Condition and Gatewell Retention Time of Yearling and Subyearling Chinook Salmon Guided from Modified Turbine Intakes at Bonneville Dam Second Powerhouse, 2008-2009

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Report of research by

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Contracts W66QKZ80320321 and W66QKZ90156395

October 2012

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EXECUTIVE SUMMARY

In 2008 and 2009, we evaluated mortality, descaling, and passage time for juvenile Chinook salmon through the bypass system at Bonneville Dam Second Powerhouse. Fish were fin-clipped or tagged, released at specific points within the system, and recaptured at the juvenile fish monitoring facility. Separate test series were conducted for Spring Creek National Fish Hatchery subyearling Chinook, river-run yearling Chinook, and river-run subyearling Chinook salmon.

Treatment groups were released to Gatewells 12A and 14A in 2008 and to the A intake of Turbine Unit 14 in both years. Reference groups were released to the juvenile bypass collection channel in both years. We compared mortality, descaling, and passage time between treatment groups released during different turbine operating conditions. These conditions were the lower, lower-middle, middle, middle-upper, and upper 1% of peak turbine efficiency. Target turbine unit flows (kcfs) ranged from 11.7 for lower-1%, 13.5 for lower-middle-1%, 14.7 for middle-1%, 16.3 for middle-upper-1%, and 17.8 for upper-1% operations. Release group sizes were planned to allow us to detect a minimum additive difference of 3% in mortality and descaling between treatments ($\alpha = 0.05$, $\beta = 0.2$).

Spring Creek Hatchery Subyearling Chinook Salmon

In 2008, four series of tests were conducted with subyearling Chinook salmon obtained from Spring Creek National Fish Hatchery. For Test Series 1 (3-4 March 2008), we fin-clipped study fish and released treatment groups to Gatewell 12A and reference groups to the juvenile bypass collection channel. Mortality of recaptured fish was 0.3% for reference groups and 1.9, 14.2, and 32.3% for lower-, middle-, and upper-1% operation groups, respectively. Differences between groups were statistically significant by *t*-test. These results provided evidence that passage mortality in Spring Creek Hatchery subyearling Chinook salmon increased as turbine operation was raised to higher levels within the 1% peak efficiency range.

In Test Series 2 (18-21 March 2008), we marked Spring Creek National Fish Hatchery subyearlings using passive integrated transponder (PIT) tags. Treatment groups were released to Gatewell 14A and to the A intake of Turbine Unit 14, and reference groups were again released to the collection channel. Respective mortality rates were 1.8 and 6.9% for intake release groups at lower- and upper-1% operations, but the difference was not significant ($P = 0.079$).

For Test Series 3 (26 March-18 April), groups of PIT-tagged hatchery subyearlings were again released to the collection channel, to Gatewell 14A, and to the A intake of Turbine 14. For fish released to the turbine intake, mortality was 1.3% for lower-1% operation and 12.7% for upper-1% operation; the difference was significant (ANOVA; $P = 0.005$).

Results from Test Series 1-3 confirmed that lower-1% operation was less detrimental than upper-1% operation for Spring Creek Hatchery subyearling Chinook. After consulting with U.S. Army Corps of Engineers personnel, we changed the design for Test Series 4 to compare middle- vs. upper-1% operation: further evaluation of passage performance at lower-1% operation was not deemed necessary. Results from Test Series 4 showed that fish released to the intake had mortality rates of 2.7% for middle-1% and 18.1% for upper-1% operation. These differences were significant (ANOVA; $P < 0.001$).

In 2009, we continued tests with Spring Creek Hatchery subyearling Chinook salmon due to regional concern for the passage performance of these fish. Since it was clear from results in 2008 that upper-1% operation was associated with high mortality, work in 2009 compared mortality rates between lower-middle-and middle-1% operations. Tests series in 2009 were divided into an early period (25 March-11 April) and a late period (20 April-8 May). Results from both the early and late test series showed that mortality increased with turbine operation level. For fish released to the intake, respective increases in mortality from lower-middle- to middle-1% operation were 4.4 to 6.8% in the early series and 1.8 to 3.3% in the late series. These differences were significant in the early series ($P = 0.008$), but not in the late series. Logistic regression modeling using fork length data suggested that for Spring Creek Hatchery fish, mortality at each operating level decreased as fish size increased.

Timing data for Spring Creek Hatchery test fish recaptured alive showed that survivors of treatment groups with highest mortality also had the most rapid passage timing. However, groups with higher mortality and shorter passage times also tended to have lower recapture rates. Although this finding was counterintuitive, we concluded that it was related to the truncated distribution of passage time: the longer fish remained in the gatewells, the less likely they were to survive the experience.

Run-of-River Yearling Chinook Salmon

During the 2008 test period, high flows with heavy debris loads had repeatedly clogged the vertical barrier screens, and they had to be pulled on several dates. Because of these interruptions, we were unable to complete the test series. From the single test

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block released in 2008, recapture rates were high for all treatment groups. Reference fish had a descaling rate[1] of 1.6% and a mortality rate of 1.4%. For intake treatment fish, descaling rates were 0.5 for middle-1% and 4.7% for upper-1% operation, and mortality rates were 4.9% for middle- and 0.0% for upper-1% operation. Data from these tests were insufficient for meaningful statistical comparison.

In 2009, we again compared passage performance between middle- and upper-1% operational levels for river-run yearling Chinook. Recapture rates were again high for all groups, and we completed 8 test blocks. For releases to the intake, we found significant differences between operations in mortality, descaling, and passage time ($P \leq 0.05$). All parameters increased as turbine efficiency increased from middle- to upper-1% operational ranges: mortality increased from 0.5 to 4.4%, descaling increased from 1.0 to 11.5%, and median passage time increased from 1.7 to 2.7 h.

River-Run Subyearling Chinook Salmon

In summer 2008, river-run subyearling Chinook salmon were collected from the smolt-monitoring sample for comparisons of middle- vs. upper-1% operation. Three test blocks were completed, and all groups had high rates of recapture. Reference fish released to the collection channel had 0.4% mortality and 0.7% descaling.[2] For releases to the intake, mortality increased from 0.6 to 2.6% and descaling increased from 0.4 to 3.3% between middle- and upper-1% operations; these differences were not statistically significant.

In 2009, more extensive tests were conducted for river-run subyearling Chinook. At the request of USACE, we added a treatment replicate to test passage metrics with one vs. two gatewell orifices open during upper-1% operation. These treatments were meant to evaluate the hypothesis that passage from gatewells could be expedited by providing an additional open orifice, and that the resulting faster passage timing would lead to lower rates of mortality and descaling during upper-1% operations.

Tests were alternated in the following sequence: middle-1% operation with one open orifice, upper-1% operation with one open orifice, and upper-1% operation with two open orifices. Results showed that with one gatewell orifice open, mortality and descaling rates were 2-3% higher at upper-1% than at middle-1% operation. In comparisons between middle- and upper-1% operation, mortality increased from 2.6 to 4.3%, descaling increased from 0.5 to 2.6%, and median passage time increased from

[1-2] For these and all other tests, descaled fish were defined as those with at least 20% of the scales missing from at least one side of the body.

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2.6 to 6.4 h; these differences were significant (ANOVA; $P \leq 0.05$). Results from tests at upper-1% operation with two open orifice gates were promising, with reductions in gatewell retention time, mortality, and descaling. These results were not statistically different from those of the middle-1% operation with one open orifice.

Fish Health Survey

For surveys of fish health, we used subsamples of the yearling and subyearling Chinook salmon collected for passage tests. In the laboratory, tissues were evaluated to detect viral hemorrhagic septicemia virus (VHSV), infectious hematopoietic necrosis virus (IHNV), *Renibacterium salmoninarum*, and *Myxobolus cerebralis*. Kidney tissue was cultured to isolate *Aeromonas salmonicida* (furunculosis), *Yersinia ruckeri* (enteric redmouth disease),and *Pseudomonas* spp. (fin rot).

In 2008, we were unable to collect sufficient numbers of either yearling or subyearling Chinook for meaningful comparisons. Among the 87 yearling Chinook and 148 subyearling Chinook salmon submitted for disease surveys, VHSV was not detected. The IHNV virus was isolated from a pool of 29 yearling Chinook salmon. *Renibacterium salmoninarum* was detected in one yearling and one subyearling Chinook salmon; *Myxobolus cerebralis* was not detected in any fish samples.

In 2009, 179 river-run yearling Chinook salmon and 237 river-run subyearling Chinook salmon were sampled for disease workups. Of the two viral pathogens, VHSV was not found, but 3 yearling Chinook salmon tested positive for IHNV. *Renibacterium salmoninarum* was detected in one yearling Chinook salmon, but other bacterial pathogens were not found in samples of kidney tissue. As in 2008, *Myxobolus cerebralis* was not detected. Examination of the hindgut of one subyearling Chinook salmon showed *Ceratomyxa shasta* present at a low level.

Neither our surveys nor those conducted by the U.S. Fish and Wildlife Service in 2008 and 2009 found pathogens in Spring Creek Hatchery fish at levels of prevalence or severity that would have compromised their ability to survive after release.

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CONTENTS

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INTRODUCTION

Bonneville Dam Second Powerhouse was designed to include a bypass system to divert juvenile salmonids from turbine intakes into a collection and transport system. Juvenile salmonids using the system would potentially have improved rates of survival, since they would not be subject to turbine passage. However, after completion of the powerhouse in 1982, evaluations showed that for all salmon species, fish guidance efficiency (FGE) was lower than the specified minimum criteria of 70% (Krcma et al. 1984). In subsequent years, passage structures were modified and tested. Fish guidance efficiency improved, but not to the specified levels (Gessel et al. 1991; Monk et al. 1994, 1995; Ploskey et al. 2001).

Further modification of second powerhouse intakes was initiated in 2001 with the objective of increasing FGE. These modifications are shown in Figure 1 and included:

1) Increasing the length of vertical barrier screens by removing a portion of the gatewell beam
2) Installation of a turning vane below the horizontal picking beam of the submersible traveling screens
3) Installation of a gap closure device on the intake ceiling downstream from the top edge of submersible traveling screens

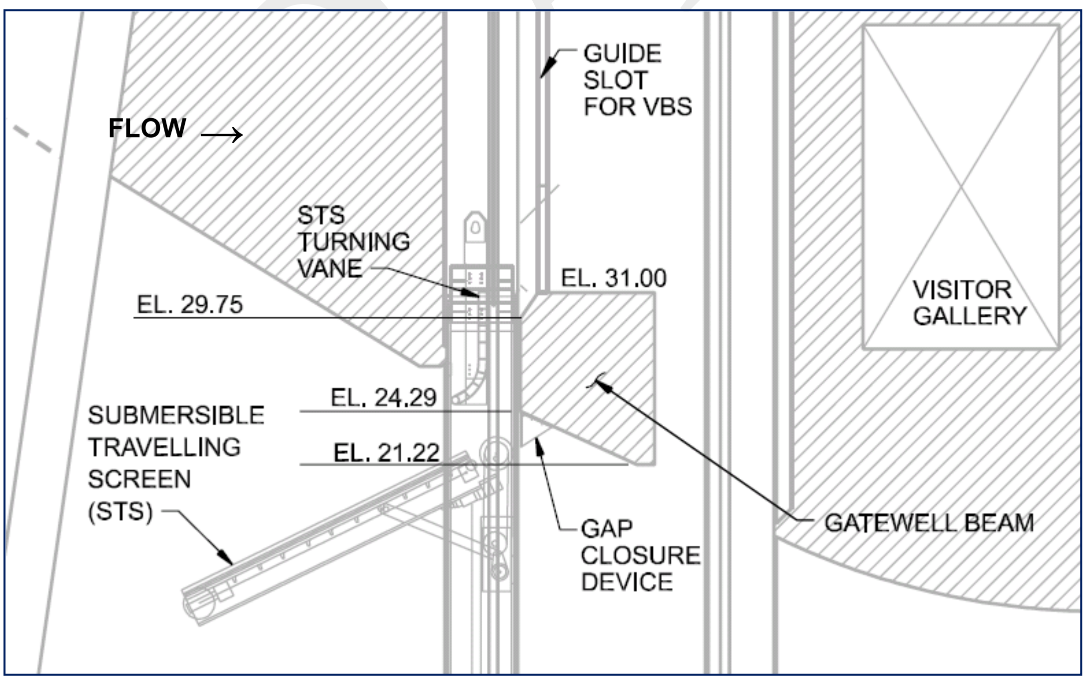

Figure 1. Section through a Bonneville Dam Second Powerhouse turbine intake showing modifications to the gatewell in 2001-2002. Drawing courtesy of U.S. Army Corps of Engineers.

Turning-vane and gap-closure devices were designed to increase flow to the turbine intake gatewells and minimize passage of fish between the top of the STS and bottom of the gatewell beam. Vertical barrier screens (VBSs) were lowered by 6 ft and redesigned to pass the increased flow volume at a uniform maximum normal velocity of about 1 ft per second across the screen surface.

Modeling data provided estimates of flow in the turbine intake and gatewell after these modifications (Table 1). These estimates indicated that gatewell discharge through the VBSs would increase nearly twofold as turbine operation shifted from lower to upper levels within the 1% peak efficiency range. Increased flow to the gatewells presented an opportunity for improved FGE, but also the possibility of adverse effects to juvenile salmonids exposed to a more turbulent gatewell environment.

Table 1. Estimates of intake and gatewell flow after modification of turbine intakes and gatewells at the Bonneville Dam Second Powerhouse in 2001.

Nominal turbine operation	Turbine intake flow (cfs)	Gatewell discharge (cfs)
Lower 1%	3,280	260
Middle 1%	4,790	370
Upper 1%	6,540	490

Evaluation of the prototype modifications in 2001 and 2002 showed that FGE increased in the modified intakes and that descaling was not significantly different between modified and unmodified intakes (Monk et al. 2002, 2004). During tests in 2002, turbine units were operated under automatic governing control, which balances loading across the powerhouse to operate turbines within the upper range of 1% peak efficiency. Thus, in 2001 and 2002, respective average discharge levels in test units operated within the upper-1% peak efficiency range were 13.6 and 13.9 kcfs in spring and 13.8 and 14.9 kcfs in summer. In contrast, the present value of flows in the middle and upper range of 1% peak efficiency are 14.7 and 17.8 kcfs, respectively. Therefore, the initial evaluations were conducted under unit flows that are defined presently as lower-middle- and middle-1% rather than upper-1% peak efficiency levels.

In 2007, data from the Bonneville Dam Smolt Monitoring Program (SMP) indicated that substantial mortality occurred during second powerhouse passage of tule stock Chinook salmon *Oncorhynchus tshawytscha* released in March and April from the Spring Creek National Fish Hatchery (D. Ballinger, PSMFC, personal communication).

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Daily mortality rates measured at the sampling facility ranged from 1.6 to 11.7% during passage of the early March releases (7-13 March). Fish from the April release began arriving at the monitoring facility at about 0645 PDT on 13 April, and from that time until 0900, the mortality rate was 10.1%. In contrast, SMP data from daily samples (≥100) of these same stocks showed that from 2000 to 2006, passage mortality had exceeded 1% on only one date in March (16 March 2002) and three dates in April (1 April 2002 and 17-18 April 2004).

Inspection of passage facilities at the second powerhouse did not identify problems, nor did necropsy of passage mortalities, which showed no evidence of disease. Regional consultation led to a reduction in turbine operating level to the lower end of the 1% peak efficiency range, which resulted in decreased mortality rates in the SMP samples. Observations of passage mortality sustained by Spring Creek Hatchery Chinook salmon in 2007 led to the evaluations of fish condition described in this report.

STUDY DESIGN

In 2008 and 2009, we conducted tests using juvenile Chinook salmon obtained directly from Spring Creek National Fish Hatchery, as well as run-of-river yearling and subyearling Chinook salmon smolts from the Bonneville SMP sample. Comparisons were made between turbine operation levels within the 1% peak efficiency range. Data were obtained for mortality, descaling, and passage timing of marked groups. We released reference groups to the bypass system collection channel and treatment groups to either a turbine intake or modified gatewell (2008 only). The following null and alternate hypotheses were tested:

1. Mortality rates:
   H_0: Mortality rates are not significantly different between test condition 1 and condition 2
   H_1: Mortality rates are not equal between test conditions 1 and 2

2. Descaling rates:
   H_0: Descaling rates are not significantly different between test condition 1 and condition 2
   H_1: Descaling rates are not equal between test conditions 1 and 2

3. Passage timing:
   H_0: Passage time *T* is not significantly different between test condition 1 and 2
   H_1: Passage time *T* is not equal between test condition 1 and 2

where *test condition* refers to turbine operational level and passage time T is defined as elapsed time from release at the second powerhouse to detection at the sort-by-code (SbyC) separator gate monitor at the juvenile monitoring facility for fish marked with passive integrated transponder (PIT) tags.

Research summaries for the 2008-2009 studies specified detection of a minimum additive difference of 3% at $\alpha = 0.05$ and $\beta = 0.20$. Treatment group sizes were calculated using the following equation from Zar (1999), where d is the specified additive difference, p_1 is the expected background or control effect, and $t_{\alpha/2}$ and t_β are the t-values corresponding to $\alpha = 0.05$ and $\beta = 0.20$:

$$n \approx \frac{(t_{\alpha/2} + t_\beta)^2 [p_1(1-p_1) + (p_1 + d)(1 - p_1 - d)]}{d^2} \approx \frac{8[p_1(1-p_1) + (p_1 + d)(1 - p_1 - d)]}{d^2}$$

To the extent possible, treatment group sizes were equivalent for all treatment groups, and the number of fish in each treatment group was split equally among test blocks. Since treatment groups were composed of the number of fish recaptured rather than the number released, treatment group sizes varied with expected recapture rate.

This report is organized into separate sections for subyearling Chinook salmon obtained directly from Spring Creek Hatchery, river-run yearling Chinook salmon, and river-run subyearling Chinook salmon. We evaluated these fish groups separately because results from one group may not be reflective of the other groups, given the differences among these groups in origin, life history, physiology, migration timing, and river environment.

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SPRING CREEK HATCHERY SUBYEARLING CHINOOK SALMON

2008 Evaluation

Tule stock subyearling Chinook salmon were obtained directly from Spring Creek National Fish Hatchery and used in tests conducted from 4 March to 9 May 2008. The test period covered the historical range of release dates for this hatchery; thus, our study fish included the typical variations in size and experienced the typical river temperatures encountered by fish released from this location. Tests were conducted in four series, as described in following sections, with a total of 31,988 fish released: 4,253 with fin-clip combinations and 27,735 with PIT tags.

Test Series 1: 4-5 March

Methods**—**In late February 2008, the U.S. Army Corps of Engineers (USACE) requested an unscheduled test to provide guidance for operation of the second powerhouse during the expected passage in March of 7.4 million hatchery subyearling Chinook salmon. These fish were scheduled for release from Spring Creek Hatchery on 5-6 March. In response, we obtained fish from the hatchery and released test replicates into the bypass-system collection channel and into Gatewell 12A (elevation +43.0 ft msl). Fish were released using the canister release system described by Absolon and Brege (2003). This test series was somewhat ad hoc in nature, primarily due to the short lead time available for preparation. The release hose had not been installed in the turbine intake designated for testing, the designated test turbine (Turbine 14) was not available, and PIT tags for the study had not been delivered.

A total of 4,253 fish were released (average fork length 63 mm). In lieu of PIT-tags, test groups were marked with fin-clip combinations. Unit flows were switched at 4-h intervals among the lower-1% (11.6-11.8 kcfs), middle-1% (13.9-14.0 kcfs), and upper-1% (16.8-16.9 kcfs) operational settings. Fish were released at 0800, 1200, and 1600 PDT on 4 and 5 March. Recapture of test fish was accomplished by setting the SbyC to divert 100% of fish passing the second powerhouse juvenile monitoring facility during the first 24 h after release. The work was facilitated by collaboration with the Smolt Monitoring Program, which provided personnel to monitor and tally the catch at 1-h intervals during the test period. Normal SMP sampling schedules were reinstated before arrival of fish from the 5 and 6 March Spring Creek Hatchery production releases.

We used *t*-tests to compare mortality and recapture rates for fish released under the three turbine operation settings. Descaling rate was not evaluated for tests using

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Spring Creek Hatchery subyearlings because these fish are essentially parr and thus rarely show descaling levels sufficiently high for meaningful analysis.

Results—The 4-h test duration proved sufficient to ensure that surviving fish exited the gatewell prior to switching to the next operating condition. Only 3 of 3,658 test fish were recaptured from the gatewell more than 4 h after release. Observed mortality at recapture was 0.3% for collection-channel releases and 1.9, 14.2, and 32.3% for releases at lower-, middle-, and upper-1% operations, respectively (Table 2). Recapture percentages diminished from 98% for collection-channel releases to about 80% for lower- and middle-1% releases and 67% for upper-1% releases. Since the fate of fish not recaptured was unknown, fish in this category were not included in computation of mortality.

Table 2. Observed recapture and mortality for Spring Creek Hatchery subyearling Chinook salmon fin-clipped and released at Bonneville Dam Second Powerhouse in 2 test blocks on 3 and 4 March 2008. Average fork length of test fish was 63 mm. Turbine operation settings were relative to the 1% peak efficiency range.

Release location	Turbine operation	Flow range (kcfs)	Released (N)	Recaptured (%)	Mortality (%)
Collection channel	N/A	N/A	1,801	98.3	0.3
Gatewell 12A	Lower 1%	11.6-11.8	799	82.7	1.9
Gatewell 12A	Middle 1%	13.9-14.0	854	81.3	14.2
Gatewell 12A	Upper 1%	16.8-16.9	799	66.6	32.3

Mortality increased significantly with each increase in turbine loading ($P < 0.01$). Recapture rates were significantly greater for fish released at lower- or middle-1% operation than for fish released at upper-1% operation ($P < 0.01$). Differences between recapture rates for fish released at lower- and middle-1% operation were not statistically significant ($P = 0.44$).

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Test Series 2: 18-21 March

Methods—Preparations for release into the A intake of Turbine 14 were complete by 18 March 2008. For these releases, Bonneville Project USACE personnel had fabricated and installed a support elbow for the release hose by mitering two sections of 24.5-cm (10-in) diameter steel pipe together. This assembly was then welded to a streamlined trashrack section. This allowed us to position the release hose in the center of the turbine intake, with the hose end turned parallel to flow. A section of 15.24-cm (6-in) diameter steel pipe was welded vertically to a second trashrack section to align with the larger-diameter pipe on the trashrack section below.

A pipe coupler on top of the 15.24-cm diameter steel pipe allowed us to connect consecutive lengths of rigid, 15.24-cm-diameter PVC pipe from about elevation +50 ft msl to the top of the intake deck parapet wall at elevation +93.5 ft msl. Consecutive sections of PVC pipe were installed as the upper trashrack section was lowered into position. With both trashrack sections and the rigid PVC pipe in final position, a flexible 10.2-cm (4-in) diameter PVC hose was threaded downward through the PVC and steel pipes into place. Figure 2 shows the intake release hose location relative to other intake and gatewell structures at the second powerhouse.

Subyearling fall Chinook salmon were obtained from Spring Creek Hatchery and transported to the juvenile fish monitoring facility in 75-L oxygenated containers. Duration of transport was about 45 min. Since rearing-pond and air temperatures were similar, it was not necessary to chill water during transport. One load per day was sufficient to provide the 1,000 fish needed for each daily set of releases. Subyearling Chinook salmon used in the tests averaged 69 mm fork length (N = 1,601).

After arrival at the juvenile facility, test fish were held on river water for 16-24 h to allow for temperature acclimation and stress reduction prior to tagging. We used the TX148511B tag, which was the smallest production PIT tag available at the time (9.0 mm long × 2.04 mm diameter) and was developed for fish less than 60-mm fork length. The 9.0-mm tag had previously been used successfully to tag Chinook salmon juveniles as small as 60 mm fork length at the Hanford Reach of the Columbia River (J. Fryer, Columbia River Inter-Tribal Fish Commission, personal communication). Size and depth of the tagging wound was minimized by using only the tip portion of a standard 12-gauge injection needle for implantation. Tagged fish were returned to 75-L containers for a second holding period prior to release on the following day.

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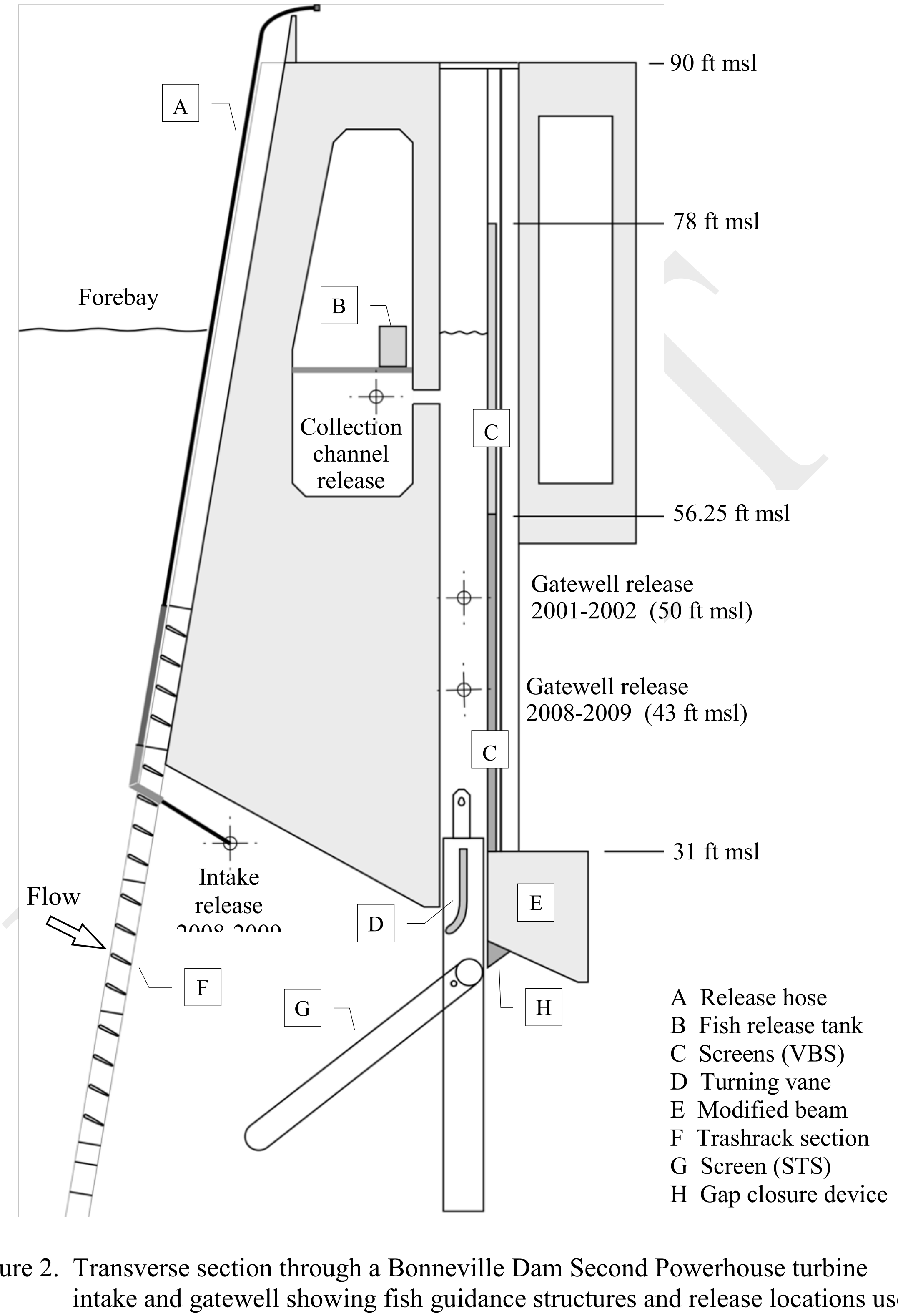

Figure 2. Transverse section through a Bonneville Dam Second Powerhouse turbine intake and gatewell showing fish guidance structures and release locations used in 2001-2002 and 2008-2009. Crosshair symbols denote release locations.

Test groups included:

1) Reference releases made into the bypass system collection channel just downstream from the discharge plume of the 14A south orifice
2) Gatewell 14A canister releases made at +43 ft msl
3) Turbine intake hose releases made at the center of the Gatewell 14A intake just below the intake ceiling and just downstream from the trashrack at +32.2 ft msl

On each of 4 test dates, gatewell and intake releases were made during turbine operations at the lower 1% (11.6-11.9 kcfs) and upper 1% (16.1-16.6 kcfs) of peak turbine efficiency. Duration of testing at each operational level was set at 4 h, based on the rapid passage times observed for the 3-4 March releases. Collection-channel releases, which were not affected by turbine operating condition, were made once per day.

Test fish were transferred from holding containers to 720-L tanks located in the collection-channel gallery (collection-channel releases) or mounted on a flatbed truck (canister and hose releases). Water-to-water transfer was made by tipping the circular holding containers to drain off excess water and then pouring the remaining fish and water into the larger release tanks. Prior to and during this step, we removed mortalities from containers and recovered shed tags.

For gatewell releases, the release canister and support frame were positioned at deck level over the gatewell with a crane. The canister was then stocked by hose transfer of fish from the truck tank and lowered to the submerged release location (+43 ft msl; Figure 2). Intake releases were made directly by hose from a second truck tank. For each specified operating level, intake releases were made first, followed about 15 min later by gatewell releases. Collection channel releases took place at midday, and 4-hour test periods began at 0800 and 1200 PDT.

From 18 to 21 March, we released at total of 4,113 test fish. The SbyC system at the juvenile facility was programmed to divert PIT-tagged test fish into the east raceway in the lower level of the facility. Recaptured test fish were anesthetized with tricaine methane sulfonate at a concentration of about 50 mg/L and scanned for presence of PIT tags. Recapture data were logged into files using P3 software and later entered into spreadsheet and database programs for validation and tabulation. Tagging and recapture files were uploaded to the PTAGIS database maintained by the Pacific States Marine Fisheries Commission. Observed recapture and mortality percentages were tested using analysis of variance (ANOVA), with the significance level set at $\alpha = 0.05$.

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Results—For tests conducted during 18-21 March 2008, collection channel releases, as expected, were characterized by high recapture rates (98.7%) and low mortality rates (0.5%; Table 3). For gatewell and intake releases, as turbine loading switched from the lower- to the upper-1% operation, recapture rates declined. Compared with the mortality rates of fish released on 4-5 March (14-32%; Table 2), mortality rates of fish released during 18-21 March were relatively low for both operating conditions and both release locations (2-6%; Table 3). However, recapture rates for the upper-1% operating level were 56.5% for gatewell releases and 38.2% for intake releases. These values were unexpectedly low compared to the 66.6% recapture rate that had been observed for releases to Gatewell 12A at upper-1% operation (Table 2).

Table 3. Observed recapture and mortality rates for 4 test blocks of Spring Creek Hatchery subyearling Chinook salmon released at Bonneville Dam Second Powerhouse, 18-21 March 2008. Average fork length of test fish was 69 mm. Turbine operations were relative to the 1% peak efficiency range.

Release location	Turbine operation	Flow range (kcfs)	Released (number)	Recaptured (%)	Mortality (%)
Collection channel	N/A	N/A	592	98.7	0.5
Gatewell 14A	Lower 1%	12.1-12.8	786	67.1	4.4
Intake 14A	Lower 1%	12.1-12.8	788	66.5	1.7
Gatewell 14A	Upper 1%	16.7-18.6	937	56.5	5.8
Intake 14A	Upper 1%	16.7-18.6	1,010	38.2	6.0

Statistical analyses of the data using ANOVA showed recapture rates were significantly lower at upper-1% than at lower-1% operation ($P = 0.034$). However, the difference in mortality rate between upper-1% (6.0%) and lower-1% operation (2.0%) was not statistically significant ($P = 0.079$). Differences in recapture and mortality were not statistically significant between gatewell and intake groups released at the same operating condition, nor were there interactions between release location and operating condition.

Examination of daily release and recapture data (Appendix Table 1) showed an abrupt reduction in recapture rates starting on 21 March, when slightly over 20% of the fish were recaptured from releases to both the gatewell and turbine intake during upper-1% operation. Video examination of the submerged VBS was conducted, but results were inconclusive. Subsequently, the screen assembly was raised to deck level for examination, and the neoprene seal between the upper and lower sections of the VBS was found missing. This missing seal resulted in a three-quarter to one-inch gap between the upper and lower VBS sections.

There was little doubt that substantial numbers of test fish had escaped from the gatewell through this gap. As the screen was being raised to deck level, several dozen test fish were observed trapped on the downstream side of the horizontal VBS structural members. Later query of the PTAGIS database showed a pulse of fish moving through the system shortly after the screen was raised. These fish were likely trapped, and raising the screen freed them back into the gatewell to resume movement through the bypass system. Due to this known escape from the gatewell, data from the 18-21 March test series was not considered representative of normal passage conditions.

Test Series 3: 26 March-18 April

Methods—Tests resumed on 26 March 2008, after replacing the defective VBS with a spare assembly. Transport, tagging, release locations, recapture methods, and data collection procedures for Spring Creek Hatchery subyearlings were identical to those described for Test Series 2 (18-21 March). For Test Series 3, turbine settings were alternated between the lower- and upper-1% operation. Unit flows were 12.1-12.8 kcfs during lower-1% operation and 16.7-18.6 kcfs during upper-1% operation. To improve upon the low recapture rates observed in Test Series 2, testing duration was increased from 4 to 48 h. This ensured test fish would have ample time to exit the gatewell, especially for releases at upper-1% operation.

Passage timing information from this test series was obtained by query of the PTAGIS database. Passage time was defined as time of release to time of first detection at the SbyC separator gate monitor (Figure 3). We used the separator-gate monitor rather than the full-flow monitor further upstream because the former has a slightly higher detection rate, especially for the small (9.0 mm) PIT tags used during the study. No appreciable holding of fish occurs between these two monitors; thus, use of the downstream monitor had no meaningful effect on timing data. Passage times were only calculated for fish that were alive at recapture. Timing data were also used to exclude fish from analyses of mortality if they were exposed to more than one operating condition.

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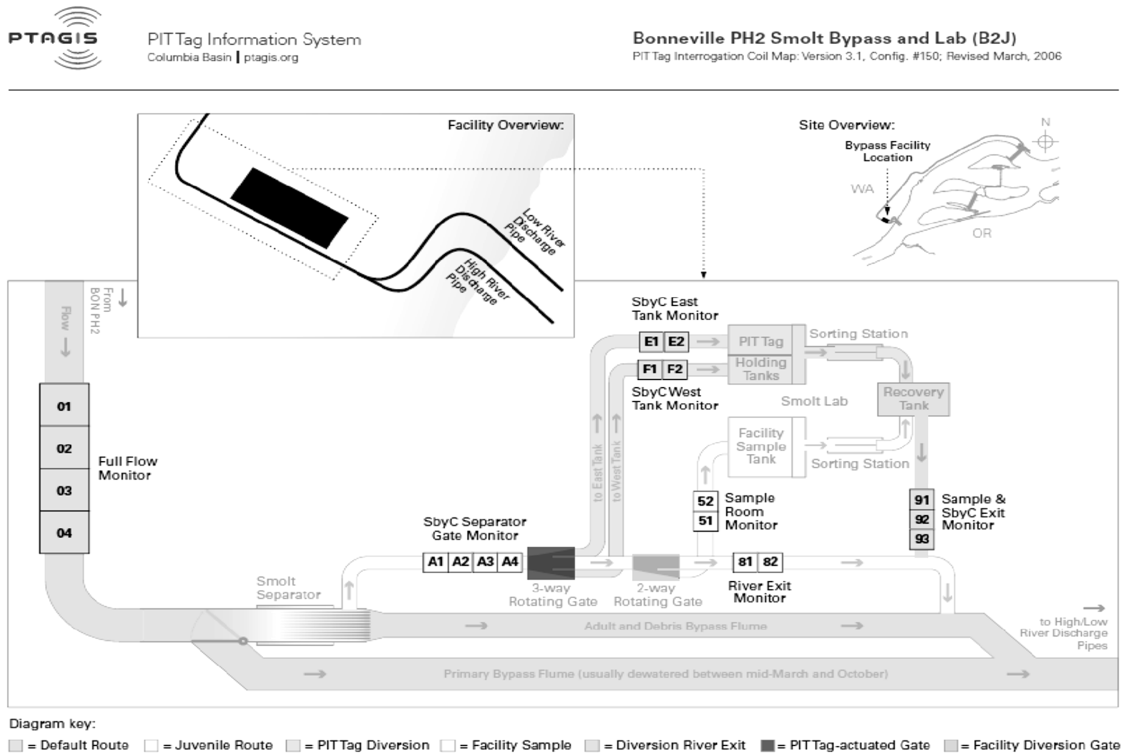

Figure 3. Diagram of the Bonneville Dam Second Powerhouse PIT-tag detection and separation-by-code system. Figure reproduced courtesy of Pacific States Marine Fisheries Commission, Pit Tag Information System.

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From 26 March to 18 April 2008, we released a total of 13,082 test fish (average fork length 74 mm). To obtain sufficient numbers of recaptures for statistical analyses, release group sizes were increased to 2,500-2,700 fish per group from the 600-1,000 per group used during 18-21 March. No testing was possible between 5 and 15 April due to USACE maintenance work on Turbine Unit 14 and due to the need to avoid upper-1% operation during the passage of 3.99 million Spring Creek Hatchery fish on 10 April.

Results—Appendix Table 1 shows data for daily releases. Initial gatewell and intake releases at lower-1% operation on 26 March showed encouraging recapture rates of about 90%. However, the first releases at upper-1% operation were recaptured at a rate of only 50%. We scheduled re-examination of the VBS at the earliest possible date. On 1 April, the screen assembly was raised to deck level, and a gap (6.35- to 9.52-mm) was observed running about one-third of the distance between screen sections. On this occasion, the gap was not caused by a lost seal but by compression of existing seal material. A second length of neoprene material was laminated over the original seal with waterproof adhesive, and the VBS was returned to service.

We scheduled weekly inspections of the VBS for the rest of the season, and no further problems of this nature were seen. Recapture rates increased to about 75% for intake releases and 85% for gatewell releases in subsequent tests of upper-1% operation in this series. It is noteworthy that the breaches in gatewell containment resulted in much higher losses of fish from the gatewell during upper-1% operations, and this was likely due to greater water velocity through the gaps at this setting.

For tests conducted from 26 March to 18 April 2008, collection-channel releases were recaptured at a high rate (98.9%) with essentially no mortality (1 of 2,681 fish released; Table 4). At lower-1% operation, recapture rates were 96.6% for gatewell and 94.6% for intake releases. In comparison, recapture rates at upper-1% operation were lower, at 74.3% for gatewell and 65.9% for intake releases. Statistical evaluation using ANOVA showed a significant difference in recapture rates between operations ($P = 0.009$). Comparison of recapture rates between gatewell and intake releases showed no significant differences, and there was no significant interaction between release location and operating level.

Table 4. Observed recapture and mortality percentages for Spring Creek Hatchery subyearling Chinook salmon released at Bonneville Dam Second Powerhouse in 3 test blocks, 26 March-18 April 2008. Average fork length of test fish was 74 mm. Turbine operations were within the 1% peak efficiency range of operation during these tests.

Release location	Turbine operation	Flow (kcfs)	Released (N)	Recaptured (%)	Mortality (%)
Collection Channel	N/A	N/A	2,681	98.9	0.0
Gatewell 14A	Lower 1%	12.1-12.8	2,658	96.6	0.8
Intake 14A	Lower 1%	12.1-12.8	2,607	94.6	1.3
Gatewell 14A	Upper 1%	16.7-18.6	2,520	74.3	5.9
Intake 14A	Upper 1%	16.7-18.6	2,616	65.9	12.8

Observed mortality rates for fish released during lower-1% operation were 0.8% for gatewell and 1.3% for intake releases. Mortality of fish during upper-1% operation was 5.9% for gatewell releases and 12.8% for intake releases. The elevated mortality at upper-1% operation was significantly different than mortality at lower-1% operation (ANOVA; $P = 0.005$). Mortality was not significantly different between release locations, nor was there a significant interaction between operating condition and release location. Median passage time for collection-channel releases was 39 min, with 10th

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and 90th percentile passage times of 36 and 42 min, respectively (Figure 4). The most rapid passage time for a fish released in the collection channel was 26 min, while the slowest was 5 d.

Test fish released into Gatewell 14A during upper-1% operation arrived at the juvenile fish facility sooner than those released during lower-1% operation. Median passage times were 2.5 h for upper-1% and 6.8 h for lower-1% operation. Respective passage times for upper- and lower-1% releases were 0.9 and 1.5 h for the 10th percentile and 6.9 and 9.3 h for the 90th. A few fish had prolonged passage times; for example, a fish released on 26 March during upper-1% operation was detected at the juvenile facility 5 d after release.

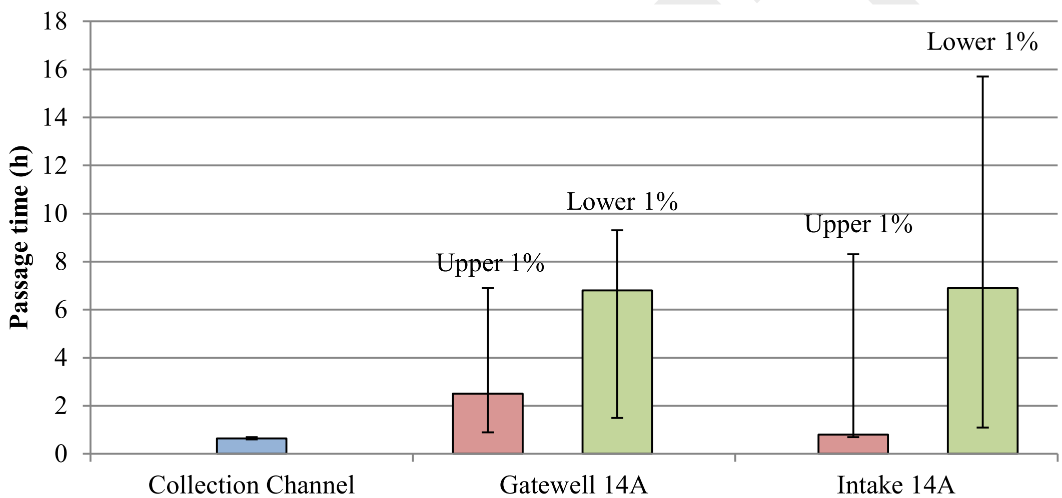

Figure 4. Median passage timing from release to arrival at the juvenile facility for Spring Creek Hatchery subyearling Chinook salmon released 26 March-18 April 2008. Vertical lines show 10th and 90th passage percentiles during upper and lower turbine operation levels within the 1% peak efficiency range. Average fork length of test fish was 74 mm.

Median passage time for test fish released to the A intake of Turbine Unit 14 was also lower for fish released at the upper-1% operation (0.8 h) than for those at released at the lower-1% operation (6.9 h). The 10th percentile passage times for releases at upper- and lower-1% operation were 0.7 and 1.1 h, respectively. The 90th percentile time was 8.3 h for upper-1% and 15.7 h for lower-1% operations. The slowest passage time was a surprising 46 d for a fish released on 26 March during upper-1% operation. Fish released on 26 March, when the VBS seal was compromised, had extended passage time also. It is likely these fish were trapped on the downstream side of the VBS assembly and remained at that location until the screen was raised for cleaning.

Analysis of timing data showed that the difference in passage time between upper- and lower-1% operation was statistically significant (ANOVA; $P = 0.008$). Passage timing was not significantly different between gatewell and intake release locations, and no significant interactions were found between release location and operating conditions.

Test Series 4: 23 April-9 May

Methods—Tests from early March to 18 April 2008 had clearly indicated that lower-1% operation was less detrimental than upper-1% operation for Spring Creek Hatchery subyearling Chinook. Therefore, USACE personnel suggested that we alter the test design by substituting releases at middle-1% operation for releases at the lower-1% operation used in the previous two test series.

Test Series 4 was conducted from 23 April to 9 May 2008, with a 5-d break in testing between 2 and 7 May. This break was needed to avoid upper-1% operations during the passage of 3.49 million Chinook salmon released from Spring Creek Hatchery on 2 May. Hatchery personnel made special provisions to hold sufficient fish back from their final release to provide for our testing after 2 May.

Procedures in Test Series 4 were identical to those in Test Series 2 and 3, except for the substitution of middle- for lower-1% turbine operation. During the test series, middle-1% flows ranged 14.9-15.7 kcfs and upper-1% flows ranged 17.9-18.7 kcfs. Test duration was 48 h, and we released a total of 10,559 subyearling Chinook salmon during the test period (average fork length 83 mm).

Results—Collection-channel releases in Test Series 4 had high rates of recapture (98.5%) and low rates of mortality (0.2%; Table 5). For gatewell releases, recapture rates were 97.1% during middle-1% operation and 83.9% during upper-1% operation. Recapture rates of turbine intake releases were 96.4% for middle- and 78.9% for upper-1% operation. Recapture rates were significantly greater for middle-1% than for upper-1% releases (ANOVA; $P = 0.001$). Differences between recapture rates for gatewell and intake releases and interactions between release location and turbine operation were not significant.

At middle-1% operation, observed mortality was 1.3% for fish released to Gatewell 14A and 2.7% for releases to the A intake of Turbine Unit 14. At upper-1% operation, observed mortality increased to 12.4% for gatewell releases and 17.8% for intake releases. The difference in mortality rates between the two operating conditions was highly significant ($P < 0.000$), whereas the effect of release location and interactions between operating conditions and release location were not significant.

Table 5. Observed recapture and mortality percentages for Spring Creek Hatchery subyearling Chinook salmon released at Bonneville Dam Second Powerhouse, 23 April-9 May 2008. Three test blocks were released, and the overall average fork length of test fish was 83 mm. Turbine operations were relative to the 1% peak efficiency range of operation during these tests.

Release location	Turbine operation	Flow (kcfs)	Released (N)	Recaptured (%)	Mortality (%)
Collection Channel	N/A	N/A	899	98.5	0.2
Gatewell 14A	Middle 1%	14.9-15.7	2,369	97.1	1.3
Intake 14A	Middle 1%	14.9-15.7	2,433	96.4	2.7
Gatewell 14A	Upper 1%	17.9-18.7	2,464	83.9	12.5
Intake 14A	Upper 1%	17.9-18.7	2,394	79.0	18.1

Passage timing was similar for fish released at upper- vs. middle-1% turbine operation (Figure 5). At upper-1% operation, median passage time was about 1 h for fish released to both the gatewell and intake. At middle-1% operation, passage time increased to 1.4 h for gatewell and 2.0 for intake releases. The relatively small difference in median passage time between releases at the two operating conditions was not significant (P = 0.149, ANOVA), nor were the effects of release location or the interaction between release location and turbine operating conditions. The 90th percentile passage times were also similar for all groups, ranging from 10 to 12 h.

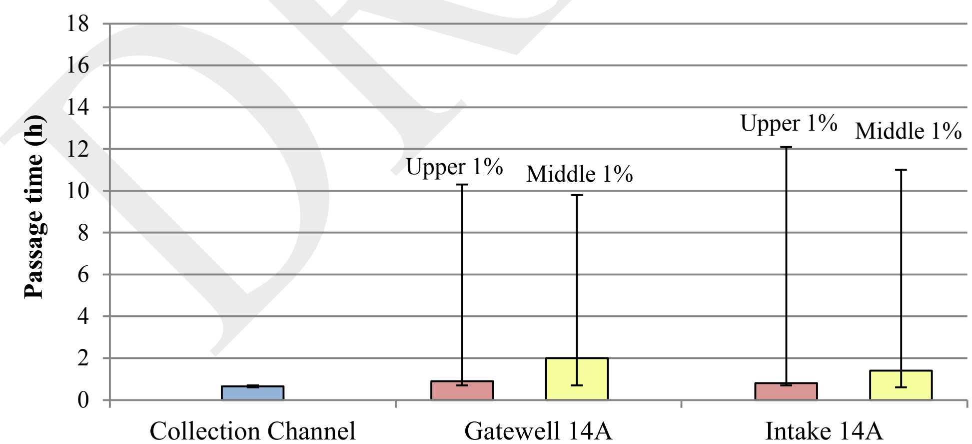

Figure 5. Median passage timing from release to arrival at the juvenile monitoring facility for Spring Creek Hatchery subyearlings released 23 April-9 May 2008. Vertical lines denote 10th and 90th passage percentiles during upper and middle operational levels within the 1% peak efficiency range. Average fork length of test fish was 83 mm.

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2009 Evaluation

Results from 2008 confirmed prior observations of high mortality for Spring Creek Hatchery subyearling Chinook during passage through the juvenile bypass system at Bonneville Dam Second Powerhouse. Both the limited testing in Turbine 12 and more extensive tests in Turbine 14 showed unacceptable mortality resulting from passage during turbine operations at the upper end of the 1% peak efficiency range.

Regional discussion of these results led to additional evaluations in 2009. In the second year of testing, we compared observed passage mortality between turbine operation at nominal lower-middle (13.5 kcfs) and middle settings (14.7 kcfs) within the 1% peak efficiency range. Test releases began on 26 March and concluded on 8 May. During this time, we released a total of 13,498 fish from Spring Creek National Fish Hatchery. Columbia River temperature during tests ranged 5.6-10.6°C. Average fork length of fish in PIT-tagged release groups ranged 63-81 mm.

Methods

In 2008 we had observed considerable variation in unit flow within turbine operating levels, largely because operations were based on unit loading in megawatts (Appendix Table 2). For 2009, turbine operation was regulated based on flow, and this allowed a narrower range of flows within each operating level (Appendix Table 4). We scheduled weekly inspections of the VBS assembly in Gatewell 14A to monitor debris loading and confirm the integrity of the horizontal seal between screen sections.

We conducted tests over an extended period in 2009 to allow separate evaluation of results for early (25 March-11 April) vs. late (20 April-8 May) date ranges within the test period. These date ranges were chosen to represent potential effects for fish released during the April and May production releases from Spring Creek National Fish Hatchery. Duration of tests was set at 24 h.

Test fish were obtained from Spring Creek Hatchery, transported, PIT-tagged, recaptured, and examined using protocols identical to those described for our 2008 study. Results from the early and late test periods were analyzed separately for statistical significance using ANOVA at $\alpha = 0.05$.

Our study design differed from 2008 in that we did not release fish from Gatewell 14A (canister releases). Examination of the 2008 data suggested that passage conditions for canister releases at Gatewell 14A were redundant to releases into the Gatewell 14A turbine intake and were possibly less representative of typical passage

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conditions. A principal concern was that canister-released fish had entered the gatewell within about 2 ft of the VBS, and therefore could be subject to immediate impingement, depending on flow through the VBS at that location. A second concern was that canister releases placed fish into the gatewell at about elevation +43 ft msl (Figure 2). At this location, test fish would not experience normal intake passage through the throat area at the top of the submersible traveling screens, nor would they encounter the lower portion of the VBS assembly unless carried downward by gatewell currents.

Our observations from 2008 also suggested that the degree of passage mortality experienced by Spring Creek Hatchery subyearling Chinook was correlated with fish size. Since we recorded fork length for a subsample rather than for all test fish, there was insufficient data to investigate this relationship. In 2009, all test fish were measured to facilitate this analysis.

We investigated the relationship between fish size and mortality for each turbine operating level by analyzing mortality data with a model that included release date and individual fish length as explicit covariates. Logistic regression was used, since the mortality process was presumed to be binomially distributed (McCullagh and Nelder 1983). Akaike's Information Criterion was used to compare the relative value of models in the candidate model set (Burnham and Anderson 2002). The final model set included release date (as a surrogate for river temperature), turbine operating level, and fish length, as well as the two-way interactions between these variables.

We also conducted a holding experiment to address the question of whether our recapture method measured the full extent of the passage effect or whether test fish were subject to latent mortality. River temperatures during the test period were favorable for holding fish, and space was available in the juvenile facility holding tanks. Test fish recaptured live were held for 10 d in 500-gallon circular tanks and fed with a commercial diet obtained from Spring Creek Hatchery. Mortalities that occurred during the course of holding and survivors were scanned for PIT-tag code to determine release date and group. Resulting data were analyzed with ANOVA and logistic regression.

Information from the 2009 releases of fish tagged with the 9.0-mm TX148511B PIT tag were used to determine reading efficiency of the full-flow and separator gate monitors at the juvenile facility. These results were published online in the PTAGIS Newsletter (August 2010, Volume 9, Issue 3). This analysis determined that detection rate for the 9.0-mm tag was 96.3% at the separator gate monitor; this rate was somewhat lower than the 99.3% detection rate for the standard, 12.3-mm TX1400SST-1 PIT tags.

Results

Spring Creek Hatchery subyearling Chinook salmon test groups were released as planned in 2009. Unit flow was controlled within a narrow range, and there were no instances of compromised sealing gaskets on the VBS. The only disruption in testing occurred on 28 April, when the test unit was unavoidably taken out of service for oil leak repair. Fish affected by that event were excluded from analyses.

Collection-channel releases showed generally high recapture rates with low observed mortality (Table 6). Recapture rates for fish released to the Turbine 14A intake ranged 90.4-94.4%. Mortality during the early test period was 4.4 and 6.8% for lower-middle- and middle-1% releases, respectively. In the later test period, conducted with larger fish, mortality was reduced to 1.8 and 3.3% for lower-middle- and middle-1% releases, respectively. Statistical evaluation of the data with ANOVA showed that observed differences in recapture rate between operating conditions were significant for tests during the early period ($P = 0.007$), but not for those during the late test period ($P = 0.142$).

Table 6. Observed recapture and mortality percentages for Spring Creek subyearling Chinook salmon PIT-tagged, released, and recaptured at Bonneville Dam Second Powerhouse during two test periods in 2009. Average fork length ranged 63-70 mm for test fish during the early test period and 72-81 mm for test fish during the late period. All turbine operations were within the 1% peak efficiency range during these tests.

Test period and release location	Turbine operation	Flow (kcfs)	Released (N)	Recaptured (%)	Mortality (%)
Early test period, 25 March to 11 April, 8 test blocks					
Collection channel	N/A	N/A	795	99.1	1.0
Intake 14A	Lower-middle 1%	13.3-13.6	3,311	93.3	4.4
Intake 14A	Middle 1%	14.6-14.8	3,337	90.4	6.8
Late test period, 20 April to 8 May, 6 test blocks					
Collection channel	N/A	N/A	598	95.2	0.0
Intake 14A	Lower-middle 1%	13.3-13.6	2,519	93.0	1.8
Intake 14A	Middle 1%	14.6-14.8	2,377	94.4	3.3

Differences in observed mortality between operating conditions were also significant for fish released during the early test period (*P* = 0.008), whereas they were not for those released during the later period (*P* = 0.153). The finding of significance for an additive difference in mortality rate of only 2.4% between operating conditions in the early test period reflected the consistency of results among test blocks, number of blocks in the test, and number of fish used in each release group.

Passage timing for Spring Creek Hatchery subyearling Chinook released during the early and late test periods of 2009 is shown in Figure 6. One-half of test fish released to the collection channel arrived at the juvenile facility within 39 min, and 90% arrived within 42 min. Median passage times for the early releases were 1.9 and 1.3 h during lower-middle and middle-1% operations, respectively. In the late test period, median passage times were greater, at 4.5 h for releases at the lower-middle-1% and 3.0 h for releases at middle-1% t operation. Differences between median passage times for fish released at the different turbine operating levels were not statistically significant for either test period ($P > 0.05$, ANOVA).

Comparison of median and 90th percentile passage time between early and late test periods (Figure 6) showed distinct differences between the two periods. Median passage time for larger fish released in the late period was about twice that of smaller fish released in the early period. The 90th percentile passage time also increased markedly, from about 7 h in the early period to about 19 h for fish released in the late period. Results suggested that larger fish may be more capable of escaping the entrapment flows present near the orifice entrance. Also, despite longer residence time in the gatewell, mortality was lower for the larger fish, suggesting they may be better able to avoid hazards, such as impingement on the VBSs.

Using the 2009 data for Spring Creek subyearling Chinook, we tested a series of logistic regression models and selected the best fitting model using Akaike's Information Criterion (AIC). A summary of this model selection is shown in Appendix Table 5. The final model included turbine operation level, fish length, release date, and the two-way interactions between them. Release date was highly correlated and monotonic with river temperature, allowing use of release date as a main effect and substitute for river temperature. The highest ranked AIC model included the main effects of turbine operational level and fish length, but not the effect of release date. Models that did not include the effects of turbine treatment and length were ranked lower by AIC.

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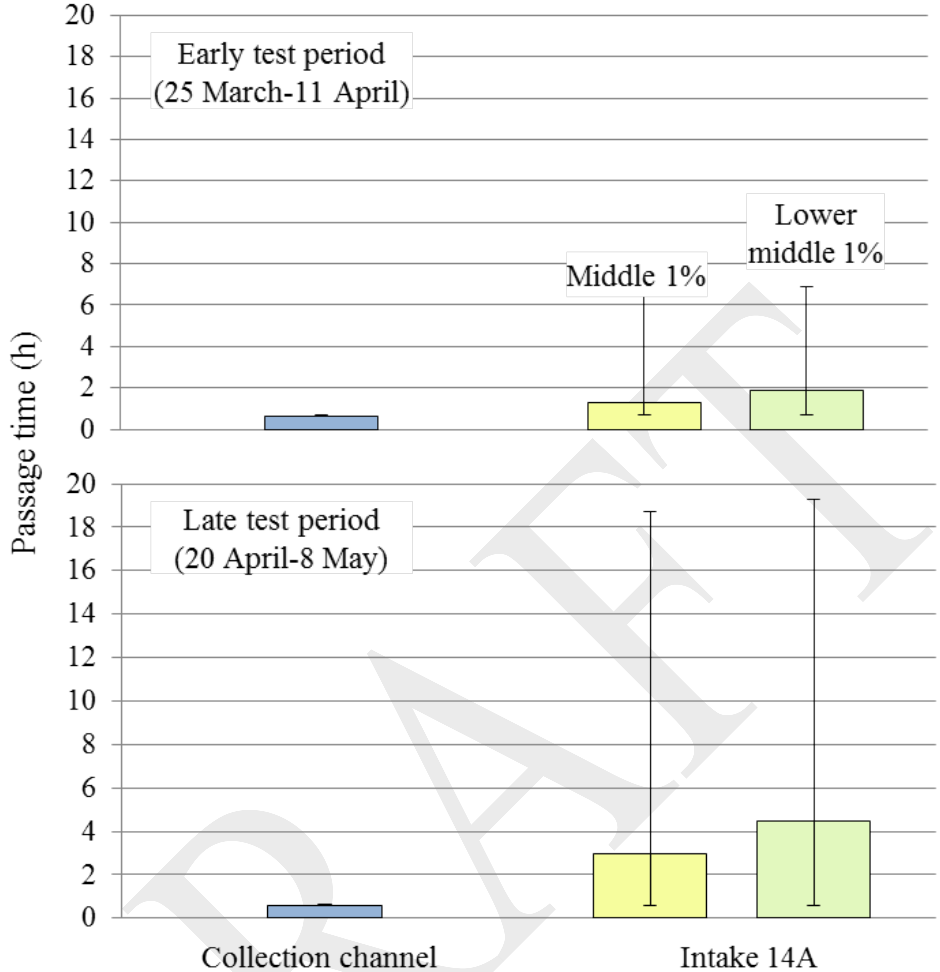

Figure 6. Median passage time from release to the juvenile fish facility at Bonneville Dam Second Powerhouse for Spring Creek Hatchery subyearling Chinook released under two turbine operation levels during early and late periods, 2009. Vertical lines denote 10th and 90th passage percentiles. Turbine operation levels were within the 1% peak efficiency range during all tests.

Modeling results provided an estimate of how the strength of the relationship between fish length and mortality varied among turbine operations (Figure 7). Middle-1% turbine operation resulted in greater mortality than lower middle-1% operation throughout the range of fish sizes, although the extent of mortality and the absolute difference between mortality at the two turbine operations both decreased with larger test fish.

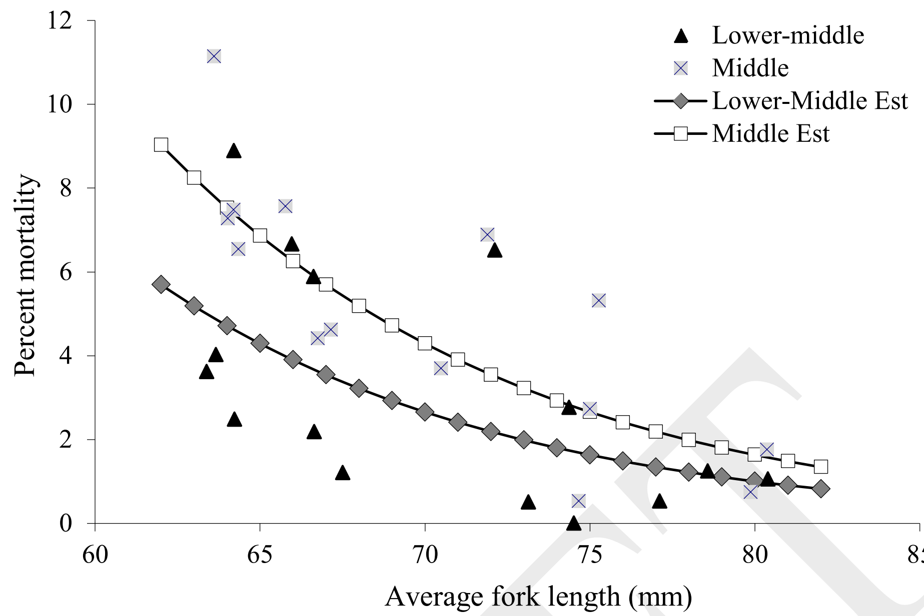

Figure 7. Results of logistic regression data from Spring Creek Hatchery juvenile Chinook salmon in 2009. Fish were released to the Turbine 14A intake at Bonneville Dam Second Powerhouse and recaptured in the juvenile facility. Test alternated between lower-middle and middle-1% efficiency operation.

We also held subyearling Chinook salmon recaptured at the juvenile facility. These fish were held for 10 d, with holding experiments designed to determine the extent of delayed mortality resulting from handling and to evaluate whether delayed mortality differed between fish released at lower-middle vs. middle-1% turbine operations. Although transport, tagging, release, and recapture of test fish involved a relatively high degree of handling, we saw no evidence of delayed mortality in reference groups released into the bypass system collection channel (Table 7). These results suggested that the fish-handling techniques used in the study were benign.

Table 7. Overall results of 10-d holding tests to evaluate delayed mortality.

Test blocks	Release location	Turbine operation	Fish held (N)	Mortality (N)	Mortality (%)
14	Channel	N/A	1,340	1	0.1
15	Intake 14A	Lower-middle	5,590	47	0.9
14	Intake 14A	Middle	5,049	21	0.4

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Similarly, low mortality rates were seen at other junctures in the process. For example, only 1 of 14,059 fish died during transport from the hatchery, 10 died during holding prior to tagging, and 72 died after tagging but before release. Of the 72 fish that died after tagging, 28 were from a single group of fish tagged for release during lower-middle 1% operation on 25 March 2009. The cause of these mortalities was unknown, but they were likely related to an overdose of anesthetic. Together, these data suggested that test fish obtained from Spring Creek Hatchery were in good condition and thus provided representative results for the stock.

Mortality rates after 10-day holding for releases into the turbine intake were 0.9% for fish released during lower-middle and 0.4% for fish released at middle-1% turbine operations. Review of the data showed that 26 of the 47 mortalities from the lower-middle 1% releases were from a single test block, whereas mortality totals for all other blocks ranged from 0 to 5 fish (Appendix Table 6).

Comparison of these data by ANOVA (outlier removed) showed no significant difference between the turbine operation treatments. Logistic regression also showed no significant difference when the outlier was removed from the data set, but a significant difference when the outlier was included. We concluded that inferences based on statistical analyses of these mortality data were not prudent, given the effects of the one influential outlier. However, the overall data set did not suggest a noteworthy delayed mortality effect.

The 10-d delayed mortality holding period also provided an opportunity to determine short-term tag loss through recovery of shed PIT tags and presence of untagged fish when the tests were terminated. For the 11,979 fish in this subset of data, a total of 11 were found to have shed tags during holding. Eight of the 11 instances were during the first 4 test blocks, when fork length of tagged fish ranged from 63 to 66 mm. We concluded that tag loss did not have a meaningful effect on recapture rate.

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RUN-OF-RIVER YEARLING CHINOOK SALMON

2008 Evaluation

Methods

Test fish were river-run yearling Chinook salmon collected from the smolt monitoring program sample at Bonneville Dam. The daily sample rate was increased to provide about 600 test fish for each release date. Known hatchery-origin fish were selected based on absence of the adipose fin. Since descaling was a principal test parameter, candidates for marking were screened to exclude fish with pre-existing descaling of about 10% or more. As a result, most test fish were ranked in the "partially descaled" category (> 3 < 20% descaling on at least one side) described by Ceballos et al. (1993). Figure 8 depicts descaling at the 3 and 20% levels.

Figure 8. Representation of threshold descaling values. Panel A shows 3% descaling; Panel B shows 20% descaling.

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Tests were scheduled to begin in mid-May in order to include as many fish from upriver locations as possible. Fish from upriver locations were preferred, partly because they are more prone to descaling (due higher degrees of smoltification) than fish from releases to nearby Bonneville Pool tributaries. In addition, the upriver fish are from ESA-listed stocks, and thus passage effects are of greater concern.

Yearling Chinook salmon selected by smolt-monitoring program personnel were held until the following day and then tagged with a 12.3-mm long, TX1400SST-1 PIT tag. Use of fish with pre-existing descaling required careful notation of descaling level at the time of tagging. This information was entered into P3 tagging files along with fork length (mm) and weight (g). Level of anesthetic was calibrated to produce anesthesia in about 2 minutes. Required anesthetic concentrations ranged from 50 to 70 mg/L, depending on water temperature, fish size, and fish condition. After tagging, fish were held with a flow-through river water supply pending release the following day.

Releases were made into the bypass system collection channel and into the A intake of Turbine 14. Releases into Gatewell 14A were discontinued for this and later tests with concurrence of the USACE. On the day of release, fish were transported to the intake deck of the second powerhouse in 720-L tanks provided with oxygenation (intake releases) or in oxygenated 75-L containers (channel releases). Other release procedures were identical to those used previously for tests of Spring Creek Hatchery fish.

Operating levels compared were the middle vs. the upper range of 1% peak turbine efficiency. Tests of each operational level were planned for 24-h periods, with operating conditions alternating from day to day. However, the first and only release block took place on 14 and 16 May 2008 because a 1-d suspension of testing was needed to clean the VBS assembly between releases.

Recaptured test fish were examined at the juvenile monitoring facility. Descaled areas on each fish were carefully estimated and entered into P3 recapture files using methods similar to those described by Gilbreath et al. (2004). Data were loaded into a database program, and descaling of each fish between tagging and recapture was compared to determine the net increase in descaling. Processed data for mortality, descaling, and timing were analyzed for statistical significance by ANOVA. Injuries other than descaling were too few to warrant analysis.

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Results

Tests of river-run yearling Chinook salmon were not completed in 2008 due to the regional decision to pull all submersible traveling screens at the Bonneville Dam Second Powerhouse, beginning about 21 May. This decision was related to an increase in river flow from about 300 kcfs on 17 May to about 400 kcfs on 20 May. This flow increase was due to system-wide heavy runoff, which carried a large amount of suspended debris that plugged VBSs rapidly.

Despite considerable effort, Bonneville Project personnel were unable to clean the VBSs rapidly enough to maintain the criteria for head differential across the screens. In addition to risking screen failure, the increased velocity through partially clogged screens was sufficient to impinge and kill juvenile salmonids of all species. Figure 9 shows a representative clogged screen on 19 May 2008. Submersible traveling screens at the second powerhouse remained out of service until late June, when river flows decreased to about 300 kcfs.

Figure 9. Bonneville Dam Second Powerhouse VBS panel on 19 May 2008. Photo shows the lower VBS section clogged with debris.

A single test block was completed prior to pulling the submersible traveling screens. Of 255 yearling Chinook salmon released into the collection channel, 97% were recaptured. For these releases, overall mortality was 1.4%, descaling (≥ 20%) was 1.6%, and median passage time was 40 min (Table 8). Data from these releases were insufficient for meaningful statistical analysis. Lack of mortality in releases during upper-1% operation was surprising; however, we were unable to detect errors in data recording or other test procedures that would have accounted for these low rates of mortality. One additional group of 289 fish was released on 21 May at upper-1% operation. Results from this release were compromised by a clogged VBS, and mortality and descaling rates for this group were 13.5 and 9.3%, respectively.

Table 8. Data from releases of river-run yearling Chinook salmon to the collection channel and from a single test block of releases to the A intake of Turbine 14 at middle- and upper-1% turbine operations, 2008.

Release	Released (N)	Recaptured (%)	Mortality (%)	Descaling ≥20% (%)	Timing (h)
Channel	255	97.0	1.4	1.6	0.7
Intake 14A, middle 1%	250	98.8	4.9	0.5	1.6
Intake 14A, upper 1%	275	99.6	0.0	4.7	2.1

2009 Evaluation

Methods

In 2009, methods for acquisition of test fish, tagging, holding, release, recapture, data collection, and data processing were identical to those used in 2008 for river-run yearling Chinook salmon. Primary statistical analysis of block data was by ANOVA, with the significance level set at $\alpha = 0.05$. We began testing on 12 May and concluded on 5 June 2009. Turbine operation was switched between middle- and upper-1% settings on alternate days. Eight test blocks were completed, each of which included reference releases into the bypass system collection channel and releases at each turbine operating level. A total of 6,770 fish were released during testing. Average fork length of test fish was 142 mm and average weight was 28.9 g (grand average for all release groups).

As an exploratory measure, we also conducted a post-hoc comparison of the timing distributions for river-run yearling Chinook in each of the three descaling categories (descaled, partially descaled, and non-descaled). Within the subset of all test

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fish recaptured alive, we collected 318 descaled, 262 partially descaled, and 2,229 non-descaled fish for this comparison. Assignment to a group was based on net change in descaling status between time of tagging and time of recapture. Passage distributions were estimated using a non-parametric Kaplan-Meier method (Lawless 1982). This method estimated the proportion from each descaling category that passed at each successive discrete point where passage of one or more fish occurred. Significant differences between descaling level cumulative curves were determined using a log-rank chi-square test (Tableman and Kim 2004). Due to the similarity of the descaled and partially descaled categories, these groups were pooled for comparison to the non-descaled group.

Results

The overall test results (Table 9) were characterized by high recapture rates for all release groups. Mortality and descaling rates were less than 1% for reference groups released to the bypass system collection channel and only slightly higher for fish released to the intake of Turbine 14A during middle 1% operation. However, with unit operation in the upper 1% range, mortality and descaling levels increased markedly, to 4.4 and 11.5%, respectively. The small difference in recapture rate between turbine operations was statistically significant ($P = 0.050$, ANOVA), as was the 3.9% increase in mortality observed for releases at upper-1% operation ($P = 0.003$). Similarly, the increase in descaling rate at upper-1% operation was highly significant ($P = 0.002$).

Table 9. Observed recapture, mortality, and descaling percentages for PIT-tagged run-of-river yearling Chinook salmon released at Bonneville Dam Second Powerhouse and recaptured at the juvenile monitoring facility. Eight test blocks were completed between 12 May and 5 June 2009. Turbine operations were ranges within 1% of peak operating efficiency during these tests.

Release location	Turbine operation	Flows (kcfs)	Released (N)	Recaptured (%)	Mortality (%)	Descaling ≥20% (%)
Collection channel	N/A	N/A	389	97.7	0.3	0.3
Intake 14A	Middle 1%	14.6-15.1	3,228	98.4	0.5	1.0
Intake 14A	Upper 1%	17.3-17.9	3,153	97.4	4.4	11.5

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Median passage time for river-run yearling Chinook released into the bypass system collection channel was 38 min, with the 90th passage percentile attained 43 min after release (Figure 10). Median passage times for fish released into the 14A intake were 1.7 and 2.7 h for releases at middle and upper 1% operation, respectively. The 90th passage percentiles were 5.3 h for middle 1% releases and 8.9 h for releases at upper 1% turbine operation. Statistical analysis showed the longer median passage time shown by releases at upper 1% operation were significant ($P = 0.007$).

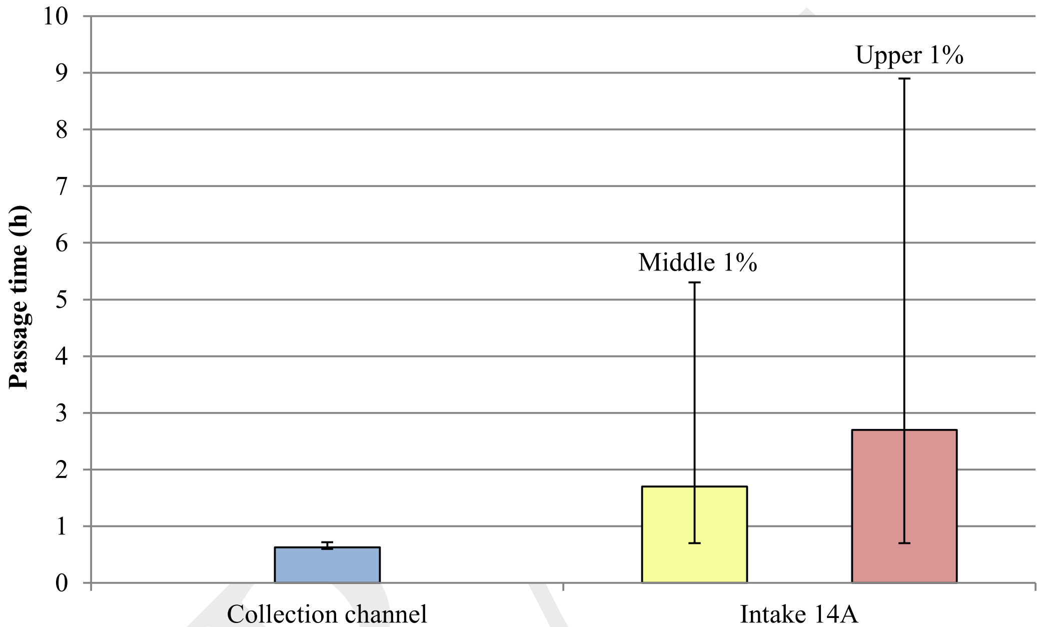

Figure 10. Median passage timing for river-run yearling Chinook from release at two locations within the Bonneville Dam Second Powerhouse to arrival at the juvenile monitoring facility, 2009. Vertical lines denote 10th and 90th passage percentiles for turbine operational levels within the middle and upper middle range of 1% peak efficiency.

We examined the timing data further by charting passage time by descaling classification (Figure 11). These examinations indicated more rapid timing for fish in the non-descaled than descaled categories, suggesting that a post-hoc statistical comparison between descaling classification groups would be warranted.

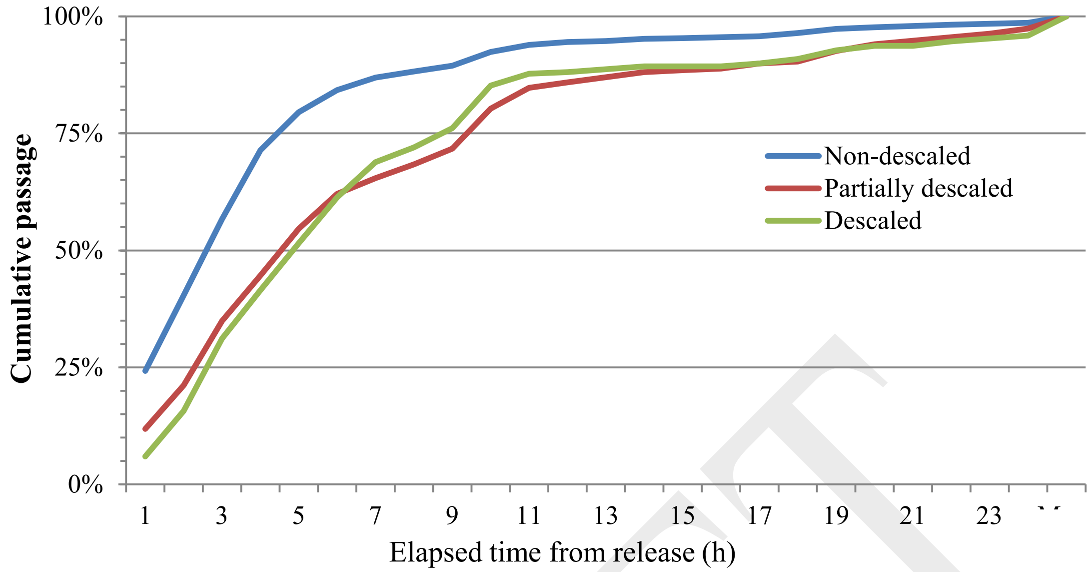

Figure 11. Cumulative passage time distributions for run-of-river yearling Chinook salmon released at Bonneville Dam Second Powerhouse in 2009. Fish were classified by extent of descaling after recapture at the juvenile monitoring facility. Data are for releases into Turbine 14A intake at upper 1% operation.

Significant *P*-values for this post-hoc test suggested that higher levels of descaling may be associated with longer gatewell residence times (Table 10). This hypothesis could be further tested by releasing fish into a gatewell with closed orifice(s). Orifice gates could be opened after specific time intervals and descaling levels compared among release groups exposed to the different confinement times.

Table 10. Results from post-hoc comparison of cumulative passage data by descaling rank using the non-parametric Kaplan-Meir method.

Group	N	Median time to failure (h)	SE	95% CI	Median (h)
Descaled	318	7.4	0.5	6.4-8.4	4.8
Non-descaled	2,229	3.7	0.1	3.5-3.9	2.3
Partially descaled	262	7.2	0.5	6.2-8.2	4.6
Pooled descaling	587	7.3	0.4	6.6-8.0	4.7

Test	χ2	df	*P*	Conclusion
Log-rank, 3 groups	183.02	2	<0.001	Non-descaled < descaled & partially descaled
Log-rank, 2 groups	182.90	1	<0.001	Non-descaled < any descaled

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RUN-OF-RIVER SUBYEARLING CHINOOK SALMON

2008 Evaluation

Methods

Tests using river-run subyearling Chinook salmon began in July, after the high river flows had subsided and submersible traveling screens had been replaced in the second powerhouse turbine intakes. Potential test fish were selected from the daily smolt monitoring program (SMP) sample by program personnel. Typically, the daily SMP sample rate was increased to provide about 350 test fish on each release date: 100 for the collection channel release and 250 for the turbine intake release. Fish with and without adipose-fin clips were selected. Other fish-handling protocols were identical to those used for yearling Chinook tests in 2008. Data were analyzed using a two-sample *t*-test ($\alpha = 0.05$).

River-run subyearling Chinook salmon were released into the bypass system collection channel and Turbine 14A intake during middle- and upper-1% turbine operation. Test duration was set at 24 h, with turbine operation alternated between tests. One test block was conducted per week during the first 3 weeks of July. River flow fell from over 300 kcfs in week 1 to about 170 kcfs in week 3, while river temperature during this same period increased from 17.8 to 20.6°C. Turbine operational levels for each release date are shown in Appendix Table 2.

A total of 2,123 fish were released, with 560 released into the collection channel, 743 into the intake at middle 1% operation, and 820 into the intake at upper 1% operation. Average size of fish in individual release groups ranged from 97 to 111 mm, and the grand average of fish used in tests was 103 mm.

Results

The river-run subyearlings used in the study responded well to handling, despite river temperatures increasing to 20.6°C by the final test date. Mortality during the approximate 24-h period between tagging and release was 0.6%. There was no observed PIT-tag loss between tagging and release.

Recapture rates ranged from 97.4% for collection-channel releases to about 95% for turbine-intake releases (Table 11). Recapture rates between turbine-intake releases were similar and not statistically different between operation levels. Observed mortality increased from 0.6 to 2.6% as turbine operation shifted from middle- to upper-1% levels;

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however, the difference was not significant ($P = 0.288$). Similarly, the increased descaling rate at upper-1% operation was not significantly different between turbine treatments ($P = 0.175$).

Table 11. Observed recapture, mortality, and descaling percentages for run-of-river subyearling Chinook salmon released at Bonneville Dam Second Powerhouse and recaptured at the juvenile monitoring facility. Three test blocks were completed between 1 and 17 July 2008. Turbine operations were within the 1% peak efficiency range during all tests, with flows of 14.1-15.1 kcfs during middle-1% tests and 16.6-18.1 kcfs during upper-1% tests.

Release location	Turbine operation	Released (N)	Recaptured (%)	Mortality (%)	Descaling ≥ 20% (%)
Collection channel	N/A	560	97.4	0.4	0.7
Intake 14A	Middle 1%	743	94.6	0.6	0.4
Intake 14A	Upper 1%	820	94.9	2.6	3.3

For collection-channel releases of river-run subyearling Chinook salmon in 2008, median passage time was 38 min, and the 90th percentile passed within 44 min of release (Figure 12). Increases in turbine operation from the middle-1% to the upper 1% levels resulted in an increase in median passage time from 2.7 to 4.0 h. The 90th percentile passage timing also increased from 8.4 h for middle-1% to 12.6 h for upper-1% operation. The difference in median passage time between these two turbine operations was not statistically significant ($P = 0.241$, df = 4).

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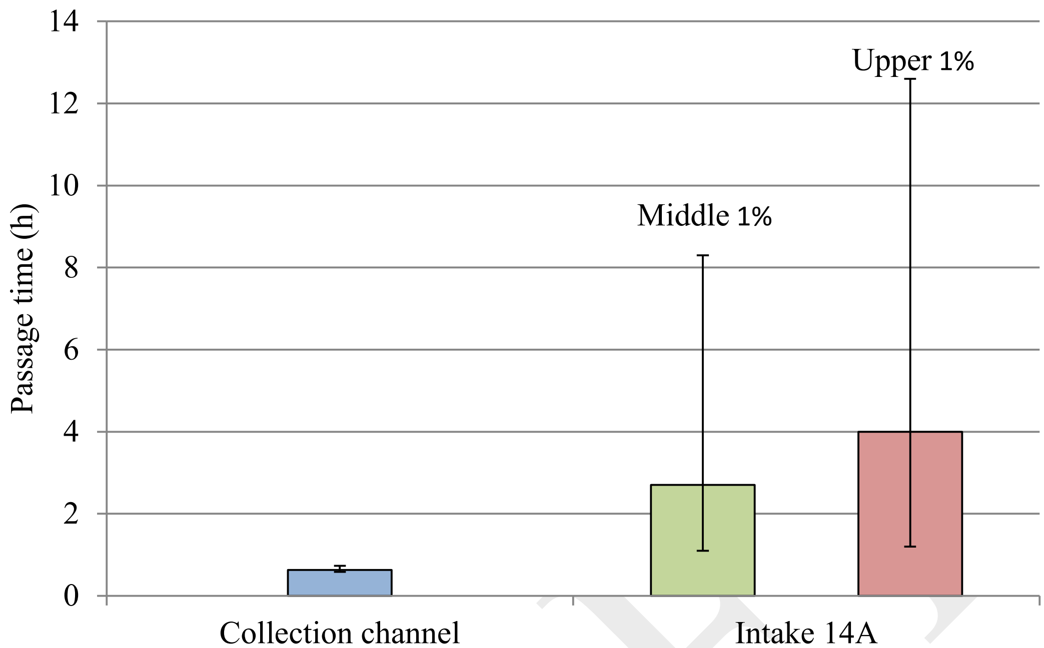

Figure 12. Median passage timing for PIT-tagged, run-of-river subyearling Chinook salmon from release at the Bonneville Dam Second Powerhouse to arrival at the juvenile monitoring facility in 2008. Vertical lines denote 10th and 90th passage percentiles. Annotations refer to turbine operational levels within the 1% peak efficiency range.

2009 Evaluation

Methods

In 2009, run-of-river subyearling Chinook were selected from the smolt monitoring sample using the same criteria detailed above for 2008 testing. However, we increased release sizes for turbine intake groups from about 350 fish in 2008 to about 410 fish in 2009. Collection channel release sizes were minimized, from about 100 fish per release in 2008 to about 50 per release in 2009. Other fish-handling protocols were identical to those used for subyearling Chinook salmon tests in 2008. Data were analyzed for statistical significance using ANOVA ($\alpha = 0.05$).

Prior to beginning of testing, USACE personnel requested that we add a third treatment group to the test design: a turbine intake release during upper-1% operation with both gatewell orifice gates open. We adjusted the release schedule to include this new treatment group. Releases began on 16 June 2009 and were conducted in 3-d blocks with each test running 24 h. Tests were alternated in the following sequence: middle-1% operation with 1 open orifice, upper-1% operation with 1 open orifice, and upper-1% operation with 2 open orifice gates. Collection channel releases were made on the second day of each 3-d test block. Data for individual releases is listed in Appendix Table 3.

Four test blocks were completed prior to 2 July, when decreasing river flows increased operating head to the point where turbine loading was in the upper 1% efficiency level before unit flow reached the 17.8 kcfs required for upper 1% testing. After consultation with the USACE personnel, we decided to complete testing by substituting a "middle upper-1%" operation (16.3 kcfs) for the upper-1% operation (17.8 kcfs) used during 16 June-1 July. Three total and one partial test blocks were completed during 2-12 July under this revised design. Operational data for all release dates is shown in Appendix Table 4.

A total of 10,137 river-run subyearling Chinook salmon were released for all tests. Average fork length in individual release groups ranged 100-110 mm, with a grand average fork length of 105 mm.

Results

Mortality in the 24-h period between tagging and release was 0.2%, and passage mortality for reference groups released into the bypass system collection channel was 0.3%. These low mortality rates suggested that fish condition was not compromised by study protocols. Loss of PIT tags between tagging and release was 0.1%. River temperatures were moderate for summer, increasing from 16.5 to 19.3°C during testing.

Recapture rates were uniformly high, ranging 95.9-97.3%, with no significant differences between operations (ANOVA; Table 12). Overall statistical analysis determined that mortality for upper-1% releases with one open orifice (4.3%) was significantly greater than for all other test conditions ($P = 0.012$), and that mortality did not differ significantly among other test groups.

Direct statistical comparisons of recapture and mortality rates were also made between releases with one vs. two open orifice gates for both the upper and middle-upper 1% operations. Recapture rates were not significantly different in either comparison. Mortality was significantly higher with one vs. two open gates at upper 1% operation ($P = 0.040$). At the mid-upper 1% operation, the difference in mortality between gate configurations was not significant.

Descaling rates were low for all release groups and exceeded 0.5% only for intake releases at upper 1% operation. For intake releases at the upper 1% operation, descaling was 2.6% for tests with one orifice open and 1.2% for those with two open. Comparison of the overall data by ANOVA showed that for fish released at upper 1% operation with one orifice open, descaling was significantly greater than that of fish released at all other configurations ($P = 0.002$). Descaling rates did not differ significantly among the remaining test groups.

We also compared descaling with one or both orifice gates open for fish released at upper vs. middle-upper 1% turbine operation. Results from these analyses showed that at the upper 1% operation, the difference between orifice configurations was nearly significant ($P = 0.056$) while at the mid-upper 1% operation, the difference between orifice configurations was not significant ($P = 0.936$).

Table 12. Observed recapture, mortality, and descaling percentages for PIT-tagged run-of-river subyearling Chinook salmon released at Bonneville Dam Second Powerhouse and recaptured at the juvenile monitoring facility in 2009. Turbine operations were within the 1% peak efficiency range for all tests, with flows of 14.6-14.8 kcfs during the middle-1%, 15.5-16.5 kcfs during middle-upper 1%, and 17.4-17.9 kcfs during upper 1% evaluations.

Release location	Turbine operation	Orifice open (N)	Released (N)	Recaptured (%)	Mortality (%)	Descaling ≥ 20% (%)
Channel	N/A	N/A	400	96.7	0.3	0.3
Intake 14A	Middle 1%	1	3,167	97.2	2.6	0.5
Intake 14A	Upper 1%	1	2,058	96.8	4.3	2.6
Intake 14A	Upper 1%	2	1,641	95.9	2.4	1.2
Intake 14A	Mid-up 1%	1	1,228	96.9	2.8	0.5
Intake 14A	Mid-up 1%	2	1,643	97.3	1.4	0.4

For river-run subyearling Chinook released to the collection channel, median passage time was 38 min, and 90th percentile passage time to the juvenile monitoring facility was 48 min (Figure 13). We released test fish into the A intake of Turbine 14 with one orifice open during middle, middle-upper, and upper operations within the 1% peak turbine efficiency range. For the first time during the 2008-2009 testing, we were also able to determine passage timing for fish released with both Gatewell 14A orifice gates open. Passage with two open orifice gates was tested at the middle-upper-1% and upper-1% turbine operations.

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Median passage times with one open gatewell orifice were 2.6, 3.5, and 6.4 h, respectively, for releases at middle, middle-upper, and upper 1% turbine operation. The 90th passage percentiles also increased in a stepwise manner from 9.9 h at middle-1% to 15.4 h at upper-1% operation.

With both orifice gates open, median passage times were similar for middle-upper-1% (2.9 h) and upper-1% operation (2.8 h). These values were very close to the 2.6 h passage time observed for fish released with one open orifice at the reduced middle 1% operation. Passage with two open orifice gates produced a notable reduction in the 90th percentile passage times, from 15.4 h with one open orifice to 8.0 h with two.

Statistical analysis of overall passage time data showed that median passage time of treatment groups released during upper-1% operation with one open orifice was significantly greater than that of all other treatment groups. Median passage time was not significantly different among the other treatment groups ($P = 0.028$, ANOVA). Direct comparisons of median passage time between releases with one vs. two open orifice gates showed no significant differences at either the middle-upper 1% ($P = 0.335$) or upper-1% operation ($P = 0.100$).

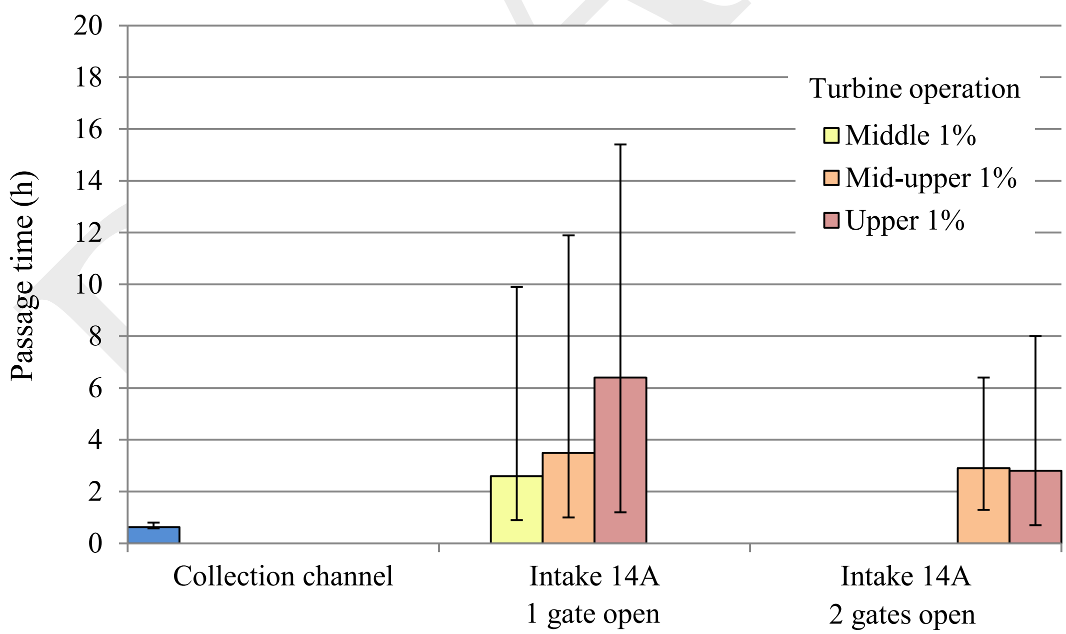

Figure 13. Median passage time of run-of-river subyearling Chinook salmon from release at the Bonneville Dam Second Powerhouse to arrival at the juvenile monitoring facility in 2009. Whiskers denote 10th and 90th passage percentile times.

FISH HEALTH SURVEY

Methods

Given the scope of the existing fish-health monitoring program for Spring Creek National Fish Hatchery by the U.S. Fish and Wildlife Service (FWS), we did not need to survey these fish for health evaluations. For river-run yearling and subyearling Chinook salmon, fish-health surveys required sacrifice of about 174 fish of each run type. This sample size followed the recommendation of Piper et al. (1982) for minimum numbers required to obtain estimates with a 95% confident interval for a minimum difference of 5% in incidence of disease.

Labor and materials for the sampling were provided by staff of the U.S. Fish and Wildlife Service Lower Columbia River Fish Health Center. Subsamples of 29-30 river-run juvenile Chinook salmon were removed from the pool of potential test fish on each of 8 d during the study. In 2008, yearling Chinook salmon were collected on 13, 15, and 20 May and subyearling Chinook on 30 June and 7, 9, 14, and 16 July. Fish were euthanized, placed on ice, and transported to the Lower Columbia River Fish Health Center.

Pooled samples were cultured on the epithelioma papulosum cyprini (EPC), and Chinook salmon embryo (CHSE-214) cell lines. The EPC samples were then analyzed to detect the presence of viral hemorrhagic septicemia virus (VHSV), and the CHSE-214 to detect infectious hematopoietic necrosis virus (IHNV). Kidney smears from individual fish were evaluated by direct fluorescent antibody test (DFAT) to detect *Renibacterium salmoninarum*, the causative agent of bacterial kidney disease (BKD). Wet mounts from pepsin-trypsin digest of pooled cartilage samples were scanned for the myxozoan parasite *Myxobolus cerebralis*, the cause of whirling disease.

In 2009, subsamples of 26 to 60 juvenile river-run Chinook salmon were collected on each of 13 d during the study. Yearling Chinook salmon were obtained on 20 and 27 May and on 2 and 4 June. Subyearling Chinook salmon were sampled on 15, 17, 23, 25, and 30 June and on 2, 7, and 9 July. As in 2008, samples were tested to detect presence of VHSV, IHNV, *Renibacterium salmoninarum*, and *Myxobolus cerebralis*. In addition, kidney tissue was plated on tryptic soy agar (TSA) or brain heart infusion agar (BHIA) media for primary isolation of bacterial pathogens causing other fish diseases, including *Aeromonas salmonicida* (furunculosis), *Yersinia ruckeri* (enteric redmouth disease), and *Pseudomonas* spp. (fin rot).

Results

Fish health surveys conducted by the U.S. Fish and Wildlife Service in 2008 and 2009 did not detect any conditions in Spring Creek Hatchery production fish that would have compromised their ability to survive after release (Susan Gutenberger, FWS, personal communication).

In 2008, we were unable to sample the target number of either yearling or subyearling Chinook salmon. Totals of 87 yearling and 148 subyearling Chinook were submitted for disease surveys in 2008. The viral pathogen VHSV was not detected, but the IHNV virus was isolated from a pool of 29 yearling Chinook salmon sampled on 15 May. *Renibacterium salmoninarum* antigen was detected in two fish; a yearling Chinook salmon sampled on 15 May and a subyearling Chinook salmon sacrificed on 30 June. *Myxobolus cerebralis* was not detected.

In 2009, 179 river-run yearling Chinook salmon and 237 river-run subyearling Chinook salmon were sampled for disease workups. Of the two viral pathogens, VHSV was not found, however one 3-fish pool of yearling Chinook salmon tested positive for IHNV. The bacterial pathogen *Renibacterium salmoninarum* was detected from one yearling Chinook salmon sacrificed on 4 June. Other bacterial pathogens were not found in smears of kidney tissue on TSA media. As in 2008, *Myxobolus cerebralis* was not detected. Examination of the hindgut of one subyearling Chinook salmon showed *Ceratomyxa shasta* present at a low level.

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DISCUSSION

After completion of the Bonneville Dam Second Powerhouse in 1982, research focused on methods to improve fish guidance efficiency to meet the minimum criteria of 70%. Acceptable FGE was eventually realized through structural modifications that increased upward flow into the gatewells (described in our Introduction and in Figure 1). The increased gatewell flow in turn required a new design for the vertical barrier screen (VBS) to balance flow through its surface area at a velocity safe for the passage of salmonid fry. Gatewell modifications were biologically tested in 2001 and 2002 (Monk et al. 2002, 2004) under the prevailing operational mode (Automatic Governing Control in 2002) and with the prototype VBS configuration available at that time.

Although structural modifications to the VBSs and a new VBS dual-guide system were adopted after 2002, no further biological testing has been done until our work in 2008-2009, which was prompted by mortality to Spring Creek Hatchery fish in 2007. The following observations from review of Monk et al. (2002, 2004) suggest that additional biological testing would have been prudent:

1) Turbine unit flows at the upper-1% efficiency operation (17.8 kcfs) were not tested in 2001-2002. Flow levels that were tested averaged 13.6-15.8 kcfs, values now associated with middle 1% operation. Historical daily flow at Bonneville was obtained from the Columbia River DART database (CRDART 1998). These data suggest that flows at upper 1% operation were not realized in 2001 due to low river flows (107.5-180.4 kcfs during spring tests and 83.2-166.3 kcfs in summer).

   However, river flows in 2002 were favorable, ranging 198.2-313.6 kcfs in spring and 216.7-359.5 kcfs in summer. Although the reason is unknown, tests at reduced unit flow levels in 2002 may have resulted from balanced powerhouse operation under Automatic Governing Control.

2) The gatewell release location in 2001-2002 (Figure 2, elev. +50) did not expose test fish to gatewell entry or to the lower three-quarters of the profile-wire VBS panel during initial gatewell ascent.

3) Small coho *O. kisutch* fry (average 40.9 mm fork length) were released into a test gatewell in 2002. Although no impingement of these fish was observed on the VBS, only 57% were recaptured at the juvenile monitoring facility. This low recapture rate suggests that further investigation was warranted.

4) Spring Creek Hatchery fish were not used in the 2001-2002 studies, although excessive passage mortalities for these fish were observed in March 1999, soon after

initial water-up of the conveyance pipe from the second powerhouse to the location of the present juvenile monitoring facility.

5) Following prototype modifications in 2001-2002, the upstream-to-downstream span of the gatewell was about 5 ft, while the present dimension is about 4 ft due to installation of dual VBS guides. This modification effectively reduced volume of the gatewell holding area by 20%. As a result, fish are potentially forced closer to the VBS panels during gatewell residence.

Spring Creek Hatchery Subyearling Chinook Salmon

Test releases of PIT-tagged Spring Creek Hatchery subyearling Chinook salmon in 2008-2009 provided consistent evidence that passage mortality in this stock increased in a stepwise manner as second powerhouse turbine operation was raised to higher levels within the 1% peak efficiency range (Table 13). We found no reason to suspect that poor fish condition in this stock contributed to these mortality rates. Fish health surveys conducted by the U.S. Fish and Wildlife Service in these years did not detect disease conditions that would have predisposed fish to passage mortality (S. Gutenberger, personal communication). Further, direct mortality during handling and tagging was minimal, and mortality during a 10-d holding period after recapture was low. We therefore concluded that observed mortality during tests was a function of turbine operational level, which in turn created adverse flow conditions within the A gatewell of Turbine Units 12 and 14.

Although mortality was most severe during upper-1% operation, each increase in operational level resulted in higher mortality to Spring Creek Hatchery test fish. Examination of the 2008-2009 data revealed that for test fish released into turbine intakes, higher operating levels resulted in increased mortality for 22 of 24 individual test blocks (Appendix Tables 1 and 3). Summary data shows that in all 11 comparisons, mortality was greater at the higher operating level (Table 13), and the difference was statistically significant in 8 of the 11 comparisons.

The extent of mortality decreased as Spring Creek Hatchery fish grew to larger sizes, as suggested by logistic regression modeling and comparison of early and late-season test results in 2009 (Figure 7 and Table 6). Based on these observations, it may be possible to operate turbines at a higher level within the 1% peak efficiency range during release of production fish in May; however, this would not be advisable during April. On the other hand, a relatively small increase in potential mortality at upper 1% operational levels may be acceptable when balanced against competing demands, such as reducing dissolved gas, maximizing FGE, or generating power.

Field observations and test results also point to the importance of careful observation and maintenance of the horizontal seal between VBS sections. Even small breaches in the integrity of this seal will allow fish to pass into the downstream side of the VBS assembly; such movement will increase potential mortality and injury as fish are scraped or wedged while passing through the gaps. Based on recapture rates observed during Test Series 2 and 3 in 2008, loss of Spring Creek Hatchery fish through gaps in the seal was proportionately greater at upper-1% than at lower-1% turbine operation (Tables 3 and 4).

At present, in-season VBS removal for cleaning and inspection is undertaken when the head differential across the VBS assembly exceeds criteria levels. Removal and cleaning may be adequate to maintain criteria flow through the VBSs; however, additional inspections are necessary to detect problems with gasket seals in the VBS assembly. Based on our experience in 2008, video inspection alone did not ensure detection of problems.

Timing data for Spring Creek Hatchery releases shows more rapid passage for fish released at the higher operational levels (Table 13). This was observed in all six comparisons in 2008-2009, even after Spring Creek fish had reached larger sizes (Test Series 4 in 2008 and Test Series 2 in 2009). The finding that test fish released under the least favorable condition (i.e. upper-1% operation), would have shorter passage times while sustaining the highest levels of mortality was counterintuitive. Typically, shorter passage time equates to less exposure to adverse conditions in the gatewell, and consequently lower rates of mortality, injury, and descaling. The low recapture rates of fish released at upper-1% operation may provide insight into this finding—simply put, the longer these small subyearling Chinook salmon remained in the gatewell, the more likely they were to escape, either through gaps within the gatewell or via the orifice, or to be impinged and trapped on the VBS. Evidence of impingement, including intact and decomposed mortalities still bearing PIT tags, were observed on most occasions when the VBS assembly was raised for inspection and cleaning.

We propose the following hypothesis: Spring Creek Hatchery subyearlings that are entrained in turbulent gatewell flows gradually tire and become susceptible to impingement on VBSs, even at otherwise benign velocities. For this stock, the effect of fatigue may result in impingement at flows that would not be problematic in other passage situations. This hypothesis could be tested by a variety of methods, including test of swimming stamina and measurement of plasma lactate levels in fish with known gatewell residence times.

We caution that the results observed with Spring Creek Hatchery fish cannot be used for inferences about other sensitive stocks, such as naturally produced salmon fry or

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juvenile sockeye salmon *O. nerka*. However, it is worthwhile to consider that while problems with these stocks are seldom observed in smolt monitoring program samples, a portion of mortalities may remain impinged on VBSs and thus may not be detected in routine monitoring.

A second qualifier for our results is that, with the exception of the brief test series conducted with fin-clipped fish in 2008, all testing was done in the A intake of Turbine 14. Of the A, B, and C intakes for each turbine unit, the A intake typically has the greatest inflow. Therefore, A intakes would be expected to show the greatest adverse passage effects. Similarly, it is unknown whether Turbine 14 represents a "best-case" or "worst-case" passage situation relative to other turbine units of the second powerhouse.

Run-of-River Yearling Chinook Salmon

Adverse river conditions prevented completion of testing in 2008; however, the full test series was conducted without incident in 2009. Our results from 2009 showed statistically significant differences between turbine operations for mortality, descaling, and passage timing ($\alpha = 0.05$; Table 9). All parameters increased as turbine settings switched from middle- to upper-1% operation, with mortality rates increasing by 3.9% and descaling rates by 10.5%. These results showed that upper-1% operation was problematic. The ad hoc treatment of timing data by descaling classification (Figure 11) pointed to length of gatewell residence as a key factor in generation of adverse passage effects.

These results are subject to the same caveats mentioned above for Spring Creek Hatchery subyearling Chinook salmon: the ability to make inferences to other river-run yearlings is limited in that only one intake of one turbine unit was evaluated. Further, by design, our results were more representative of the yearling Chinook that passed during the latter portion of the migration season than of those that passed during late April to early May, when large numbers of fish are present from releases of Bonneville pool hatcheries.

Run-of-River Subyearling Chinook Salmon

Work with this species was delayed until after the high water problems of late May and June 2008 had subsided and submersible traveling screens were replaced. Tests of middle- vs. upper-1% operation with river-run subyearling Chinook salmon produced similar results in summer 2008 and 2009. In both years, mortality and descaling increased 2 to 3% in tests with one orifice gate open (Table 9). In 2008, differences

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between operating conditions were not statistically significant, whereas more extensive testing in 2009 yielded results that were significantly different between operational levels for both mortality and descaling ($P \leq 0.05$).

In 2009, we modified our experimental design at the request of USACE personnel to include releases at upper-1% operation with both orifice gates open. These tests were conducted to test the hypothesis that shorter gatewell retention time would result in lower mortality and descaling rates. Results were promising for tests of the upper-1% operation with two orifice gates open. These tests resulted in shorter gatewell retention time, with mortality and descaling rates that were not significantly different from values observed in tests of middle-1% operation with one orifice gate open (Table 8). The considerable benefit associated with more rapid passage from the test gatewell strongly suggested that adverse passage effects were due to gatewell conditions.

All gatewells of Turbine Units 11-14 are equipped with two orifice gates; the gatewells of Units 15-18 also have two orifice gates, but only one is equipped with an operating valve. Since completion of our tests, operation with two orifice gates open has been conducted in a limited manner to improve passage conditions. Unfortunately, the bypass system collection channel was engineered with a limited dewatering capacity; therefore, the greatly increased flows that result from expanded operation with two orifice gates open cannot be dissipated. In addition, higher flows within the collection channel would adversely affect its upstream-to-downstream flow characteristics.

Work to improve gatewell conditions has been ongoing since 2009. To date, extensive modeling based on computational fluid dynamics has identified turbulent upwelling zones at both ends of the gatewells. A number of potential structural modifications to reduce the turbulence are under consideration, and installation and biological testing of these modifications may begin in spring 2013. Less gatewell turbulence may allow juvenile salmonids to locate an orifice more readily, thereby reducing fatigue and its resultant contact or impingement on VBSs.

Should this approach fail to produce measurable benefits, reduction of gatewell turbulence may be possible only by reducing flow volume into the gatewells. Doing so would almost certainly reduce fish guidance efficiency, exposing more fish to turbine passage and to predation in the immediate tailrace of the second powerhouse.

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Table 13. Results summary for juvenile Chinook salmon released to evaluate bypass system passage effects at Bonneville Dam Second Powerhouse in 2008-2009. Turbine operating levels were lower, lower-middle (LoMid), middle, and upper settings within the 1% peak efficiency range. Shaded cells identify significant differences between turbine operating levels ($P \leq 0.05$); dashes indicate data were insufficient for statistical analysis.

Test and release	Mortality (%)					Descaling (≥20%)					Passage time (h)				
location	Lower	LoMid	Middle	Upper	Δ	Lower	LoMid	Middle	Upper	Δ	Lower	LoMid	Middle	Upper	Δ
Spring Creek Hatchery subyearling Chinook salmon 2008															
Test series 1															
Gatewell	1.9		14.2		+12.3										
Gatewell	1.9			32.3	+30.4										
Gatewell			14.2	32.3	+18.1										
Test series 2															
Gatewell	4.3			6.6	+2.3										
Intake	1.8			6.9	+5.1										
Test series 3															
Gatewell	0.8			6.3	+5.5						6.8			2.5	−4.3
Intake	1.3			12.7	+11.4						6.9			0.8	−6.1
Test series 4															
Gatewell			1.3	12.4	+11.1								2.0	0.9	−1.1
Intake			2.8	17.8	+15.0								1.4	0.8	−0.6
Spring Creek Hatchery subyearling Chinook salmon 2009															
Early series		4.5	7.0		+2.5							1.9	1.3		−0.6
Late series		1.8	3.0		+1.2							5.1	3.0		−2.1
Run-of-river yearling Chinook salmon															
2008			--	--	--			--	--	--			--	--	--
2009			0.5	4.4	+3.9			1.0	11.5	+10.5			1.7	2.7	+2.0
Run-of-river subyearling Chinook salmon															
2008			0.6	2.6	+2.0			0.4	3.3	+2.9			2.7	4.0	+1.3
2009			2.6	4.3	+1.7			0.5	2.6	+2.1			2.6	6.4	+3.8

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CONCLUSIONS AND RECOMMENDATIONS

1) For Spring Creek Hatchery subyearling Chinook salmon passing Bonneville Dam Second Powerhouse, turbine operation at the upper end of the 1% peak efficiency range results in unacceptable mortality levels. This is particularly so for smaller production fish released in April. We recommend that turbine units be operated at the lowest possible setting within the 1% peak efficiency range that is consistent with overall passage and operational objectives. Operation at lower 1% peak efficiency could be focused on the relatively brief (1-3 d) peak passage periods for this stock.

2) For run-of-river yearling and subyearling Chinook salmon; powerhouse operation at the upper-1% range of peak efficiency is associated with statistically significant increases in mortality and descaling rates. We recommend the COE and the region continue seeking reasonable structural improvements to improve gatewell conditions.

3) Vertical barrier screens are well designed. Early modeling data showed that velocities normal to the porous section of VBS assemblies are favorable, at about 1 ft/second, and evenly distributed over the screen surface. The upper, non-porous section provides a smooth surface and may provide a refuge area for fish guided toward the gatewell surface. The close spacing of the vertical bars in the VBSs provides favorable conditions for salmonid fry.

   Despite these positive characteristics, VBSs are inefficient at passing fine debris associated with seasonal periods of peak flow. We recommend continued funding and effort be directed toward screen inspection and cleaning. During inspections, particular attention should be paid to VBS seals.

4) Specified turbine operation for fish passage should be based on unit flow rather than megawatt output, since more flow is required to reach a given megawatt rating at the lower operating heads characteristic of spring and early summer than at other times of the year. For example, running a unit that is set at the upper-1% megawatt rating may be more benign in late summer than in spring because unit flows are less.

5) We emphasize the importance of hands-on examination of fish condition as presently conducted by the Bonneville Smolt Monitoring Program. These examinations should include targeted release and recapture studies to measure the effects of structural modifications as they are implemented.

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ACKNOWLEDGMENTS

Corps of Engineers personnel facilitated many critical aspects of the 2008-2009 work. In 2008, Patrick Hunter of the Bonneville Project technical group provided designs for the turbine intake release hose assembly and modification of an existing gatewell dip basket to fit 2008 gatewell dimensions. Andy DeBriae led the Bonneville Project structural crew, who fabricated the release hose assembly and provided crane service for installation. Randy Price headed the second powerhouse structural crew, who deployed the gatewell inspection camera and raised the VBSs for inspection and cleaning. Dennis Schwartz was the Portland District COTR for the project, and Tammy Mackey of Portland District coordinated study activities and project access. Ben Hausmann and Jon Rerecich of the Bonneville Project Fisheries Office assisted in daily aspects of the work at Bonneville Dam. We thank all for their respective contributions.

U.S. Fish and Wildlife personnel, including Spring Creek Hatchery manager Larry Marchant and assistant manager Mark Ahrens, helped with acquisition of test fish in both years. Susan Gutenberger of the FWS Lower Columbia River Fish Health Center suggested appropriate disease workups, and Eric Pelton performed the tests.

In conclusion, the senior authors wish to thank fellow NOAA Fisheries personnel for their essential contributions. Foremost are Mike Gessel and Dean Brege, both now retired after long and productive careers conducting field research at locations throughout the Federal Columbia River Power System. Finally, we appreciate the capable assistance of Lila Charlton, Cheryl Engle, and Laura Leighton, our contract staff from Pacific States Marine Fisheries Commission.

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REFERENCES

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

Burnham, K. P., and D. R. Anderson. 2002. Model Selection and Multmodel Inference, 2nd Ed. Springer. New York.

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

CRDART (Columbia River Data Access in Real Time). 1998. Columbia Basin Research, School of Aquatic & Fishery Sciences, University of Washington, Seattle. Available at www.cbr.washington.edu/dart/river.html (7 July 2012).

Gessel, M. H., J. G. Williams, D. A. Brege, R. F. Krcma, and D. R. Chambers. 1991. Juvenile salmonid guidance at Bonneville Dam Second Powerhouse, Columbia River, 1983-1989. North American Journal of Fisheries Management 11:400-412.

Gilbreath, L. G., E. F. Prentice, and S. L. Downing. 2004. Post-construction evaluation of the juvenile bypass collection channel, transportation flume, and fish-monitoring facilities at Bonneville Dam Second Powerhouse, 1999-2000. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon. Available at www.nwfsc.noaa.gov/publications/searchdoc.cfm (September 2012).

Krcma, R.F., M. H. Gessel, W. D. Muir, C. S. McCutcheon, L. G. Gilbreath, and B. H. Monk. 1984. Evaluation of the juvenile collection and bypass system at Bonneville Dam-1983. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon. Available at www.nwfsc.noaa.gov/publications/searchdoc.cfm (September 2012).

Lawless, J. F. 1982. Statistical Models and Methods for Lifetime Data. Wiley & Sons. New York.

McCullagh, P., and J. A. Nelder. 1983. Generalized Linear Models. Chapman and Hall. New York.

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Monk, B. H., R. F. Absolon, B. P. Sandford, and J. W. Ferguson. 2002. Evaluation of intake modifications at Bonneville Dam Second Powerhouse, 2001. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon. Available at www.nwfsc.noaa.gov/publications/searchdoc.cfm (September 2012).

Monk, B. H., B. P. Sandford, D. A. Brege, and J. W. Ferguson. 2004. Evaluation of intake modifications at the Bonneville Dam Second Powerhouse, 2002. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon. Available at www.nwfsc.noaa.gov/publications/searchdoc.cfm (September 2012).

Monk, B. H., B. P. Sandford, and D. B. Dey. 1994. Evaluation of the fish guidance efficiency of submersible traveling screens and other modifications at Bonneville Dam Second Powerhouse, 1993. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon. Available at www.nwfsc.noaa.gov/publications/searchdoc.cfm (September 2012).

Monk, B. H., B. P. Sandford, and D. B. Dey. 1995. Evaluation of the fish guidance efficiency of submersible traveling screens and other modifications at Bonneville Dam Second Powerhouse, 1994. Report of the National Marine Fisheries Service to the U.S. Army Corps of Engineers, Portland, Oregon. Available at www.nwfsc.noaa.gov/publications/searchdoc.cfm (September 2012).

Piper, R. G., McElwain, I. B., Orme, L. E., McCraren, J. P., Fowler, L. G., and Leonard, J. R. 1982. Fish Hatchery Management (third ed. with corrections, 1986). U.S. Department of the Interior, Fish and Wildlife Service, Washington D. C. (reprinted by the American Fisheries Society).

Ploskey, G. R., W. T. Nagy, L. R. Lawrence, D. S. Patterson, C. R. Schilt, P. N. Johnson, and J. R. Skalski. 2001. Hydroacoustic evaluation of juvenile salmonid passage through experimental routes at Bonneville Dam in 1998. Internal report of the U.S. Army Corp of Engineers ERDC/EL TR-01-2. Available at el.erdc.usace.army.mil/publications.cfm?Topic=techreport&Code=general (September 2012).

PSMFC (Pacific States Marine Fisheries Commission). 1996. The Columbia Basin PIT Tag Information System (PTAGIS). PSMFC, Gladstone, Oregon. Available at www.ptagis.org (July 2012).

Tableman, M., and J. S. Kim. 2003. Survival Analysis Using S: Analysis of Time-to-Event Data. Chapman & Hall/CRC Texts in Statistical Science, Boca Raton, Florida.

Zar, J. H. 1999. Biostatistical Analysis, 4th ed. Prentice Hall, New Jersey.

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APPENDIX

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Appendix Table 1. Release and recapture data for juvenile Chinook salmon fin-clipped or PIT tagged for evaluation of post passage fish condition at Bonneville Dam Second Powerhouse in 2008. Lower, middle, and upper are turbine operations within the 1% peak efficiency range. Test fish were recaptured at the second powerhouse juvenile monitoring facility. Release locations were the bypass system collection channel just downstream from the 14A south gatewell orifice (Channel), a submerged canister released to the test gatewell at elevation +45.0 ft msl (Gatewell 12A or 14A), and the A intake of Turbine 14 near the intake ceiling on the downstream side of the trashrack (Intake).

Test series/	Test	Turbine	Release	Clipped/		Recaptured and examined			
Release date	block	operation	location	Tagged	Released	Live	Dead	Total	Rec. %
Series 1 – Spring Creek Hatchery subyearling Chinook salmon									
4 Mar	1	N/A	Channel	897	897	888	2	890	99.2
4 Mar	1	Lower	Gatewell 12A	399	399	265	8	273	68.4
4 Mar	1	Middle	Gatewell 12A	399	399	249	68	317	79.4
4 Mar	1	Upper	Gatewell 12A	399	399	118	104	222	55.6
5 Mar	2	N/A	Channel	904	904	877	3	880	97.3
5 Mar	2	Lower	Gatewell 12A	400	400	385	3	388	97.0
5 Mar	2	Middle	Gatewell 12A	455	455	352	26	378	83.1
5 Mar	2	Upper	Gatewell 12A	400	400	255	55	310	77.5
Series 2 - Spring Creek Hatchery subyearling Chinook salmon									
18 Mar	1	N/A	Channel	150	147	141	1	142	96.6
18 Mar	1	Lower	Gatewell 14A	200	191	139	3	142	74.3
18 Mar	1	Lower	Intake	200	194	138	0	138	71.1
18 Mar	1	Upper	Gatewell 14A	242	234	160	2	162	69.2
18 Mar	1	Upper	Intake	243	237	81	3	84	35.4
19 Mar	2	N/A	Channel	150	149	147	0	147	98.7
19 Mar	2	Lower	Gatewell 14A	200	200	161	3	164	82.0
19 Mar	2	Lower	Intake	200	200	151	1	152	76.0
19 Mar	2	Upper	Gatewell 14A	200	197	138	6	144	73.1
19 Mar	2	Upper	Intake	316	314	151	5	156	49.7
20 Mar	3	N/A	Channel	150	148	147	1	148	100.0
20 Mar	3	Lower	Gatewell 14A	200	197	116	8	124	62.9
20 Mar	3	Lower	Intake	200	197	129	5	134	68.0
20 Mar	3	Upper	Gatewell 14A	201	200	110	11	121	60.5
20 Mar	3	Upper	Intake	262	260	103	10	113	43.5
21 Mar	4	N/A	Channel	150	148	146	1	147	99.3
21 Mar	4	Lower	Gatewell 14A	200	198	88	9	97	49.0
21 Mar	4	Lower	Intake	200	197	97	3	100	50.8
21 Mar	4	Upper	Gatewell 14A	307	306	61	10	71	23.2
21 Mar	4	Upper	Intake	199	199	42	6	48	24.1

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Appendix Table 1. Continued.

Test series/ Release date	Test block	Turbine operation	Release location	Clipped/ Tagged	Released	Recaptured and examined			
						Live	Dead	Total	Rec. %
Series 3 - Spring Creek Hatchery subyearling Chinook salmon									
26 Mar	1	N/A	Channel	541	538	532	0	532	98.9
26 Mar	1	Lower	Gatewell 14A	819	817	752	3	755	92.4
26 Mar	1	Lower	Intake	800	797	701	11	712	89.3
28 Mar	1	N/A	Channel	600	599	587	0	587	98.0
28 Mar	1	Upper	Gatewell 14A	870	867	406	41	447	51.6
28 Mar	1	Upper	Intake	973	968	415	48	463	47.8
2 Apr	2	N/A	Channel	600	598	584	0	584	97.7
2 Apr	2	Upper	Gatewell 14A	800	799	639	42	681	85.2
2 Apr	2	Upper	Intake	800	800	483	126	609	76.1
4 Apr	2	N/A	Channel	650	649	644	0	644	99.2
4 Apr	2	Lower	Gatewell 14A	1,025	1,024	1,000	9	1,009	98.5
4 Apr	2	Lower	Intake	986	986	942	11	953	96.7
16 Apr	3	N/A	Channel	150	147	146	0	146	99.3
16 Apr	3	Lower	Gatewell 14A	817	817	800	9	809	99.0
16 Apr	3	Lower	Intake	824	824	797	9	806	97.8
18 Apr	3	N/A	Channel	151	150	150	0	150	100.0
18 Apr	3	Upper	Gatewell 14A	856	854	709	26	735	86.1
18 Apr	3	Upper	Intake	849	848	581	44	625	73.7
Series 4 - Spring Creek Hatchery subyearling Chinook salmon									
23 Apr	1	N/A	Channel	150	150	148	0	148	98.7
23 Apr	1	Middle	Gatewell 14A	770	769	735	12	747	97.1
23 Apr	1	Middle	Intake	837	836	770	24	794	95.0
25 Apr	1	N/A	Channel	150	150	147	0	147	98.0
25 Apr	1	Upper	Gatewell 14A	869	867	604	68	672	77.5
25 Apr	1	Upper	Intake	800	798	466	92	558	69.9
29 Apr	2	N/A	Channel	150	150	146	2	148	98.7
29 Apr	2	Upper	Gatewell 14A	800	799	593	71	664	83.1
29 Apr	2	Upper	Intake	800	796	570	75	645	81.0
1 May	2	N/A	Channel	150	149	146	0	146	98.0
1 May	2	Middle	Gatewell 14A	800	800	762	9	771	96.4
1 May	2	Middle	Intake	800	798	742	25	767	96.1
7 May	3	N/A	Channel	150	150	148	0	148	98.7
7 May	3	Middle	Gatewell 14A	800	800	774	8	782	97.8
7 May	3	Middle	Intake	800	799	769	14	783	98.0
9 May	3	N/A	Channel	150	150	148	0	148	98.7
9 May	3	Upper	Gatewell 14A	800	798	608	119	727	91.1
9 May	3	Upper	Intake	800	800	513	176	689	86.1

Appendix Table 1. Continued.

Test series/ Release date	Test block	Turbine operation	Release location	Clipped/ Tagged	Released	Recaptured and examined: Live	Dead	Total	Rec. %
Run-of-river yearling Chinook salmon									
14 May	1	N/A	Channel	100	100	94	3	97	97.0
14 May	1	Middle	Intake	250	250	235	12	247	98.8
16 May	1	N/A	Channel	61	61	60	0	60	98.4
16 May	1	Upper	Intake	275	275	274	0	274	99.6
21 May	2	N/A	Channel	94	94	89	1	90	95.7
21 May	2	Upper	Intake	289	288	230	36	266	92.4
Run-of-river subyearling Chinook salmon									
1 Jul	1	N/A	Channel	100	100	91	2	93	93.0
1 Jul	1	Middle	Intake	250	249	233	2	235	94.4
3 Jul	1	N/A	Channel	80	79	78	0	78	98.7
3 Jul	1	Upper	Intake	275	274	240	15	255	93.1
8 Jul	2	N/A	Channel	100	100	96	0	96	96.0
8 Jul	2	Upper	Intake	274	273	257	2	259	94.9
10 Jul	2	N/A	Channel	91	90	89	0	89	98.9
10 Jul	2	Middle	Intake	250	245	235	1	236	96.3
15 Jul	3	N/A	Channel	100	100	98	0	98	98.0
15 Jul	3	Middle	Intake	250	249	231	1	232	93.2
17 Jul	3	N/A	Channel	91	91	91	0	91	100.0
17 Jul	3	Upper	Intake	275	273	262	3	265	97.1

Appendix Table 2. Operating conditions during test releases of juvenile Chinook salmon at Bonneville Dam Second Powerhouse in 2008. Lower, middle, and upper refer to turbine operations within 1% of peak efficiency. MW = megawatt, FB = forebay, TR = tailrace, and Head = operating head. Forebay and tailrace elevations are in feet msl. Dashes indicate data are not available.

Date	Time (PDT)	Turbine operation	Orifice open (N)	MW	kcfs	FB (ft)	TR (ft)	Head (ft)	Temp (°C)
Spring Creek Hatchery subyearling Chinook salmon									
4 Mar	0830	Lower	1	49.7	11.6	73.3	15.0	58.3	5.6
4 Mar	1200	Upper	1	72.0	16.8	73.1	15.3	57.8	5.6
4 Mar	1600	Middle	1	61.6	13.9	73.5	14.1	59.4	5.6
5 Mar	0800	Lower	1	50.2	11.8	74.2	15.9	58.3	5.6
5 Mar	1200	Middle	1	62.7	14.0	75.1	15.6	59.5	5.6
5 Mar	1602	Upper	1	74.5	16.9	74.6	15.8	58.8	5.6
18 Mar	0840	Lower	1	52.0	11.6	73.7	12.8	60.9	6.1
18 Mar	1300	Upper	1	75.6	16.3	74.4	12.3	62.1	6.1
19 Mar	0800	Lower	1	52.3	11.8	74.1	14.1	60.0	6.1
19 Mar	1240	Upper	1	75.8	16.6	74.9	13.6	61.3	6.1
20 Mar	0820	Lower	1	52.4	11.7	74.9	14.2	60.7	6.7
20 Mar	1210	Upper	1	75.4	16.4	75.4	13.9	61.5	6.7
21 Mar	0815	Lower	1	52.5	11.9	74.4	14.7	59.7	6.7
21 Mar	1205	Upper	1	73.3	16.1	75.4	14.1	61.3	6.7
25 Mar	1200	Lower	1	--	--	75.3	15.6	59.7	6.7
26 Mar	1200	Lower	1	55.5	12.8	74.0	15.9	58.1	6.7
28 Mar	1150	Upper	1	75.0	18.6	72.9	17.6	55.3	6.7
2 Apr	1137	Upper	1	75.0	17.1	74.4	15.1	59.3	7.2
4 Apr	1200	Lower	1	55.0	12.1	74.4	13.4	61.0	7.2
16 Apr	1145	Lower	1	54.0	12.4	75.8	17.5	58.3	8.3
18 Apr	1132	Upper	1	74.0	16.7	75.2	15.6	59.6	8.3
23 Apr	1145	Middle	1	61.0	14.9	72.8	17.2	55.6	8.9
25 Apr	1200	Upper	1	74.0	17.9	73.4	17.7	55.7	8.9
29 Apr	1149	Upper	1	74.0	18.4	73.1	18.3	54.8	10.0
1 May	1203	Middle	1	61.0	15.0	74.6	19.1	55.5	10.0
7 May	1209	Middle	1	62.0	15.7	75.2	21.8	53.4	11.1
9 May	1202	Upper	1	70.0	18.7	75.8	24.2	51.6	11.1
9 May	1212	Upper	1	70.0	18.7	75.8	24.2	51.6	11.1
Run-of-river yearling Chinook salmon									
14 May	1210	Middle	1	60.0	15.6	74.6	20.1	54.5	11.7
16 May	1158	Upper	1	62.0	17.4	72.5	23.1	49.4	12.8
21 May	1205	Upper	1	55.0	17.6	73.5	29.3	44.2	12.8
Run-of-river subyearling Chinook salmon									
1 Jul	1204	Middle	1	54.0	14.1	74.8	22.9	51.9	17.8
3 Jul	1152	Upper	1	66.0	18.1	75.4	24.9	50.5	17.8
8 Jul	1159	Upper	1	69.0	18.2	73.2	19.8	53.4	18.3
10 Jul	1212	Middle	1	60.0	15.1	73.9	19.1	54.8	19.4
15 Jul	1202	Middle	1	60.0	14.3	73.5	16.0	57.5	20.0
17 Jul	1458	Upper	1	72.0	16.6	73.6	15.3	58.3	20.6

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Appendix Table 3. Release and recapture data for tests of juvenile Chinook passage at Bonneville Dam Second Powerhouse, 2009. Turbine operations are within the lower-middle, middle, middle-upper, and upper range of 1% peak turbine efficiency. Test fish were recaptured and examined at the juvenile monitoring facility. Release locations were: the bypass system collection channel just downstream from the 14A south gatewell orifice (Channel) and the A intake of Turbine 14 near the intake ceiling on the downstream side of the trashrack (Intake).

Test series/ Release date	Test block	Turbine operation	Release location[a]	Orifice open (N)	Tagged	Released	Recaptured and examined			
							Live	Dead	Total	Rec. %
Spring Creek Hatchery subyearling Chinook salmon										
25 Mar	1	Low-mid	Intake	1	420	390	334	14	348	89.2
26 Mar	1	Middle	Intake	1	420	411	343	24	367	89.3
26 Mar	1	N/A	Channel	1	100	100	99	1	100	100.0
27 Mar	2	Low-mid	Intake	1	420	415	338	34	372	89.6
28 Mar	2	Middle	Intake	1	426	423	334	27	361	85.3
28 Mar	2	N/A	Channel	1	100	100	97	1	98	98.0
30 Mar	3	Low-mid	Intake	1	420	416	336	24	360	86.5
31 Mar	3	Middle	Intake	1	420	410	295	40	335	81.7
31 Mar	3	N/A	Channel	1	100	98	95	1	96	98.0
1 Apr	4	Low-mid	Intake	1	420	418	373	16	389	93.1
2 Apr	4	Middle	Intake	1	420	416	344	27	371	89.2
2 Apr	4	N/A	Channel	1	100	99	98	1	99	100.0
3 Apr	5	Low-mid	Intake	1	420	418	393	10	403	96.4
4 Apr	5	Middle	Intake	1	420	419	368	17	385	91.9
4 Apr	5	N/A	Channel	1	100	100	98	1	99	99.0
6 Apr	6	Low-mid	Intake	1	420	416	368	25	393	94.5
7 Apr	6	Middle	Intake	1	420	420	342	35	377	89.8
7 Apr	6	N/A	Channel	1	100	99	99	0	99	100.0
8 Apr	7	Low-mid	Intake	1	420	419	403	9	412	98.3
9 Apr	7	Middle	Intake	1	420	418	392	19	411	98.3
9 Apr	7	N/A	Channel	1	100	100	99	1	100	100.0
10 Apr	8	Low-mid	Intake	1	420	419	408	5	413	98.6
11 Apr	8	Middle	Intake	1	420	420	391	17	408	97.1
11 Apr	8	N/A	Channel	1	99	99	96	1	97	98.0
20 Apr	9	Low-mid	Intake	1	420	420	373	26	399	95.0
21 Apr	9	Middle	Intake	1	420	420	365	28	393	93.6
21 Apr	9	N/A	Channel	1	100	100	98	0	98	98.0
23 Apr	10	Low-mid	Intake	1	420	420	391	4	395	94.0
24 Apr	10	Middle	Intake	1	420	420	392	13	405	96.4
24 Apr	10	N/A	Channel	1	100	100	95	0	95	95.0
25 Apr	11	Low-mid	Intake	1	420	420	388	0	388	92.4
26 Apr	11	Middle	Intake	1	420	419	374	23	397	94.7

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Appendix Table 3. Continued.

Test series/ Release date	Test block	Turbine operation	Release location[a]	Orifice open (N)	Tagged	Released	Recaptured and examined			
							Live	Dead	Total	Rec. %
Spring Creek Hatchery subyearling Chinook salmon (cont.)										
26 Apr	11	N/A	Channel	1	100	100	95	0	95	95.0
27 Apr	12[a]	Low-mid	Intake	1	420	420	387	11	398	94.8
29 Apr	13	Middle	Intake	1	420	420	377	4	381	90.7
29 Apr	13	N/A	Channel	1	100	100	96	0	96	96.0
30 Apr	13	Low-mid	Intake	1	420	420	376	2	378	90.0
5 May	14	Low-mid	Intake	1	420	420	397	5	402	95.7
6 May	14	Middle	Intake	1	420	419	399	3	402	95.9
6 May	14	N/A	Channel	1	100	99	90	0	90	90.9
7 May	15	Low-mid	Intake	1	419	419	376	5	381	90.9
8 May	15	Middle	Intake	1	420	420	391	8	399	95.0
8 May	15	N/A	Channel	1	100	99	95	0	95	96.0
Run-of-river yearling Chinook salmon										
12 May	1	Middle	Intake	1	412	411	406	0	406	98.8
13 May	1	Upper	Intake	1	412	409	397	7	404	98.8
13 May	1	N/A	Channel	1	47	47	46	0	46	97.9
14 May	2	Middle	Intake	1	412	410	404	2	406	99.0
15 May	2	Upper	Intake	1	412	407	387	16	403	99.0
15 May	2	N/A	Channel	1	50	48	46	0	46	95.8
19 May	3	Middle	Intake	1	405	401	394	2	396	98.8
20 May	3	Upper	Intake	1	412	403	377	6	383	95.0
20 May	3	N/A	Channel	1	50	49	48	0	48	98.0
21 May	4	Middle	Intake	1	412	407	401	2	403	99.0
22 May	4	Upper	Intake	1	394	389	373	10	383	98.5
22 May	4	N/A	Channel	1	50	50	48	0	48	96.0
26 May	5	Middle	Intake	1	412	409	400	2	402	98.3
27 May	5	Upper	Intake	1	411	405	370	28	398	98.3
27 May	5	N/A	Channel	1	50	48	46	1	47	97.9
28 May	6	Middle	Intake	1	412	407	399	1	400	98.3
29 May	6	Upper	Intake	1	414	406	359	34	393	96.8
29 May	6	N/A	Channel	1	50	50	49	0	49	98.0
2 Jun	7	Middle	Intake	1	394	377	368	2	370	98.1
3 Jun	7	Upper	Intake	1	393	375	348	13	361	96.3
3 Jun	7	N/A	Channel	1	50	49	48	0	48	98.0
4 Jun	8	Middle	Intake	1	411	406	390	5	395	97.3
5 Jun	8	Upper	Intake	1	365	359	326	20	346	96.4
5 Jun	8	N/A	Channel	1	50	48	48	0	48	100.0
16 Jun	1	Middle	Intake	1	413	409	396	1	397	97.1
17 Jun	1	Upper	Intake	1	412	412	382	16	398	96.6
17 Jun	1	N/A	Channel	1	50	50	49	1	50	100.0
18 Jun	1	Upper	Intake	2	411	411	393	4	397	96.6

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Appendix Table 3. Continued.

Test series/ Release date	Test block	Turbine operation	Release location[a]	Orifice open (N)	Tagged	Released	Recaptured and examined Live	Dead	Total	Rec. %
Run-of-river subyearling Chinook salmon										
19 Jun	2	Middle	Intake	1	412	412	387	10	397	96.4
20 Jun	2	Upper	Intake	1	412	411	380	18	398	96.8
20 Jun	2	N/A	Channel	1	50	50	49	0	49	98.0
21 Jun	2	Upper	Intake	2	412	411	382	10	392	95.4
23 Jun	3	Middle	Intake	1	290	290	275	11	286	98.6
24 Jun	3	Upper	Intake	1	412	411	377	21	398	96.8
24 Jun	3	N/A	Channel	1	50	50	49	0	49	98.0
25 Jun	3	Upper	Intake	2	412	407	387	7	394	96.8
26 Jun	4	Middle	Intake	1	412	412	388	13	401	97.3
27 Jun	4	Upper	Intake	1	412	411	380	19	399	97.1
27 Jun	4	N/A	Channel	1	50	50	49	0	49	98.0
28 Jun	4	Upper	Intake	2	412	412	374	16	390	94.7
30 Jun	5	Middle	Intake	1	412	411	403	3	406	98.8
1 Jul	5	N/A	Channel	1	52	52	51	0	51	98.1
1 Jul	5	Upper	Intake	1	412	412	388	11	399	96.8
2 Jul	5	Mid-up[b]	Intake	2	412	412	396	5	401	97.3
3 Jul	6	Middle	Intake	1	412	412	382	11	393	95.4
4 Jul	6	Mid-up	Intake	1	412	411	394	4	398	96.8
4 Jul	6	N/A	Channel	1	50	50	48	0	48	96.0
5 Jul	6	Mid-up	Intake	2	412	412	392	4	396	96.1
7 Jul	7	Middle	Intake	1	412	411	387	13	400	97.3
8 Jul	7	Mid-up	Intake	1	408	405	387	8	395	97.5
8 Jul	7	N/A	Channel	1	50	49	46	0	46	93.9
9 Jul	7	Mid-up	Intake	2	412	408	392	6	398	97.5
10 Jul	8	Middle	Intake	1	412	410	381	16	397	96.8
11 Jul	8	Mid-up	Intake	1	412	412	376	21	397	96.4
11 Jul	8	N/A	Channel	1	50	49	45	0	45	91.8
12 Jul	8	Mid-up	Intake	2	412	411	395	8	403	98.1

a Turbine was taken out of service shortly after release. Data not used.

b Due to increasing head differential between forebay and tailrace, the upper-1% MW limit was reached before unit flows reached the specified levels (17.8 kcfs). Nominal middle-upper flows (16.3 kcfs) were achievable and used to complete testing.

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Appendix Table 4. Operating conditions during test releases of juvenile Chinook salmon at Bonneville Dam Second Powerhouse in 2009. Lower-middle, middle, middle-upper, and upper are turbine operations relative to the 1% peak efficiency range. MW = megawatt, FB = forebay, TR = tailrace, and Head = operating head. Forebay and tailrace elevations are in feet msl. Dashes indicate data are not available.

Date	Time	Turbine operation	Orifice open (N)	MW	kcfs	FB (ft)	TR (ft)	Head (ft)	Temp (°C)
Spring Creek Hatchery subyearling Chinook salmon									
25 Mar	1206	Lower-middle	1	63	13.3	75.9	13.4	62.5	5.8
26 Mar	1202	Middle	1	65	14.7	75.1	15.9	59.2	5.9
27 Mar	1200	Lower-middle	1	59	13.5	74.4	16.0	58.4	6.1
28 Mar	1202	Middle	1	67	14.7	75.8	14.7	61.1	6.2
30 Mar	1220	Lower-middle	1	57	13.4	74.5	17.3	57.2	6.4
31 Mar	1158	Middle	1	65	14.7	75.2	16.2	59.0	6.4
1 Apr	1216	Lower-middle	1	61	13.6	75.5	15.6	59.9	6.4
2 Apr	1203	Middle	1	65	14.6	74.8	15.3	59.5	6.5
3 Apr	1205	Lower-middle	1	62	13.5	75.1	14.4	60.7	6.6
4 Apr	1201	Middle	1	66	14.7	75.3	15.1	60.2	6.8
6 Apr	1202	Lower-middle	1	60	13.6	74.3	15.1	59.2	7.2
7 Apr	1155	Middle	1	65	14.6	74.5	15.2	59.3	7.4
8 Apr	1202	Lower-middle	1	61	13.4	74.0	13.7	60.3	7.6
9 Apr	1210	Middle	1	63	14.7	74.5	17.5	57.0	7.8
10 Apr	1201	Lower-middle	1	57	13.5	75.0	18.6	56.4	7.8
11 Apr	1159	Middle	1	61	14.8	75.1	19.6	55.5	7.9
20 Apr	1203	Lower-middle	1	54	13.5	73.0	18.5	54.5	9.7
21 Apr	1201	Middle	1	57	14.7	72.4	19.9	52.5	9.9
23 Apr	1203	Lower-middle	1	51	13.4	73.5	21.9	51.6	9.9
24 Apr	1203	Middle	1	55	14.8	75.2	25.7	49.5	9.8
25 Apr	1201	Lower-middle	1	49	13.5	73.4	24.7	48.7	9.9
26 Apr	1200	Middle	1	54	14.6	73.7	23.9	49.8	9.9
27 Apr	1200	Lower-middle	1	51	13.5	74.2	22.7	51.5	9.9
29 Apr	1200	Middle	1	56	14.8	73.3	22.3	51.0	10.1
30 Apr	1202	Lower-middle	1	53	13.6	74.7	21.0	53.7	10.1
5 May	1203	Lower-middle	1	54	13.5	74.6	20.1	54.5	10.3
6 May	1200	Middle	1	56	14.7	75.0	21.4	53.6	10.4
7 May	1200	Lower-middle	1	49	13.5	74.2	23.5	50.7	10.3
8 May	1200	Middle	1	56	14.8	72.2	20.8	51.4	10.4
Run-of-river yearling Chinook salmon									
12 May	1201	Middle	1	59	14.7	74.9	20.0	54.9	11.0
13 May	1202	Upper	1	69	17.7	74.6	21.4	53.2	11.0
14 May	1202	Middle	1	57	14.6	74.1	21.2	52.9	11.1
15 May	1200	Upper	1	69	17.9	73.4	21.0	52.4	11.5
19 May	1200	Middle	1	55	14.6	73.6	22.0	51.6	12.8

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Appendix Table 4. Continued.

Date	Time	Turbine operation	Orifice open (N)	MW	kcfs	FB (ft)	TR (ft)	Head (ft)	Temp (°C)
Run-of-river yearling Chinook salmon (continued)									
20 May	1210	Upper	1	66	17.8	74.0	23.5	50.5	12.7
21 May	1200	Middle	1	52	15.1	73.5	26.6	46.9	12.9
22 May	1200	Upper	1	62	17.3	74.1	25.0	49.1	13.3
26 May	1202	Middle	1	52	14.6	73.2	25.2	48.0	14.2
27 May	1212	Upper	1	61	17.7	73.2	26.0	47.2	14.3
28 May	1200	Middle	1	52	14.7	73.2	25.1	48.1	14.5
29 May	1200	Upper	1	59	17.4	72.4	23.7	48.7	14.9
2 Jun	1200	Middle	1	52	14.7	73.7	25.2	48.5	15.3
3 Jun	1200	Upper	1	62	17.8	73.0	25.1	47.9	15.5
4 Jun	1200	Middle	1	53	14.9	73.4	25.3	48.1	15.6
5 Jun	1200	Upper	1	63	17.6	74.2	26.5	47.7	15.4
Run-of-river subyearling Chinook salmon									
16 Jun	1200	Middle	1	61	14.8	75.2	19.7	55.5	16.5
17 Jun	1200	Upper	1	73	17.8	75.5	19.8	55.7	16.6
18 Jun	1200	Upper	2	71	17.9	74.7	20.0	54.7	16.9
19 Jun	1200	Middle	1	55	14.6	75.0	22.0	53.0	17.0
20 Jun	1203	Upper	1	66	17.4	72.8	22.2	50.6	17.0
21 Jun	1200	Upper	2	71	17.6	75.3	20.3	55.0	16.9
23 Jun	1202	Middle	1	58	14.7	74.8	21.7	53.1	16.7
24 Jun	1200	Upper	1	69	17.9	74.9	22.2	52.7	17.1
25 Jun	1200	Upper	2	71	17.7	75.0	21.2	53.8	17.3
26 Jun	1200	Middle	1	60	14.6	74.7	18.9	55.8	17.2
27 Jun	1200	Upper	1	73	17.9	74.9	19.5	55.4	17.1
28 Jun	1200	Upper	2	71	17.9	74.3	20.5	53.8	17.4
30 Jun	1200	Middle	1	63	14.9	75.5	19.0	56.5	17.7
1 Jul	1200	Upper	1	76	17.7	75.6	18.5	57.1	17.6
2 Jul	1200	Middle-upper	2	76	16.5	75.3	14.0	61.3	18.3
3 Jul	1202	Middle	1	67	14.7	74.3	14.2	60.1	18.6
4 Jul	1200	Middle-upper	1	76	15.5	76.0	12.6	63.4	18.9
5 Jul	1200	Middle-upper	2	74	15.7	75.5	12.6	62.9	19.2
7 Jul	1200	Middle	1	63	14.8	74.4	16.2	58.2	18.7
8 Jul	1202	Middle-upper	1	68	16.1	75.2	17.7	57.5	18.6
9 Jul	1200	Middle-upper	2	69	16.4	75.3	17.5	57.8	18.7
10 Jul	1200	Middle	1	63	14.7	75.4	17.7	57.7	19.1

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Appendix Table 5. Summary of logistic model selection by Akaike's Information Criterion (AIC), using mortality data from release and recapture of Spring Creek Hatchery subyearling Chinook salmon at Bonneville Dam Second Powerhouse in 2009. Logistic log (L) is the value of the log likelihood for the model, k is the number of parameters in the model plus one, Δ AIC is the comparison of each model to the "best" one, and model weight is the probability that the model is the best given the set. Abbreviations are RD, release date; TO, turbine operation; and FL, fork length.

Terms included in the model						Logistic			Model
Factors			Interactions			log (L)	k	Δ AIC	weight
	TO	FL				-1785.769	4	0.000	0.342
RD	TO	FL				-1785.354	5	1.170	0.191
RD	TO	FL	RD × TO		TO × FL	-1781.560	9	1.582	0.155
	TO	FL			TO × FL	-1785.328	6	3.118	0.072
RD	TO	FL		RD × FL		-1785.341	6	3.144	0.071
RD			RD × TO	RD × FL	TO × FL	-1781.545	10	3.552	0.058
RD	TO	FL			TO × FL	-1784.889	7	4.240	0.041
RD	TO	FL	RD × TO			-1784.916	7	4.294	0.040
RD	TO	FL		RD × FL	TO × FL	-1784.873	8	6.208	0.015
RD	TO	FL	RD × TO	RD × FL		-1784.910	8	6.282	0.015
		FL				-1798.649	2	21.760	0.000
RD		FL				-1798.234	3	22.930	0.000
RD		FL		RD × FL		-1798.229	4	24.920	0.000
RD	TO					-1809.524	4	47.510	0.000
RD	TO		1RD × TO			-1809.224	6	50.910	0.000
RD						-1821.998	2	68.458	0.000
	TO					-1865.333	3	157.128	0.000

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Appendix Table 6. Mortality during 10-d holding of Spring Creek Hatchery subyearling Chinook recaptured following bypass system passage at Bonneville Dam Second Powerhouse in 2009. All turbine operations were within 1% of peak efficiency based on unit flow: Lower-middle (~13.5 kcfs); Middle (~14.7 kcfs).

Test block	Turbine operation	Fish held (N)	Mortality (N)	Mortality (%)
Releases to the bypass system collection channel				
1	N/A	99	0	0.0
2	N/A	96	0	0.0
3	N/A	95	0	0.0
4	N/A	97	0	0.0
5	N/A	98	0	0.0
6	N/A	98	0	0.0
7	N/A	96	0	0.0
8	N/A	95	0	0.0
9	N/A	97	0	0.0
10	N/A	94	1	1.1
11	N/A	94	0	0.0
13	N/A	96	0	0.0
14	N/A	90	0	0.0
15	N/A	95	0	0.0
Releases to the A intake of Turbine Unit 14				
1	Lower-middle	329	3	0.9
2	Lower-middle	336	1	0.3
3	Lower-middle	335	1	0.3
4	Lower-middle	369	2	0.5
5	Lower-middle	390	3	0.8
6	Lower-middle	364	0	0.0
7	Lower-middle	402	2	0.5
8	Lower-middle	406	2	0.5
9	Lower-middle	359	26	7.2
10	Lower-middle	388	5	1.3
11	Lower-middle	387	1	0.3
12	Lower-middle	383	1	0.3
13	Lower-middle	373	0	0.0
14	Lower-middle	396	0	0.0
15	Lower-middle	373	0	0.0
1	Middle	337	2	0.6
2	Middle	330	1	0.3
3	Middle	288	1	0.3
4	Middle	339	4	1.2
5	Middle	365	1	0.3
6	Middle	339	0	0.0
7	Middle	390	4	1.0
8	Middle	388	1	0.3
9	Middle	360	2	0.6
10	Middle	389	3	0.8
11	Middle	370	0	0.0
13	Middle	372	0	0.0
14	Middle	394	2	0.5
15	Middle	388	0	0.0

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