2000 (Holmgren et al. 2000). In the USGS studies, median travel times from the downstream end of the collection channel to the outfall area were 60 min in 1999 and 48 min in 2000.

Results and Discussion 2000

Chinook Salmon Fry

Because fry were not PIT tagged, exact passage timing could not be determined. Fry did, however, move through the system rapidly. On 2 March 2000, we recaptured 304 fry, of which 97% were recaptured in the first hour following release, 1.5% in the second hour, and 1.5% in the third hour. Recapture timing for subsequent fry releases was similar.

River-run Yearling and Subyearling Chinook Salmon

Timing data acquired in 2000 for chinook salmon was ancillary to the principal objective, determination of passage effects on fish condition. However, since test fish were PIT-tagged, timing data were calculated for tests using river-run yearling and subyearling chinook salmon. These data are summarized by release date and location in Appendix Table 7. Overall timing for each species is shown in Figure 7.

In 2000, passage timing of river-run yearling chinook salmon from the upper collection channel to detection at the fish-monitoring facility was similar to that observed in 1999. Median passage time in 2000 was 47 min, compared to 46 min in 1999. The 90th percentile of passage was 59 min in 2000 and 64 min in 1999.

For river-run subyearling chinook salmon, median passage time from the upper collection channel to the fish-monitoring facility was also similar in 2000 (37 min) and in 1999 (42 min). The 90th percentile of passage was 57 min in 2000, compared to 54 min in 1999.

River-run Sockeye Salmon

Timing data for sockeye salmon releases is shown by date and release location in Appendix Table 7. Overall timing for each release location is charted in Figure 8. Median passage times from release site to the fish-monitoring facility were about 11 h for forebay releases, 100 min for fish released into gatewells, and 45 min for fish released at the upper end of the collection channel. The 90th percentile passage time was 45 h for forebay releases, about 6 h for gatewell releases, and about 1 hour for collection channel releases.

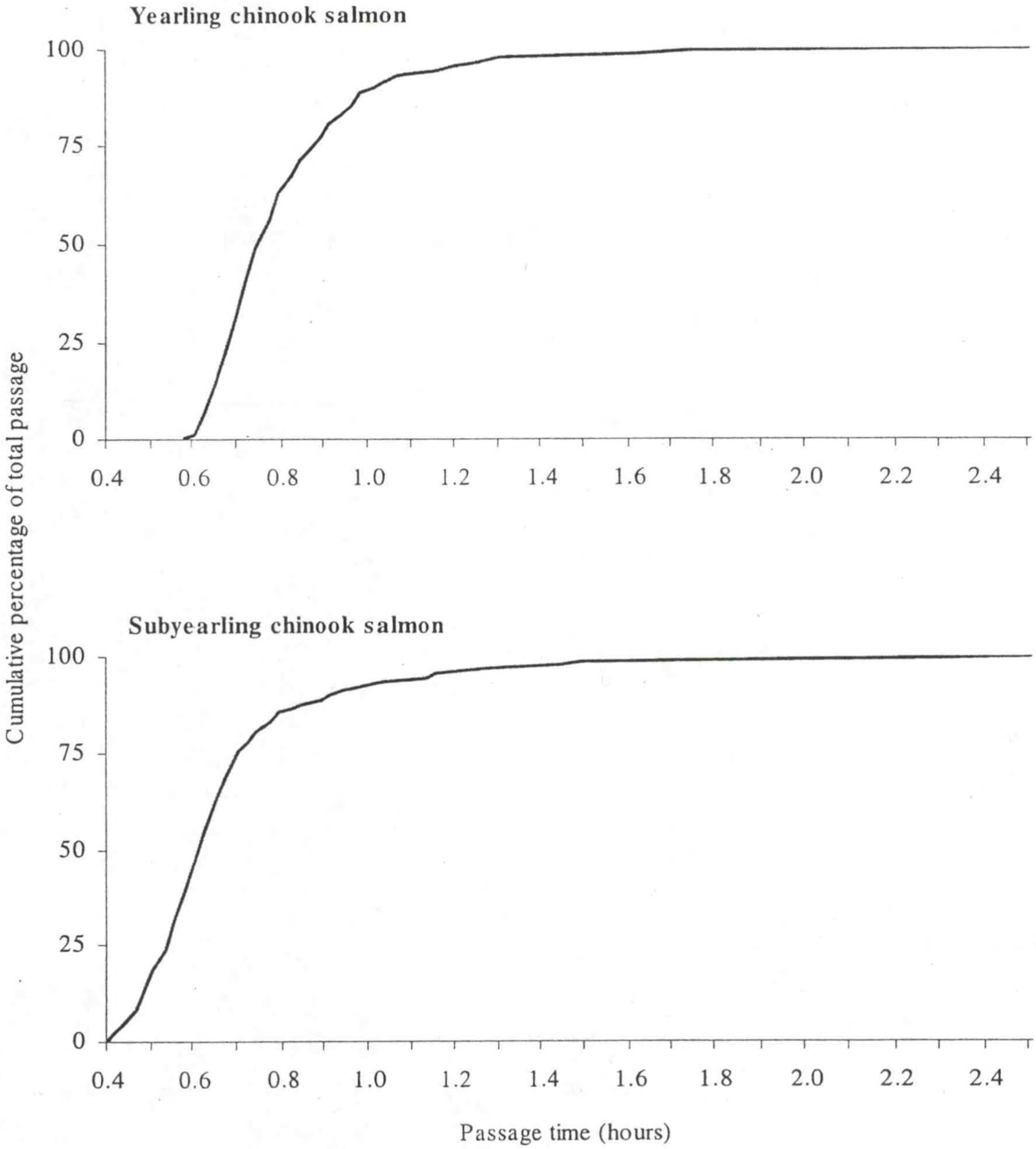


Figure 7. Passage timing of river-run juvenile chinook salmon released into the bypass system collection channel of the Bonneville Dam Second Powerhouse during 2000.

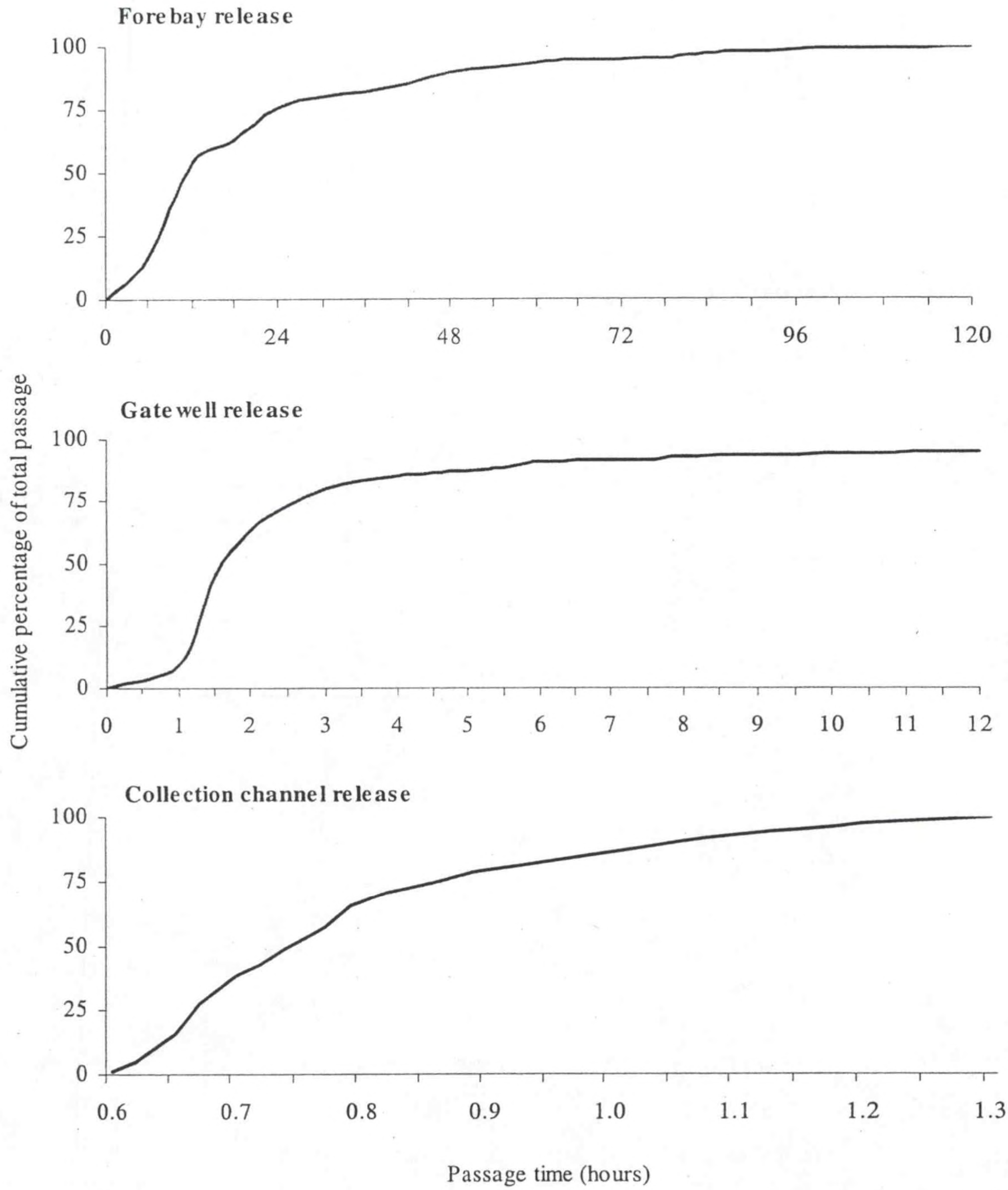


Figure 8. Passage timing of juvenile sockeye salmon released into the forebay, gatewells, and bypass system collection channel of the Bonneville Dam Second Powerhouse during 2000. Note that the x-axis scales differ.

CONCLUSIONS

Based on our post-construction evaluations of the rebuilt juvenile bypass system at Bonneville Dam Second Powerhouse in 1999 and 2000, we offer the following conclusions regarding PIT-tag detection and separation efficiencies, bypass system effects on fish condition, and passage timing through the system.

1) The SbyC separator gate, river exit, SbyC east tank, and SbyC west tank monitors have potential detection efficiencies ranging from 99 to 100%. Although detection efficiency for the sample/SbyC exit monitor is potentially high, in situations where many PIT-tagged fish exit the holding tank over a short period, interference may result in relatively low efficiency (about 91%). This problem may be mitigated by controlling the rate at which fish leave the holding tank.

2) Diversion efficiency of the SbyC separator gate (a three-way rotational gate) varied from 96 to 100% in tests using hatchery subyearling chinook salmon and steelhead at gate-open times of 800 or 1,000 ms. Diversion efficiency of the gate exceeded 99% during release and recapture tests conducted in 2000 with river-run yearling and subyearling chinook salmon. Based on our experience at the site, achievement of high diversion efficiencies depends on diligent monitoring of gate function and timely maintenance.

3) Bycatch of non-target fish during SbyC operations can be excessive. We observed bycatch to target-fish ratios approaching 4:1, even though we scheduled tests to avoid some periods of peak fish movement (such as on days following releases from Spring Creek NFH).

4) In the reconnaissance level study conducted in 1999, we found minimal mortality, external injury, and descaling in the FTOT "descaled" category (≥20%) attributable to the rebuilt collection channel or the new transportation flume. Low levels of descaling equivalent to the FTOT "partially descaled" category (>3%<20%) were found in test groups of yearling chinook salmon, steelhead, and subyearling chinook salmon released into the upper collection channel and at the entrance to the transportation flume.

5) Based on releases of chinook salmon fry into the system in March 2000, we determined that there was no indication of fry impingement on collection channel dewatering screens. We identified faulty gate seals at the upstream switch gate as a source of fry loss and injury. The problem has since been addressed through successive modifications to the gate seals. This situation illustrates that maintaining safe passage conditions for fry requires elimination of what may appear to be minor leakage problems.

6) Our evaluation of the completed system in 2000 using yearling and subyearling chinook salmon again demonstrated lack of gross passage problems. The partial descaling observed in 1999 was also evident in 2000. We determined that most partial descaling originated from the holding and final processing of fish diverted from the system, and thus did not impact the great majority of fish, which are not subject to diversion while passing through the bypass system. Resolution of the problem would likely require redesign of the pipe flume used to transfer anesthetized fish from the pre-anesthesia tank to examination troughs in the upper level of the monitoring facility.

7) Median passage times for river-run yearling and subyearling chinook salmon moving through the collection channel, transportation flume, and downstream system components suggest rapid movement with minimal delay. Passage times for river-run steelhead were greater than for chinook salmon, but still rapid. The slower passage of steelhead likely reflects its greater swimming ability and tendency to seek out areas in which to hold.

8) Final evaluation of the effect of bypass systems and other structures on fish condition and passage timing should be conducted with river-run test fish, not salmonids obtained directly from hatcheries.

ACKNOWLEDGMENTS

Funding for this work was provided through the Anadromous Fish Evaluation Program of the U.S. Army Corps of Engineers. Project oversight was provided by Mr. Blaine Ebberts of the Portland District, U.S. Army Corps of Engineers. Coordination of research activities with Bonneville Project was facilitated by Mr. Erich Gaedeke, Bonneville Dam Fisheries Biologist, USACE. Hatchery fish for tests conducted in 1999 and 2000 were provided by the Washington State Department of Fish and Wildlife and the U.S. Fish and Wildlife Service. Installation of temporary PIT-tag monitoring equipment was accomplished by Mr. Brad Peterson and Mr. Bruce Jonasson of NMFS Sand Point Electronics Shop. Mr. Jim Simonson from NMFS Pasco Field Station fabricated, installed, and maintained equipment used during the study. Programming of PIT-tag separation-by-code functions was accomplished by Mr. Dave Marvin, Pacific States Marine Fisheries Commission. Mr. Dean Ballinger, Pacific States Marine Fisheries Commission, assisted in acquisition of river-run test fish at the Bonneville Dam Second Powerhouse Juvenile Fish-monitoring Facility.

In addition to the individuals and organizations acknowledged above, we wish to thank Lila Charlton, Cheryl Engle, Laura Leighton, Jerry Rogers, and Dennis Quaempts, PSMFC contract employees, for their assistance in the day-to-day conduct of this research.

REFERENCES

Absolon, R. F., and D. A. Brege. 2003. Canister for releasing marked fish at depth in hydroelectric dam gatewells and forebays. North American Journal of Fisheries Management 23(2):606-611.

Absolon, R. F., D. A. Brege, and John W. Ferguson. 2000b. Post-construction evaluation of the juvenile bypass at John Day Dam, 1999. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Absolon, R. F., B. P. Sandford, and D. B. Dey. 2000a. Post-construction evaluation of the new juvenile bypass system and guidance screen modifications at John Day Dam, 1998. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Ceballos, J. R., S. W. Pettit, J. L. McKern, R. R. Boyce, and D. F. Hurson. 1993. Fish transportation team annual report - FY 1992. Transport operations on the Snake and Columbia rivers. NOAA Technical Memorandum NMFS F/NWR-32.

Dawley, E. M., L. G. Gilbreath, and R. D. Ledgerwood. 1988. Evaluation of juvenile salmonid survival through the second powerhouse and turbines and downstream migrant bypass system at Bonneville Dam, 1987. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Dawley, E. M., L. G. Gilbreath, R. D. Ledgerwood, P. J. Bentley, B. P. Sandford, and M. H. Schiewe. 1989. Survival of subyearling chinook salmon which have passed through the turbines, bypass system, and tailrace basin of Bonneville Dam Second Powerhouse, 1988. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Dawley, E. M., L. G. Gilbreath, R. D. Ledgerwood, P. J. Bentley, and B. P. Sandford. 1998. Effects of bypass system passage at Bonneville Dam Second Powerhouse on downstream migrant salmon and steelhead; direct capture assessment, 1990-1992. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Deacon, J. E. 1961. A staining method for marking large numbers of small fish. Prog. Fish-Cult. 23:41-42.

Gessel, M. H., D. A. Brege, B. H. Monk, and J. G. Williams. 1990. Continued studies to evaluate the juvenile bypass systems at Bonneville Dam - 1989. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Gessel, M. H., R. F. Krcma, W. D. Muir, C. S. McCutcheon, L. G. Gilbreath, and B. H. Monk. 1985. Evaluation of the juvenile collection and bypass systems at Bonneville Dam, 1984. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Gessel, M. H., L. G. Gilbreath, W. D. Muir, and R. F. Krcma. 1986. Evaluation of the juvenile collection and bypass systems at Bonneville Dam, 1985. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Gessel, M. H., L. G. Gilbreath, W. D. Muir, B. H. Monk, and R. F. Krcma. 1987. Evaluation of the juvenile salmonid collection and bypass systems at Bonneville Dam, 1986. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Gessel, M. H., B. H. Monk, D. A. Brege, and J. G. Williams. 1989. Fish guidance efficiency studies at Bonneville Dam First and Second Powerhouses - 1988. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Gessel, M. H., B. H. Monk, and J. G. Williams. 1988. Evaluation of the juvenile fish collection and bypass systems at Bonneville Dam--1987. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Gessel, M. H., B. P. Sandford, and D. B. Dey. 1997. Post-construction evaluation of the juvenile salmonid bypass system at Ice Harbor Dam, 1996. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Gessel, M. H., J. G. Williams, D. A. Brege, R. A. Krcma, and D. R. Chambers. 1991. Juvenile salmon guidance at the Bonneville Dam Second Powerhouse, Columbia River, 1983-1989. N. Am. J. Fish. Manage. 11:400-412.

Hockersmith, E. E., S. L. Downing, and D. B. Dey. 2003. Post-construction evaluation of the modified PIT-tag diversion and bypass system at Little Goose Dam, 2002. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Hockersmith, E. E., W. D. Muir, B. P. Sandford, and S. G. Smith. 2000. Evaluation of specific trouble areas in the juvenile fish facility at Lower Monumental Dam for fish passage improvement, 1999. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Hockersmith, E. E., B. P. Sandford, and D. B. Dey. 2002. Post-construction evaluation of the modified PIT-tag diversion system at Lower Granite Dam, 2001. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Holmberg, G. S., R. E. Wardell, M. G. Mesa, N. S. Adams, and D. W. Rondorf. Evaluation of the Bonneville Dam Second Powerhouse new juvenile bypass system, 1999. Report of the U.S. Geological Survey, Columbia River Research Laboratory to the U.S. Army Corps of Engineers, Portland, Oregon.

Holmberg, G. S., R. E. Wardell, M. G. Mesa, N. S. Adams, and D. W. Rondorf. Evaluation of the Bonneville Dam Second Powerhouse juvenile bypass system, 2000. Report of the U.S. Geological Survey, Columbia River Research Laboratory to the U.S. Army Corps of Engineers, Portland, Oregon.

Krcma, R. F., M. H. Gessel, D. A. Brege, and R. D. Ledgerwood. 1986. Evaluation of the rehabilitated juvenile salmonid collection and passage system at John Day Dam, 1985. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Krcma, R. F., M. H. Gessel, W. D. Muir, C. S. McCutcheon, L. G. Gilbreath, and B. H. Monk. 1984. Evaluation of the juvenile collection and bypass system at Bonneville Dam, 1983. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Ledgerwood, R. D., Dawley, E. M., L. G. Gilbreath,, P. J. Bentley, B. P. Sandford, and M. H. Schiewe. 1990. Relative survival of subyearling chinook salmon which have passed Bonneville Dam via the spillway or the second powerhouse turbines or bypass system in 1989, with comparisons to 1987 and 1988. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Ledgerwood, R. D., Dawley, E. M., L. G. Gilbreath,, P. J. Bentley, B. P. Sandford, and M. H. Schiewe. 1991. Relative survival of subyearling chinook salmon that have passed through the turbines or bypass system of Bonneville Dam Second Powerhouse, 1990. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Ledgerwood, R. D., Dawley, E. M., L. G. Gilbreath,, L. T. Parker, B. P. Sandford, and S. J. Grabowski. 1994. Relative survival of subyearling chinook salmon at Bonneville Dam, 1992. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Marsh, D. M., B. H. Monk, B. P. Sandford, and G. M. Matthews. 1996a. Preliminary evaluation of the new juvenile collection, bypass, and sampling facilities at McNary Dam, 1994. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., B. P. Sandford, and G. M. Matthews. 1995. Preliminary evaluation of the new juvenile collection, bypass, and sampling facilities at Lower Monumental Dam, 1993. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Marsh, D. M., L. K. Timme, B. P. Sandford, S. Achord, and G. M. Matthews. 1996b. Preliminary evaluation of the new juvenile collection, bypass, and sampling facilities at Lower Monumental Dam, 1994. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

McConnell, R. J., and W. D. Muir. 1982. Preliminary Evaluation of the Bonneville Juvenile Bypass System–Second Powerhouse. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Monk, B. H., R. F. Absolon, B. P. Sandford, and J. W. Ferguson. 2002. Evaluation of intake modifications at Bonneville Second Powerhouse, 2001. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Monk, B. H., M. H. Gessel, and J. W. Ferguson. 1999. An evaluation of the biological database for improving fish guidance efficiency at Bonneville Dam Second Powerhouse. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Monk, B. H., B. P. Sandford, and D. B. Dey. 1994. Evaluation of the fish guidance efficiency of submersible traveling screens and other modifications at Bonneville Dam Second Powerhouse, 1993. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Monk, B. H., B. P. Sandford, and D. B. Dey. 1995. Evaluation of the fish guidance efficiency of submersible traveling screens and other modifications at Bonneville Dam Second Powerhouse, 1994. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Monk, B. H., B. P. Sandford, and J. W. Ferguson. 20004. Evaluation of intake modifications at Bonneville Second Powerhouse, 2002. In prep. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon.

Monk, B. H., B. P. Sandford, and J. G. Williams. 1992. Evaluation of the juvenile fish collection, transportation, and bypass facility at Little Goose Dam, 1990. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Walla Walla, Washington.

NMFS (National Marine Fisheries Service). 1995. Endangered Species Act–Section 7 consultation. Biological opinion. Reinitiation of consultation on 1994-1998 operation of the federal Columbia River power system and juvenile transportation program in 1995 and future years. Northwest Region, Seattle.

PSMFC (Pacific States Marine Fisheries Commission). 1996. PIT tag information system (PTAGIS). Pacific States Marine Fisheries Commission, Gladstone, OR. Online database available www.psmfc.org/ptagis (Accessed June 2004).

PTOC (Pit Tag Operations Committee). 2000. PITTag2, version 1.0. Pit Tag Operations Committee, Portland, Oregon.

USACE (U.S. Army Corps of Engineers). 1996a. Design report for the combined juvenile fish monitoring facilities at Bonneville Dam. Report of the U.S. Army Corps of Engineers, Portland, Oregon.

USACE (U.S. Army Corps of Engineers). 1996b. Bonneville Second Powerhouse, design memorandum no. 9, supplement no. 6; downstream migrant system. Report of the U.S. Army Corps of Engineers, Portland, Oregon.

USACE (U.S. Army Corps of Engineers). 1996c. Bonneville Second Powerhouse, design memorandum no. 9, supplement no. 7; downstream migrant system. Report of the U.S. Army Corps of Engineers, Portland, Oregon.

APPENDIX

Appendix Table 1. Releases of PIT-tagged juvenile salmonids used to evaluate mortality, external injury, descaling, and timing of smolts passing through the Bonneville Dam Second Powerhouse juvenile bypass system during 1999.

Date	Release location [a]	Number released	Detected No.	Detected % [b]	Recaptured No.	Recaptured % [c]
	Yearling chinook salmon					
Carson National Fish Hatchery						
20 April	Collection channel at 11B	60	57	95.0	56	98.2
22 April	Collection channel at 11B	120	114	95.0	113	99.1
27 April	Collection channel at 11B	30	29	96.7	29	100.0
	Overall channel	**210**	**200**	**95.2**	**198**	**99.0**
20 April	Transport flume entrance	60	58	96.7	57	98.3
22 April	Transport flume entrance	119	114	95.8	113	99.1
27 April	Transport flume entrance	30	28	93.3	26	92.9
	Overall flume	**209**	**200**	**95.7**	**196**	**98.0**
27 April	Gatewell 11B	61	55	90.2	51	92.7
27 April	Gatewell 18B	58	53	91.4	50	94.0
	Overall gatewell	**119**	**108**	**90.8**	**101**	**93.5**
22 April	Transport flume at Hatch #2	30	30	100.0	30	100.0
22 April	Transport flume at Hatch #5	30	30	100.0	30	100.0
22 April	Transport flume at Hatch #7	30	30	100.0	30	100.0
22 April	Transport flume at Hatch #9	30	30	100.0	30	100.0
	Overall flume	**120**	**120**	**100.0**	**120**	**100.0**
20 April	Upstream switch gate	60	58	96.7	58	100.0
	Overall switch gate	**60**	**58**	**96.7**	**58**	**100.0**
River-run						
5 May	Collection channel at 11B	49	49	100.0	0 [d]	0.0
11 May	Collection channel at 11B	50	46	92.0	44	95.7
13 May	Collection channel at 11B	49	47	95.9	30 [d]	63.8
19 May	Collection channel at 11B	50	48	96.0	47	97.9
	Overall channel	**198**	**190**	**96.0**	**121**	**63.7**
5 May	Transport flume entrance	50	50	100.0	1 [d]	2.0
11 May	Transport flume entrance	51	51	100.0	47	92.2
13 May	Transport flume entrance	50	50	10.0	34 [d]	68.0
19 May	Transport flume entrance	10[e]	7	70.0	6	85.7
	Overall flume	**161**	**158**	**98.1**	**88**	**55.7**

Appendix Table 1. Continued.

Date	Release location [a]	Number released	Detected No.	Detected % [b]	Recaptured No.	Recaptured % [c]
	Subyearling chinook salmon					
River-run						
23 June	Collection channel at 11B	50	48	96.0	48	100.0
30 June	Collection channel at 11B	47	45	95.7	43	95.6
8 July	Collection channel at 11B	40	38	95.0	35	92.1
14 July	Collection channel at 11B	48	46	95.8	44	95.7
	Overall channel	**185**	**177**	**95.7**	**170**	**96.0**
23 June	Transport flume entrance	50	49	98.0	48	98.0
30 June	Transport flume entrance	50	45	90.0	43	95.6
8 July	Transport flume entrance	46	46	100.0	43	93.5
14 July	Transport flume entrance	48	48	100.0	47	97.9
	Overall flume	**194**	**188**	**96.9**	**181**	**96.3**
	Steelhead					
Skamania Hatchery						
18 April	Collection channel at 11B	118	99	83.9	81	81.8
20 April	Collection channel at 11B	60	52	86.7	36	69.2
27 April	Collection channel at 11B	30	25	83.3	24	96.0
	Overall channel	**208**	**176**	**84.6**	**141**	**80.1**
18 April	Transport flume entrance	120	116	96.7	90	77.6
20 April	Transport flume entrance	60	59	98.3	47	79.7
27 April	Transport flume entrance	30	28	93.3	27	96.0
	Overall channel	**210**	**203**	**96.7**	**164**	**80.8**
27 April	Gatewell 11B	59	52	88.1	41	78.8
27 April	Gatewell 18B	60	52	86.7	50	96.0
	Overall gatewell	**119**	**104**	**87.4**	**91**	**87.5**
16 April	Upstream switch gate	30	5	16.7	0 [f]	0.0
16 April	Upstream switch gate	87	75	86.2	0 [f]	0.0
20 April	Upstream switch gate	59	59	100.0	49	83.0
	Overall switch gate	**176**	**139**	**79.0**	**49**	**35.3**

Appendix Table 1. Continued.

Date	Release location [a]	Number released	Detected No.	Detected % [b]	Recaptured No.	Recaptured % [c]
			Steelhead			
River-run						
11 May	Collection channel at 11B	22	22	100.0	18	81.8
13 May	Collection channel at 11B	19	18	94.7	17	94.4
19 May	Collection channel at 11B	24	24	100.0	23	95.8
26 May	Collection channel at 11B	25	22	88.0	22	100.0
1 June	Collection channel at 11B	98	96	98.0	92	95.8
	Overall channel	**188**	**182**	**96.8**	**172**	**94.0**
11 May	Transport flume entrance	25	24	96.0	19	79.2
13 May	Transport flume entrance	25	23	92.0	22	95.0
26 May	Transport flume entrance	38	31	81.6	27	87.1
1 June	Transport flume entrance	93	92	98.9	92	100.0
	Overall flume	**181**	**170**	**93.9**	**160**	**94.1**

[a] Release locations: Collection channel at 11B = released at the north end of the channel just downstream from the 11B gatewell discharge plume; Transport flume entrance = released at the transition from the channel dewatering screens to the circular transport flume; Gatewells 11B and 18B = released into B-slot gatewells of Turbines 11 and 18; Transport flume at Hatch # = released into the flume at access hatches along its length (hatches numbered from powerhouse); and Upstream switch gate = released at the bypass/sample mode switchgate located near the juvenile monitoring facility.

[b] Percentage of number released.

[c] Percentage of number detected.

[d] Known malfunction of the three-way separator gate during release.

[e] Small release number due to pre-release mortality caused by water failure.

[f] System was not programmed for separation during this release.

Appendix Table 2. Releases of PIT-tagged river-run juvenile salmonids used to evaluate mortality, external injury, descaling, and timing of fish passing through the Bonneville Dam Second Powerhouse juvenile bypass system during 2000.

Date	Release location [d]	Tagged	TL [e]	PM [f]	Released	Detected [a] No.	Detected [a] %	Separated [b] No.	Separated [b] %	Recaptured and examined [c] Live	Dead	Total	%
Yearling chinook salmon													
3 May	Channel	100	0	0	100	98	98.0	98	100.0	98	0	98	100.0
9 May	Channel	100	0	0	100	100	100.0	100	100.0	98	2	100	100.0
16 May	Channel	100	0	0	100	100	100.0	100	100.0	100	0	100	100.0
23 May	Channel	93	0	0	93	93	100.0	93	100.0	91	0	91	97.8
Overall Channel		**393**	**0**	**0**	**393**	**391**	**99.5**	**391**	**100.0**	**387**	**2**	**389**	**99.0**
3 May	SDS	109	0	4	105	104	99.0	104	100.0	104	0	104	99.0
9 May	SDS	101	0	0	101	101	100.0	100	99.0	98	0	98	97.0
16 May	SDS	100	0	0	100	100	100.0	98	98.0	98	0	98	98.0
23 May	SDS	123	1	1	121	120	99.2	118	98.3	116	0	116	95.9
Overall SDS		**433**	**1**	**5**	**427**	**425**	**99.5**	**420**	**98.8**	**416**	**0**	**416**	**97.4**
3 May	Tank	100	1	1	98	-- [g]	--	--	--	96	0	96	98.0
9 May	Tank	100	0	0	100	--	--	--	--	97	0	97	97.0
16 May	Tank	99	0	0	99	--	--	--	--	99	0	99	100.0
Overall Tank		**299**	**1**	**1**	**297**	**--**	**--**	**--**	**--**	**292**	**0**	**292**	**98.3**
Subyearling chinook salmon													
27 June	Channel	100	0	0	100	100	100.0	98	98.0	96	0	96	96.0
29 June	Channel	100	0	0	100	100	100.0	100	100.0	97	0	97	97.0
6 July	Channel	100	0	1	99	99	100.0	98	99.0	97	1	98	99.0
11 July	Channel	100	0	0	100	100	100.0	99	99.0	99	0	99	99.0
Overall Channel		**400**	**0**	**1**	**399**	**399**	**100.0**	**395**	**99.0**	**389**	**1**	**390**	**97.7**
27 June	SDS	100	0	3	97	97	100.0	97	100.0	90	0	90	92.8
29 June	SDS	100	0	0	100	100	100.0	100	100.0	92	1	93	93.0
6 July	SDS	100	0	1	100	100	100.0	99	99.0	96	0	96	96.0
11 July	SDS	100	0	0	100	100	100.0	99	99.0	98	1	99	99.0
Overall SDS		**400**	**0**	**3**	**397**	**397**	**100.0**	**395**	**99.5**	**376**	**2**	**378**	**95.2**
27 June	Tank	100	0	1	99	--	--	--	--	88	0	88	88.9
29 June	Tank	104	0	0	104	--	--	--	--	102	0	102	98.1
6 July	Tank	77	0	0	77	--	--	--	--	77	0	77	100.0
11 July	Tank	100	0	0	100	--	--	--	--	100	0	100	100.0
Overall Tank		**381**	**0**	**1**	**380**	**–**	**--**	**--**	**--**	**367**	**0**	**367**	**96.6**

Appendix Table 2. Continued.

Date	Release location [d]	Tagged	TL [e]	PM [f]	Released	Detected [a] No.	Detected [a] %	Separated [b] No.	Separated [b] %	Recaptured and examined [c] Live	Dead	Total	%
						Sockeye salmon							
18 May	Forebay	201	0	2	199	48	24.1	48	100.0	42	5	47	23.6
23 May	Forebay	250	0	2	248	147	59.3	147	100.0	119	27	146	58.9
1 June	Forebay	176	0	0	176	104	59.1	104	100.0	100	2	102	58.0
Overall	**Forebay**	**627**	**0**	**4**	**623**	**299**	**48.0**	**299**	**100.0**	**261**	**34**	**295**	**47.4**
12 May	Gatewell	100	2	1	97	97	100.0	94	96.9	90	3	93	95.9
23 May	Gatewell	100	0	2	98	98	100.0	97	99.0	80	15	95	96.9
1 June	Gatewell	50	1	0	49	49	100.0	49	100.0	40	7	47	95.9
Overall	**Gatewell**	**250**	**3**	**3**	**244**	**244**	**100.0**	**240**	**98.4**	**210**	**25**	**235**	**96.3**
23 May	Channel	43	0	2	41	41	100.0	41	100.0	35	6	41	100.0
1 June	Channel	50	0	0	50	49	98.0	49	100.0	49	0	49	98.0
Overall	**Channel**	**93**	**0**	**2**	**91**	**90**	**98.9**	**90**	**100.0**	**84**	**6**	**90**	**98.9**

a Number and percentage of live PIT-tagged fish released into the bypass system which were later detected by the separation-by-code monitor. Except for forebay released fish, differences between release and detection numbers were due to unknown tag loss or non detection of tags at the separate-by-code monitor. Forebay released fish, in addition to the reasons noted above, may have not been detected because they passed the second powerhouse via the turbines rather than via the bypass system.

b Number and percentage of PIT-tagged fish detected at the separation-by-code monitor and then either diverted from the sample flume by the three-way rotational gate into holding raceways or by the two-way rotational gate into the Smolt Monitoring Program (SMP) subsample (the three-way gate is deactivated during periods of SMP sampling). For other than forebay released fish, differences between numbers diverted and numbers recaptured and examined were due to non recovery of fish diverted to the SMP subsample, malfunction of the rotational gates, escape of fish from holding raceways, or failure to log recaptures.

c Number and percentage of live PIT-tagged fish released into the bypass system which were later recaptured and examined. Test fish were recovered from the SMP subsample whenever possible.

d Release locations: Channel = surface release into the bypass system collection channel adjacent to the 11B (north) gatewell orifice; SDS = the bypass sample flume at the Secondary Dewatering Structure; Tank = the more easterly of the two tanks used to hold separation-by-code catch within the examination building; Forebay = surface release into the second powerhouse forebay within the inner boat restricted zone; and Gatewell = surface release into either Gatewell 11B or Gatewell 18B.

e PIT tag lost prior to release.

f Pre-release mortality.

g Dashes indicate no data. Fish released directly into the East SbyC Tank did not pass through the separate-by-code monitor and diversion gates, and therefore were not detected or separated.

Appendix Table 3. Mortality, external injury, and descaling (change from pre-release condition) of PIT-tagged juvenile salmonids after passage through the Bonneville Dam Second Powerhouse bypass system during 1999.

			Descaling Categories [a]				
Date	Release location [b]	Examined [c]%	A %	B %	C %	Injury %	Mortality %
		Yearling chinook salmon					
Carson National Fish Hatchery							
20 April	Channel at 11B	55	0.0	0.0	0.0	0.0	0.0
22 April	Channel at 11B	104	0.0	0.0	0.0	0.0	1.9
27 April	Channel at 11B	29	0.0	0.0	0.0	0.0	0.0
	Overall	**188**	**0.0**	**0.0**	**0.0**	**0.0**	**1.1**
20 April	Flume entrance	56	0.0	0.0	0.0	0.0	5.4
22 April	Flume entrance	106	0.0	0.0	0.0	0.0	0.0
27 April	Flume entrance	26	0.0	0.0	0.0	0.0	0.0
	Overall	**188**	**0.0**	**0.0**	**0.0**	**0.0**	**1.6**
One-time releases - no replication							
27 April	Gatewell 11B	51	0.0	0.0	0.0	0.0	0.0
27 April	Gatewell 18B	50	0.0	0.0	0.0	0.0	6.0
22 April	Flume Hatch #2	28	0.0	0.0	0.0	0.0	0.0
22 April	Flume Hatch #5	28	0.0	0.0	0.0	0.0	0.0
22 April	Flume Hatch #7	27	0.0	0.0	0.0	0.0	0.0
22 April	Flume Hatch #9	28	0.0	0.0	0.0	0.0	0.0
20 April	Switch gate	57	0.0	0.0	0.0	0.0	0.0
River-run							
11 May	Channel at 11B	44	13.6	0.0	2.3	0.0	0.0
13 May	Channel at 11B	30	6.7	0.0	3.3	0.0	0.0
19 May	Channel at 11B	47	6.4	2.1	4.3	0.0	0.0
	Overall	**121**	**9.1**	**0.8**	**3.3**	**0.0**	**0.0**
5 May	Flume entrance	1	0.0	0.0	0.0	0.0	0.0
11 May	Flume entrance	47	10.6	4.3	2.1	0.0	0.0
13 May	Flume entrance	34	0.0	0.0	0.0	2.9	0.0
19 May	Flume entrance	6	16.7	0.0	0.0	0.0	0.0
	Overall	**88**	**6.8**	**2.3**	**1.1**	**1.1**	**0.0**

Appendix Table 3. Continued

Date	Release location [b]	Examined [c]%	Descaling Categories [a] A %	B %	C %	Injury %	Mortality %
			Subyearling chinook salmon				
River-run							
23 June	Channel at 11B	48	2.1	4.2	0.0	0.0	0.0
30 July	Channel at 11B	43	0.0	0.0	0.0	0.0	0.0
8 July	Channel at 11B	35	0.0	0.0	0.0	0.0	0.0
14 July	Channel at 11B	44	4.5	0.0	0.0	0.0	2.3
	Overall	**170**	**1.8**	**1.2**	**0.0**	**0.0**	**0.6**
23 June	Flume entrance	48	0.0	0.0	0.0	0.0	0.0
30 July	Flume entrance	43	0.0	0.0	0.0	0.0	0.0
8 July	Flume entrance	43	0.0	0.0	0.0	0.0	2.3
14 July	Flume entrance	47	4.3	0.0	0.0	0.0	2.1
	Overall	**181**	**1.1**	**0.0**	**0.0**	**0.0**	**1.1**
			Steelhead				
Skamania Hatchery							
18 April	Channel at 11B	81	0.0	0.0	0.0	0.0	0.0
20 April	Channel at 11B	36	0.0	0.0	0.0	0.0	0.0
27 April	Channel at 11B	24	0.0	0.0	0.0	0.0	0.0
	Overall	**141**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
18 April	Flume entrance	90	0.0	0.0	0.0	0.0	0.0
20 April	Flume entrance	47	0.0	0.0	0.0	0.0	0.0
27 April	Flume entrance	27	0.0	0.0	0.0	0.0	0.0
	Overall	**164**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
One-time releases - no replication							
20 April	Switch gate	49	0.0	0.0	0.0	0.0	0.0
27 April	Gatewell 11B	41	0.0	0.0	0.0	0.0	0.0
27 April	Gatewell 18B	50	0.0	0.0	0.0	0.0	0.0
River-run							
11 May	Channel at 11B	18	0.0	0.0	0.0	0.0	0.0
13 May	Channel at 11B	17	0.0	0.0	0.0	0.0	0.0
19 May	Channel at 11B	23	0.0	0.0	0.0	0.0	0.0
26 May	Channel at 11B	22	13.6	9.1	0.0	0.0	0.0
1 June	Channel at 11B	92	3.3	8.7	0.0	0.0	0.0
	Overall	**172**	**3.5**	**5.8**	**0.0**	**0.0**	**0.0**

Appendix Table 3. Continued.

Date	Release location [b]	Examined [c]%	Descaling Categories [a] A %	B %	C %	Injury %	Mortality %
			Steelhead				
River-run (continued)							
11 May	Flume entrance	19	0.0	0.0	0.0	0.0	0.0
13 May	Flume entrance	22	0.0	0.0	0.0	0.0	0.0
26 May	Flume entrance	27	7.4	3.7	0.0	0.0	0.0
1 June	Flume entrance	92	9.8	8.7	0.0	0.0	0.0
	Overall	**160**	**6.9**	**5.6**	**0.0**	**0.0**	**0.0**

[a] Descaling categories: A = >0≤ 10% descaled; B = ≥10≤20% descaled; and C = ≥20% descaled. Descaling was determined traditional NMFS descaling criteria.

[b] Release locations: Channel at 11B = released at the north end of the collection channel just downstream from the Gatewell 11B discharge plume; Flume entrance = released at the transition from the channel dewatering screens to the circular transport flume; Gatewells 11B and 18B = released into B-slot gatewells of Turbines 11 and 18; Flume Hatch # = released into the flume at access hatches along its length (hatches numbered from powerhouse); and Switch gate = released at the bypass/sample mode switchgate located near the juvenile monitoring facility.

[c] Number of fish examined (not all recaptured fish could be examined).

Appendix Table 4. Mortality and external injury data for PIT-tagged river-run juvenile salmonids recaptured and examined after passage through the Bonneville Dam Second Powerhouse juvenile bypass system during 2000.

		No. recaptured				External injuries [a b]						
Date	Release location [c]	Live	Dead	Total	Mortality (%)	CA (%)	FU (%)	GB (%)	GB, HE (%)	HE (%)	HE, FU (%)	OP (%)
					Yearling chinook salmon							
3 May	Channel	98	0	98	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 May	Channel	98	2	100	2.0	0.0	0.0	10.2	0.0	0.0	0.0	0.0
16 May	Channel	100	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 May	Channel	91	0	91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Overall	**387**	**2**	**389**	**0.5**	**0.0**	**0.0**	**2.6**	**0.0**	**0.0**	**0.0**	**0.0**
3 May	SDS	104	0	104	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 May	SDS	98	0	98	0.0	0.0	0.0	7.1	0.0	1.0	0.0	0.0
16 May	SDS	98	0	98	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
23 May	SDS	116	0	116	0.0	0.0	0.0	0.0	0.0	0.9	0.0	0.0
	Overall	**416**	**0**	**416**	**0.0**	**0.0**	**0.0**	**1.8**	**0.0**	**0.7**	**0.0**	**0.0**
3 May	Tank	96	0	96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
9 May	Tank	97	0	97	0.0	0.0	0.0	14.4	0.0	0.0	0.0	0.0
16 May	Tank	99	0	99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Overall	**292**	**0**	**292**	**0.0**	**0.0**	**0.0**	**4.8**	**0.0**	**0.0**	**0.0**	**0.0**
					Subyearling chinook salmon							
27 June	Channel	96	0	96	0.0	0.0	0.0	4.2	0.0	4.2	0.0	0.0
29 June	Channel	97	0	97	0.0	0.0	0.0	4.1	0.0	3.1	0.0	0.0
6 July	Channel	97	1	98	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 July	Channel	99	0	99	0.0	0.0	2.0	0.0	0.0	2.0	0.0	0.0
	Overall	**389**	**1**	**390**	**0.3**	**0.0**	**0.5**	**2.1**	**0.0**	**2.3**	**0.0**	**0.0**
27 June	SDS	90	0	90	0.0	0.0	0.0	5.6	1.1	4.4	0.0	0.0
29 June	SDS	92	1	93	1.1	0.0	0.0	3.3	1.1	2.2	0.0	0.0
6 July	SDS	96	0	96	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11 July	SDS	98	1	99	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Overall	**376**	**2**	**378**	**0.5**	**0.0**	**0.0**	**2.2**	**0.6**	**1.7**	**0.0**	**0.0**
27 June	Tank	88	0	88	0.0	0.0	0.0	10.2	0.0	2.3	0.0	0.0
29 June	Tank	102	0	102	0.0	0.0	0.0	3.9	0.0	1.0	0.0	0.0
6 July	Tank	77	0	77	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.0
11 July	Tank	100	0	100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Overall	**367**	**0**	**367**	**0.0**	**0.0**	**0.0**	**3.5**	**0.0**	**1.2**	**0.0**	**0.0**

Appendix Table 4. Continued.

Date	Release location [c]	No. recaptured Live	Dead	Total	Mortality (%)	External injuries [a b] CA (%)	FU (%)	GB (%)	GB, HE (%)	HE (%)	HE, FU (%)	OP (%)
					Sockeye salmon							
18 May	Forebay	42	5	5	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 May	Forebay	119	27	146	18.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1 June	Forebay	100	2	102	2.0	0.0	6.0	0.0	0.0	7.0	3.0	1.0
	Overall	**219**	**34**	**253**	**13.4**	**0.0**	**2.0**	**0.0**	**0.0**	**2.3**	**1.0**	**0.3**
12 May	Gatewell	90	3	93	3.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
23 May	Gatewell	80	15	95	15.8	2.5	0.0	0.0	0.0	0.0	0.0	1.3
1 June	Gatewell	40	7	47	14.9	0.0	0.0	0.0	0.0	2.5	0.0	0.0
	Overall	**210**	**25**	**235**	**10.6**	**0.8**	**0.0**	**0.0**	**0.0**	**0.8**	**0.0**	**0.4**
23 May	Channel	35	6	41	14.6	0.0	0.0	0.0	0.0	0.0	0.0	5.7
1 June	Channel	49	0	49	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Overall	**84**	**6**	**90**	**6.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**2.9**

[a] Injury codes: CA = caudal fin damage; FU = fungus; GB = gas bubble trauma; GB, HE = gas bubble trauma and hemorrhage; HE = hemorrhage; HE, FU = hemorrhage and fungus; OP = opercle damage.

[b] Percentage of recaptured live fish with specified injury. Injury categories are mutually exclusive.

[c] Release locations: Channel = surface release into the bypass system collection channel adjacent to the 11B (north) gatewell orifice; SDS = the bypass sample flume at the Secondary Dewatering Structure; Tank = the more easterly of the two tanks used to hold separation-by-code catch within the examination building; Forebay = surface release into the second powerhouse forebay within the inner boat restricted zone; and Gatewell = surface release into either Gatewell 11B or Gatewell 18B.

Appendix Table 5. Estimated descaling (change from pre-release condition) of river-run juvenile salmonids recaptured after passage through the Bonneville Dam Second Powerhouse Bypass System during 2000. Results are given as percentages of the number of fish released which were judged as descaled in each category. Percentages were derived separately using two different sets of descaling criteria.

			By NMFS study criteria [a]						By FTOT criteria [b]		
Date	Release location [c]	Number examined	1 %	2 %	3 %	4 %	5 %	6 %	N %	P %	D %
			Yearling chinook salmon								
3 May	Channel	98	82.7	17.3	0.0	0.0	0.0	0.0	100.0	0.0	0.0
9 May	Channel	98	89.8	8.2	2.0	0.0	0.0	0.0	99.0	1.0	0.0
16 May	Channel	100	92.0	6.0	2.0	0.0	0.0	0.0	99.0	1.0	0.0
23 May	Channel	91	80.2	9.9	9.9	0.0	0.0	0.0	93.4	6.6	0.0
	Overall	**387**	**86.2**	**10.4**	**3.5**	**0.0**	**0.0**	**0.0**	**97.9**	**2.1**	**0.0**
3 May	SDS	104	77.9	21.1	1.0	0.0	0.0	0.0	100.0	0.0	0.0
9 May	SDS	98	93.9	5.1	1.0	0.0	0.0	0.0	99.0	1.0	0.0
16 May	SDS	98	89.8	7.1	3.1	0.0	0.0	0.0	99.0	1.0	0.0
23 May	SDS	116	89.7	6.9	3.4	0.0	0.0	0.0	100.0	0.0	0.0
	Overall	**416**	**87.8**	**10.1**	**2.1**	**0.0**	**0.0**	**0.0**	**99.5**	**0.5**	**0.0**
3 May	Tank	96	76.0	24.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
9 May	Tank	97	92.8	5.2	2.1	0.0	0.0	0.0	100.0	0.0	0.0
16 May	Tank	99	93.9	5.1	1.0	0.0	0.0	0.0	99.0	1.0	0.0
	Overall	**292**	**87.6**	**11.4**	**1.0**	**0.0**	**0.0**	**0.0**	**99.7**	**0.3**	**0.0**
			Subyearling chinook salmon								
27 June	Channel	96	79.2	12.5	5.2	1.0	2.1	0.0	93.7	4.2	2.1
29 June	Channel	97	96.9	2.1	1.0	0.0	0.0	0.0	100.0	0.0	0.0
6 July	Channel	97	97.0	1.0	1.0	1.0	0.0	0.0	97.9	2.1	0.0
11 July	Channel	99	95.0	1.0	3.0	0.0	1.0	0.0	98.0	1.0	1.0
	Overall	**389**	**92.0**	**4.2**	**2.6**	**0.5**	**0.8**	**0.0**	**97.4**	**1.8**	**0.8**
27 June	SDS	90	88.9	7.8	3.3	0.0	0.0	0.0	96.7	3.3	0.0
29 June	SDS	92	94.6	4.3	1.1	0.0	0.0	0.0	100.0	0.0	0.0
6 July	SDS	96	98.0	1.0	1.0	0.0	0.0	0.0	99.0	1.0	0.0
11 July	SDS	98	91.8	3.1	4.1	0.0	1.0	0.0	94.9	4.1	1.0
	Overall	**376**	**93.3**	**4.1**	**2.4**	**0.0**	**0.3**	**0.0**	**97.7**	**2.1**	**0.3**
27 June	Tank	88	89.8	5.7	3.4	1.1	0.0	0.0	97.7	2.3	0.0
29 June	Tank	102	91.2	5.9	2.9	0.0	0.0	0.0	99.0	1.0	0.0
6 July	Tank	77	98.7	1.3	0.0	0.0	0.0	0.0	100.0	0.0	0.0
11 July	Tank	100	97.0	1.0	2.0	0.0	0.0	0.0	98.0	2.0	0.0
	Overall	**367**	**94.2**	**3.5**	**2.1**	**0.3**	**0.0**	**0.0**	**98.7**	**1.3**	**0.0**

Appendix Table 5. Continued.

Date	Release location [c]	Number examined	By NMFS study criteria [a] 1 %	2 %	3 %	4 %	5 %	6 %	By FTOT criteria [b] N %	P %	D %
			Sockeye salmon								
18 May	Forebay	42	92.7	4.4	2.9	0.0	0.0	0.0	97.1	2.9	0.0
23 May	Forebay	119	60.0	15.4	19.9	1.9	1.8	1.8	80.6	15.7	3.7
1 June	Forebay	100	62.5	19.1	16.4	2.0	0.0	0.0	88.8	11.2	0.0
	Overall	**261**	**71.7**	**13.0**	**13.1**	**1.3**	**0.6**	**0.6**	**88.8**	**9.9**	**1.2**
12 May	Gatewell	90	67.5	17.8	5.6	2.2	4.5	2.3	86.5	6.7	6.8
23 May	Gatewell	80	63.7	16.0	16.3	1.4	2.5	0.0	86.2	11.3	2.5
1 June	Gatewell	40	41.7	12.5	34.4	5.2	0.0	6.3	56.3	37.5	6.3
	Overall	**210**	**57.6**	**15.4**	**18.8**	**2.9**	**2.3**	**2.9**	**76.3**	**18.5**	**5.1**
23 May	Channel	35	71.4	20.0	5.7	2.9	0.0	0.0	91.4	8.6	0.0
1 June	Channel	49	63.3	10.2	24.5	0.0	2.0	0.0	81.6	16.3	2.0
	Overall	**84**	**67.4**	**15.1**	**15.1**	**1.5**	**1.0**	**0.0**	**86.5**	**12.5**	**1.0**

[a] Descaling criteria used by the National Marine Fisheries Service to categorize degree of descaling at Bonneville Dam in 2000: 1 = no change from pre-passage condition; 2 = >0≤1% descaled; 3 = ≥1≤ 5% descaled; 4 = ≥5≤10% descaled; 5 = ≥10≤20% descaled; and 6 = ≥20% descaled. Percentages in categories 2-6 are percentages of total lateral surface area.

[b] Descaling criteria adopted by the Fisheries Transportation Oversight Team in 1991 and used at Columbia and Snake River sampling locations. N = not descaled (0-3%); P = partially descaled (>3<20%); and D = descaled (≥20%).

[c] Release locations: Channel = surface release into the bypass system collection channel adjacent to the 11B (north) gatewell orifice; SDS= the bypass sample flume at the Secondary Dewatering Structure; Tank = the more easterly of the two tanks used to hold separation-by-code catch within the examination building; Forebay = surface release into the second powerhouse forebay within the inner boat restricted zone; and Gatewell = surface release into either Gatewell 11B or Gatewell 18B.

Appendix Table 6. Passage timing (h) for PIT-tagged yearling chinook salmon, subyearling chinook salmon, and steelhead released into the Bonneville Dam Second Powerhouse bypass system during 1999.

Date	Release location [b]	Number [c]	Passage time (h) [a] Median	10%	90%	Min.	Max.
			Yearling chinook salmon				
Carson National Fish Hatchery							
20 April	Channel at 11B	57	0.77	0.69	1.21	0.62	57.58
22 April	Channel at 11B	114	0.67	0.74	1.22	0.62	297.84
27 April	Channel at 11B	29	0.70	0.74	0.98	0.67	2.86
	Overall	**200**	**0.77**	**0.67**	**1.15**	**0.62**	**297.84**
20 April	Flume entrance	58	0.65	0.55	0.84	0.50	1.75
22 April	Flume entrance	114	0.67	0.58	1.20	0.50	9.65
27 April	Flume entrance	28	0.60	0.48	0.78	0.46	1.03
	Overall	**200**	**0.65**	**0.60**	**0.91**	**0.46**	**9.65**
One-time releases - no replication							
27 April	Gatewell 11B	56	2.34	1.64	18.14	0.74	104.26
27 April	Gatewell 18B	55	1.85	1.35	19.70	0.79	76.52
22 April	Flume Hatch #2	30	0.58	0.55	1.29	0.53	1.58
22 April	Flume Hatch #5	30	0.41	0.38	0.76	0.38	1.25
22 April	Flume Hatch #7	30	0.31	0.29	1.00	0.26	232.08
22 April	Flume Hatch #9	30	0.17	0.14	0.32	0.12	0.60
20 April	Switch gate	58	0.10	0.10	0.43	0.10	17.42
River-run							
5 May	Channel at 11B	49	0.77	0.67	0.95	0.65	1.32
11 May	Channel at 11B	46	0.74	0.67	1.12	0.65	3.60
13 May	Channel at 11B	47	0.79	0.69	1.02	0.65	2.30
19 May	Channel at 11B	48	0.78	0.65	1.19	0.62	2.18
	Overall	**190**	**0.77**	**0.67**	**1.06**	**0.62**	**3.60**
5 May	Flume entrance	50	0.74	0.62	0.96	0.58	1.13
11 May	Flume entrance	51	0.67	0.62	0.77	0.58	2.90
13 May	Flume entrance	50	0.70	0.60	0.96	0.55	1.22
19 May	Flume entrance	7	0.62	0.53	1.09	0.46	1.68
	Overall	**158**	**0.70**	**0.60**	**0.94**	**0.46**	**2.90**

Appendix Table 6. Continued.

Date	Release location [b]	Number [c]	Passage time (h) [a] Median	10%	90%	Min.	Max.
			Subyearling chinook salmon				
River-run							
23 June	Channel at 11B	48	0.70	0.65	0.85	0.62	1.58
30 July	Channel at 11B	45	0.70	0.65	0.83	0.62	17.28
8 July	Channel at 11B	38	0.72	0.64	0.99	0.62	46.20
14 July	Channel at 11B	46	0.70	0.62	0.90	0.60	1.39
	Overall	**177**	**0.70**	**0.62**	**0.90**	**0.60**	**46.20**
23 June	Flume entrance	49	0.65	0.60	0.78	0.55	1.06
30 July	Flume entrance	45	0.65	0.58	0.82	0.55	1.25
8 July	Flume entrance	46	0.62	0.58	0.83	0.55	260.38
14 July	Flume entrance	48	0.61	0.55	0.77	0.53	0.98
	Overall	**188**	**0.62**	**0.58**	**0.80**	**0.53**	**260.38**
			Steelhead				
Skamania Hatchery							
18 April	Channel at 11B	99	8.69	1.97	28.73	0.65	376.87
20 April	Channel at 11B	52	3.85	1.25	28.12	0.79	336.48
27 April	Channel at 11B	25	2.47	1.03	10.15	0.84	54.79
	Overall	**176**	**5.62**	**1.31**	**27.70**	**0.65**	**376.87**
18 April	Flume entrance	116	4.70	1.42	10.42	1.03	38.35
20 April	Flume entrance	59	2.06	1.15	16.11	0.84	77.83
27 April	Flume entrance	28	1.20	0.80	7.11	0.62	24.74
	Overall	**203**	**3.34**	**1.10**	**10.63**	**0.62**	**77.83**
16 April	Switch gate	80	0.53	0.23	1.63	0.07	3.19
20 April	Switch gate	59	0.31	0.10	3.36	0.07	22.39
	Overall	**139**	**0.53**	**0.10**	**1.66**	**0.07**	**22.39**
One-time releases - no replication							
27 April	Gatewell 11B	52	6.84	2.51	40.00	2.06	245.14
27 April	Gatewell 18B	52	4.49	1.61	34.68	0.84	74.03
River-run							
11 May	Channel at 11B	22	1.24	0.82	1.94	0.77	2.16
13 May	Channel at 11B	18	1.09	0.81	2.09	0.76	2.40
19 May	Channel at 11B	24	1.22	0.80	1.97	0.67	2.78
26 May	Channel at 11B	22	0.82	0.60	1.06	0.58	1.54
1 June	Channel at 11B	96	0.92	0.70	2.02	0.65	49.62
	Overall	**182**	**1.03**	**0.70**	**1.99**	**0.58**	**49.62**

Appendix Table 6. Continued.

Date	Release location [b]	Number [c]	Passage time (h) [a] Median	10%	90%	Min.	Max.
			Steelhead				
River-run (continued)							
11 May	Flume entrance	24	1.06	0.79	1.62	0.62	2.11
13 May	Flume entrance	23	0.82	0.68	1.45	0.65	2.14
26 May	Flume entrance	31	0.79	0.65	1.37	0.58	1.54
1 June	Flume entrance	92	0.94	0.65	1.70	0.53	6.48
	Overall	**170**	**0.94**	**0.65**	**1.59**	**0.53**	**6.48**

[a] Times are from the listed release location to the interrogation site at the Hamilton Island Juvenile Fish-monitoring Facility.

[b] Release locations: Channel at 11B = released at the north end of the collection channel just downstream from the Gatewell 11B discharge plume; Flume entrance = released at the transition from the channel dewatering screens to the circular transport flume; Gatewells 11B and 18B = released into B-slot gatewells of Turbines 11 and 18; flume Hatch # = released into the flume at access hatches along its length (hatches numbered from powerhouse); and Switch gate = released at the bypass/sample mode switchgate located near the juvenile monitoring facility.

[c] Number of live fish detected and recaptured.

Appendix Table 7. Passage timing (h) for PIT-tagged river-run yearling and subyearling chinook salmon and sockeye salmon released into the Bonneville Dam Second Powerhouse bypass system and forebay during 2000.

Date	Release location [a]	Number [b]	Median	Percentiles 10th	Percentiles 90th	Min.	Max
Yearling chinook salmon							
3 May	Channel	98	0.77	0.70	0.91	0.65	1.66
9 May	Channel	98	0.89	0.69	1.15	0.62	1.78
16 May	Channel	100	0.74	0.65	1.06	0.62	1.63
23 May	Channel	91	0.70	0.62	0.84	0.58	1.25
	Overall	**387**	**0.78**	**0.67**	**0.99**	**0.62**	**1.58**
Subyearling chinook salmon							
27 June	Channel	96	0.65	0.55	0.84	0.50	1.75
29 June	Channel	97	0.67	0.58	1.20	0.50	9.65
6 July	Channel	97	0.60	0.48	0.78	0.46	1.03
11 July	Channel	99	0.53	0.43	0.99	0.38	2.57
	Overall	**389**	**0.61**	**0.51**	**0.95**	**0.46**	**3.75**
Sockeye salmon							
18 May	Forebay	42	6.37	2.60	23.87	1.58	44.35
23 May	Forebay	119	7.94	5.49	64.75	0.84	120.67
1 June	Forebay	100	18.17	2.66	46.58	0.96	78.94
	Overall	**261**	**10.83**	**3.58**	**45.07**	**1.13**	**81.32**
12 May	Gatewell	90	1.57	0.96	5.04	0.74	108.94
23 May	Gatewell	80	1.57	1.12	3.64	0.72	61.32
1 June	Gatewell	40	1.88	1.20	10.21	0.77	59.40
	Overall	**210**	**1.67**	**1.09**	**6.30**	**2.23**	**76.55**
23 May	Channel	35	0.78	0.67	1.05	0.61	1.30
1 June	Channel	49	0.72	0.65	1.06	0.60	1.20
	Overall	**84**	**0.75**	**0.66**	**1.06**	**0.61**	**1.25**

[a] Release locations: Channel = surface release into the bypass system collection channel adjacent to the Gatewell 11B north orifice; Forebay = surface release into the second powerhouse forebay within the inner boat restricted zone; and Gatewell = surface release into either Gatewell 11B or Gatewell 18B.

[b] Number of live fish detected and recaptured.