Continuing Studies to Evaluate and Improve Submersible Traveling Screens for Fish Guidance at Bonneville Dam First Powerhouse, 1991

by
Bruce H. Monk
Gregory E. Varney
Stephen J. Grabowski

August 1992

COASTAL ZONE AND ESTUARINE STUDIES

CONTINUING STUDIES TO EVALUATE AND IMPROVE SUBMERSIBLE TRAVELING SCREENS FOR FISH GUIDANCE AT BONNEVILLE DAM FIRST POWERHOUSE, 1991

by

Bruce H. Monk
Gregory E. Varney
Stephen J. Grabowski

Annual Report of Research

Funded by

U.S. Army Corps of Engineers
Project E96910012

and

Coastal Zone and Estuarine Studies Division
Northwest Fisheries Science Center
National Marine Fisheries Service
National Oceanic and Atmospheric Administration
2725 Montlake Boulevard East
Seattle, Washington 98112-2097

August 1992

CONTENTS

INTRODUCTION

In 1981, the National Marine Fisheries Service (NMFS) 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% (SE = 2.7) for all salmonid species during the period 30 April to 13 May. Fish guidance efficiency was lower during individual studies conducted later in May, but the decrease was attributed to large amounts of debris on the trashracks (Krcma et al. 1982). Based on these results, a complete set of STS was installed at the dam prior to the 1983 juvenile salmonid outmigration.

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 Bonneville Dam First 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 to provide a more complete FGE baseline, so that any changes in FGE associated with changes in flow or the addition of the new guidewall would be observed in later tests. Between 30 May and 5 June, FGE for subyearling chinook salmon (*Oncorhynchus tshawytscha*) averaged 40.7% (SE = 6.2) which was well below the FGE of 71.5% measured for these fish during the same time period in 1981. Between 6 and 27 July, FGE for subyearling chinook salmon averaged 11% (SE = 2.0) (Gessel et al. 1989).

To document the change in FGE, further tests were expanded in 1989 to include both the spring and summer outmigrations of yearling and subyearling chinook salmon. Between 9 and 14 May, FGE for yearling chinook salmon averaged 42% (SE = 2.3). Between 27 and 30 May, FGE for yearling and subyearling chinook salmon averaged 31 (SE = 7.6) and 37% (SE = 4.3), respectively. Between 12 and 24 July, FGE for subyearling chinook salmon averaged 4.4% (SE = 0.9)(Gessel et al. 1990).

In 1977, NMFS also conducted FGE studies at Bonneville Dam First Powerhouse, but with a short bar-screen deflector (BSD). Fish guidance efficiency with the BSD ranged from 16 to 62% with a stored operating gate (SOG) (Fig. 1) and 43 to 78% with a raised operating gate (ROG, operating gate raised approximately 30 ft). Gatewell flow increased from 90 to 250 cfs with a ROG and it was concluded that the significant increase in FGE was the result of the increased flow into the gatewell. When gatewell flows at other hydroelectric projects were increased, FGE also increased (Krcma et al. 1978, 1979).

NMFS conducted studies at Bonneville Dam First Powerhouse during the 1991 juvenile salmonid outmigration to investigate the low guidance levels measured in 1988 and 1989 and to further evaluate the potential to increase guidance of juvenile salmonids with a ROG.

The objectives of the 1991 study were to:

1) Determine if FGE was similar in various turbine intakes across the face of the powerhouse.
2) Evaluate the effects of a raised operating gate on FGE.

METHODS AND MATERIALS

Procedures and methods for these FGE studies were similar to those used at Bonneville Dam First Powerhouse in 1988 and 1989 (Gessel et al. 1989, 1990). Screens were set at the standard elevation of 44 ft mean sea level (MSL) for all tests, with the pivot point of the screen at 39 ft MSL (Fig. 1).

Gatewell dipnet catches provided the number of guided fish; gap, closure, and fyke nets attached to the STS provided the number of unguided fish. Fish guidance efficiency was calculated as gatewell catch divided by the total number of fish (by species) passing through the intake during the test period.

$$FGE = (GW / (GW + GN + CN + FN)) \times 100$$

GW = gatewell catch
GN = gap net catch
CN = closure net catch
FN = fyke net catch[1]

FGE tests conducted during the spring outmigration targeted yearling chinook salmon. Data for other salmonids [subyearling chinook, coho (O. kisutch), and sockeye salmon (O. nerka), and steelhead (O. mykiss)] were also collected. Individual tests lasted a minimum of 1 hour, typically beginning at 2000 h and

[1]Net catches using only the middle column of nets were expanded by a factor of 3.

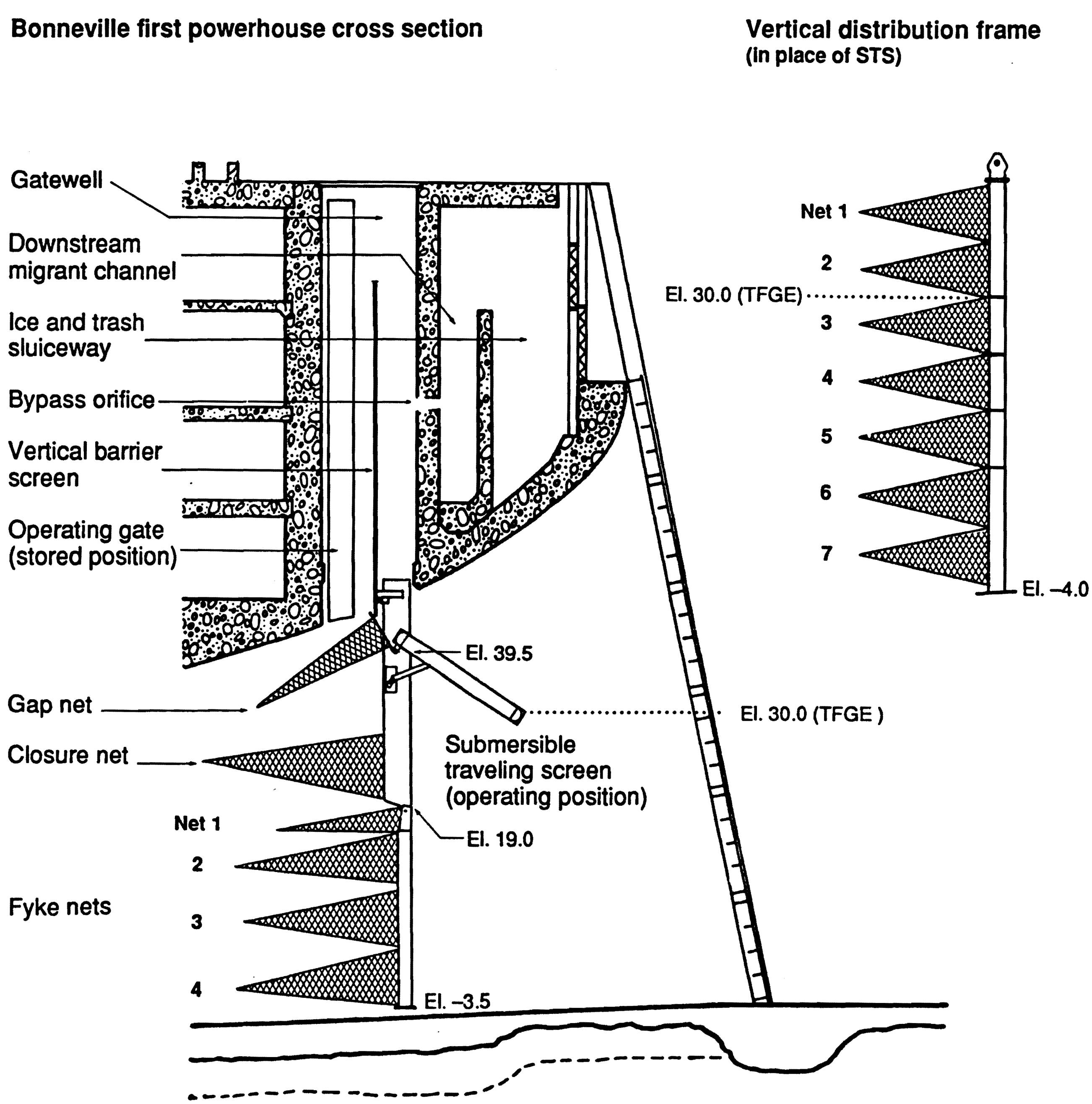

Figure 1.--Cross-section of turbine unit at Bonneville Dam First Powerhouse, showing sampling apparatus, design of fish bypass system, stored operating gate, and associated structures.

ending between 2100 and 2300 h (determined by the number of guided fish). Unit discharge during testing ranged between 11,300 and 14,200 cfs.

To determine if differences in FGE existed among turbine units at Bonneville Dam First Powerhouse, simultaneous FGE testing occurred in Units 3 and 8 from 22 to 27 April (Series 1, Table 1) and 20 to 24 May (Series 4), and in Units 5 and 8 from 29 April to 4 May (Series 2). The operating gates were in the stored position during these test series. To compare the effect on FGE of a raised versus a stored operating gate, the operating gate in Unit 8 was alternately raised and stored during the period 5-15 May (Series 3). All FGE tests except Series 4 included a vertical distribution measurement in each unit tested, to estimate depth distribution of fish within the turbine intakes.

Five replicates were used for all test series. Paired t-tests were used to test for significant differences in FGE. To test for differences between units, results were paired within days. To test for differences between raised and stored operating gates within a unit, adjacent days were paired together (randomly selected). Based on previous data, it was determined that five pairs of tests would allow detection of significant FGE differences of 5 to 10%, using the following formula:

$$t = \frac{\overline{X_d}}{s/\sqrt{n}}$$

where,

X_d = mean of the observed pair differences
s = standard deviation of the observed pair
n = number of paired differences.

Table 1.--Fish guidance efficiency test series conducted at Bonneville Dam First Powerhouse, 1991. One day of vertical distribution was conducted during each series except Series 4.

Series	Dates	Objective
1	4/22-4/27	Compare Units 3 and 8
2	4/29-5/4	Compare Units 5 and 8
3	5/5-5/15	Compare raised vs. stored operating gate in Unit 8
4	5/20-5/24	Compare Units 3 and 8

These data were then used to estimate theoretical fish guidance efficiency (TFGE). Because an STS effectively intercepts fish to a depth equal to two rows of nets on the vertical distribution frame, TFGE was calculated by dividing the gatewell catch plus the number of fish caught in the first two rows of nets by the total number of fish in both the gatewell and in all nets (Fig. 1).

Analysis of data from previous FGE tests showed that the middle net collected one-third of the fish at a given depth level (Gessel et al. 1986). Therefore, to minimize the number of fish captured in nets during the vertical distribution measurements, only a middle column of nets was used. The number of fish captured at each net level was expanded by a factor of three to estimate the total number of fish passing through the fyke-netted area.

All fish captured in the gatewells during FGE tests and vertical distribution measurements were examined for descaling and other injuries using guidelines established by the Fish Transportation Oversight Team (Ceballos et al. 1991). Descaling was determined by dividing the fish into five equal areas per side; if any two areas on a side were estimated to be 40% or more descaled, the fish was classified as descaled (Ceballos et al. 1991).

RESULTS AND DISCUSSION

Differences in Fish Guidance Efficiency Between Units

In Series 1, FGE averaged 45.8% (SE = 5.1) in Unit 3 and 31.7% (SE = 5.3) in Unit 8 for yearling chinook salmon (Fig. 2, top). Because of the large variance, the difference in mean FGE between these two units (14.1%) was not significant ($P = 0.17$). Although the average FGE during Series 1 was higher in Unit 3 than Unit 8, the TFGE (from same day vertical distribution measurements on 27 April) was slightly higher in Unit 8 (Table 2). The difference in FGE between units ranged from +41.5% to -7.0% (Appendix Table 1; Unit 3 minus Unit 8). This large variation could have resulted from changes in the composition of the migrant population from day to day. During the earlier part of the spring outmigration, the fish populations migrating through Bonneville Dam were largely composed of hatchery releases from tributaries flowing into the Bonneville and The Dalles reservoirs; smolt release numbers were obtained from weekly Fish Passage Center reports. These populations tended to arrive during a 2- to 3-day period (Hawkes et al. 1991) and may not have spread out horizontally across the face of the dam (Krcma et al. 1982); therefore, a large part of the variation in FGE between turbine units at this time of year could have resulted from difference in behavior and horizontal distribution among these populations of hatchery fish.

In Series 4 from 20 to 24 May (a repeat of Series 1), FGE averaged 46.5% (SE = 3.5) in Unit 3 and 45.4% (SE = 4.8) in

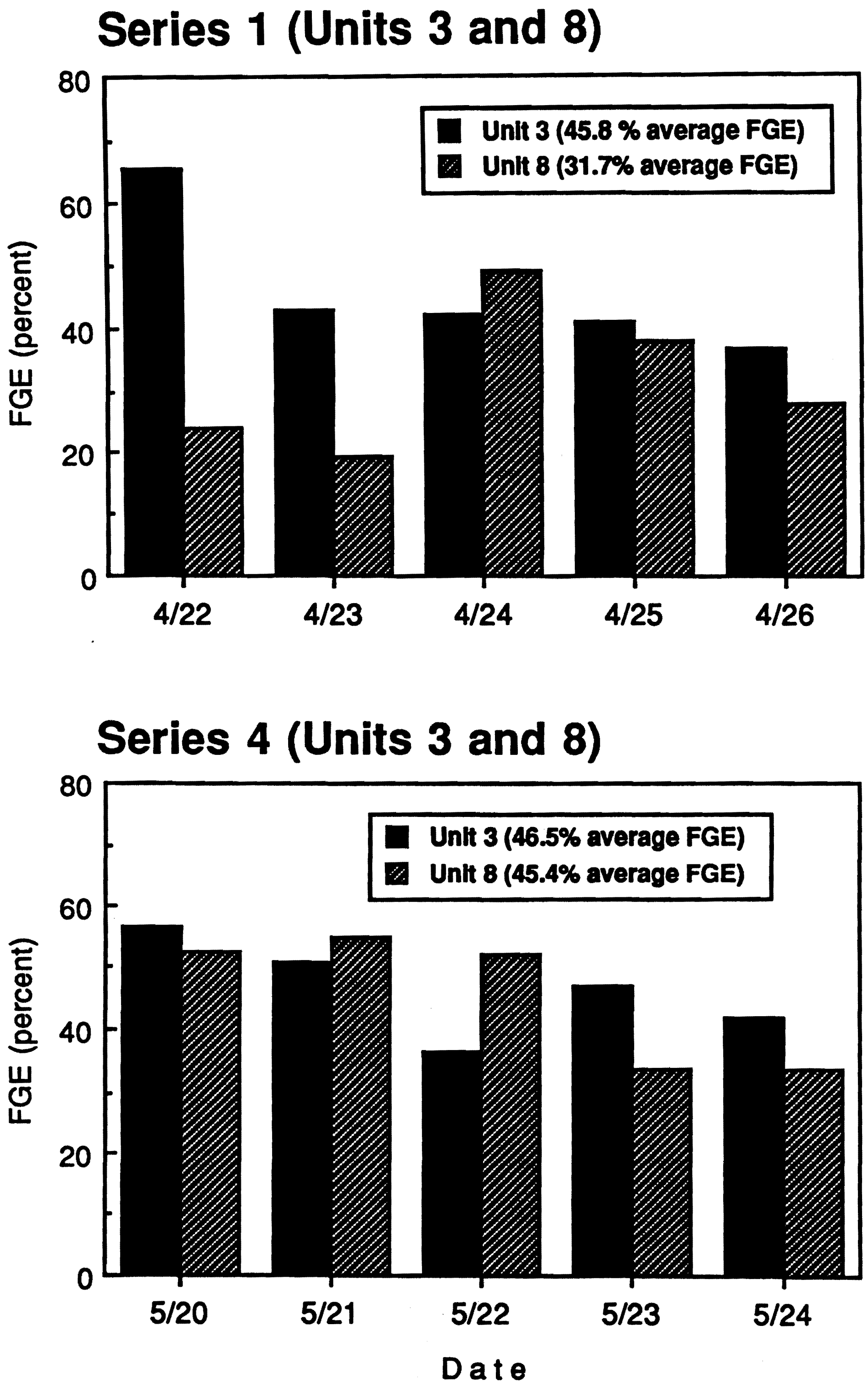

Figure 2.--Fish guidance efficiency (FGE) for yearling chinook salmon in Units 3 and 8 (Series 1 and 4) at Bonneville Dam First Powerhouse, 1991.

Table 2.--Cumulative percentages of yearling chinook salmon caught in the gatewell and at each net level during vertical distribution measurements at Bonneville Dam First Powerhouse, 1991.

Turbine unit	3B	5B	8B	8B	8B
Date	4/27	4/29	4/27	4/29	5/15
Level					
Gatewell	7.4	34.1	7.3	12.3	6.6
1	51.0	48.7	49.6	40.6	54.0
2*	74.4	70.7	78.2	57.6	76.4
3	86.1	78.7	89.1	74.6	88.2
4	92.5	85.3	90.5	85.9	94.8
5	97.8	85.3	98.7	85.9	98.7
6	98.9	100.0	100.0	94.4	100.0
7	100.0	100.0	100.0	100.0	100.0

* Cumulative percent at Level 2 represents TFGE.

Unit 8. The difference of 1.1% was not significant (P = 0.83) (Fig. 2, bottom).

In Series 2, FGE averaged 28.9% (SE = 3.3) in Unit 5 and 38.7% (SE = 1.9) in Unit 8 (Fig. 3). The difference in mean FGE between these units (9.8%) was significant (P = 0.05). The average FGE of 28.9% measured in Unit 5 was the lowest of any of the units, and the TFGE of 70.7% was the second lowest (Table 2). However, FGE in Unit 5 was only measured for a total of 5 days and thus may not represent FGE over the entire migration period.

The FGE values and the respective t-values for each test in Series 1, 2, and 4 are given in Appendix Table 1. The numbers of fish (by species) collected for each FGE test and vertical distribution measurement (all series) are in Appendix Tables 2 and 3, respectively.

Raised Operating Gate Effects on Fish Guidance Efficiency

In Unit 8, FGE for yearling chinook salmon averaged 28.9% (SE = 3.30) with the operating gate stored and 49.5% (SE = 2.08) with the operating gate raised, a significant increase (P = 0.01) (Fig. 4). These results were similar to those obtained at Lower Granite Dam by Swan et al. (1984, 1986).

The five vertical distribution measurements taken throughout the season also indicated that a large percentage of the yearling chinook salmon avoided interception by the STS unless flow conditions were improved by raising the operating gate. The average TFGE was 71.5% (SE = 3.7) for all turbine units (ranging from 57.6 to 78.2%; Table 2). The difference between the average

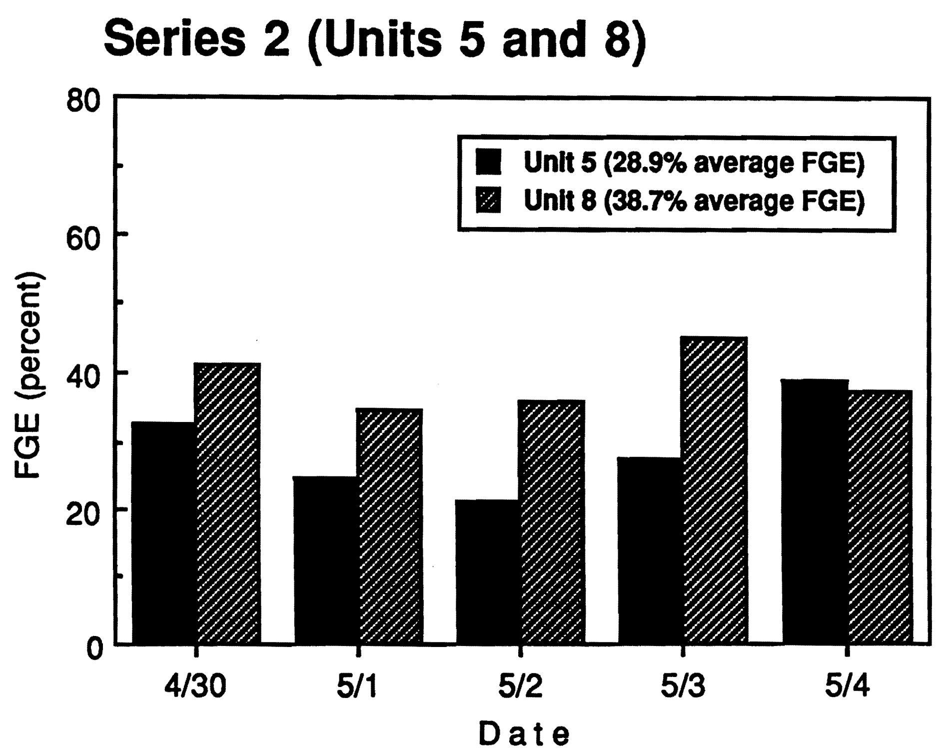

Figure 3.--Fish guidance efficiency (FGE) for yearling chinook salmon in Units 5 and 8 (Series 2) at Bonneville Dam First Powerhouse, 1991.

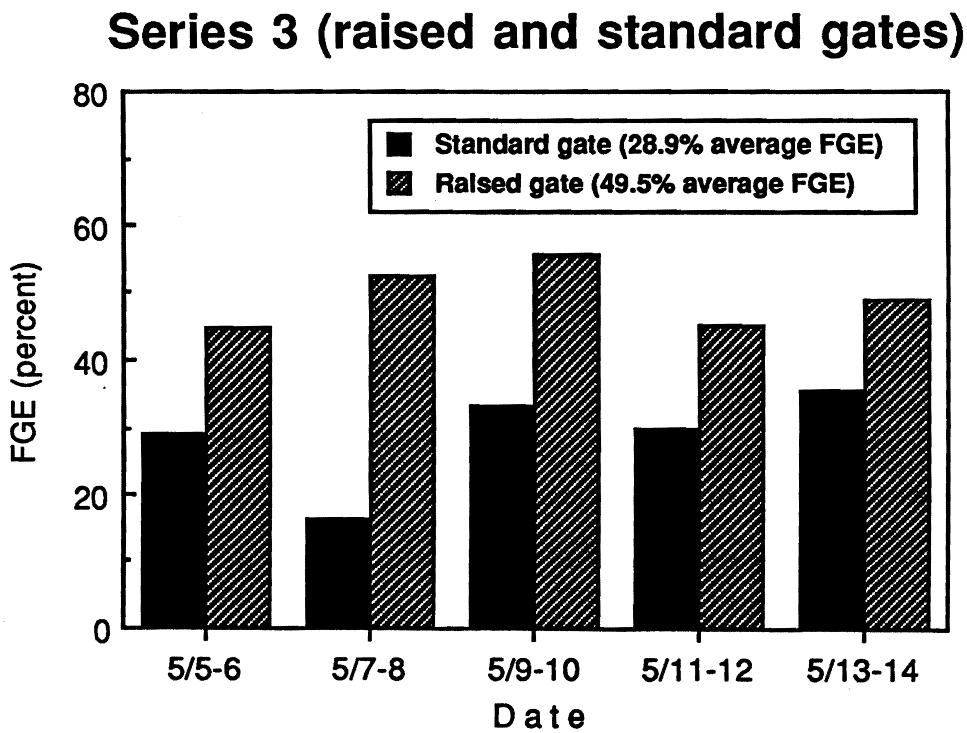

Figure 4.--Fish guidance efficiency (FGE) for yearling chinook salmon at Bonneville Dam First Powerhouse, with operating gates in raised and standard (stored) position in Unit 8 (Series 3), 1991.

FGE for each unit in a series and the TFGE (from one corresponding vertical distribution measurement per unit) ranged from 18.9 to 46.5%.

The FGE values and the respective t-values for each test in Series 3 are given in Appendix Table 1.

Other Salmonids

Subyearling chinook, coho, and sockeye salmon and steelhead were also captured, counted, and examined for descaling and other injuries during all of the FGE tests. Fish guidance efficiency for these fish was not analyzed statistically because they were not the target species and, in cases where the total number of fish was less than 100, the variance in FGE was large. However, in many cases, the numbers of fish were sufficient to show trends in FGE. For all species, FGE in Unit 8 increased by raising the operating gate (Table 3), with FGE for sockeye salmon showing the largest increase (from 25.4 to 57.7%). Combining all tests with a stored operating gate, the weighted (by total number of fish in all replicates) average FGE was 32.9% for subyearling chinook salmon, 58.2% for coho salmon, 27.4% for sockeye salmon, and 59.1% for steelhead. The numbers of fish captured in these tests ranged from 0 to 106 for subyearling chinook salmon; from 4 to 229 for coho salmon; from 0 to 280 for sockeye salmon; and from 0 to 203 for steelhead (Appendix Table 2).

Fish Quality

The weighted averages for descaling, obtained by combining all the tests for each species, were 4.8, 3.3, 8.2, and 9.4% for

Table 3.--Averaged fish guidance efficiency (FGE) for subyearling chinook, coho, and sockeye salmon and steelhead in Units 3, 5, and 8 (N = number of replicates; n = total number of fish in all replicates).

	N	n	FGE (%)	±SE	N	n	FGE (%)	±SE
	Unit 3--Stored Gate				Unit 5--Stored Gate			
Subyearling chinook	10	459	32.9	4.29	5	34	29.1	9.93
Coho	10	887	74.6	5.48	5	431	44.6	3.85
Sockeye	5	338	32.2	7.54	4	17	31.2	16.09
Steelhead	10	804	60.0	5.27	5	192	61.8	3.42
	Unit 8--Stored Gate				Unit 8--Raised Gate			
Subyearling chinook	20	452	33.1	3.95	5	18	39.8	14.10
Coho	20	1823	53.4	4.93	5	807	62.2	4.10
Sockeye	13	830	25.4	3.12	4	52	57.7	14.16
Steelhead	19	1029	57.8	3.50	5	258	73.0	2.28

yearling chinook salmon, coho salmon, sockeye salmon, and steelhead, respectively. Because of the small number of subyearling chinook salmon captured, descaling data were not calculated for this species. Appendix Table 4 provides the percentage of descaled fish for the gatewell catches in selected FGE tests and vertical distribution measurements.

CONCLUSIONS

1) During the early part of the spring outmigration, there was a large variation in FGE for yearling chinook salmon both within and among turbine units. Therefore, to avoid a possible unit effect, tests to compare effects of various modifications on FGE (e.g., a lowered STS or a change in operating gate position), should be conducted in one turbine unit.

2) Raising the operating gate in Unit 8 significantly increased FGE for yearling chinook salmon, from 28.9 to 49.5%. This indicated that, with the operating gate in the stored position, flows were less effective in moving fish up into the gatewell slot.

RECOMMENDATIONS

1) We recommend additional studies to determine the effect on FGE of increased flows into the gatewell slot at Bonneville Dam First Powerhouse. Studies at other dams have shown that a lowered STS opens the throat area between the top edge of

the STS and the gatewell slot, thereby increasing flow into the gatewell slot (Monk et al. 1987).

2) Because earlier studies indicated a high number of juvenile salmonids in the middle units (Units 4, 5, and 6) at Bonneville Dam First Powerhouse and because of the low average FGE of 28.9% in Unit 5 (from 30 April to 4 May), we recommend additional FGE measurements in the middle units. This would establish FGE in each of these units and identify changes in FGE as the outmigration progresses.

ACKNOWLEDGMENTS

We express our appreciation to Virgil Goodpastor, Project Engineer at Bonneville Lock and Dam, Thomas Thorsen, Chief of Maintenance, and Edward Willits, Structures and Utility Foreman, for their cooperation and suggestions. We also thank their respective staffs whose help made the research possible, especially Randy Price, gantry operator, who provided the necessary expertise and assistance needed for accomplishing the work safely and successfully.

We also thank Portland District Corps of Engineers personnel and the Chief of Operations, Darrell Hunt, and his staff for the extensive effort in coordinating unit startups and shutdowns for the respective tests.

LITERATURE CITED

Ceballos, J. R., S. W. Pettit, and J. L. McKern.
1991. Fish Transportation Oversight Team Annual Report--FY 1990. Transport Operations on the Snake and Columbia Rivers. NOAA Technical Memorandum NMFS F/NWR-29. 75 p. plus Appendix. (Available from Environmental and Technical Services Division, 911 N.E. 11th Avenue, Room 620, Portland, Oregon 97232.)

Gessel M. H., D. A. Brege, B. H. Monk, J. G. Williams.
1990. Continued studies to evaluate the juvenile bypass systems at Bonneville Dam--1989. Report to U.S. Army Corps of Engineers, Contract DACW68-84-H-0034, 19 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112-2097.)

Gessel, M. H., L. G. Gilbreath, W. D. Muir, and R. F. Krcma.
1986. Evaluation of the juvenile collection and bypass systems at Bonneville Dam--1985. Report to U.S. Army Corps of Engineers, Contract DACW57-85-H-0001, 63 p. plus Appendix. (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 U.S. Army Corps of Engineers, Contract DACW57-87-F-0322, 22 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112-2097.)

Hawkes, L. A., W. W. Smith, R. D. Martinson, W. A. Hevlin, and R. F. Absolon.
1991. Monitoring of downstream salmon and steelhead at federal hydroelectric facilities--1990. Report to Bonneville Power Administration, Contract DE-AI79-85BP20733, 19 p. plus Appendices. (Available from Environmental and Technical Services Division, 911 NE 11th Avenue, Room 620, Portland, OR 97232.)

Krcma, R. F., D. A. DeHart, M. H. Gessel, C. W. Long, and C. W. Sims.
1982. Evaluation of submersible traveling screens, passage of juvenile salmonids through the ice and trash sluiceway, and cycling of gatewell orifice operation at the Bonneville First Powerhouse, 1981. Report to U.S. Army Corps of Engineers, Contract DACW57-81-F-0342, 36 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112-2097.)

Krcma, R. F., C. W. Long, and C. S. Thompson.
1978. Research on the development of a fingerling protection system for low-head dams--1977. Report to U.S. Army Corps of Engineers, Contract DACW57-77-F-0307, 32 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112-2097.)

Krcma, R. F., C. W. Long, C. S. Thompson, W. E. Farr, T. W. Newcomb, and M. H. Gessel.
1979. The development of an improved fingerling protection system for low-head dams, 1978. Report to U.S. Army Corps of Engineers, Contract DACW57-78-F-0354, 40 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112-2097.)

Monk, B. H., W. D. Muir, and M. H. Gessel.
1987. Studies to evaluate alternative methods of bypassing juvenile fish at The Dalles Dam--1986. Report to U.S. Army Corps of Engineers, Contract DACW57-85-F-0295, 12 p. plus Appendix. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112-2097.)

Swan, G. A., R. F. Krcma, and F. J. Ossiander.
1984. Research to develop an improved fingerling protection system for Lower Granite Dam. Report to U.S. Army Corps of Engineers, Contract DACW68-78-C-0051, 20 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112-2097.)

Swan, G. A., R. F. Krcma, and F. J. Ossiander.
1986. Continuing studies to improve and evaluate juvenile salmon collection at Lower Granite Dam--1985. Report to U.S. Army Corps of Engineers, Contract DACW68-84-H-0034, 31 p. plus Appendices. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd E., Seattle, WA 98112-2097.)

Appendix Table 1.--FGE values and t-test results for yearling chinook salmon, comparing units or conditions.

Series 1 Unit 3 vs. Unit 8

Date	Unit 3 FGE (%)	Unit 8 FGE (%)	Difference FGE (%)	Results
4/22	65.3	23.8	41.5	
4/23	43.3	19.3	24.0	t = 1.66
4/24	42.5	49.5	-7.0	P = 0.17
4/25	41.1	37.9	3.2	nonsignificant
4/26	36.9	28.0	8.9	
	$\bar{x}$ = 45.8 SE = 5.00	$\bar{x}$ = 31.7 SE = 5.41	$\bar{x}$ = 14.1 SE = 8.48	

Series 2 Unit 5 vs. Unit 8

Date	Unit 5 FGE (%)	Unit 8 FGE (%)	Difference FGE (%)	Results
4/30	32.4	41.2	-8.8	
5/01	24.7	34.7	-10.0	t = -2.97
5/02	21.2	35.5	-14.3	P = 0.05
5/03	27.3	45.0	-17.7	significant
5/04	38.9	37.1	1.8	
	$\bar{x}$ = 28.9 SE = 3.09	$\bar{x}$ = 38.7 SE = 1.93	$\bar{x}$ = -9.8 SE = 3.30	

Series 3 Raised vs. Stored Operating Gate

Date	Raised Gate FGE (%)	Stored Gate FGE (%)	Difference FGE (%)	Results
5/5-6	44.9	29.1	15.8	
5/7-8	52.6	16.5	36.1	t = 4.97
5/9-10	55.6	33.3	22.3	P = 0.01
5/11-12	45.2	30.0	15.2	significant
5/13-14	49.2	35.5	13.7	
	$\bar{x}$ = 49.5 SE = 2.08	$\bar{x}$ = 28.9 SE = 3.30	$\bar{x}$ = 20.6 SE = 4.14	

Appendix Table 1.--continued.

Series 4	Unit 3 vs. Unit 8			
Date	Unit 3 FGE (%)	Unit 8 FGE (%)	Difference FGE (%)	Results
5/20	56.6	52.6	4.0	
5/21	50.8	54.9	-4.1	t = 0.23
5/22	36.4	52.2	-15.8	P = 0.83
5/23	46.9	33.6	13.3	nonsignificant
5/24	42.0	33.6	8.4	
	$\bar{x}$ = 46.5 SE = 3.48	$\bar{x}$ = 45.4 SE = 4.83	$\bar{x}$ = 1.2 SE = 5.12	

Appendix Table 2.--Numbers of fish collected in the individual replicates of FGE tests at Bonneville Dam First Powerhouse, 1991 (SC = subyearling chinook, YC = yearling chinook, ST = steelhead, CO = coho, and SO = sockeye).

Date (Test Unit-series number)

Location	22 April (3B-1)					22 April (8B-1)					23 April (3B-1)				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	7	139	5	18	0	5	36	2	4	0	5	139	4	39	0
Gap Net	*	*	*	*	*	0	2	0	0	0	0	6	0	0	0
Closure	3	20	1	0	0	4	17	0	0	0	3	32	0	0	0
First	0	0	0	0	0	0	12	0	0	0	9	24	0	0	0
Second	13	37	1	0	0	14	52	0	0	0	16	68	8	0	0
Third	7	14	1	0	0	8	17	0	0	0	7	40	3	0	0
Fourth	3	3	0	0	0	3	15	0	0	0	3	12	0	0	0
Totals	**33**	**213**	**8**	**18**	**0**	**34**	**151**	**2**	**4**	**0**	**43**	**321**	**15**	**39**	**0**

Location	23 April (8B-1)					24 April (3B-1)					24 April (8B-1)				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	2	44	0	16	0	5	77	3	11	0	3	46	1	5	0
Gap Net	0	1	0	0	0	0	3	0	0	0	0	1	0	0	0
Closure	2	23	0	0	0	3	21	0	0	0	1	8	0	0	0
First	0	15	0	0	0	3	15	0	0	0	0	6	0	0	0
Second	0	74	0	0	0	4	33	3	0	0	4	24	2	0	0
Third	3	62	0	0	0	3	26	0	0	0	1	8	0	0	0
Fourth	0	9	0	0	0	0	6	0	0	0	0	0	0	0	0
Totals	**7**	**228**	**0**	**16**	**0**	**18**	**181**	**6**	**11**	**0**	**9**	**93**	**3**	**5**	**0**

Location	25 April (3B-1)					25 April (8B-1)					26 April (3B-1)				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	2	104	7	24	0	1	67	3	19	0	5	73	6	51	0
Gap Net	0	1	0	0	0	1	2	0	0	0	0	1	0	2	0
Closure	0	35	0	2	0	1	17	0	3	0	0	30	0	7	0
First	0	18	0	0	0	0	18	3	0	0	0	9	0	6	0
Second	5	67	3	4	0	3	34	0	3	0	2	57	2	21	0
Third	2	19	0	5	0	4	33	1	7	0	0	25	4	9	0
Fourth	0	9	0	0	0	6	6	0	3	0	3	3	0	3	0
Totals	**9**	**253**	**10**	**35**	**0**	**16**	**177**	**7**	**35**	**0**	**10**	**198**	**12**	**99**	**0**

* No data, equipment problem.

Appendix Table 2.--Continued.

Date (Test Unit-series number)

	26 April (8B-1)					30 April (5B-2)					30 April (8B-2)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	1	44	4	20	0	1	57	12	18	0	1	73	12	24	0
Gap Net	0	2	0	0	0	1	3	0	0	0	0	4	0	0	0
Closure	0	9	1	3	0	0	20	0	0	0	0	14	0	1	0
First	0	9	0	6	0	3	18	0	3	0	0	21	0	0	0
Second	3	65	4	14	0	1	55	2	5	0	1	50	1	6	0
Third	1	22	0	9	0	0	20	2	2	0	1	15	1	4	0
Fourth	0	6	0	6	0	0	3	0	3	0	0	0	0	6	0
Totals	**5**	**157**	**9**	**58**	**0**	**6**	**176**	**16**	**31**	**0**	**3**	**177**	**14**	**41**	**0**

	1 May (5B-2)					1 May (8B-2)					2 May (5B-2)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	2	41	13	25	0	5	101	13	22	0	0	36	28	20	3
Gap Net	0	1	0	1	0	0	4	0	1	0	0	4	0	2	0
Closure	0	13	3	0	0	0	33	0	6	0	1	17	2	6	0
First	0	27	0	3	0	0	21	6	3	0	0	21	6	6	0
Second	2	57	3	7	1	2	88	6	22	1	1	60	6	10	1
Third	3	21	2	10	0	2	26	1	14	0	2	26	7	5	0
Fourth	0	6	0	6	0	0	18	0	6	0	3	6	0	3	0
Totals	**7**	**166**	**21**	**52**	**1**	**9**	**291**	**26**	**74**	**1**	**7**	**170**	**49**	**52**	**4**

	2 May (8B-2)					3 May (5B-2)					3 May (8B-2)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	1	66	24	26	3	4	54	36	49	2	0	99	41	36	3
Gap Net	0	1	0	1	1	0	4	0	4	0	0	3	0	2	0
Closure	0	19	2	5	1	0	19	2	4	1	0	16	4	5	1
First	0	21	6	6	0	3	18	3	9	0	0	21	3	6	0
Second	3	45	5	15	4	0	64	12	33	1	0	47	11	39	1
Third	1	25	3	5	1	0	30	9	22	2	0	25	2	20	3
Fourth	0	9	0	0	0	0	9	0	9	0	3	9	0	9	0
Totals	**5**	**186**	**40**	**58**	**10**	**7**	**198**	**62**	**130**	**6**	**3**	**220**	**61**	**117**	**8**

Appendix Table 2.--Continued.

Date (Test Unit-series number)

	4 May (5B-2)					4 May (8B-2)					5 May (8B-3) (Standard Gate)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	3	82	25	67	1	1	103	25	87	1	2	91	8	51	1
Gap Net	0	0	0	2	0	0	4	0	5	0	0	9	1	2	0
Closure	0	12	4	8	0	0	21	2	11	0	0	13	0	1	0
First	0	21	0	15	0	0	27	0	12	0	3	45	3	15	3
Second	0	49	11	44	1	2	67	10	49	1	0	95	8	45	4
Third	1	35	4	15	1	1	41	2	21	2	0	48	1	25	0
Fourth	3	12	0	15	3	3	15	0	0	0	0	12	0	3	0
Totals	**7**	**211**	**44**	**166**	**6**	**7**	**278**	**39**	**185**	**4**	**5**	**313**	**21**	**142**	**8**

	6 May (8B-3) (Raised Gate)					7 May (8B-3) (Standard Gate)					8 May (8B-3) (Raised Gate)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	1	157	16	67	6	1	72	8	73	0	3	112	16	87	2
Gap Net	0	0	0	0	0	0	2	0	7	0	0	0	0	2	0
Closure	0	21	0	3	0	1	29	1	11	0	1	7	3	4	0
First	0	27	0	9	0	0	60	6	12	0	0	33	0	9	0
Second	1	92	4	20	3	2	149	2	41	2	0	46	2	21	2
Third	0	41	1	14	1	4	82	1	20	0	0	15	0	12	2
Fourth	0	12	0	9	0	0	42	0	6	0	0	0	0	3	12
Totals	**2**	**350**	**21**	**122**	**10**	**8**	**436**	**18**	**170**	**2**	**4**	**213**	**21**	**138**	**18**

	9 May (8B-3) (Raised Gate)					10 May (8B-3) (Standard Gate)					11 May (8B-3) (Raised Gate)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	0	65	39	140	5	1	38	29	51	0	1	123	24	118	1
Gap Net	0	0	0	1	0	0	4	0	9	1	0	0	0	0	0
Closure	0	6	0	3	1	1	11	1	13	0	0	23	0	14	0
first	0	6	0	12	0	0	6	3	6	3	0	24	0	15	0
Second	0	31	13	19	1	1	32	6	33	2	3	59	5	42	0
Third	0	9	1	13	1	1	20	3	11	3	0	37	3	31	0
Fourth	0	0	0	3	0	0	3	3	3	3	3	6	0	9	0
Totals	**0**	**117**	**53**	**191**	**8**	**4**	**114**	**45**	**126**	**12**	**7**	**272**	**32**	**229**	**1**

Appendix Table 2.--Continued.

Date (Test Unit-series number)

	12 May (8B-3) (Standard Gate)					13 May (8B-3) (Standard Gate)					14 May (8B-3) (Raised Gate)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	4	64	40	63	3	3	38	49	83	4	1	64	84	87	8
Gap Net	0	4	0	6	0	0	4	0	7	0	0	0	0	0	0
Closure	1	17	1	10	0	0	12	6	10	2	1	6	0	7	1
First	3	36	12	9	0	0	6	12	27	6	0	6	3	0	0
Second	1	68	13	49	7	1	33	25	32	3	1	41	31	23	2
Third	2	24	7	16	2	0	11	5	19	1	2	13	10	10	4
Fourth	0	0	3	6	0	0	3	6	6	0	0	0	3	0	0
Totals	**11**	**213**	**76**	**159**	**12**	**4**	**107**	**103**	**184**	**16**	**5**	**130**	**131**	**127**	**15**

	20 May (3B-4)					20 May (8B-4)					21 May (3B-4)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	45	98	49	84	16	41	111	50	36	8	32	32	108	83	25
Gap Net	3	3	1	7	1	7	10	3	7	4	0	6	6	8	4
Closure	10	12	5	12	1	11	13	1	8	2	8	3	8	9	4
First	9	6	9	0	0	6	18	3	3	6	3	0	9	6	6
Second	19	32	20	15	6	11	40	11	17	10	7	18	40	23	46
Third	17	13	8	8	4	17	19	6	4	9	5	4	12	9	23
Fourth	3	9	3	6	0	9	0	6	0	0	6	0	3	0	9
Totals	**106**	**173**	**95**	**132**	**28**	**102**	**211**	**80**	**75**	**39**	**61**	**63**	**186**	**138**	**117**

	21 May (8B-4)					22 May (3B-4)					22 May (8B-4)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	28	56	115	75	101	22	28	137	64	17	22	71	106	43	47
Gap Net	5	10	1	13	20	1	1	3	7	3	2	6	0	2	11
Closure	9	14	10	10	29	6	5	8	6	10	5	9	7	9	14
First	3	3	15	6	15	0	3	9	6	3	3	15	6	6	36
Second	5	13	37	6	76	11	20	31	13	22	11	26	14	13	35
Third	1	6	14	2	33	5	5	15	7	7	7	9	9	3	20
Fourth	0	0	6	0	6	6	15	0	3	6	0	0	6	0	6
Totals	**51**	**102**	**198**	**112**	**280**	**51**	**77**	**203**	**106**	**68**	**50**	**136**	**148**	**76**	**169**

Appendix Table 2.--Continued.

Date (Test Unit-series number)

Location	23 May (3B-4)					23 May (8B-4)					24 May (3B-4)				
	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	22	67	102	89	28	29	49	58	46	31	16	74	140	130	27
Gap Net	1	3	1	6	2	1	4	1	3	5	1	5	2	12	0
Closure	12	13	5	9	2	7	6	1	5	6	5	10	9	12	9
First	9	9	6	9	6	6	15	0	12	18	6	15	0	12	0
Second	27	42	12	12	15	12	15	9	18	48	12	57	6	9	9
Third	15	9	0	0	21	9	21	0	6	6	6	12	6	3	3
Fourth	0	0	3	3	3	0	0	0	3	6	3	3	3	3	0
Totals	**86**	**143**	**129**	**128**	**77**	**64**	**146**	**69**	**93**	**120**	**49**	**176**	**166**	**181**	**48**

Location	24 May (8B-4)				
	SC	YC	ST	CO	SO
Gatewell	17	51	50	41	59
Gap Net	1	3	0	3	4
Closure	4	14	1	13	5
First	9	18	3	12	15
Second	9	48	12	12	36
Third	6	9	3	3	27
Fourth	9	9	3	9	3
Totals	**55**	**152**	**72**	**93**	**149**

Appendix Table 3.--Numbers of fish collected in the individual replicates of vertical distribution tests at Bonneville Dam First Powerhouse, 1991. For all tests, the operating gate was in the stored position (SE = subyearling chinook, YC = yearling chinook, ST = steelhead, CO = coho, and SO = sockeye).

Date (Test Unit-series number)

	27 April (3B-1)					27 April (8B-1)					29 April (5B-2)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	0	21	8	14	0	1	16	5	10	0	2	28	3	6	0
First	0	123	6	33	0	0	93	3	15	0	0	12	0	3	0
Second	0	66	6	15	3	3	63	6	9	0	3	18	0	0	0
Third	3	33	6	3	0	0	24	3	3	0	0	6	0	3	0
Fourth	3	18	0	3	0	3	3	0	0	0	0	6	0	0	0
Fifth	0	15	0	6	0	0	18	0	3	0	0	0	0	0	0
Sixth	0	3	0	0	0	0	3	0	0	0	0	12	0	0	0
Seventh	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	**9**	**282**	**26**	**74**	**3**	**7**	**220**	**17**	**40**	**0**	**5**	**82**	**3**	**12**	**0**

	29 April (8B-2)					15 May (8B-3)				
Location	SC	YC	ST	CO	SO	SC	YC	ST	CO	SO
Gatewell	0	13	5	3	0	1	15	40	37	3
First	0	30	3	3	0	6	108	66	117	15
Second	0	18	0	3	0	6	51	39	75	6
Third	0	18	6	0	0	3	27	12	33	3
Fourth	0	12	0	0	0	3	15	6	6	3
Fifth	0	0	0	0	0	0	9	6	12	0
Sixth	0	9	0	0	0	3	3	0	0	0
Seventh	0	6	0	0	0	0	0	3	0	0
Totals	**0**	**106**	**14**	**9**	**0**	**22**	**228**	**172**	**280**	**30**

Appendix Table 4.--Total numbers of fish in the gatewells and percent descaling for all species examined during selected FGE and vertical distribution measurements at Bonneville Dam First Powerhouse, 1991.

				Yearling chinook		Coho		Steelhead		Sockeye	
			Gate	Descaling		Descaling		Descaling		Descaling	
Unit	Date	Test	Pos.	No.	%	No.	%	No.	%	No.	%
3B	5-20	FGE	Std.	98	3.1	84	0.0	49	8.2	16	6.3
3B	5-21	FGE	Std.	32	9.4	83	6.0	108	7.4	25	12.0
3B	5-22	FGE	Std.	28	7.1	64	1.6	137	5.1	17	29.4
3B	5-24	FGE	Std.	74	9.5	130	3.1	140	4.3	27	7.4
5B	4-29	VD	Std.	28	0.0	6	0.0	3	0.0	0	NA
8B	4-26	FGE	Std.	44	6.8	20	0.0	4	0.0	0	NA
8B	5-5	FGE	Std.	91	2.2	51	3.9	8	12.5	1	0.0
8B	5-7	FGE	Std.	72	2.8	73	2.7	8	25.0	0	NA
8B	5-8	FGE	Rsd.	112	1.8	87	2.3	16	18.8	2	0.0
8B	5-9	FGE	Rsd.	65	4.6	140	4.3	39	12.8	5	40.0
8B	5-10	FGE	Std.	38	10.5	51	2.0	29	17.2	0	NA
8B	5-11	FGE	Rsd.	123	4.1	118	3.4	24	8.3	1	0.0
8B	5-12	FGE	Std.	64	0.0	63	4.8	40	5.0	3	33.3
8B	5-13	FGE	Std.	38	5.3	83	8.4	49	10.2	4	50.0
8B	5-14	FGE	Rsd.	64	4.7	87	3.5	84	7.1	8	12.5
8B	5-20	FGE	Std.	111	5.4	36	0.0	50	22.0	8	0.0
8B	5-22	FGE	Std.	71	9.9	43	0.0	106	8.5	47	8.5
8B	5-23	FGE	Std.	49	4.1	46	2.2	58	10.3	31	3.2
8B	5-24	FGE	Std.	51	7.8	41	4.9	50	0.0	59	3.4