Effects of bypass system passage at Bonneville Dam Second Powerhouse on downstream migrant salmon and steelhead; direct capture assessment, 1990-1992

Fish Ecology Division

Northwest Fisheries Science Center

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Seattle, Washington

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Earl M. Dawley, Lyle G. Gilbreath,
Richard D. Ledgerwood,
Paul J. Bentley, and
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Fish Ecology Division
Northwest Fisheries Science Center
National Marine Fisheries Service
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Seattle, Washington 98112-2097

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EXECUTIVE SUMMARY

Passage survival tests at Bonneville Dam using coded-wire-tagged subyearling chinook salmon, from 1987 to 1992, indicated substantially poorer survival for fish using the bypass systems than other passage routes through the dam. In 1990, we began research designed to identify conditions and physical features of the bypass system at the Bonneville Dam Second Powerhouse which debilitated or injured juvenile salmonids during passage. Marked fish were released into the bypass system and then captured at the terminus of the discharge conduit using a trap-net. Fish were immediately evaluated for stress and injury.

Results from the aggregate of tests conducted in 1990 and 1991 showed few consistent adverse passage effects except that descaling of river-run coho and yearling chinook salmon was high (8.5-28.6%). Although less definitive, injury and mortality were greater than expected for both hatchery and river-run subyearling chinook salmon. There were no obvious detrimental impacts to hatchery steelhead, yearling chinook salmon, or coho salmon released, only minor scale loss and low percentages of injury, mortality, and delayed mortality.

In late 1991, tests were conducted at low tailwater elevation to assess worst-case effects; i.e., greatest water velocity and greatest shear forces at the pipe terminus. Results of those tests showed markedly increased descaling and mortality. Through further testing in 1992, it became apparent that descaling and impingement were occurring in conjunction with capture of test fish and impacts from bypass passage could not be separated from impacts occurring during trap-net recovery of test fish. We believe that differences of descaling and mortality between release groups within individual tests did provide relative

comparisons of stress and fatigue related to the various flow conditions and sections of the bypass encountered by the test fish.

We concluded that injury and mortality of test fish was not occurring during passage through the bypass system at the Second Powerhouse. However, we believe passage through the bypass system caused stress and fatigue in juvenile migrants, and could contribute to diminished predator avoidance. Additionally, we know that northern pikeminnow predation is particularly intense at the outlet of the bypass system. Therefore, we speculate that 1) the point source release from the bypass discharge conduit allows for increased predation; 2) migration through the low velocity tailrace basin results in increased predation; and 3) the location of the bypass outlet on the north side of the tailrace in conjunction with the southward bend in the river tends to direct outmigrants shoreward toward rip-rap areas that are prime habitat for northern pikeminnow.

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INTRODUCTION

The efficacy of bypass systems as a safe means of passing juvenile salmonids (*Oncorhynchus* spp.) through dams has generally been established by site-specific testing. Virtually all testing focused on the portion of the system beginning at interception of the outmigrant juvenile salmonids by the submersible traveling screens and ending just prior to release into a conduit or channel through which the fish were carried to the tailrace below the dam. There have been few rigorous assessments of fish survival through an entire bypass system from forebay to the tailrace or beyond at any dam. The principal constraint in conducting such tests is the difficulty of obtaining an unbiased sample of fish exiting a bypass system prior to their reaching the next downstream dam, where assessments become complicated by the uncertainties of collection efficiency.

At Bonneville Dam, the lowermost hydroelectric project on the Columbia River, approximately 157 km of free-flowing river separate the dam from an established sampling station located at the head of the estuary at Jones Beach (River Kilometer 75; Fig. 1). A history of over 20 years of sampling outmigrating juvenile salmon, using beach and purse seines, demonstrated that an unbiased estimate can be made at Jones Beach (Dawley et al. 1986).

As the last dam on the Columbia River, Bonneville Dam is in the critical position of passing more juvenile salmon than any other dam in the river; this alone is a compelling reason for verifying assumed high passage survival. However, no thorough assessments of passage survival were conducted at the dam after construction of the spillway flow deflectors in 1975, the Second Powerhouse in 1983, and the two downstream migrant bypass systems in 1981 and 1984. Information specific to these separate passage routes was needed for management of fish passage relative to power production.

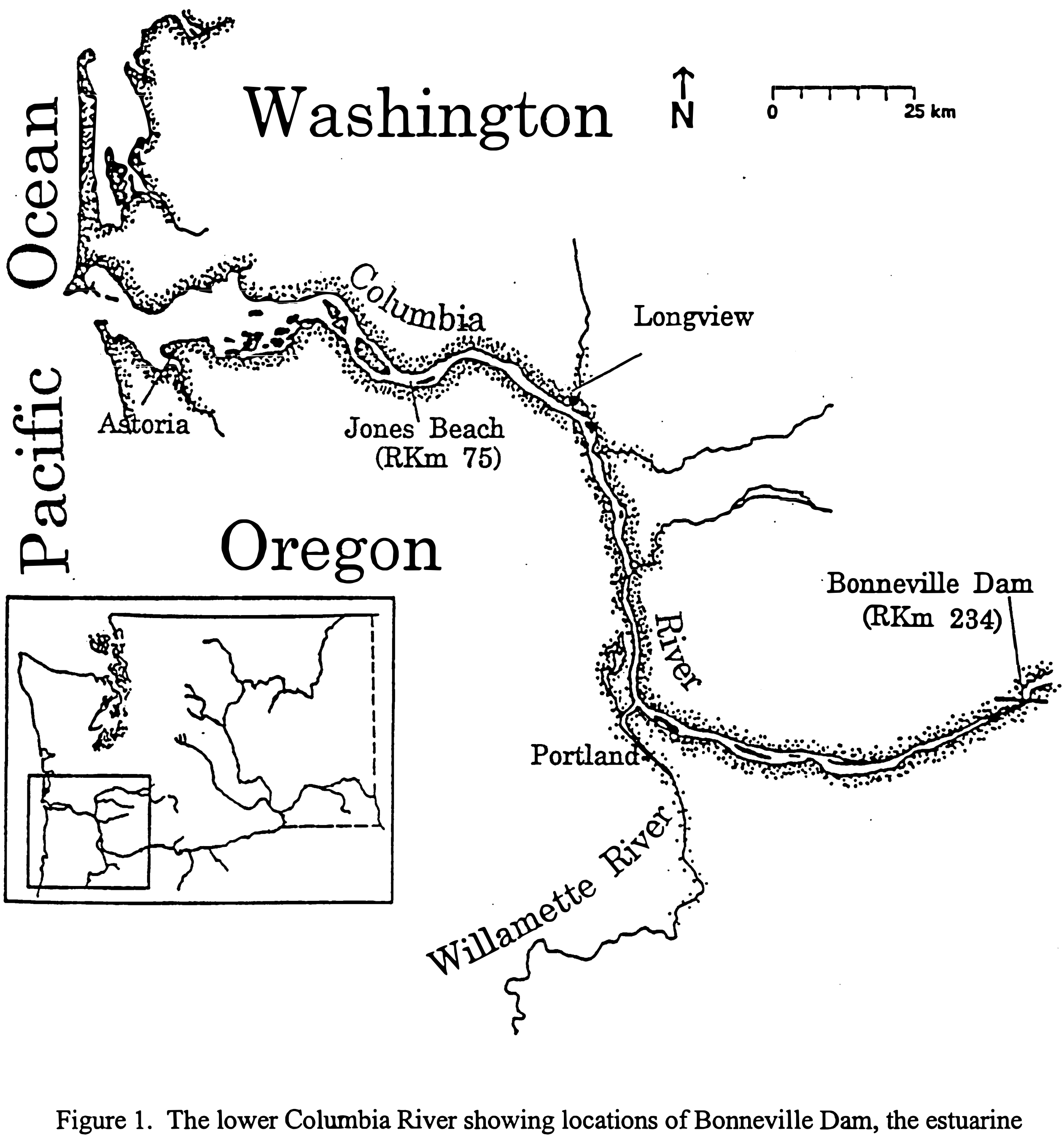

Figure 1. The lower Columbia River showing locations of Bonneville Dam, the estuarine sampling site at Jones Beach, Oregon and the river mouth.

Passage Route Survival Comparisons

In 1987, the National Marine Fisheries Service (NMFS) began a multi-year study in cooperation with the U.S. Army Corps of Engineers (COE) to evaluate survival of subyearling fall chinook salmon (*O. tshawytscha*) passing Bonneville Dam. During June, July, and August 1987 through 1990 and in 1992, groups of juvenile chinook salmon marked with coded wire tags (CWT) were simultaneously released to pass Bonneville Dam via the spillway, the Second Powerhouse turbines, or the bypass system (Fig. 2). Additional releases were made in the Second Powerhouse tailrace at the downstream edge of the turbine boil, at the First Powerhouse, and in mid-river downstream from the dam. About nine million fish were tagged and released for these evaluations. Estimates of short-term relative survival were based on recoveries of juveniles by beach and purse seines in the estuary at Jones Beach, Oregon. Estimates of long-term relative survival were based on recoveries of tagged adult fish from the fisheries and from hatchery returns.

The most striking finding of the Bonneville Survival Study was that differences in estuarine recoveries of juvenile salmon from turbine and bypass release groups suggested little survival benefit associated with the bypass system (Table 1; Dawley et al. 1993). In the first two years (1987 and 1988), recoveries of bypass released groups were significantly less than recoveries of turbine-released groups; mean differences were 10.8 and 13.6%. In 1989 and 1990, recoveries of bypass-released groups were also less (though not significantly) than recoveries of turbine-released groups (mean differences were 3.3 and 2.5%, respectively). The difference between the first two and the following two years of study may have been associated with lower river flow and resulting lower tailwater

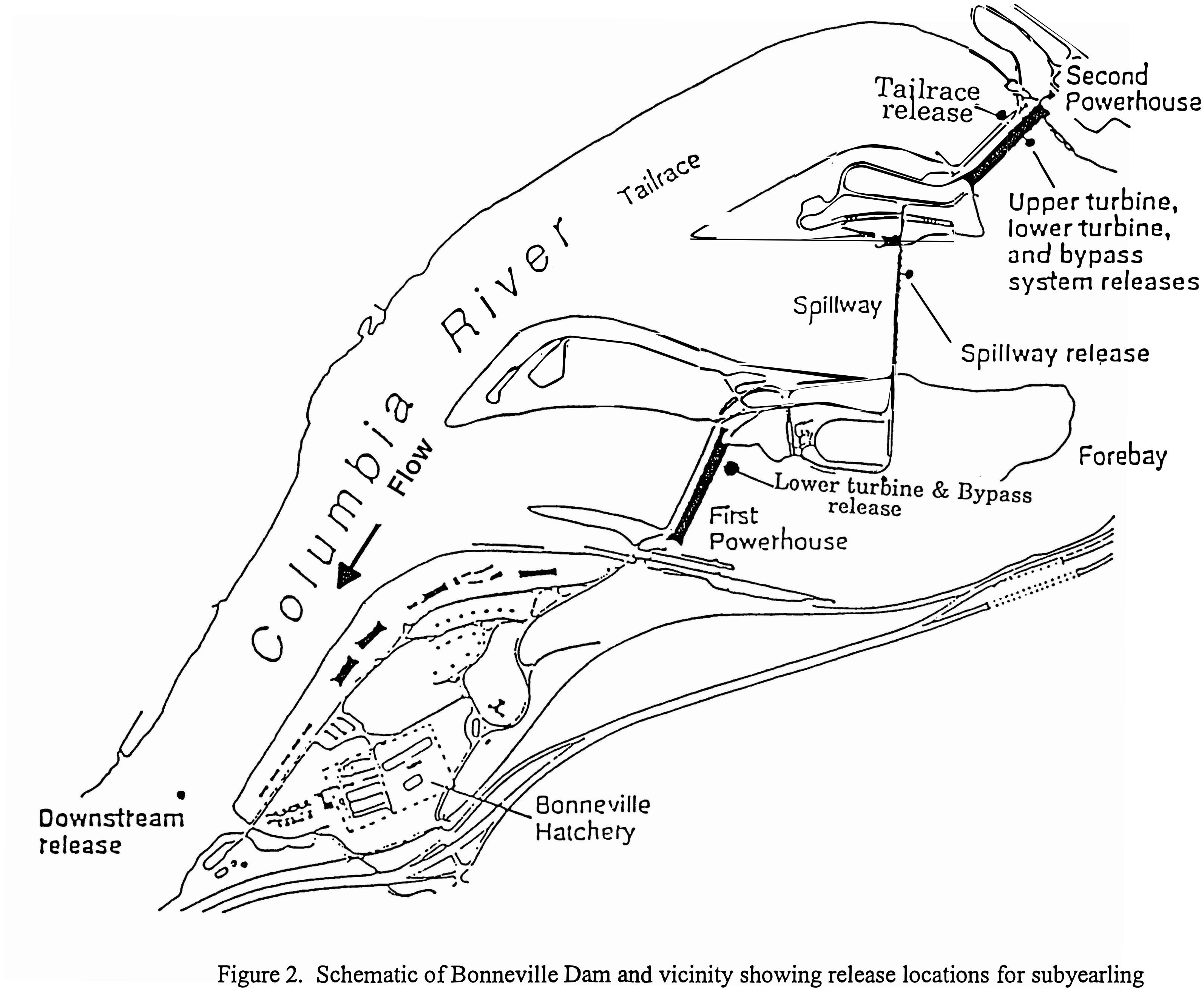

Figure 2. Schematic of Bonneville Dam and vicinity showing release locations for subyearling chinook salmon during 1987-1992 studies.

Table 1. Differences in relative survival between fish passing through the bypass systems and other passage routes at Bonneville Dam based upon juvenile recovery data from estuarine sampling.

Release site/ Treatment	1987	1988	1989	1990	1992	Average
	Percent difference of bypass recoveries from indicated treatment[a]					
Second Powerhouse Bypass						
Turbine: Released at the ceiling and mid-depth of the turbine intake. Passage through the turbine and through the Second Powerhouse tailrace.	-10.8*	-13.6*	-3.3	-2.5[b]	---	-7.6*
Tailrace: Released at the downstream side of turbine discharge boil. Passage through the Second Powerhouse tailrace.	----	-14.1*	-7.3	-3.6	---	-8.3*
Spillway: Released 0.5 m above spillway crest. Passage over the spillway, through stilling basin and spillway tailrace.	----	----	-16.6*	----	---	-16.6*
Downstream: Released downstream from dam and tailraces at a swift-water site.	----	-23.1*	-11.6*	----	---	-17.4*
First Powerhouse Bypass						
Turbine: Released at mid-depth of the turbine intake. Passage through the turbine and through the First Powerhouse tailrace.	---	---	---	---	-11.8*	-11.8*
Downstream: Released downstream from dam and tailraces at a swift-water site.	---	---	---	---	-28.3*	-28.3*

[a] Calculated using annual means for recovery percent of treatment groups,
where: BY = bypass, and TR = other treatment groups/passage routes.
[(BY% - TR%) ÷ TR%] x 100.

[b] Only the mid-depth release site was used to provide increased numbers of replicates.

* Statistically significant at P = 0.95.

elevation during the first two years. The lower tailwater elevation caused greater water velocity (estimated at 8.1 m/second--0.5 m/second greater) within the 0.9-m diameter bypass discharge conduit and increased turbulence and shear forces at the conduit terminus.

Comparisons of recovery differences between bypass and other release groups were also made, but included fewer years of comparison (Table 1). Based on three years of releases, the recoveries of bypass-released groups averaged 8.3% less than recoveries of tailrace-released groups. From two years of releases, recoveries of bypass-released groups averaged 17.4% less than recoveries of downstream-released groups. Based on data from a single year (1989), bypass-released groups averaged 16.6% less than spillway-released groups. This latter comparison is noteworthy because the spillway has long been believed to provide the safest passage and the bypass was assumed to be equivalent.

Results of adult recovery data are equivocal due to unexpectedly poor ocean survival causing low adult return percentages; two years of data indicate bypass passage groups had poorer survival than turbine passage groups and two years of data indicate the opposite. None of the differences were statistically significant ($P \leq 0.05$) with the low numbers of recovery (Gilbreath, et al 1993, Gilbreath in preparation).

Perceived Problems of the Bypass System

The original design and location of the bypass outlet were engineered to provide the best possible protection for outmigrants against predation by birds and fish. The discharge end of the 0.9-m diameter bypass conduit is a teardrop-shaped cement monolith projecting 9 m upward from the river bottom to the outlet at 7-14 m below the tailwater surface. The monolith is located in relatively high velocity water 76 m downstream from the dam, 85 m from the north shore, and 30 m downstream from the turbine discharge boil. The river bottom at the outlet site is smooth and the distance from any geologic relief was thought to eliminate predator sanctuary areas near the egressing juvenile salmon.

However, results of the aforementioned passage survival tests prompted a change of research objectives to focus on the apparent detrimental impacts to outmigrating juvenile salmon using the bypass system. Decreased survival may have been a consequence of either physical damage occurring during passage through the system, increased predation after egress from the bypass discharge conduit, or a combination of both.

Studies of northern pikeminnow (*Ptychocheilus oregonensis)* in the tailrace of Bonneville Dam indicated greater predation on fish egressing from the bypass system than from other locations at the dam. Ward et al. (1992) stated that trolling with lures at the bypass outlet produced the highest catches of northern pikeminnow--substantially higher than any other location in the forebay or tailrace of the dam. In 1990, when passage survival tests were conducted, greater percentages of bypass fish were consumed by northern pikeminnow than tailrace or turbine released fish (Thomas Poe, unpublished report, U.S. Fish and Wildlife Service, Columbia River Field Station, 501A Cook Underwood Rd., Cook WA 98605, March 1991).

Initial investigations of the physical features of the bypass system by NMFS and the COE provided little evidence of problems. A video inspection of the discharge conduit revealed no structural problems sufficient to cause injuries to fish. At operating conditions identical to that under which the survival tests were conducted, water velocities adjacent to the discharge monolith varied from 1 to 1.6 m/sec, similar to model predictions. Literature regarding habitat suitability for northern pikeminnow, thought to be the primary piscivore on juvenile salmon in the Columbia River (Poe et al. 1991; Vigg et al. 1991), suggested that velocities of that magnitude would be exclusionary (Faler et al. 1988). Purse seining at the outlet of the bypass produced little evidence of injury or mortality, but insufficient numbers of fish were recovered to allow rigorous assessment (unpublished data).

In 1990, we began using a trap-net recovery system to assess the physical condition of juvenile salmonids egressing from the bypass system. The general objective of this research was to isolate water flow conditions and sections of the Second Powerhouse bypass system that may cause physical trauma to juvenile salmonids during passage.

METHODS

During 1990, 1991, and 1992 with various controlled water conditions in the bypass system, test fish were released systematically into particular locations of the bypass system and at the outlet to effect simultaneous egress into a trap-net attached to the bypass discharge. Physical condition and blood chemistry of recovered test fish were compared and the differences related to bypass conditions and sections tested. Tests utilizing hatchery reared juvenile steelhead and spring chinook, fall chinook, and coho salmon as well as feral coho, spring chinook and fall chinook salmon were conducted at moderate (13.5-19.5 ft) and low (9-10.5 ft) tailwater elevations and a variety of water conditions in the bypass system. Water temperatures during our tests ranged from 5.6 to 21.1°C.

Structural Features of the Bypass System

The tested portions of the bypass system at Bonneville Dam Second Powerhouse included the collection channel, water control weir, energy dissipation area, dewatering screen, downwell, discharge conduit, and an adjoining conduit from the fish sampling room (Fig. 3). The collection channel (channel) is a 2.7 m wide flume which extends about

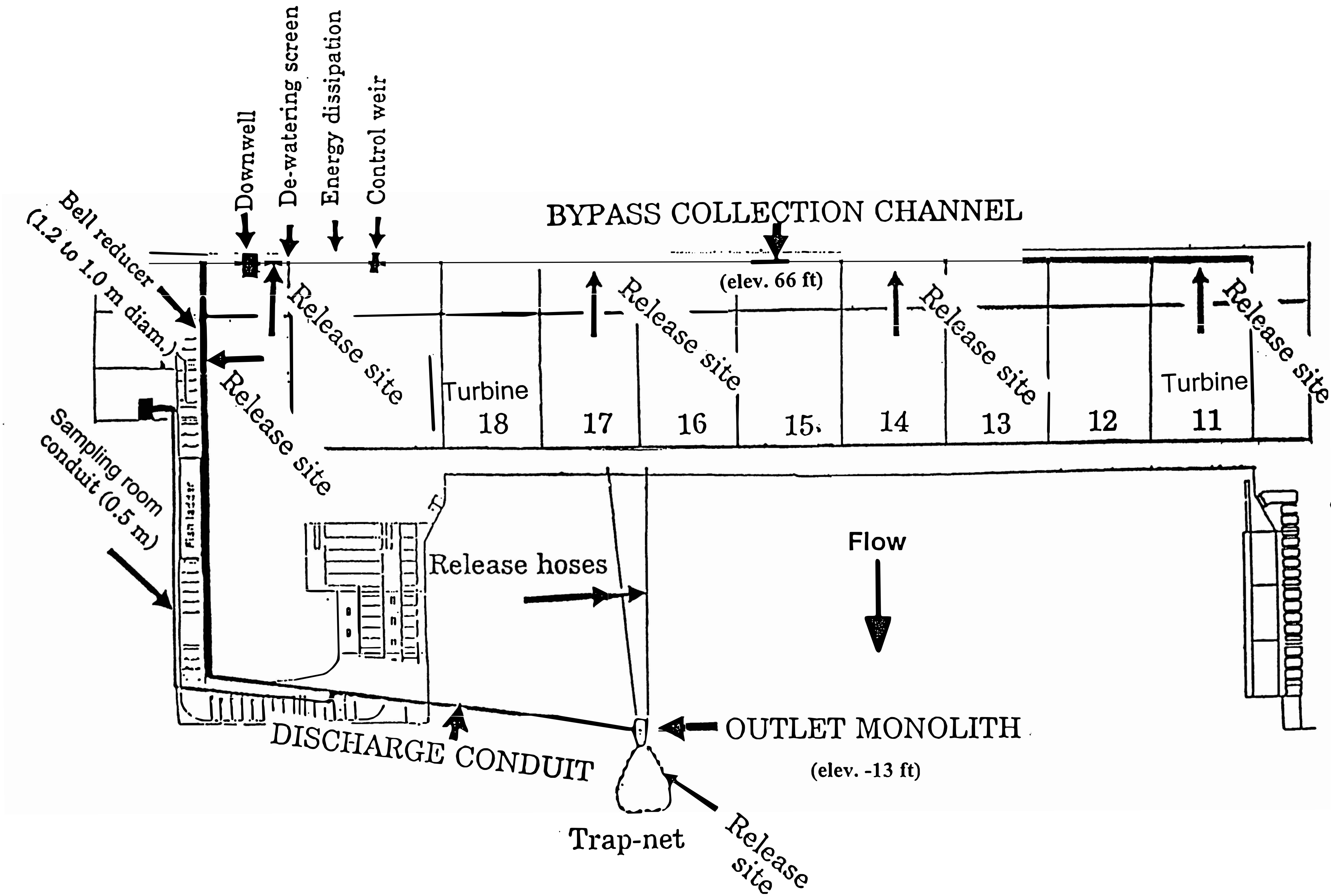

Figure 3. Plan view of the downstream migrant bypass system at Bonneville Dam Second Powerhouse indicating major features, fish release sites, and the trap-net location.

244 m from the south end of the powerhouse at Turbine Unit 11 to the north end at Turbine Unit 18 and is fed by water from one 0.3 m orifice at each of the 24 gatewells. The water volume and velocity in the channel increases from 0.2 m/second at the south end to about 0.8 m/second at the north end.

At the north end of the collection channel a control weir maintains about 2.4 m of depth and water surface elevation about 66 ft above sea level (English units by COE convention). Fish and water pass over the control weir into a turbulent energy dissipation section about 15 m long with slow downstream velocity. Velocity increases to about 1 m/second as water passes downstream over a 17 m long dewatering screen to an overfall weir adjoining a downwell. Water surface elevation is about 61 ft and the depth passing over the downwell overfall weir is controlled automatically. Supplemental flows are added to automatically maintain the downwell surface elevation at 55.0 to 57.0 f. The automatic controls were originally designed to maintain the surface elevation at about 58 ft, but were inadequate to prevent overflow of the downwell; thus, the lower elevations were selected.

At the bottom of the downwell, there is a 1.2 m diameter, 1 m radius, 90° elbow that connects to a 1.2 m diameter discharge conduit which extends 19 m before reducing to 0.9 m diameter. The conduit extends downward another 268 m to the tailrace and terminates at the outlet structure. The fish sampling room has a downwell and 0.5 m conduit which extends 123 m to a "Y" intersection with the bypass discharge conduit 105 m upstream from the outlet. The outlet is at elevation -13 ft (6 to 14 m under the tailwater surface depending on river volume) and angled upward from the horizontal at 23°.

Trap-Net and Recovery System

In 1990, a trap-net system was installed to capture test fish upon egress from the bypass outlet. The exit to the bypass is submerged several meters beneath the water surface; therefore, a specially designed trap-net and positioning structure were constructed to recover test fish (Fig. 4). Several alternative designs for this trapping facility were developed under contract to the COE and are detailed in Summit Technology Consulting Engineers, Inc., P.S. (1990). Of the designs presented, the trap-net was chosen because turbine flow was unnecessary for operating that recovery system which produced the worst-case conditions of shear velocities at the bypass outlet. The trap-net attached directly to a steel carriage permanently affixed to the bypass discharge conduit outlet monolith. The juvenile trap-net was designed to be operated at tailwater elevations between 7 and 20 ft. The upper limit tailwater elevation corresponds to river flows of about 250,000 ft^3/second (English units used by COE convention). Based on 1978-88 Columbia River flow data at Bonneville Dam, we thought it possible to operate the trapping facility on any desired date between mid-July and mid-December as well as selected dates in March, April, and May during an average or low flow year.

Major components of this trap-net recovery equipment were first a net positioning structure attached to the outlet monolith with a carriage for lowering the trap-net mouth to a position surrounding the discharge conduit outlet, and second, a triangular trap-net made of 1.75-cm stretch measure knotless nylon webbing attached to a mouth frame. The surface perimeter corkline was 30 x 30 x 24 m with sides tapering from 6.1 m deep at the downstream corners to 10 m at the upstream mouth. The floor was held in position by leadlines attached to the perimeter and through the center. A funnel-shaped mouth

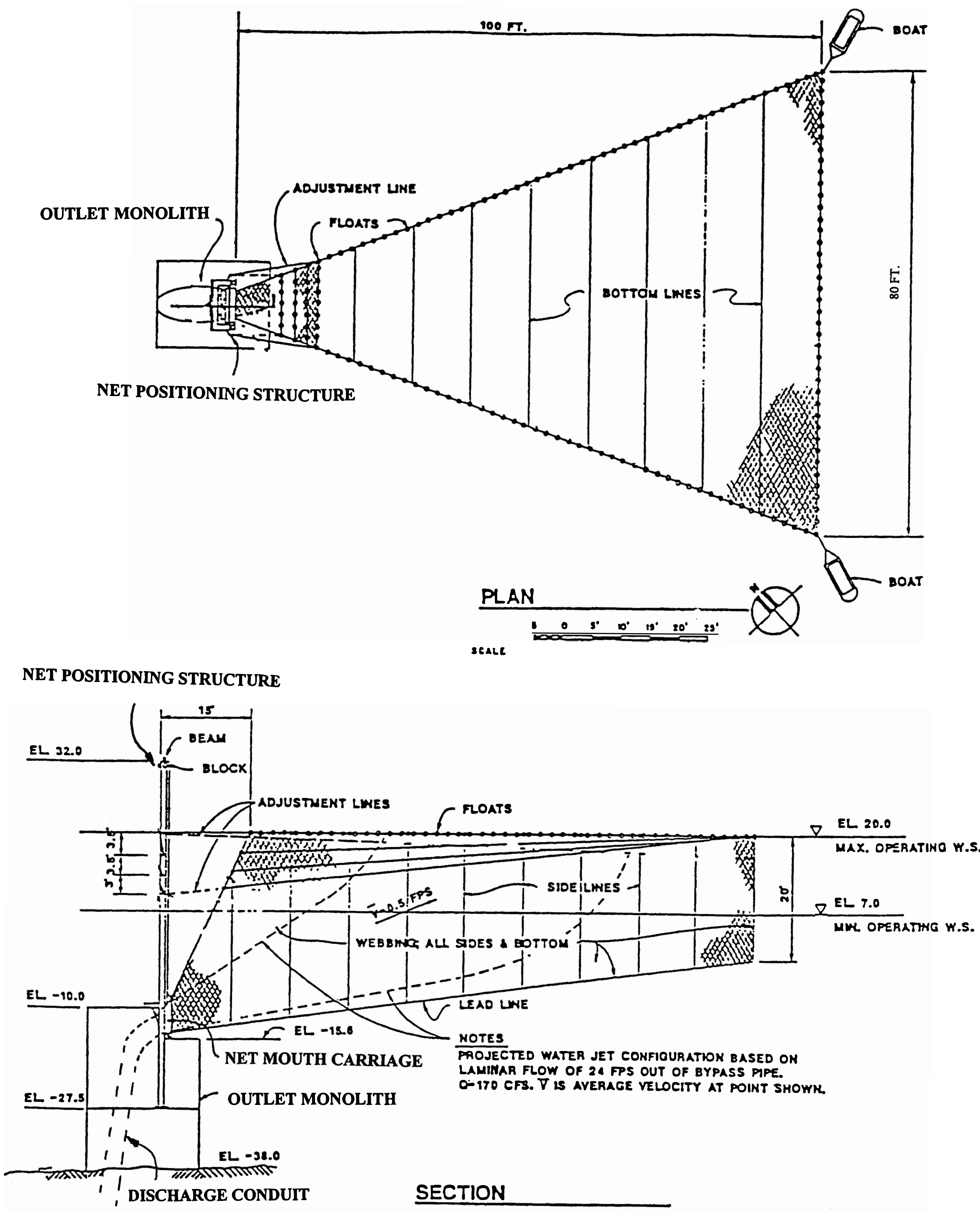

Figure 4. Plan and section views of the trap-net used to intercept test fish exiting the bypass discharge conduit.

extended down 10 m where it was pinned to the carriage of the positioning structure. The size and construction was thought to capture fish in an enclosure which would provide sanctuary from moderate water velocities (less than 1 m/second). The third trap-net component consisted of two 10.2 cm-diameter fish release hoses, extended 76 m from the tailrace deck of the Second Powerhouse at elevation 55 ft to the outlet monolith at elevation -13 ft. The terminus of each hose was reduced to 7.2 cm and angled 10° from parallel into the plume of the bypass discharge. The hose assemblies were designed to provide discharge velocities equivalent to that of the bypass discharge plume. The hose releases were used to assess effects of lateral movement of the trap-net during testing which we speculated might cause abrasion and injury of fish at the sides of the discharge plume. During non-test periods when turbine flows created fluctuating currents up to 2 m/second, these hoses were twice severely damaged and required replacement[1].

Experimental Design

In response to the results of passage survival tests and perceived hydraulic conditions within the bypass system that were thought to harm fish, we designed tests to isolate passage effects through various sections of the bypass system. Differences of descaling, injury, mortality, delayed mortality, and changes in blood chemistry thought to be stress related were assessed over a range of river flows to evaluate potential detrimental impacts. The particular research tasks were as follows:

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[1] Any further need for a long hose passing through the tailrace should be redesigned to provide for an above water attachment with a rigid pipe transporting fish down to the outflow.

1990-1991, Tests at Low and Moderate Tailwater Elevations

1) Develop protocols for regulating bypass conditions, adult fishway flows, and turbine flows.

2) Develop protocols for fish marking, releases, trap-net deployment and retrieval, and evaluation of fish condition.

3) Evaluate the effects of passage through the entire bypass system by releasing test fish into the collection channel and the trap-net at low (9-10.5 ft) and moderate (13.5-19.5 ft) tailwater elevations. Tests were conducted over a wide range of dates, river flows, and water temperatures using several fish stocks including both hatchery and river-run (fish collected from the river). Water flow and passage conditions within the bypass system were maintained at normal ranges (e.g., water surface elevation in the collection channel just upstream of the downwell between 60.0 and 61.0 ft and in the downwell between 55.0 and 57.0 ft).

In 1990, tests were intended to ensure that the experimental protocols and equipment would provide reliable results. Starting in the spring of 1991, tests were conducted to determine effects of bypass system passage using fish from hatcheries. Subsequent testing included use of river-run fish which, due to differences in degree of smoltification, may have responded to the effects of bypass system passage differently than fish obtained directly from a hatchery. In the fall of 1991, tests were conducted to evaluate effects of bypass passage at low tailwater (9 to 10.5 ft) to assess worst-case effects; i.e., greatest water velocity and greatest shear forces at the outlet of the discharge conduit.

1992, Tests at Low Tailwater Elevations

Because of variable results in 1991, tests were conducted in 1992 to evaluate effects at high (58.5 ft) vs. low (55.5 ft) downwell water surface elevations, flow vs. no water flow over the downwell overfall weir, and full vs. empty fish sampling room conduit. Tasks were as follows:

1) Determine background percentages of descaling and mortality associated with the trap-net recovery process by releasing control fish groups at the water surface within the net at the beginning of each test.
2) Determine effects of passage through the net mouth opening by releasing test fish groups through tailrace release hoses attached to each side of the discharge conduit outlet.
3) Isolate the effects of passage through the 90° elbow at the bottom of the downwell and the discharge conduit at maximum and minimum downwell water levels, with and without air entrainment[2], by releasing fish at locations a) slightly upstream from or directly into the downwell, b) into the 0.9 m diameter discharge conduit about 23 m past the elbow, and c) into the trap-net.
4) Isolate the effects of passage through portions of the collection channel and the energy dissipation/dewatering area--by releasing fish at the south end, middle, and north end of the collection channel and slightly upstream from the downwell.
5) Assess the effects of passage through the bypass discharge conduit at various flow conditions with a full vs. partially filled fish sampling room conduit–by releasing fish slightly upstream from or into the downwell to compare with fish released into the trap-

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[2] Decreased air entrainment as a result of minimum water volume and distance of fall into the bypass downwell and maintaining a full downwell in the fish processing room.

net. The various conditions included low vs. high downwell levels and normal vs. no overflow into the downwell. (The fish sampling room conduit adjoins the bypass discharge conduit 105 m from the outlet). The fish sampling room conduit was engineered to be full, but is generally operated empty which may cause air introduction or withdrawal from the bypass discharge conduit.)

Test Fish

A variety of sizes and stocks of juvenile steelhead, chinook salmon, and coho salmon were used in tests. We obtained test fish from several hatcheries and from the smolt monitoring facilities at Bonneville Dam First Powerhouse and McNary Dam (Table 2). Test fish were transported to the Adult Fish Facility (AFF) at Bonneville Dam Second Powerhouse for marking. Hatchery fish were transported in a 3,785-L tanker truck, fish from McNary Dam in a 13,250-L tanker truck, and fish from Bonneville First Powerhouse in a 750-L slide-on tank.

Marking Procedures

Because accurate identification of fish by treatment was required under difficult conditions (i.e., aboard a fishing vessel), we used easily identified marks, including excision of a tip of the left or right ventral fin or the upper or lower lobe of the caudal fin. Unique marks were simultaneously applied to each release group within a test. Typically, 400-600 fish/treatment group/test were used, with tests replicated four times over a 2 to 4 day period--smaller groups and fewer replicates were utilized during exploratory evaluations.

Table 2. Dates and test fish for evaluations of stress,[a] descaling, injury, and mortality to juvenile salmonids passing through all or portions of the bypass system (collection channel, downwell, and discharge conduit) at the Bonneville Dam Second Powerhouse, 1990-92.

Year	Test fish[b]	Source	Fork length (mm)	Dates: Transport	Dates: Marking	Dates: Test[c]	Water temp. °C	Tailwater elevat. ft.	Treatment groups[d]
1990									
	Subyr. fall chin.	Bonneville H.	140	16 Nov	16 Nov	19-20 Nov	11.7	17.5	Collection channel,
	(URB stock)		140	23 Nov	23 Nov	26-27 Nov	10.6	13.5	Egress, Net
1991									
	Yr. spring chin.	Lookingglass H.	126	21 Mar	25-26 Mar	28-29 Mar	5.5	17	Collection channel, Egress, Net
	Steelhead	Irrigon H.	193	27 Mar	30 Mar	2, 4 Apr	6.0	15.5-16.9	Collection channel, Net
	Yr. coho	Bonneville H.	133	8 Apr	9-10 Apr	11-12 Apr	6.8	17.5-18	Collection channel, Egress, Net
	Yr. coho (River run)	Bonneville Dam	137	25-27 Apr	25-27 Apr	1-2 May	9.0	19.5	Collection channel, Net
	Yr. chin.	McNary Dam	167	26 Apr	27 Apr	1-2 May	9.0	19.5	Collection channel,
	(River run)		151	2 May	3 May	7 May	9.0	19.5	Net
	Subyr. fall chin. (URB stock)	Bonneville H.	85	3 Jul	5 Jul	10-11 Jul	18.3	19.5	Col. chan., Conduit, Egress, Net
	Subyr. chin. (River run)	Bonneville Dam	100	13-15 Jul	13-15 Jul	16-17 Jul	18.9	15-18.5	Collection channel, Net
	Subyr. fall chin. (URB stock)	Bonneville H.	116	28 Aug	30 Aug	3-5 Sep	21.1	9-10.5	Collection channel, Egress, Net
	Subyr. coho	Cascade H.	125	18 Oct	21 Oct	22-25 Oct	16.5	9.0-9.5	Collection channel, Conduit, Net
1992									
	Subyr. coho	Cascade H.	105	7 Oct	11-14 Oct	13-16 Oct	15.3	9.5-10.5	Col. chan., Dwnwel, Conduit, Net
	Subyr. fall chin. (Tule stock)	Lit. Wh. Sal. NFH	132	July	18-21 Oct	20-23 Oct	16.0	10-10.5	Collection channel, Downwell, Net

[a] Stress was assessed through changes in blood chemistry of subyearling chinook salmon in 1990, yearling chinook salmon in April 1991, and subyearling chinook salmon in July 1991.
[b] Generally, four replicate tests were conducted in each series.
[c] One or two tests/day on dates listed.
[d] In addition to the groups listed, killed or anesthetized hatchery fish were released during one or more of the four individual tests in each series.

At the AFF, fish were transferred to a 13,600-L holding tank and hatchery fish were allowed to acclimate in Columbia River water for 48 hours prior to marking, river-run fish were held for shorter periods. Fish were removed from the holding tank using a dip-net, anesthetized with 50 mg/L tricaine methane sulfonate, and given single or multiple fin clips to indicate treatment assignment. Yearling chinook salmon obtained at McNary Dam and subyearling chinook salmon obtained at Bonneville Dam (fish obtained from the river) were anesthetized prior to dip-netting to minimize descaling caused by struggling in the nets. Hatchery fish required no pre-anesthesia (not fully smolted). After marking, fish were placed in 300-L or 3,400-L holding tanks; all fish for an individual test were held in the same size tank. Hatchery fish were held for 48 hours; run-of-the-river fish were held 24 hours prior to release.

Release Sites and Procedures

In 1990 and 1991, all test series included releases into the bypass system collection channel and into the recapture net. In some test series we also released fish into the bypass system discharge conduit or into the tailrace release hoses providing a submerged release into the discharge conduit outflow plume.

Release sites varied among tests in conjunction with the objectives of the particular test. Selection of hours for testing, noon to 4 PM, was based on low adult salmon counts at entrances to Bonneville Dam fish ladders (Turner et al. 1984), a perceived need for daylight operations, and low power demands. Unless otherwise stated, all releases were through 7.6-cm diameter hoses.

In aggregate, the release sites were: 1) water surface at the south end of the channel at Turbine Unit 11 through a 15 m long hose; 2) water surface at the middle of the channel at

Unit 14 through a 15 m hose; 3) water surface at the north end of the channel at Unit 17 through a 15 m long hose (release site used in previous survival studies); 4) water surface at the dewatering screen about 10 m upstream from the downwell through a 30 m long hose; 5) water surface of the downwell through a 15-m hose; 6) submerged in the discharge conduit about 20 m downstream from the downwell and just downstream from the 1.2 to 0.9 m restriction through a 30 m long hose; 7) submerged at the exit of the discharge conduit, alternately through one of two 10.2 cm dia. x 76 m long tailrace release hoses; and 8) water surface adjacent to the south side of the trap-net through a 10.2-cm diameter x 2 m long hose. Shear forces on fish leaving the hoses were well below the 15 m/second threshold thought to cause problems with fish of this size (Groves 1972).

A few minutes prior to release, holding tanks containing control fish for release into the trap-net were lowered from the deck of the dam onto a boat. The boat then maneuvered to the south perimeter of the trap-net where fish were released.

Releases of test fish groups were made in sequence to provide similar timing of entrance into the trap-net for all treatment groups; deviations from this procedure are noted in tables. Generally, control fish were released when the first test fish were observed entering the trap-net. However, when releases were made at the south end or middle of the collection channel, control fish were released about 10 minutes prior to termination of the test because of the long time period of bypass passage. Passage time through the discharge conduit averaged about 45 seconds (268 m at about 6 m/sec). Differences of descaling, injury, mortality, and delayed mortality percentages among treatment and control groups were assessed to identify detrimental impacts associated with passage through the various sections of the bypass system at the flow conditions tested.

To provide the least amount of disturbance at release, tanks and release hoses were coupled with matching cam and groove aluminum fittings (machined to remove all sharp interior edges and roughness) and slide gates were opened using handles external to the tank. Once the tanks were emptied of fish and water, the release hoses were flushed with additional water.

Turbine and Fishway Operating Requirements

The trap-net could not be easily deployed, retrieved, or maintained in fishing position against strong currents or cross currents present in the tailrace. It was therefore necessary to request special powerhouse and adult fishway operations during testing; these included: 1) shut down seven of the eight Second Powerhouse main turbine units (11 or 12 and 13-18); 2) diminish flows from the north upstream entrance of the Washington shore fishway by raising the control weir to 0.3-1.2 m below tailwater elevation; 3) operate the fishway water supply turbines to sustain about a 0.4 m differential to tailwater elevation (3 cm less than standard operational specifications); and 4) during some tests, adjust the small fishway Turbine Units F1 and F2 to 1.3 to 1.2 ft to reduce the flow from the fishway. Special operations were maintained for 3 to 5 hours on each test day beginning at noon with tests initiated 1 hour or more following turbine shut down.

For deployment and retrieval of the trap-net, COE personnel diverted flow from the bypass conduit by opening the emergency relief gate (ERG); the ERG was closed during tests.

Recovery and Evaluation Procedures

Following the passage of most test fish into the trap-net, the ERG was opened and the carriage, with the net-mouth attached, was lifted to the surface. The net was then laboriously retrieved to the deck of a barge moored to the net positioning structure. A pocket of web (1.2 x 2.4 x 1.2 m deep) was left in the water for holding. The test fish were then lifted from the web pocket with a sanctuary net (41 x 122 x 36 cm deep) and apportioned into 2, 3, or 4 (depending on size of fish) 400-L containers for holding prior to anesthetization and examination for descaling, injury, and mortality. Fish were categorized as descaled (>25% of scales lost on one side), injured, or moribund. Observations of physical trauma were recorded, and all injured and descaled fish plus a 100-fish subsample of healthy fish from each release group were transported to the juvenile fish processing room at the Second Powerhouse. Delayed mortality was assessed after 48-hours of holding.

Periodic releases of killed or anesthetized fish were made into the bypass system collection channel to compare recovery rates of live and dead fish. Of concern was the possibility that fish injured during passage through the system may have a different capture rate than uninjured fish, thus causing a potential bias in test results.

Stress Evaluation

November 1990

Stress assessments were conducted by Alec Maule (Oregon State University) under contract to NMFS. Juvenile fall chinook salmon (upriver bright stock) obtained from Bonneville Hatchery were marked and released as previously described. During each of the four test replications, samples of 10-12 fish were taken from the three treatment groups 1 hour before release, and at 0.5, 2, 4, 6, 18, and 42 hours after recapture. The first post-release stress assessment samples were taken as soon as recaptured fish became available, generally 20 to 40 minutes following release. Subsamples of about 120 fish/treatment group were held in the Fish Observation Room of the Visitor Observation Building to provide a pool of fish for stress assessment samples. Fish were anesthetized in buffered, 200 mg/L tricaine methane sulfonate, the caudal peduncle severed, and blood withdrawn into heparinized capillary tubes. Plasma was separated by centrifugation and stored frozen prior to assay. Plasma cortisol was determined by the radioimmunoassay method (Redding et al. 1984). Plasma glucose was measured as described by Wedemeyer and Yasutake (1977) and plasma lactate assayed by fluorimetry (Passonneau 1974).

April and May 1991

Juvenile yearling chinook salmon obtained from the collection facility at McNary Dam were marked and released as previously described. However, the tailrace release hose (submerged release into the bypass outlet plume--egress release) was eliminated while retaining the release into the bypass channel and the surface release into the net. In each of four replicate tests, samples of 12 fish were taken from the two release groups at the same time intervals used during November 1990. Sampling protocol, sample assays, and data analyses were as in November 1990 tests.

To provide a measure of capacity to respond to stress, we subjected separate 100-fish groups to acute and chronic stresses. Acute stress was induced by netting fish from the holding container, keeping them out of the water for 30 seconds, and then placing them back into the water in a second holding container. Chronic stress was induced by crowding. Fish were placed into 19-L plastic buckets which were immersed in a large holding tank. Holes drilled in the sides of the buckets allowed for water exchange. The density of fish in each bucket was maintained at 150-200 g/L by raising the buckets slightly as fish were removed at sampling intervals. Samples of 12 fish were removed from the initial holding container just before beginning the tests, and from the final holding containers at 0.5, 2, 4, 6, 18, and 42 hours after the start of the tests. Sampling protocol, sample assays, and data analyses were as in November 1990 tests.

July 1991

Juvenile chinook salmon were obtained from the First Powerhouse Smolt Monitoring Facility at Bonneville Dam. In each of four replicate tests, samples of 4-14 fish were taken from the two release groups 2-4 hours prior to release, and at 0.5, 2, 4, 6, 18, and 42 hours after recapture. Acute and chronic stress characterizations were conducted as in April and May 1991. Sampling protocol, samples assays, and data analyses were as in previous tests.

Statistical Procedures

The experimental design adopted was a release of 400-fish groups at various locations replicated four times. We expected 95% recovery of test fish and 2% background injury/mortality due to recovery procedures. We anticipated detecting 2% differences of injury/mortality among groups passing through the various passage routes ($\alpha = 0.05$ and $\beta = 0.2$) (Cochran and Cox 1957). Data were analyzed by t-test (Sokal and Rohlf 1981).

Stress assessment data were analyzed by two-way analysis of variance followed by comparison of means using Fisher's Protected Least Significant Difference (FPLSD) procedures at the 5% probability level (Petersen 1985).

RESULTS

Preliminary Tests

Beginning in November 1990, procedures were developed to deploy and retrieve a specially designed recapture net. Minor gear problems were resolved (Figs. 3-4) and fishway flows were established which provided the least turbulence during trap-net operations. Subyearling chinook salmon were released into the bypass system just upstream from the downwell and at the water surface in the recapture net. At moderate tailwater level 13.5 to 17.5 ft, descaling averaged 3% for bypass releases and about half of that for control releases through the submerged tailrace release hoses and directly into the net (Table 3). Even though descaled percentages for control releases were about half of the bypass released fish, there was no statistical difference ($\alpha = 0.05$). Injury plus mortality of bypass released fish averaged less than 0.5% and was not statistically different from controls ($\alpha = 0.05$).

The trap-net recovered 80-100% of the live test fish and 93-100% of the killed fish released into the bypass channel (Table 3). The high recovery percentage of killed fish allowed us to assume that injured, moribund, and dead test fish exiting the bypass were proportionally represented in recovery data.

The stress response as measured by levels of cortisol, glucose, and lactate rose significantly from the pre-release sample to the first post-release sample at 0.5 hours (Appendix Table 1). Cortisol levels at 2 hours decreased slightly for the bypass channel and egress release groups, but increased slightly for the net release group. Cortisol levels for all treatments fell significantly at 4 hours, then remained fairly constant until sampling was completed at 42 hours. The response curve for the egress group was significantly

Table 3. Direct assessment of descaling, injury, and mortality among hatchery reared subyearling chinook salmon passing through the Bonneville Dam Second Powerhouse bypass system, 1990; at tailwater elevation 13.5-17.5 ft and water temperature 10.6 - 11.7°C.

Release information[b]			Recovery information [a]						
			Catch		Descaled		Dead/injured[c]		Delayed Mort.[d]
Date	Site	No.	No.	%	No.	%	No.	%	%
19 Nov	By	581	574	98.8	16	2.8	3	0.5	0.7
	Eg	576	498	86.5	9	1.8	0	0.0	0.0
	Nt	576	559	97.0	11	2.0	3	0.5	0.0
20 Nov	By	578	561	97.1	19	3.4	5	0.9	0.8
	Eg	578	445	77.0	9	2.0	2	0.4	0.0
	Nt	578	550	95.2	9	1.6	0	0.0	0.0
26 Nov	By	577	560	97.1	12	2.1	1	0.2	0.0
	Eg	579	540	93.3	12	2.2	4	0.7	0.0
	Nt	577	560	97.1	11	2.0	0	0.0	0.0
27 Nov	By	591	577	97.6	22	3.8	1	0.2	0.0
	By--killed[e]	658	570	86.6					
	Eg	579	515	88.9	5	1.0	1	0.2	0.8
	Nt	581	578	99.5	2	0.3	0	0.0	0.0
Total/Mean(SE)									
	By	2,327	2,272	97.6(0.4)	69	3.0(0.4)	10	0.4(0.2)	0.4(0.2)
	By--killed	658	570	86.6					
	Eg[f]	2,312	1,998	86.4(3.4)	35	1.8(0.3)	7	0.4(0.2)	0.2(0.2)
	Nt	2,312	2,247	97.2(0.9)	33	1.5(0.4)	3	0.1(0.1)	0.0

[a] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.

[b] Site codes are By = bypass entrance release, Eg = egress hose release, Nt = surface release into recovery net.

[c] Of the fish grouped as dead or injured, only eight were dead and all were from the bypass release group (0.35% of the total release).

[d] Groups of 120 fish were held 48 hours following tests to evaluate delayed mortality. Additionally, descaled and injured fish recovered in the last 2 days of testing were held 24 hours to assess delayed mortality and included in the presented results.

[e] Killed fish were released into the bypass system along with the live fish. We estimated 15 to 20 fish taken from the net by sea gulls during the 27 November test--substantially more than in tests where no killed fish were released.

[f] A gap between the net mouth and stanchions probably reduced recovery. An underwater video tape of the structure revealed this problem after testing was completed.

higher than for the net group. Glucose levels remained fairly constant from 2 hours through the duration of the test and the response curves for bypass channel and egress groups were significantly higher than for the net group. Lactate levels gradually returned to pre-treatment levels and showed no differences among treatment groups.

The significant rise in cortisol observed at the first post-recapture (time = 0) samples indicates all groups were only slightly stressed. Maximum cortisol levels for bypass and egress treatment groups were 120.5 and 140.2 ng/ml, respectively, somewhat higher than the maximum of 94.6 ng/ml observed for the net release. Note that the maximum cortisol level was seen in bypass and egress releases at recapture, while the maximum for net releases was seen at the second post-recapture sample at 2 hours post release. Because the egress group elicited a stronger stress response than the bypass group, it appears that passage through the 10.2-cm x 76-m hose to the bypass outlet caused more stress than the bypass system.

1991 Tests

Moderate Tailwater

From March through July 1991, tests were conducted at moderate tailwater elevations 15 to 19.5 ft using hatchery reared steelhead and hatchery as well as river-run coho and yearling and subyearling chinook salmon. Results suggested impacts from bypass passage were minimal in relation to losses suggested from earlier studies. Mean descaling in all test series was higher for fish released into the bypass system than for control releases, and the magnitude of the difference was greatest for river-run fish (Table 4; Appendix Tables 2-10). Descaling of bypass passage groups was not significantly different ($\alpha = 0.05$) from controls for hatchery yearling chinook salmon or for hatchery steelhead. Differences were near

Table 4. Results of trap-net recovery data for tests of Bonneville Second Powerhouse bypass system conducted in 1991; mean percentages of recovery, descaling, injury, mortality, and delayed mortality at moderate and low tailwaters.

Stock [a] Tailwater	Treatment [b]	%Recov.	%Kil.rec. [c]	%Descale	%Injury	%Mort.	%Del.mort. [d]
MODERATE TAILWATER–15.0 to 19.5 ft MSL							
Coho salmon							
Hatchery [e]	By channel	99.6	96.3	3.0	0.6	0.2	0.0
TW=18 ft	Egress	92.5	--	1.9	0.3	0.1	0.8
	Net	98.8	--	0.8	0.5	0.2	0.0
Riv.-run [f]	By channel	94.1	100.0 [g]	8.5	1.2	0.2	0.5
TW=20 ft	Net	99.4	--	1.2	0.6	0.6	0.0
Yearling spring chinook salmon							
Hatchery [e]	By channel	97.6	97.4	1.1	0.4	0.5	0.2
TW=17 ft	Egress	91.7	--	0.3	0.0	0.1	0.0
	Net	98.0	--	0.5	0.1	0.2	0.2
Riv.-run	By channel	92.2	100.0 [g]	11.6	0.5	0.6	1.4
TW=20 ft	Net	86.1	--	0.3	0.4	0.4	0.5
Steelhead							
Hatchery	By channel	74.9	95.0	0.2	0.3	0.1	0.0
TW=16 ft	Net	101.6	--	0.1	0.4	0.0	0.0
Subyearling fall chinook salmon							
Hatchery	By channel	84.6	94.2	3.0	0.2	5.6	5.1
TW=19 ft	By conduit	85.9	--	2.6	0.3	3.0	4.1
	Egress	82.6	--	1.6	0.2	1.9	1.3
	Net	85.5	--	0.4	0.0	0.5	1.2
Riv.-run	By channel	84.9	92.5 [g]	28.6	3.8	2.4	7.7
TW=16 ft	Net	94.6	--	1.4	0.2	1.2	2.8

Table 4. Continued.

Stock[a] Tailwater	Treatment[b]	%Recov.	%Kil.rec.[c]	%Descale	%Injury	%Mort.	%Del.mort.[d]
			LOW TAILWATER ELEVATION–				
			Subyearling fall chinook salmon (21°C water temperature)				
Hatchery	By channel	90.8	95.0	6.5	0.8	28.5	4.2
TW=9-	By conduit	92.8	--	4.2	0.5	17.1	1.0
10.5 ft	Eggress	75.1	--	2.1	0.2	4.8	0.8
	Net	99.2	--	0.1	0.2	1.5	2.5

Date	TW elev.(ft)	Mortality % Net	Egress	By conduit	Bychannel
Sept 3	10.5	0.3	0.4	2.3	6.3
Sept 4	9.5	0.5	0.4	3.4	7.0
Sept 5	9.0	0.8	6.3	23.2	49.2
Sept 5	9.0	4.2	12.1	39.5	51.1

Subyearling coho salmon (16.5°C water temperature)

Stock Tailwater	Treatment[a]	%Recov.	%Kil.rec.[b]	%Descale	%Injury	%Mort.	%Del.mort.[d]
Hatchery	By channel	79.9	95.0	0.9	0.3	8.5	0.8
TW=9-	By conduit	85.1	--	0.7	0.1	5.5	0.0
9.5 ft	Net	96.3	--	0.2	0.1	0.7	0.0

Date	TW elev.(ft)	Mortality % Net	Egress	By conduit	By channel
Oct 22	9.5	0.0	--	0.0	0.0
Oct 23	9.5	1.3	--	19.4	31.5
Oct 24	9.0	1.3	--	2.3	1.8
Oct 25	9.0	0.0	--	0.3	0.8

[a] Hatchery or river-run (collected from McNary or Bonneville bypass systems). TW = water surface elevation (ft) of the tailrace.

[b] Generally 400 fish per treatment and four replicates, other group sizes and numbers of replicates are indicated. Where: By channel = 10 m upstream from downwell; By conduit = 20 m downstream from downwell; Egress = through release hoses into outflow plume; Net = at water surface of the trap-net.

[c] Percent recovery of fish which were killed before release into the bypass.

[d] Delayed mortality of injured, descaled plus 100 fish subsample after 48 hours.

[e] Group size was 600 fish per treatment; four replicates.

[f] Only two replicates; total about 800 fish per treatment.

[g] Hatchery fish used for fish group released dead.

significance level in tests with hatchery subyearling chinook salmon and hatchery coho salmon, and highly significant in test series with river-run fish. Descaling for bypass system releases of river-run fish was 8.5% for coho salmon, 11.6% for yearling chinook salmon, and 28.6% for subyearling chinook salmon.

Prevalence of injuries from bypass passage was generally less than 1% of the live recaptured fish; there were generally no significant differences between bypass system and control releases. An exception was the test series with river-run subyearling chinook salmon where injuries were observed on 3.8% of fish released into the bypass system, compared to 0.2% of control fish.

Prevalence of mortality related to bypass passage was generally less than 1% of the fish at recovery and 48-hour delayed mortality was less than 1.5%. However, in tests with subyearling chinook salmon on 10, 11, 16, and 17 July, direct and 48-hour delayed mortality attributed to bypass system passage averaged 5.6 and 5.1%, respectively, for fish obtained from Bonneville Hatchery, and 2.4 and 7.7% respectively for river-run fish (Table 4).

Impacts to fish passing through the tailrace release hoses were no different than fish groups released into the trap-net at the surface. To reduce the number of test fish necessary for subsequent tests, the tailrace hose releases were eliminated.

Killed and heavily sedated fish were captured at as high or higher a percentage than the uninjured test fish (Appendix Tables 2-8), thus we abandoned the practice of releasing killed fish along with test groups in subsequent tests.

To evaluate stress during bypass passage, blood plasma levels of cortisol, glucose, and lactate were measured in both river-run yearling and river-run subyearling chinook salmon. Generally, these measurements indicated significantly greater stress to bypass-released fish groups than to controls (Appendix Tables 11-12). Concentrations of plasma cortisol for bypass groups were significantly higher than controls for an 18-hour period following passage (Fig. 5). Plasma glucose increased and peaked significantly higher than controls at 6 to 18 hours post test. Plasma lactic acid peaked significantly higher than controls immediately after the test (Fig. 6). Test fish stressed in the laboratory by crowding and netting, to establish comparison points of known stress, showed cortisol levels of similar magnitude to those produced from bypass passage.

Plasma cortisol levels attained after passage through the bypass system at Bonneville Dam Second Powerhouse were compared with those at Lower Granite (Congleton et al. 1984), Little Goose (Monk et al. 1991), and McNary Dams (Maule et al. 1988). For both river-run yearling and river-run subyearling chinook salmon, levels measured at Bonneville were within the ranges already measured at the other dams (Figs. 7-8).

Low Tailwater

At low tailwater elevations (9-10.5 ft), we conducted two additional tests to evaluate what we believed would be the most detrimental conditions of bypass passage, because of greater hydrostatic head. Those tests revealed an apparent high variability of passage conditions which caused intermittent high mortality ranging from 6 to 51% for subyearling chinook salmon and from 0 to 32% for subyearling coho salmon (Table 4; Appendix Tables 9-10).

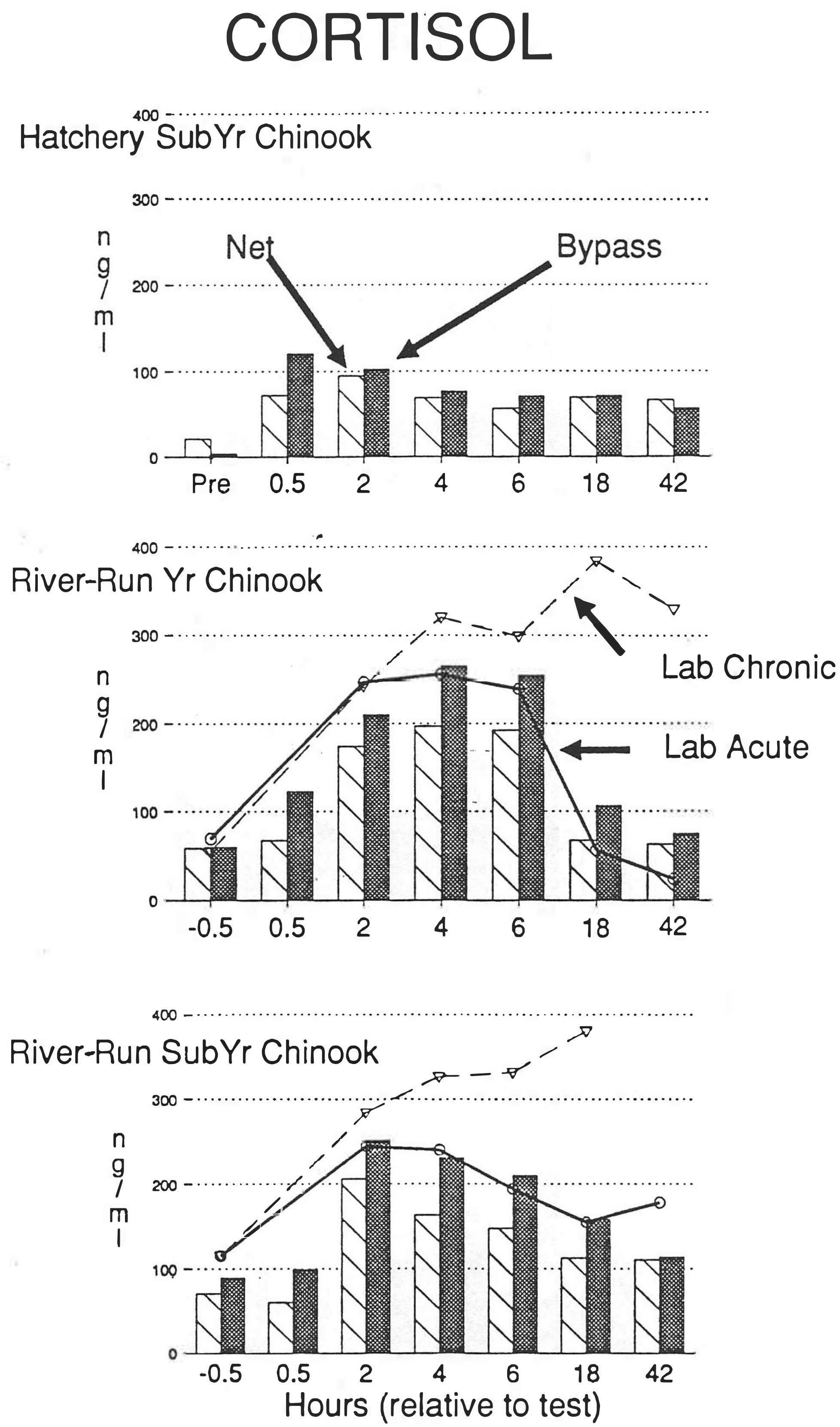

Figure 5. Cortisol levels of river-run yearling and subyearling chinook salmon before and after bypass passage compared to counterparts released in the trap-net (Net) and to laboratory test fish stressed by dipnetting (Acute) and by continuous crowding (Chronic).

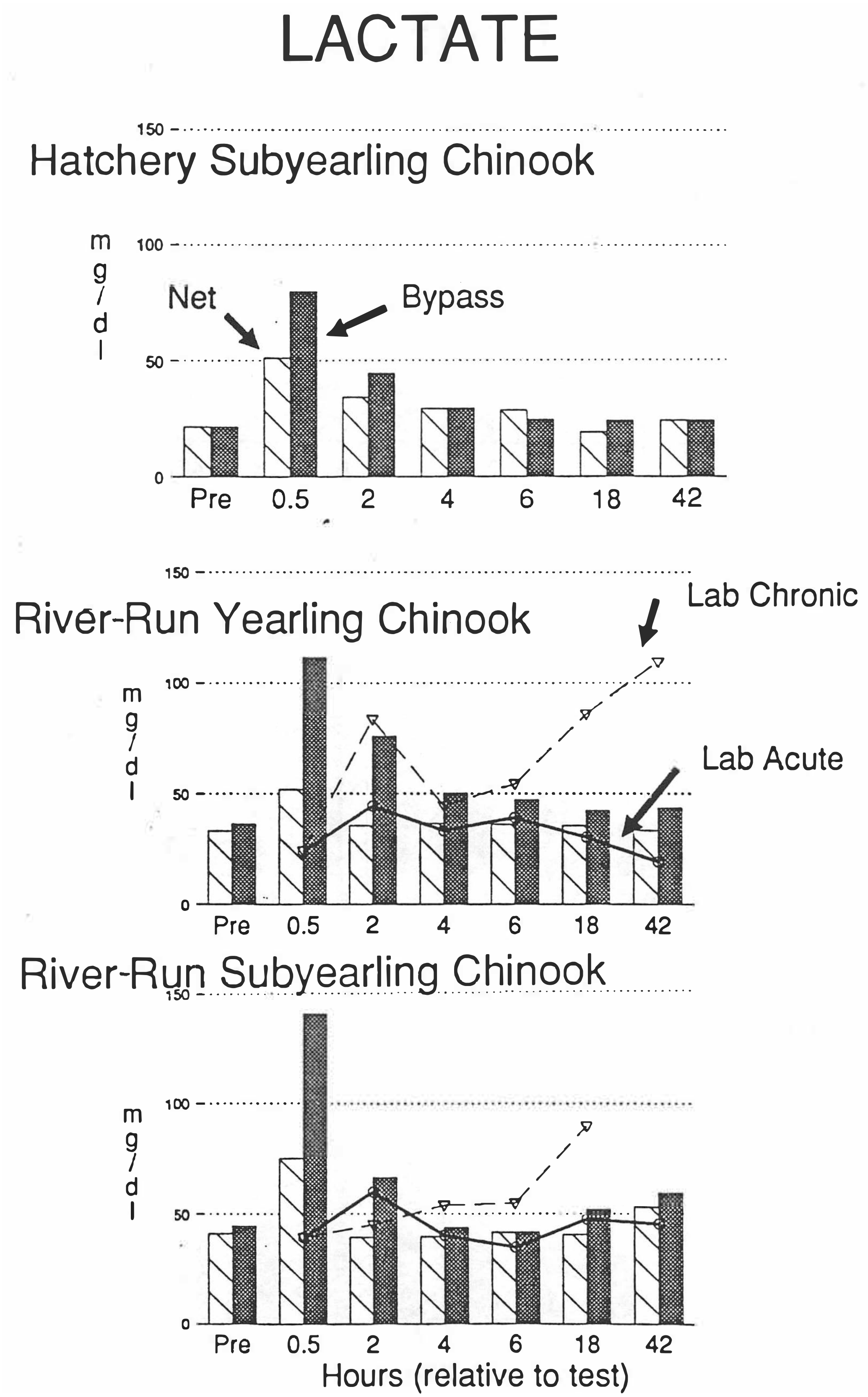

Figure 6. Lactate levels of river-run yearling and subyearling chinook salmon before and after bypass passage compared to counterparts released in the trap-net (Net) and to laboratory test fish stressed by dipnetting (Acute) and by continuous crowding (Chronic).

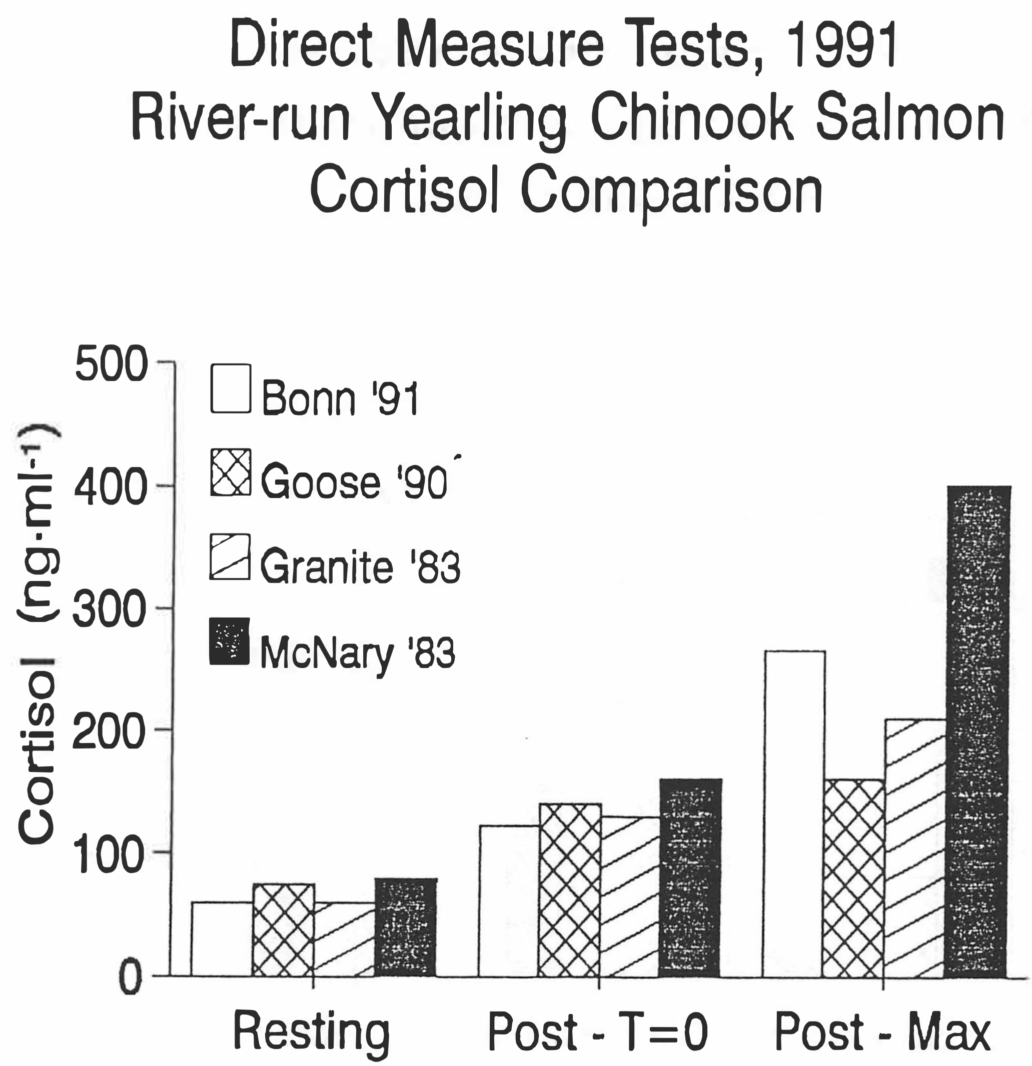

Figure 7. Cortisol levels of river-run yearling chinook salmon after passage through the bypass system a Bonneville Dam Second Powerhouse compared with levels measured at other dams on the Snake and Columbia Rivers.

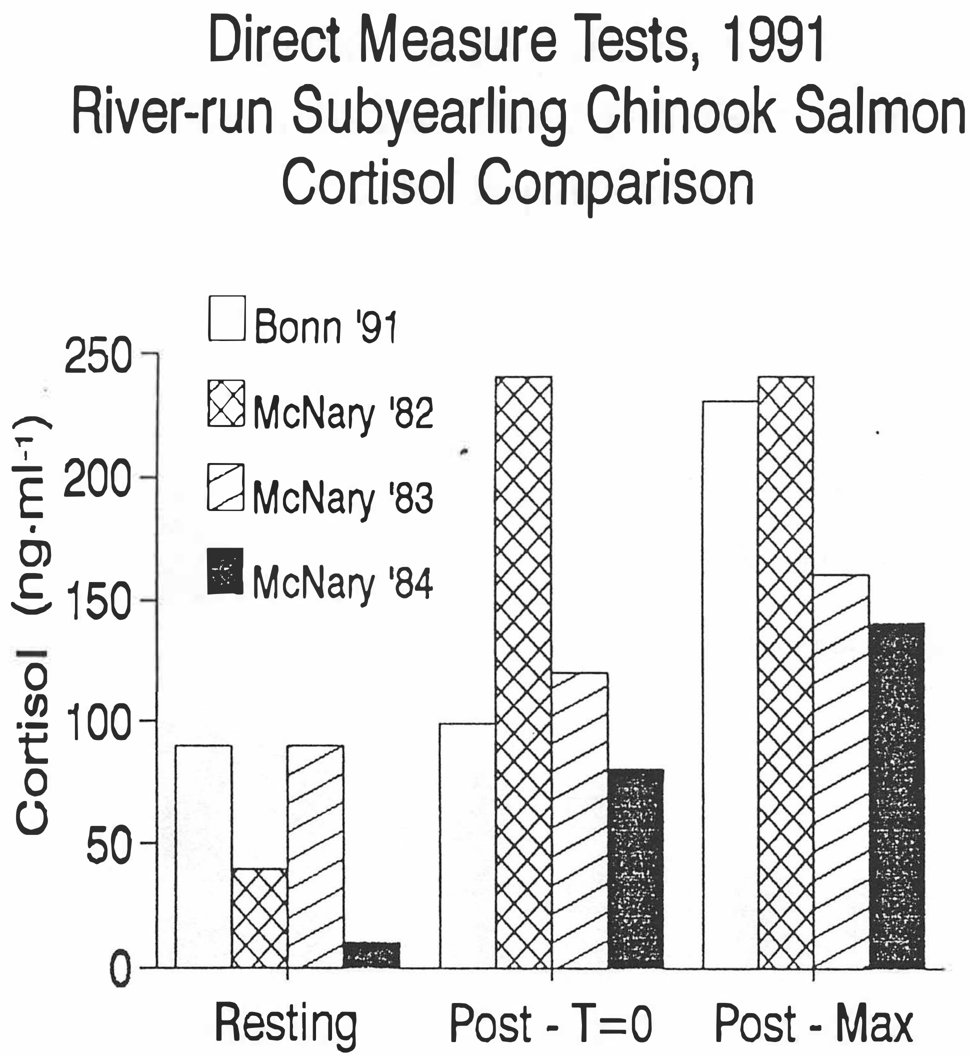

Figure 8. Cortisol levels of river-run subyearling chinook salmon after passage through the bypass system a Bonneville Dam Second Powerhouse compared with levels measured at other dams on the Snake and Columbia Rivers.

Fluctuating conditions which caused the intermittent problems during fish passage were not identifiable during the conduct of the experiments, although distance of passage through the system generally corresponded with increased descaling, injury, and mortality. Impacts to fish released at the mid-point of the bypass system were less, 2-40% mortality for subyearling chinook salmon and 0-19% mortality for subyearling coho salmon. We believe that all of the mortality was associated with impingement on the trap-net; however, the difference among groups is speculated to be a consequence of fatigue and/or stress associated with the rigors of passage through particular bypass segments.

Test Conditions that Affected Results

At initiation of the October tests, it became apparent that water velocity through the trap-net was changing substantially in conjunction with downwell water surface elevation. Water velocity measurements at the outlet of the conduit varied from 5.1 m/second at low downwell level (56.5 ft) to 6.6 m/second at high downwell level (58.5 ft). Surface water velocity at the downstream side of the net, 30 m from the outlet, varied from 0.5-0.8 m/second at low downwell levels to 0.9-1.4 m/second at high downwell levels.

Water velocity measured at the downstream side of the trap-net seemed unrelated to air entrainment. At high downwell levels, air entrainment could be almost eliminated by eliminating the water flow over the downwell overfall weir and replacing it with water from the supplemental supply valves. Thus, we were able to assess the water velocities with and without entrained air at high downwell levels. We found no substantial difference in water velocity at the two conditions; however, there was considerable variability. We found that substantial air entrainment occurred at all operational conditions when the downwell water surface was low, thus effects of air entrainment on velocity could not be assessed. Amount of entrained air seemed unaffected by the status (empty or full) of the fish sampling room conduit (Fig. 3); however, this assessment was only a visual comparison over time and small differences could not be differentiated.

Evaluation of Adverse Bypass Conditions

Variation of impacts from bypass passage observed in fall 1991 tests, created speculation that hydraulic conditions were changing associated with changes of water surface elevation in the downwell and air entrainment. Further study of the physical characteristics of the bypass system by NMFS biologists and engineers indicated two potential sources of hazard within the bypass discharge conduit: 1) entrained air may cause severe pressure fluctuations throughout the conduit, and 2) a short radius 1.2-m diameter 0.9-m radius 90° elbow at the bottom of the downwell may produce non-laminar flow and pressure conditions which might be detrimental to fish (Edward Meyer, unpublished report, NMFS, ETSD, Portland, OR 97232-2737, October 1991). During fish passage tests in 1987 through 1991, the downwell water level was controlled automatically (normal system operation). Downwell water level was recorded at the end of each test, but may not have properly represented the average level of each test. Theoretically, change of the downwell levels altered: 1) the severity of non-laminar flows and negative pressures presumed to be present at the inside of the 90° elbow at the bottom of the elbow, 2) the distance of plunge for water passing over the overfall weir into the downwell causing more or less air entrainment, and 3) the volume of air vented or introduced through the 0.5-m diameter conduit connected to the fish sampling room.

1992 Tests at Low Tailwater

Results of biological and physical tests conducted in 1991 suggested that additional fish passage tests at low tailwater elevations were necessary. In those tests several additional objectives were entertained to provide a clearer understanding of impacts related to physical aspects of the bypass system and to test the fish recovery process. Tests were conducted in October 1992 at tailwater elevations of 9.5 to 10.5 ft.

In general, all tests during 1992 showed progressively larger percentages of descaling and mortality (% detriment) in direct relation to the distance of passage through the bypass.

Passage Effects at High vs. Low Downwell Water Surface Elevation

The high water velocity in the trap-net at the high downwell level confounded interpretation of test results intended to evaluate high vs. low downwell water surface levels. Mortality and descaling occurred to large percentages of fish from all release groups captured in the trap-net during tests with a high downwell level (Table 5). We believe that the observed descaling and mortality were a direct result of impingement on the net and only relate to fatigue and stress of passage through the bypass system. We believe that comparison among replicates and among different tests should only be made in a relative fashion--proportional to the other groups in that replicate. With the configuration of the trap-net utilized, it appears impossible to assess differences in passage effects related to downwell level.

Effects from Suspected Negative Pressures in the Short Radius Elbow

Results from the eight tests conducted 13-16 October 1992 suggest no differences between fish groups released into the downwell (upstream and downstream of the short

Table 5. October 1992 tests using hatchery coho salmon to evaluate effects of the downwell water level and the 90° elbow at the bottom of the downwell; at tailwater elevation 9.5-10.5 ft and water temperature 16°C.

Date	Downwell surf.elev. (status)[b]	Percent detriment by release location[a]				Avg.water velocity (m/second)
		Coll.chan[c]	Downwell[d]	Conduit[e]	Net	
13	high	51	19	14	2	1.2[f]
14	high	49	35	22	13[g]	1.5[f]
15	high	66	24	33	10	1.1
16	high	39	12	17	12	1.2[f]
13	low	17	8	5	2	<0.9[f]
14	low	8	2	1	---	0.9[f]
15	low	3	1	2	1	0.7
16	low	2	0	0	0	<0.9[f]

[a] Detriment percentage--percent descaling of live fish plus percent mortality.

[b] High downwell elevations were 58.0 - 58.5 ft which is the highest possible water level. Low relates to the lowest of the portion of the elevation range normal to the automatic level control system 55.0 - 56.5 ft. Fish sampling room conduit was empty.

[c] Fish were released into the collection channel adjacent to Turbine Unit 17 located at the north end of the powerhouse; the release site used in all previous tests.

[d] A release site just upstream from the suspect elbow.

[e] Released through a 30-m hose ending just downstream from the 1.2 to 0.9 m-restriction.

[f] Estimated water velocity at the downstream side of the trap-net.

[g] Released at the surface adjacent to the downstream side of the trap-net where water velocity appears to be greatest. Normal site is on the south side in lower velocities.

radius 90° elbow) and groups released into the conduit (downstream from the 90° elbow). Differences in percentage of detriment for downwell groups and conduit groups (Table 5) were insignificant (P = 0.72).

Effects of Diminished Air Entrainment

To evaluate the effects of air entrainment, we conducted two tests at high downwell level comparing passage impacts under conditions of normal flow at the downwell overfall weir to that of no water flow over the downwell overflow weir (no overflow). Simultaneous release at both conditions was impossible, thus fish releases at "no overflow" conditions were conducted immediately prior to and after releases with the normal overflow conditions. Fish were released at the surface of the downwell.

Results of tests conducted on October 21 and 22 suggested no significant difference in percentage detriment between the two conditions (entrained air vs. no entrained air/overflow vs. "no overflow") (P = 0.98; Table 6). However, the results varied considerably in association with the duration of each test. Detriment to all groups increased with the number of minutes fish spent in the trap-net; those effects far out-weighed the effects of air entrainment.

In an attempt to decrease the time fish spent in the trap-net, three additional tests were conducted on October 23 comparing overflow to "no overflow." In those tests, the EGR was opened (stopping flow through the discharge conduit) 3 minutes after fish were released into the downwell (Table 6). Differences between overflow and "no flow" conditions were minimal although differences between the downwell released fish and net released fish were marginally significant (P = 0.14) at both conditions.

Table 6. October 1992 tests using hatchery fall chinook salmon to evaluate effects of air entrainment in the conduit at tailwater elevation 10-10.5 ft. Mechanisms evaluated were elimination of water flow over the end sill and occlusion of fish sampling room conduit.

Date	Downwell surf.elev. (status)[b]	Sample Rm. pipe (status)[c]	Percent detriment by release location[a] Collection channel 11 or 14[d]	Collection channel 17	Downwell Overflow[e]	Downwell No overflow[e]	Net
21	high	full	---	31	20	56[f]	6
22	high	full	---	89	81	17[g]	10
21	high	empty	---	33	26	74[f]	35[f]
22	high	empty	---	58	33	11[g]	12
23	high	full	---	---	---	7[g]	2
23	high	full	37	15	4	---	2
23	high	empty	---	---	---	7[g]	3

[a] Detriment percentage--percent descaling of live fish plus percent mortality.

[b] High downwell elevations were 58.0 - 58.5 ft which is the highest possible water level. Low relates to the lowest of the portion of the elevation range normal to the automatic level control system 55.0 - 56.5 ft.

[c] The downwell for the 0.5-m conduit extending from the sampling room to a mid-point Y in the 0.9-m bypass conduit was filled with water or empty (occluding or allowing possible air introduction to the bypass conduit).

[d] Fish were released into the collection channel adjacent to TurbineUnits 11, 14, and 17 located at the south end, middle, and north end of the powerhouse. The Unit 17 release point is the release site used in all previous tests.

[e] When water flowed over the end sill into the bypass system downwell (normal operation), air was entrained causing substantially increased boiling at the water surface of the outflow plume in the tailrace. Tests with no water flow over the end sill were conducted to evaluate the effects of air. The water volume and velocities were similar under both conditions.

[f] Released early--held in trap-net about 10 minutes longer than other groups.

[g] Released late--held in trap-net about 10 minutes less time than other groups.

Effects from Operation with Full vs. Empty Fish Sampling Room Conduit

We believed there may have been air entrainment in the bypass system occurring from the normally empty fish sampling room conduit which joins the bypass conduit about 105 m from the outlet. To test the relevance of this potential air entrainment, tests were conducted with the fish sampling room conduit empty of water (normal condition) in which air entrainment could occur, comparing these to tests with the fish sampling room conduit filled with water preventing any air introduction. Paired fish releases were made into various locations of the bypass system with full or empty sampling room conduit (Table 6). Although the combined data used for this comparison had a wide variation, the difference among paired tests showed that with otherwise similar conditions, no significant differences could be associated to the status of the sampling room conduit ($P = 0.55$). From inspection of the data, we believe that the wide range of detriment was associated with varying duration in the trap-net, and variation of downwell elevation.

Effects from Passage Through Particular Segments of the Collection Channel

In most tests, the greatest increase in detriment occurred between the north end of the collection channel at Turbine Unit 17 and the downwell (Fig. 3). This increased detriment ranged from 0.1 to 4 times that of downwell released fish (% detriment Unit 17 ÷ % detriment downwell; Table 7). The variability between tests is a result of variation in time spent in the trap-net and the difference in water velocity through the net. Direct comparisons between tests are inappropriate because of unequal times in the trap-net prior to system shutdown and net retrieval.

Results for fish releases at the middle and south end of the collection channel appear to suggest substantial detriment associated with passage through the channel; 1.4 to 3.2 times

Table 7. October 1992 tests using hatchery coho and chinook salmon to evaluate the effects of passage through the collection channel and energy dissipation area and dewatering screen; at tailwater elevation 9.5-10.5 ft and water temperature 15.2 to 16.5°C.

		Percent detriment by release location[a]					Detriment relationship among releases[b]				
	Dwnwll	Collection channel[c]									
Date	elev[d]	11 or 14	17	Downwell	Conduit	Net	11,14/17	17/Dw	Dw/Co	Dw/Nt	Co/Nt
13	low	---	17	8	5	2	---	2.1	1.6	4.0	2.5
14	low	---	8	2	1	---	---	4.0	2.0	---	---
15	low	---	3	1	2	1	---	3.0	0.5	1.0	2.0
16	low	---	2	0	0	0	---	---	---	---	---
20	low	27	19	8	---	2	1.4	2.4	---	4.0	---
13	high	---	51	19	14	2	---	2.7	1.4	9.5	7.0
14	high	---	49	35	22	13[e]	---	1.4	1.6	2.7	1.7
15	high	---	66	24	33	10	---	2.8	0.7	2.4	3.3
16	high	---	39	12	17	12	---	3.3	0.7	1.0	1.4
20	high	100	31	21	---	20[f]	3.2	1.5	---	1.1	---
21	high	---	31	20	---	6	---	1.6	---	3.3	---
21	high	---	---	74[f]	---	35[f]	---	---	---	2.1	---
21	high	---	33	26	---	---	---	1.3	---	0.7	---
22	high	---	89[f]	81[f]	---	10	---	1.1	---	8.1	---
22	high	---	58	33	---	12	---	1.8	---	2.8	---
23	high	37	15	4	---	2	---	2.5	---	2.0	---
23	high	---	---	7[g]	---	2	---	---	---	2.1	---
23	high	---	---	7[g]	---	3	---	---	---	2.3	---
						Average:	2.3	2.3	1.2	3.1	3.0

[a] Detriment percentage = percent descaling of live fish plus percent mortality.

[b] 11,14/17 = Unit 14 or Unit 11 detriment % / Unit 17 detriment %; 17/Dw = Unit 17 detriment % / downwell detriment %. Dw/Co = Downwell detriment % / Conduit detriment %; Dw/Nt = Downwell detriment % / net detriment %. Co/Nt = Conduit detriment % / Net detriment %.

[c] Fish were released into the collection channel adjacent to Turbine Units 11, 14, and 17 located at the south end, middle, and north end of the powerhouse. The Unit 17 release point is the release site used in all previous tests.

[d] High downwell elevations were 58.0 - 58.5 ft which is the highest possible water level. Low relates to the lowest of the portion of the elevation range normal to the automatic level control system 55.0 - 56.5 ft.

[e] Released at the water surface of the downstream side of the trap-net into high velocity water.

[f] Released early--held in trap-net about 10 minutes longer than other fish groups.

[g] Released late--held in trap-net about 10 minutes less time than other fish groups.

greater descaling plus mortality for releases at the south end of the collection channel at Unit 11 than for releases at the north end at Unit 17 (Table 7). Test fish releases at the south end of the collection channel traveled the full length of the dam. Consequently, they spent a much longer time in passage to the exit; also, the fastest moving fish may have resided in the trap-net longer than fish released elsewhere. Level of detriment caused to the fish in the trap-net was directly related to the elapsed time between entry into the net and the opening of the ERG.

Tests conducted at low downwell level (i.e., lower water velocity through the trap-net) produced less descaling and mortality than tests at high downwell with water flow over the overfall weir. However, the same relationship of greater detriment for longer passage prevailed. The energy dissipation and dewatering section of the bypass system (Fig. 3) consistently produced a substantial increase of detrimental effects (% detriment Unit 17 ÷ % detriment Downwell; Table 7).

Injuries Observed During Bypass Passage Tests

Percentages of injury, other than descaling and mortality, which were attributable to passage through the bypass system ranged from 0 to 7 % (test fish injury % - control fish injury %) and averaged 0.9% for all tests (Table 8; Appendix Tables 2-10 and 13-14). The injuries identified were typical of those described by other authors (Oligher and Donaldson 1966, Groves 1972, Johnson 1976) induced by shear, high velocity impact, and negative pressures--head and eye abrasion, hemorrhaging, and damage to the isthmus and opercula. However, the injuries were generally slight and in most instances did not represent a direct threat to survival. Delayed mortality (48 hours) for injured and descaled fish was generally

Table 8. Direct assessment of injury among juvenile salmonids passing through the bypass system at Bonneville Dam Second Powerhouse, 1991 and 1992.

Recovery information[b]		Injury information[a]										Total	
		Eye/Head		Hemorrhage		Isthmus damage		Laceration		Opercle damage			
Treatment	no.	no.	%	no.	%	no.	%	no.	%	no.	%	no.	%
1991 tests													
Bypass[c]	14,748	46	0.31	53	0.36	3	0.02	17	0.11	20	0.14	139	0.94
Control[d]	18,502	12	0.06	7	0.04	3	0.02	9	0.05	5	0.03	36	0.19
1992 tests													
Bypass	12,765	110	0.90	37	0.29	2	0.02	15	0.12	18	0.14	182	1.42
Control	4,211	20	0.47	3	0.07	0	0.00	0	0.00	5	0.12	28	0.66
Combined total (1991, 1992)													
Bypass	27,513	156	0.57	90	0.33	5	0.02	32	0.12	38	0.14	321	1.16
Control	22,713	32	0.14	10	0.04	3	0.01	9	0.04	10	0.04	64	0.28

[a] Descaling injury has been evaluated separately.
[b] Represents the number of test fish recovered after release.
[c] Represents all bypass system releases combined.
[d] Includes both egress hose releases and surface net releases.

high, but there was no difference between treatment and control fish. Injuries were rather inconsequential in comparison to descaling and mortality.

Descaled fish appeared to be slightly larger and mortalities slightly smaller than the average size of both chinook and coho salmon release populations (October 1992 tests) (Table 9). We hypothesize that the fish initially contacting the trap-net were of similar size to those released, but those freeing themselves from the net were the larger fish and sustained descaling in the process, while those remaining impinged were smaller than the average fish and were unable to break free of the net.

DISCUSSION

In 1992, water clarity improved from that of all previous tests and impinged fish were observed on webbing panels in the trap-net. The impingement appeared to increase at the highest water velocities (1.1 to 1.5 m/second at the downstream edge of the net) associated with low tailwater elevation and high downwell elevation (greater hydrostatic head within the bypass discharge conduit). This helped frame our conclusion that stress and fatigue caused during passage through the bypass system was directly related to physical trauma observed in tests with river-run salmonids and in low tailwater tests. The differences of stress and fatigue between various treatment and control groups were manifested by differences of descaling and mortality. We believe that the extent of descaling and mortality provides a relative index to the degree of stress and fatigue generated during passage through various sections of the bypass at the various flow conditions tested. Fatigue and stress appear to substantially increase with the distance of migration through the collection channel. However, the greatest increase occurred between the north end of

Table 9. Fork length of fish released compared to descaled and dead fish recovered from the trap-net; October 1992 tests.

Group[a]	Descaled Sample no.	Descaled Mean fork length mm	Mortalities Sample no.	Mortalities Mean fork length mm
		Coho salmon tests		
Test population; n = 200, mean fork length = 110.7 mm				
Bypass system	1,490	111.7	430	107.4
Control	168	115.3	62	105.5
		Chinook salmon tests		
Test population; n = 200, mean fork length = 132.1 mm				
Bypass system	194	135.8	899	130.3
Control	48	136.5	113	127.5

[a] Includes fish released at all locations within the bypass system.

the collection channel at Turbine Unit 17 and the downwell (Fig. 3). Within that section of the bypass, there is 46 m of collection channel where the downstream velocity is greater than 0.6 m/second, a control weir, an energy dissipation area of about 15 m with heavy turbulence, and a dewatering screen 17 m long with screened area of about 72 m^2 where velocities were about 1 m/second.

CONCLUSIONS

1) The trap-net did not provide sufficient sanctuary to subyearling salmon to allow benign recovery of test fish at moderate and low tailwater elevations. The maximum flow of the 0.9-m diameter bypass conduit (6 to 6.6 m/second) and direction of flow caused excessive water velocity at the downstream edge of the net (1.1 to 1.5 m/second). We believe that the size of the net was about maximum for hauling by hand, and that it would be necessary to substantially increase the size to eliminate impingement of subyearlings at moderate and low tailwater conditions.
2) Bypass passage appears to cause significant stress. However, loss of scales and direct mortality observed in 1991 tests were ascribed to problems associated with the recovery of test fish and not to bypass conditions. During summertime low river flows, the resulting low tailwater elevations appear to substantially increase flow velocity and therefore the negative effects of net recovery.
3) Based on differences of descaling and mortality among test fish groups released at different locations in the bypass system, we speculate that fatigue and stress increased with increased distance of passage.

4) Based on eight tests in October 1992, we assume that the effects of passage through the 90° short radius elbow at the bottom of the downwell were not substantial.

5) Based on 17 tests in October 1992, we assume that air entrainment in the effluent of the bypass conduit is a result of air entrapment in the downwell regardless of the water surface elevation. With the present bypass system design, air entrainment could not be eliminated in normal operation of the system. Although documentation is poor, air entrainment apparently caused no substantial impairment to the test fish.

6) Effects of high vs. low downwell elevation could not be assessed because of the water velocity change in the trap-net. Other methods of recovery must be employed to make that assessment.

7) From visual assessment of air volume in the bypass effluent, we concluded that there was no effect from a full or empty sampling room discharge pipe. Also, there appeared to be no effect of full or empty sampling room discharge pipe on fish.

8) It is probable that reduced survival of test fish bypassed through the Bonneville Dam Second Powerhouse in the summers of 1987-1990 resulted from both physical impacts of passage through the bypass discharge conduit and predation during migration through the tailrace. Physical problems within the bypass conduit will be remedied in so far as possible, but since the conduit is 287 m long, mostly 0.9-m diameter, and partially submerged, it may be difficult to identify and correct all problem areas. However, the inherent impact from predation following egress from the system cannot easily be remedied. Predation may be an insurmountable problem as a result of 1) increased stress from passage causing diminished avoidance reactions [laboratory studies showed that severe stress or severe turbulence caused loss of equilibrium and abnormal avoidance

behavior (Groves 1972, Sigismondi and Weber 1988, Olla and Davis 1992)]; 2) point source release from the bypass inducing predators to congregate; 3) migration through the low velocity tailrace basin providing a large area of suitable habitat for northern pikeminnow; and 4) a bypass outlet location on the north side of a tailrace that angles to the south about 90°, tending to direct outmigrants shoreward toward rip-rap areas that are prime habitat for northern pikeminnow.

9) From CWT passage survival tests conducted from 1987 to 1990, estimated survival for test fish released 2.5 km downstream from the dam was significantly higher than for fish released into the bypass system. The physical conditions at the downstream release location that most likely produced the increase were 1) high water velocity--1.5 to 2.1 m/sec; 2) long distance from shore--about 100 m; 3) rapid downstream dispersal of fish resulting in decreased juvenile salmon density in the migration route and increased time for orientation prior to encountering predators; 4) release in a reach of river where current direction was parallel to the shoreline; 5) lack of predator attraction from a continuous egress of juvenile salmon at a single location or along a localized migration route; and 6) nighttime releases which minimized avian predation.

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APPENDICES

Appendix Table 1. Statistical assessment of stress related blood serum parameters of hatchery reared subyearling chinook salmon after passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 13.5-17.5 ft and water temperature 10.6-11.7°C.

Methods

Cortisol, glucose and lactate levels were measured from samples of about size ten on each of four days (two days for lactate) for three treatments (bypass, egress and net) at seven times (pre-experiment, hour 0 post-experiment, hour 2, hour 4, hour 6, hour 18 and hour 42). Also, one day of hour 66 was measured but I ignored this in the analyses. All analyses were done on the mean of each sample for each day/treatment/time combination as experimental replication was done at the "day level" not at the "fish level."

Treatment and time comparisons were done using two-way ANOVA and Fisher's Protected Least Significant Difference (FPLSD) procedures. A significant treatment by time interaction term in the ANOVA would indicate the cortisol (or glucose or lactate) level response curve over time was different for different treatments. A significant treatment effect would indicate that the time response curves for at least one of the treatments was shifted higher or lower than for the others. A significant time effect would indicate that at least one of the measured times had a higher or lower level than did the others.

Appendix Table 1. Continued.

Plasma Cortisol

	Pre	Hour 0.5	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Bypass	3.6	120.5	102.6	76.7	70.9	71.2	56.6
Egress	14.7	140.2	123.5	64.7	72.2	92.5	70.6
Net	20.7	72.1	94.6	68.5	56.3	69.1	65.9

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	2	6679.9	3339.9	5.0	0.0095
Time	6	75485.8	12581.0	18.9	<.0001
Tr X Ti	12	10190.4	849.2	1.3	0.2553
Error	63	41942.4	665.8		
Total	83	134298.4			

Means

Treatment	Mean
Net	63.9[a]
Bypass	71.7[ab]
Egress	85.5[b]

Time	Mean
Pre	13.0[a]
Hour 42	64.4[b]
Hour 4	70.0[b]
Hour 6	73.1[b]
Hour 18	77.6[b]
Hour 2	106.9[c]
Hour 0	110.9[c]

Appendix Table 1. Continued.

Plasma Glucose

	Pre	Hour 0.5	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Bypass	55.2	85.3	87.5	86.5	81.2	79.7	77.2
Egress	57.5	79.8	90.9	79.4	81.3	91.6	84.2
Net	53.4	80.5	82.5	72.8	71.3	73.4	66.7

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	2	1314.5	657.3	6.2	0.0036
Time	6	7435.2	1239.2	11.6	<.0001
Tr X Ti	12	867.1	72.3	0.7	0.7668
Error	63	6723.5	106.7		
Total	83	16340.3			

Means

Treatment	Mean
Net	71.5^{a}
Bypass	78.9^{b}
Egress	80.7^{b}

Time	Mean
Pre	55.4^{a}
Hour 42	76.0^{b}
Hour 6	77.9^{b}
Hour 4	79.6^{bc}
Hour 18	81.6^{bc}
Hour 0	81.9^{bc}
Hour 2	87.0^{c}

Appendix Table 1. Continued.

Plasma Lactic Acid

	Pre	Hour 0.5	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Bypass	21.6	79.8	44.5	29.6	24.5	24.1	24.0
Egress	23.3	81.0	51.3	34.5	26.1	18.4	24.2
Net	21.6	51.0	34.1	29.3	28.5	19.1	24.0

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	2	416.5	208.3	1.8	0.1844
Time	6	11467.8	1911.3	16.8	<.0001
Tr X Ti	12	1128.6	94.0	0.8	0.6224
Error	63	2384.0	113.5		
Total	83	15396.8			

Means

Treatment	Mean
Net	29.6
Bypass	35.4
Egress	37.0

Time	Mean
Hour 18	20.5[a]
Pre	22.1[a]
Hour 42	24.1[a]
Hour 6	26.3[a]
Hour 4	31.1[ab]
Hour 2	43.3[b]
Hour 0	70.6[c]

Appendix Table 2. Direct assessment of descaling, injury, and mortality among hatchery reared yearling chinook salmon[a] passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 17 ft and water temperature 5.5 °C.

Release information[c]			Recovery information[b]					Delayed mortality[e]
			Catch		Descaled	Injured[d]	Dead	
Date	Site	No.	No.	%	%	%	%	%
28 Mar	By	600	578	96.3	1.4	0.9	0.7	0.0
	Eg	600	541	90.2	0.2	0.0	0.0	0.0
	Nt	600	619	103.2	0.2	0.0	0.0	0.0
28 Mar	By	600	547	91.2	2.2	0.4	1.1	0.0
	Eg	600	528	88.0	0.2	0.0	0.4	0.0
	Nt	600	598	99.7	0.8	0.0	0.0	0.0
29 Mar	By	600	610	101.7	0.5	0.2	0.3	0.0
	By--killed	300	296	98.7				
	Eg	600	592	98.7	0.3	0.0	0.0	0.0
	Nt	600	531	88.5	0.0	0.2	0.4	0.0
29 Mar	By	600	608	101.3	0.2	0.0	0.0	0.9
	By--killed	300	288	96.0				
	Eg	600	539	89.8	0.4	0.0	0.0	0.0
	Nt	600	604	100.7	0.8	0.2	0.2	0.8
Total/Mean(SE)								
	By	2,400	2,343	97.6(2.5)	1.1(0.5)	0.4(0.2)	0.5(0.2)	0.2(0.2)
	By--killed	600	584	97.4(1.0)				
	Eg	2,400	2,200	91.7(2.4)	0.3(0.1)	0.0(0.0)	0.1(0.1)	0.0
	Nt	2,400	2,352	98.0(3.0)	0.5(0.2)	0.1(0.1)	0.2(0.1)	0.2(0.2)

[a] Yearling spring chinook salmon obtained from Lookingglass Hatchery (Oregon Department of Fish and Wildlife) mean fork length 126 mm.

[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.

[c] Site codes are By = 10 m upstream from the downwell, Eg = egress hose release, Nt = surface release into recovery net.

[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.

[e] All injured and descaled and approximately 100 healthy fish from each release site were held 48 hours for assessment of delayed mortality.

Appendix Table 3. Direct assessment of descaling, injury, and mortality among hatchery reared juvenile steelhead[a] passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 15.5-16.9 ft and water temperature 6.0°C.

Release information[c]			Recovery information[b]					
			Catch		Descaled	Injured[d]	Dead	Delayed mortality[e]
Date	Site	No.	No.	%	%	%	%	%
2 Apr	By	400	169	42.3	0.6	0.6	0.0	0.0
	By--killed	300	282	94.0				
	Nt	400	399	99.8	0.0	0.8	0.0	0.0
2 Apr	By	400	232	58.0	0.0	0.0	0.0	0.0
	Nt	400	412	103.0	0.5	0.7	0.0	0.0
4 Apr	By	400	405	101.3[f]	0.0	0.2	0.2	0.0
	By--killed	300	288	96.0				
	Nt	400	474	118.5	0.0	0.0	0.0	0.0
4 Apr	By	400	392	98.0[f]	0.0	0.5	0.0	0.0
	Nt	400	340	85.0	0.0	0.3	0.0	0.0
Total/Mean(SE)								
	By	1,600	1,198	74.9[f](7.3)	0.2(0.2)	0.3(0.1)	0.1(0.1)	0.0
	By--killed	600	570	95.0(1.0)				
	Nt	1,600	1,625	101.6(3.4)	0.1(0.1)	0.4(0.2)	0.0(0.0)	0.0

[a] Juvenile steelhead obtained from Irrigon Hatchery (Oregon Department of Fish and Wildlife) mean fork length 193 mm.

[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.

[c] Site codes are By = 10 m upstream from the downwell, Eg = egress hose release, Nt = surface release into recovery net.

[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.

[e] All injured and descaled and approximately 100 healthy fish from each release site were held 48 hours for assessment of delayed mortality.

[f] Because fish were delaying in the bypass channel, releases made on 4 April were made directly into the discharge conduit.

Appendix Table 4. Direct assessment of descaling, injury, and mortality among hatchery reared juvenile coho salmon[a] passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 17.5-18 ft and water temperature 6.5-7°C.

Release information[c]			Recovery information[b]					Delayed mortality[e]
			Catch		Descaled	Injured[d]	Dead	
Date	Site	No.	No.	%	%	%	%	%
11 Apr	By	600	584	97.3	2.4	0.5	0.2	0.0
	Eg	600	539	89.8	2.0	0.4	0.0	0.0
	Nt	600	598	99.7	0.3	0.0	0.2	0.0
11 Apr	By	600	613	102.2	2.9	0.2	0.3	0.0
	Eg	600	561	93.5	1.6	0.4	0.2	0.0
	Nt	600	594	99.0	1.0	0.2	0.5	0.0
12 Apr	By	600	611	101.8	3.6	0.8	0.0	0.0
	By--killed	225	215	95.6				
	Eg	600	576	96.0	1.2	0.3	0.2	2.0
	Nt	600	605	100.8	0.3	0.8	0.0	0.0
12 Apr	By	600	582	97.0	2.2	0.3	0.2	0.0
	By--killed	300	291	97.0				
	Eg	600	544	90.7	2.4	0.2	0.0	1.0
	Nt	600	574	95.7	0.9	0.5	0.0	0.0
Total/Mean(SE)								
	By	2,400	2,390	99.6(1.4)	3.0(0.3)	0.6(0.1)	0.2(0.1)	0.0
	By--killed	525	506	96.3(0.7)				
	Eg	2,400	2,200	92.5(1.4)	1.9(0.2)	0.3(0.1)	0.1(0.1)	0.8(0.5)
	Nt	2,400	2,371	98.8(1.1)	0.8(0.3)	0.5(0.1)	0.2(0.1)	0.0

[a] Yearling coho salmon obtained from Bonneville Hatchery (Oregon Department of Fish and Wildlife) mean fork length 133 mm.
[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.
[c] Site codes are By = bypass entrance release, Eg = egress hose release, Nt = surface release into recovery net.
[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.
[e] All injured and descaled and approximately 100 healthy fish from each release site were held 48 hours for assessment of delayed mortality.

Appendix Table 5. Direct assessment of descaling, injury, and mortality among river-run yearling coho salmon[a] passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 19.5 ft and water temperature 9.0°C.

Release information[c]			Recovery information[b]					Delayed mortality[e]
			Catch		Descaled	Injured[d]	Dead	
Date	Site	No.	No.	%	%	%	%	%
1 May	By	400	400	100.0	12.3	1.0	0.3	1.0
	By--killed	300	300	100.0				
	Nt	174	173	99.4	1.2	0.0	0.6	0.0
2 May	By	397	350	88.2	4.6	0.6	0.0	0.0
	Nt	0						
Total/Mean(SE)								
	By	797	750	94.1(5.9)	8.5(3.9)	1.2(0.6)	0.2(0.2)	0.5(0.5)
	By--killed	300	300	100.0				
	Nt	174	173	99.4	1.2	0.6	0.6	0.0

[a] Yearling coho salmon obtained from the Columbia River at Bonneville Dam. Mean fork length was 137 mm.

[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.

[c] Site codes are By = 10 m upstream from the downwell and Nt = surface release into recovery net. Previous series of tests indicated no differences between net released and egress (Eg) released fish; to decrease the number necessary for tests, the egress release was not used.

[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.

[e] All injured and descaled and approximately 100 healthy fish from each release site were held 48 hours for assessment of delayed mortality.

Appendix Table 6. Direct assessment of descaling, injury, and mortality among river-run yearling chinook salmon[a] passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 19.5 ft. and water temperature 9°C.

Release information[c]			Recovery information[b]					Delayed mortality[e]
			Catch		Descaled	Injured[d]	Dead	
Date	Site	No.	No.	%	%	%	%	%
1 May	By	381	379	99.5	13.0	0.4	0.8	0.1
	By--killed[f]	150	150	100.0				
	Nt	487	488	100.2	0.2	0.9	0.9	0.0
2 May	By	387	364	94.1	4.9	0.4	0.0	5.4
	By--killed[f]	150	150	100.0				
	Nt	387	371	95.9	0.4	0.0	0.0	1.0
7 May	By	472	402	85.2	18.0	0.8	1.1	0.0
	Nt	486	474	97.5	0.3	0.0	0.6	0.0
7 May	By	474	426	89.9	10.6	0.4	0.4	0.0
	Nt	459	233	50.8	0.4	0.7	0.0	1.0
Total/Mean(SE)								
	By	1,714	1,571	92.2(3.0)	11.6(2.7)	0.5(0.1)	0.6(0.2)	1.4(1.3)
	By--killed[f]	300	300	100.0				
	Nt	1,819	1,566	86.1(11.8)	0.3(0.0)	0.4(0.2)	0.4(0.2)	0.5(0.3)

[a] Yearling spring/summer chinook salmon obtained from the Columbia River at McNary Dam. Mean fork length for test dates 1 and 2 May was 167 mm and for 7 May was 151 mm.

[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number. About 100 fish from each treatment were removed and examined for stress. These fish were not used in the descaling and injury evaluations.

[c] Site codes are By = 10 m upstream from the downwell and Nt = surface release into recovery net. Previous series of tests indicated no differences between net released and egress (Eg) released fish; to decrease the number of fish necessary for tests, the egress release was not used.

[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.

[e] All injured and descaled and approximately 100 healthy fish from each release site were held 48 hours for assessment of delayed mortality.

[f] Heavily sedated and killed hatchery reared coho salmon were used as surrogates for moribund chinook to evaluate their recovery rates.

Appendix Table 7. Direct assessment of descaling, injury, and mortality among hatchery reared subyearling chinook salmon[a] passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 19.5 ft and water temperature 18.3 °C.

Release information[c]			Recovery information[b]						
			Catch		Descaled	Injured[d]	Dead	Delayed mortality[e]
Date	Site	No.	No.	%	%	%	%	%
10 July	By channel	400	319	79.8	2.2	0.3	11.9	6.8
	By conduit	400	351	87.8	1.4	0.3	5.1	3.5
	By--killed	399	340	85.2				
	Eg	400	313	78.3	1.3	0.0	4.1	1.1
	Nt	400	393	98.3	1.3	0.0	0.8	1.8
10 July	By channel	400	362	90.5	1.9	0.0	3.3	4.2
	By conduit	400	351	87.8	2.6	0.6	2.6	5.3
	By--killed	400	400	100.0				
	Eg	399	365	91.3	0.5	0.0	0.5	3.0
	Nt	400	329	82.3	0.0	0.0	1.2	1.0
11 July	By channel	399	296	74.2	3.4	0.3	4.0	3.0
	By conduit	399	353	88.5	3.7	0.3	3.7	3.5
	By--killed	400	378	94.5				
	Eg	382	280	73.3	1.4	0.4	1.8	1.2
	Nt	400	341	85.3	0.3	0.0	0.0	1.1
11 July	By channel	400	375	93.8	4.5	0.3	3.2	7.6
	By conduit	400	318	79.5	2.5	0.0	0.6	4.0
	By--killed	400	388	97.0				
	Eg	399	350	87.7	3.1	0.3	1.1	0.0
	Nt	400	304	76.0	0.0	0.0	0.0	0.9
Total/Mean(SE)								
	By channel	1,599	1,352	84.6(4.6)	3.0(0.6)	0.2(0.1)	5.6(2.1)	5.4(1.1)
	By conduit	1,599	1,373	85.9(2.1)	2.6(0.5)	0.3(0.1)	3.0(0.9)	4.1(0.4)
	By--killed	1,599	15,06	94.2(3.2)				
	Eg	1,580	1,308	82.6(4.2)	1.6(0.5)	0.2(0.1)	1.9(0.8)	1.3(0.6)
	Nt	1,600	1,367	85.5(4.7)	0.4(0.3)	0.0	0.5(0.3)	1.2(0.2)

[a] Subyearling upriver bright fall chinook salmon obtained from Bonneville Hatchery (Oregon Department of Fish and Wildlife) mean fork length 84.9 mm.

[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.

[c] Site codes are By channel = about 10 m upstream from the downwell; By conduit = about 20 m downstream from the downwell; By--killed = fish intentionally killed and released 10 m upstream from the downwell; Eg = egress hose; Nt = surface release into recovery net.

[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.

[e] All injured and descaled and approximately 100 healthy fish from each release site were held 48 hours for assessment of delayed mortality.

Appendix Table 8. Direct assessment of descaling, injury, and mortality among river-run subyearling chinook salmon[a] passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 15-18.5 ft and water temperature 18.9°C.

Release information[c]			Recovery information[b]						
			Catch		Descaled	Injured[d]	Dead	Delayed mortality[e]
Date	Site	No.	No.	%	%	%	%	%
16 July	By	376	313	83.2	25.2	1.6	4.9	8.1
	Nt	345	315	91.3	2.3	0.0	1.6	2.0
16 July	By	330	238	72.1	35.1	7.0	1.7	10.8
	By--killed	798	757	94.9				
	Nt	329	316	96.0	0.9	0.9	0.0	7.5
17 July	By	319	317	99.4	22.9	4.8	1.2	11.0
	Nt	321	316	98.4	2.2	0.0	0.0	1.1
17 July	By	323	275	85.1	31.2	1.6	2.4	1.0
	By--killed	400	363	90.1				
	Nt	372	345	92.7	0.0	0.0	0.0	1.0
Total/Mean(SE)								
	By	1,348	1,143	84.9(5.6)	28.6(2.9)	3.8(1.3)	2.4(0.9)	7.7(2.3)
	By--killed	1,198	1,120	92.5(2.4)				
	Nt	1,367	1,292	94.6(1.6)	1.4(0.6)	0.2(0.2)	1.2(0.8)	2.8(1.5)

[a] Subyearling fall chinook salmon obtained from the Columbia River at Bonneville Dam. Mean fork length was 99.5 mm.

[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.

[c] Site codes are By = release into gallery 10 m upstream of overfall weir and downwell; By conduit = about 20 m downstream from downwell; By--killed = fish intentionally killed and released 10 m upstream from the downwell; Nt = surface release into recovery net.

[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.

[e] All injured and descaled and approximately 100 healthy fish from each release site were held 48 hours for assessment of delayed mortality.

Appendix Table 9. Direct assessment of descaling, injury, and mortality among hatchery reared subyearling chinook salmon[a] passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 9-10.5 ft and water temperature 21.1°C.

Release information[c]			Recovery information[b]					Delayed mortality[e]
			Catch		Descaled	Injured[d]	Dead	
Date	Site	No.	No.	%	%	%	%	%
3 Sept	By channel	374	323	86.4	3.7	0.0	6.5	5.2
	By conduit	394	341	86.5	1.5	1.2	2.3	1.1
	By--killed	400	386	96.9				
	Eg	370	252	68.1	2.4	0.0	0.4	0.0
	Nt	393	381	96.9	0.0	0.0	0.3	1.9
4 Sept	By channel	378	373	98.7	3.2	1.3	7.0	6.3
	By conduit	375	355	94.7	2.2	0.6	3.4	0.0
	By--killed	395	328	83.0				
	Eg	383	282	73.6	3.2	0.7	0.4	2.1
	Nt	421	414	98.3	0.2	0.7	0.5	3.9
5 Sept[f]	By channel	366	315	86.1	10.0	0.6	49.2	1.0
	By conduit	381	336	88.2	8.9	0.0	23.2	0.0
	By--killed	400	391	97.8				
	Eg	389	316	81.2	2.4	0.0	6.3	1.0
	Nt	380	386	101.6	0.3	0.0	0.8	2.0
5 Sept[f]	By channel	394	362	91.9	9.0	1.1	51.1	4.2
	By conduit	378	385	101.9	4.3	0.0	39.5	2.9
	By--killed	400	411	102.8				
	Eg	362	281	77.6	0.4	0.0	12.1	0.0
	Nt	385	385	100.0	0.0	0.0	4.2	2.0
Total/Mean(SE)								
	By channel	1,512	1,373	90.8(3.0)	6.5(1.8)	0.8(0.3)	28.5(12.5)	4.2(1.1)
	By conduit	1,528	1,417	92.8(3.5)	4.2(1.7)	0.5(0.3)	17.1(8.9)	1.0(0.7)
	By--killed	1,595	1,516	95.0(4.2)				
	Eg	1,504	1,131	75.1(2.8)	2.1(0.6)	0.2(0.2)	4.8(2.8)	0.8(0.5)
	Nt	1,579	1,566	99.2(1.0)	0.1(0.1)	0.2(0.2)	1.5(0.9)	2.5(0.5)

[a] Subyearling upriver bright stock fall chinook salmon obtained from Bonneville Hatchery (Oregon Department of Fish and Wildlife); mean fork length 116 mm.

[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.

[c] Site codes are By channel = 10 m upstream from the downwell; Bypass conduit = about 20 m downstream from downwell; Eg = egress hose release; Nt = surface release into recovery net.

[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.

[e] About 100 healthy fish from each release were held for 48-hour delayed mortality.

[f] Descale and injury percentages for 5 September tests were calculated using the total number recovered less mortality.

Appendix Table 10. Direct assessment of descaling, injury, and mortality among hatchery reared subyearling coho salmon[a] passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 9 - 9.5 ft and water temperature 16.5 °C.

Release information[c]			Recovery information[b]					Delayed mortality[e]
			Catch		Descaled	Injured[d]	Dead	
Date	Site	No.	No.	%	%	%	%	%
22 Oct	By channel	386	332	86.0	0.3	0.0	0.0	0.0
	By conduit	400	343	85.7	0.6	0.3	0.0	0.0
	Nt	400	382	95.5	0.3	0.3	0.0	0.0
23 Oct	By channel	400	232	58.0	1.3	0.4	31.5	1.0
	By conduit	400	277	69.3	1.1	0.0	19.4	0.0
	Nt	400	388	97.0	0.0	0.0	1.3	0.0
24 Oct	By channel	400	324	81.0	1.8	0.3	1.8	2.2
	By conduit	400	351	87.8	0.6	0.0	2.3	0.0
	Nt	400	372	93.0	0.3	0.0	1.3	0.0
25 Oct	By channel	400	378	94.5	0.0	0.3	0.8	0.0
	By conduit	400	391	97.7	0.3	0.0	0.3	0.0
	Nt	399	401	100.0	0.0	0.0	0.0	0.0
Total/Mean(SE)								
	By channel	1,586	1,266	79.9(6.8)	0.9(0.4)	0.3(0.1)	8.5(6.6)	0.8(0.5)
	By conduit	1,600	1,362	85.1(5.1)	0.7(0.1)	0.1(0.1)	5.5(4.1)	0.0(—)
	Nt	1,599	1,543	96.3(1.2)	0.2(0.1)	0.1(0.1)	0.7(0.3)	0.0(—)

[a] Subyearling coho salmon obtained from Cascade Hatchery (Oregon Department of Fish and Wildlife) mean fork length 125 mm.
[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.
[c] Site codes are By channel = upstream from weir; By conduit = about 20 m downstream from downwell; Nt = surface release into recovery net.
[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.
[e] All injured and descaled and approximately 100 healthy fish from each release site were held 48 hours for assessment of delayed mortality.

Appendix Table 11. Statistical assessment of stress related blood serum parameters of river-run yearling chinook salmon after passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 19.5 ft and water temperature 9°C.

Methods

Cortisol, glucose and lactic acid levels were measured from samples of chinook salmon of about size twelve on one day for two treatments (acute and chronic) at six times (hour 0, hour 2, hour 4, hour 6, hour 18 and hour 42). Since there was no replication, all analyses had to be done using only fish-to-fish sampling variation.

Cortisol, glucose and lactic acid levels were also measured from samples of about size twelve on each of four days for two treatments (bypass and net) at seven times (pre-experiment, hour 0 post-experiment, hour 2, hour 4, hour 6, hour 18 and hour 42). All analyses were done on the mean of each sample for each day/treatment/time combination as experimental replication was done at the "day level" not at the "fish level."

Treatment and time comparisons for both experiments were done using two-way ANOVA and Fisher's Protected Least Significant Difference (FPLSD) procedures (Petersen 1985). A significant treatment by time interaction term in the ANOVA would indicate the cortisol (or glucose or lactate) level response curve over time was different for different treatments. A significant treatment effect would indicate that the time response curves for one of the treatments was shifted higher or lower than for the others. A significant time effect would indicate that at least one of the measured times had a higher or lower level than did the others. If a significant interaction was detected, treatment and time effects would not be analyzed.

Appendix Table 11. Continued.

Plasma Cortisol

	Pre	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Bypass	59.7	122.3	210.2	265.2	255.0	106.1	74.4
Net	58.2	66.9	174.4	196.9	192.4	67.3	63.0

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	1	21422.5	21422.5	23.8	<0.0001
Time	6	276122.4	46020.4	51.1	<0.0001
Tr X Ti	6	7726.6	1287.8	1.4	0.2258
Error	42	37799.6	900.0		
Total	55	343071.6			

Means

Treatment	Mean
Net	117.0[a]
Bypass	156.1 [b]

Time	Mean
Pre	58.9[a]
Hour 42	68.9[ab]
Hour 18	86.7[ab]
Hour 0	94.6 [b]
Hour 2	192.3 [c]
Hour 6	223.7 [d]
Hour 4	231.1 [d]

	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Acute	68.9	247.0	256.0	239.0	56.2	23.8
Chronic	55.1	242.8	320.1	298.5	383.8	329.0

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	1	403004.4	403044.4	100.3	<0.0001
Time	5	875828.0	175165.6	43.6	<0.0001
Tr X Ti	5	616688.8	123337.8	30.7	<0.0001
Error	125	502160.3	4017.3		
Total	136	2461250.7			

Acute	Mean
Hour 42	23.8[a]
Hour 18	56.2[a]
Hour 0	68.9[a]
Hour 6	239.0 [b]
Hour 2	247.0 [b]
Hour 4	256.0 [b]

Chronic	Mean
Hour 0	55.1[a]
Hour 2	242.8 [b]
Hour 6	298.5 [c]
Hour 4	320.1 [c]
Hour 42	329.0 [c]
Hour 18	383.8 [d]

Appendix Table 11. Continued.

Plasma Lactic Acid

	Pre	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Bypass	36.2	111.6	76.0	50.2	47.2	42.2	43.5
Net	33.0	51.9	35.4	36.4	35.9	35.4	33.2

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	1	6057.6	6057.6	80.3	<0.0001
Time	6	12939.7	2156.6	28.6	<0.0001
Tr X Ti	6	5329.9	888.3	11.8	<0.0001
Error	42	3169.4	75.5		
Total	55	27496.6			

Bypass	Mean	Net	Mean
Pre	36.2[a]	Pre	33.0[a]
Hour 18	42.2[ab]	Hour 42	33.2[a]
Hour 42	43.5[ab]	Hour 2	35.4[a]
Hour 6	47.2[ab]	Hour 18	35.4[a]
Hour 4	50.2[b]	Hour 6	35.9[a]
Hour 2	76.0[c]	Hour 4	36.4[a]
Hour 0	111.6[d]	Hour 0	51.9[b]

	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Acute	23.7	44.4	33.1	39.0	30.2	19.2
Chronic	24.0	83.6	44.5	54.4	85.9	109.6

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	1	32967.6	32967.6	216.9	<0.0001
Time	5	24792.1	4958.4	32.6	<0.0001
Tr X Ti	5	25924.5	5184.9	34.1	<0.0001
Error	125	19003.2	152.0		
Total	136	102172.6			

Acute	Mean	Chronic	Mean
Hour 42	19.2[a]	Hour 0	24.0[a]
Hour 0	23.8[ab]	Hour 4	44.5[b]
Hour 18	30.2[bc]	Hour 6	54.4[b]
Hour 4	33.1[bc]	Hour 2	83.6[c]
Hour 6	39.0[cd]	Hour 18	85.9[c]
Hour 2	44.4[d]	Hour 42	109.6[d]

Appendix Table 11. Continued.

Plasma Glucose

	Pre	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Bypass	82.4	91.6	82.0	101.9	100.4	154.5	104.0
Net	73.2	88.1	77.5	77.2	89.2	94.0	79.0

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	1	5495.3	5495.3	29.2	<0.0001
Time	6	11274.7	1879.2	10.0	<0.0001
Tr X Ti	6	4774.5	795.7	4.2	0.0021
Error	42	7911.6	188.4		
Total	55	29456.1			

Bypass	Mean	Net	Mean
Hour 2	82.0[a]	Pre	73.2[a]
Pre	82.4[ab]	Hour 4	77.2[ab]
Hour 0	91.6[abc]	Hour 2	77.5[ab]
Hour 6	100.4[abc]	Hour 42	79.0[ab]
Hour 4	101.9[bc]	Hour 0	88.1[ab]
Hour 42	104.0[c]	Hour 6	89.2[ab]
Hour 18	154.5[d]	Hour 18	94.0[b]

	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Acute	80.2	109.3	129.2	137.2	122.8	72.6
Chronic	77.3	69.8	81.6	88.6	260.2	352.1

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	1	28627.1	28627.1	20.8	<0.0001
Time	5	219658.1	73931.6	32.0	<0.0001
Tr X Ti	5	397442.1	79488.4	57.9	<0.0001
Error	125	171715.0	1373.7		
Total	136	810447.2			

Acute	Mean	Chronic	Mean
Hour 42	72.6[a]	Hour 2	69.8[a]
Hour 0	80.2[a]	Hour 0	77.3[a]
Hour 2	109.3[ab]	Hour 4	81.6[a]
Hour 18	122.8[b]	Hour 6	88.6[ac]
Hour 4	129.2[b]	Hour 18	260.2[b]
Hour 6	137.2[b]	Hour 42	352.1[c]

Appendix Table 12. Statistical assessment of stress related blood serum parameters of river-run subyearling chinook salmon after passing through the bypass system at Bonneville Dam Second Powerhouse, 1991; at tailwater elevation 15-18.5 ft and water temperature 18.9°C.

Methods

Cortisol, glucose and lactic acid levels were measured from samples of chinook salmon of size ten on one day for two treatments (acute and chronic) at five times (hour 0, hour 2, hour 4, hour 6, and hour 18). Hour 42 was sampled only for the acute treatment. One sample constituted the response for hour 0 for both treatments. Since there was no replication, all analyses had to be done using only fish-to-fish sampling variation. The hour 0 sample was not included in the analyses of variance since it provided no information on sampling error, however, it was included for subsequent comparison procedures.

Cortisol, glucose and lactic acid levels were also measured from samples of about size twelve on each of four days for two treatments (bypass and net) at seven times (pre-experiment, hour 0 post-experiment, hour 2, hour 4, hour 6, hour 18 and hour 42). All analyses were done on the mean of each sample for each day/treatment/time combination as experimental replication was done at the "day level" not at the "fish level."

Treatment and time comparisons for both experiments were done using two-way ANOVA and Fisher's Protected Least Significant Difference (FPLSD) procedures (Petersen 1985). A significant treatment by time interaction term in the ANOVA would indicate the cortisol (or glucose or lactate) level response curve over time was different for different treatments. A significant treatment effect would indicate that the time response curves for one of the treatments was shifted higher or lower than for the others. A significant time effect would indicate that at least one of the measured times had a higher or lower level than did the others. If a significant interaction was detected, treatment and time effects would not be analyzed.

Appendix Table 12. Continued

Plasma Cortisol

	Pre	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Bypass	89.7	99.4	251.6	230.8	209.8	158.2	113.6
Net	70.3	59.8	206.0	163.6	147.6	112.4	110.5

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	1	22874.9	22874.9	46.2	<0.0001
Time	6	164475.2	27412.5	55.3	<0.0001
Tr X Ti	6	6165.3	1027.5	2.1	0.0769
Error	42	20814.2	495.6		
Total	55	214329.5			

Bypass	Mean
Pre	89.8^{a}
Hour 0	99.4^{a}
Hour 42	113.6^{a}
Hour 18	158.2^{b}
Hour 6	209.8^{c}
Hour 4	230.8^{cd}
Hour 2	251.6^{d}

Net	Mean
Hour 0	59.8^{a}
Pre	70.3^{a}
Hour 42	110.5^{b}
Hour 18	112.4^{b}
Hour 6	147.6^{c}
Hour 4	163.6^{c}
Hour 2	206.0^{d}

	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Acute	115.6	244.7	240.2	194.3	155.1	178.2
Chronic	115.6	284.2	326.6	331.8	380.5	

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	3	5640.4	1880.1	0.5	0.6239
Time	1	269231.3	269231.3	84.4	<0.0001
Tr X Ti	3	89514.4	29838.1	9.4	<0.0001
Error	72	220014.3	3188.6		
Total	79	587073.3			

Acute	Mean
Hour 0	115.6^{a}
Hour 18	155.1^{ab}
Hour 42	178.2^{b}
Hour 6	194.3^{bc}
Hour 4	240.2^{c}
Hour 2	244.7^{c}

Chronic	Mean
Hour 0	115.6^{a}
Hour 2	284.2^{b}
Hour 4	326.6^{b}
Hour 6	331.8^{bc}
Hour 18	380.5^{c}

Appendix Table 12. Continued

Plasma Glucose

	Pre	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Bypass	85.8	70.1	98.5	109.0	125.0	122.3	94.1
Net	84.5	75.3	85.4	96.0	96.9	92.7	86.2

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	1	2204.4	2204.4	33.6	<0.0001
Time	6	8728.9	1454.8	22.2	<0.0001
Tr X Ti	6	1985.7	330.9	5.0	0.0006
Error	42	2758.0	65.7		
Total	55	15676.7			

Bypass	Mean	Net	Mean
Hour 0	70.1^{a}	Hour 0	75.3^{a}
Pre	85.8^{b}	Pre	84.5^{ab}
Hour 42	94.1^{bc}	Hour 2	85.4^{abc}
Hour 2	98.5^{cd}	Hour 42	86.2^{abc}
Hour 4	109.0^{de}	Hour 18	92.7^{bc}
Hour 18	122.3^{ef}	Hour 4	96.0^{bc}
Hour 6	125.0^{f}	Hour 6	96.9^{c}

	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Acute	89.7	114.8	116.0	123.6	118.4	84.8
Chronic	89.7	108.3	153.6	165.6	195.4	

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	3	19548.8	6515.3	6.8	0.0005
Time	1	25279.9	25279.9	26.2	<0.0001
Tr X Ti	3	16672.3	5557.4	5.8	0.0014
Error	72	66579.0	964.9		
Total	79	126476.7			

Acute	Mean	Chronic	Mean
Hour 42	84.8^{a}	Hour 0	89.7^{a}
Hour 0	89.7^{ab}	Hour 2	108.3^{a}
Hour 2	114.8^{bc}	Hour 4	153.6^{b}
Hour 4	116.0^{bc}	Hour 6	165.6^{b}
Hour 18	118.4^{c}	Hour 18	195.4^{c}
Hour 6	123.6^{c}		

Appendix Table 12. Continued

Plasma Lactic Acid

	Pre	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Bypass	44.6	140.7	66.5	43.8	42.0	52.0	59.4
Net	41.2	75.1	39.5	39.7	41.7	40.8	53.1

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	1	3965.3	3965.3	85.8	<0.0001
Time	6	26971.2	4495.2	97.2	<0.0001
Tr X Ti	6	6490.1	1081.7	23.4	<0.0001
Error	42	1941.1	46.2		
Total	55	39368.0			

Bypass	Mean	Net	Mean
Hour 6	42.0^{a}	Hour 2	39.5^{a}
Hour 4	43.8^{ab}	Hour 4	39.7^{a}
Pre	44.6^{ab}	Hour 18	40.9^{a}
Hour 18	52.0^{bc}	Pre	41.2^{a}
Hour 42	59.4^{cd}	Hour 6	41.7^{a}
Hour 2	66.5^{d}	Hour 42	53.1^{b}
Hour 0	140.7^{e}	Hour 0	75.1^{c}

	Hour 0	Hour 2	Hour 4	Hour 6	Hour 18	Hour 42
Acute	39.3	59.8	40.4	34.9	47.7	45.6
Chronic	39.3	45.2	53.8	54.8	89.7	

ANOVA

Source	df	Sum of Squares	Mean Square	F	P
Treatment	3	5616.4	1872.1	6.3	0.0008
Time	1	3944.0	3944.0	13.2	0.0005
Tr X Ti	3	7750.0	2583.3	8.7	0.0001
Error	72	20569.3	298.1		
Total	79	37588.9			

Acute	Mean	Chronic	Mean
Hour 6	34.9^{a}	Hour 0	39.3^{a}
Hour 0	39.3^{a}	Hour 2	45.2^{a}
Hour 4	40.4^{a}	Hour 4	53.8^{a}
Hour 42	45.6^{ab}	Hour 6	54.8^{a}
Hour 18	47.7^{ab}	Hour 18	89.8^{b}
Hour 2	59.8^{b}		

Appendix Table 13. Direct assessment of descaling, injury, and mortality among hatchery coho salmon[a] passing through the bypass system at Bonneville Dam Second Powerhouse, 1992; at tailwater elevation 9.5 to 10.5 and water temperature 15.3 °C.

Release information[c]				ERG open	Total time	Recovery information[b]					Delayed	Delayed mortality of descaled
						Catch		Descaled	Injured[d]	Dead	mortality[e]	& injured[f]
Date/Rep.	Site/Status[g]	No.	Hrs.[h]	Hrs.[h]	Min[h]	No.	%	%	%	%	%	%
Test conditions: downwell elev. 58.5 ft, and sampling room conduit empty												
13 Oct	By 17B	400	1318	1330	12	319	79.8	48.9	2.2	1.0	---[i]	---
1	Downwell/O	400	1321	1330	9	391	97.8	18.4	1.3	.3	---	---
	Conduit	399	1321	1330	9	379	95.0	14.5	0.8	0.0	---	---
	Net	400	1320	1330	10	391	97.8	1.0	0.0	1.5	---	---
14 Oct	By 17B	400	1302	1317	15	340	85.0	28.5	0.9	17.5	11.2	48.2
2	Downwell/O	400	1305	1317	12	372	93.0	25.5	0.8	9.0	14.8	53.3
	Conduit	400	1305	1317	12	401	100.0	15.2	0.0	7.5	2.8	55.1
	Net	398	1306	1317	11	391	98.2	1.8	0.3	10.8	27.4	2.0
15 Oct	By 17B	400	--	1322	--	374	93.5	22.5	1.3	40.0	14.3	51.0
3	Downwell/O	400	--	1322	--	385	96.3	16.1	1.3	7.8	13.5	70.2
	Conduit	400	--	1322	--	380	95.0	22.5	1.8	9.8	10.9	53.4
	Net	400	1309	1322	13	392	98.0	8.7	1.0	1.3	8.1	30.9
16 Oct	By 17B	400	1235	1246	11	329	82.3	38.0	1.2	1.0	0.0	29.6
4	Downwell/O	233	1238	1246	8	228	97.9	14.9	0.0	0.0	1.0	14.3
	Conduit	400	1238	1246	8	376	94.0	21.5	1.1	0.0	2.0	16.6
	Net	325	1240	1246	6	327	100.0	14.9	0.3	0.3	2.1	8.2
Total / (Mean square error)												
1 - 4	By 17B	1,600			12.7(1.2)		85.2(3.0)	34.5(5.8)	1.4(0.3)	14.9(9.2)	8.5(4.3)	42.9(6.7)
	Downwell/O	1,433			9.7(1.2)		96.3(1.1)	18.7(2.4)	0.9(0.3)	4.2(2.4)	9.8(4.4)	45.9(16.6)
	Conduit	1,599			9.7(1.2)		96.0(1.4)	18.4(2.1)	0.9(0.4)	4.3(2.5)	5.2(2.8)	41.7(12.6)
	Net	1,523			10.0(1.5)		98.5(0.5)	6.6(3.3)	0.4(0.2)	3.5(2.0)	12.5(7.6)	13.7(8.8)

Appendix Table 13. Continued.

Release information[c]				ERG open	Total time	Recovery information[b]					Delayed mortality[e]	Delayed mortality of descaled & injured[f]
						Catch		Descaled	Injured[d]	Dead		
Date/Rep.	Site/Status[g]	No.	Hrs.[h]	Hrs.[h]	Min[h]	No.	%	%	%	%	%	%
Test conditions: downwell elev. 56.5 ft, and sampling room conduit empty												
13 Oct	By 17B	399	1443	1454	11	327	81.9	14.1	0.0	1.2	0.0	30.8
1	Downwell/O	400	1446	1454	8	376	94.0	6.6	0.0	.8	0.0	20.5
	Conduit	400	1446	1454	8	371	92.8	4.6	0.3	0.0	0.0	21.4
	Net	400	1445	1454	9	393	98.3	0.5	0.0	0.5	0.0	33.3
14 Oct	By 17B	400	1425	1440	15	366	91.5	0.6	0.3	0.5	0.0	25.0
2	Downwell/O	400	1428	1440	12	397	99.3	0.5	0.0	0.3	0.0	0.0
	Conduit	400	1428	1440	12	379	94.8	0.5	0.5	0.0	0.0	20.0
	Net	---[j]	---	---	---	---	---	---	---	---		
15 Oct	By 17B	400	1455	1504	9	365	91.3	1.1	0.3	1.5	1.0	16.7
3	Downwell/O	400	1458	1504	6	295	73.8	0.0	0.3	1.0	0.0	50.0
	Conduit	400	1458	1504	6	391	97.8	0.3	0.3	0.3	1.0	0.0
	Net	400	1455	1504	9	388	97.0	0.0	0.0	0.3	0.0	0.0
16 Oct	By 17B	400	1343	1348	5	347	86.8	0.9	0.3	1.3	0.0	20.0
4	Downwell/O	233	1346	1348	2	218	93.6	0.0	0.0	0.0	0.0	0.0
	Conduit	400	1346	1348	2	388	97.0	0.0	0.0	0.0	0.0	0.0
	Net	321	1343	1348	5	332	100.0	0.0	0.3	0.0	1.1	0.0
Total /(Mean square error)												
1 - 4	By 17B	1,599			11.6(4.7)		87.9(2.3)	4.2(3.3)	0.2(0.1)	1.1(0.2)	0.3(0.3)	23.1(3.1)
	Downwell/O	1,433			7.0(2.1)		90.2(5.6)	1.8(1.6)	0.1(0.1)	0.5(0.2)	0.0(0)	17.6(12)
	Conduit	1,600			7.0(2.1)		97.0(0.8)	1.4(1.1)	0.3(0.1)	0.1(0.1)	0.3(0.3)	10.4(6.0)
	Net	1,121			7.7(1.3)		98.4(0.9)	0.2(0.2)	0.1(0.1)	0.3(0.1)	0.4(0.4)	11.1(11)

Appendix Table 13. Continued.

[a] Subyearling coho salmon obtained from Cascade Hatchery (Oregon Department of Fish and Wildlife); mean fork length 110.7 mm.
[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.
[c] Site codes are By 17B = water surface of bypass system collection channel at north end (elevation 66 ft); Downwell = water surface 10 m upstream from downwell or directly into the downwell during non-overflow tests (elevation 60 ft); Conduit = through a 30-m, 76-mm dia. hose 20 m downstream from the 1.2-m dia. 90 degree elbow (elevation 39 ft); Net = surface release into recovery net.
[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.
[e] Approximately 100 healthy fish from each release site were held for 48-hour delayed mortality.
[f] All descaled and injured fish plus a few uncompromised fish were held for 48-h delayed mortality.
[g] O indicates normal conditions with water overflowing into the downwell which caused air entrainment; NO indicates no water overflowing into the downwell wherein no air was entrained.
[h] Many times are estimated, but errors are no greater than 2 minutes unless noted. Generally, releases were timed to provide similar times of entrance into the trap-net for the average fish of each comparison group.
[i] --- represents that data were not available.
[j] Due to a water system failure, no fish were released for this treatment.

Appendix Table 14. Direct assessment of descaling, injury, and mortality among hatchery chinook salmon[a] passing through the bypass system at Bonneville Dam Second Powerhouse, October 1992; at tailwater elevation 10-10.5 ft and water temperature 15.8-16.5°C.

Release information[c]				ERG open	Total time	Recovery information[b]					Delayed mortality[e]	Delayed mortality of descaled & injured[f]
						Catch		Descaled	Injured[d]	Dead		
Date/Rep.	Site/Status[g]	No.	Hrs.[h]	Hrs.[h]	Min[h]	No.	%	%	%	%	%	%
Test conditions: downwell elev. 58.0 ft, and sampling room conduit full												
20 Oct	By 11A	200	1251	1328	23	14	7.0	7.1	0.0	92.8	0.0	0.0
1	By 17B	200	1320	1328	8	136	68.0	15.4	0.0	7.3	0.0	5.0
	Downwell/O	200	1323	1328	5	192	96.0	9.4	0.5	3.6	1.9	7.7
	Net	200	1320	1328	8	199	99.5	17.6	0.0	0.0	4.1	10.3
21 Oct	By 17B	200	1244	1252	8	149	74.5	11.4	0.0	16.8	2.0	5.0
2	Downwell/O	200	1247	1252	5	197	98.5	10.1	0.5	8.1	3.0	17.4
	Downwell/NO	200	1239	1252	13	189	94.5	6.8	1.1	48.1	10.9	71.4
	Net	200	1239	1252	13	202	100.0	1.0	0.0	5.0	3.8	33.3
22 Oct	By 17B	200	1258	1318	20	158	79.0	2.5	0.0	86.7	35.3	55.6
3	Downwell/O	199	1301	1318	17	196	98.0	4.1	0.0	76.5	5.4	25.0
	Downwell/NO	200	1306	1318	12	192	96.0	12.0	0.5	4.7	4.5	11.1
	Net	200	1258	1318	20	203	100.0	1.0	0.0	8.5	2.2	0.0
23 Oct	By 14A	139[i]	1225	1251	26	27[j]	19.4	22.0	0.0	29.6	4.0	25.0
4	By 17B	200	1246	1251	5	128	64.0	11.7	0.0	2.3	2.1	0.0
	Downwell/O	200	1249	1251	2	178	89.0	4.5	1.7	0.0	3.9	25.0
	Net	200	1246	1251	5	197	98.5	2.5	0.0	1.5	0.0	33.3
23 Oct	Downwell/NO	197	1350	1354	4	178	90.3	6.2	0.6	0.0	2.0	15.4
5	Net	200	1351	1354	3	219	100.0	0.5	0.0	1.5	11.4	0.0
Total / (Mean square error)												
1-5	By 11/14A	339			24.5(1.5)		13.2(6.2)	14.6(7.5)	0.0(0)	61.2(31.6)	2.0(2.0)	12.5(12.5)
	By 17B	800			10.3(3.3)		71.4(3.3)	10.3(2.7)	0.0(0)	28.3(19.7)	9.9(8.5)	16.4(13.1)
	Downwell/O	799			7.3(3.3)		95.4(2.2)	7.0(1.6)	0.7(0.4)	22.1(18.2)	3.6(0.7)	18.8(4.1)
	Downwell/NO	597			9.7(2.8)		93.6(1.7)	8.3(1.8)	0.7(0.2)	17.6(15.3)	5.8(2.7)	32.6(19.4)
	Net	1,000			9.8(3.1)		99.6(0.3)	4.5(3.1)	0.0(0)	3.3(1.5)	4.3(2.5)	15.4(7.6)

Appendix Table 14. Continued.

Date/Rep.	Release information[c] Site/Status[g]	No.	Hrs.[h]	ERG open Hrs.[h]	Total time Min[h]	Recovery information[b] Catch No.	Catch %	Descaled %	Injured[d] %	Dead %	Delayed mortality[e] %	Delayed mortality of descaled & injured[f] %
				Test conditions: downwell elev. 55.0 ft, and sampling room conduit full								
20 Oct	By 11A	200	1446	1536	50	81	40.5	1.2	0.0	22.2	6.4	66.7
1	By 17B	200	1530	1536	6	153	76.5	9.8	1.3	15.0	1.9	15.8
	Downwell/O	198	1533	1536	3	208	100.0	1.9	0.5	6.2	0.0	16.6
	Net	197	1530	1536	6	200	100.0	1.5	0.0	1.0	0.0	50.0
				Test conditions: downwell elev. 58.5 ft, and sampling room conduit empty								
21 Oct	By 17B	200	1355	1407	12	138	69.0	8.0	0.0	25.4	6.1	36.4
1	Downwell/O	200	1358	1407	9	204	100.0	9.3	1.5	15.7	2.0	33.3
	Downwell/NO	200	1344	1407	23	191	95.5	2.1	0.0	70.7	12.2	25.0
	Net	200	1345	1407	22	200	100.0	3.0	0.0	32.5	2.0	50.0
22Oct	By 17B	197	1416	1428	12	181	91.9	5.0	0.6	53.0	2.1	30.0
2	Downwell/O	199	1419	1428	9	205	100.0	9.5	2.0	24.6	7.8	18.8
	Downwell/NO	199	1422	1428	6	198	99.5	5.0	0.5	6.0	2.0	21.4
	Nt	200	1416	1428	12	205	100.0	4.0	0.5	8.0	0.0	37.5
23 Oct	Downwell/NO	200	1441	1445	4	183	91.5	2.7	0.5	3.3	0.0	0.0
3	Nt	200	1443	1445	2	205	100.0	0.5	0.0	1.5	0.0	0.0
						Total / (Mean square error)						
1-3	By 17B	397			12.0(0)		80.5(11.5)	6.5(1.5)	30.3(0.3)	39.2(13.8)	4.1(2.0)	33.2(3.2)
	Downwell/O	399			9.0(0)		100.0(0)	9.4(0.1)	1.8(1.4)	20.2(4.5)	4.9(2.9)	26.1(7.3)
	Downwell/NO	599			11.0(6.0)		95.5(2.3)	3.3(0.9)	0.3(0.2)	26.7(22.0)	4.7(3.8)	15.5(7.8)
	Net	600			12.0(5.8)		100.0(0)	2.5(1.0)	0.2(0.2)	14.0(9.4)	0.7(0.7)	29.2(15)

Appendix Table 14. Continued.

[a] Subyearling chinook salmon from Little White Salmon National Fish Hatchery, originally tag loss sample from Bonneville passage survival study; mean fork length 132.1 mm.
[b] To avoid bias from escapement, percentages for descaling and injury were calculated using recovery number rather than release number.
[c] Site codes are By 11A, 14A, and 17B = water surface of bypass system collection channel at south, middle, and north portions (elevation 66 ft); Downwell = water surface 10 m upstream from downwell or directly into the downwell during non-overflow tests (elevation 60 ft); Conduit = through a 30-m, 76-mm dia. hose 20 m downstream from the 1.2-m dia. 90 degree elbow (elevation 39 ft); Net = surface release into recovery net.
[d] Since individual fish were occasionally both descaled and injured, these numbers should not be added to obtain the total number of damaged fish.
[e] Approximately 100 healthy fish from each release site were held for 48-hour delayed mortality.
[f] All descaled and injured fish plus a few uncompromised fish were held for 48-hour delayed mortality.
[g] O indicates normal conditions with water overflowing into the downwell which caused air entrainment; NO indicates no water overflowing into the downwell wherein no air was entrained.
[h] Many times are estimated, but errors are no greater than 2 minutes unless noted. Generally, releases were timed to provide similar times of entrance into the trap-net for the average fish of each comparison group.
[i] There were 60 fish impinged on the watering screen, resulting in a lower number of fish in this group's treatment.
[j] Low recoveries due in part to fish delaying in bypass system.