Evaluation of Extended-Length Submersible Bar Screens at Bonneville Dam First Powerhouse, 2000

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Report of research by

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to

U.S. Army Corps of Engineers
Portland District
Contract W66QKZ80545753

October 2001

EXECUTIVE SUMMARY

Submersible traveling screens (STSs) are installed in all turbine units at Bonneville Dam First Powerhouse to guide juvenile salmonid migrants into a juvenile fish bypass system. In tests conducted from 1989 to 1992, fish guidance efficiency (FGE) of these screens ranged from approximately 40% for yearling chinook salmon to 60% for coho salmon and steelhead during the spring migrations. During the same testing period, FGE for sockeye salmon was approximately 25%. During the summer migrations, FGE for subyearling chinook salmon was approximately 40% in June, then decreased to less than 10% by the second week in July.

To look at the potential for increasing FGE, extended-length bar screens (ESBSs) were installed in Unit 8 at Bonneville Dam First Powerhouse and first tested in 1998. These screens are 40 ft long compared to the 20-ft long STSs and have been successful at increasing FGE at other middle Columbia and Snake River dams. To further improve FGE by increasing flows into the gatewell, operating gates were also raised in the A and C slots and the gate was removed in the B slot to accommodate a fyke-net frame used for FGE testing.

In 2000, FGE tests with ESBSs and raised operating gates were repeated. As in 1998, orifice passage efficiency (OPE) tests with the ESBSs installed were also conducted. Orifice passage efficiency is the percentage of guided fish which egress from the gatewell via the orifice in a certain amount of time (17 hours in 2000). Fish sampled from both the FGE and OPE tests were also examined for descaling and injury. For statistical comparisons, OPE and descaling-injury rates were also measured in Unit 9, in which STSs were installed with the operating gate in the stored (or standard) position.

Average FGE for the spring migration in 2000 ranged from 4 to 9% lower for all species than 1998. However, average FGE for the two years combined was 70% or greater for yearling chinook, coho, and steelhead during the spring migration. For all three species this indicated a potential increase in FGE of 23 to 34%.

In June and early July, FGE for subyearling chinook salmon averaged 47% in 1998 and 2000. In the later part of July 1998, average FGE for subyearling chinook salmon decreased to 23% (tests were not conducted in 2000 because insufficient numbers of fish were available for meaningful analysis). Compared to tests also conducted in the later part of July 1988 and 1989 with STSs, this indicated a potential increase in FGE for subyearling chinook salmon with ESBSs of approximately 13% during the later part of the summer migration.

Combined average OPE for 1998 and 2000 was over 75% for yearling chinook salmon and over 90% for subyearling chinook salmon (in both the STS and ESBS units). In 2000, passage times for both yearling and subyearling chinook salmon from the

gatewell to the passive integrated transponder (PIT)-tag detector at the downstream monitoring facility was approximately 3 hours for the STS and 4 hours for the ESBS. However, these differences in OPE and passage time were not significant, indicating that fish passage from the gatewell to the bypass channel was not changed by the ESBS.

Significantly higher descaling in the ESBS unit over the STS unit was measured for yearling chinook salmon in 1998 and for subyearling chinook salmon in 2000. However, these differences only ranged from 1.5 to 2%. For all other species in both years, there was no significant difference in descaling between the two screens.

In 1998 and 2000, a total of 643 juvenile lamprey were collected with a average FGE of 0.1%. A total of 48 salmonid parr were also collected, with a average FGE of 48%. There was no descaling or injury of the parr. In 2000, a hinged panel blocked the top two nets from the remaining lower nets so that any impinged fish that were swept off the ESBS by the bar sweep would be caught in these nets. No lamprey or parr were caught in these top two nets, indicating that neither species was being impinged and swept over the top of the ESBS.

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INTRODUCTION

In 1981, the U.S. National Marine Fisheries Service (NMFS) and U.S. Army Corps of Engineers (COE) conducted prototype studies to evaluate the potential fish guidance efficiency (FGE) of submersible traveling screens (STS) at Bonneville Dam First Powerhouse. Initial estimates of FGE were greater than 70% for all salmonid species from 30 April to 13 May 1981. Fish guidance efficiency was lower during individual tests conducted later in May, but the decrease was attributed to large amounts of debris on the trash racks. Based on these results, a complete set of STSs was installed at the dam prior to the 1983 juvenile salmonid migration (Krcma et al. 1982).

Construction of a new, larger navigation lock at Bonneville Dam began in the fall of 1988. Part of this construction involved placement of rock groins in the forebay, removal of the tip of Bradford Island, and dredging in an attempt to straighten and distribute flow more evenly across the width of the powerhouse. A navigation guidewall was also constructed along the south side of the forebay.

In the late spring and summer of 1988, prior to this construction, additional studies were conducted at Bonneville Dam First Powerhouse, so that any changes in FGE associated with changes in flow or the addition of the new guidewall could be identified in later tests. Between 30 May and 5 June 1988, FGE for subyearling chinook salmon averaged 41%, which was well below the 72% FGE measured for these fish during a similar period in 1981. Between 6 and 27 July 1988, FGE for subyearling chinook salmon averaged only 11% (Gessel et al. 1989).

To document potential changes in FGE, tests were expanded in 1989 to include the early spring juvenile migration period as well as the summer period. Between 9 and 14 May 1989, FGE for yearling chinook salmon averaged 42%. Between 27 and 30 May 1989, FGE for yearling and subyearling chinook salmon averaged 31 and 37%, respectively. Between 12 and 24 July 1989, FGE for subyearling chinook salmon averaged only 4% (Gessel et al. 1990).

During the juvenile salmonid migration in 1991 and 1992, NMFS and the COE conducted additional FGE studies at Bonneville Dam First Powerhouse to examine other methods of improving guidance, including lowering the STS and raising the operating gate (Monk et al. 1992, 1993). Procedures and methods for these FGE studies were similar to those used previously, but lowering the STS did not improve FGE for yearling chinook salmon, and results were mixed with the raised operating gate.

However, results from vertical distribution measurements indicated that 71 to 78% of the yearling chinook salmon were in the zone intercepted by the STS, suggesting that inadequate flows up into the gatewell and deflection of fish under the STS were responsible, in part, for the low FGE. This information, results of physical model studies, and research at other Columbia and Snake River dams comparing STSs and extended-length submersible bar screens (ESBSs) indicated the potential for significant increases in FGE at Bonneville Dam First Powerhouse if ESBSs were used (McComas et al. 1993, Gessel et al. 1994).

Modeling studies conducted at the COE Waterways Experimental Station indicated that the highest flows into the gatewell slot, and therefore the best potential for raising FGE, were created when the operating gate was removed from the bulkhead slot. However, given the difficulty in removing and storing all operating gates at Bonneville Dam First Powerhouse, it was considered prudent to test the degree of benefit to FGE gained by using ESBSs and raising the operating gates (without removing them). In order to handle the increased flow into the gatewell, a new vertical barrier screen was designed and installed which incorporated a perforated plate behind the mesh of the screen.

Orifice passage efficiency (OPE) is the percent of guided fish which exit the gatewell via the orifice in a fixed period. Estimates of OPE for all species at other Columbia and Snake River dams with ESBSs installed have been greater than 90% in most cases (Brege et al. 1997, 1998; Monk et al. 1997). Apparently, because of increased flows and velocities in the gatewell caused by the ESBS, fish are forced up to the level of the orifice and quickly pass through. However, the increased flows can also increase descaling and injury if fish do not readily exit the orifice; therefore, measurements of OPE at Bonneville Dam First Powerhouse with an ESBS installed and examinations of guided fish for descaling and injury were also necessary.

In 1998, ESBSs were installed in all three slots of Unit 8. To further increase FGE by improving flow into the gatewell, operating gates were raised in the A and C slots, and the gate was removed in the B slot (to accommodate the fyke-net frame used for FGE testing). Measurements of FGE were conducted in Unit 8 (B slot) only, while OPE and fish conditions ere observed in Units 8 and 9 (with standard STSs and stored operating gates) so that comparisons between the two screens could be made.

During both the spring migration (24 April to 21 May) and the summer migration (22 June to 15 July), substantial increases in FGE were seen with the ESBS and raised operating gate compared to earlier estimates with an STS. These increases ranged from 26 to 34% for all species tested in the earlier tests (yearling chinook, coho, and sockeye salmon and steelhead) and 10 to 15% for subyearling chinook salmon in the later tests (Monk et al. 2000).

During the spring 1998 tests, OPE for yearling chinook salmon was significantly higher with the ESBS compared to the STS, 90 and 80%, respectively ($P = 0.01$). During summer tests, there was no difference in mean OPE for subyearling chinook salmon between the ESBS (97%) and STS (98%). Descaling for yearling chinook salmon was significantly higher with the ESBS than the STS ($P = 0.01$), although the difference was only 1.4% (9.6% compared to 8.2%, respectively).

For all other species guided in the spring and for subyearling chinook salmon guided in the summer there were no significant differences in descaling or injury. Based on these promising results, and to substantiate available data on the ESBSs, all of the 1998 tests were repeated in 2000. Research objectives for 2000 were as follows:

1) Evaluate the FGE of a prototype ESBS during spring and summer juvenile salmonid migrations

2) Evaluate OPE for juvenile fish bypass orifices with the ESBSs during spring and summer migrations.

3) Evaluate the effects of the ESBS and associated guidance devices (including the vertical barrier screen) on juvenile salmonids and lamprey.

OBJECTIVE 1: EVALUATE FISH GUIDANCE EFFICIENCY OF AN EXTENDED-LENGTH BAR SCREEN DURING SPRING AND SUMMER JUVENILE SALMONID MIGRATION

Approach

In the spring of 1998, ESBSs were installed in all three intake slots of Bonneville Dam First Powerhouse Turbine Unit 8 (slots A, B, and C) and tested. These tests were repeated in 2000 and, as in 1998, FGE tests were conducted in the center slot (B) during the spring and summer juvenile migrations.

Methods for determining FGE were the same as those used in previous STS studies (Monk et al. 1992, 1993, 2000). A fyke-net frame with an array of nets was installed in the downstream gate (or bulkhead) slot of the turbine intake and all FGE testing was done with the operating gate removed (Fig. 1). In the A and C slots, the operating gates were raised 19 ft (5.8 m). Gatewell dip-net catches provided the number of guided fish, and fyke-net catches provided the number of unguided fish. The FGE for each species was calculated as gatewell catch (guided fish) divided by the total number of fish (guided plus unguided) passing through the intake during the test period:

$$FGE = \frac{GW}{(GW + FN)} \times 100$$

$$GW = \text{Gatewell catch}$$
$$FN = \text{Fyke-net catch}$$

During both the spring and summer testing, each test was started at 2000 and ended when approximately 200 of the target species had been collected (2100-2300). During all testing, Turbine Units 8 and 9 were operated within the 1% efficiency range for existing water levels as prescribed by the COE Fish Passage Plan.

In the spring, average discharge and output of Turbine Units 8 and 9 were 10.8 kcfs and 40.6 MW and 10.6 kcfs and 40.5 MW, respectively. In the summer, discharge and output for Turbine Units 8 and 9 were 10.5 kcfs and 42.0 MW and 10.5 kcfs and 42.5 MW, respectively. These levels were comparable to 1998 for both periods. Also in 1998 and 2000, Turbine Units 7 and 10 were operated during all testing (sometimes at reduced loads) so that any edge effect into the intakes was diminished.

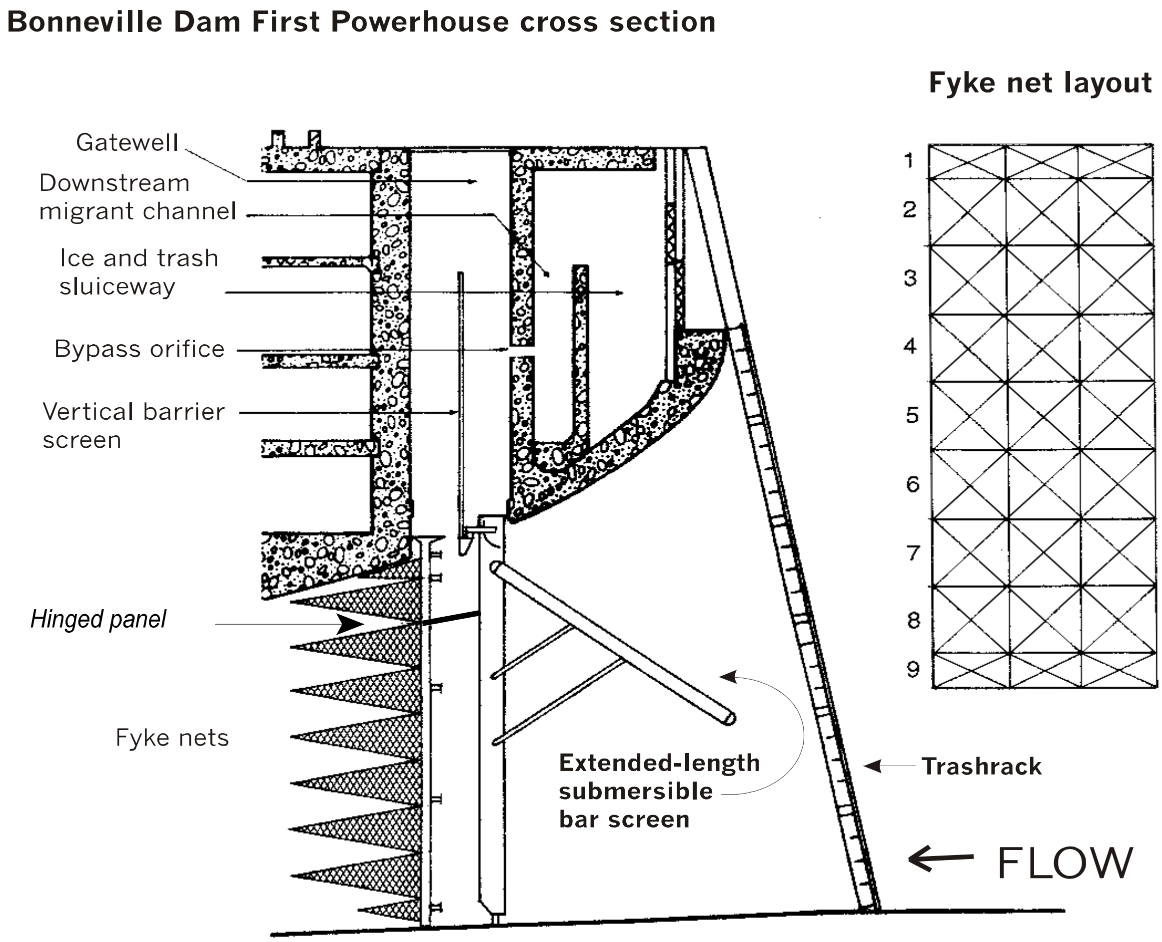


Figure 1. Cross section of turbine intake at Bonneville Dam First Powerhouse, showing extended-length bar screen and fish bypass system. Fyke-net layout shows nine net levels and three columns of nets.

At other projects (McNary, The Dalles, and Little Goose Dams) where the two screen types have been tested concurrently, the ESBS has consistently shown higher FGE than the STS (McComas et al. 1993, Brege et al. 1994, Gessel et al. 1994). Therefore, direct comparisons of FGE between an ESBS and STS were not made in either 1998 or 2000. Given the constraints of the Endangered Species Act, we did not believe it necessary to sacrifice additional fish to show that FGE is markedly higher with the extended-length bar screens. Based on 1996 results from McNary Dam and from 1998 results at Bonneville Dam First Powerhouse, we determined that 20 FGE replicates using 200 total fish of the target species in each test would result in sufficient precision for annual mean FGE estimates.

Results and Discussion

Spring Testing

From 24 April to 24 May, 23 FGE tests were completed. Gatewell catches, fyke-net catches, and resulting FGE for yearling and subyearling chinook, coho, and sockeye salmon and steelhead are given in Appendix Table 1 for all tests.

For yearling chinook salmon, FGE ranged from 52 to 76% with a mean of 66% (SE = 1.8). Fish guidance efficiency for both steelhead and coho averaged 76% (SE = 1.9 and 1.6, respectively)(Fig. 2). For all three species, the average FGE was less than 1998 averages by 4 to 9% (Table 1). Because of low numbers, FGEs for subyearling chinook and sockeye salmon were not calculated in these earlier tests in 2000.

Summer Testing

From 12 June to 7 July, 18 FGE tests were conducted with subyearling chinook salmon only. Gatewell catches, fyke-net catches, and resulting FGE are given in Appendix Table 1.

Past studies with STSs at Bonneville First Powerhouse have shown that FGEs for subyearling chinook salmon in June remain close to those obtained during spring (April and May) and then drop markedly in July. Test results in 2000 were similar, with FGE values for subyearling chinook salmon ranging from 62% (13 June) to 25% (6 July) with a mean of 46% (SE = 2.7)(Table 1, Fig. 3).

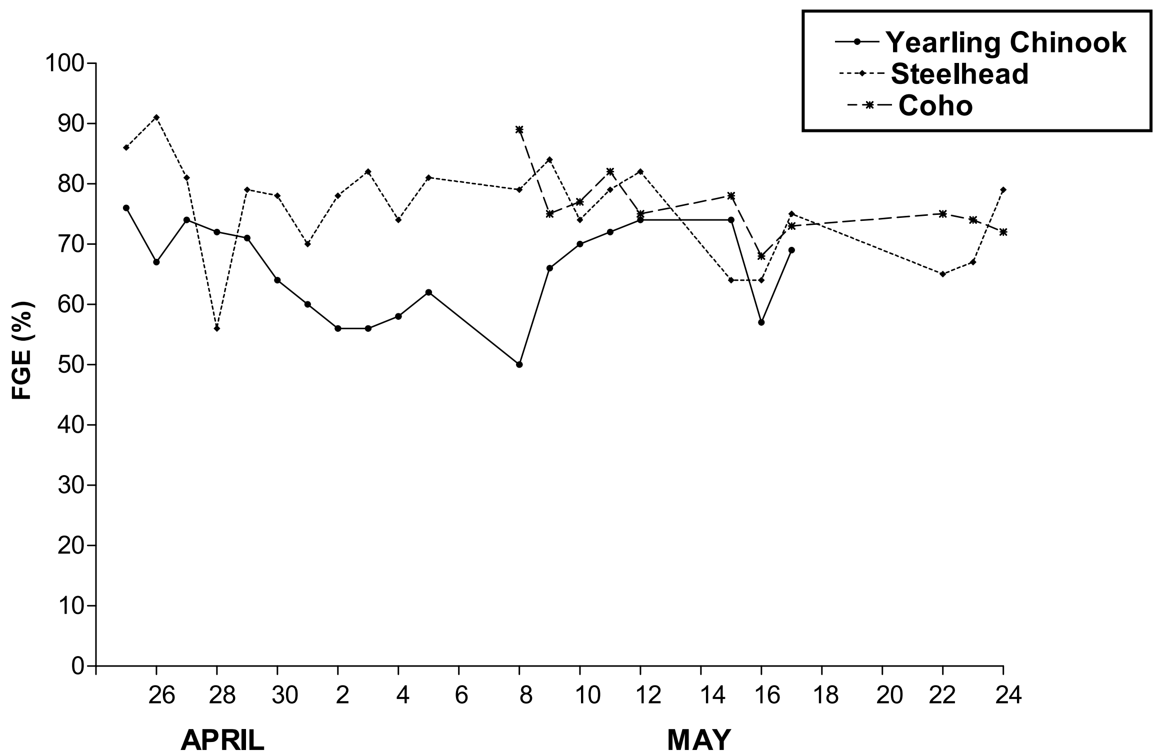


Figure 2. Daily fish guidance efficiency (FGE) for yearling chinook and coho salmon and steelhead in Turbine Unit 8 (with ESBS) during spring migration at Bonneville Dam First Powerhouse, 2000.

Table 1. Average fish guidance efficiency (FGE) and standard errors for all species, with an extended-length bar screen and raised operating gate in 1998 and 2000 (all tests were conducted in Turbine Unit 8).

	Extended-length bar screen with raised operating gate 1998		Extended-length bar screen with raised operating gate 2000	
	FGE (%)	SE	FGE (%)	SE
Spring Testing				
Subyearling chinook salmon[a]	67	4.7		
Yearling chinook salmon	72	1.9	66	1.8
Steelhead	85	1.5	76	1.9
Coho salmon	80	2.3	76	1.6
Sockeye salmon[a]	51	5		
Summer Testing				
Subyearling chinook salmon				
22 June-2 July1998	48	2.7		
6 July-17 July 1998	23	1.1		
12 June-7 July 2000			46	2.7

[a] In 2000, insufficient numbers of subyearling chinook and sockeye salmon were available for meaningful analysis.

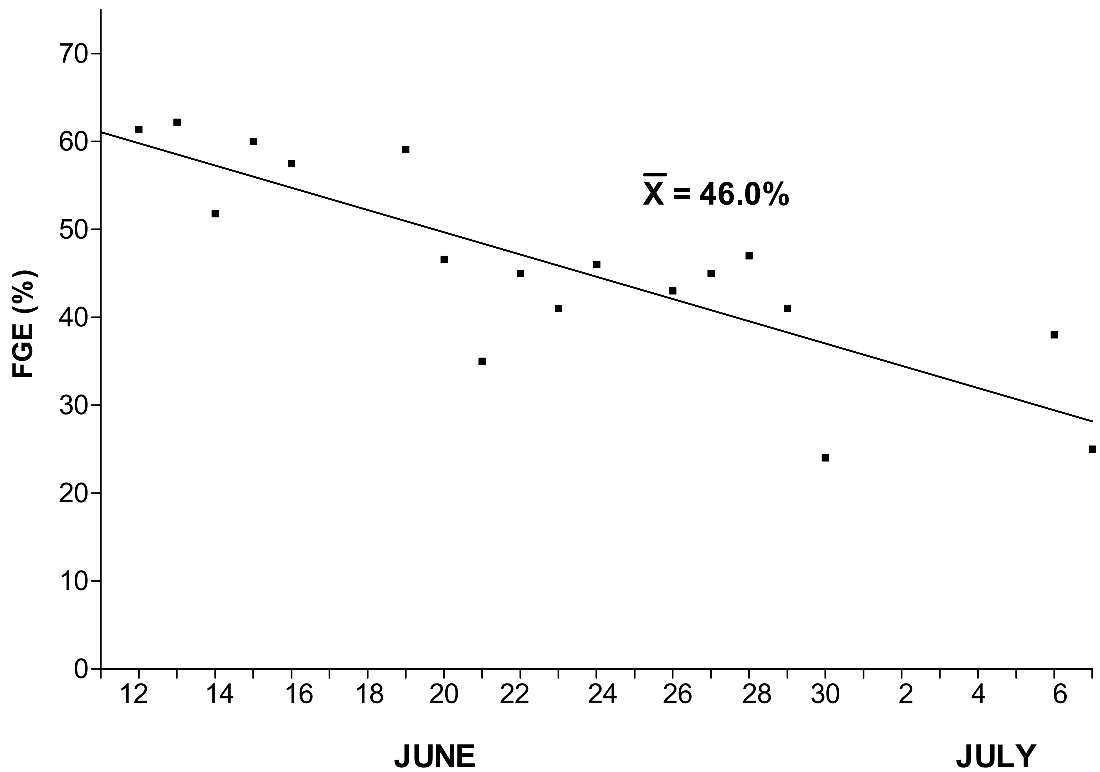


Figure 3. Daily fish guidance efficiency (FGE) for subyearling chinook salmon with extended-length bar screens in Turbine Unit 8 (B slot) during the summer migration at Bonneville Dam First Powerhouse, 2000.

OBJECTIVE 2: EVALUATE ORIFICE PASSAGE EFFICIENCY OF JUVENILE FISH BYPASS ORIFICES WITH EXTENDED-LENGTH BAR SCREENS DURING THE SPRING AND SUMMER MIGRATION

Approach

In 2000, orifice passage efficiency tests were done differently than in 1998. Test fish were marked with passive integrated transponder (PIT) tags, instead of fin-clipped, and released into the test gatewells. Fish leaving the gatewell and exiting via the bypass channel could then be detected at the flat-plate PIT-tag detector located in the downstream monitoring facility at the downstream end of the bypass channel. In these tests, OPE is the percent of released fish that were detected within 17 hours (time from release until the test units were taken off-line for setting up the FGE tests). Use of PIT tags also enabled us to calculate passage time, the time from release to detection.

To conduct these tests, groups of 200 juvenile salmon (yearling chinook salmon in the spring and subyearling chinook salmon in the summer) were anesthetized, PIT tagged, held for approximately 5 hours, and released into Gatewell Slots 8A and 9A at approximately 2300 (approximately 100 fish released to each gatewell). A 240-L (63 gal) aluminum canister (Absolon and Brege in prep.) was used to lower the fish 4.6 m (15 ft) below the orifice at elevation 14 m (45 ft) m.s.l. All releases were made with the units operating and orifices open.

Since our objective was to evaluate the effects of an ESBS and a raised operating gate on juvenile salmonids, OPE tests were conducted in Turbine Unit 8 (A slot), where the operating gate was raised and positioned at 5.8 m (19 ft) above the forebay deck level, raising the bottom of the gate from 13.1 to 18.9 m (43 to 62 ft) m.s.l. Comparison OPE tests were done concurrently in Turbine Unit 9 (A slot), with an STS and a stored operating gate. During the tests, both units were operated within COE Fish Passage Plan curves (within 1% of peak efficiency), and an effort was made to maintain similar discharges between the two units for the duration of the 17-hour tests.

Paired t-tests (paired by day) were used to compare both OPE and passage time between the two screen types.

Results and Discussion

Spring Testing

From 25 April to 17 May, 13 OPE tests were conducted in both Turbine Units 8 and 9. In these tests, OPE for yearling chinook salmon ranged from 61 to 92% with an average of 76% (SE = 3.1) with the ESBS, and from 63 to 87% with an average of 73% (SE = 3.6) with the STS. The average median passage times were 3.3 and 2.7 hours for the ESBS and STS, respectively (Fig. 4). Paired *t*-tests (paired by day) showed no significant differences in either OPE (P = 0.52) or passage time (P = 0.30) between the ESBS and the STS.

Summer Testing

During the summer migration, total river flows were not always sufficient to maintain required load capacities in Turbine Units 8 and 9 and also meet spill requirements and unit priorities during the 17-hour OPE tests. Therefore, only five paired OPE tests were conducted with subyearling chinook salmon. However, because OPE was extremely high with little variability in both units, we believe the five tests gave a reliable estimate of OPE. Orifice passage efficiency in Turbine Unit 8 for subyearling chinook salmon ranged from 84 to 93% with an average of 87% (SE = 1.8), and OPE in Turbine Unit 9 ranged from 84 to 94% with an average of 89% (SE = 0.7)(Fig. 4). The averages of the median passage times for subyearling chinook salmon for the five tests were 4.2 and 3.9 hours for the ESBS and STS, respectively. Paired t-tests (paired by day) showed no significant differences in either OPE (P = 0.32) or passage time (P = 0.47) between the ESBS and the STS.

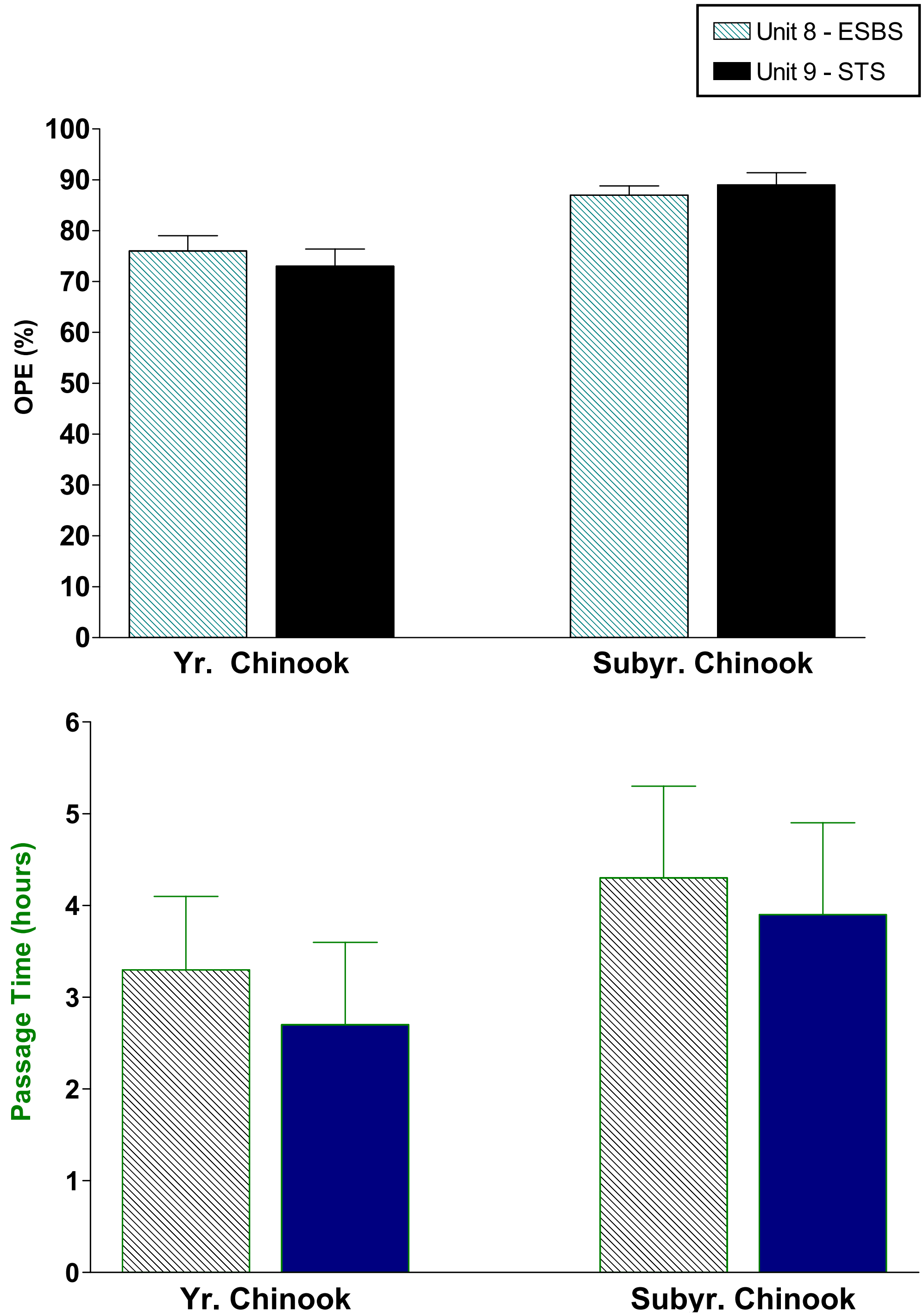


Figure 4. Average daily orifice passage efficiency (OPE) and the averages of the median passage times for yearling chinook salmon (spring) and subyearling chinook salmon (summer) with an extended-length bar screen and a submersible traveling screen at Bonneville Dam First Powerhouse, 2000.

OBJECTIVE 3: EVALUATE EFFECTS OF EXTENDED-LENGTH BAR SCREEN ON JUVENILE SALMONIDS AND LAMPREY

Approach

All fish collected in the Turbine Unit 8 B slot during FGE tests with the ESBS were examined for descaling and injury. To compare these results with STSs, all fish were removed from the Turbine Unit 9 B slot prior to each FGE test and again at the end of the test (with orifice closed), so that fish examined for descaling and injury had been in both gatewells for approximately the same amount of time (2-3 hours).

Because of increased velocities in the gatewell caused by the ESBS, it was important to determine percent descaling and injury on fish that could have been in the gatewell and exposed to these velocities for longer periods of time. Therefore, at the end of the 17-hour OPE tests, any fish recovered from Gatewell 8A or 9A were also examined for descaling and injury so that comparisons between the ESBS and STS could be made. Since fish were entering both gatewells while the OPE tests were being conducted, all fish examined were not necessarily in the gatewell for the entire 17 hours, but a portion of the fish were at least exposed to the gatewell environment for longer periods than fish examined after the FGE tests.

A fish was determined to be descaled if cumulative scale loss exceeded 20% on either side (Ceballos et al. 1992). Fish with obviously old scale loss (with scale regeneration or fungal growth) were not classified as descaled, and descaling caused by birds, when obvious, was not counted. However, fresh descaling (in the last 24 hours) is not always easy to determine, and, as in most FGE studies to date, descaling results give only a general picture of descaling levels on the migrating population. Therefore, comparisons between units were made to determine if significant differences in descaling were occurring between the two screen types. Although the entire fish was examined for injuries, all injuries noted were on the head and consisted of folded or torn operculums or hemorrhaged eyes.

Paired t-tests (paired by day) were used to compare descaling rates of fish guided with an ESBS (Unit 8) with those of fish guided with an STS (Unit 9).

Concerns that smaller fish, specifically salmonid parr and juvenile lamprey, might be impinged on the ESBS have been raised in regional discussions. If impinged fish die and are swept off the ESBS by the bar sweep, they would not be detected on the screen when it was pulled and inspected. To address this, a hinged panel was placed between the ESBS and the bottom of the second net to force any fish that went over the top of the ESBS into one of the upper two net levels (Fig. 1).

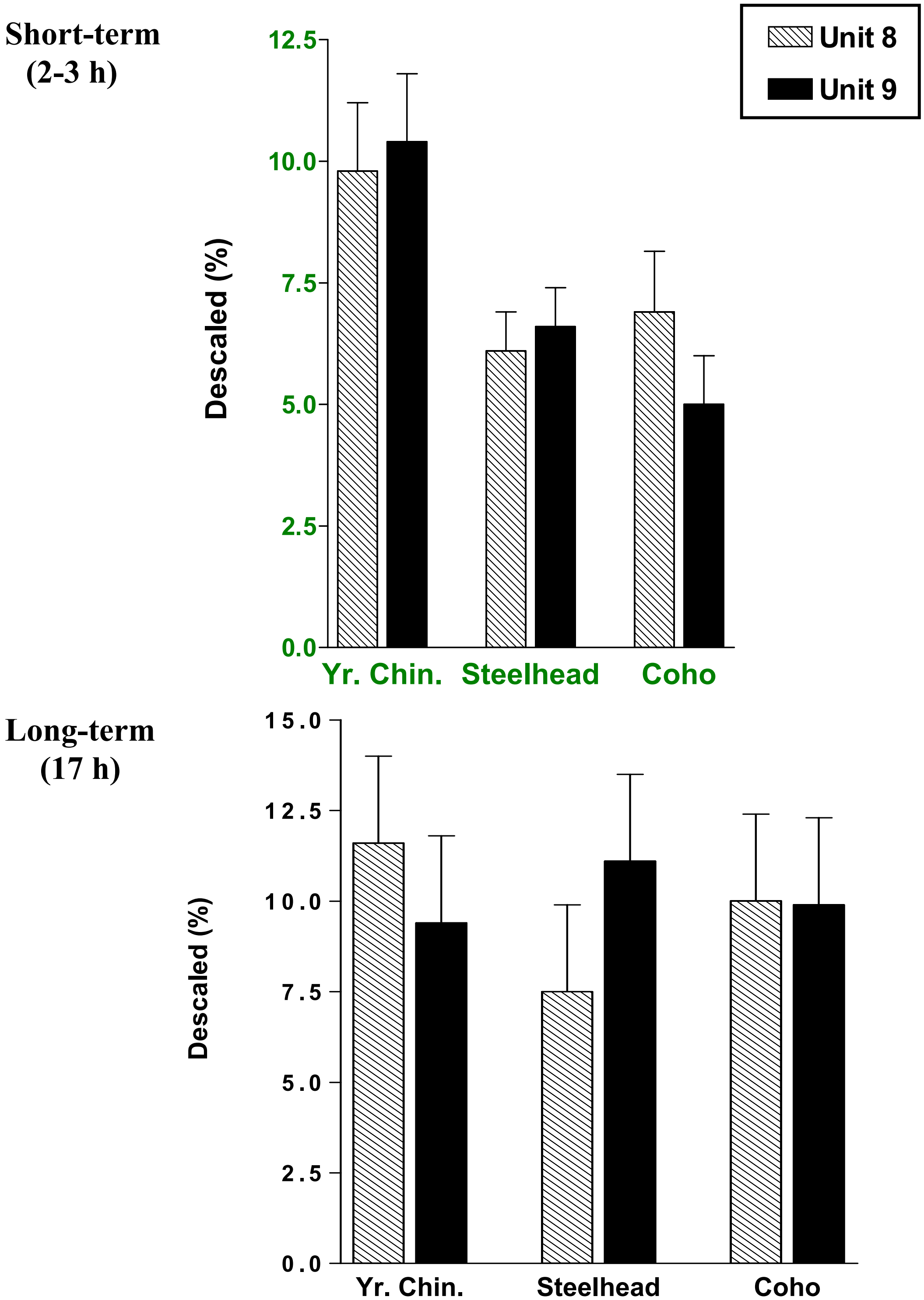


Figure 5. Short-term and long-term descaling and standard errors for all species examined during spring migration in Turbine Unit 8 (ESBS) and Unit 9 (STS) at Bonneville Dam First Powerhouse, 2000.

Table 2. Percent descaling and injuries with standard errors for all species examined during fish guidance and orifice passage efficiency tests (short-term and long-term tests combined) at Bonneville Dam First Powerhouse, 2000 (*denotes significant difference between extended-length bar screen and submersible traveling screen, $P < 0.05$).

	Turbine Unit 8 extended-length bar screen with raised operating gate		Turbine Unit 9 submersible traveling screen with standard operating gate	
	Descaling (%)	Injuries (%)	Descaling (%)	Injuries (%)
Spring Testing				
Yearling chinook salmon	9.9 (1.3)	0.8 (0.40)	10.7 (1.5)	0.4 (0.13)
Steelhead	6.0 (0.7)	0.1 (0.06)	7.9 (1.3)	0.5 (0.33)
Coho salmon	8.2 (1.0)	0.1 (0.10)	6.7 (1.3)	0.3 (0.20)
Sockeye salmon	24 (8.0)	0	31 (9.0)	0
Summer Testing				
Subyearling chinook salmon	5.7 (0.7)*	0.2 (0.10)	4.2 (0.8)	0.7 (0.40)

Results and Discussion

Spring Testing

Appendix Table 2 gives the numbers of fish examined and classified as descaled or injured during both the FGE (2 hour) and OPE (17 hour) tests. During the spring migration, no significant differences in descaling for yearling chinook or coho salmon or steelhead were found either in the short-term or long-term descaling examinations (Fig. 5; P values given in Appendix Table 3). Since there were also no significant differences between short-term and long-term descaling results, they were combined to compare differences between the ESBS and the STS. In these comparisons, there were no significant differences in descaling between the ESBS and the STS for any species, and descaling was actually slightly higher with the STS compared to the ESBS unit for yearling chinook salmon and steelhead (Table 2).

Summer Testing

During the summer, short-term descaling for subyearling chinook salmon ranged from 0.8 to 11.1% with an average of 5.0% (SE = 0.7) in Unit 8 and from 0 to 9% with an average of 4.0% (SE = 0.8) in Unit 9 (with no significant differences between the two screens)(Fig. 6). However, long-term descaling for subyearling chinook salmon was significantly higher with the ESBS (8.5%, SE = 1.3) than the STS (3.7%, SE = 1.6) ($t = 2.23$, $P = 0.040$). When short-term and long-term descaling were combined, descaling with the ESBS was still slightly significant ($t = 2.12$, $P = 0.049$); however, the difference was only 1.5% (Table 2, Appendix Table 3).

During both the spring and summer migration, the only injuries found on any species were hemorrhaged eyes and bent or torn operculums. In both the test and control units, the total injury rate was less than 1% for all species with no significant differences between units. For all species except yearling chinook salmon, the injury rate was higher with the STS than the ESBS (Table 2).

Effects of Extended-Length Bar Screen on Juvenile Lamprey and Salmon Parr

Only18 salmonid parr were collected during spring and summer testing. Ten of these (56%) were collected in the gatewell (Fig. 7, Appendix Table 4). There was no descaling or injury on any of these fish. No parr were caught in the top two nets (blocked from the lower seven nets), indicating that they were apparently not being swept over the top of the screen. For all other species combined (spring and summer), the percent of the total catch in these two nets was 3.1%, indicating that these nets were catching some fish that had gone over the top of the ESBS.

Short-term
(2-3 h)

Long-term
(17 h)

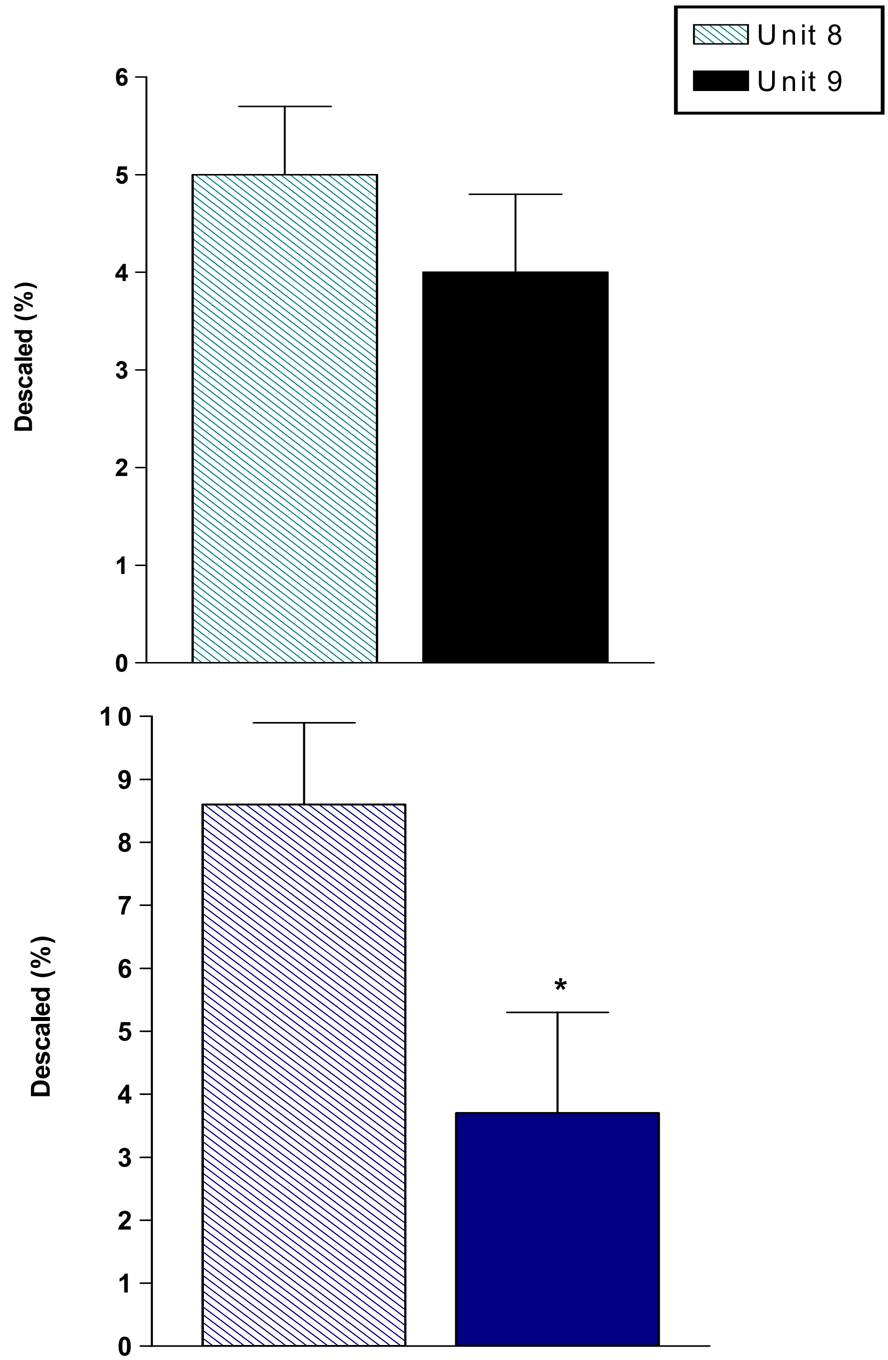
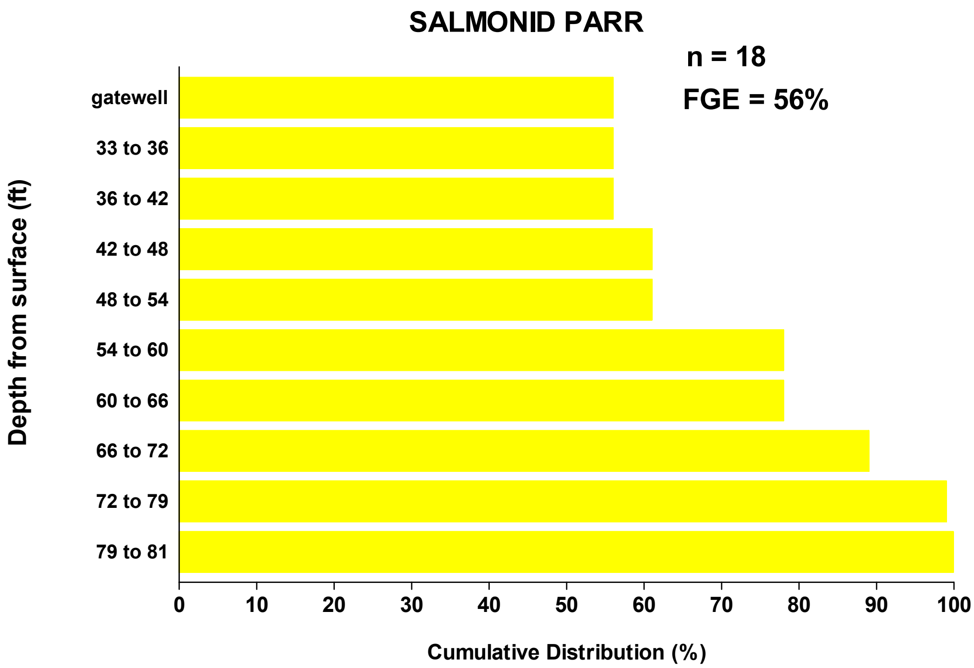


Figure 6. Short-term and long-term descaling and standard errors for subyearling chinook salmon examined during spring migration in Turbine Unit 8 (ESBS) and Unit 9 (STS) at Bonneville Dam First Powerhouse, 2000 (* denotes significant difference, P < 0.05).



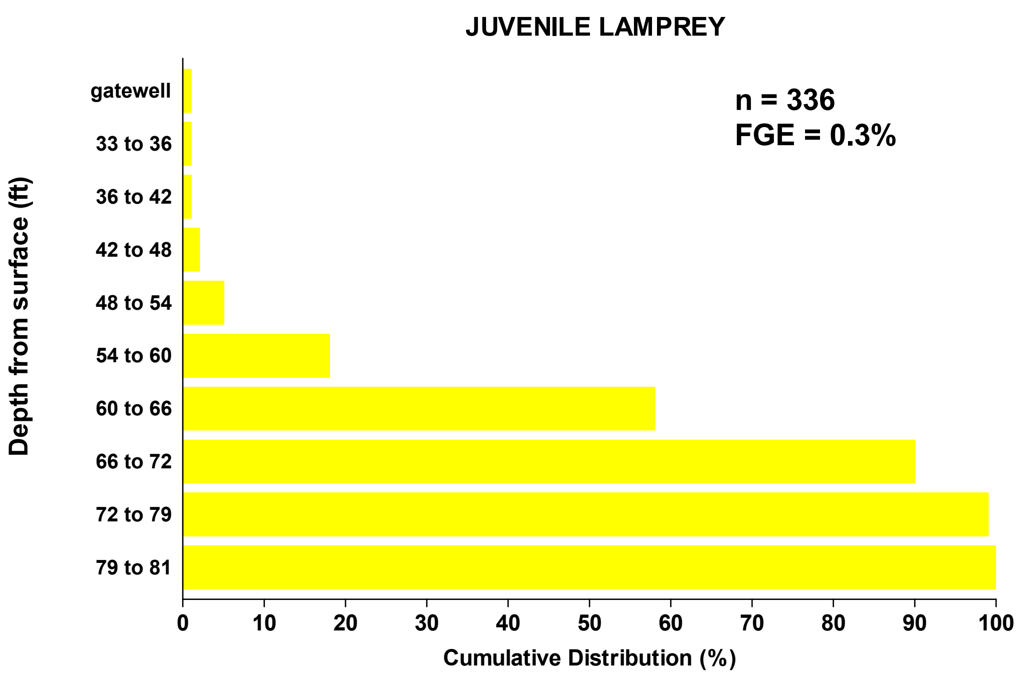


Figure 7. Cumulative distribution of salmonid parr and juvenile lamprey caught in gatewell through fyke-net levels 1 to 9. Fyke-net levels are shown by depth from forebay surface in feet. (n = total number of fish examined during spring and summer testing.)

During spring and summer FGE testing, a total of 335 juvenile lamprey were collected in fyke nets and one in the gatewell. As with salmonid parr, no juvenile lamprey were collected in the top two net levels, again indicating that none came over the top of the STS (Fig. 7; Appendix Table 4). In 1998, when there was no hinged panel blocking the top two net levels, 1.6% of the total catch of juvenile lamprey was collected in these nets. In 2000, we assumed that any fish (live or dead) coming over the ESBS would be caught in these top two net levels. The fact that no lamprey or parr were caught in these nets indicates that impingement of these two species on the ESBS is not likely a problem.

SUMMARY OF 1998 AND 2000 RESULTS

To estimate the potential for improvements in FGE with an ESBS and raised operating gate at Bonneville Dam First Powerhouse, FGE for the two years of testing during the spring migration was average and compared with FGE data collected during similar time periods in Unit 8 (1988 and 1991) and Unit 3 (1989) with an STS and a stored operating gate (Table 3). Although average FGE with an ESBS for all species in 2000 was lower by 4 to 9% than 1998, average FGE for the two years combined (all species) was higher with an ESBS by 23 to 34% during the spring. Since the STS results were in a different year and unit (for subyearling chinook salmon), a statistical comparison of the two screen types was not made.

In 1998, during the summer migration, FGE for subyearling chinook salmon was divided into two sets of ten replicates. In the earlier tests, from 22 June to 2 July, FGE averaged 48%; in the later tests, from 6 July to 17 July, FGE averaged 23%. From 12 June to 7 July, 2000, FGE for subyearling chinook salmon averaged 46%, similar to the earlier test results in 1998; similar to 1998, there was a decrease in FGE during the migration (Fig. 8).

All FGE measurements in past years for subyearling chinook salmon with STSs and stored operating gates were made during the later part of the summer migration. Therefore, for comparisons between the two screen types, only the later tests in 1998 with the ESBS were used to compare with STS tests in 1988 and 1989. Average FGE for these tests with the ESBS was approximately 13% higher than the STS (Table 3). Because the STS tests were conducted 10 years ago in a different unit, this comparison is provided as a estimate of the increase in FGE associated with ESBSs for subyearling chinook salmon during the summer migration.

Table 3. Average fish guidance efficiency and standard errors for all species using a submersible traveling screen (STS) and stored operating gate or an extended-length bar screen (ESBS) and raised operating gate at Bonneville Dam First Powerhouse. Increases in fish guidance efficiency of ESBS over STS (Δ ESBS) are also shown.

	STS with stored operating gate		ESBS with raised operating gate		Δ ESBS
	FGE (%)	SE	FGE (%)	SE	(%)
Spring testing[a]					
Yearling chinook salmon	36	2.4	70	1.4	+34
Steelhead	58	3.5	81	1.4	+23
Coho salmon	53	4.9	80	1.7	+27
Sockeye salmon[b]	25	3.1	51	5.0	+26
Summer Testing					
Subyearling chinook salmon					
12 June-7 July			46	2.0	
6 July-17 July[b]	10[c]	1.3	23	1.1	+13

[a] Submersible traveling screen tested in 1991 (Unit 8). Extended-length bar screen tested in 1998 and 2000 combined (Unit 8).

[b] Extended-length bar screen data from 1998 only.

[c] Submersible traveling screen tested in 1988 and 1989 combined (Unit 3). Extended-length bar screen tested in 1998 and 2000 combined (Unit 8).

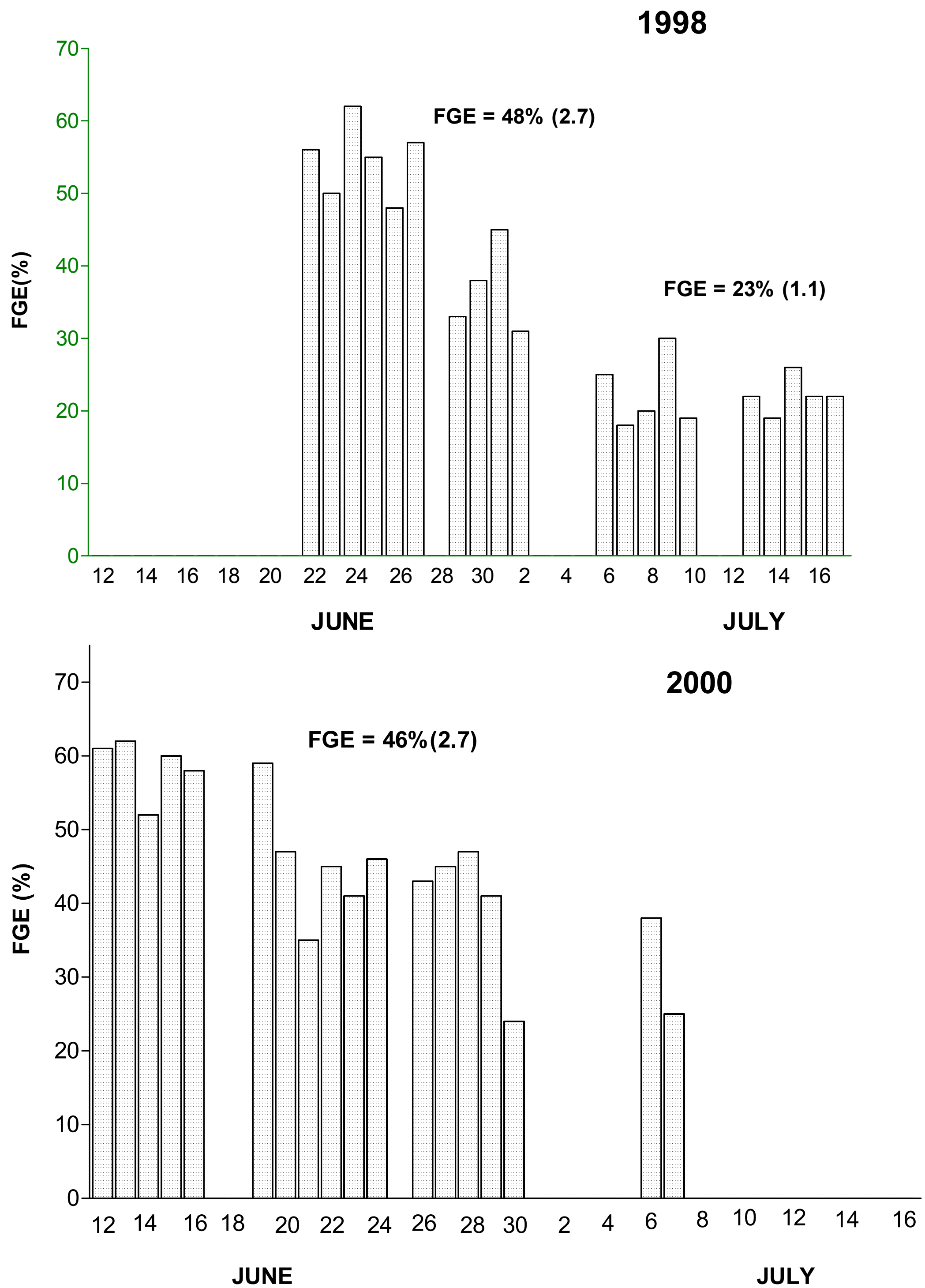


Figure 8. Daily fish guidance efficiency (FGE) for subyearling chinook salmon with extended-length bar screen in Turbine Unit 8 at Bonneville Dam First powerhouse, 1998 and 2000.

In 1998, the difference in OPE between the ESBS and the STS was significant for yearling chinook salmon, 90 and 80%, respectively. In 2000, the difference in OPE between the ESBS and STS for yearling chinook salmon was not significant, 76 and 73%, respectively. During summer testing, there was no significant difference in OPE for subyearling chinook salmon in either 1998 or 2000. In both years, OPE with both screens was over 90%. As seen at other projects (Brege et al. 1997, Monk et al. 1997), the ESBS and new vertical barrier screen design did not seem to hinder passage of fish from the gatewell.

In 2000, there were no significant differences between the ESBS and STS in average median passage times from the gatewell to the downstream monitoring facility. For both screens, average median time was approximately 3 hours for PIT-tagged yearling chinook salmon and approximately 4 hours for PIT-tagged subyearling chinook salmon.

In 1998 and 2000, there was one case each where the descaling rates were significantly higher with the ESBS over the STS (spring testing with yearling chinook salmon and summer testing with subyearling chinook salmon, respectively). For all other species, in both years, there was no significant difference between the two screens and, in 2000, descaling was slightly higher in the STS unit for yearling chinook, sockeye salmon, and steelhead. The difference in descaling between the two screens for yearling chinook (1998) and subyearling chinook salmon (2000), although significant, was small (2 and 1.5%, respectively).

CONCLUSIONS: 1998 AND 2000

1) Average FGE with the ESBSs in 1998 and 2000 was 70% or greater for yearling chinook, coho salmon, and steelhead during the spring migration. For sockeye salmon, FGE averaged 51%. These averages indicate a potential increase in FGE over the present STSs of 23 to 34% for these species.

2) Average FGE with the ESBSs in 1998 and 2000 (combined) during the early part of the summer migration for subyearling chinook salmon was 46%. In 1998, during the later part of the migration, FGE decreased to 23%. In a comparison to 1988 and 1989 FGE tests conducted with STSs in the later part of the summer migration, this represented an increase in FGE of approximately 13%.

3) Both OPE and passage times for yearling chinook salmon and subyearling chinook salmon in 1998 and 2000 indicated that fish passage from the gatewell is not impaired by the ESBS and the new vertical barrier screen and may be slightly improved.

4) Although significantly higher descaling with ESBSs was measured once for yearling chinook salmon (1998) and once for subyearling chinook salmon (2000), these differences ranged from only 1.5 to 2%. For all other species in both years, there was no difference in descaling rates between the two screens.

5) Hemorrhaged eyes and torn or bent operculums were the only injuries found in 1998 or 2000 with either screen. In both years, the injury rate was 1% or less for all species during both spring and summer testing, with no significant differences between the two screens.

6) In 1998 and 2000, a total of 643 juvenile lamprey were caught in the fyke nets with one guided into the gatewell. In 2000, none of the lamprey in the nets were in the top two net levels (blocked off from the lower nets), indicating that lamprey were not being impinged and pushed over the top of the ESBS by the bar sweep.

7) Of the 48 salmonid parr collected during spring testing in 1998 and 2000, 23 (48%) were guided. There was no descaling or injury on these fish and none were caught in the top two net levels, indicating that they were not being impinged and pushed over the top of the ESBS by the bar sweep.

ACKNOWLEDGMENTS

We would like to thank all COE personnel who gave support and assistance during the study. Dennis Schwartz and Mark Smith, District Biologists, helped initiate the project and coordinated daily with the project and reservoir control. Gene LaDoucer, Chief of Maintenance, and Andy DeBriae, Structural Foreman, were very helpful in coordinating crews and giving support for the initial setup of equipment and nightly testing. Every member of the structural crew, who helped with the nightly testing, was enthusiastic and helpful. Carl Zerfing, Crew Foreman, was always able to suggest ways of conducting the various tasks in a safe and efficient manner. Darrel Hunt, Chief of Operations, and the operations staff also were very helpful in coordinating unit outages and discharge levels so that the two test units could be operated at required levels every night. We also extend special thanks to Project Biologists Jennifer Sturgill and Tammy Mackey, who made sure all coordination was accomplished and that everyone involved was aware of what was needed to complete the study.

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APPENDIX TABLES

Appendix Table 1. Numbers of fish caught in gatewell or fyke nets (1-9) and Fish Guidance Efficiency (FGE) for individual replicates of tests in Unit 8 (B) at Bonneville Dam First Powerhouse, 2000. (SC = subyearling chinook salmon, YC = yearling chinook salmon, ST = steelhead, CO = coho, SO = Sockeye).

	24 April					25 April					26 April				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	0	163	26	22	0	2	85	42	11	0	0	72	96	6	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0
4	0	4	1	0	0	0	1	1	1	0	0	5	2	0	0
5	0	12	1	0	0	5	3	4	0	0	0	6	3	0	0
6	1	16	0	1	0	4	7	0	0	0	0	9	0	0	0
7	1	32	0	0	0	5	10	2	0	0	1	13	3	1	0
8	0	13	0	0	0	0	6	0	0	0	0	2	2	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**2**	**242**	**29**	**23**	**0**	**16**	**112**	**49**	**12**	**0**	**1**	**107**	**106**	**7**	**0**
FGE (%)	**0**	**67**	**90**	**96**		**13**	**76**	**86**	**92**		**0**	**67**	**91**	**86**	

	27 April					28 April					29 April				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	2	88	87	10	2	106	112	19	5	1	1	50	38	10	1
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0
3	0	0	0	1	0	0	1	0	0	0	0	2	1	0	0
4	0	3	1	1	0	0	3	0	0	0	0	1	1	0	0
5	0	7	8	0	0	1	6	8	0	1	0	3	4	0	0
6	0	6	5	1	1	0	11	2	0	0	0	8	0	0	0
7	1	11	5	0	1	1	9	4	0	1	0	2	2	0	0
8	1	4	2	0	0	0	13	1	1	0	0	4	1	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**4**	**119**	**108**	**13**	**4**	**108**	**156**	**34**	**6**	**3**	**1**	**70**	**48**	**10**	**1**
FGE (%)	**50**	**74**	**81**	**77**	**50**	**98**	**72**	**56**	**83**	**33**	**100**	**71**	**79**	**100**	

Appendix Table 1. Continued

Location	30 April					1 May					2 May				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	S O	SC	YC	ST	CO	SO
Gatewell	1	57	65	10	1	2	82	37	13	1	1	65	60	24	5
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0
3	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
4	1	4	5	0	0	0	6	3	0	1	0	4	1	0	0
5	0	3	5	0	0	0	6	3	0	0	0	8	0	1	0
6	0	9	1	0	1	0	16	3	0	2	0	14	1	1	0
7	0	11	2	0	0	2	19	5	0	1	0	15	10	0	3
8	0	4	3	0	0	0	8	2	1	0	1	9	3	0	0
9	0	0	0	0	0	0	0	0	0	0	0	9	1	0	0
Totals	**2**	**88**	**83**	**10**	**2**	**4**	**137**	**53**	**14**	**5**	**2**	**124**	**77**	**26**	**8**
FGE (%)	**50**	**65**	**78**	**100**	**50**	**50**	**60**	**70**	**93**	**20**	**50**	**52**	**78**	**92**	**63**

Location	3 May					4 May					5 May				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	2	94	88	26	1	1	89	49	20	3	4	168	85	23	2
1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
2	0	0	0	0	0	0	0	1	0	0	0	3	0	0	0
3	0	1	0	0	1	0	0	2	0	0	0	0	0	0	0
4	0	6	1	0	1	0	4	3	0	0	0	8	3	0	0
5	0	11	9	0	1	0	20	4	0	1	0	12	7	0	1
6	0	18	5	0	1	1	11	2	0	1	1	28	3	0	1
7	0	26	5	0	3	0	17	1	0	1	0	27	3	0	1
8	0	12	1	0	1	0	13	4	0	0	0	22	2	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**2**	**168**	**109**	**26**	**9**	**2**	**154**	**66**	**20**	**6**	**5**	**269**	**103**	**23**	**5**
FGE (%)	**100**	**56**	**81**	**100**	**11**	**50**	**58**	**74**	**100**	**50**	**80**	**62**	**83**	**100**	**40**

Appendix Table 1. Continued.

	8 May					9 May					10 May				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	0	114	68	102	3	0	128	71	67	6	1	156	119	83	7
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	4	1	0	1	0	1	1	1	1
3	0	1	1	0	0	0	1	0	1	0	0	1	3	1	0
4	0	12	1	0	0	0	3	2	3	3	0	4	3	2	1
5	0	17	9	4	0	0	7	4	5	2	0	6	14	9	2
6	2	31	4	4	3	0	16	3	3	4	1	13	8	7	1
7	1	40	2	5	3	0	19	2	8	5	0	25	8	4	4
8	7	14	1	0	1	0	15	2	2	3	0	15	5	3	0
9	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Totals	**10**	**229**	**86**	**115**	**10**	**0**	**193**	**85**	**89**	**24**	**2**	**222**	**161**	**110**	**16**
FGE (%)	**0**	**50**	**79**	**89**	**30**	**0**	**66**	**84**	**75**	**25**	**50**	**70**	**74**	**75**	**44**

	11 May					12 May					15 May				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	1	140	84	50	3	0	126	101	69	4	0	89	81	66	3
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	0	0	0	0	0	0	1	0	0	1	0	2	1
3	0	1	0	0	0	0	3	2	1	1	0	0	1	0	0
4	1	5	4	1	0	1	5	3	2	2	0	3	6	2	3
5	1	5	5	5	0	0	7	6	6	2	0	5	11	4	0
6	0	10	2	3	1	1	3	0	6	0	0	7	5	6	7
7	0	21	10	1	4	0	22	9	6	4	0	10	19	3	4
8	0	10	1	1	2	1	5	2	1	2	0	5	3	2	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**3**	**193**	**106**	**61**	**10**	**3**	**171**	**123**	**92**	**15**	**0**	**120**	**126**	**85**	**18**
FGE (%)	**33**	**73**	**79**	**82**	**30**	**0**	**74**	**82**	**75**	**27**		**74**	**64**	**78**	**17**

Appendix Table 1. Continued

Location	16 May					17 May					22 May				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	0	88	114	111	1	0	88	118	90	2	285	33	62	64	1
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	2	2	1	1	0	0	0	0	0	12	0	0	0	0
3	0	1	1	1	0	0	0	0	0	0	5	0	2	0	0
4	0	12	5	11	0	0	4	6	4	3	31	6	5	5	0
5	0	10	22	11	2	0	10	13	11	2	53	2	14	4	0
6	1	13	9	11	4	0	7	4	8	3	56	6	5	5	1
7	0	20	21	12	1	0	7	11	8	6	46	8	5	4	2
8	0	8	5	5	4	0	11	5	1	3	16	3	3	3	0
9	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Totals	**1**	**154**	**179**	**163**	**13**	**0**	**127**	**157**	**123**	**19**	**504**	**58**	**96**	**85**	**4**
FGE (%)	**0**	**57**	**64**	**68**	**8**		**69**	**75**	**73**	**11**	**57**	**57**	**65**	**75**	**25**

Location	23 May					24 May				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	152	24	57	79	2	83	29	81	54	4
1	0	0	0	1	0	0	0	0	0	0
2	2	1	1	0	0	2	0	1	0	0
3	0	0	1	0	0	1	0	0	0	0
4	12	0	1	2	0	11	0	5	1	2
5	20	2	5	12	1	9	2	7	6	1
6	29	5	6	6	1	19	11	2	6	8
7	33	9	9	6	2	14	13	4	7	2
8	22	4	5	1	0	8	4	3	1	1
9	0	0	0	0	0	0	0	0	0	0
Totals	**270**	**45**	**85**	**107**	**6**	**147**	**59**	**103**	**75**	**18**
FGE (%)	**56**	**53**	**67**	**74**	**33**	**56**	**49**	**79**	**72**	**22**

Appendix Table 1. Continued.

Location	12 June					13 June					14 June				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	390	21	6	6	0	120	7	29	5	0	115	7	9	6	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	18	0	0	0	0	8	0	0	1	0	10	0	0	1	0
3	4	0	1	0	0	4	0	0	0	0	4	0	0	0	0
4	31	0	0	1	0	12	1	0	0	0	20	0	0	0	0
5	32	0	1	1	0	11	1	4	0	0	20	0	1	0	0
6	51	1	0	0	0	19	0	1	0	0	27	0	1	0	0
7	70	0	1	0	0	13	0	1	2	0	20	1	0	1	0
8	39	1	0	0	0	6	0	0	1	0	6	1	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**635**	**23**	**9**	**8**	**0**	**193**	**9**	**35**	**9**	**0**	**222**	**9**	**11**	**8**	**0**
FGE (%)	**61**	**91**	**67**	**75**		**62**	**78**	**83**	**56**		**52**	**78**	**82**	**75**	

Location	15 June					16 June					19 June				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	144	10	5	6	0	84	9	5	5	0	207	13	3	4	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	6	0	1	0	0	4	0	0	1	0	7	0	0	0	0
3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	11	0	1	0	0	7	0	0	0	0	18	0	1	0	0
5	22	0	0	0	0	13	0	0	0	0	29	0	0	0	0
6	28	1	0	0	0	13	0	0	0	0	41	3	0	0	0
7	17	3	2	1	0	17	0	0	0	0	31	1	1	0	0
8	8	0	1	0	0	8	2	0	0	0	17	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**240**	**14**	**10**	**7**	**0**	**146**	**11**	**5**	**6**	**0**	**350**	**17**	**5**	**4**	**0**
FGE (%)	**60**	**71**	**50**	**86**		**58**	**82**	**100**	**83**		**59**	**76**	**60**	**100**	

Appendix Table 1. Continued

	20 June					21 June					22 June				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	128	4	0	0	0	114	4	2	0	2	147	3	0	2	5
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	3	0	0	0	0	6	0	0	0	0	0	0	0	0	0
3	2	0	0	0	0	4	0	0	0	0	1	0	0	0	0
4	17	0	0	0	0	29	0	0	0	0	16	1	0	0	0
5	26	0	0	0	0	49	1	0	0	0	33	1	0	0	0
6	36	0	0	0	0	49	0	0	0	0	57	0	0	0	0
7	42	0	0	0	0	51	2	1	0	0	51	3	0	0	0
8	21	0	0	0	0	24	0	1	0	0	19	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**275**	**4**	**0**	**0**	**0**	**326**	**7**	**4**	**0**	**2**	**324**	**8**	**0**	**2**	**5**
FGE (%)	**47**	**100**				**35**	**57**	**50**		**100**	**45**	**38**		**100**	**100**

	23 June					24 June					26 June				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	96	5	1	5	4	181	18	2	4	4	141	21	0	0	0
1	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
2	4	0	0	0	0	3	0	0	0	0	9	0	0	0	0
3	0	0	0	0	0	11	0	0	0	0	2	0	0	0	0
4	9	0	0	0	0	20	0	0	0	0	12	2	0	0	0
5	25	1	0	0	0	35	2	0	0	0	38	1	0	0	0
6	37	1	1	0	0	57	1	1	0	0	47	2	0	0	0
7	46	3	0	0	0	62	4	0	0	0	61	2	0	0	0
8	18	2	0	1	1	23	2	0	0	0	22	2	0	0	0
9	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
Totals	**236**	**12**	**2**	**6**	**5**	**392**	**28**	**3**	**4**	**5**	**332**	**30**	**0**	**0**	**0**
FGE (%)	**41**	**42**	**50**	**83**	**80**	**46**	**64**	**67**	**100**	**80**	**42**	**70**			

Appendix Table 1. Continued

	27 June					28 June					29 June				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	98	5	0	0	1	119	8	0	0	0	145	8	0	1	2
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	5	0	0	0	0	3	0	0	0	0	10	0	0	0	0
3	1	0	0		0	4	0	0	0	0	8	1	0	0	0
4	21	0	0	0	0	11	0	0	0	0	27	0	0	0	0
5	20	0	0	0	0	27	0	0	0	0	31	0	0	0	0
6	42	1	0	0	1	34	1	0	0	0	41	0	1	0	0
7	49	2	0	0	2	37	0	0	0	0	61	0	0	0	0
8	30	2	0	1	0	21	0	0	1	0	29	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**266**	**10**	**0**	**1**	**4**	**256**	**9**	**0**	**1**	**0**	**352**	**9**	**1**	**1**	**2**
FGE (%)	**37**	**50**		**0**	**25**	**46**	**89**		**0**		**41**	**89**	**0**	**100**	**100**

	30 June					6 July					7 July				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	81	0	0	0	1	61	2	0	0	0	28	8	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	4	0	0	0	0	3	0	0	0	0	3	0	0	0	0
3	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0
4	21	0	0	0	0	3	0	0	0	0	5	0	0	0	0
5	30	1	0	0	0	19	0	0	0	0	9	0	0	0	0
6	81	0	0	0	1	29	0	0	0	0	20	0	0	0	0
7	71	0	0	2	0	28	3	0	0	1	27	2	0	0	0
8	51	1	0	0	0	19	1	0	0	0	18	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**342**	**2**	**0**	**2**	**2**	**162**	**6**	**0**	**0**	**1**	**111**	**10**	**0**	**0**	**0**
FGE (%)	**24**	**0**		**0**	**50**	**38**	**33**				**25**	**80**			

Appendix Table 2. Numbers of fish examined and numbers classified as descaled or with eye or gill injuries during FGE (short-term) and OPE (long-term) tests in Units 8 and 9 at Bonneville Dam First Powerhouse, 2000.

Yearling chinook salmon

	Unit 8 (B) ESBS - Short-term				Unit 8 (A) ESBS -Long-term			
Date	No. Exam	Desc.	Eye Injury	Gill Injury	No. Exam.	Desc.	Eye Injury	Gill Injury
24 April	163	0	0	0				
25 April	85	0	0	0	128	4	0	0
26 April	72	3	0	0	100	8	0	0
27 April	88	4	0	0	0			
28 April	0		0	0	82	1	0	1
29 April	50	4	0	0	121	4	0	0
30 April	57	1	0	0	27	2	0	0
1 May	2	0	0	0	83	2	0	0
2 May	65	5	0	0	100	2	0	1
3 May	94	3	0	0	58	3	1	0
4 May	89	13	0	0	41	7	0	2
5 May	168	20	0	0	98	10	1	1
8 May	114	16	1	0	34	6	0	0
9 May	128	14	1	0	82	16	3	0
10 May	156	14	0	0	77	12	1	0
11 May	140	15	0	2	57	8	0	0
12 May	126	13	1	1	45	9	0	1
15 May	89	18	0	0	26	2	2	0
16 May	88	12	0	0	22	4	4	0
17 May	88	13	1	0	14	3	0	0
22 May	33	7	2	1	3	0	0	0
23 May	24	5	0	0	2	0	2	0
24 May	29	4	0	0	2	1	0	0
TOTAL	1948	184	6	4	1202	104	14	6

	Unit 9 (B) STS - Short-term				Unit 9 (A) STS -Long-term			
Date	No. Exam	Desc.	Eye Injury	Gill Injury	No. Exam.	Desc.	Eye Injury	Gill Injury
24	92	0			0			
25 April	76	0	0	0	120	3	0	0
26 April	97	5	2	0	114	1	0	0
27 April	86	2	0	0	0		0	0
28 April	130	7	0	1	137	8	0	0
29 April	40	4	1	0	80	4	0	1
30 April	76	3	0	0	24	2	0	0
1 May	96	1	0	0	52	4	0	0
2 May	58	3	0	0	45	5	0	0
3 May	67	9	1	0	67	7	1	0
4 May	124	9	0	0	36	5	0	2
5 May	124	16	0	0	52	4	2	0
8 May	153	19	0	0	68	9	0	0
9 May	129	19	1	0	52	7	0	0

Appendix Table 2. Continued.

Yearling chinook salmon, continued

Date	Unit 9 (B) STS - Short-term				Unit 9 (A) STS - Long-term			
	No. Exam	Desc.	Eye Injury	Gill Injury	No. Exam.	Desc.	Eye Injury	Gill Injury
10 May	118	11	0	0	59	5	0	0
11 May	69	7	0	0	18	2	0	0
12 May	61	8	1	0	15	1	0	0
15 May	60	12	0	0	8	1	1	0
16 May	35	7	0	0	12	1	1	0
17 May	23	5	0	0	10	1	0	0
22 May	4	0	0	0	5	2	0	0
23 May	16	3	0	0	2	0	0	0
24 May	7	3	0	0	4	0	0	0
TOTAL	393	56	1	0	133	13	2	0

Steelhead

Date	Unit 8 (B) ESBS - Short-term				Unit 8 (A) ESBS-Long-term			
	No. Exam	Desc.	Eye Injury	Gill Injury	No. Exam.	Desc.	Eye Injury	Gill Injury
24 April	26	0	0	0	0			
25 April	7	0	0	0	7	0	0	0
26 April	96	6	0	0	14	0	0	0
27 April	88	4	0	0	0			
28 April	0				12	1	0	0
29 April	38	1	0	0	22	0	0	0
30 April	65	4	0	0	20	0	0	0
1 May	82	5	0	0	4	0	0	0
2 May	60	7	0	0	17	0	0	0
3 May	88	6	0	0	19	2	0	0
4 May	49	8	0	0	16	0	0	0
5 May	85	7	0	0	21	1	0	0
8 May	68	8	0	1	14	1	0	0
9 May	71	6	0	0	12	2	0	0
10 May	119	8	0	0	19	3	0	1
11 May	84	3	0	0	10	0	0	0
12 May	101	6	0	0	17	3	0	0
15 May	81	4	0	0	9	1	0	0
16 May	114	3	0	0	6	1	0	0
17 May	118	6	0	0	0			
22 May	62	3	0	0	3	1	0	0
23 May	57	5	0	0	1	0	0	0
24 May	81	2	0	0	0			
TOTAL	1640	102	0	1	243	16	0	1

Appendix Table 2. Continued

Steelhead, continued

	Unit 9 (B) STS- Short-term				Unit 9 (A) STS - Long-term			
Date	No. Exam	Desc.	Eye Injury	Gill Injury	No. Exam.	Desc.	Eye Injury	Gill Injury
24 April	0				0			
25 April	9	1	0	0	8	1	0	0
26 April	48	3	0	0	7	2	0	0
27 April	38	8	0	0	0			
28 April	46	2	0	0	15	0	0	0
29 April	40	0	0	1	17	2	1	0
30 April	37	2	0	0	5	0	0	0
1 May	29	1	0	0	8	0	0	0
2 May	36	1	0	0	10	1	0	0
3 May	39	2	0	0	18	3	0	0
4 May	46	5	0	0	20	1	1	0
5 May	42	2	0	0	17	6	0	0
8 May	68	13	0	0	79	21	0	0
9 May	64	6	0	0	15	1	0	0
10 May	37	3	0	1	25	5	0	0
11 May	35	1	0	0	10	1	0	0
12 May	58	4	0	1	13	1	0	0
15 May	77	4	0	0	35	2	0	0
16 May	54	4	0	1	15	3	0	0
17 May	28	1	0	0	24	4	0	0
22 May	13	0	0	0	8	0	0	0
23 May	13	0	0	0	1	0	0	0
24 May	25	0	0	0	1	0	0	0
TOTAL	787	51	0	4	336	51	2	0

Coho Salmon

	Unit 8 (B) ESBS - Short-term				Unit 8 (A) ESBS - Long-term			
Date	No. Exam	Desc.	Eye Injury	Gill Injury	No. Exam.	Desc.	Eye Injury	Gill Injury
24 April	22	0	0	0	0			
25 April	11	2	0	0	5	1	0	0
26 April	6	0	0	0	6	1	0	0
27 April	10	2	0	0	0			
28 April	0				13	1	0	0
29 April	10	2	0	0	12	0	0	0
30 April	10	0	0	0	7	0	0	0
1 May	37	1	0	0	13	1	0	0
2 May	24	2	0	0	10	1	0	0
3 May	26	1	0	0	13	0	0	0
4 May	20	1	0	0	25	6	0	0
5 May	23	0	0	0	12	1	0	0
8 May	102	10	0	0	27	4	0	0
9 May	67	8	0	0	38	4	0	0
10 May	83	4	0	0	42	5	0	0
11 May	50	2	0	0	28	3	0	0
12 May	69	6	0	0	28	0	0	0

Appendix Table 2. Continued.

Coho salmon, continued

Date	Unit 8 (B) ESBS - Short-term No. Exam	Desc.	Eye Injury	Gill Injury	Unit 8 (A) ESBS - Long-term No. Exam.	Desc.	Eye Injury	Gill Injury
15 May	66	5	0	0	11	1	0	1
16 May	111	7	0	1	10	2	0	0
17 May	90	5	0	0	22	3	0	0
22 May	64	1	1	0	21	2	1	0
23 May	79	7	0	0	16	1	0	0
24 May	54	3	0	0	22	0	0	0
TOTAL	464	28	1	1	102	9	1	1

Date	Unit 9 (B) STS - Short-term No. Exam.	Desc.	Eye Injury	Gill Injury	Unit 9 (A) STS - Long-term No. Exam.	Desc.	Eye Injury	Gill Injury
24 April	34	0	0	0	0			
25 April	7	1	0	0	28	0	0	0
26 April	11	0	0	0	21	7	1	0
27 April	5	0	0	0	0			
28 April	12	1	0	0	10	0	0	0
29 April	24	1	0	0	13	1	0	0
30 April	11	0	0	0	4	0	0	0
1 May	9	0	0	0	3	0	0	0
2 May	17	1	0	0	12	0	0	0
3 May	12	1	0	0	8	0	0	0
4 May	22	0	0	0	15	1	0	0
5 May	32	0	1	0	11	1	0	0
8 May	40	5	0	0	46	8	1	0
9 May	61	4	0	0	30	6	0	0
10 May	39	2	0	0	38	3	0	0
11 May	28	1	2	0	10	1	0	0
12 May	20	4	0	0	9	0	0	0
15 May	20	0	0	0	6	1	0	0
16 May	21	2	0	0	10	1	0	0
17 May	8	0	0	0	14	3	0	0
22 May	7	1	0	0	3	1	0	0
23 May	14	1	0	0	13	2	0	0
24 May	18	0	0	0	12	1	0	0
TOTAL	438	25	3	0	316	37	2	0

Appendix Table 2. Continued.

Sockeye salmon

	Unit 8 (B) ESBS - Short-term				Unit 8 (A) ESBS - Long-term			
Date	No. Exam	Desc.	Eye Injury	Gill Injury	No. Exam.	Desc.	Eye Injury	Gill Injury
24 April	2	0	0	0				
26 April					1	1	0	0
27 April	2	1	0	0	0			
28 April	0				1	0	0	0
29 April	1	0	0	0	1	1	0	0
30 April	0				1	0	0	0
1 May	1	1	0	0	0			
2 May	5	1	0	0	1	1	0	0
3 May	1	1	0	0	0			
4 May	3	1	0	0	2	1	0	0
5 May	2	1	0	0	2	0	0	0
8 May	3	2	0	0	1	0	0	0
9 May	6	0	0	0	5	1	0	0
10 May	7	0	0	0	1	0	0	0
11 May	3	2	0	0	0			
12 May	4	0	0	0	0			
15 May	3	0	0	0	1	0	0	0
16 May	1	1	0	0	1	1	0	0
17 May	2	0	0	0	0			
22 May	1	0	0	0	0			
23 May	2	0	0	0	0			
24 May	4	1	0	0	0			
TOTAL	10	2	0	0	1	1	0	0

	Unit 9 (B) STS - Short-term				Unit 9 (A) STS - Long-term			
Date	No. Exam.	Desc.	Eye Injury	Gill Injury	No. Exam.	Desc.	Eye Injury	Gill Injury
27 April	1	0	0	0	0			
28 April	2	0	0	0	0			
3 May	0				1	0	0	0
4 May	0				1	1	0	0
5 May	1	1	0	0	0			
8 May	1	1	0	0	1	0	0	0
9 May	1	1	0	0	0			
10 May	3	0	0	0	0			
12 May	1	0	0	0	0			
TOTAL	10	3	0	0	3	1	0	0

Appendix Table 2. Continued.

Subyearling chinook salmon

	Unit 8 (B) ESBS - Short-term				Unit 8 (A) ESBS - Long-term			
Date	No. Exam	Desc.	Eye Injury	Gill Injury	No. Exam.	Desc.	Eye Injury	Gill Injury
12 June	390	5	0	0	25	3	0	0
13 June	120	1	0	0	23	0	0	0
14 June	115	2	0	0	35	4	1	0
15 June	144	6	0	0	23	0	0	0
16 June	84	7	0	0	17	2	0	0
19 June	207	23	0	0	10	0	0	0
20 June	128	10	0	0	52	5	0	0
21 June	114	6	0	0	23	1	0	0
22 June	147	9	0	0	26	3	0	0
23 June	96	2	0	0	6	1	0	0
24 June	181	7	0	0	18	2	0	0
26 June	141	10	0	1	41	5	0	0
27 June	98	6	0	1	22	2	0	0
28 June	119	10	0	0	17	3	1	0
29 June	145	6	0	0	15	1	0	0
30 June	81	3	0	0	17	2	0	0
6 July	61	5	0	0	0			
7 July	28	0			11	1	0	0
TOTAL	2399	118	0	2	381	35	2	0

	Unit 9 (B) STS - Short-term				Unit 9 (A) STS - Long-term			
Date	No. Exam.	Desc.	Eye Injury	Gill Injury	No. Exam.	Desc.	Eye Injury	Gill Injury
12 June	109	0	0	1	13	0	0	0
13 June	50	1	0	0	83	4	0	0
14 June	31	1	0	0	4	0	0	0
15 June	38	0	0	0	5	1	0	0
16 June	19	1	0	0	10	1	0	0
19 June	34	3	0	0	1	0	0	0
20 June	19	1	0	0	3	0	0	0
21 June	37	0	0	0	9	0	0	0
22 June	53	3	0	0	14	0	0	0
23 June	32	2	0	0	7	0	0	0
24 June	40	3	0	0	15	3	0	0
26 June	75	2	0	1	22	0	0	0
27 June	66	4	0	0	39	2	0	1
28 June	20	2	1	0	5	0	1	0
29 June	32	0	0	0	12	0	0	0
30 June	111	1	0	0	16	1	1	0
6 July	12	1	0	0	0	0	0	0
7 July	14	0	0	0	5	0	0	0
TOTAL	792	25	1	2	263	12	2	1

Appendix Table 3. Results of paired t-tests comparing short-term and long-term descaling rates between submersible traveling screen and extended-length bar screen (* denotes significant difference, $P < 0.05$).

	df	*t*	P
Spring testing			
Yearling chinook			
Short-term	21	0.19	0.848
Long-term	20	0.66	0.516
Steelhead			
Short-term	21	0.02	0.984
Long-term	18	1.17	0.257
Coho			
Short-term	21	1.31	0.203
Long-term	21	0.01	0.994
Summer testing			
Subyearling chinook			
Short-term	17	1.56	0.138
*Long-term	17	2.23	0.040
*Combined	17	2.12	0.049

Appendix Table 4. Numbers of juvenile lamprey and parr caught in gatewell or fyke nets (1-9) and fish guidance efficiency for individual replicates of tests in Unit 8 (B) from 24 April to 7 July at Bonneville Dam First Powerhouse, 2000.

LAMPREY

	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3	5/4	5/5
Gatewell	1	0	1	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	1	0	0	0	0
4	1	1	1	1	4	0	1	1	0	0	0	0
5	1	1	3	1	2	2	1	2	1	3	0	0
6	5	5	5	6	5	4	5	2	3	7	5	8
7	6	5	5	2	4	1	1	1	2	5	3	4
8	1	4	2	0	0	1	1	1	1	0	1	1
9	0	0	0	0	0	0	0	0	0	0	0	0
Totals	15	16	17	10	15	8	9	8	7	15	9	13
FGE (%)	7	0	6	0	0	0	0	0	0	0	0	0

	5/8	5/ 9	5/10	5/11	5/12	5/15	5/16	5/17	5/22	5/23	5/24
Gatewell	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0
3	0	0	1	0	0	1	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	2	2	1	0	1	0	3	0	0	4
6	4	2	3	3	5	4	5	3	1	0	8
7	0	2	2	7	1	2	3	1	6	7	4
8	3	0	1	0	0	1	1	0	1	0	1
9	0	0	0	0	0	0	0	0	0	0	1
Totals	7	6	9	11	6	9	9	7	8	7	18
FGE (%)	0	0	0	0	0	0	0	0	0	0	0

Appendix Table 4. Continued.

SALMONID PARR

	4/24	4/26	4/27	4/28	4/30	5/1	5/9	5/16	5/23	6/15	6/28	6/29
Gatewell	0	1	1	1	1	1	0	0	2	1	1	0
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	1	0	0	0	0
6	0	1	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	1	0	0	1
8	1	0	0	0	0	0	1	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
Totals	1	2	1	1	1	1	1	1	3	1	1	1
FGE (%)	0	50	100	100	100	100	0	0	67	100	100	0