Evaluation of Fish Guidance Efficiency of Submersible Traveling Screens and Other Modifications at Bonneville Dam Second Powerhouse, 1994

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Coastal Zone and Estuarine Studies Division

Northwest Fisheries Science Center

National Marine Fisheries Service

Seattle, Washington

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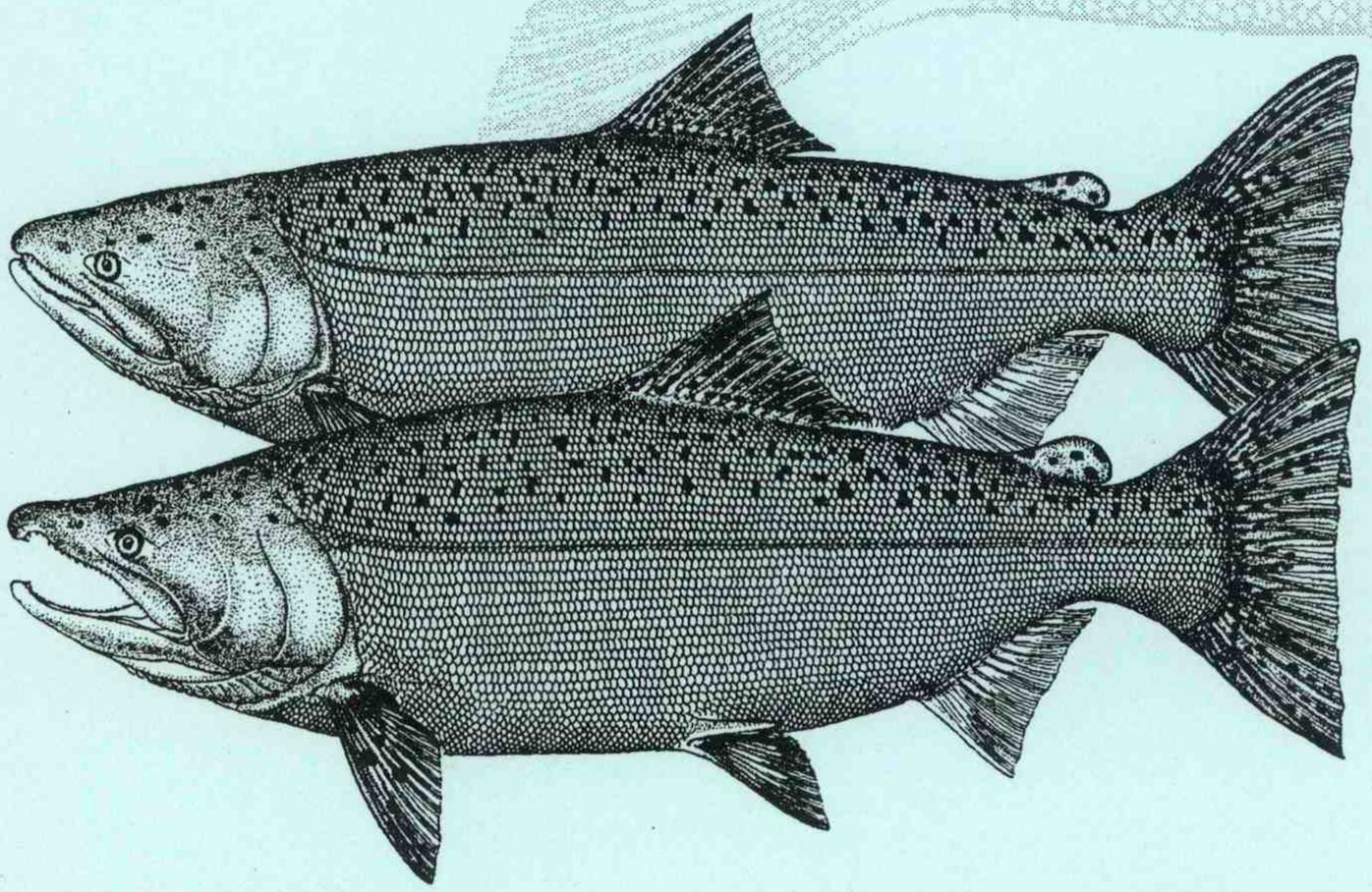

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INTRODUCTION

The Bonneville Dam Second Powerhouse was completed in 1982 and the National Marine Fisheries Service (NMFS) began evaluating fish guidance efficiency (FGE) at this facility in 1983. Initial measurements of FGE with standard-length submersible traveling screens (STSs) were less than 25% for yearling chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) and approximately 33% for steelhead (*O. mykiss*). These guidance levels were considerably lower than the expected design level of greater than 70% for all species (Krcma et al. 1984).

From 1984 to 1989, the U. S. Army Corps of Engineers and NMFS tested various design modifications to improve FGE at Bonneville Dam Second Powerhouse. The results of this research indicated that modifications to increase flows above the STS and smooth flows into and within the turbine intake could substantially increase FGE for yearling chinook salmon during the spring outmigration (Gessel et al. 1991). This was accomplished by lowering the STSs 0.8 m (30 in) and installing streamlined trashracks and turbine intake extensions (TIEs) (Fig. 1). From 1987 to 1989, FGE tests were conducted with these modifications installed in Units 11, 12, and 13. Mean FGE in Unit 12 (for 4- to 5-day test series) ranged from 51 to 74%. Although this FGE testing was done at the south end of the powerhouse, with only partial powerhouse operation, NMFS recommended the installation of these modifications across the entire powerhouse.

In 1993, studies were conducted during the spring and summer juvenile salmonid outmigrations to evaluate FGE after the full

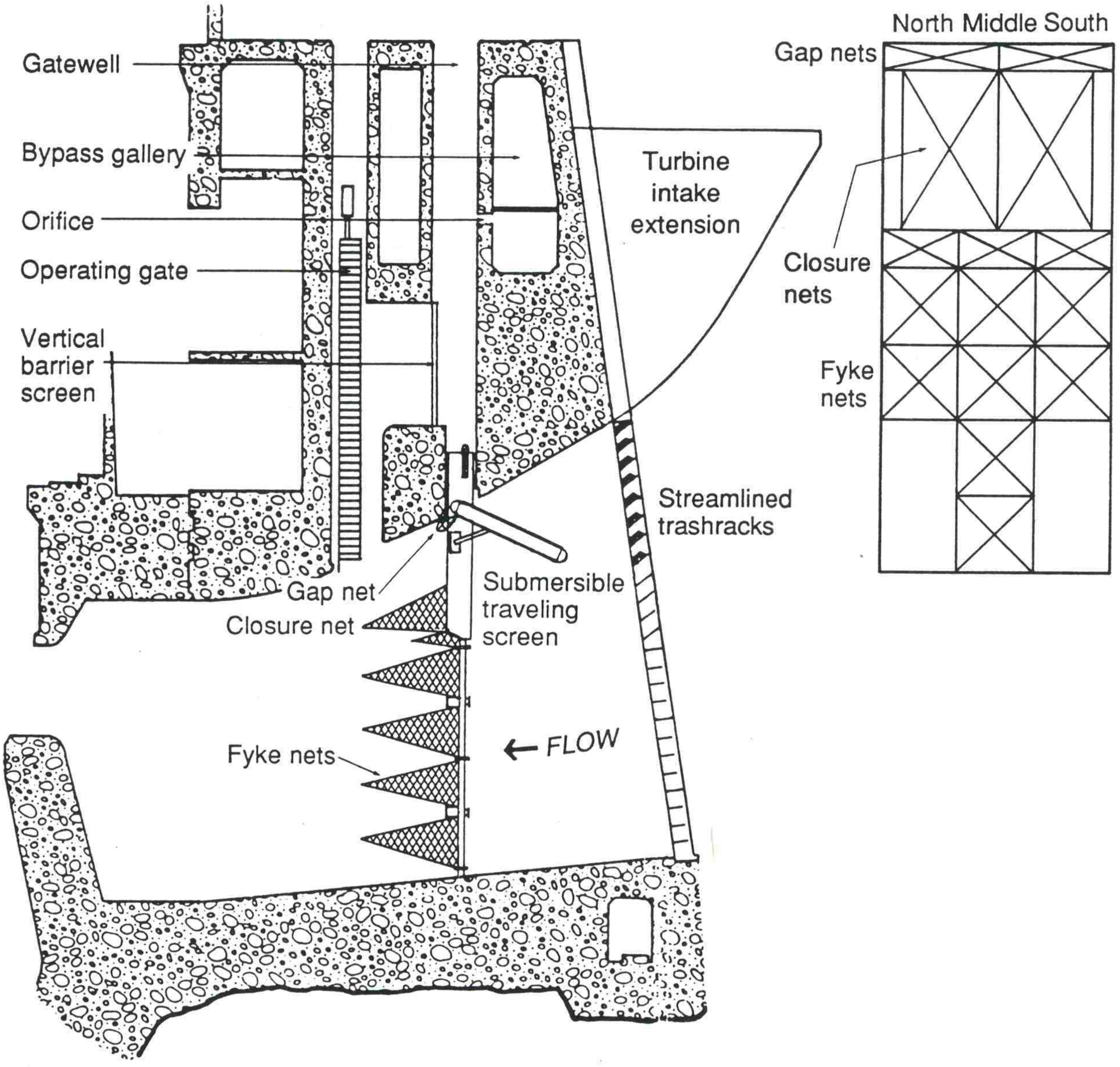

Figure 1. Cross section of turbine intake at Bonneville Dam Second Powerhouse, showing submersible traveling screen, streamlined trashracks, turbine intake extension, fyke nets, fish bypass system, and associated structures.

installation of TIEs (in alternate slots), lowered STSs, and streamlined trashracks at the second powerhouse. To fully evaluate the effects of these changes, tests were conducted in north, middle, and south turbine units (Units 17, 15, and 12, respectively) under full (8 unit) and partial (4 and 6 unit) powerhouse operation. All three of these units were tested under full powerhouse operation, but only the high priority units (12 and 17) were tested under partial powerhouse operation. With 4, 6, or 8 units in operation, mean FGEs for yearling chinook salmon in Turbine Units 12, 15, and 17 were 47, 54, and 41%, respectively. The highest mean FGE (54%) was obtained in Unit 15 under full powerhouse operation, while the lowest (34%) was in Unit 17, also under full powerhouse operation. With 4, 6, or 8 turbine units in operation, FGE for all other species ranged from 35 to 60%. Compared to past research results (Gessel et al. 1987, 1988, 1989), FGE for all species at the second powerhouse was lower than expected with the modifications in place.

Because of the need to establish and confirm accurate FGE values at this dam, a short series of FGE tests was conducted during the 1994 spring outmigration to evaluate how representative or anomalous the 1993 FGE results were. These tests were also conducted in Turbine Units 12, 15, and 17, but only in the non-TIE slots (1993 tests had been conducted in adjacent TIE and non-TIE slots). Since the 1993 results did not indicate large differences between 4- and 6-unit operation, 4-unit tests were not conducted in 1994 and comparisons were made between 6- and 8-unit operation only.

METHODS AND MATERIALS

Procedures and methods for FGE tests were similar to those used at Bonneville Dam in previous years (Gessel et al. 1989, 1990; Monk et al. 1992). Gatewell dip-net catches provided the number of guided fish; gap and fyke nets attached to the STS provided the number of unguided fish (Fig. 1). Fish guidance efficiency for each species was calculated by dividing the gatewell catch by the total number of fish of that species passing through the turbine intake during the test period.

$$FGE = \frac{GW}{GW + GN + 3(FN)} \quad X \quad 100\%$$

GW = gatewell catch
GN = gap-net catch
FN = fyke-net catch (1/3 sample)

Fish guidance efficiency tests were conducted from 10 to 19 May and targeted yearling chinook salmon but data for other salmonid species were also collected.

Individual tests lasted a minimum of 1 hour beginning at 2000 h and ending between 2100 and 2300 h depending on numbers of guided fish (preferably 250 to 300 fish of the target species). When mixed stocks of fish were passing the powerhouse, fewer numbers of some species were recovered to limit the impact on the most prevalent species.

To evaluate the effects of the guiding devices on the juvenile salmonids, all fish were examined for descaling and injuries. Descaling was monitored using standard Fish Transportation Oversight Team fish descaling criteria (Ceballos et al. 1992).

Statistical Analysis

The conditions tested provided two sets of comparisons which were statistically analyzed. In one analysis, a 2-factor Analysis of Variance (ANOVA) compared unit (12 or 17) and number of units in operation (6 or 8). In the other, a 1-factor ANOVA compared Units 12, 15, and 17, with all 8 units in operation. For both tests, means were compared using the Fisher's Protected Least Significant Difference multiple comparison technique (Petersen 1985). Significance was established at $\alpha = 0.05$. Confidence intervals were determined for all means.

RESULTS

Fish Guidance Efficiency

The results of individual replicates of FGE tests in Units 12, 15, and 17 are presented in Appendix Table 1. The ANOVAs and detectable differences (between units and between six- and eight-unit powerhouse operation) are presented in Appendix Table 2 and daily descaling data in Appendix Table 3.

Mean FGE for yearling chinook salmon ranged from 32 (Unit 17 with 6 units in operation) to 57% (Unit 15 with all 8 units in operation) (Table 1). With Units 12 and 17 combined, there was no significant difference in mean FGE between 6- and 8-unit powerhouse operation. However, combining 6- and 8-unit operation, the mean FGE for Unit 12 was significantly higher than for Unit 17 (49 vs. 34%) (Table 2). In a comparison of mean FGE between units with all 8 units in operation, mean FGE for

Table 1. Number of replicates, mean fish guidance efficiency (FGE) and 95% confidence intervals for each turbine unit at 2 different powerhouse operation conditions (6 and 8 units) for all salmonids tested at Bonneville Dam Second Powerhouse, spring 1994. Within each species, a common letter indicates no significant difference between FGE values.

Turbine unit and slot	Units in operation*	Replicates	FGE (%)
Yearling chinook salmon			
12A	6	5	53 (42-65) a
12A	8	5	44 (33-55) a
15B	8	5	57 (48-65) c
17B	6	5	32 (21-43) b
17B	8	5	36 (25-47) b
Subyearling chinook salmon			
12A	6	5	44 (34-54) a
12A	8	5	53 (42-64) a
15B	8	5	60 (53-68) a
17B	6	4	44 (33-55) a
17B	8	5	46 (36-56) a
Coho salmon			
12A	6	5	65 (56-74) a
12A	8	5	58 (49-67) ab
15B	8	5	69 (62-75) c
17B	6	5	41 (33-50) b
17B	8	5	52 (43-60) b
Steelhead			
12A	6	5	50 (43-57) b
12A	8	5	38 (31-45) ab
15B	8	5	49 (44-55) b
17B	6	5	36 (29-44) a
17B	8	5	39 (32-47) a
Sockeye salmon			
12A	6	5	39 (28-50) a
12A	8	5	37 (26-48) a
15B	8	5	49 (39-58) a
17B	6	5	13 (2-24) b
17B	8	5	29 (18-40) ab

*Unit 15 only tested with 8-unit operation.

Table 2. Mean fish guidance efficiency (%) and standard error for all species in Turbine Units 12, 15, and 17 (non-TIE slots) with 6- and 8-unit operation combined at Bonneville Dam Second Powerhouse, spring 1993 and 1994.

	12A		15B		17B	
Species	1993	1994	1993	1994	1993	1994
Yearling chinook salmon	49(5)	49(5)	54(2)	56(3)	37(5)	34(3)
Subyearling chinook salmon	44(8)	49(5)	64(3)	60(9)	51(4)	45(4)
Coho salmon	63(5)	62(4)	63(3)	69(9)	47(4)	47(5)
Steelhead	52(5)	44(2)	50(5)	50(9)	36(5)	40(3)
Sockeye salmon	41(7)	38(4)	35(5)	49(6)	*	21(4)

*All tests excluded because of insufficient numbers of fish.

yearling chinook salmon was significantly higher for Unit 15 than for either Unit 12 or 17 (57 vs. 44 and 36%, respectively). With 6 units in operation, mean FGE was significantly higher in Unit 12 (53%) than in Unit 17 (32%).

For subyearling chinook salmon, mean FGE ranged from 44 to 60% and there were no significant differences among units or powerhouse operation conditions (Table 1). Mean FGE was 49, 60, and 45% for Units 12, 15, and 17, respectively (Table 2).

For coho salmon, mean FGE ranged from a low of 41% (Unit 17 with 6 units in operation) to a high of 69% (Unit 15 with 8 units in operation). There was significant interaction among units and the number of units in operation (Table 1). Mean FGE for Unit 12 with 6 units in operation was significantly higher than for Unit 17 with 6 units in operation; however, with 8 units in operation, there was no significant difference between these units. As with yearling chinook salmon, with all 8 units in operation, mean FGE for Unit 15 was significantly higher than for Units 12 or 17 (69 vs. 58 and 52%, respectively).

For steelhead, mean FGE ranged from 36 to 50%. As with coho salmon, there was interaction among units and number of units in operation (Table 1). Mean FGE for Unit 12 was significantly higher than for Unit 17 with 6 units operating, but there was no significant difference with all 8 units in operation. With all 8 units in operation, mean FGE for Unit 15 was again higher than for Unit 12 or 17 (50 vs. 38 and 39%, respectively). This difference was not significant, although nearly so ($P = 0.07$).

For sockeye salmon (*O. nerka*), mean FGE ranged from 13 to 49%, and, with all 8 units in operation, there was no significant difference among Units 12, 15, or 17 (37, 49, and 29%, respectively, Table 1). There was no interaction among units and number of units in operation, and average FGE for combined 6- and 8-unit operation was significantly higher for Unit 12 than for Unit 17 (38 and 21%, respectively) (Table 2).

Descaling

Since 1983, when FGE studies were first conducted at the second powerhouse, descaling rates have generally been low (5 to 8%) for all species except sockeye salmon. In 1994, however, descaling rates for chinook salmon and steelhead were considerably higher than in 1993 (Table 3). Because of concern that these high levels of descaling might be caused by the guidance systems, our descaling data were compared with descaling data collected during the same time period at the second powerhouse by the Fish Passage Center's Smolt Monitoring Program. The descaling values collected by the Smolt Monitoring Program, which to some degree reflect the effects of guidance devices and other bypass system components on fish condition, were much lower than the values collected during 1994 FGE testing and were comparable to most descaling data collected at the second powerhouse from 1983 to 1989 (both from smolt monitoring and FGE studies.

Table 3. Total numbers and percent descaling for all salmonids examined during fish guidance efficiency (FGE) tests at Bonneville Dam Second Powerhouse, spring 1993 and 1994. Included are data from Smolt Monitoring (SM) Program, spring 1994.

Species	1993 (FGE)		1994 (FGE)		1994 (SM)*	
	No.	Desc.(%)	No.	Desc.(%)	No.	Desc.(%)
Yearling chinook salmon	9,486	5.2	2,219	15.0	1,383	6.5
Subyearling chinook salmon	1,220	2.4	830	6.6	218	1.8
Coho salmon	7,896	3.0	4,998	5.5	1,655	3.1
Steelhead	2,445	8.3	1,050	13.9	415	8.4
Sockeye salmon	1,167	41.8	1,320	49.6	210	16.7

* Provided by Fish Passage Center's smolt monitoring program.

DISCUSSION

Because the 1993 FGE results at Bonneville Dam Second Powerhouse were lower than expected, it was hoped that a limited series of FGE tests in 1994 would verify whether the 1993 data represented appropriate values upon which to base annual fish passage efficiency estimates. However, because of the inability to obtain a year-to-year variance with only 2 years' worth of data (in the same turbine units and under the same powerhouse conditions), a statistical comparison between 1993 and 1994 was not attempted.

In 1993 and 1994, for all species tested, the highest FGE values were obtained in Unit 15 and, for the most part, FGE values in Unit 12 were higher than in Unit 17. A 6-unit operation created the largest variation between years in Units 12 and 17 for yearling chinook salmon. This may have been due to the large daily variance in FGE in these outside units, which increased with partial powerhouse operation. However, by averaging together six- and eight-unit operation, mean FGE values for the three units were similar between years for all species tested (Table 2).

Higher FGE in Unit 15 was probably due to the fact that the flow in the middle of the powerhouse is more laminar than on either side. Even though the TIEs help straighten the flow across the entire length of the powerhouse, large eddies and turbulence form on both sides of the powerhouse adjacent to Units 12 and 17 when only 4 or 6 units are operating. Although these eddies tend to recede at full powerhouse operation, they

still exist and apparently either pull fish away from the water surface or disorient fish so that they seek greater depth.

Although there was no apparent reason to suspect that our dipnetting or fish handling procedures caused increased descaling in 1994, this may have been the case. In tests at McNary Dam, McComas et al. (1994) found that descaling averages of 7.8% for yearling chinook salmon, 3.0% for coho salmon, 4.0% for steelhead, and 27.5% for sockeye salmon may have been caused by dipnetting and fish handling procedures alone. However, it is difficult to understand how the same handling procedures used in previous studies at Bonneville Dam could lead to a descaling increase of this magnitude.

CONCLUSIONS

1) With 6- and 8-unit operation combined, mean FGE for yearling chinook salmon was significantly higher in Unit 12 (49%) than in Unit 17 (34%).
2) With 8-unit operation, FGE for yearling chinook salmon was significantly higher in Unit 15 (57%) than in Units 12 (44%) and 17 (36%); FGE was also significantly higher in Unit 12 than in Unit 17.
3) With 6-unit operation, FGE for yearling chinook salmon was significantly higher in Unit 12 (53%) than in Unit 17 (32%).
4) For all species evaluated, FGE values were similar to 1993 results. In most cases, the highest values were obtained in Unit 15 with 8-unit operation and the lowest values in Unit 17 with 6-unit operation.

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REFERENCES

Ceballos, J. R., S. W. Pettit, and J. L. McKern. 1992. Fish Transportation Oversight Team Annual Report - FY 1991. Transport Operations on the Snake and Columbia Rivers. NOAA Technical Memorandum NMFS F/NWR-31, 77 p. plus Appendix. (Available from Environmental and Technical Services Division, 525 N.E. Oregon Street, Suite 500, Portland, OR 97232-2737.)

Gessel, M. H., D. A. Brege, B. H. Monk, and J. G. Williams. 1990. Continued studies to evaluate the juvenile bypass systems at Bonneville Dam - 1989. Report to the U.S. Army Corps of Engineers, Delivery Order E8689095, 20 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Gessel, M. H., L. G. Gilbreath, W. D. Muir, B. H. Monk, and R. F. Krcma. 1987. Evaluation of the juvenile salmonid collection and bypass systems at Bonneville Dam - 1986. Report to the U.S. Army Corps of Engineers, Contract DACW57-86-F-0270, 53 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Gessel, M. H., B. H. Monk, D. A. Brege, and J. G. Williams. 1989. Fish guidance efficiency studies at Bonneville Dam First and Second Powerhouses - 1988. Report to the U.S. Army Corps of Engineers, Delivery Order DACW57-87-F-0322, 22 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Gessel, M. H., B. H. Monk, and J. G. Williams. 1988. Evaluation of the juvenile salmonid collection and bypass systems at Bonneville Dam, 1987. Report to the U.S. Army Corps of Engineers, Contract DACW57-87-F-0322, 35 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

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

Krcma, R. F., M. H. Gessel, W. D. Muir, C. S. McCutcheon, L. G. Gilbreath, and B. H. Monk. 1984. Evaluation of the juvenile collection and bypass system at Bonneville Dam, 1983. Report to the U.S. Army Corps of Engineers, Contract DACW57-83-F-0315, 56 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

McComas, R. L., B. P. Sandford, and D. B. Dey. 1994. Studies to evaluate the effectiveness of extended-length screens at McNary Dam, 1993. Report to U.S. Army Corps of Engineers, Contract E86910060, 25 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112-2097.)

Monk, B. H., G. E. Varney, and S. J. Grabowski. 1992. Continuing studies to evaluate and improve submersible traveling screens for fish guidance at Bonneville Dam First Powerhouse, 1991. Report to U.S. Army Corps of Engineers, Contract E96910012, 20 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Monk, B. H., B. P. Sandford, and D. B. Dey. 1994. Evaluation of fish guidance efficiency of submersible traveling screens and other modifications at Bonneville Dam Second Powerhouse, 1993. Report to U.S. Army Corps of Engineers, Contract E96930031, 26 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112-2097.)

Petersen, R. G. 1985. Design and analysis of experiments. Marcel Dekker, New York. 429 p.

APPENDIX TABLES

Appendix Table 1. Numbers of fish collected in individual replicates of FGE tests in Turbine Units 12, 15, and 17 at Bonneville Dam Second Powerhouse, 1994 (SC = subyearling chinook, YC = yearling chinook, ST = steelhead, CO = coho, and SO = sockeye).

	Date (test unit and slot) (number of units operating)														
	10 May (12A) (6)					10 May (17B) (6)					11 May (12A) (8)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	29	769	366	1236	103	1	189	54	253	6	3	37	47	147	24
Gap Net	1	2	0	11	0	0	2	0	0	0	0	1	1	2	1
Closure	5	251	102	173	59	0	40	17	65	11	1	12	10	34	14
First	25	10	84	111	21	3	15	0	21	3	0	3	15	9	6
Second	7	237	45	344	65	2	64	29	93	20	3	34	28	59	30
Third	2	112	21	158	41	2	59	13	32	10	1	38	23	32	29
Fourth	0	57	1	84	6	0	45	15	24	6	0	15	6	12	0
Fifth	0	1	0	9	0	0	3	3	0	0	0	3	0	0	0
Totals	**69**	**1,439**	**619**	**2,126**	**295**	**8**	**417**	**131**	**488**	**56**	**8**	**143**	**130**	**295**	**104**
FGE (%)	**42**	**53**	**59**	**58**	**35**	**13**	**45**	**41**	**52**	**11**	**38**	**26**	**36**	**50**	**23**

	11 May (15B) (8)					11 May (17B) (8)					12 May (12A) (6)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	19	147	52	454	27	13	41	23	116	15	19	108	99	204	98
Gap Net	0	2	0	2	2	2	0	0	2	0	1	1	1	2	8
Closure	6	46	14	97	22	9	16	5	21	3	2	21	19	21	41
First	0	12	12	12	0	3	3	0	3	0	3	9	15	24	27
Second	3	27	21	32	9	4	17	5	32	7	1	54	60	62	89
Third	0	20	11	20	6	5	17	6	14	12	5	44	36	28	65
Fourth	0	0	0	0	0	0	9	3	12	0	0	33	12	9	60
Fifth	0	6	6	3	6	0	3	0	0	0	3	3	12	3	3
Totals	**28**	**260**	**116**	**620**	**72**	**36**	**106**	**42**	**200**	**37**	**34**	**273**	**254**	**353**	**391**
FGE (%)	**68**	**57**	**45**	**73**	**38**	**36**	**39**	**55**	**58**	**41**	**56**	**40**	**39**	**58**	**25**

	12 May (17B) (6)					13 May (12A) (8)					13 May (15B) (8)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	28	74	66	231	32	18	106	87	152	129	59	141	19	224	62
Gap Net	0	3	0	1	1	0	1	1	4	3	0	2	0	3	2
Closure	11	47	20	93	48	1	14	13	12	23	10	52	10	68	24
First	0	27	15	30	33	12	33	27	18	45	9	18	9	15	3
Second	16	90	47	89	63	3	39	49	59	97	6	26	10	33	7
Third	3	46	25	58	84	6	40	30	26	65	2	8	3	11	10
Fourth	3	42	12	33	51	1	24	15	12	21	0	3	0	0	0
Fifth	0	0	0	6	3	0	3	0	0	6	0	3	0	0	3
Totals	**61**	**329**	**185**	**541**	**315**	**41**	**260**	**222**	**283**	**269**	**86**	**253**	**51**	**354**	**111**
FGE (%)	**46**	**22**	**36**	**43**	**10**	**44**	**41**	**39**	**54**	**100**	**69**	**56**	**37**	**63**	**56**

Appendix Table 1. Continued.

Location	Date (test unit and slot) (number of units operating) 13 May (17B) (8) SC	YC	ST	CO	SO	14 May (12A) (6) SC	YC	ST	CO	SO	14 May (17B) (6) SC	YC	ST	CO	SO
Gatewell	27	58	28	113	18	40	287	104	364	211	50	102	27	84	35
Gap Net	1	2	0	2	1	2	2	0	1	6	0	0	0	3	2
Closure	14	28	9	26	26	2	5	11	16	17	16	38	18	37	35
First	3	6	6	9	15	3	15	9	6	15	12	24	6	15	6
Second	3	41	30	41	42	23	52	28	23	59	29	78	23	40	70
Third	5	38	12	24	36	9	14	19	16	26	10	61	16	43	78
Fourth	3	15	3	12	33	6	9	6	0	18	6	24	12	30	51
Fifth	0	6	0	0	6	0	3	3	0	3	6	0	0	3	3
Totals	**56**	**194**	**88**	**227**	**177**	**85**	**387**	**180**	**426**	**355**	**129**	**327**	**102**	**255**	**280**
FGE (%)	**48**	**30**	**32**	**50**	**10**	**47**	**74**	**58**	**85**	**59**	**39**	**31**	**26**	**33**	**13**

Location	15 May (12A) (8) SC	YC	ST	CO	SO	15 May (15B) (8) SC	YC	ST	CO	SO	15 May (17B) (8) SC	YC	ST	CO	SO
Gatewell	32	142	48	114	105	42	176	27	206	68	23	64	16	60	19
Gap Net	1	0	0	0	4	0	4	0	0	4	1	2	0	0	0
Closure	0	5	5	6	7	16	50	13	43	39	3	26	7	10	4
First	3	15	9	9	18	6	15	0	12	21	0	9	0	0	3
Second	12	52	26	38	57	11	57	6	24	36	7	36	13	16	8
Third	3	29	18	22	48	4	27	1	14	19	6	19	8	10	18
Fourth	0	24	21	21	33	3	6	6	0	15	6	18	0	18	6
Fifth	0	3	0	1	3	0	3	0	0	3	0	0	3	3	0
Totals	**51**	**270**	**127**	**211**	**275**	**82**	**338**	**53**	**299**	**205**	**46**	**174**	**47**	**117**	**58**
FGE (%)	**63**	**53**	**38**	**54**	**38**	**51**	**52**	**51**	**69**	**33**	**50**	**37**	**34**	**51**	**33**

Location	16 May (12A) (6) SC	YC	ST	CO	SO	16 May (17B) (6) SC	YC	ST	CO	SO	17 May (12A) (8) SC	YC	ST	CO	SO
Gatewell	8	233	89	495	141	25	87	28	176	31	11	68	90	284	52
Gap Net	1	2	0	6	10	3	3	3	5	1	0	3	2	4	5
Closure	11	38	24	47	39	9	61	16	48	21	1	4	15	20	9
First	0	15	24	33	21	0	21	0	45	24	0	15	24	39	15
Second	7	51	34	56	79	0	65	14	37	35	9	54	66	95	52
Third	5	19	28	35	42	7	81	20	67	65	10	20	31	54	48
Fourth	1	24	9	21	21	3	45	9	60	36	0	12	0	15	0
Fifth	0	0	0	0	3	0	18	0	12	0	0	9	3	0	3
Totals	**33**	**382**	**208**	**693**	**356**	**47**	**381**	**90**	**450**	**213**	**31**	**185**	**231**	**511**	**184**
FGE (%)	**24**	**61**	**43**	**71**	**40**	**53**	**23**	**31**	**39**	**15**	**35**	**37**	**39**	**56**	**28**

Appendix Table 1. Continued.

Location	Date (test unit and slot) (number of units operating) 17 May (15B) (8) SC	YC	ST	CO	SO	17 May (17B) (8) SC	YC	ST	CO	SO	18 May (12A) (8) SC	YC	ST	CO	SO
Gatewell	60	136	34	368	57	48	50	18	100	9	39	158	65	587	125
Gap Net	1	0	0	2	0	2	1	1	1	0	0	2	0	16	5
Closure	34	47	14	73	31	18	14	5	17	2	1	15	10	41	6
First	21	3	3	21	0	12	0	3	18	0	3	12	21	42	9
Second	5	34	9	44	15	8	17	6	26	4	9	35	40	59	34
Third	3	5	7	25	3	12	25	6	24	1	4	17	25	28	28
Fourth	0	3	0	15	0	3	6	6	15	6	0	6	6	0	0
Fifth	3	0	0	0	0	0	3	3	3	0	0	6	3	0	0
Totals	**127**	**228**	**67**	**548**	**106**	**103**	**116**	**48**	**204**	**22**	**56**	**251**	**170**	**773**	**207**
FGE (%)	**47**	**60**	**51**	**67**	**54**	**47**	**43**	**38**	**49**	**41**	**70**	**63**	**38**	**76**	**60**

Location	18 May (15B) (8) SC	YC	ST	CO	SO	18 May (17B) (8) SC	YC	ST	CO	SO	19 May (12A) (6) SC	YC	ST	CO	SO
Gatewell	75	101	16	242	29	50	30	7	116	5	64	72	64	257	77
Gap Net	1	1	0	1	0	1	0	0	3	0	0	0	0	8	2
Closure	24	45	5	65	11	26	8	1	28	1	10	15	11	22	15
First	6	6	3	9	0	3	3	3	6	0	6	9	9	30	6
Second	1	9	0	9	2	15	22	4	31	5	19	37	18	100	57
Third	6	11	1	10	1	9	16	3	24	5	26	23	16	59	39
Fourth	0	0	0	3	3	0	9	0	24	6	9	27	9	15	29
Fifth	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0
Totals	**113**	**173**	**25**	**339**	**46**	**104**	**91**	**18**	**232**	**22**	**134**	**183**	**127**	**491**	**225**
FGE (%)	**66**	**58**	**64**	**71**	**63**	**48**	**33**	**39**	**50**	**23**	**48**	**39**	**50**	**52**	**34**

Location	19 May (17B) (6) SC	YC	ST	CO	SO
Gatewell	60	39	26	111	19
Gap Net	4	3	1	3	1
Closure	14	8	3	49	12
First	12	3	1	18	6
Second	24	22	10	52	39
Third	15	27	10	25	22
Fourth	0	3	3	15	18
Fifth	0	0	0	0	6
Totals	**129**	**105**	**54**	**273**	**123**
FGE (%)	**47**	**37**	**48**	**41**	**1**

Appendix Table 2. ANOVAs, FGE means, mean comparisons, and 95% confidence intervals for all species at Bonneville Dam Second Powerhouse for Units 12, 15, and 17 with 6 or 8 units in operation.

YEARLING CHINOOK SALMON

Two factor ANOVA for FGE estimates in Units 12 and 17 with 6 and 8 units in operation.

Source	df	SS	MS	F	p
Unit	1	1067.3	1067.3	7.82	0.0129
Units on	1	33.5	33.5	0.25	0.6319
Interaction	1	252.8	252.8	1.85	0.1923
Error	16	2182.5	136.4		
Total	19	3536.1			

Condition	Mean FGE (%)	95% CI (%)	Difference*
Unit 12, 6 units	53.5	42.4 - 64.6	a
Unit 12, 8 units	43.8	32.7 - 54.9	a
Unit 17, 6 units	31.8	20.7 - 42.9	a
Unit 17, 8 units	36.3	25.2 - 47.4	a

ANOVA for FGE estimates in Units 12, 15, and 17 with 8 units in operation.

Source	df	SS	MS	F	p
Unit	2	1038.3	519.1	6.50	0.0122
Error	12	958.0	79.8		
Total	14	1996.2			

Unit	Mean FGE (%)	95% CI (%)	Difference*
12	43.8	35.1 - 52.5	a
15	56.5	47.8 - 65.2	b
17	36.3	27.6 - 45.0	a

Appendix Table 2. Continued.

SUBYEARLING CHINOOK SALMON

Two factor ANOVA for FGE estimates in Units 12 and 17 with 6 and 8 units in operation.

Source	df	SS	MS	F	p
Unit	1	59.8	59.8	0.55	0.4787
Units on	1	125.2	125.2	1.15	0.3017
Interaction	1	53.1	53.1	0.49	0.5036
Error	14	1524.2	108.9		
Total	17	1745.2			

Condition	Mean FGE (%)	95% CI (%)	Difference*
Unit 12, 6 units	44.2	34.1 - 54.2	a
Unit 12, 8 units	52.9	41.7 - 64.1	a
Unit 17, 6 units	44.0	32.8 - 55.1	a
Unit 17, 8 units	45.8	35.8 - 55.8	a

ANOVA for FGE estimates in Units 12, 15, and 17 with 8 units in operation.

Source	df	SS	MS	F	p
Unit	2	522.8	261.4	2.21	0.1559
Error	11	1300.4	118.2		
Total	13	1823.1			

Unit	Mean FGE (%)	95% CI (%)	Difference*
12	52.9	44.5 - 61.4	a
15	60.3	52.7 - 67.8	a
17	45.8	38.2 - 53.4	a

Appendix Table 2. Continued.

COHO SALMON

Two factor ANOVA for FGE estimates in Units 12 and 17 with 6 and 8 units in operation.

Source	df	SS	MS	F	p
Unit	1	1105.6	1105.6	12.75	0.0025
Units on	1	11.1	11.1	0.13	0.7289
Interaction	1	377.6	377.6	4.36	0.0532
Error	16	1387.0	86.7		
Total	19	2881.3			

Condition	Mean FGE (%)	95% CI (%)	Difference*
Unit 12, 6 units	65.0	56.2 - 73.8	a
Unit 12, 8 units	57.8	49.0 - 66.6	ab
Unit 17, 6 units	41.4	32.6 - 50.3	c
Unit 17, 8 units	51.6	42.8 - 60.4	bc

ANOVA for FGE estimates in Units 12, 15, and 17 with 8 units in operation.

Source	df	SS	MS	F	p
Unit	2	757.2	378.6	8.41	0.0052
Error	12	540.2	45.0		
Total	14	1297.5			

Unit	Mean FGE (%)	95% CI (%)	Difference*
12	57.8	51.3 - 64.3	a
15	68.8	62.3 - 75.3	b
17	51.6	45.1 - 58.1	a

Appendix Table 2. Continued.

STEELHEAD

Two factor ANOVA for FGE estimates in Units 12 and 17 with 6 and 8 units in operation.

Source	df	SS	MS	F	p
Unit	1	180.6	180.6	3.08	0.0982
Units on	1	97.2	97.2	1.66	0.2159
Interaction	1	265.7	265.7	4.54	0.0490
Error	16	937.1	58.6		
Total	19	1480.6			

Condition	Mean FGE (%)	95% CI (%)	Difference*
Unit 12, 6 units	49.8	42.6 - 57.1	b
Unit 12, 8 units	38.1	30.9 - 45.4	a
Unit 17, 6 units	36.5	29.3 - 43.8	a
Unit 17, 8 units	39.4	32.1 - 46.7	a

ANOVA for FGE estimates in Units 12, 15, and 17 with 8 units in operation.

Source	df	SS	MS	F	p
Unit	2	391.5	195.6	3.27	0.0736
Error	12	718.7	59.9		
Total	14	1110.2			

Unit	Mean FGE (%)	95% CI (%)	Difference*
12	38.1	32.8 - 43.5	a
15	49.5	44.2 - 54.9	a
17	39.4	34.1 - 44.7	a

Appendix Table 2. Continued.

SOCKEYE SALMON

Two factor ANOVA for FGE estimates in Units 12 and 17 with 6 and 8 units in operation.

Source	df	SS	MS	F	p
Unit	1	1381.1	1381.1	10.14	0.0058
Units on	1	269.4	269.4	1.98	0.1788
Interaction	1	441.8	441.8	3.24	0.0906
Error	16	2179.8	136.2		
Total	19	4272.1			

Condition	Mean FGE (%)	95% CI (%)	Difference*
Unit 12, 6 units	38.7	27.6 - 49.8	a
Unit 12, 8 units	36.7	25.6 - 47.7	a
Unit 17, 6 units	12.7	1.6 - 23.7	a
Unit 17, 8 units	29.4	18.4 - 40.5	a

ANOVA for FGE estimates in Units 12, 15, and 17 with 8 units in operation.

Source	df	SS	MS	F	p
Unit	2	946.7	473.4	2.63	0.1130
Error	12	2160.3	180.0		
Total	14	3107.0			

Unit	Mean FGE (%)	95% CI (%)	Difference*
12	36.6	27.4 - 45.9	a
15	48.7	39.4 - 57.9	a
17	29.4	20.2 - 38.7	a

*Common letter indicates no significant difference.

Appendix Table 3. Total numbers of fish in the gatewells and percent descaling for all salmonids examined during FGE tests conducted at Bonneville Dam Second Powerhouse, 1994. Units = the number of turbine units operating during the test.

			Yearling chinook		Subyearling chinook		Sockeye		Coho		Steelhead	
Test slot	Date	Units	No.	%	No.	%	No.	%	No.	%	No.	%
12A	5-11	8	37	0.0	3	0.0	24	58.3	147	4.8	47	8.5
15B	5-11	8	147	16.3	19	10.5	27	40.7	454	4.0	52	19.2
17B	5-11	8	41	14.6	13	7.7	15	60.0	116	6.0	23	13.0
12A	5-12	6	108	13.0	19	5.3	98	64.2	204	8.8	99	15.1
17B	5-12	6	74	23.0	28	0.0	32	40.6	231	6.5	66	13.6
12A	5-13	8	106	16.0	18	16.7	129	60.4	152	15.1	87	25.3
15B	5-13	8	141	19.9	59	6.7	62	35.5	224	14.7	19	31.6
17B	5-13	8	58	15.5	27	3.7	18	22.2	113	4.4	28	10.7
12A	5-14	6	287	16.4	40	22.5	211	55.9	364	10.7	104	10.6
17B	5-14	6	102	18.6	50	2.0	35	8.6	84	3.6	27	66.7
12A	5-15	8	142	14.8	32	25.0	105	64.8	114	15.8	48	18.7
17B	5-15	8	64	10.9	23	4.3	19	52.6	60	5.0	16	18.7
12A	5-16	6	233	13.3	8	62.5	141	51.7	495	5.4	89	7.8
17B	5-16	6	25	12.0	87	11.4	31	58.1	176	4.5	28	3.5
12A	5-17	6	68	10.2	11	9.0	52	42.3	284	2.1	90	7.8
15B	5-17	6	136	13.2	60	3.0	57	45.6	368	2.9	34	5.9
17A	5-17	6	50	32.0	45	4.1	9	44.4	100	0.0	15	16.7
12A	5-18	6	158	8.8	39	2.6	125	38.4	587	1.7	65	6.1
15B	5-18	6	101	13.0	75	1.3	29	34.0	242	2.1	16	0.0
17B	5-18	4	30	11.6	50	0.0	5	60.0	116	3.4	0	0.0
12A	5-19	4	72	19.4	64	3.1	77	39.0	257	5.4	64	6.2
17B	5-19	8	39	7.7	60	0.0	19	50.0	111	2.7	26	7.7
	TOTALS/MEANS		**2,219**	**15.0**	**830**	**6.6**	**1,320**	**49.6**	**4,998**	**5.5**	**1,050**	**13.9**