Evaluation of extended-length submersible bar screens

at Bonneville Dam First Powerhouse, 1998

Fish Ecology Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

by
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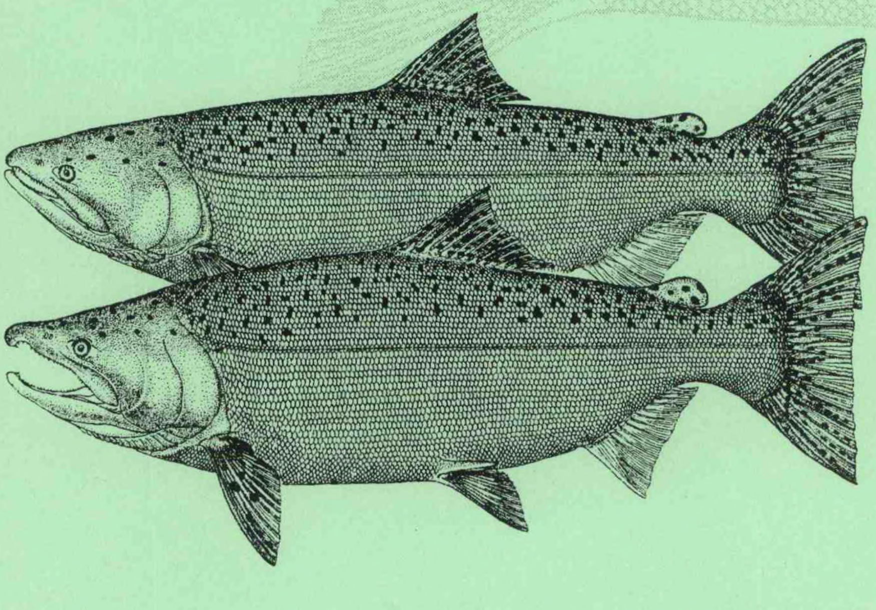
November 1999



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by

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Report of Research

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EXECUTIVE SUMMARY

In 1998, we conducted research at Bonneville Dam First Powerhouse to determine levels of improvement in fish guidance efficiency (FGE), 24-hour orifice passage efficiency (OPE), and levels of descaling and injury using three extended-length submersible bar screens (ESBSs) installed in Turbine Unit 8. To further improve FGE by increasing flows into the gatewell, operating gates were raised in the A and C slot of Turbine Unit 8, and the gate was removed in the B slot to accommodate a fyke-net frame for FGE testing.

In 23 FGE tests conducted from 24 April to 21 May 1998, FGE for yearling chinook salmon averaged 72% (SE = 1.9). For subyearling chinook salmon, steelhead, coho salmon, and sockeye salmon, FGE was 67, 85, 80, and 51% respectively. Improvements in FGE obtained by using the ESBS and a raised operating gate, rather than the standard submersible traveling screen (STS) and stored operating gate, ranged from 26 to 34% for each species (compared to 1991 results).

During the same time period, in a comparison of 24-hour orifice passage efficiency (OPE) between an ESBS with a raised operating gate (Turbine Unit 8A) and an STS with a stored gate (Turbine Unit 9A), there was a significant increase in OPE with the ESBS slot (90%) over the standard STS slot (80%).

During the spring migration, there was a significant difference in descaling between yearling chinook salmon guided with an ESBS (10%) and those guided with an STS (8%). However, for subyearling chinook salmon, steelhead, coho salmon, and sockeye salmon, there were no significant differences in descaling between the two screens, though descaling rates were slightly higher with the STS for steelhead and coho. In both units, gill and head injuries combined were less than 1% for all species except sockeye salmon, which were just over 1% in both units.

From 22 June to 17 July 1998, 20 FGE tests and OPE and descaling tests were conducted focusing on subyearling chinook salmon, again with three ESBSs in Turbine Unit 8 and three standard STS in Turbine Unit 9. For subyearling chinook salmon, FGE averaged 55% (SE = 2.0) from 22 to 27 June 1998 and 27% (SE = 2.1) from 29 June to 17 July 1998. In contrast, FGE tests of subyearling chinook salmon in July 1988 and 1989 resulted in average FGEs of 11 and 4%, respectively. These earlier tests were conducted in Turbine Unit 3 with a standard STS and stored operating gate.

During the 1998 summer migration, OPE averaged 97% with the ESBS and 98% with the standard STS. Descaling averaged 3% with the ESBS and 2% with the standard STS (not significantly different), and injury rates averaged less than 1% in both units.

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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 during the test period, 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 outmigration (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 the flow more evenly across the width of the powerhouse. A navigation guidewall was also constructed along the south side of the forebay. In the 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 time 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 both the spring and summer juvenile salmonid outmigration periods. 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, and between 12 and 24 July 1989, FGE for subyearling chinook salmon averaged only 4% (Gessel et al. 1990).

During the juvenile salmonid outmigration 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, which suggested that inadequate flows up into the gatewell and deflection of fish under the STS were responsible, in part, for the low FGE. This information and the results of physical model studies and research at other Snake and Columbia 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 the ESBS and raising the operating gates (without removing them).

Orifice Passage Efficiency (OPE) is the percent of guided fish which exit the gatewell via the orifice in a 24-hour period. Estimates of OPE for all species at other Columbia and Snake

River dams with ESBSs installed have been greater 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 the first powerhouse with an ESBS installed were also necessary.

Based on these considerations, the COE, through NMFS Regional Forum, decided to test 40-ft ESBSs at Bonneville Dam First Powerhouse in an attempt to improve FGE. Research objectives for 1998 were as follows:

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

2) Evaluate orifice passage efficiency (OPE) of juvenile fish bypass orifices with the ESBSs during spring and summer outmigration.

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

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

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 FGE tests were conducted in the center slot (B) during the spring and summer outmigrations.

Past FGE studies have utilized fyke nets attached to a frame beneath the STS to collect unguided fish. With the ESBS, this configuration was not possible because the framework blocked the entire guide slot from floor to intake ceiling. Therefore, a fyke-net frame with an array of nets was installed in the downstream gate (or bulkhead) slot 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).

Methods for determining FGE were the same as those used in previous STS studies (Monk et al. 1992, 1993). 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:

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

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

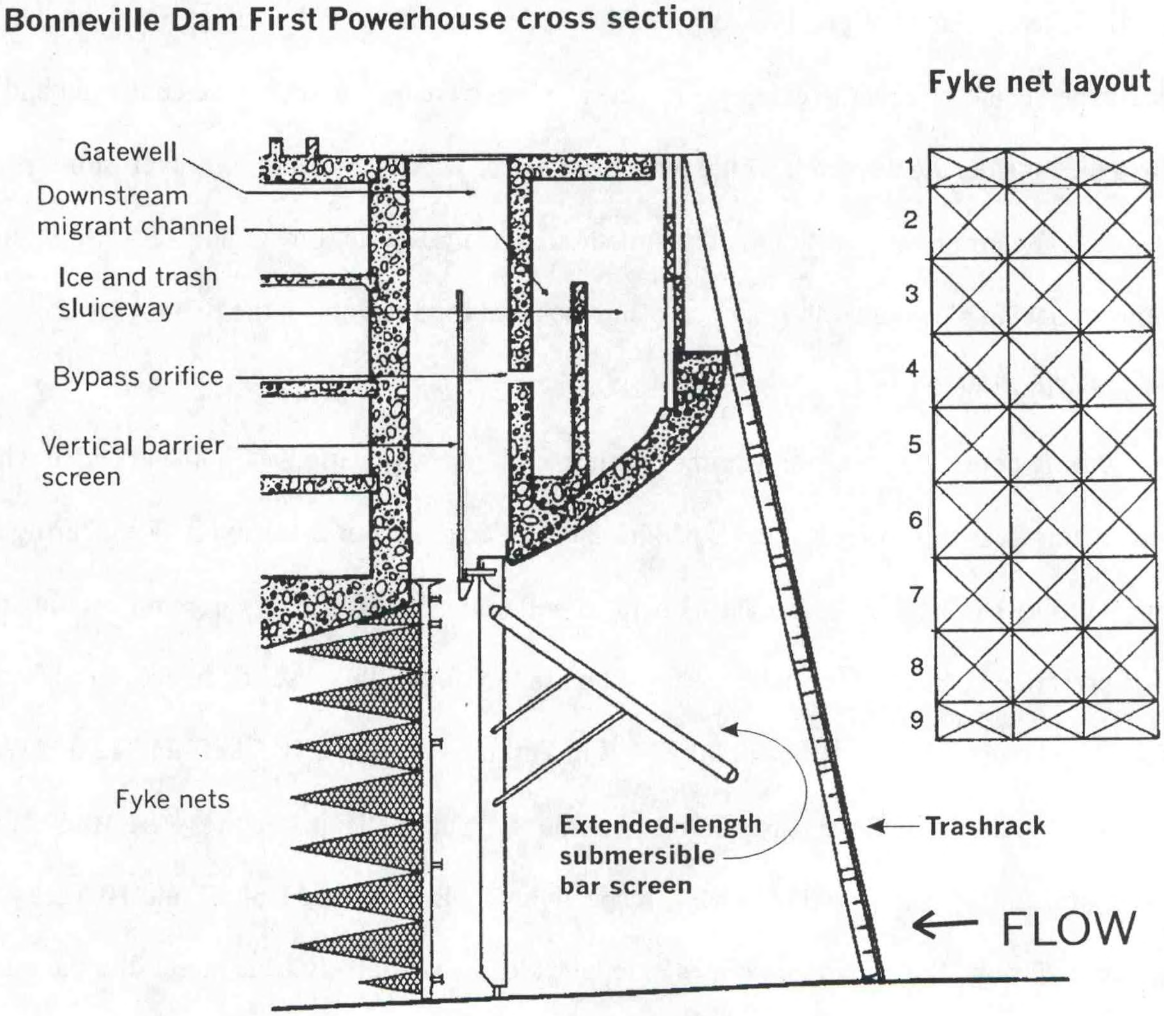


Figure 1. Cross section of turbine intake at Bonneville Dam First Powerhouse, showing extended-length bar screen and fish bypass system. Fyke-net layout shows nine net levels and three columns of nets.

For 14 of the 23 FGE tests conducted during the spring migration, only the center column of fyke nets were used, and the net catch was multiplied by three to get the total fyke-net catch (Fig. 1). By using this configuration, only a third of the fish that would have been caught and killed by the nets were actually caught. However, if fish were able to detect the center net and move to the outside, the net catch would have been biased downward, and FGE overestimated. Therefore, to determine the accuracy of this method, nine FGE tests were conducted with all three columns of nets in place (a total of 36 nets), and the resulting FGEs from the two methods compared using paired t-tests.

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 (between 2100 and 2300). During all testing, Turbine Units 8 and 9 were both operated within the 1% efficiency range for existing net head as prescribed by the COE Fish Passage Plan. In the spring, this resulted in an average discharge and output of 10.8 kcfs and 40.9 MW in Turbine Unit 8 and 10.5 kcfs and 42.0 MW in Turbine Unit 9. In the summer, discharge and output for Turbine Units 8 and 9 were 10.0 kcfs and 41.2 MW and 10.1 kcfs and 40.5 MW, respectively. Also, Turbine Units 7 and 10 were kept in operation during all testing (sometimes at reduced loads) so that any edge effect into the intakes was diminished.

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. Given the constraints of the Endangered Species Act, we did not believe it would be prudent to sacrifice additional fish to show that FGE is markedly higher with the extended-length bar screens. Based on 1996 results from McNary Dam, we determined that 20 FGE replicates using 200 total fish of the target species would result in sufficient precision for mean FGE estimates.

Results and Discussion

Spring Testing

From 24 April to 21 May, 23 FGE tests were completed. Gatewell catches, fyke-net level catches, and resulting FGE for yearling and subyearling chinook salmon, coho salmon, sockeye salmon, and steelhead are given in Appendix Table 1 for all these tests.

For yearling chinook salmon, FGE ranged from 53 to 87% with a mean of 72% (SE = 1.9; Fig. 2). For subyearling chinook salmon, steelhead, coho and sockeye, FGE averaged 67 (SE = 4.7), 85 (SE = 1.5), 80 (SE = 2.3), and 51% (SE = 5.0), respectively.

To estimate the potential for improvements in FGE with an ESBS, comparisons of 1998 FGE data (without statistical analysis) were made with FGE data collected in 1991 in Turbine Unit 8 with an STS and stored operating gate (four sets of five replicates from 22 April to 24 May). For subyearling and yearling chinook salmon and sockeye salmon, FGE with the ESBS at least doubled over FGE with the STS. For steelhead and coho salmon, FGE increased from 58 to 85% and from 53 to 80%, respectively (Table 1).

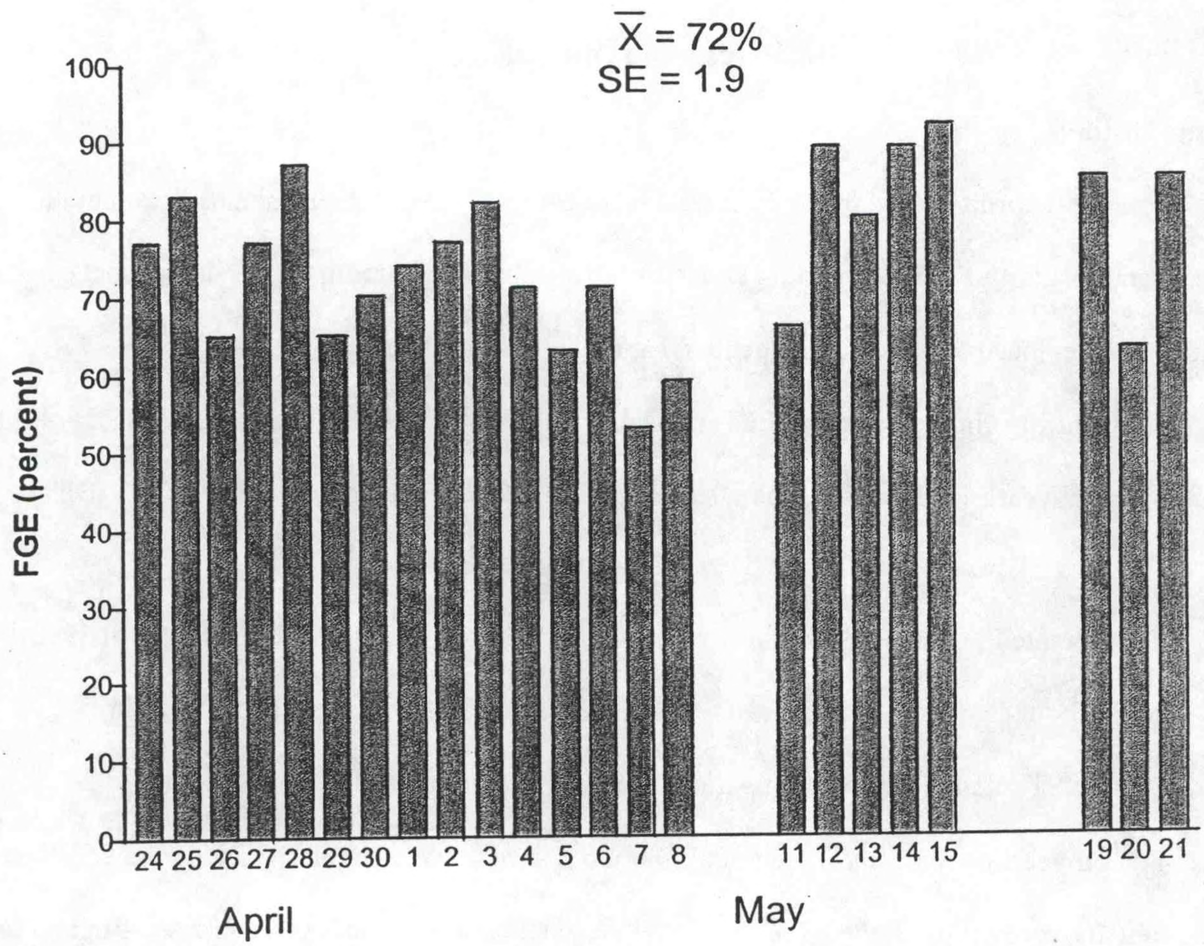


Figure 2. Daily fish guidance efficiency for yearling chinook salmon in Turbine Unit 8 (with ESBS) during spring migration at Bonneville Dam First Powerhouse, 1998.

Table 1. Fish guidance efficiency and standard errors for all species using an extended-length bar screen and raised operating gate in 1998 and a submersible traveling screen and stored operating gate in 1988, 1989, and 1991 at Bonneville Dam First Powerhouse (1998 and 1991 tests were conducted in Turbine Unit 8; 1988 and 1989 tests were conducted in Turbine Unit 3).

	Extended-length bar screen with raised operating gate		Submersible traveling screen with stored operating gate	
	FGE (%)	SE	FGE (%)	SE
Spring Testing (1998 and 1991)				
Subyearling chinook salmon	67	4.7	33	4.0
Yearling chinook salmon	72	1.9	36	2.4
Steelhead	85	1.5	58	3.5
Coho salmon	80	2.3	53	4.9
Sockeye salmon	51	5	25	3.1
Summer Testing				
Subyearling chinook salmon				
22 June-2 July1998	48	2.7		
6 July-17 July 1998	23	1.1		
6 July-27 July 1988			11	2.0
12 July-24 July 1989			4	1.0

Three Columns of Nets Compared to Single Column

In the 9 tests conducted with nets in all three columns of the fyke-net frame, FGE for yearling chinook salmon was 69% (SE = 2.7), which was not significantly different than FGE for the 14 tests with nets only in the center column of the frame (74%, SE = 2.4) (Fig. 3). However, for both steelhead and coho salmon, FGE obtained with nets only in the center column was significantly higher than FGE obtained with nets in all three columns (91 versus 79% for steelhead and 86 versus 74% for coho salmon; $P = 0.0001$, and 0.0042, respectively).

Based on these results, it appeared that using nets only in the center column of the frame might give an inflated value for FGE (especially for steelhead and coho salmon). Therefore, we recommend that in future FGE studies, a full complement of nets be used (with cod-ends possibly removed from the outside nets to reduce mortality). Since the FGE values reported here are the means of all 23 tests (9 with and 14 without nets in the outside columns), the effect of inflated FGE estimates is somewhat diminished. However, for coho salmon and steelhead, FGE values reported here are 3-5% higher than values that would have been attained with nets in all three columns.

Summer Testing

From 22 June to 17 July, 20 FGE tests were conducted with subyearling chinook salmon only. Gatewell catches, fyke-net catches, and resulting FGE are given in Appendix Table 1. Fish guidance efficiency for subyearling chinook salmon in these tests ranged from 18 to 62% (Fig. 4). 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.

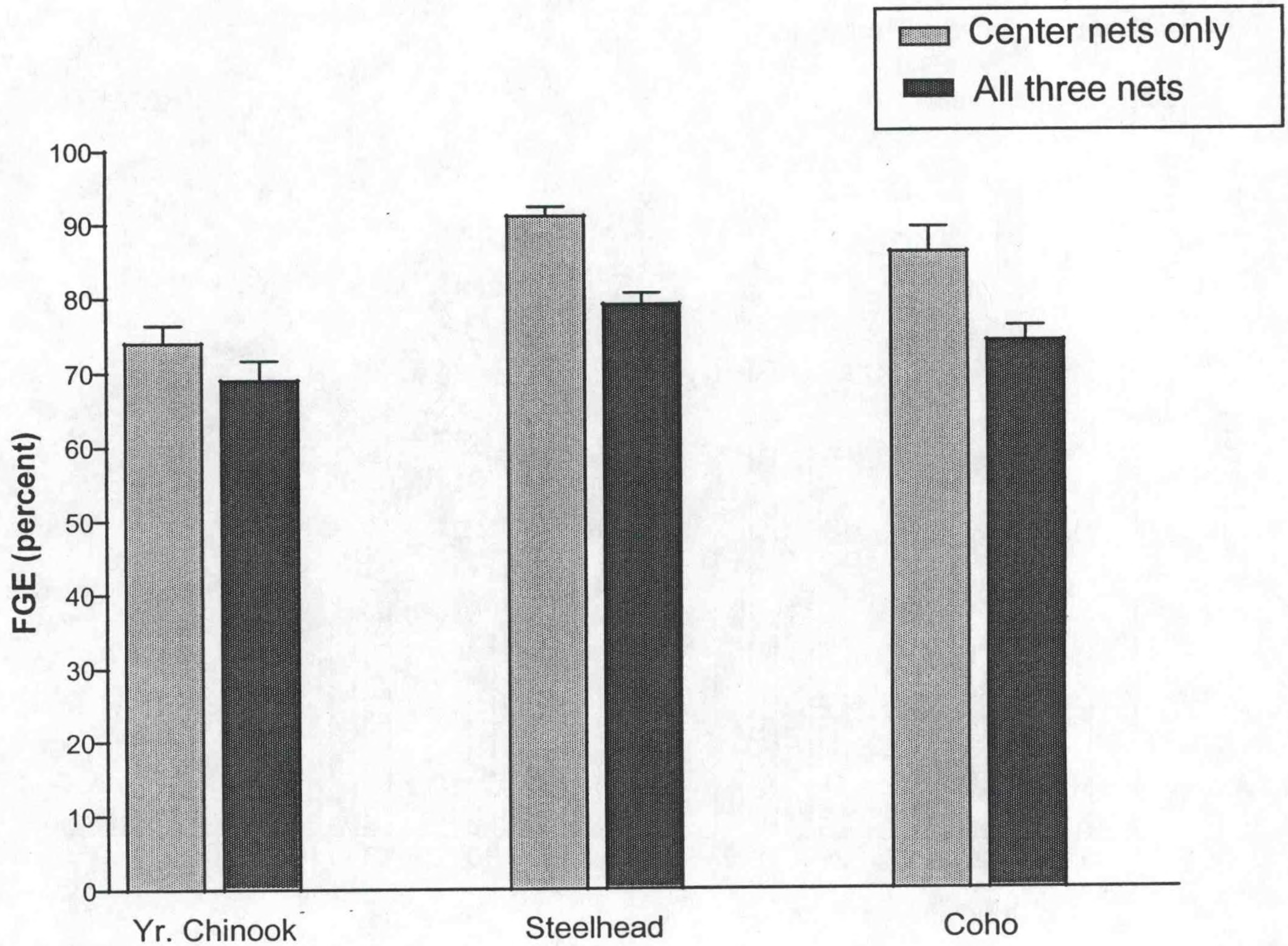


Figure 3. Mean fish guidance efficiency and standard error during spring migration for yearling chinook salmon, steelhead, and coho salmon with center nets only and with all three columns of nets in the fyke-net frame at Bonneville Dam First Powerhouse, 1998.

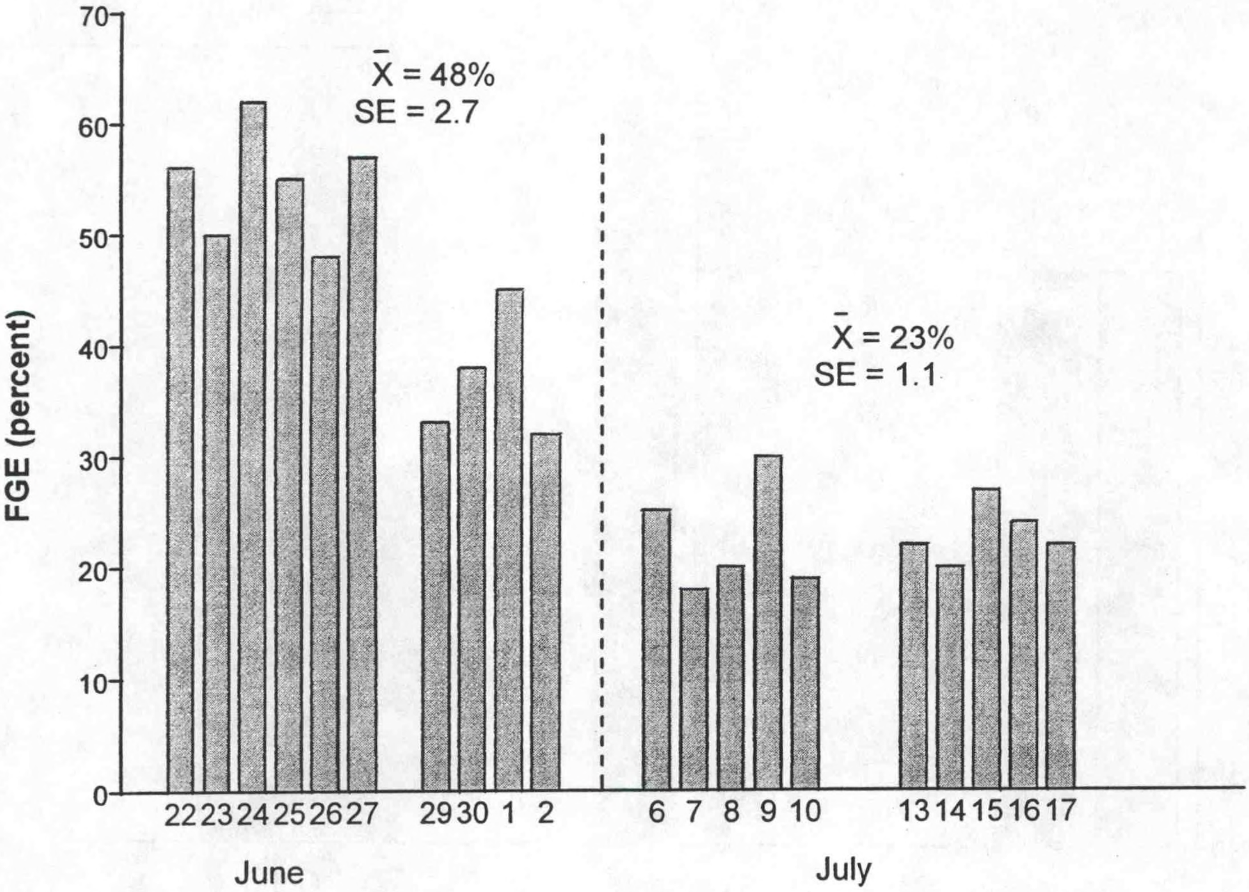


Figure 4. Daily fish guidance efficiency (FGE) for subyearling chinook salmon with extended-length bar screens (ESBSs) in Turbine Unit 8 (B slot) at Bonneville Dam First Powerhouse, 1998.

The most recent sets of FGE tests at Bonneville Dam First Powerhouse with subyearling chinook salmon were conducted only in July (Gessel et al. 1989, 1990); therefore, for comparisons of 1998 test results with these earlier STS results, 1998 results were divided into 2 sets of 10 replicates, with one set from 22 June to 2 July and the other from 6 to 17 July. In the first set of tests, FGE for subyearling chinook salmon averaged 48% (SE = 2.7); in the latter set, FGE for subyearling chinook salmon averaged 23% (SE = 1.1). These FGEs were double the rates obtained in 1988 and more than 5 times the rates in 1989 (1989 tests were conducted in Turbine Unit 3; Table 1).

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

Approach

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 (this raised the bottom of the gate from 43 to 62 ft m.s.l.). Comparison OPE tests were done concurrently in Turbine Unit 9 (A slot) which was configured 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. Discharge and load levels maintained in Turbine Units 8 and 9 during FGE tests were held for the 18-hour OPE tests.

To conduct OPE tests, 200 juvenile salmon (yearling chinook salmon in the spring and subyearling chinook salmon in the summer) were anesthetized, fin-clipped (upper or lower caudal fin), 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 was used to lower the fish 4.6 m (15 ft) below the orifice at elevation 14 m (45 ft) m.s.l. (Absolon and Brege in prep.). All releases were made with the unit in operation and the orifice opened. The next day, at 1600 (a typical test lasted 17 hours), the orifices were closed, and all fish were removed from the two gatewell slots with a dip basket. Orifice passage efficiency was calculated as the number of clipped fish that exited the gatewell divided by the total number released.

The gatewell dipnetting technique for OPE relies on the assumptions that fish survive the marking process in good condition, that fish exiting the gatewell do so via the bypass orifice (and not the turbine intake), and that all of the fish remaining in the gatewell are captured by the dip basket. To ensure the reliability of these assumptions, dip-net efficiency tests were conducted periodically throughout the spring and summer outmigration. During these tests, fish were fin-clipped, held for 3 to 4 hours, and released in the gatewell during FGE tests (with the orifice closed). Then, after 2 to 3 hours, the gatewell was dipnetted and fin-clipped fish were recovered and counted.

Comparison of OPE between Turbine Units 8 and 9 was made using a paired t-test (paired by day). Based on results of ESBS research conducted in 1996 at John Day Dam (Brege et al. 1997), we estimated that with 20 days of testing, significant differences in OPE between units could be detected. Minimum detectable differences were 8.6% for yearling chinook salmon (spring migration) and 3.9% for subyearling chinook salmon (summer migration).

Results and Discussion

Dip-basket Efficiency Testing

Two dip-basket efficiency tests were conducted during both spring and summer testing. In all four tests, 98 to 100% of all released fish were recovered in the dip basket, and all were in good condition. Therefore, the assumptions required for OPE testing were validated: fish survived the tagging/release regime, and, at most, a small percent exited from the gatewell (into the turbine intake) or were not recovered in the dip basket.

Spring Testing

Because of spill and unit priorities, it was not always possible to run both turbine units at the required load capacity for 17 hours. Therefore, from 26 April to 8 May, only 12 paired OPE tests were conducted in Turbine Units 8 and 9 (A slots), instead of the 20 originally planned.

In these tests, OPE in Turbine Unit 8 (with the ESBS) for yearling chinook ranged from 68 to 97% with an average of 90% (SE = 2.3), and OPE in Turbine Unit 9 (with the STS) ranged from 52 to 92% with an average of 80% (SE = 3.6; Fig. 5). The 10% improvement in OPE in Turbine Unit 8 was significant (P = 0.01).

Summer Testing

During the summer migration, total river flows again were not sufficient to meet spill requirements and unit priorities and also to run Turbine Units 8 and 9 at required load capacities during the OPE tests. Therefore, only five paired OPE tests were conducted in those units with subyearling chinook salmon. However, because OPEs observed in both units were extremely high with little variability, we believe the five tests gave a reliable estimate of OPE in both units (Fig. 6). For these tests, OPE in Turbine Unit 8 for subyearling chinook salmon ranged from 93 to 99% with an average of 97% (SE = 1.1) and OPE in Turbine Unit 9 ranged from 96 to100% with an average of 98% (SE = 0.7).

As seen at other projects (Brege et al. 1997, Monk et al. 1997), the high OPEs obtained during spring and summer testing indicated that the ESBS and newly designed vertical barrier screen create currents within the gatewell that eliminate sanctuary areas for fish, thus expediting passage through the orifice.

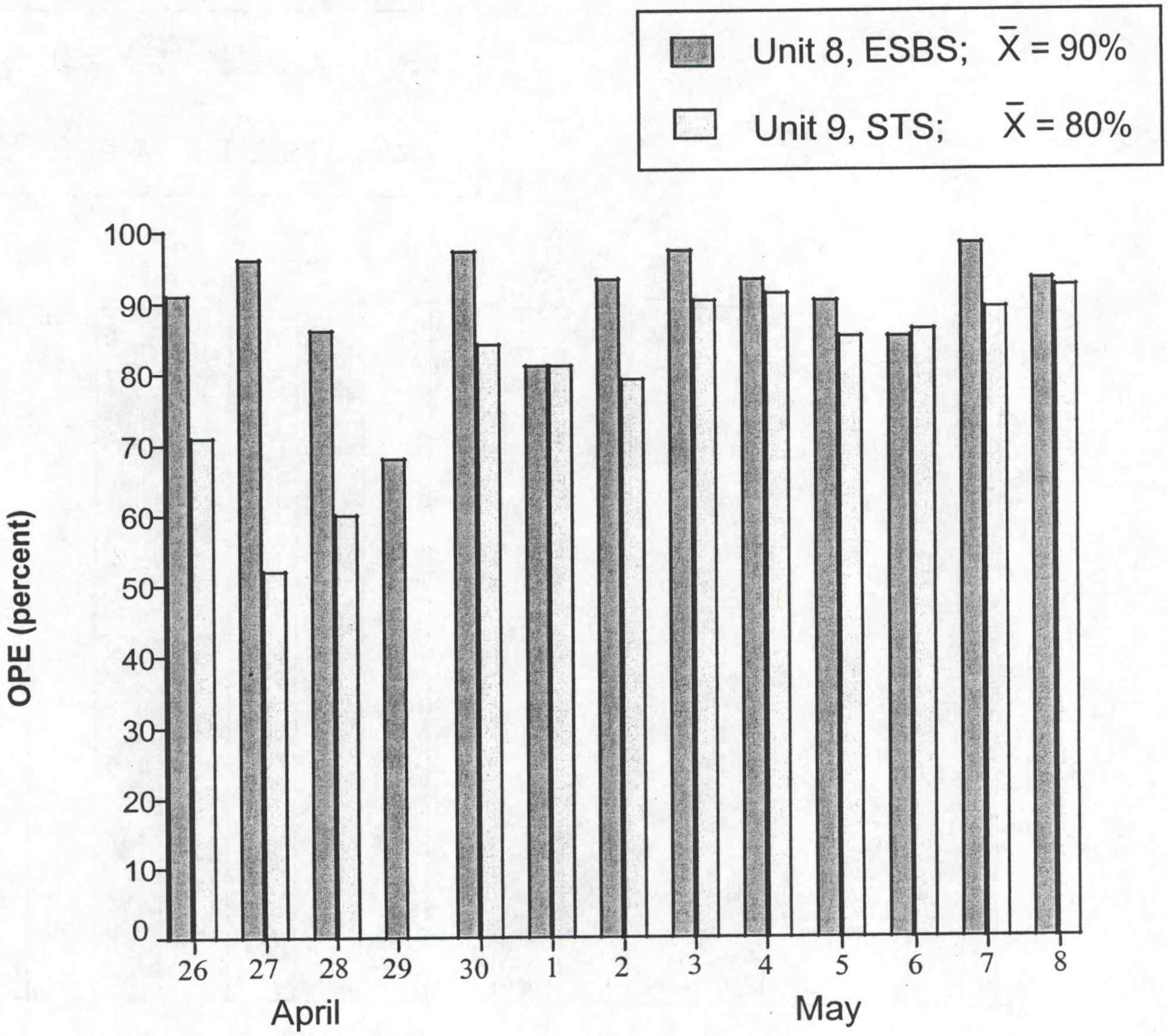


Figure 5. Daily orifice passage efficiency (OPE) for yearling chinook salmon in Turbine Unit 8 (A slot) with extended-length bar screen (ESBS) and in Turbine Unit 9 (A slot) with submersible traveling screen (STS) at Bonneville Dam First Powerhouse, 1998.

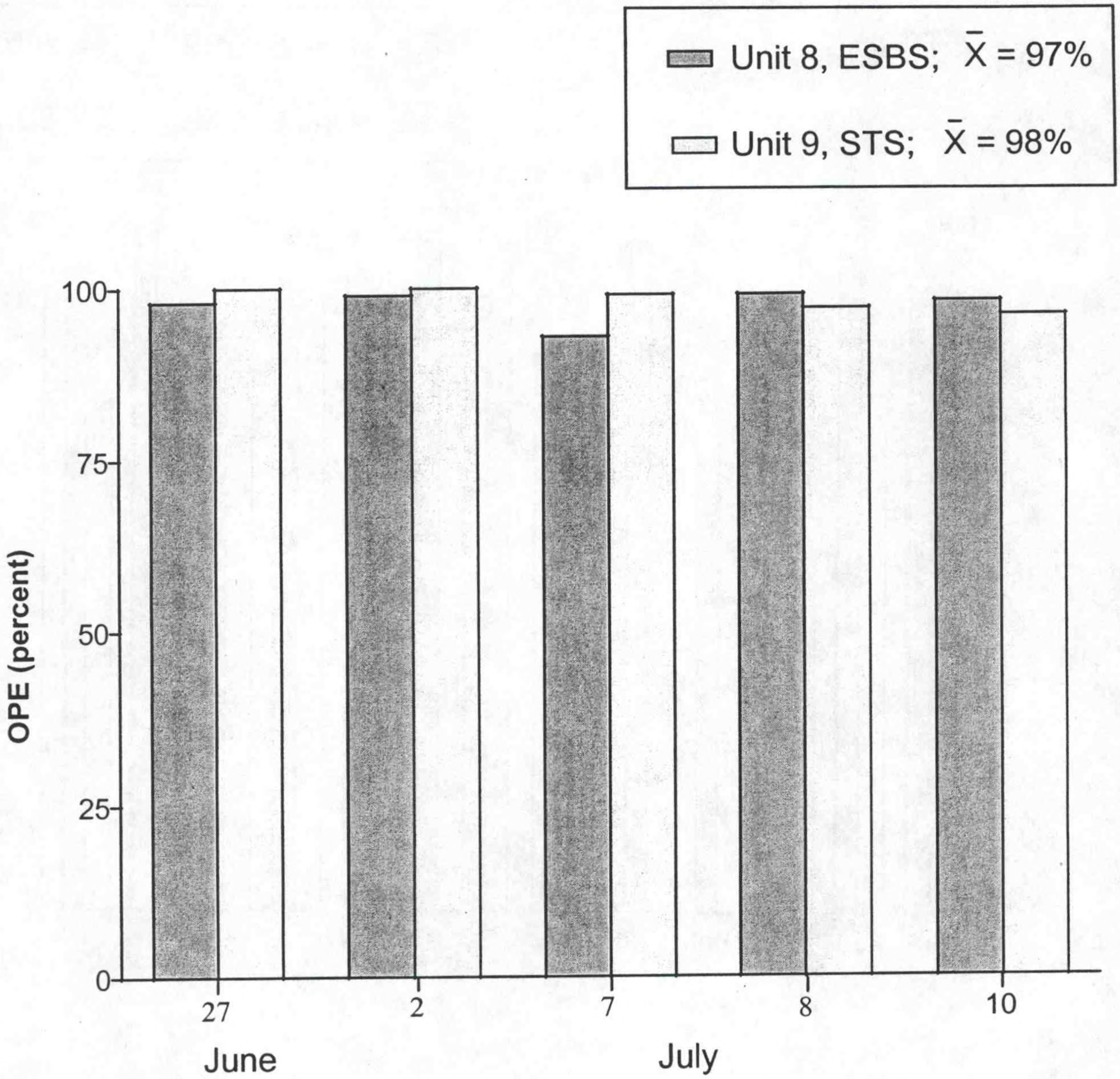


Figure 6. Daily orifice passage efficiency (OPE) for subyearling chinook salmon in Turbine Unit 8 (A slot) with extended-length bar screen (ESBS) and in Turbine Unit 9 (A slot) with submersible traveling screen (STS) at Bonneville Dam First Powerhouse, 1998.

OBJECTIVE 3: EVALUATE THE EFFECTS OF THE ESBS AND ASSOCIATED GUIDANCE DEVICES (INCLUDING THE NEWLY DESIGNED VERTICAL BARRIER SCREEN) ON JUVENILE SALMONIDS AND LAMPREY

Approach

All fish collected in Turbine Unit 8 (B slot) during FGE tests with the ESBS were examined for descaling and injury. To compare these results with those obtained with the STS, all fish were removed from Turbine Unit 9 (B slot) prior to the FGE test and again at the end of the tests (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 thus 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, along with marked study fish, were examined for descaling. Prior to the start of the OPE test, all fish were removed from gatewell 9A, and then any fish remaining in gatewell 9A at the end of the OPE tests 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 percentage of the fish were at least exposed to the gatewell velocities for longer periods than fish examined after the FGE tests.

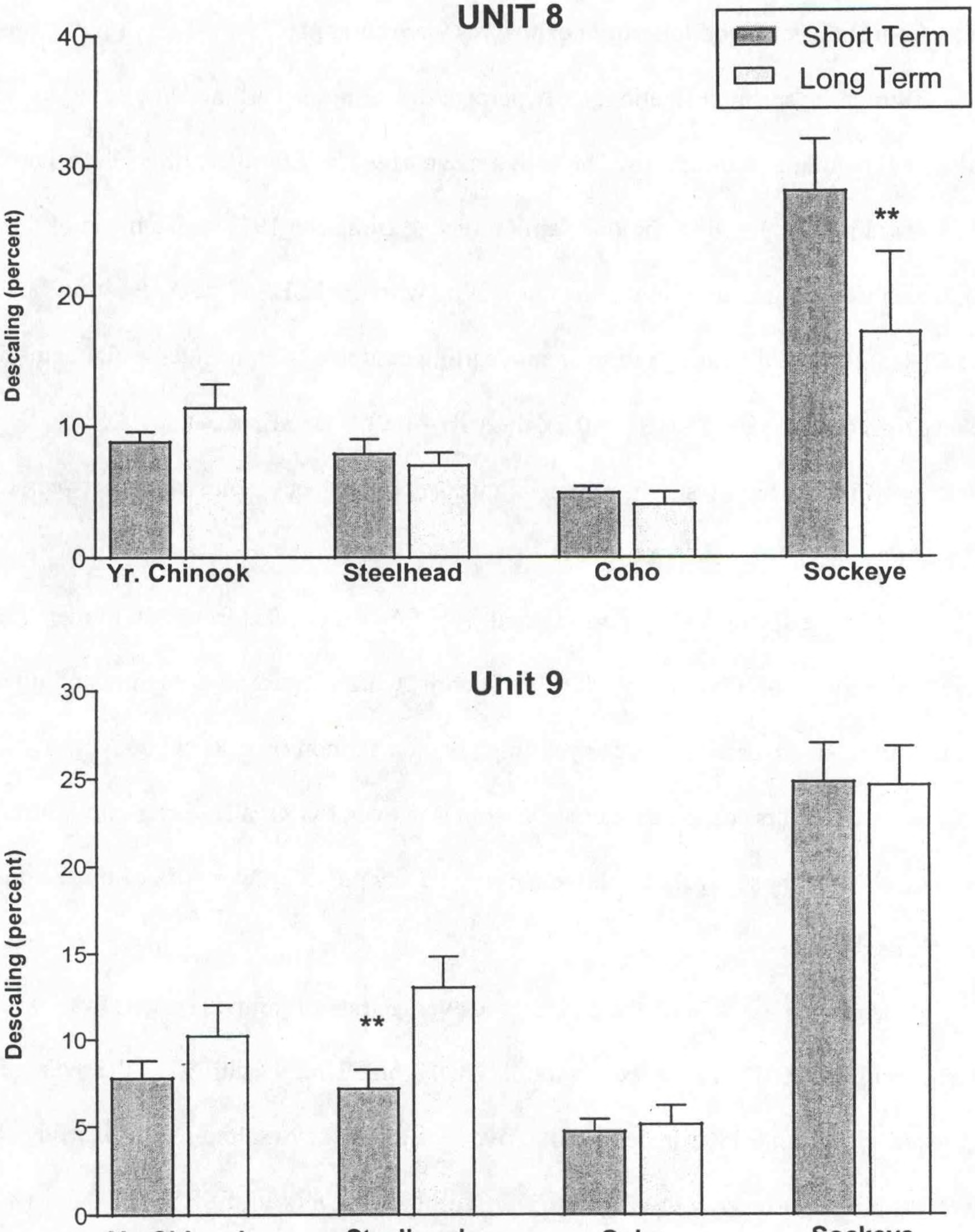
A fish was determined to be descaled if cumulative scale loss exceeded 20% on either side (Ceballos et al. 1992). Since the objective was to determine whether tests were adversely affecting fish condition, fish with scale regeneration or fungal growth were not classified as descaled, and descaling caused 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, these descaling results can give only a general picture of descaling levels on the migrating population. Comparisons between units were made to determine if any significant differences were occurring. Although the entire fish was examined for injuries, almost all injuries were to the head, and these were usually folded operculums or eye injuries. To ensure that evaluations of descaling and injury were as consistent as possible, the same individuals examined the fish throughout the study period.

Paired t-tests (paired by day) were used to compare descaling rates of fish guided with ESBS in Turbine Unit 8 with those of fish guided in the STS in Turbine Unit 9. For 20 days of testing, detectable differences of 0.7% for yearling chinook salmon and 0.5% for subyearling chinook salmon were expected, based on results of ESBS research conducted in 1996 at John Day Dam (Brege et al. 1997).

Results and Discussion

Spring Testing

Appendix Table 2 gives the numbers of fish examined and classified as descaled or injured from the total collected during both FGE (2 hour) and OPE (17 hour) tests. The only significant increase in descaling between short-term and long-term exposures appeared with steelhead in Turbine Unit 9 (Fig. 7). Because of the high OPE found in both units, we are confident that most fish probably did not spend more than 2 to 3 hours in the gatewell. These durations of exposure diminish the chances of an increase in descaling.



S hor
t and long-term descaling and standard error for all species examined during spring migration in Turbine Unit 8 (ESBS) and Unit 9 (STS) at Bonneville Dam First Powerhouse, 1998 (** denotes P < 0.01).

Therefore, for comparisons of descaling and injury percentages between the ESBS and STS, results from short-term and long-term exposures were combined.

During the spring migration, daily percent descaling in Turbine Unit 8 for yearling chinook salmon ranged from 3 to 17% with a mean of 9.6% (SE = 0.7; ESBS). In Turbine Unit 9 (STS), descaling for yearling chinook salmon ranged from 2 to 19% with a mean of 8.2 % (SE = 0.7), which was significantly lower than descaling with the ESBS ($t = 2.8$; $P = 0.011$). In Turbine Unit 8 (with ESBS), descaling rates for subyearling chinook salmon, steelhead, coho salmon, and sockeye salmon averaged 2% (SE = 0.7), 8% (SE = 0.9), 4% (SE = 0.4), and 25% (SE = 2.2), respectively, but paired t-tests showed no significant differences in descaling between the ESBS and STS (Table 2).

During the spring testing period, total river flows increased from 200 to over 350 kcfs. These higher flows brought heavier levels of debris, which increased descaling and injury levels in both turbine units, particularly for yearling chinook salmon (Fig. 8). On 6 May, daily injury levels in the two units combined increased from 0 to over 1% for all species combined and remained close to those levels for the remaining testing period. Over 90% of these injuries were hemorrhaged eyes.

In Turbine Unit 8 (with the ESBS), the average rate of injuries ranged from 0.05% for coho salmon to over 1% for sockeye salmon. In Turbine Unit 9 (with STS) the average rate of injuries ranged from 0.1% for steelhead to over 1% for sockeye salmon. For yearling chinook salmon, injuries averaged 0.9% (SE = 0.3) in Turbine Unit 8 (with ESBS) and 0.5% (SE = 0.2) in Turbine Unit 9 (no significant difference, $P = 0.34$). For steelhead, coho salmon, and sockeye salmon, there were also no significant differences in injury rates between the two screens.

Table 2. Percent descaling and injuries (gill and head combined) and standard errors for all species examined during fish guidance efficiency and orifice passage efficiency tests at Bonneville Dam First Powerhouse, 1998 (* denotes significant difference between Turbine Unit 8 and Turbine Unit 9, $\alpha = 0.05$).

	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				
Subyearling chinook salmon	2 ± 0.9	0	2 ± 1.5	0
Yearling chinook salmon*	10 ± 0.9	1 ± 0.2	8 ± 1.0	1 ± 0.2
Steelhead	8 ± 0.9	0.1 ± 0.05	9 ± 1.0	0.1 ± 0.06
Coho salmon	4 ± 0.4	0.1 ± 0.05	5 ± 0.7	0.1 ± 0.09
Sockeye salmon	25 ± 2.2	1.4 ± 0.48	25 ± 3.1	1.1 ± 0.50
Summer Testing				
Subyearling chinook salmon	3 ± 0.4	0.9 ± 0.21	2 ± 0.5	0.7 ± 0.29

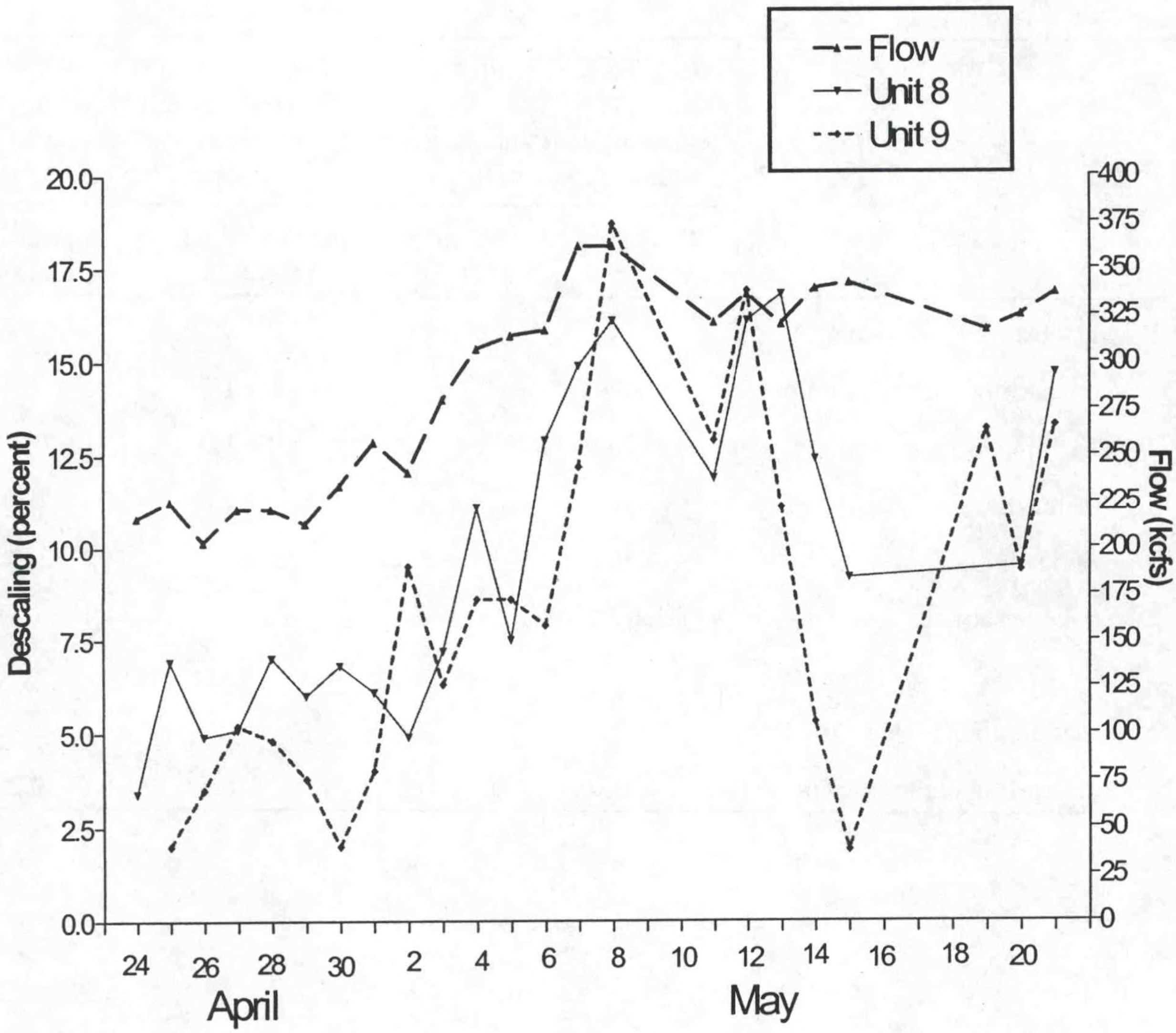


Figure 8. Daily percent descaling for yearling chinook salmon in Units 8 and 9 and total flow during spring migration at Bonneville Dam First Powerhouse, 1998.

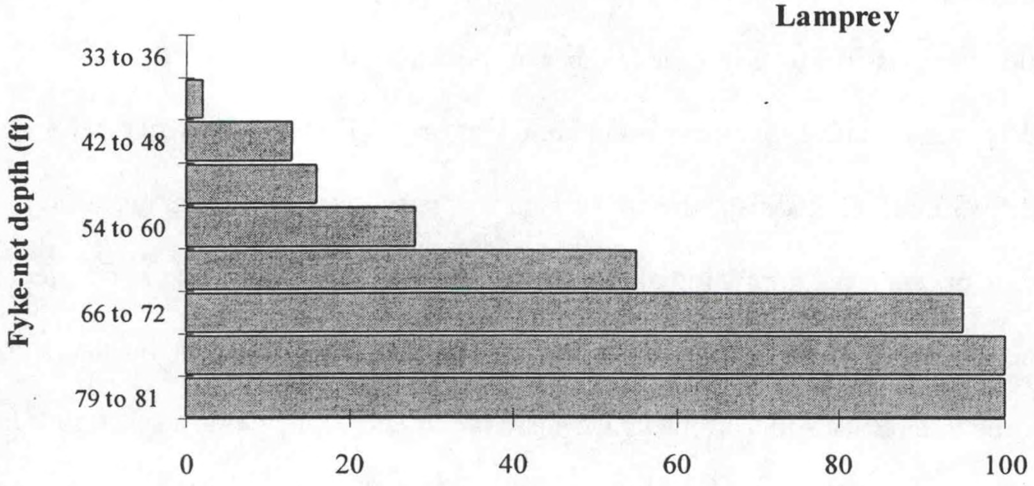
Effects of Extended-length Bar Screen on Juvenile Lamprey and Salmon Parr

There has been concern that smaller fish (salmon parr and juvenile lamprey) might be impinged between the bars of the ESBS. Since the trash sweep would then clean these fish off the bars, it would be impossible to assess the number of fish affected.

To determine whether this was a problem, it was originally proposed that NMFS would inspect the ESBS for impinged fish when the screen was raised for mechanical inspection (approximately once a week during initial running of screen). However, because of safety concerns, the screens could not be raised until load cells had been installed on the gantry crane. On 16 June, the three ESBSs in Turbine Unit 8 were raised to deck level for inspection. On one of these screens (B slot) the trash sweep stop was not adjusted properly, so the top 1 foot of the screen was not being cleaned. In this 1-foot section, two impinged juvenile lamprey and six parr were found by COE personnel (Dennis Schwartz, COE Portland District, Pers. commun., June 1998).

During spring FGE testing, a total of 308 juvenile lamprey were collected in fyke nets, and none were collected in the gatewell. Of these, approximately 13% were collected in the top three net levels, located behind the ESBS. It seems likely that these fish would have come from over the top of the screen, as opposed to swimming up into these upper net levels (only 6% of yearling chinook salmon were collected in the top three nets; Fig. 9; Appendix Table 3).

Only 30 salmonid parr were collected during spring testing; 13 of these or 43% were collected in the gatewell. There was no descaling or injury on these 13 fish (Appendix Table 3).



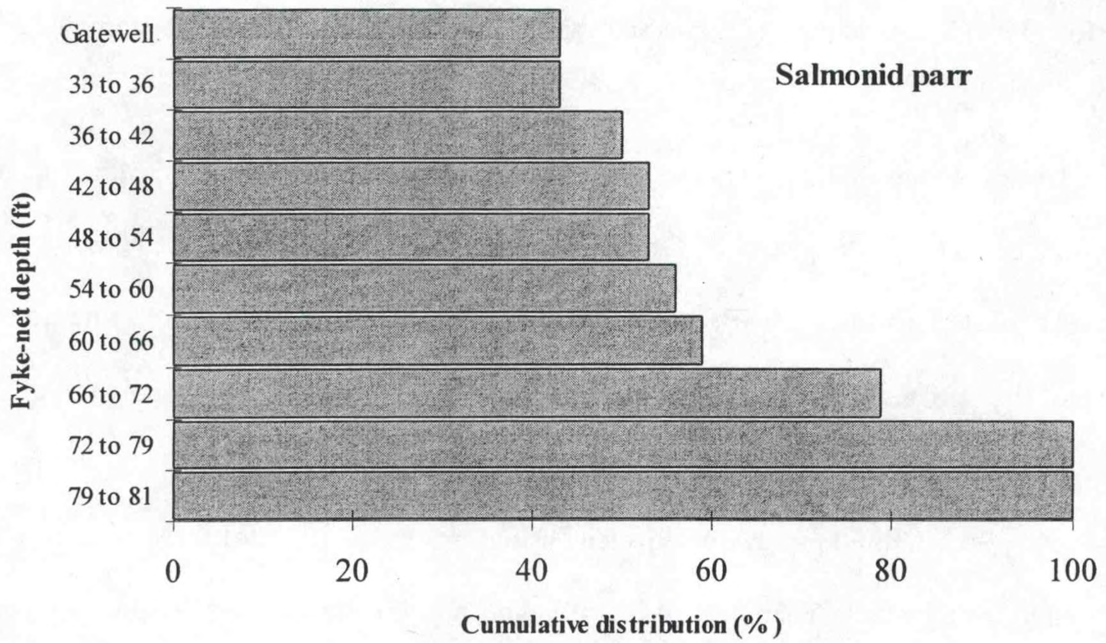


Figure 9. Cumulative distribution of juvenile lamprey and salmonid parr caught in gatewell and fyke-nets (levels 1 to 9). Cumulative distributions are shown as a percent of total catch. Fyke-net levels are shown by depth from forebay surface in feet.

Summer Testing

During summer testing, there was no significant difference in percent descaling for subyearling chinook salmon between the two screens (P = 0.3). Percent descaling averaged 3% (SE = 0.4) in Turbine Unit 8 (ESBS) and 2% (SE = 0.5) in Turbine Unit 9 (STS; Table 2). Percent injury for subyearling chinook salmon averaged 0.9 (SE = 0.21) and 0.7% (SE = 0.29) in Turbine Units 8 and 9, respectively, and there was no significant difference between injury rates using the two screens (P = 0.6).

CONCLUSIONS AND RECOMMENDATIONS

1) With an ESBS and raised operating gate, FGE for all species tested was substantially increased over 1991 results with an STS (1991 tests were also conducted in Turbine Unit 8 with a stored operating gate).

2) In FGE tests from 22 June to 2 July, FGE for subyearling chinook salmon averaged 48%; in later tests (6 July to 17 July), FGE decreased to a mean of 23%, which was double the FGE in 1988 and more than 5 times the FGE in 1989 for tests made during the same time period.

3) Mean OPEs for yearling chinook salmon with the ESBS and STS were 90 and 80%, respectively, and the difference, 10% ± 3.0, was statistically significant.

4) Mean OPEs for subyearling chinook (summer testing) with the ESBS and STS were 97 and 98%, respectively (with no statistical difference).

5) There was a significant difference in descaling percentages between yearling chinook salmon guided with the ESBS (9.6%) and those guided with the STS (8.2%) during the spring outmigration (paired $t = 2.8$; $P = 0.011$). However, for subyearling chinook salmon, steelhead, coho salmon, and sockeye salmon during the spring outmigration, and for subyearling chinook salmon during the summer outmigration there were no significant differences in descaling or injury rates between the ESBS and STS.

6) All of the juvenile lamprey collected (308) were caught in the fyke nets (none were guided into the gatewell). However, 13% of these were in the top three nets and most likely would have come over the top of the ESBS.

7) Of the 30 salmonid parr collected during spring testing, 13 (43%) were guided. There was no descaling or injury on these fish.

8) In a comparison of FGE results in tests using nets only in the center column of the fyke-net frame to tests with nets in all three columns, FGE was higher for yearling chinook salmon, coho salmon, and steelhead. This difference was significant for coho and steelhead. The difference indicates that using nets only in the center column of the fyke-net frame, and then multiplying the catch by three to estimate FGE, would result in estimates of FGE that are biased upward.

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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 Turbine Unit 8 (B) at Bonneville Dam First Powerhouse, 1998. (SC = subyearling chinook salmon, YC = yearling chinook salmon, ST = steelhead, CO = coho, SO = Sockeye).

	24 April [a]					25 April [a]					26 April [a]				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	105	203	72	72		31	189	557	171	1	18	170	63	56	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	18	0	0	0		6	6	0	0		0	0	0	0	
4	0	3	0	0		0	0	0	0		0	3	0	0	
5	21	9	1	1		3	6	0	3		0	12	0	0	
6	12	3	0	2		6	6	0	0		0	12	0	0	
7	27	21	0	7		6	12	9	3		0	33	3	6	
8	18	24	0	0		0	9	3	0		0	30	3	6	
9	0	0	0	0		0	0	0	0		0	0	0	0	
Totals	**201**	**263**	**73**	**82**	**0**	**52**	**228**	**569**	**177**	**1**	**18**	**260**	**69**	**68**	**0**
FGE (%)	**52**	**77**	**99**	**88**		**60**	**83**	**98**	**97**		**100**	**65**	**91**	**82**	

	27 April [a]					28 April [a]					29 April [a]				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	18	230	198	107		16	277	148	87	0	5	193	130	110	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	3	3	0	
5	0	6	3	0		0	3	0	6		3	3	3	9	
6	0	21	0	3		0	6	0	3		6	0	0	15	
7	0	21	9	9		9	21	3	15		0	15	15	0	
8	0	21	9	6		3	15	6	18		0	6	6	15	
9	0		0	0		0	0	0	0		0	0	0	0	
Totals	**18**	**299**	**219**	**125**	**0**	**28**	**322**	**157**	**129**	**0**	**14**	**220**	**157**	**149**	**0**
FGE (%)	**100**	**77**	**90**	**86**		**57**	**86**	**94**	**67**		**36**	**88**	**83**	**74**	

[a] Only center column of nets used - catch multiplied by three

Appendix Table 1. Continued.

	30 April [a]					1 May [b]					2 May [b]				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	14	242	136	105	0	8	285	123	76	0	3	229	141	63	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	1	1	0	0	2	1	0	0
3	0	5	3	2	0	0	4	3	1	0	1	2	5	4	0
4	1	5	2	5	0	0	9	6	3	0	0	2	1	1	0
5	0	15	3	11	0	0	19	9	7	0	1	11	10	8	0
6	1	27	5	11	0	2	16	7	3	0	0	19	9	4	0
7	3	30	5	11	0	2	34	9	5	0	0	22	6	11	0
8	0	24	5	7	0	0	16	4	2	0	0	11	4	3	0
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**19**	**348**	**159**	**152**	**0**	**12**	**383**	**162**	**98**	**0**	**5**	**298**	**177**	**94**	**0**
FGE (%)	**74**	**70**	**86**	**69**		**67**	**74**	**76**	**78**		**60**	**77**	**80**	**67**	

	3 May [b]					4 May [b]					5 May [b]				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	5	209	169	139		7	145	129	112		6	142	106	119	
1	0	0	1	0		0	0	0	0		0	0	0	0	
2	0	1	2	0		0	0	0	0		0	2	0	1	
3	0	5	6	4		0	5	0	7		0	8	3	6	
4	1	2	3	6		0	9	9	3		0	9	0	5	
5	0	8	14	8		0	18	8	13		0	13	6	7	
6	2	4	3	9		0	4	4	3		0	14	1	5	
7	1	19	15	9		2	16	7	13		1	26	8	0	
8	0	8	6	3		0	8	3	2		0	12	1	0	
9	0	0	0	1		0	0	0	0		0	0	0	0	
Totals	**9**	**256**	**219**	**179**	**0**	**9**	**205**	**160**	**153**	**0**	**7**	**226**	**125**	**143**	**0**
FGE (%)	**56**	**82**	**77**	**78**		**78**	**71**	**81**	**73**		**86**	**63**	**85**	**83**	

[a] Only center column of nets used - catch multiplied by three.

[b] All three columns of nets used.

Appendix Table 1. Continued.

Location	6 May [b]					7 May [b]					8 May [b]				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	11	139	123	101	5	7	81	122	53	12	4	85	119	78	12
1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	6	1	0	1	0	3	0	1	0	0	2	2	3	2
3	0	6	2	5	0	0	11	2	3	0	0	9	0	7	4
4	0	6	6	4	0	0	5	9	5	2	0	3	9	8	6
5	1	7	9	7	1	1	8	5	1	2	0	3	10	7	9
6	0	5	4	8	0	0	12	5	1	1	0	11	7	2	10
7	0	20	8	6	0	0	21	9	1	1	0	17	12	14	7
8	1	5	4	1	0	2	13	2	1	0	0	13	7	4	2
9	1	1	1	0	0	0	0	0	0	0	0	1	0	0	0
Totals	**14**	**195**	**159**	**132**	**7**	**10**	**154**	**154**	**66**	**18**	**4**	**144**	**166**	**123**	**52**
FGE (%)	**79**	**71**	**77**	**77**	**71**	**70**	**53**	**79**	**80**	**67**	**100**	**59**	**72**	**63**	**23**

Location	11 May [b]					12 May [a]					13 May [a]				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	10	59	133	84	74	7	84	272	71	92	4	105	169	84	57
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	1	1	1	4	0	0	0	0	0	0	0	0	0	0
3	1	4	4	3	19	0	0	0	0	3	0	0	3	0	6
4	0	4	8	7	19	0	0	3	0	0	0	0	0	3	0
5	1	3	12	8	17	0	3	0	3	0	0	6	6	0	3
6	1	5	10	1	30	0	9	9	0	21	0	9	6	6	12
7	2	11	12	5	44	0	18	15	3	54	0	27	21	21	15
8	1	3	7	8	10	0	6	6	0	21	0	9	6	6	15
9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**16**	**90**	**187**	**117**	**217**	**7**	**120**	**305**	**77**	**191**	**4**	**156**	**211**	**120**	**108**
FGE (%)	**63**	**66**	**71**	**72**	**34**	**100**	**70**	**89**	**92**	**48**	**100**	**67**	**80**	**70**	**53**

[b] All three columns of nets used.

[a] Only center column of nets used - catch multiplied by three.

Appendix Table 1. Continued.

	14 May [a]					15 May [a]					19 May [a]				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	8	79	163	87	113	136	72	109	50	41	73	100	133	100	72
1	0	0	0	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	0	0	0
3	0	0	0	0	0	15	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	6	3	0	0	0	3	0	0	0	0
5	0	3	6	3	6	18	3	6	0	3	0	3	3	0	6
6	0	9	0	0	6	42	0	3	0	15	6	0	0	0	15
7	3	21	12	6	21	69	3	0	0	12	6	3	6	0	30
8	0	9	3	9	15	15	12	0	0	0	3	12	3	3	27
9	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0
Totals	**11**	**121**	**184**	**105**	**161**	**301**	**93**	**118**	**50**	**71**	**91**	**118**	**145**	**106**	**150**
FGE (%)	**73**	**65**	**89**	**83**	**70**	**45**	**77**	**92**	**100**	**58**	**80**	**85**	**92**	**94**	**48**

	20 May [a]					21 May [a]				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	29	96	155	94	75	50	85	111	132	24
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	3	0	0	0	0
4	0	0	3	0	6	9	3	3	0	3
5	3	3	6	0	6	6	3	0	3	0
6	18	12	0	3	9	6	3	0	0	3
7	12	33	3	3	15	6	0	3	0	6
8	0	9	0	0	9	0	6	6	0	0
9	0	0	0	0	0	0	0	0	0	0
Totals	**62**	**153**	**167**	**100**	**120**	**80**	**100**	**123**	**135**	**36**
FGE (%)	**47**	**63**	**93**	**94**	**63**	**63**	**85**	**90**	**98**	**67**

[a] Only center column of nets used - catch multiplied by three.

Appendix Table 1. Continued.

Location	22 June [a]					23 June [a]					24 June [a]				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	296	1	1	3		187	1	1	0	0	212	1	0	0	0
1	0	0	0	0		0					0				
2	0	0	0	0		0					0				
3	3	0	0	0		3					3				
4	6	0	0	0		3					0				
5	21	0	0	0		39					21				
6	45	0	0	0		63					27				
7	87	0	0	0		54					39				
8	66	0	0	0		27					36				
9	0	0	0	0		0					3				
Totals	**524**	**1**	**1**	**3**	**0**	**376**	**1**	**1**	**0**	**0**	**341**	**1**	**0**	**0**	**0**
FGE (%)	**56**	**100**	**100**	**100**		**50**	**100**	**100**			**62**	**100**			

Location	25 June [a]					26 June [a]					27 June [a]				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	168					87					137				
1	0					0					0				
2	0					0					0				
3	0					3					9				
4	9					0					3				
5	12					21					18				
6	30					15					27				
7	66					18					21				
8	21					39					24				
9	0					0					3				
Totals	**306**	**0**	**0**	**0**	**0**	**183**	**0**	**0**	**0**	**0**	**242**	**0**	**0**	**0**	**0**
FGE (%)	**55**					**48**					**57**				

[a] Only center column of nets used - catch multiplied by three.

Appendix Table 1. Continued.

	29 June [a]					30 June [a]					1 July [a]				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	133					121					138				
1	0					0					0				
2	0					0					0				
3	3					0					0				
4	6					0					3				
5	30					24					21				
6	45					48					39				
7	99					63					66				
8	84					57					39				
9	3					3					3				
Totals	**403**	**0**	**0**	**0**	**0**	**316**	**0**	**0**	**0**	**0**	**309**	**0**	**0**	**0**	**0**
FGE (%)	**33**					**38**					**45**				

	2 July [a]					6 July [a] 7					7 July [a]				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	104					142					66				
1	0					0					0				
2	0					0					0				
3	0					0					0				
4	9					18					3				
5	36					27					30				
6	39					36					63				
7	48					159					138				
8	90					180					63				
9	0					0					3				
Totals	**326**	**0**	**0**	**0**	**0**	**562**	**0**	**0**	**0**	**0**	**366**	**0**	**0**	**0**	**0**
FGE (%)	**32**					**25**					**18**				

[a] Only center column of nets used - catch multiplied by three

Appendix Table 1. Continued.

	8 July [a]					9 July [a]					10 July [a]				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	60					84					85				
1	0					0					0				
2	0					0					0				
3	3					0					0				
4	12					6					6				
5	45					18					48				
6	51					51					69				
7	87					75					117				
8	36					42					120				
9	0					0					3				
Totals	**294**	**0**	**0**	**0**	**0**	**276**	**0**	**0**	**0**	**0**	**448**	**0**	**0**	**0**	**0**
FGE (%)	**20**					**30**					**19**				

	13 July [a]					14 July [a]					15 July [a]				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	52					47					39				
1	0					0					0				
2	0					0					0				
3	0					0					0				
4	3					0					0				
5	15					27					9				
6	21					30					30				
7	96					78					36				
8	48					51					33				
9	0					0					0				
Totals	**235**	**0**	**0**	**0**	**0**	**233**	**0**	**0**	**0**	**0**	**147**	**0**	**0**	**0**	**0**
FGE (%)	**22**					**20**					**27**				

[a] Only center column of nets used - catch multiplied by three

Appendix Table 1. Continued.

	16 July [a]					17 July				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	36					86				
1	0					0				
2	0					0				
3	0					6				
4	0					3				
5	18					45				
6	21					45				
7	45					126				
8	33					78				
9	0					0				
Totals	**153**	**0**	**0**	**0**	**0**	**389**	**0**	**0**	**0**	**0**
FGE (%)	**24**					**22**				

[a] Only center column of nets used - catch multiplied by three

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, 1998.

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	203	7	0	0				
25 April	189	13	0	0				
26 April	170	9	0	0	33	1	0	0
27 April	230	13	0	0	179	8	0	0
28 April	277	29	0	0	211	5	0	0
29 April	193	12	0	0	290	17	0	0
30 April	242	14	0	0	142	12	0	0
1 May	285	17	0	0	109	7	0	0
2 May	229	12	0	0	116	5	0	0
3 May	209	12	0	0	167	15	0	0
4 May	145	13	0	0	152	9	0	0
5 May	142	9	0	0	84	8	0	0
6 May	139	11	1	0	93	19	10	0
7 May	81	9	1	0	73	14	3	0
8 May	85	13	0	0	95	16	1	0
11 May	59	7	1	0				
12 May	84	11	1	0	40	9	0	0
13 May	105	17	0	0	14	3	0	0
14 May	79	8	0	0	34	6	4	0
15 May	72	4	1	0	26	5	0	0
19 May								
20 May	96	10	0	0	9	0	2	0
21 May	85	12	0	0	10	2	0	0
TOTAL	3399	262	5	0	1877	161	20	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
24 April								
25 April	200	4	0	0				
26 April	243	13	0	0	522	14	0	0
27 April	177	3	0	0	208	8	0	0
28 April	141	8	0	0	172	7	0	0
29 April	157	6	0	0	129	5	0	0
30 April	241	4	0	0	110	3	0	0
1 May	211	9	0	0	163	6	0	0
2 May	137	10	0	0	158	18	0	0
3 May	155	7	0	0	116	10	0	0
4 May	139	13	0	0	59	4	0	0
5 May	180	17	0	0	52	3	0	0
6 May	137	7	1	0	66	9	0	0
7 May	107	13	2	0	41	5	0	0
8 May	125	23	2	0	30	6	0	0
11 May	70	9	2	0				
12 May	47	7	3	0	24	5	0	0
13 May	93	11	0	0	33	3	0	0
14 May	93	4	0	0	40	3	0	0
15 May	75	2	0	0	31	1	1	0
19 May	68	8	0	0				
20 May	142	3	0	0	49	15	0	0
21 May	93	11	0	0	20	4	0	0
TOTAL	3031	192	10	0	2023	129	1	0

Appendix Table 2. Continued.

STEELHEAD

	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	41	6	0	0				
25 April	557	33	0	0				
26 April	63	4	0	0	15	1	0	0
27 April	198	30	0	0	52	3	0	0
28 April	148	29	0	0	61	4	0	0
29 April	130	12	0	0	74	9	0	0
30 April	136	3	0	0	53	6	0	0
1 May	123	9	0	0	44	3	0	0
2 May	141	8	0	0	38	0	0	0
3 May	169	20	0	0	93	10	0	0
4 May	129	7	0	0	41	2	0	0
5 May	106	8	0	0	48	3	0	0
6 May	123	6	0	0	30	3	0	0
7 May	122	18	1	0	33	2	0	0
8 May	119	16	0	0	20	1	0	0
11 May	133	14	0	0				
12 May	272	14	0	0	21	2	1	0
13 May	169	7	1	0	9	1	0	0
14 May	163	6	0	0	9	1	0	0
15 May	109	3	0	0	12	0	0	0
19 May				0				
20 May	155	0	0	0	5	0		0
21 May	111	1	0	0	16	0	1	1
TOTAL	3417	254	2	0	674	51	2	1

	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								
25 April	7	0	0	0				
26 April	24	1	0	0	14	4	0	0
27 April	21	3	0	0	19	1	0	0
28 April	24	3	0	0	42	9	0	0
29 April	37	2	0	0	42	9	0	0
30 April	41	4	0	0	49	13	0	0
1 May	66	2	0	0	54	9	0	0
2 May	42	5	0	0	45	3	0	0
3 May	42	1	0	0	97	15	0	0
4 May	27	5	0	0	54	6	0	0
5 May	107	9	0	0	17	1	0	0
6 May	62	6	0	0	24	2	0	0
7 May	96	10	1	0	29	3	0	0
8 May	112	11	0	0	36	1	0	0
11 May	165	9	0	0				
12 May	199	8	1	0	21	5	0	0
13 May	174	6	0	0	46	5	0	0
14 May	129	6	0	0	45	4	0	0
15 May	116	0	1	0	64	6	1	0
19 May	85	4	0	0				
20 May	166	1	0	0	114	13	0	0
21 May	116	0	0	0	60	1	0	0
TOTAL	1858	96	3	0	872	110	1	0

Appendix Table 2. Continued

COHO

	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	72	1	0	0				
25 April	171	3	0	0				
26 April	56	3	0	0	12	0	0	0
27 April	107	7	0	0	68	2	0	0
28 April	87	5	0	0	39	0	0	0
29 April	110	4	0	0	94	3	0	0
30 April	105	9	0	0	55	2	0	0
1 May	76	2	0	0	56	0	0	0
2 May	63	3	0	0	41	2	0	0
3 May	139	4	0	0	93	3	0	0
4 May	112	4	0	0	106	3	0	0
5 May	119	2	0	0	84	3	0	0
6 May	101	5	0	0	66	4	0	0
7 May	53	3	0	0	45	2	0	0
8 May	78	2	0	0	17	0	0	0
11 May	84	3	0	0				
12 May	71	7	0	0	25	0	0	0
13 May	84	6	0	0	12	2	0	0
14 May	87	5	1	0	25	1	0	0
15 May	50	1	0	0	25	1	0	0
19 May								0
20 May	94	2	0	0	10	1	0	0
21 May	132	6	0	0	35	1	0	0
TOTAL	2051	87	1	0	908	30	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
24 April								
25 April	146	2	0	0				
26 April	110	4	0	0	123	1	0	0
27 April	95	7	0	0	33	2	0	0
28 April	42	2	0	0	44	0	0	0
29 April	60	1	0	0	64	1	0	0
30 April	95	1	0	0	56	4	0	0
1 May	45	0	0	0	52	3	0	0
2 May	40	2	0	0	26	3	0	0
3 May	59	1	0	0	66	3	0	0
4 May	91	0	0	0	106	3	0	0
5 May	105	6	0	0	69	3	0	0
6 May	48	1	0	0	38	4	0	0
7 May	47	4	0	0	34	0	0	0
8 May	38	2	0	0	21	0	0	0
11 May	72	6	2	0				
12 May	49	5	0	0	20	2	0	0
13 May	37	3	0	0	42	7	0	0
14 May	38	2	0	0	38	0	0	0
15 May	19	1	0	0	34	2	0	0
19 May	32	0	0	0				
20 May	66	5	0	0	79	3	0	0
21 May	44	2	0	0	54	2	0	0
TOTAL	1378	57	2	0	999	43	0	0

Appendix Table 2. Continued

SOCKEYE

	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
5 May	1	0	0	0	1	0	0	0
6 May	5	1	0	0	9	1	0	0
7 May	12	5	0	0	17	4	1	0
8 May	12	6	0	0	28	5	0	0
11 May	74	26	1	0				
12 May	92	32	0	0	87	9	2	2
13 May	57	16	0	0	41	8	0	1
14 May	113	25	0	0	41	4	3	2
15 May	41	7	0	0	27	3	0	0
19 May								
20 May	75	22	0	0	8	2	0	0
21 May	24	8	0	0	23	6	2	0
TOTAL	506	148	1	0	282	42	8	5

	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
5 May	2	0	0	0				
6 May	2	1	0	0	7	1	0	0
7 May	8	2	0	0	5	0	0	0
8 May	19	12	0	0	35	11	0	0
11 May	44	19	2	0				
12 May	35	6	1	0	26	10	0	0
13 May	17	5	0	0	44	9	0	1
14 May	19	4	0	0	39	5	1	1
15 May	12	2	0	0	61	12	2	0
19 May	7	2	0	0				
20 May	23	5	0	0	11	3	0	0
21 May	11	0	0	0	15	3	0	0
TOTAL	199	58	3	0	243	54	3	2

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
22 June	296	2	0	0				
23 June	187	2	0	0				
24 June	212	7	0	0				
25 June	168	6	1	1				
26 June	87	2	0	0				
27 June	137	3	3	0	23	2	0	0
29 June	133	5	0	0				
30 June	121	2	3	1				
1 July	138	3	0	1	13	2	0	0.
2 July	104	2	0	0	31	0	1	0
6 July	142	4	1	1				
7 July	66	0	1	0	22	0	0	0
8 July	60	5	1	0	17	1	0	0
9 July	84	1	1	0				
10 July	85	2	0	1	21	0	0	0
13 July	52	3	0	1				
14 July	47	3	1	0	4	0	0	0
15 July	39	0	0	0	25	2	0	0
16 July	36	1	0	0				
17 July	86	3	0	0				
TOTAL	2280	56	12	6	156	7	1	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
22 June	116	0	2	0				
23 June	155	1	1	0				
24 June	98	2	1	0				
25 June	108	2	1	0				
26 June	53	3	0	1				
27 June	77	0	0	0	30	2	1	0
29 June	69	0	0	0				
30 June	55	0	1	2				
1 July	65	4	0	0				
2 July	30	0	0	0	15	0	0	0
6 July	48	3	0	0				
7 July	36	1	0	0	13	0	0	0
8 July	26	0	0	0	12	0	0	0
9 July	36	0	0	0				
10 July	50	2	0	0	18	0	0	0
13 July	44	1	0	0				
14 July	48	1	0	0	20	0	0	0
15 July	43	2	0	0	28	0	0	0
16 July	37	0	0	0				
17 July	48	2	1	0				
TOTAL	910	16	6	3	58	2	1	0

Appendix Table 3. Numbers of 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 21 May at Bonneville Dam First Powerhouse, 1998.

LAMPREY

	4/25	4/27	4/28	4/29	4/30	5/1	5/2	5/3	5/4	5/5
Gatewell	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	3
3	0	0	0	0	0	0	0	3	0	3
4	0	1	0	0	0	0	0	0	0	0
5	0	0	0	1	1	0	0	0	3	5
6	1	0	0	0	1	2	2	1	3	2
7	0	0	0	4	10	4	2	4	1	11
8	0	0	1	0	1	1	0	0	1	3
9	0	0	0	0	0	0	0	0	0	0
Totals	1	1	1	5	13	7	4	8	8	27
FGE (%)	0	0	0	0	0	0	0	0	0	0

	5/6	5/7	5/8	5/11	5/12	5/13	5/14	5/15	5/19	5/20	5/21
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	2	0	0	0	0	0	0	0	0	0
3	1	5	5	1	3	3	3	0	3	0	3
4	0	2	3	3	0	0	0	0	0	0	0
5	2	1	1	4	3	9	3	3	0	0	0
6	1	3	8	5	6	6	12	15	0	15	0
7	2	9	10	10	6	24	0	12	9	0	6
8	1	0	1	0	6	0	0	0	3	0	0
9	0	0	0	0	0	0	0	0	0	0	0
Totals	7	22	28	23	24	42	18	30	15	15	9
FGE (%)	0	0	0	0	0	0	0	0	0	0	0

Appendix Table 3. Continued

SALMONID PARR

	5/6	5/7	5/8	5/11	5/12	5/15	5/21
Gatewell	2	3	1	2	2	2	1
1	0	0	0	0	0	0	0
2	2	0	0	0	0	0	0
3	0	0	1	0	0	0	0
4	0	0	0	0	0	0	0
5	0	1	0	0	0	0	0
6	0	1	0	0	0	0	0
7	0	1	0	2	0	3	0
8	0	1	1	1	0	0	3
9	0	0	0	0	0	0	0
Totals	4	7	3	5	2	5	4
FGE (%)	50	43	33	40	100	40	25